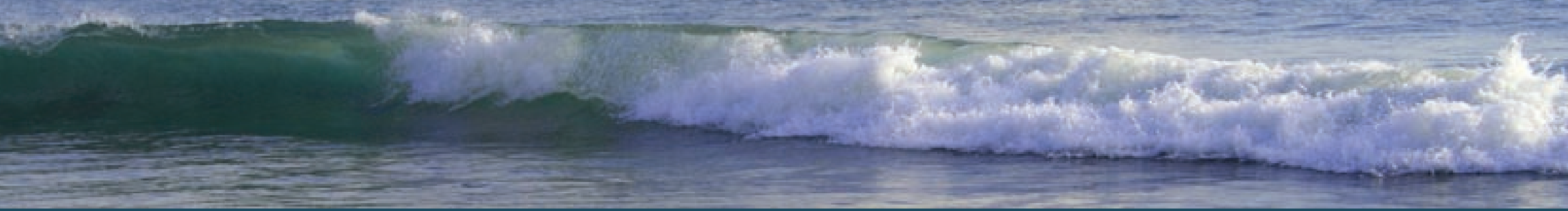


Monitoring keystone components of sub-Arctic food webs – ecosystem dynamics of the White Sea

Background
The White Sea is a unique semi-enclosed sub-Arctic sea, south of the North Polar Circle. It was formed during the last interglacial period about 6,000 yrs ago and later lost its direct connection with the Arctic region due to rising temperatures and the penetration of the warm North Cape Current into the southern part of the Barents Sea. This Fact Sheet introduces some of the results in continuous observations of major abiotic features in the White Sea over the last 50 years, and investigates the possible response of key planktonic species to future climate change.

A keystone species is a species that plays a disproportionate role in its environment relative to its abundance. An ecosystem may experience a dramatic shift if a keystone species is removed, even though that species may have accounted for only a small part of the ecosystem in terms of biomass and/or productivity.

The results discussed here are based on long-term observations, obtained every ten days in the White Sea, on temperature, salinity and plankton species abundance. These observations describe the interactions between ecosystem components, and the information can be used to infer future ecosystem changes and in support of management decisions. Combined with additional ecophysiological investigations, these results could assist in the development of predictive capacity to evaluate climate-induced changes in pelagic ecosystems.

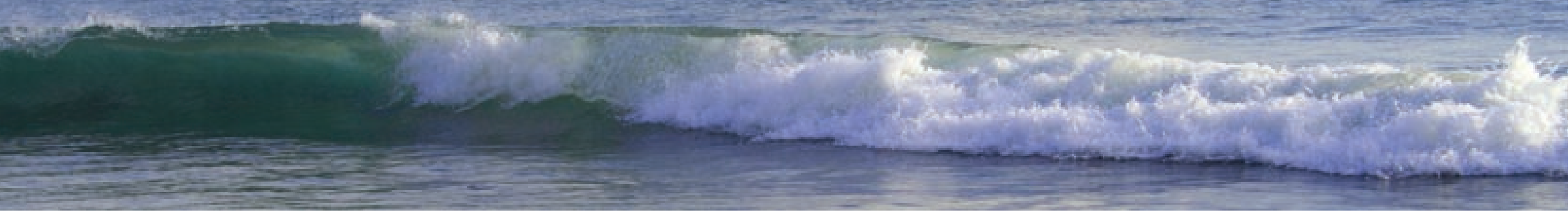
Climate change records and species success

The marine fauna of the White Sea is diverse and adapted to salinities as low as 24-28% (per thousand), compared to the 30-32% of the open ocean. The long (up to 6 months per year) periods of ice-coverage, and the considerable warming of the surface waters in the summer (>20°C) has allowed the coexistence of three major biogeographic groups of species: boreal, arcto-boreal and arctic.

Long-term observations of zooplankton in the White Sea began in the 1960's near the Biological station of the Zoological Institute, Russian Academy of Sciences, located in Kandalaksha Bay (Station, D-1, 66°19'50"N, 33°40'06"E).

The fifty-year data (Figure 1) shows a warming trend in the ecosystem for the last 40 years. It also reveals large interannual variability in the Arctic keystone species *Calanus glacialis*, overlaying a long-term pattern of increased abundance until the mid 1990s, decreasing since. Such long term changes appear to be more significant than year-to-year deviations.

The White Sea population of *Calanus glacialis* is a relict of the glacial period, currently isolated from other Arctic populations. *C. glacialis* is one of the most active under-ice and open-water consumers constituting a key link between primary production and higher trophic levels in the sub-Arctic. Climate-induced changes in food availability and, as a result, growth and reproduction periods, may have knock-on effects throughout sub-Arctic food web. *C. glacialis* is dependent on the ice algae and spring phytoplankton bloom for successful reproduction and population maintenance, and will be strongly affected by any spatial and temporal changes of ice coverage. Female abundance in the upper water layer in springtime is strongly constrained from year to year by adequate water temperature. In the White Sea *C. glacialis* is one of the key producers of faecal pellet organic carbon, vital for benthic species, and itself a major source of energy for all developmental stages of the White Sea endemic herring species *Clupea pallasi maris-albi*, larvae of endemic cod species *Gadus morhua maris-albi*, and top predators such as marine birds and mammals, especially ringed seals and beluga whales.



Long-term monitoring and scenarios of climate-induced ecosystem changes

Climate change has become increasingly obvious in recent decades, both for sub-Arctic as well as Arctic regions. Continuous observations of the White Sea reveal an unprecedented reduction in the ice coverage season over the last decade and increasing annual sea surface temperatures (0.6ºC since 1957, Figure 1). The abundance of *C. glacialis*, while showing large variability and a certain dependence on the previous year's abundance, appear to be negatively related to increases in surface temperature, thus being open to warming impacts (Figure 1). Monitoring observations not only provide data on the past and ongoing changes, but would also provide early warnings of future trends in ecosystem parameters. Because predictive capacity increases with the number of observations; long-term, multi-variable monitoring is essential to ensure we make reliable predictions of future ecosystem state.

Preliminary analyses also show the importance of concurrent physical and biological research targeted at modelling climate impact scenarios to predict the outcome of vulnerable keystone species. Complex models are required to assess and forecast the impacts of climate and anthropogenic forcing on food-web dynamics, incorporating knowledge on ecosystem productivity and trophic interactions from phytoplankton to top predators, at both interannual and multidecadal scales.

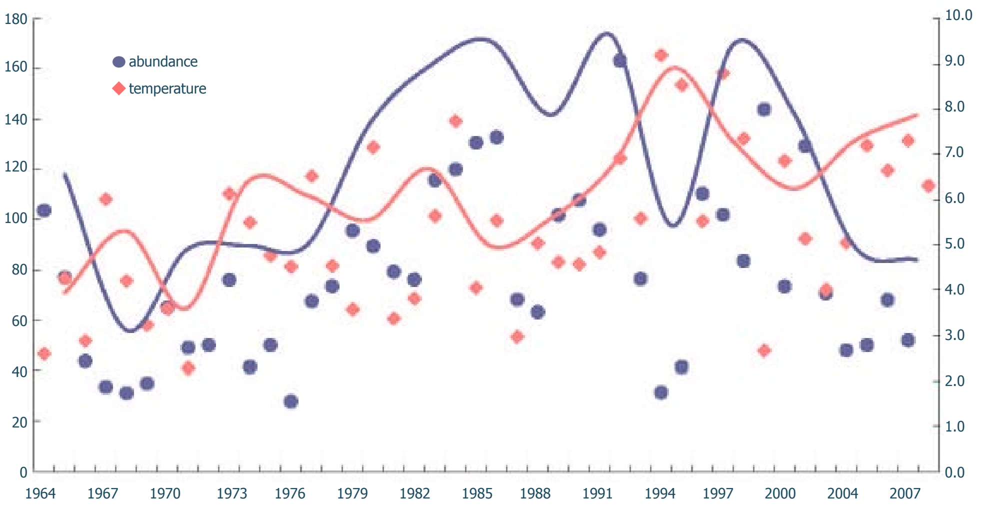


Figure 1. Long-term trends in spring surface temperature (red) and *Calanus glacialis* females adundance (blue) in the upper layer, 0-50m, in the White Sea for the last 40 years. Curves are plotted on average values for every 3 years.

Under a warming Arctic and sub-Arctic scenario the White Sea will be deeply affected, as past records indicate. A shorter ice cover period is likely to reduce the success of key species such as *Calanus glacialis*. This will mostly be due to a mismatching between spring phytoplankton blooms and copepod gonad maturation and reproduction. This mismatch will decrease copepods energy resources during their most vulnerable period. It is expected that this prediction will apply to other species as well. Further investigations are needed to assess ecosystem changes and support future management options.

Action Points

1. Further data is urgently required in order to evaluate the effects of, and possible adaptation to, the increasing surface water temperature and decreasing ice coverage period in sub-Arctic pelagic ecosystems.
2. In order to advise on the management of ecosystem services, ongoing studies should monitor hydrological parameters, phyto- and zooplankton community parameters and foodweb structure. These studies must continue their focus on the reproduction biology of key plankton species, particularly in relation to a changing climate.
3. Continued international collaboration between specialists working in different Arctic and sub-Arctic areas is essential to support the implementation of an ecosystem approach to fisheries, biodiversity and socio-economic management. These collaborations are absolutely necessary to increase sampling coverage and precision, and to generate scientific understanding prior to any socio-economic analysis of the consequences of change.

Research Network ARCTOS

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White Sea Biological Station

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