IMR/PINRO
1
2019
Joint Report Series

BK-0025

JOINT REPORT

INFLUENCE OF ECOSYSTEM CHANGES ON HARVESTABLE RESOURCES AT HIGH LATITUDES

Proceedings of the 18th Russian-Norwegian Symposium
Murmansk, 5–7 June 2018

Institute of Marine Research – IMR

Polar Research Institute of Marine Fisheries and Oceanography – PINRO

Perspectives of snow crab *Chionoecetes opilio* fishery in the Russian Exclusive Economic Zone in the Barents Sea

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Abstract

The paper describes the current state of the snow crab stock in the Barents Sea. The main factors affecting the acclimatization in the new area are examined. Based on the spatial distribution modeling, the potential area and probable future commercial concentrations of the snow crab after the complete naturalization are estimated. Commercial stock biomass of snow crab in the Russian waters of the Barents Sea at present is estimated at 400 thousand tons with the possibility of annual catch of 40–80 thousand tons.

Keywords: Barents Sea, snow crab, fishery

Introduction

The first captures of the snow crab *Chiloecetes opilio* in the Barents Sea were registered in the mid-1990s (Kuzmin et al., 1998). Following 20 years the crab-invader actively reproduced itself, occupying new waters where sometimes forming there commercial densities. Since 2013, the unregulated snow crab fishery began in the open part of the Barents Sea (the "Loophole"). In 2013–2016 the total international snow crab catch in these waters exceeded 50 thousand tons. In 2016 the fishery for snow crab was started also in the Exclusive Economic Zone of the Russian Federation (Russian EEZ).

The aim of the work is to assess the perspectives for the Russian snow crab fishery in the Russian EEZ in the Barents Sea. The analysis of data on the modern state of the crab population was used in achieving of the aim. A probability model of species distribution (species distribution model (SDM): Elith, Leathwick, 2009) application was used to investigate the influence of some environmental factors on the snow crab present spatial distribution as well as the possibility of further area expanding. The complex results, obtained by the SDM model and the Leslie depletion model, were used to extrapolate and estimate the total and commercial stocks biomass of snow crab in the Barents Sea.

Material and methods

The PINRO's data of the snow crab catches in the Barents Sea, collected in the Russian-Norwegian ecosystem survey in 2005–2017 were used. These annual surveys were carried out according to the standard methods during the summer-autumn and covered major part of the Barents Sea on an area about 1,500 thousand km² each year (Eriksen, 2012).

The snow crab stock condition in the Barents Sea was assessed by some indicators: the occurrence of the crab in space, number and the biomass of the commercial stock. To assess the snow crab spatial distribution in the Barents Sea and to analyze the environmental factors determining the acclimatization success, a family of SDM distribution cartographic models implemented in the Biomod2 library of the statistical environment R were used. The choice of the probability model to analyze the snow crab distribution, model diagnostics, and also the evaluation of the variables influence on the simulation results were performed by the functions of the "biomod2" library. The method essence is in the correlation relationship analysis between the predicted values of two

variants modeled: with the standard set of independent variables and when the analyzed variable is replaced by randomized analogue. The lower the correlation, the higher the influence of the variable analyzed (Mielke, Berry, 2001). The index of the snow crab stock number was calculated as the arithmetic mean catch (spec. per 1 n. mile of trawling) in the surveyed area of the Russian EEZ in 2005–2017. To assess the stock in the fishery area, the Leslie model of depletion with a time step of one quarter was used (Bakanev, 2015a).

To obtain the minimum value of the snow crab commercial stock biomass in the Russian EEZ, the density of crabs obtained in the "Loophole" in 2014 (before the fishery in the Russian EEZ) was extrapolated to the area of commercial sized crabs distribution in the Russian EEZ estimated in ecosystem surveys 2012-2017.

Results and discussion

From the first captures of the snow crab in 1996 up to the start of commercial fishery (2013), an explosive-like population growth, active spreading to the eastern part of the Barents Sea, forming of commercial concentrations and new rich generations were observed (Bakanev, 2015b). Currently, the area of this specie is about 900 thousand km², close to 30% of the total Barents Sea area. The snow crab becomes one of the most wide-spread creature of the bottom fauna in the eastern and northeastern parts of the Barents Sea.

According to the results of analysis of the some factors influencing the crab distribution, the only variable – the distance from the core of initial crab settlement is most significant. Climatic and landscape factors currently do not significantly affect the crab distribution. The bottom sediments on the major part of the Barents Sea is optimal for the snow crab and does not limit its spreading. Almost the total bottom surface of the Barents Sea is covered by sandy mud (64%) and muddy sand (22%), where the majority of snow crabs were observed. The near bottom water temperature is a one of main factor limiting the further dispersal of the crab to the areas with rather high water temperatures (Bakanev, 2015b). Crab is currently found in the near bottom waters temperatures from –1.9°C to 6.5°C. One of the factors possibly limiting the crab penetration to the coastal areas is the near bottom waters salinity, which are often rather low (Anger, 2003). At the same time, it is known that crab often forms concentrations of rather high densities at low salinity even about 32 (Slizkin, 1982). Based on the assumption that 2/3 of the Barents Sea area is under the Atlantic waters influence where the salinity exceeds 34, while in the rest of the sea the salinity varies between 32 and 34 (Dobrovolsky , Zalogin, 1982), the salinity factor will not play a significant role in the further snow crab distribution. The role of nitrates, phosphates and oxygen is rather high. Such a significant contribution of these factors is primarily due to the distribution of the species in relation to the distribution of the Barents Sea water masses types. At present crab is almost not found in the Atlantic waters of the western part of the Barents Sea (west of 35 ° E) (Ozhigin et al., 2016). Thus, the main environmental factors in the Barents Sea, influencing the snow crab spatial distribution, do not prevent its successful acclimatization, colonization of new areas and formation of high densities concentrations.

Analyzing the factors affecting the snow crab distribution, some authors are pointing out such biotic features as the feed benthos and predators (Kobyakova, 1958; Slizkin, 1982; Galkin, 1985). The absence of cannibalism and numerous predators, which could decrease the population number on the early life stages, is essential. The inclusion of benthic by-catch data collected during ecosystem surveys (benthos distribution density) in modeling of the snow crab distribution shows that the influence of such variable is currently insignificant compared to natural factors. Based on the index of population number dynamics, there were three periods in the crab stock history: low number in 2005–2008, active growth in 2009–2010 and high number in 2011–2016. Changes in the size composition in crab catches show that some rich generations periodically appear in the crab

population. This could affect the population dynamics, as well as the commercial stock biomass. Thus, the high uncertainty in the population indices of the Barents Sea snow crab does not allow using them as confident indicators of stock status in a certain year of assessment. Therefore, such results of trawl surveys as changes in the size composition of catches, the distribution area and general trends in the stock number dynamics in recent years could only indirectly be used to estimate the status of the crab stock. The basis for future commercial stock estimates and the forecast of the snow crab total allowable catch (TAC) could be the data obtained during the fishery. In case of poor information, the crab stock assessment could be performed by one of the most promising analytical methods - regression models of the productivity reducing during the fishery season, based on the accumulated catch, i.e. depletion models (Bakanev, 2015a).

The commercial snow crab fishery in the Barents Sea began in mid-2013 in the central region of the Barents Sea outside of the national economic zones. Since the beginning of the unregulated snow crab fishery in the "Loophole", the total Russian catch to the end of 2016 exceeded 20 thousand tons, while the foreign catch reached 35 thousand tones. Upon the intensive and rather large-scaled new established fishery, the productivity decline was observed, indicating a significant overfishing these areas. In this regard, targeting to protect the stock, in mid-2016 the Russian Federation and the Kingdom of Norway in frames of the Joint Russian-Norwegian Fishery Commission agreed to regulate the snow crab fishery in the "Loophole" jointly. In 2016, the snow crab fishery started in the Russian EEZ of the Barents Sea. First results of the fishery in 2016 showed that the density of crab concentrations allows to harvest the new stock at the same stable productivity, as in the Pacific. To estimate the snow crab commercial stock biomass in the Russian EEZ of the Barents Sea, the values of the crab's commercial stock density in the "Loophole" before the fishery opening (774 t / thousand km^2) were extrapolated to the area of commercial-sized snow crab distribution in the Russian EEZ obtained by modelling the probability of spatial distribution. The commercial stock biomass of snow crab in the Russian waters of the Barents Sea is currently estimated at a median level of 400 thousand tons.

Conclusions

The snow crab commercial stock biomass dynamics has no clear trends in the Barents Sea. Last two years the area of the snow crab is not increase. Despite that, the potential for further distribution of snow crab in the Barents Sea remains rather high. The previous optimistic estimates of the commercial stock of snow crab in the Russian EEZ in the Barents Sea, resulted from ecosystem surveys, confirmed by the fishery statistics. The snow crab commercial stock in the Russian part of the Barents Sea is currently estimated of about 400 thousand tons. There are some clear evidences of rich yearclasses of the snow crab in the Barents Sea periodically appearing. It is a sign of rather stable future recruitment to the commercial stock. The level of exploitation for stable and high commercial stocks may constitute about 10–20% of the commercial biomass. Under the current condition, the biologically grounded annual TAC of snow crab in the Russian EEZ in the Barents Sea could vary from 40 to 80 thousand tons.

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