Mechanisms of the Adaptation of the Kildin Cod *Gadus morhua kildinensis* Derjugin, 1920 (Pisces: Gadidae) to the Specific Conditions of Lake Mogilnoye


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Abstract—The mechanisms of the adaptation of the Kildin cod to the conditions of a meromictic lake were analyzed based on the study of morphological, biological, and genetic characteristics. Significant differences between the Kildin cod and Atlantic cod have been found in their morphological and genetic characteristics. The results of an X-ray microanalysis of otoliths, which were conducted for the first time, confirm that the distribution range of the Kildin cod in Lake Mogilnoye also extends to brackish waters. It has been shown that the formation of the reproductively isolated lacustrine population of Kildin cod is accompanied by specialization in a number of characteristics (body color, feeding strategy, behavior, etc.) and by a decrease in genetic diversity.

Keywords: Kildin cod, morphobiological characteristics, genetic polymorphism, X-ray microanalysis of otoliths

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INTRODUCTION

The study of the mechanisms that form biodiversity in marine ecosystems is currently one of the most important research objectives. The Atlantic cod, *Gadus morhua*, which has effectively occupied a wide range of waters in the boreal-arctic region, represents a species with a high level of biological flexibility [13, 23]. The situation with the Kildin cod, *Gadus morhua kildinensis* Derjugin, 1920, is of special interest, because of the more than 200 fish species that inhabit the Barents Sea [35] only the Atlantic cod, which is considered as a special taxon at the rank of subspecies, was able to form a productive and stable reproductively isolated group that has existed for a long period of time in the specific conditions of a subpolar, exogenous, meromictic, and exothermic relic lake, Mogilnoye, situated on the Kildin Island, Barents Sea [7].

The goal of this work was to summarize and systematize the materials on the strategies of the formation of an isolated population, obtained as a result of our field- and laboratory-based studies, as well as the relevant data from the literature.

MATERIALS AND METHODS

The material was collected during expeditions to Lake Mogilnoye organized by the Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) in 1997, 1998, and 2000, as well as during complex expeditions by researchers from PINRO, the Yavllov Institute of General Genetics, Russian Academy of Sciences (VIGG RAS), and the Department of Ichthyology, Moscow State University (MSU), in 2011 and 2012. Previously published data were also used [14, 25, 27, etc.]. Such traits as body color, measurements, the trace-element composition of otoliths, and variation of genetic parameters were analyzed within the framework of the study of the morphobiological and genetic characteristics of Kildin cod.

Morphometry (Fig. 1) was performed using photographs, because, in accordance with the instructions of the Ministry of Natural Resources and Environment of the Russian Federation, all caught Kildin cod must be released. Morphometric traits were expressed in terms of ratios (to body length, to body length at the edge of scaled area, and to head length). Statistical analysis was based on the standard methods [8, 9, 22].
altered through reduction and specialization (only one type of body color pattern remained from the spectrum of various patterns typical of the original form; the head became enlarged and widened; mature individuals performed a transition to territorial behavior; etc.). Thus, in a number of characteristics, the Kildin cod retained the versatility inherent in the parental species, while in other characteristics a process of specialization occurred. It is probable that this specialization provided a significantly lower level of genetic diversity. The population of cod in Lake Mogilnnoye reached a relative genetic equilibrium, at which the process of its adaptation to the specific conditions of this body of water continued. The combination of high fecundity and cannibalism in the Kildin cod is likely to be one of the key factors that provide the stability and productivity of this lacustrine group, as it contributes to maintaining the abundance and increasing the efficiency of the energy transfer from the underutilized stocks of planktonic communities to the community of large mature cod.

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