JIA Qinxian, Elena ANUFRIIEVA, LIU Shasha, LIU Xifang, KONG Fanjing, ZHENG Mianping and Nickolai SHADRIN, 2014. Results of an Intentional Introduction of *Artemia sinica* in the High-Altitude Tibetan Lake Dangxiong Co: On A Base of Surveys in 2011 and 2013. *Acta Geologica Sinica* (English Edition), 88(supp. 1): 74-76.

Results of an Intentional Introduction of *Artemia sinica* in the High-Altitude Tibetan Lake Dangxiong Co: On A Base of Surveys in 2011 and 2013

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1 Introduction

The human population is projected to reach 9200 million by 2050. A fundamental question for science is whether it is possible to increase food production to meet the demands of a human population of that magnitude. It's possible only to increase an aquaculture production. Cultivation of fish/shrimp larvae is a bottleneck in a cultivation of the different organisms. Live food organisms as feed for the developing larvae is a weak link in the development of larviculture. *Artemia* nauplii are main living food for larvae now. A demand of artemian cysts continues to increase in aquaculture. Rational exploitation of *Artemia* populations in salt lakes is a key to overcome an imbalance between supply and demand of *Artemia* cysts in China. A serious decrease of *Artemia* cysts production in coastal and inland salt lakes in China is observed now.

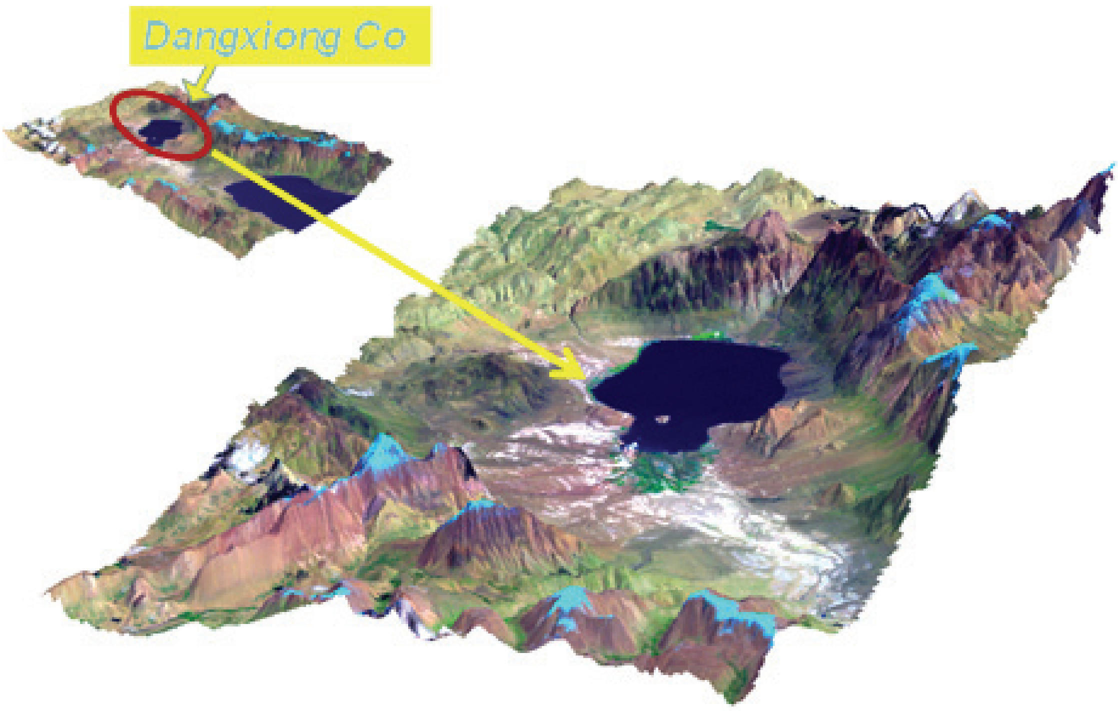

Fig. 1. Lake Dangxiong Co in Nothern Tibet.

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Salt lake on Tibet may promote to solve the problem. There are 26 saline lakes, which have salinity and temperature may support *Artemia* survival in them at an altitude of 4000-5100 m in Northern Tibet (own results). We found *Artemia* in only 15 lakes. The saline lakes with *Artemia* populations mainly belong to shallow basin lake and a majority of them are small in area. Total area of lakes without *Artemia* is more than 1000 km^2; they are deep and large. What are causes that these saline lakes are free from *Artemia*? We may assume different causes: a natural isolation and remoteness from the routes of migratory birds, which may transport cysts, scarceness of zooplankton and zoobenthos, which might attract migratory birds to stop for foraging, presence of some predators, etc. We have not enough data to understand the causes. However, we know that some Ostracoda species inhabit Tibetan lakes, as *Eucypris elliptica* (Baird, 1846), for example. Field and experimental study showed that in the Crimean lakes *Eucypris mareotica* (Fischer, 1855) lives under salinity up to 300 ppt and feeds on *Artemia* nauplii (Anufriieva and Shadrin, own data). Lake Dangxiong Co was chosen for an intentional introduction of *A. sinica* Cai, 1989. This lake is in the southwestern part of Nothern Tibetan plateau, Nagqu Prefecture of Tibet Autonomous Region (31°32′ - 31°36′N, 86°40′ - 88°48′E) on altitude 4475 m a.s.l. Its area is about 55.53 km^2, the maximum and average depths are 14.5 m and 12.4, respectively. Salinity in the lake fluctuates between 120 and 180 ppt. Climate of the area is arid; annual precipitation is about 150 mm: temperature fluctuates between -30 °C and +25 °C. In 2004 850 g of *A. sinica* cysts, originated from Qinhai, were introduced in the lake (Liu et al., 2014).

2 Material and Methods

Quantitative zooplankton samples were collected in November-December 2011 (25 samples) and in August 2013 (16 samples). The number of animals was determined by direct counting under an Olympus SZ-PT stereo microscope with subsequent recalculation on the volume of filtered water. To measure *Artemia* size we used ocular-micrometer. Results of 2011 survey were mostly published (Liu et al., 2014), and we did not give them here. Using length we calculated wet and dry mass (weight) of males and females taken known equations (1) and (2) (Khmeleva, 1968).

$$W_d = 0.00103\ L^{2.66}, \quad (1)$$

where W_d – dry weight (mg), L – length (mm).

$$W_d = 0.01083\ W_w + 0.0016, \quad (2)$$

where W_w – wet weight.

3 Results and Discussion

Main results of the *Artemia* survey in 2013 are given in tables 1-4.

Table 1 Average density of different stages of *Artemia* in two layers of Lake Dangxiong Co in August 2013

Layer, m	Average density, ind./m^3					
	cysts	nauplii	metan.	juvenils	adult fmale	adult male
0 – 7	46,000	5,800	2,800	300	500	900
7-14	188,333	3,500	2,667	167	1,000	1,500
Aver.	117,167	4,650	2,739	234	750	1,200

Table 2 Average sizes and mass of adult females and males in Lake Dangxiong Co

	cysts	female	male	Total adult
Wet weight, t	1,356	3,059	2,994	6,053
Dry wet, t	338.9	336.5	329.3	665.8

Table 3 Average biomass of *Artemia* cysts and adults in Lake Dangxiong Co

Layer, m	cysts	female	male	Total adult
	Wet biomass, mg/m^3	Wet biomass, mg/m^3	Wet biomass, mg/m^3	Wet biomass, mg/m^3
0-7	680.8	3,568	3,036	6,604
7-14	2,712	5,318	5,660	1,208
Average	1,696	4,443	4,348	10,978

Table 4 Approximate values of total biomass of *Artemia* in Lake Dangxiong Co in August 2013

Layer, m	female			male		
	Length, mm	Wet mass, mg	Dry mass, mg	Length, mm	Wet mass, mg	Dry mass, mg
0-7	12.12	7.136	0.785	9.14	3.373	0.371
7-14	10.85	5.318	0.585	9.54	3.773	0.415

In some samples taken on depth 7-14 m there was a lot of *Artemia* adults in a state of destruction. They were dead when samples were taken. We did not account these dead animals. They were much more abundant than alive adult specimens. It may be assumed as a sign of mass mortality of *Artemia* at that time. We have not enough data to analyze causes and scale of this mortality. Proportions between different stages and high nauplii density showed that population was in an active generative period. Perhaps, that it is only natural phenoptosis - programmed organism death after reproduction (Skulachev, 1999; Shadrin, 2009). During 2011 and 2013 studies *Artemia* population in the lake was in very different states: in 2013 it was in active reproductive state, but in November-December 2011 - in post-reproductive wintering state.

Average density of active stages (ind./m^3) there was higher in 2013 at 2.3 times than in November-December 2011. Average cyst density in 2013 was higher at 1.5 times. We may conclude that now there is new established stable population of *A. sinica* in the lake. Establishment of *Artemia* population as it was shown for Tibetan Lake Danqun Co (Jia, own data) may lead to an increase of species number in phytoplankton (from 1-5 to 9-12) and protozoans with decrease of their total density, and as a result, water transparency increased. Dominance in phytoplankton passed from cyanobacteria to diatoms. Development of *Artemia* in hypersaline lakes led to same results worldwide (Wurtsbaugh et al., 1990; Balushkina et al., 2009). In our opinion, it is possible to harvest at least about 100 t cysts per year from the lake as well as 2 thousands t of freezed biomass or 220 t of dried biomass of adult *Artemia*. Tibetan salt lakes have high potential for *Artemia* industry development. Development of this industry may promote to solve some social, economic, and environmental problems in Tibet. There is only sparse vegetation in northern Tibet, which is destructed by livestock overgrazing. An aquatic bioresources use may lead to shift some people from livestock to new industry to decrease a press of livestock on vegetation and soil.

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