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Report of the

FAO EXPERT WORKSHOP ON SUSTAINABLE USE AND MANAGEMENT OF *ARTEMIA* RESOURCES IN ASIA

Tianjin, China, 7–9 November 2016

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PREPARATION OF THIS DOCUMENT

This document presents the Report of the FAO Expert Workshop on "Sustainable Use and Management of *Artemia* Resources in Asia" that was held in Tianjin, China, from 7–9 November 2016. The workshop was organized by the Aquaculture Branch of the FAO Fisheries and Aquaculture Department Aquaculture Service (FAO FIAA) in collaboration with Tianjin University of Science and Technology (TUST), Tianjin, China. The report was prepared by Dr Mohammad R. Hasan (Aquaculture Officer, Aquaculture Branch, FIAA) and Dr Gilbert Van Stappen (Laboratory of Aquaculture and *Artemia* Reference Center, Ghent University, Ghent, Belgium) with the assistance of Dr Liying Sui, College of Marine and Environmental Sciences, Tianjin University of Science and Technology, Tianjin, China).

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The FAO Fisheries and Aquaculture Department would like to gratefully acknowledge all staff of the Tianjin University of Science and Technology (TUST), Tianjin, China, and in particular, Dr Liying Sui and her colleagues for their excellent cooperation and hospitality provided during the workshop. In addition, the organizers would like to thank all the participants for their time and effort.

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ABSTRACT

The FAO Expert Workshop on 'Sustainable Use and Management of *Artemia* Resources in Asia' was convened in Tianjin, China, from 7–9 November 2016. The workshop was attended by a number of key specialists in *Artemia* study from around the world. The workshop was convened by the FAO Fisheries and Aquaculture Department, Aquaculture Branch (FIAA) and was hosted by Tianjin University of Science and Technology (TUST), Tianjin, China. The workshop was organized starting from the observations that within the global landscape of *Artemia* biodiversity, exploitation and use, China is a key player and that today there is highly advanced and diverse *Artemia* expertise at different universities, research institutes and private companies in China. Nevertheless, there is no regular forum in the country where scientists, entrepreneurs, policy makers and other stakeholders, active in the field of *Artemia* study and use, can exchange thoughts and ideas, and where opportunities for synergy may arise. The workshop was also organized based on the recognition of the importance of *Artemia* in securing world food supply through aquaculture production. The objective of this workshop was therefore to bring together a critical amount of key people, active in the field of *Artemia* biological research, exploitation or use, with as ultimate goal to define the organisational structure for the sustainable management of the *Artemia* resources in China, both inland and coastal, and their optimal use in aquaculture. The workshop convened in plenary throughout the duration of the workshop. In the first day, participants attended a variety of presentations related to (1) History of *Artemia* study and use; (2) *Artemia* biodiversity and sustainable management of *Artemia* resources; (3) Contribution of *Artemia* in biological and medical research; and (4) Application of *Artemia* in aquaculture. In between the presentations, sufficient time was allocated to discussions. The second day a field trip was organised to Chengkou Salt Chemicals, where *Artemia* pond culture and cyst processing is practiced, and to a number of aquaculture facilities: Hebei Xinhai Aquatic Biotechnology (a shrimp breeding centre and hatchery) and Haifa Seafood Industrial Development Co. (a recirculation culture system for marine fish, where *Artemia* is used as live food). The third day was entirely dedicated to plenary discussions and drafting a document with conclusions and recommendations. Following general plenary discussion, the participants identified a number of recommendations in order to stimulate the use of *Artemia* as an aquaculture commodity, its study as an element of biodiversity and its use as biological model organism. The recommendations addressed the need for the establishment of an Asian Regional Artemia Reference Centre (AR-ARC) in China within the immediate future, the agreement that TUST is well-positioned to host this AR-ARC in view of is track record and expertise in *Artemia* studies, and the participants' commitment to support the establishment, organisation and functioning of the AR-ARC. A number of actions were proposed, related to the internal organisation and external linkage of the AR-ARC, and short- and mid-term deliverables, to be produced by the AR-ARC. It is anticipated that these recommendations will guide the FAO FIAA's future guidance in the establishment of the AR-ARC at TUST.

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BACKGROUND TO THE WORKSHOP

The context

The brine shrimp *Artemia* is found in hypersaline habitats such as salt lakes and coastal salt pans worldwide. It is a major live food item, used in the larval stages of aquaculture fish and shellfish. Moreover, it is an important test organism in a variety of life sciences today.

Within the global landscape of *Artemia* biodiversity, exploitation and use, China is a key player. Firstly, the country has numerous inland salt lakes and vast coastal salt works. Many of these are exploited for salt production, turning China into the largest salt producer in the world. Over one hundred of these hypersaline water bodies are inhabited by *Artemia* populations and these extreme habitats show a dazzling ecological diversity. As a consequence, China also houses an exceptionally rich *Artemia* biodiversity, probably more than anywhere else in the world. Several of these *Artemia* resources are exploited, but some of them are over-harvested, bearing the risk of extinction of unique strains. Other resources on the other hand, such as *Artemia* populations in coastal salt works, are exploited far below levels of maximal efficiency and sustainability. Finally, at the demand side, China is the biggest consumer of *Artemia* cysts for aquaculture in the world, and the pressure on the resources is expected to grow further the years to come.

SCOPE AND ORGANIZATION OF THE WORKSHOP

Today there is highly advanced and diverse *Artemia* expertise at different universities, research institutes and private companies in China. Nevertheless, there is no regular forum in the country where scientists, entrepreneurs, policy makers and other stakeholders, active in the field of *Artemia* study and use, can exchange thoughts and ideas, and where opportunities for synergy may arise. The latest international conference dedicated to *Artemia* in China dates back to 2013 and only addressed the role of *Artemia* in solar salt works. FAO FIAA recognizes the importance of *Artemia* in securing world food supply through aquaculture production.

For this reason, FAO FIAA has taken the initiative, in collaboration with Tianjin University of Science and Technology, to organise an expert workshop entitled “Sustainable Use and Management of *Artemia* Resources in Asia” in Tianjin, China, 7–9 November 2016.

Objectives

The objectives of the workshop were to:

- bring together a critical amount of key people, active in the field of *Artemia* biological research, exploitation or use, to review and analyse the existing knowledge on (1) the history of *Artemia* study and use; (2) *Artemia* biodiversity and the sustainable management of *Artemia* resources; (3) the contribution of *Artemia* in biological and medical research in China; and (4) the application of *Artemia* in Chinese aquaculture;
- identify the major issues and constraints for the sustainable management of the *Artemia* resources in China, both inland and coastal, and their optimal use; and
- prepare a list of recommendations to define/suggest the future course of action, including the establishment of an Asian Regional *Artemia* Reference Centre in China.

Participants and workshop venue

The workshop was organized by FAO, hosted by Tianjin University of Science and Technology, Tianjin, China and was held at TEDA campus, Tianjin University of Science and Technology, Tianjin, China.

Over 40 delegates from different countries (Belgium, Chile, China, Iran, Italy, Malaysia, Portugal, Russian Federation and Viet Nam) representing related disciplines of *Artemia* from research and academic institutions,

development organizations, private sectors, ministries and FAO participated in this important event. Delegates from 20 organizations from China participated in the workshop.

The following institutions from China were represented in the workshop: 1) Artemia Association of China, 2) China National Salt Industry Corporation, 3) China Salt Association, 4) Tianjin University of Science and Technology, 5) Department of Ocean Economy, Tianjin Oceanic Administration, 6) Department of Science and Technology, Bureau of Fisheries, Ministry of Agriculture, 7) Division of International Cooperation, Tianjin Municipal Science and Technology Commission, 8) Hebei Xinhai Aquatic Biotechnology Co. Ltd., 9) Huitai Investment Group Co., Ltd., 10) Institute of Mineral Resources, Chinese Academy of Geological Sciences, 11) Ocean University of China, 12) Shanghai Ocean University, 13) Tianjin Agriculture Commission, 14) Tianjin Aquatic Disease Prevention and Control Centre, 15) Tianjin International Joint Academy of Biomedicine, 16) Tianjin Overseas Science and Technology Exchange Commission, 17) Tianjin Agricultural University, 18) Xinjiang Aquaculture Research Institute, 19) Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, and 20) Zhejiang University.

Overseas delegates from six countries (Belgium: Laboratory of Aquaculture and Artemia Reference Center, Ghent University; Chile: Los Lagos University; Iran: Urmia University; Malaysia: University Malaysia Terennganu, Portugal, Russian Federation: Agrarian University of Northern Trance-Urals and Federal State Unitary Enterprise, State Research and Production Center for Fisheries and Viet Nam: Can Tho University) and FAO participated in the workshop. The list of workshop participants can be found in Appendix I.

Modus operandi of the workshop

The deliberation of the workshop was organized into following sessions spread over three days:

a) Introductory session (Day 1, 7 November 2016),
b) Keynote and major thematic presentations (Day 1, 7 November 2016),
c) Scientific presentations (Day 1, 7 November 2016),
d) Field visits to saltworks, *Artemia* cysts processing company, marine fish and shrimp farm (Day 2, 8 November 2016),
e) Discussion and roundup session (Day 3, 9 November 2016).

Professor Jinyu Han, President of Tianjin University of Science and Technology welcomed the participants while Mr Jiansan Jia, Deputy Director, Fisheries and Aquaculture Policy and Resources Division, FI, FAO formally opened the workshop. Two keynote speeches: 1) *Status of world aquaculture and global aquafeed requirement with special notes on Artemia* and 2) *Forty years of research and use of brine shrimp Artemia* spp. were presented respectively by Dr Mohammad R. Hasan of Aquaculture Branch, Fisheries and Aquaculture Department, FAO, Rome and Professor Patrick Sorgeloos of Laboratory of Aquaculture and Artemia Reference Center, Ghent University, Belgium during the Keynote and major thematic session. During this session, two thematic presentations: 1) *Use of Artemia model in biomedical research and 2) History and current status of Artemia research and applications in Bohai Bay area* were presented respectively by Professor Weijun Yang of National Science Fund for Distinguished Young Scholars of China, Zhejiang University, China and Professor Liying Sui of College of Marine and Environmental Sciences, Tianjin University of Science and Technology, China.

The scientific sessions were divided into three thematic areas:

a) *Artemia* biodiversity and sustainable management of *Artemia* resources
b) Contribution of *Artemia* in biological and medical research in China
c) Application of *Artemia* in aquaculture

Altogether 14 scientific papers were presented in this session. Based on the workshop presentations and discussion, main conclusions and recommendations of the workshop were prepared during Discussion and Roundup Session and the proposed actions were agreed. The workshop unanimously agreed that the initiative to establish the Asian Regional Artemia Reference Centre be undertaken in Tianjin University of Science and

Technology in close collaboration with all the concerned stakeholders within and outside the country to promote the sustainable use and improved management of the *Artemia* resources in the region.

The workshop agenda and timetable is presented in Appendix I and the list of participants in Appendix II. Appendix III presents a summary of statements made during the opening and closing ceremonies, Appendix IV provides summaries of the technical presentations, and a group photo is included as Appendix V. PowerPoints of all technical presentations can be found in the following link:
http://www.fao.org/fileadmin/user_upload/affris/docs/PowerPoint_Presentations.pdf

CONCLUSIONS, RECOMMENDATIONS AND PROPOSED ACTIONS

The main conclusions, recommendations and proposed actions of the workshop are summarized as follows:

1. Main conclusions derived from the workshop presentations and discussions

The workshop participants unanimously reached the following conclusions:

1.1 Artemia as an aquaculture commodity

- China is a major aquaculture producer and the biggest *Artemia* cyst consumer in the world. China is also a major supplier of *Artemia* cysts through different production systems (i.e. harvest in Chinese lakes and salt works). Moreover, there is substantial import of cysts from harvests of salt lakes in adjacent areas. There could be potential for more controlled pond production of *Artemia*. Fluctuations in the *Artemia* demand and supply side within China thus tend to have an effect on the global *Artemia* cyst market.
- The *Artemia* cyst market in China is rather complex, with a variety of strains, suppliers, product qualities etc. The market is also rather dynamic (following fluctuations in demand and supply), but also resourceful (with new products and/or application modalities being developed).
- Although the use of *Artemia* biomass is presently less prominent than that of cysts, it has high potential in China (both at the supply and application side).
- There is a general need for more knowledge on correct application modalities of *Artemia* products in the sector (especially given the above described complex landscape). Dissemination of knowledge/tools from academia to the aquaculture sector is often suboptimal. Especially consensus on and knowledge of standards and methods for proper quality assurance and control (and enforcement thereof) and for better use in hatcheries are needed. Presently there is no forum adequately equipped nor having the authority to achieve these goals.

1.2 Artemia as an element of biodiversity and as a biological model organism (in aquaculture and other life sciences)

- China (and adjacent areas) has probably the largest biodiversity of *Artemia* strains/species/ecological habitats, some of which are heavily exploited and subject to invasion by non-native species. To a certain extent there is awareness of the need for improved management for sustainable exploitation; however reliable studies on this issue are rare and consensus on sustainability parameters and goals needs to be reached. A forum to achieve this is lacking.
- Salt lakes and coastal saltworks, as unique *Artemia* habitats, need adequate protection and monitoring.
- Many research centers use *Artemia* as a model organism for a variety of disciplines in life sciences, however using protocols which are not always standardized and/or not generally recognized (nationally/internationally). Concertation is needed to reach this standardization, both within China and on the international level. A forum to achieve this is lacking.
- The imminent availability of the annotated *Artemia* genome and an increasing variety of molecular markers are likely to boost its use as model organism (for aquaculture purposes and beyond), which even increases the need for concertation on deontology, protocols and methodology.

2. Recommendations of the workshop participants

Based on the above conclusions, the workshop participants

- emphasized that there is an urgent need for the establishment of an Asian Regional Artemia Reference Centre (AR-ARC) in China within the immediate future;
- agreed that Tianjin University of Science and Technology is well-positioned to host this AR-ARC, in view of its track record in *Artemia* activities and availability of expertise and infrastructure;
- expressed their strong commitment to fully support the establishment, organization and functioning of the AR-ARC;
- suggested the AR-ARC to operate in a spirit of openness and interdisciplinary with various stakeholders in China and abroad through an Advisory Board;
- took note of the commitment expressed by TUST and by the competent authorities at the central and municipal level, and encourage them to provide full support for the establishment and operation of the AR-ARC.

3. Proposed actions

In order to implement the AR-ARC, the workshop participants thus propose the following actions:

a) Actions related to internal organization and external linkage of AR-ARC:

- Establishment of AR-ARC structure within TUST as soon as possible, following the recommendations of the FAO Expert Workshop;
- Set-up of proper AR-ARC internal structure, including an Advisory Board with representation of the academic sector, the Artemia Association of China (AAC), the government, aquaculture associations, the Artemia Reference Centre (ARC) of Ghent University, Centres of *Artemia* Study elsewhere in Asia (e.g., Iran, Russian Federation, Viet Nam and others) and FAO. The advisory board will prepare and approve a proper activity programme with prioritization of activities, taking into account recommended actions as formulated during the FAO Expert Workshop and summarized hereunder;
- Maintain close links with FAO Fisheries and Aquaculture Department to obtain necessary assistance and support;
- Increase policy awareness about the vital role of China's *Artemia* resources for biodiversity conservation, improved aquaculture outputs and increased salt quality in solar salt works: organization of high-level information sessions to apply for funding of AR-ARC activities; and
- Formalize Chinese interdisciplinary *Artemia* collaboration under the form of a 'Chinese Study of *Artemia*' through regular (annual) meetings at the national and eventually at international level.

b) Actions needed to come to the following deliverables:

Short-term (2 years):

- Consolidate structure of gene bank and associated database, and make it available for the scientific community in China and abroad.
- Set up of web-site of AR-ARC with regular update of relevant information (e.g. publications, events…).
- Establishment of procedures for quality assurance and AR-ARC quality certification of cyst products (develop manual of guidelines and procedures, including inter-calibration with ARC).
- Establishment and extension (e.g. by training course(s) and/or manual(s)) of guidelines and procedures for optimal use of *Artemia* products in Chinese aquaculture (in close collaboration with ARC and AAC).
- Facilitate the setting up of a legal framework for sustainable exploitation and introduction of *Artemia* in China, eventually to be adapted in other *Artemia* producing countries in Asia and elsewhere.

Mid-term (4 years):

- Facilitate and coordinate studies in salt works to document improved salt quality through *Artemia* integration.
- Facilitate and coordinate studies for improved management aiming at sustainable exploitation of *Artemia* habitats in China.

APPENDIX I

WORKSHOP AGENDA AND TIMETABLE

Tianjin, China, 7–9 November 2016

Venue: Meeting Room, Yifu Building, TEDA Campus, TUST

Time	ACTIVITIES
6th November 2016	
	Arrival of the participants in Tianjin
7th November 2016 – Workshop day 1	
08:30–09:00	Registration
Session I: Opening and Welcome Remarks	
09:00–09:40	• Welcome address – *Professor Jinyu Han, President, Tianjin University of Science and Technology, Tianjin, China* • Opening of the workshop – *Mr Jiansan Jia, Deputy Director, Fisheries and Aquaculture Policy and Resources Division, Fisheries and Aquaculture Department, FAO, Rome, Italy* • Message – *Mr Xueguang Wang, Head of Department of Science and Technology, Bureau of Fisheries, Ministry of Agriculture, Beijing, China* • Message – *Mr Li Ding, Head of Tianjin Overseas Science and Technology Exchange Commission, Tianjin, China*
Session II: Presentations – Historical Aspects	
09:40–10:10	Keynote: Status of world aquaculture and global aquafeed requirement with special notes on *Artemia* – *Mohammad R. Hasan, Aquaculture Branch, Fisheries and Aquaculture Policy and Resources Division, Fisheries and Aquaculture Department, FAO, Rome, Italy*
10:10–11:00	Group photo
	Short visit to TUST Laboratories and Artemia Gene Bank
	Coffee/Tea break
11:00–11:30	Keynote: Forty years of research and use of brine shrimp *Artemia* spp. – *Patrick Sorgeloos, Laboratory of Aquaculture and Artemia Reference Center, Ghent University, Belgium*
11:30–11:50	Use of Artemia model in biomedical research – *Weijun Yang, National Science Fund for Distinguished Young Scholars of China, Zhejiang University, China*
11:50–12:10	History and current status of Artemia research and applications in Bohai Bay area – *Liying Sui, College of Marine and Environmental Sciences, Tianjin University of Science and Technology, China*
12:10–13:30	Lunch
Topic 1: Artemia biodiversity and sustainable management of Artemia resources Chair: Professor Patrick Sorgeloos	
13:30–13:45	History and role of the Artemia Reference Center at Ghent University, Belgium – *Gilbert Van Stappen, Ghent University, Belgium*
13:45–14:00	Use of molecular tools in the study of *Artemia* biodiversity – *Gonzalo Gajardo, Los Lagos University, Chile*
14:00–14:15	Biodiversity and biogeography of *Artemia* spp. from China and other places around the world – *Jinshu Yang, Zhejiang University, China*
14:15–14:30	*Artemia* resources in Azerbaijan, Iran and Turkmenistan – *Naser Agh, Urmia University, Iran*
14:30–14:45	*Artemia* resources in Russia and Kazakhstan – *Liudmila Litvinenko, Federal State Unitary Enterprise, State Research and Production Centre for Fisheries, Russia and Marina Korentovich, Agrarian University of Northern Trance-Urals, Russia*
14:45–15:00	Impact of environmental changes on ecology and *Artemia* cyst industry of Aibi Lake in China – *Yan Guo, Xinjiang Aquaculture Research Institute, China*
15:00–15:15	Integrated production of salt and *Artemia* in artisanal salt ponds in Viet Nam – *Nguyen Van Hoa, Can Tho University, Viet Nam*
15:15–15:35	Discussion
15:35–15:50	Coffee/Tea Break

Topic 2: Contribution of Artemia in biological and medical research in China Chair: Professor Gonzalo Gajardo	
15:50–16:05	Selective breeding research with *Artemia*: possible model for commercial crustacean species? – *Shen Luan, Yellow Sea Fisheries Research Institute, CAFS, China*
16:05–16:20	Heat shock proteins in Artemia: role and possible applications in aquaculture – *Yik Sung Yeong, University Malaysia Terennganu, Malaysia*
16:20–16:35	Structural view on Artemin, an important chaperon in Artemia – *Xiang Liu, Tianjin International Joint Academy of Biomedicine, China*
16:35–16:50	Halophilic bacteria as food for Artemia – *Ruy Dos Santos, Ghent University, Belgium*
16:50–17:10	Discussion
Topic 3: Application of Artemia in aquaculture Chair: Professor Liying Sui	
17:10–17:25	*Artemia* market situations in China – *Bo Zhang, Tianjin University of Science and Technology, China and Song Gao, President of Artemia Association of China*
17:25–17:40	Use of *Artemia* in the larviculture of commercially important crab species in China – *Xugan Wu, Shanghai Ocean University, China*
17:40–17:55	INVE's experiences in the exploration of new commercial *Artemia* resources for the aquaculture industry – *Patrick Sorgeloos on behalf of INVE Aquaculture*
17:55–18:15	Discussion
19:00	Dinner
8th November 2016 – Workshop day 2	
FIELD TRIP	
1	Facilities for *Artemia* pond culture, cysts processing and seafood processing, Huitai Group, Shandong Province
2	*Litopenaeus vannamei* breeding centre and hatchery, Hebei Xinhai Aquatic Biotechnology, Hebei Province
3	Recirculation culture system of marine fish, Tianjin Haifa Seafood Industrial Development Co. Ltd., Tianjin City
9th November 2016 – Workshop day 3	
Venue: Meeting Room, Yifu Building, TEDA Campus, TUST	
09:00–12:00	*Round table discussion and concluding remarks* Chair: Mr Jiansan Jia
12:00	Closing address – *Professor Fuping Lu, Deputy Rector, Tianjin University of Science and Technology*
12:30–13:30	Lunch
14:00	City sightseeing tour upon request – visit to ancient culture street in Tianjin City
10th November 2016	
	Participants depart Tianjin

APPENDIX II

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APPENDIX III

OPENING AND CLOSING REMARKS

Welcome address

Professor Jinyu Han, President, Tianjin University of Science and Technology, Tianjin, China

Dear academician Zheng Mianping, Mr Jiansan Jia, distinguished guests, ladies and gentlemen, good morning!

Today, we are here to witness the opening of FAO Experts workshop on sustainable use and management of Artemia resources in Asia. On behalf of all the faculty and students of TUST, I would like to express my warmest welcome to all the experts from home and abroad. My thanks also go to all the leaders and friends for your care and support of TUST over the years. TUST was set up in 1958, being one of the earliest light industry universities in China. In recent years, TUST has seized the opportunity and deepened reform and achieved remarkable growth. With the internationalization effort, TUST stands by the Bohai Rim with a new profile. Our agrology is listed the top 1 percent ESI globally, bio-engineering top 1 percent in China, light industry, food science and engineering top 5 percent in China. We have partnered with over 80 universities and research institutes in 30 different countries. We had around a score of national and municipal key labs, coordinated innovation centre, engineering centres and research commercialization centres, all of which have contributed a lot to the students' cultivation, scientific research, social services and international communications. TUST is known as the cradle of salt-based chemical engineering and production and has achieved quite a reputation at home and abroad in the area of use and management of *Artemia* resources. We set up the first *Artemia* breeding database and we are a starting member of Chinese association of *Artemia* resources. We have conducted extensive and concrete cooperation with Chinese and foreign research centres and universities in joint research, exchange of researchers, academic exchanges and students. China is rich in *Artemia* resources and has achieved a leading position in the world after dozens of years of research and accumulation.

The workshop today will greatly boost international exchanges and cooperation to achieve a sustainable development and use of *Artemia* resources in Asia. I would expect all the experts here today would contribute your wisdom and promote research in *Artemia* resources and related disciplines. Meanwhile, I would like to wait for your advice and suggests for academic development at TUST.

I wish the workshop can promote understanding and closer partnership and more fruitful research. Finally, I wish the workshop a great success and enjoy your stay in Tianjin, Good health to everyone.

Thank you!

Opening of the workshop

Mr Jiansan Jia, Deputy Director, Fisheries and Aquaculture Policy and Resources Division, Fisheries and Aquaculture Department, FAO, Rome, Italy

Distinguished guests and friends, dear colleagues, ladies and gentlemen,

It is my great pleasure to attend on behalf of FAO Fisheries and Aquaculture Department at this important Expert Workshop on Sustainable Use and Management of *Artemia* Resources in Asia. To set the scene, I would like to briefly present the current status, trends and future perspectives of global aquaculture so that it will help to facilitate the successive discussions. I apologize that I am speaking in English. With the kind assistance of the interpreters, I hope the messages will be delivered to those who speak Chinese only.

The total global fisheries and aquaculture production in 2014 was 167.3 million tonnes. World aquaculture production of aquatic animals accounted for 73.8 million tonnes. In 2014, we reached a milestone when the aquaculture sector's contribution to the supply of fish for human consumption overtook that of capture fisheries for the first time. In 2014, fish harvested from aquaculture amounted to 73.8 million tonnes, with an estimated first-sale value of USD160.2 billion. Almost all fish products produced from aquaculture are destined for human

consumption, although certain amount of by-products from fish processing are used for non-food purposes. And aquaculture is perceived as having the greatest potential to meet the growing demand for fish and other aquatic products. Aquaculture plays a vital role in global efforts to reduce hunger and malnutrition. In 2014, the fish consumption reached a historic high of 20.1 kg per person per year world-wide with aquaculture contributing to 50.4 percent of total fish and aquatic products consumed. Fish and other aquatic foods are rich in protein, essential fatty acids, vitamins and minerals, which are of significant importance in improving human nutrition. Non-food products from aquaculture are also making significant contribution to the local livelihoods and economic growth. Most aquaculture is produced in the developing countries. As a whole, Asia contributes 90 percent of total aquaculture production of food fish. The top ten producers are predominant by developing countries. It is a widely accepted fact that the aquaculture contributes towards food security, support to livelihood of the rural poor and reduced urban migration and increased protein intake in addition to creating employment, contributing to GDP growth and local revenue generation and taxation, etc. The sector contributes to development and improves incomes, provides employment and increases the returns on resource use. According to FAO's study, aquaculture employed about 30 million people globally, with about 19 million direct and 11 million indirect employments.

Considering the projected population growth over the next decades, if the world is to meet the demand for fish supply, it has to come from aquaculture since the capture fisheries landings have stagnated. It is estimated that an additional 35 million tonnes of aquatic food will be needed by 2030 just to maintain current consumption levels. In not too distant future, the share of supply for human consumption by aquaculture will increase to somewhere between 60–70 percent. The prospective analysis of the sector conducted by FAO showed a very promising future with a number of observations. One of them is that the sector goes for more intensified and diversified production systems and species due to access to scarce land and water resources. It appears a shrinking availability of suitable locations for developing aquaculture, there is a growing trend towards sea-farming where many countries are facing feed problems including in particular that of the larval stage. Sustainable management and use of *Artemia* resources is one of the key impediment factors faced by mariculture.

So much about the importance of aquaculture in providing food for improving food and nutrition security, employment, socio-economic development and growth. However, what makes sense is that we all understand that it is also closely related to the subject of today's discussion here on sustainable management and use of *Artemia* resources. As you are all aware, the brine shrimp *Artemia* is found in hypersaline habitats such as salt lakes and coastal salt pans worldwide. It is a major live food item that is widely used in the larval stages of aquaculture fish and shellfish. Moreover, it is also an important test organism in a variety of life sciences today.

Within the global landscape of *Artemia* biodiversity, exploitation and use, China is a key player. Firstly, the country has numerous inland salt lakes and vast coastal salt works. Many of these are exploited for salt production, turning China into the largest salt producer in the world. And these hypersaline water bodies are inhabited by *Artemia* populations and these extreme habitats show a dazzling ecological diversity. As a consequence, China also houses an exceptionally rich *Artemia* biodiversity, probably more than anywhere else in the world. Several of these *Artemia* resources are exploited, but some of them are over-harvested, with the risk of extinction of unique strains. Other resources, on the other hand, such as *Artemia* populations in coastal salt works, are exploited far below levels of maximal efficiency and sustainability. Finally, at the demand side, China is the biggest consumer of *Artemia* cysts for aquaculture in the world, and the pressure on the resources is expected to grow further in the years to come.

Today there is highly advanced and diverse *Artemia* expertise at different universities, research institutes and private companies in China. So far, there has not been regular forum in the country where scientists, entrepreneurs, policy makers and other stakeholders, active in the field of *Artemia* study and use, can share their experiences in research, conservation and development work as well exchange of renovation and ideas where opportunities for synergy may arise. The latest international conference dedicated to *Artemia* in China dates back to 2013 and only addressed the role of *Artemia* in solar salt works. The Food and Agriculture Organization (FAO) of the United Nations recognizes the importance of *Artemia* in securing world food supply through aquaculture production. For this reason it has taken the initiative to convene this meeting, aiming to bring together a critical amount of key people, active in the field of *Artemia* biological research, exploitation, conservation and sustainable use of the *Artemia* resources. The ultimate goal of this event is the sustainable management of the *Artemia* resources in China and neighbouring countries, both inland and coastal, and their optimal use in

aquaculture, and eventually to establish an Asian Regional Artemia Reference Centre that will facilitate collaborations among stakeholders for improving management and use of *Artemia* resources in the country.

Last but not the least, I would take the opportunity to express my sincere grateful appreciations to Tianjin University of Science and Technology for hosting the event, and to Tianjin Municipal Government for their support provided to the event, and also to the Ministry of Agriculture and Bureau of Fisheries, Chinese Academy of Fishery Sciences, and other organizations/institutions.

I wish you all a happy stay in Tianjin and a fruitful discussion.

Thank you!

Message – *Mr Xueguang Wang, Head of Department of Science and Technology, Bureau of Fisheries, Ministry of Agriculture, Beijing, China*

Dear Academician Zheng Mianping, Mr Jia Jiansan, Distinguished guests, good morning.

It is my great pleasure to be invited to the FAO Experts Workshop on Sustainable Use and Management of *Artemia* Resources in Asia. First, please allow me to express my warm congratulations to the workshop on behalf of Fisheries Bureau, Ministry of Agriculture. I would also like to thank world food and agriculture organization and all the friends for your support and care of fisheries in China.

Ladies and gentlemen, the Chinese fishery has undergone a relatively high speed of growth over the years with an evident increase of product, higher quality safety and abundant market supply. In 2015, we produced 6 699 tonnes, 76 percent of which are from the aquaculture. Sampling test indicated that 99.6 percent of the marine products are above quality standard. The total size of fishery economy reached 2.2 trillion Yuan, the output value of fishery reached 1.13 trillion Yuan. The per capita income of fisherman reached 15 000 Yuan, the international trade value of aquatic products reached USD29.3 billion with a surplus of USD11.35 billion. The fast development of fishery has made remarkable contribution to China's food security, increase of fisherman's income, and promotion of social and economic development. It is also a major contributor to world food security. Lester Brown, an American agriculture and ecologist, thinks high of what Chinese aquaculture to the world. He said he was impressed by two Chinese contributions to the world, one is aquaculture, the other being family planning.

Dear friends! As it is known to all, the theme of our workshop is *Artemia*, though small, it is quite powerful. It is not only an important lab insect used for life science research, but also a major living feed to juveniles of sea life, an indispensable ingredient for aquaculture.. We know that aqua-breeding is the basis of aquaculture, and *Artemia* is the most fundamental element in aqua-breeding. Therefore, the development and research on *Artemia* has always been our prioritized interest.

China is rich in *Artemia*, which profuse in salt pans and inland hypersaline waters, particularly in northwest China and Bohai rim. Its annual production capacity is around 800 – 1 200 tonnes, about 1/3 of the world total. Despite our enormous capacity, China still needs to import 300 – 400 tonnes of *Artemia* to meet the need of Chinese aquaculture industry. "Need is the incubator of invention" the strong demand from Chinese aquaculture industry will drive *Artemia* industry to develop and guarantees a bright future in Chinese market.

Currently we are doing our best to restructure our fisheries in China. During the 13th five-year plan period, we will improve the quality, elevate the efficiency, reduce the amount, raise the income for a green development to enrich the fishermen and to meet the need of side supply reform. We will orient the industry to healthy culture, reasonable harvest, preserve the resources and intensify the industry, improve the breeding. We will reduce the traditional production with low production high pollution, striving to develop standard healthy aquaculture, raise our quality standard, protect the environment, improve the infrastructure, add more information device, use science and technology to boost the industry and use law to govern the development of fishery so that we will have a new environment friendly fishery pattern with efficient yield, safe products, resource-conservation.

science and technology to boost the industry and use law to govern the development of fishery so that we will have a new environment friendly fishery pattern with efficient yield, safe products, resource-conservation.

The 13th 5-year plan period will be a major strategic restructuring period. According to statistics, the rate of genetic improvement in the Chinese aquaculture is only 25 percent, and the fine breed coverage is only 50 percent. Therefore, there is still large room for development for aquaculture industry, in another word, there is lots of potential for *Artemia* industry, which will play a more important role in the future development of aquaculture industry in China. I believe that the UNFAO has made the right decision to have the workshop in the right place at the right time. I hope the Chinese researchers and industrialists will seize the opportunity to work on the sustainable use and management of *Artemia* resources with our foreign friends, for China and for the world fishery.

During the 13th 5-year plan period, we will focus on "improving breeding, setting up a fine breeding research system, incubating some corporations that integrate breeding, culturing and marketing, elevating fine breed coverage, support the development of *Artemia* industry in China. We will make use of our strength in Chinese *Artemia* industry and work together with our international colleagues to conduct *Artemia* resource diversity preservation, promote exchange of information on breeding, production and application service platform. Let's join our hands to promote the sustainable development of *Artemia* resources for a successful fishery restructuring in China.

On behalf of fisheries bureau of Chinese Ministry of Agriculture, I would sincerely welcome the establishment of Regional Artemia Centre in China and we will be very happy to coordinate and facilitate related work.

Finally, I wish the workshop a great success and I wish great health and happiness to our distinguished guests and your family.

Thanks

Message – *Mr Li Ding, Head of Tianjin Overseas Science and Technology Exchange Commission, Tianjin, China*

Dear Mr Jiansan Jia, Mr Mohammad Hasan, Mr Zhengmianping, Liu Xueguang, Liuyingjie, lijiahua, President Han Jinyu, distinguished guests, ladies and gentlemen, good morning!

It is my great honour to join the workshop. First, on behalf of Tianjin Municipal Committee of science and technology, I would like to give my heartfelt congratulations to the opening of the workshop.

Artemia is an indispensable ingredient in marine economic industrial chain. China is rich in *Artemia* variety and quantity, China is also a major consumer of *Artemia* cysts. Tianjin is a very important city in *Artemia* research and *Artemia* cysts production. The sales of *Artemia* cysts from Tianjin occupies half of the Chinese market.

Since the 1980s, with the support from UNDP, EU framework and Chinese ministry of science and technology, TUST and China Salt Production S&T research centre began to study the feature of *Artemia* in China and its application in aquaculture. We have made some remarkable achievements in international joint research, personnel cultivation and research commercialization.

Over the years, the Tianjin Committee of science and technology has always prioritized scientific innovation in our work and we believe that S&T driven corporations are the key for us to accelerate our development, economic restructure and encourage scientific innovation. By far, in Tianjin, there are around 90 000 S&T driven corporations and 4 000 of which has an annual sale exceeding ¥ 100 million. By the end of 2015, the percentage of R&D is 3.08 percent of the total city GDP, making Tianjin a leader in S&T in China. For the past 14 years, Tianjin has always been ranked top three cities in China in the comprehensive scientific and technological progress.

The workshop today is organized by FAO of UN and has gathered lots of leading experts in *Artemia* research. The workshop will focus on sustainable use and management of *Artemia* resources in Asia, particularly in China. We expect the workshop to promote basic and applied research on *Artemia*, improve technology and utility of *Artemia* cysts and play a positive role in aquaculture industry.

As China is very important in the amount of *Artemia* resources and sea life breeding in the world, we propose to set up an Asian Regional Artemia Centre and make use of the resources and advantages in *Artemia* resources, providing information and training to OBOR countries, support fishery and aquaculture, to help to hit the target of UN millennium goal in poverty relief, food nutrition and safety, environment protection and biodiversity preservation.

Dear friends, Tianjin is a very open and dynamic city. We warmly welcome international organizations, universities, research centres to carry out in-depth cooperation with universities in Tianjin. As the chief S&T management body the city, we will do our best to provide all-round services and support, to help to achieve a win-win result.

Finally I wish the workshop a great success, enjoy your stay in Tianjin.

Thanks!

Wrap up and closure

The workshop was wrapped up by Professor Fuping Lu, Deputy Rector, Tianjin University of Science and Technology, who indicated that he was satisfied that the objectives of the workshop had been achieved and thanked all the participants and the organizers for helping to make the event the success that it was. He wished everyone a safe trip home.

APPENDIX IV

SUMMERIES OF TECHNICAL PRESENTATIONS

Keynote presentation

Status of world aquaculture and global aquafeed requirement with special notes on *Artemia*

Mohammad R. Hasan, Aquaculture Branch, Fisheries and Aquaculture Policy and Resources Division, Fisheries and Aquaculture Department, FAO, Rome, Italy

In 2014, global aquaculture production reached 101.1 million tonnes, 73.8 million tonnes of aquatic animals and 27.3 million tonnes of aquatic plants, growing at an average annual rate (APR) of 6.7 percent since 1995. This increasing trend is projected to continue in future decades; consequently, the aquaculture sector is expected to play a significantly greater role in contributing to food security, poverty alleviation and economic development of the poor.

During the period 1995 – 2014, production from feed-dependent aquaculture increased almost about fourfold from 12.2 to 48.6 million tonnes, largely through intensification of production methods. The use of aquatic species/species groups such as tilapias, carps, shrimp and salmonids with established aquaculture technologies provided firm market opportunities for increasing production and driving production efficiency. In 2014, about 48.6 million tonnes of farmed fish (including Indian major carps) and crustaceans (48.0 percent of the total global aquaculture production including aquatic plants or 65.8 percent excluding aquatic plants) was dependent upon the supply of external nutrient inputs provided in the form of fresh feed ingredients, farm-made feeds or commercially manufactured feeds. In 2014, fed aquaculture contributed to 85.5 percent of global farmed finfish and crustacean production of 48.6 million tonnes. During the period from 1995 – 2014, production of industrial aquafeed has increased from 7.6 to 44.3 million tonnes. These estimates took no account of the commercial feed used by Indian major carp, which are increasingly fed with commercial feed along with supplementary feeds.

Although there are precise estimate of global aquaculture production and subsequently the data of industrial feed used/produced for global aquaculture, there has been dearth of information on production and use feed/live food for larval stages for many of the freshwater/brackishwater fish and shell fish. Most of the aquaculture fish/shell fish species require specialized feed specifically the live food in their larval stage after absorption of egg yolk. Also often the broodstock require specialized diet or live food to meet their special requirement which cannot be met by normal dry feed. Commonly used larval food are phytoplankton/algae and zooplankton (e.g. rotifer). Although *Artemia* are the ideal live food for fish and shell fish larvae, its use has been limited by its volume of production and subsequently the cost. In most of marine finfish and crustacean hatcheries, phyto and zooplankton are used and then weaned to specialized dry diet. Often the use of the phyto and zooplankton result sub-optimal nutrition of the larvae resulting in low survivability and then weaning to specialized larval dry diet will increase the cost of production.

Commercial availability of *Artemia* cysts were reported from salt lakes in the San Francisco Bay (SFB) area of the United States of America in early 1960s. From 1970s new commercial source of *Artemia* were available from the Great Salt Lake (Utah, United States of America) in much larger quantities (over 100 tonnes) as compared to SFB (around 10 tonnes). For many years the Great Salt Lake has been the main source of *Artemia* cysts, however, due to seasonal conditions harvests were very variable. From 1980s new sources (but small quantities: around 10 tonnes) were available from Australia, Brazil and China.

From mid 1990s new quantities of *Artemia* (over 100 tonnes) became from Central Asia (primarily Turkmenistan, Siberia of Russian Federation, Kazakhstan). Presently some 1 500 tonnes of tonnes per year enter into the market from the countries of Central Asia. Expansion of cyst products from China as several new sources were tapped (coastal salt pans and inland salt lakes) ((Aibi Lake and Bohai Bay area), at times over 500 tonnes per year. However, significant drop was recorded in recent years; where China was a net exporter of cysts, they now import large quantities, mainly from Central Asia. At present the world production of *Artemia* cysts is estimated at over 4 000 tonnes per year with about 1/3 each from Great Salt Lake, Central Asia and China.

Biggest consumer of *Artemia* cysts is China with over 50 percent of what is available worldwide. Global consumption of *Artemia* has increased significantly over the last few decades. Estimated annual consumption of *Artemia* cysts was only few tonnes in the 1970s and was just over 100 tonnes in the 1980s. Fast expansion of *Artemia* consumption in 1990s was in parallel with the fast expansion of the hatchery sector (especially of shrimp). The consumption of *Artemia* was 1 500 tonnes in the late 90s, while it was more than 3 000 tonnes as of 2010.

Although *Artemia* can be considered as an ideal larval live food, its consumption is limited mostly to marine shrimp (whiteleg shrimp, *Litopenaeus vannamei* and black tiger shrimp, *Penaeus monodon*) (85 percent of all cyst consumption is in shrimp hatcheries with 3 to 6 kg of cysts needed for the production of 1 million PLs). *Artemia* consumption was also reported by selected high value marine finfish (European seabass, *Dicentrarchus labrax* and Gilthead seabream, *Sparus aurata*).

An additional 27 million tonnes of aquatic food will be required by 2030 considering the projected population growth and to maintain the per caput consumption. Availability of feed will be one of the most important inputs if aquaculture has to maintain its sustained growth to meet its challenge of increased production. Aquafeed production is expected to continue growing at a similar rate to 49.7 million tonnes by 2015 and 69.0 million tonnes by 2020. If this growth is to be sustained then feed ingredient and feed input supply must grow at a similar rate. Similarly live food for hatchery will remain a critical factor, *Artemia* being the most important live food. Although production and use of *Artemia* are increasing, demand cannot match the production/ availability. Based on FAO production statistics (2016) data and Market survey, Inve Aquaculture calculated global shrimp PL stocking in 2014 to be 607 billion for whiteleg shrimp and 41 billion for black tiger shrimp and estimated the *Artemia* cysts requirements of 2 278 tonnes for these two species alone. Unfortunately, there has been no coordinated effort in production, use and management of this resources unlike that of industrial aquafeed. Therefore there are need for global/regional efforts for sustainable production, use and management of this important resources.

Forty years of research and use of brine shrimp Artemia spp.
Patrick Sorgeloos, Laboratory of Aquaculture and Artemia Reference Center, Ghent University, Belgium

The 1976 FAO Technical Conference on Aquaculture in Kyoto (Japan) was an important trigger for research in Asia, Europe and the America's on various aspects of the use of *Artemia* in the larviculture of commercially important species of fish and crustaceans:

- large-scale cyst hatching and use of freshly-hatched nauplii as food source
- nutritional enrichment of the meta-nauplii
- use of *Artemia* biomass for feeding nursery and maturation stages of fish and shrimp
- characterization of different geographical strains of *Artemia* through the interdisciplinary research program "International Study on *Artemia*"
- harvesting and processing of cysts and biomass from salt lakes and salt ponds
- production of biomass and cysts in seasonal saltworks

Over the years *Artemia* has become a model organism for basic research in different biological disciplines of direct and indirect interest for innovations in aquaculture: host-microbe interactions, breeding studies, epigenetics, immunology, nutritional studies (bioflocs), ecotoxicology and cell cycle studies. The recent annotation of the *Artemia* genome will provide even more tools for further expansion of basic research with brine shrimp *Artemia* species.

Technical presentation

Use of *Artemia* model in biomedical research

Weijun Yang, Institute of Cell and Developmental Biology, College of Life Sciences, Zhejiang University, Hangzhou, Zhejiang, China

In eukaryotes, tRNA trafficking between the nucleus and cytoplasm is a complex process and connects cell cycle regulation, such trafficking is therefore of fundamental importance in cell biology and disruption of this process has grave consequences for cell viability and survival. To cope with harsh habitats, *Artemia* has evolved a special reproductive mode to release encysted embryos in which cell division can be maintained at a dormancy state for long period. Using *Artemia* as a peculiar model of cell cycle study, a La-related protein from *Artemia*, named as Ar-Larp, was found to bind to tRNA and accumulate in the nucleus leading to cell cycle arrest and controlling the onset of diapause formation of *Artemia*. Furthermore, the exogenous gene expression of Ar-Larp could also induce cell cycle arrest in the cancer cells and suppress tumor growth in a xenograft mouse model similar to the results obtained with diapause embryo of *Artemia*. Our study on tRNA trafficking indicated that Ar-Larp controls cell cycle arrest by binding to tRNAs and influencing their retrograde movement from the cytoplasm to the nucleus which is connected to pathways involved in cell cycle checkpoints. These findings will offer new insights into the mechanism of cell cycle arrest regulation, as well as providing a potentially novel approach to study tRNA retrograde movement from the cytoplasm to the nucleus.

History and current status of *Artemia* research and applications in Bohai Bay area

Liying Sui, College of Marine and Environmental Sciences, Tianjin University of Science and Technology, Tianjin, China; Naihong Xin, Salt Research Institute of CNSIC, Tianjin, China

Bohai Bay coast is the major sea salt producing area in China, with dozens of saltworks covering 1500 km^2 and a total annual yield of 20 million tonnes. Most of the saltworks have been used for salt production for hundreds of years. As a major population inhabited in evaporation saltponds, there is the positive role of proper *Artemia* management in salt production. Moreover production of the valuable product (cysts and biomass) also benefit to the local saltworks.

The commercialization of *Artemia* cysts in Bohai Bay costal area dated from late 1980s. In early 1990s, with support of UNDP and EEC, Salt Research Institute (SRI) of China National Salt Industry Corporation has taken an initiative in a number of studies regarding to a better biological management of saltponds, improvement and characterization of local *Artemia* strain, and improved techniques for hatching and use of *Artemia* in the farms. The outcome of these studies has played a key role in field of *Artemia* research and *Artemia* industry at the time.

Artemia cysts from Bohai Sea salt ponds are known as higher hatchability and better nutritional value and thus highly demanded in the market. However, presently *Artemia* cysts and biomass production from the Bohai Bay saltworks is below capacity, due to insufficient management, brine water acidification and culture of shrimp in lower salinity. Currently the average annual dry cysts production from Bohai Sea saltponds is less than 200 tonnes, accounting for about 20–30 percent of its total production in the 1990s.

To move towards the challenge on Bohai Bay *Artemia* resources, since 2008 Tianjin University of Science and Technology (TUST) has made great efforts on *Artemia* research and its application, focusing on improving *Artemia* pond production, *Artemia* biodiversity and population dynamic study, and use of gnobiotic *Artemia* model in study of aquatic disease control. The works have been done in the framework of domestic and international collaboration with a number of universities as well as aquaculture companies. Recently TUST has established *Artemia* Gene Bank, aiming to extensively collect and proper preserve *Artemia* cysts around the world, and to protect *Artemia* resource biodiversity; to set up information platform and network for local and international scientists, enhance and coordinate inter-discipline *Artemia* research.

History and role of the Artemia Reference Center at Ghent University, Belgium
Gilbert Van Stappen and Patrick Sorgeloos, Laboratory of Aquaculture and Artemia Reference Center, Ghent University, Ghent, Belgium

Research at Ghent University on the brine shrimp *Artemia* and its use in aquaculture started in 1970, first as part of the Laboratory of Ecology, and later on as part of the Laboratory of Mariculture. The Artemia Reference Center (ARC) was set up as a section of the Laboratory of Mariculture in 1978, coordinated by Patrick Sorgeloos, under the auspices of the Food and Agriculture Organisation of the United Nations. It became an independent Research Center of the Faculty of Agricultural Sciences (now: Faculty of Bioscience Engineering) in 1985. In view of the expansion and diversification of research and training activities the name "Laboratory of Aquaculture and Artemia Reference Center" was adopted in 1989.

Since 1978 the ARC has gained a leading role in research on larviculture of fish and shellfish species of aquaculture interest. Initially, the main research effort focused on the universally used brine shrimp *Artemia* as vital food source for fish and shellfish larvae, namely: brine shrimp culturing biology, natural occurrence, production techniques, strain characterisation, nutritional value and enrichment. Gradually, research activities extended into the other live food organisms, and to zootechnical, microbiological and immunological aspects of larviculture. Therefore, the ARC engaged in a multidisciplinary collaboration effort with specialists from different research institutes, local and abroad, in the framework of nationally and internationally funded R&D projects. As one of its achievements, ARC has accumulated the biggest collection of *Artemia* cyst samples in the world, which it makes internationally available for research purposes. Moreover, as ‘reference’ center, it has played, and is still playing, a decisive coordinating and stimulating role in *Artemia* study worldwide.

Use of molecular tools in the study of *Artemia* biodiversity
Gonzalo Gajardo, Laboratory of Genetics, Aquaculture and Biodiversity, University Los Lagos, Osorno, Chile

The suggestion by the Convention on Biological Biodiversity (CBD) “to maintain genetic diversity of farmed and domesticated animals and to develop strategies for minimizing genetic erosion and safeguarding their genetic diversity” has enormous relevance for an extremophile like *Artemia*, as the potential to cope with the harsh ecological conditions. Hypersaline natural or artificial environments impose on survival and reproduction depends on genetic diversity. The aquaculture use of *Artemia* has promoted premeditated and unintended translocation of regionally-adapted species as well as locally adapted populations, risking production predictability but also natural *Artemia* diversity that stands as genetic reservoirs for the sustainable use of *Artemia* in aquaculture.

The haploid *Artemia* genome is roughly estimated to be 1 Gb. This presentation reviews past and present tools and the available markers to assess genetic diversity at different levels (from individuals to species) and to scrutinize coding and not coding regions throughout the linkage groups of *A. franciscana* (diploid number, 2n=42). Such markers (including sex-linked) allow also to identify genes involved in adaptation to natural or artificial conditions, and those underlying important productive traits, and to map their location in the *Artemia* chromosomes. The future exploitation of *Artemia* in costal ponds will require monitoring how key productive-related genes (for example, those involved in cyst production), or the associated markers, evolve during the production cycle for more predictable outputs.

Biodiversity and biogeography of *Artemia* spp. from China and other places around the world
Jinshu Yang, Institute of Cell and Developmental Biology, College of Life Sciences, Zhejiang University, Hangzhou, Zhejiang, China

Artemia is one of the most important live food items used in larval aquaculture worldwide. Although *A. franciscana* is the most popular species applied in practice, a variety of geographically separated *Artemia* strains are distributed all over the saline waters on Earth. Merely in China, we have two native bisexual *Artemia* species (*A. sinica* and *A. tibetiana*), as well as plenty of parthenogenetic strains that are distributed in northwestern areas and along the eastern-southern sea coasts of the country. Along with expanding inoculation and competing overgrowth of *A. franciscana*, many endemic strains have been gradually replaced by this foreign invader. Therefore, characterizing and preserving local biodiversities becomes more and more important, especially for

the ancient crustacean *Artemia*. Our study aims to reveal biogeographical clues by using complete mitochondrial genomes of different *Artemia* strains. We investigated *Artemia* strains from China and other places all over the world, including those undergo both bisexuality and parthenogenesis. Our results provide consolidated evolutionary relationships of these geographically distributed lineages, which also give us an explainable evolutionary history of different *Artemia* species/strains. Our study will help to understand origin and evolution of this small crustacean, as well as to direct protecting precious biological resources that are confronted with the danger of extinction.

Artemia resources in Iran, Azerbaijan and Turkmenistan

Naser Agh, Artemia and Aquaculture Research Institute, Urmia Lake Research Institute, Urmia University, Urmia, Iran

Lake Urmia in northern west of Iran, was known as one of the largest natural biotopes of *Artemia* in the world. Based on the studies by the team of experts from Artemia Reference Center, University of Ghent, Belgium, headed by Professor Patrick Sorgeloos, production of *Artemia* cysts in Lake Urmia accounted to as high as 30 000 tonnes annually. But the lake has been facing grave crisis since 20 years and production of *Artemia* has ceased since 5 years. Two populations of *Artemia* (bisexual *Artemia urmiana* and a parthenogenetic population) used to coexist in Lake Urmia. Seventeen other lakes and wetlands with *Artemia* populations were recognized in Iran, but most of them have dried during last decade. Therefore a number of artificial lakes and ponds were constructed attempting to produce *Artemia* cysts for the growing aquaculture activities in Iran. Currently the largest pond production of *Artemia* is located in central province of Iran, Kerman, producing *Artemia franciscana*. Pond production in two more sites will begin from next year.

Azerbaijan Republic seems to have the capacity to partially compensate the loss of *Artemia* from Lake Urmia. A number of saline lakes were recognized in Azerbaijan dominated by parthenogenetic populations of *Artemia*. We started studying the saline lakes of Azerbaijan and helping a local company in exploitation, processing and marketing of the cysts. During first year we could harvest about 12 tonnes of cysts from two pond (250 ha) and we predict to increase the harvest up to 20 tonnes next year.

Karabogaz Lake (18 000 km^2) was one of the largest natural biotopes of *Artemia* in the world, located in Turkmenistan, Central Asia. The salinity of the lake has increased significantly, crossed 300 ppt, due to gradual decrease in the water flow from the Caspian Sea, as major water resource of the lake. Studies have been initiated to find out possible methods for restoration of *Artemia* population in the lake or at the surroundings of the lake.

Artemia resources in Russia and Kazakhstan

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On the territory of Russian Federation and Kazakhstan there are about 120 and 90 natural reservoirs respectively where *Artemia* habit. Only half of the lakes have commercial value. In the territory of the northern part of the Eurasian area within the coordinates 30^0–90^0 E and 40^0–55^0N, *Artemia parthenogenetica* are noted in dominate amount. However, on the western and eastern boundaries of this area and in Kazakhstan bisexual populations were found. Part of them was identified as *A. urmiana* (according to the research group of authors headed by T.J. Abatzopoulos) and *A. salina* (according G. Mura, L. Nagorskaya and others) in the Crimea, *A. sinica* (according to E. Boiko) in Tuva (Svatikovo lake), *Artemia* sp. (Pilla and Beardmore, 1994) in Kazakhstan.

In Russia harvests of *Artemia* cysts have been conducted since the 1970s. For 45 years of harvesting, the volumes of cysts harvest have been increasing significantly. Since 2000 harvest has stabilized. It has made 1 000 tonnes of cysts in wet weight in the average for 15 years. The maximum amount of harvest in volume 1 620 tonnes was obtained in 2007. In 2015 harvest was 1 383 tonnes. Due to the favorable conditions associated with increased water availability after 5 years period of low water content the harvest exceeding of 2 000 tonnes is expected in 2016. In Kazakhstan, the volume of available catch ranges 1 040–1 350 tonnes of *Artemia* cysts, including 120–220 tonnes in the Aral Sea. Analysis of the custom data of Kazakhstan and Russia for recent three years has showed that approximately the quantity of exported cysts from Russia is about 800–900 tonnes per year in wet weight and 100–200 tonnes cysts in dry weight, from Kazakhstan it is about 1 000 tonnes in wet weight. The

main country for cyst import is China, Thailand, and Germany. The analysis of literature data and personnel communication showed that about 3–4 thousand tonnes of dry cysts are produced annually in the world, among which about 500 tonnes *Artemia* cysts are harvested annually in Russia. Thus, Russian's share in the world market of cysts is about 15 percent, approximately the same quantity as for Kazakhstan.

Impact of environmental changes on the ecology and *Artemia* cyst industry of Aibi Lake in China
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Aibi Lake is located in the lowest point (194 m above sea level) of Junggar Basin in Xinjiang. At present, Aibi Lake is the largest salt lake in China. Its water surface fluctuates between 300–800 km^2. There are more than 20 rivers in the drainage basin, but only 2 rivers flow into the lake throughout the year. Annually there are about 168 windy days (> 6 level). The average evaporation is 1 662 mm, and average precipitation is 90.9 mm. The water surface of Aibi Lake fluctuates due to the regional environment changes, which result in constantly changes of salinity and other physio-chemical parameters. As consequence, the quality quantity of *Artemia* cysts varies significantly. Overall the cyst quality is better in salinity range of 120–150 ppt. The cysts production of Aibi Lake fluctuates tremendously from 142 tonnes in 2015 to 2 209 tonnes in 2011.

Integrated production of salt and *Artemia* in artisanal salt ponds in Viet Nam
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Artemia franciscana originated from San Francisco saltworks, USA (SFB strain) was introduced to Vinhchau saltworks in late 80's with the aim to produce *Artemia* cysts for local aquaculture hatcheries consumption. After a few years the cyst collected in Vinhchau saltworks (now called Vinhchau strain) displayed its uniques in term of cyst dimension, hatching percentage, hatching output and more than that its HUFA contents was quite high compared to other commercial products. The local hatcheries therefore take this advantage to develop for the local target species for example fresh water prawn (*Macrobrachium*), tra-catfish, tiger shrimp, white leg shrimp and other marine species recently. High quality cysts from Vinhchau therefore have a high demand not only for local hatcheries but also partly for exportation. Traditionally, Vinhchau-Baclieu solar saltworks could produce only crude salt but the market is limited due to higher content of organic matters and thus impurity salt can not make a high profit. In contrast *Artemia* culture in saltworks could bring up double or triple profit which encourage farmers to apply in their saltworks area. How to integrate *Artemia* farming into solar saltworks in system design, operation and profit margin will be further discussion.

Selective breeding research with *Artemia*: possible model for commercial crustacean species?
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Artemia sinica is bisexual species and found only in China. *Artemia sinica* is possibly an animal model for quantitative genetics in aquaculture due to its short life cycle, small body size and dormancy. Two selection lines were established in the selective breeding program of *Artemia sinica*. The base population G0 was established using a diallel cross design. In the G0 generation, eighty-eight families were produced. The FGS (fast growth) and SGS (slow growth) lines were constructed separately from the G1 generation. In each generation, full and half sib families were produced by a nested mating design, in which two dams were mated to the same sire. There were heterosis for growth (-25.36~37.56 percent) and survival (-26.51~24.25 percent) among four founder populations. Across generation, the heritability estimates for the FGS and SGS lines were 0.28±0.036 and 0.21±0.074, respectively. For survival across generation, the heritability estimates based on the probit model for the SGS and FGS lines were 0.34±0.051 and 0.43±0.06, respectively. With the inbreeding coefficient increase of 10 percent, body length depressed 4.44 percent, body weight depressed 11.21 percent. In the future, the genetics of inbreeding depression and heterosis and genotype and environment interaction at genomic level will be studied using the nucleus breeding population of *Artemia sinica*.

Heat shock proteins in *Artemia*: role and applications in aquaculture
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Disease imposes an important constraint on aquaculture and in this context vibriosis brings about massive mortalities in many commercial species, ranging from fish to shrimp, with resultant heavy monetary losses.

was explored, with gnotobiotic brine shrimp *Artemia* larvae as the model organism. My study contains several findings, featuring the interesting observation that a non-lethal heat shock at 37°C for 30 min followed by a 6 h recovery period and a combined hypothermic/hyperthermic shock with temperature reduction from 28°C to 4°C for 1 h followed by incubation at 37°C for 30 min and a 6 h recovery at ambient temperature optimally enhanced resistance of gnotobiotic *Artemia* larvae against pathogenic vibrios and induced Hsp70 maximally. The resulting two-fold increase in survival of larvae in concert with stress protein synthesis suggested that endogenous Hsp70 functions in protection. A role for Hsp70 in protecting *Artemia* nauplii against heat stress and bacterial infection was demonstrated for the first time by using RNAi to knock down the protein. The results suggest that Hsp70 assisted in maintaining protein homeostasis within stressed cells while potentially stimulating the innate immune system of *Artemia*. Information of the type generated in this work has potential for application in the culture of *Artemia* and other commercially important aquatic invertebrates.

Structural view on Artemin, an important chaperon in *Artemia*
Xiang Liu, Tianjin International Joint Academy of Biomedicine, Tianjin, China

Artemia embryos in diapuase and quiescence usually have to adapt to unfavourable environmental and physiological stresses. These stresses include low or high temperature, oxidation, radiation, anoxia and so on. So the cysts have developed several different ways to against the stress, such as synthesis of trehalose to replace water, late embryogenesis abundant protein and different protein chaperons. The two major abundant chaperons, P26 and Artemin, are essential for *Artemia* cysts. The latter chaperon Artemin, which named after *Artemia* is a unique protein in *Artemia* embryos. During the past 20 years, several papers have paid attention to the function of this protein *in vivo*, but not much information about Artemin *in vitro*. Here we expressed this protein in *E. coli* and purified it for *in vitro* research, in order to get more information about this important nano-scale protein via protein crystallography.

Halophilic bacteria as food for *Artemia*
Ruy Lopes-dos-Santos, Laboratory of Aquaculture and Artemia Reference Center, Ghent University, Ghent, Belgium

Artemia is a zooplanktonic organism belonging to the order Anostraca. Its cysts are extensively demanded by the ever growing aquaculture industry to be hatched into nauplii as live food for larvae of most farmed fish/shellfish species. As a consequence, in addition to cysts from natural salt lakes, *Artemia* culture, integrated in solar salt production, has been introduced successfully in several (sub) tropical countries where dense brine shrimp populations are maintained through a labour intensive and economically costly stimulation of microalgae blooms and supplementation with inert feeds. Recent field studies are trying to optimize this salt pond based *Artemia* production by stimulating the naturally occurring halophilic bacterial flora as additional food source for the *Artemia* nauplii. However, in these xenic and open culture systems there is no way to assess the nutritional contribution of bacterial biomass among a variety of available feeds. The results obtained from these field studies do not allow thus patent conclusions about the contribution of halophilic bacteria to the brine shrimp diet, hindering the widespread application of such techniques.

Hence, in the present research we aimed to use gnotobiotic (animals cultured in axenic conditions or with a known microflora) *Artemia* culture systems to investigate for the first time *Artemia* nauplii's ability to survive and grow on diets consisting of pure halophilic bacteria biomass. We successfully demonstrated that several halophilic bacteria strains have positive effects on survival, body length and swimming speed of *Artemia* nauplii at both marine and hypersaline salinity.

This work is therefore the first step to investigate the relative importance of different halophilic bacterial genera and species for the *Artemia* life cycle and for the surrounding hypersaline food web, shedding light into the promising potential of these microorganisms to maximize *Artemia* production in salt ponds.

Artemia market situations in China

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Artemia can be found in more than 100 nature habitats in China, including 68 inland salt lakes and 41 coastal salt works in 18 provinces of China. *Artemia* in the salt lakes of Inner Mongolia, Shanxi Province and north of Hebei province are the species of *Artemia sinica*, *Artemia* in Tibet are *Artemia tibetiana*, the others from salt lakes are parthenogenitic *Artemia*. Recent years the *Artemia* population in coastal salt ponds is mixed by local parthenogenitic *Artemia* with bisexual *Artemia* because of the inoculation of *Artemia franciscana* and the use of *Artemia* cysts for larviculture.

China have more than one fourth of *Artemia* cysts resource in the world, about 800–1 200 tonnes of *Artemia* cysts were annually harvested from inland salt lakes (mainly Aibi lake, Bulikun lake, Shuanghu lake) and coastal salt ponds of Bohai Bay. Within 20 years, the demand on *Artemia* cysts in China market increased from 200 tonnes to 1 500 tonnes due to the fast developement of marine aquaculture. On the other hand, the market price of dry *Artemia* cysts increased from 10USD/kg in 2005 to more than 50USD/kg in 2016. Since 2013, the over-demand situation has gradually turned into over-supply. It is extimated that the price of *Artemia* cysts begin falling down this year.

Use of _Artemia_ in the larviculture of commercially important crab species in China

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Chinese mitten crab (*Eriocheir sinensis*), swimming crab (*Portunus trituberculatus*) and mud crab (*Scylla Paramamosain*) are three important aquaculture crab species in China, and the anual aquaculture prodution are around 800 000, 120 000 and 150 000 tonnes, respectively. *Artemia* is one of the major live food for crab hatcheries, which accounted for around 50 percent of total food cost during the larval culture stage. Recently, it is estimated around 30 tonnes of *Artemia* cysts and 300–500 tonnes of frozen *Artemia* used in the larval breeding of commerical crab hatcheries in China. During the past 20 years, there are three major research topics for the application of *Artemia* in crab larviculture: Feeding scheme and prey density, e.g. from rotifer to *Artemia* naplii, from *Artemia* naplii to preadult *Artemia* or other live foods; nutritional enrichment of *Artemia* to improve the survival and quality of crab larvae or crabseeds; replacement of *Artemia* in crab larviculture. The research progress, present status, problems and future trends are reviewed and discussed for *Artemia* ultilization in the larviculture of commercially important crab species in China. This would provide valuable information for the rational use of *Artemia* in Chinese aquaculture.

Microbiome: criteria for the quality control of _Artemia_ products

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Biogeography and individual population shape the structural and functional composition of the *Artemia* microbiome. Exploration of the *Artemia* microbiome via powerful metagenomics and meta transcriptomic technologies can provide a deep insight into the core functional microbial communities. Single-cell resolution methods and high efficiency robot help isolate and synthesize beneficial microbial communities with functional characteristics such as disease resistance. We try to identify the bacteria with potential probiotic effect on the survival, development and enrichment of *Artemia*, and elucidate the possible link between the core microbial communities and *Vibrio* populations. The study highlights the potential utilization of synthetic microbial communities as a potential management option to improve the quality of *Artemia* products.

INVE's experiences in the exploration of new commercial _Artemia_ resources for the aquaculture industry

Eddy Naessens, INVE Aquaculture, Dendermonde, Belgium

With the rapid expansion of commercial hatchery activities in shrimp and marine fish on different continents, starting from the late 1980s, it became clear that the dependency on one main source of commercial *Artemia* cysts from the Great Salt Lake in Utah (USA) was not sustainable as this natural resource is not always predictable

the other extreme of too high water salinities resulting in low *Artemia* productivity when the balance precipitation/evaporation remains negative over long periods of time).

In the early ´90s INVE Aquaculture SA set up a multidisciplinary "*Artemia* Task Force" to identify and explore opportunities to tap new *Artemia* resources from salt lakes and salt works on different continents. This presentation will review the criteria for selection of new *Artemia* sites for potential exploitation of *Artemia* and the critical parameters for ensuring a sustainable exploitation. A few examples will be given of successful new exploitations.

Over the years this ATF approach has contributed to a significant increase in commercial availability of *Artemia* cysts, not only from a quantitative point of view, but as they come from much more diversified origins (i.e. from the America's, Central Asia and China) offering different qualities as well.

APPENDIX V

GROUP PHOTO

Group photo of the "FAO Expert Workshop on 'Sustainable Use and Management of *Artemia* Resources in Asia", which was held in Tianjin, China, from 7–9 November 2016. *Photo courtesy* Hang Zhao/TUST.

The FAO Expert Workshop on 'Sustainable Use and Management of *Artemia* Resources in Asia' was convened in Tianjin, China, from 7–9 November 2016. The objective of this workshop was to bring together a critical amount of key people, active in the field of *Artemia* biological research, exploitation or use, with as ultimate goal to define the organisational structure for the sustainable management of the *Artemia* resources in China, both inland and coastal, and their optimal use in aquaculture. The workshop convened in plenary throughout the duration of the workshop and the participants attended a variety of presentations related to (1) History of *Artemia* study and use; (2) *Artemia* biodiversity and sustainable management of *Artemia* resources; (3) Contribution of *Artemia* in biological and medical research; and (4) Application of *Artemia* in aquaculture in the first day of the workshop. During the second day a field trip was organised to visit *Artemia* pond culture and cyst processing centre, and to a number of aquaculture facilities. The third day was entirely dedicated to plenary discussions and following the general plenary discussion, the participants identified a number of recommendations in order to stimulate the use of *Artemia* as an aquaculture commodity, its study as an element of biodiversity and its use as biological model organism. The recommendations addressed the need for the establishment of an Asian Regional *Artemia* Reference Centre (AR-ARC) in China within the immediate future, the agreement that TUST is well-positioned to host this AR-ARC in view of is track record and expertise in *Artemia* studies, and the participants' commitment to support the establishment, organisation and functioning of the AR-ARC. A number of actions were proposed, related to the internal organisation and external linkage of the AR-ARC, and short- and mid-term deliverables, to be produced by the AR-ARC.

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