Workshop summary

WORKSHOP BACKGROUND

An increasing number of countries, with extensive arid and semi-arid areas, have approached the Food and Agriculture Organization of the United Nations (FAO) in recent years for technical advice in support of desert aquaculture development. Rural communities living in dry and arid regions are often among the poorest as the rigid climatic conditions dramatically reduce the variety and quantities of crops that can be adequately produced. Furthermore, the development of aquaculture as an economic activity may have positive socio-economic impacts on rural communities living in these climatically challenging regions in terms of improving the economic viability of farming activities in general while generating additional income and providing a healthy source of food to the local diet. Business and employment opportunities that may be generated may also help to avoid emigration from such areas. Additional research and the proposition of technical solutions are nevertheless required, particularly in terms of suitable feed and farming technologies that can be utilized in such areas.

Therefore, the Aquaculture Service of FAO's Fisheries and Aquaculture Department took the initiative to organize a technical workshop to discuss salient issues related to aquaculture development in desert and arid lands and to identify actions to assist in strengthening this economic sector. During the three-day workshop, the experts identified key trends and issues affecting desert aquaculture growth and discussed ways to strengthen national and regional collaboration for future responsible development of the sector. The workshop participants proposed a series of recommendations to be followed by those investors of the public and private sectors willing to start up aquaculture activities in arid lands.

WORKSHOP OBJECTIVES AND APPROACH

The main objective of the workshop was to assess the current situation and future prospects of desert and arid land aquaculture development around the globe through the seven reviews commissioned to the experts. The main output of this technical brainstorming was the identification of activities and intervention areas (covering biological, technical, policy/governance, economic and other issues) to be included as components of an FAO action programme in support of desert and arid lands aquaculture development. The workshop was organized in three main sessions focusing on the following themes:

- presentation and discussion of the country and region reviews commissioned on the status and trends of desert and arid lands aquaculture development;
- drafting of a series of recommendations based on the workshop discussions and outcomes;
- proposal, discussion and drafting of a series of priority mini and targeted project concept notes in support of desert and arid lands aquaculture development for possible funding through FAO or the donor community. The elaborated project proposal concept notes have not been included in this publication.

WORKSHOP RECOMMENDATIONS

A number of basic requirements associated with the development of aquaculture in desert and arid lands have been identified by the experts and need careful consideration. These are:

1. Education, training and communication

Education and training are the key foundations for building up the necessary skills for production, management and environment-friendly practices for desert and arid lands aquaculture. This can be achieved through:

Needs:

- Enhance education institutions with specific aquaculture programmes in their curricula covering the following subjects:
  - biology of cultured species;
  - hydrology in desert and arid lands aquaculture;
  - technology implied;
  - business management;
  - water management; and
  - integrated/organic aquaculture.
- Promote refresher courses and mentorship programmes as means of maintaining a continuous "knowledge" stream of desert and arid lands aquaculture education among stakeholders.
- Disseminate the "how to" information for starting desert and arid lands aquaculture to potential investors as an encouragement of a sustainable practice associated with a positive income.
- Facilitate networking arrangements to support exchange of specialists and sharing of technical know-how.

Actions:

- Institute demonstration and/or extension farms for training and information dissemination to local farmers (short courses, fieldwork, manuals, Web-based information sheets, etc.).
- Establish "information centres" (physical and/or online Web sites) that can supply information on desert and arid lands aquaculture.
- Promote regional and interregional cooperation and networking in the development of curricula, exchange of experience and development of educational material and training workshops.
- Establish standard schemes for training and educational components of desert aquaculture.
- Develop effective mechanisms for access to relevant and reliable information for all stakeholders.

2. Research and development

The need for new and/or adapted technologies able to withstand the aquaculture conditions in desert and arid lands is important, especially in developing countries and countries that are in a transition stage of development. The research and development (R&D) for sustainable desert and arid lands aquaculture should focus on:

Needs:

- Identify advanced technologies and infrastructures designed for new or existing aquaculture facilities adapted to local desert and arid lands conditions.
- Develop protocols to manage health-related issues of aquatic organisms on the domestic and regional level.
- Characterize water quality from aquaculture effluents in an attempt to maintain the surrounding ecosystem as pristine as possible.
- Select and introduce new aquatic species (most suitable for local conditions) with high production values.
- Produce feed using locally available feed ingredients.

- Integrate desert and arid lands aquaculture with other productive sectors such as agriculture (aquaponics, production of fodder and technical crops, etc.).

Actions:

- Establish regional desert and arid lands aquaculture research centres and aquaculture parks, ensuring stakeholder participation in research identification and implementation including demonstrations on how to diversify and/or integrate farmers' activities with aquaculture.
- Develop funding mechanisms at the national, regional and international level in R&D in desert and arid lands aquaculture involving public- and private-sector organizations.
- Implement species introduction programmes to diversify and intensify aquaculture production in desert and arid lands.
- Develop policy and technical guidelines on improved feeding and feed management in desert and arid lands aquaculture.
- Conduct training needs assessment to improve technical capacities of national aquaculture researchers and technicians.

3. Smart water use in desert and arid lands aquaculture

Aquaculture integration refers to the physical linkage of various activities (e.g. agriculture, hydroponics, recreation and tourism) by using the same volume of water each time for obtaining its final product. The strategy implied is to reduce the use of water, and reuse the water for different activities. Ultimately, the water is being maximized to produce several crops with the same amount of water. This scheme minimizes its waste and can be achieved by:

Needs:

- Set up a recommended list of water conservation technologies for all desert and arid lands aquaculture and subsidiary activities deriving from it.
- Develop water-saving strategies and/or guidelines for aquaculture stakeholders to follow, ensuring the best water use and exploitation to maximize the profit from it.

Actions:

- Implement efficient vertical and/or horizontal integration of water effluents with secondary (or more) activities that efficiently use the nutrient passage from one activity to the other, in an attempt to increase production and release water in the environment in compliance with governmental standards.

4. Clear policy and regulations

Desert and arid lands aquaculture is a relatively new industry and, in several cases and in many countries, existing policies and regulations dealing with arid land and available water resources use for aquaculture purposes are not yet developed or do not exist.

Very often, licences for desert and arid lands aquaculture activities are spread among several agencies (e.g. land use, water use, environment). This situation may significantly limit and/or even arrest the development of this sector.

Needs:

- Adopt specific policies for water use for desert and arid lands aquaculture.
- Adopt regulations for desert and arid lands aquaculture.
- Streamline licence-approval processes.
- Facilitate information access for the public.
- Promote investment in desert and arid lands aquaculture.

Actions:

- Develop comprehensive regulations and administrative procedures that encourage desert and arid lands aquaculture development (in line with existing local laws and regulations).
- Develop national policies for optimizing water use and disposal (e.g. water reuse and integrated aquaculture-agriculture systems).
- Develop a reference agency (information centre) with adequate organizational stature to assist potential investors to comply with the local regulations. The agency can be within one of the aquaculture managing agencies or coordinate collaboration between the agencies involved.
- Establish economic incentives for private investors willing to start desert aquaculture activities.

5. Environmental sustainability

Desert and arid lands aquaculture should be developed by adopting policies and practices that ensure environmental sustainability, especially through the use of environmentally sound technologies and appropriate water management. The establishment of efficient farming systems that are integrated into environmental management plans will enable more efficient use of water, land, seed and feed inputs. Countries are recommended to consider the following needs and actions:

Needs:

- Promote awareness for both small-scale and commercial activities on the codes of good practice for aquaculture (e.g. codes of conduct for sustainable aquaculture).
- Use renewable energy sources (solar, wind, etc.).
- Promote efficient use of locally made feed ingredients – small and/or rural activities.
- Ensure efficient use of water resources and effluent management.
- Develop environmental policies and regulations of a high standard at the national and regional level for desert and arid lands aquaculture.

Actions:

- Develop water-use, effluent discharge and waste-disposal regulations for aquaculture/agriculture purposes.
- Develop a code of conduct specifically for the region in question based on rural and commercial farms, and publicize the existence of codes of conduct to regulatory agencies and producers involved in desert and arid lands aquaculture.
- Increase renewable energy sources availability in an effort to promote a “green” desert and arid lands aquaculture.
- Encourage the utilization of available agriculture and by-products in fish feed formulation, especially for small-scale farms.

6. Socio-economic aspects

The purpose of increasing desert and arid lands aquaculture is to secure food supply and protein sources, provide jobs, create business opportunities and improve livelihoods in desert and arid lands locations through the development of aquaculture activities.

Needs:

- Offer both genders equal employment opportunities.
- Evaluate the economical sustainability of aquaculture production individually or integrated with secondary activities (i.e. agriculture).
- Implement credit schemes for the support of desert and arid lands aquaculture development.

- Promote the nutritional advantages of consuming aquatic organisms at the local and national level.

Actions:
- Develop strategic action plans addressing aquaculture needs and potential.
- Conduct socio-economic impact studies for pre- and post-implementation of desert and arid land aquaculture in an attempt to quantify changes over time.
- Develop credit schemes as incentives to facilitate investment in aquaculture development (e.g. microcredit programmes, especially for small-scale aquaculture development).
- Establish cooperatives and farmers associations for small-scale aquaculture.
- Implement awareness programmes aimed at highlighting benefits from agriculture integration.

7. Market development and trade

Commercial aquaculture in desert and arid lands in general should be market-oriented for its sustainability and well linked with the trends and dynamics of world seafood markets.

Needs:
- Develop market strategies to establish a continuous demand for desert aquaculture products.
- Ensure that the processing and handling of aquaculture products in harsh environments is compliant with the protocol of the Hazard Analysis and Critical Control Point (HACCP) system.
- Develop the infrastructure to enable the storage, processing and transportation of aquaculture products in remote areas.
- Facilitate transport and access to and from markets for the local communities.
- Increase consumption of aquaculture products by diversifying traditional diets.

Actions:
- Market product qualities that highlight its environmental sustainability in order to target niche markets.
- Develop and establish alternative processing protocols for extending shelf-life.
- Establishing cooperatives and/or centralized entities (facilities) for processing and trading purposes.
- Make available basic infrastructure for storage, processing and transportation of aquaculture products (e.g. cold rooms, small-scale processing plants, and roads) to ensure adequate access to the market even for the aquaculture farms located in rural areas.
- Create programmes that promote the benefits of consuming aquaculture products in order to attract local consumption.

8. Regional and interregional cooperation

Over the years, regional and interregional cooperation has brought considerable benefits to aquaculture development through dissemination of knowledge and expertise. Further strengthening of this cooperation at all levels will ensure increased benefits for the development and sustainability of desert and arid lands aquaculture. Although desert and arid land aquaculture is a relatively new sector, some countries and regions are more advanced than others in this field. Therefore, the most advanced countries should share their expertise with less advanced ones in order to facilitate the development of the sector.

Needs:

- Foster information and technical knowledge transfer between more advanced regions and/or countries and less developed ones.
- Improve interregional collaboration and networking of regional and/or national institutions specialized in desert and arid lands aquaculture to ensure synergies and exchange of expertise.
- Encourage the establishment of regional organizations for the development of desert and arid lands aquaculture in regions where they are lacking.

Actions:

- Establish regional "desert aquaculture" associations that will link States, regions and/or nearby countries.
- Establish Web-based regional information systems focusing on desert and arid lands aquaculture as a first entry point and source of information.
- Establish bilateral and/or multilateral exchange networks between regions to allow information and technical flow through regional courses, workshops, and exchange of technicians and scientists.
- Establish links with international donors and agencies to support the development of regional desert and arid lands aquaculture through the above-mentioned actions.

Annex 1 – **Agenda**

FAO EXPERT WORKSHOP ON
"AQUACULTURE DEVELOPMENT IN THE DESERT AND ARID LANDS: DEVELOPMENT CONSTRAINTS AND OPPORTUNITIES"

Hermosillo, Mexico
6–9 July 2010

	Monday, 5 July 2010
Arrival of participants and transfer to hotel	
	Tuesday, 6 July 2010
09:00–09:30	Welcome note from Centro de Investigación Alimentación y Desarrollo (CIAD) representative Opening remarks
09:30–13:00	**Workshop introduction** • *Introduction note and adoption of the agenda* Scope and main objectives to be achieved by the workshop **Review presentations** • *Australia* • *Central Asia (Aral Sea Drainage Basin)* • *Israel* • *Southern Africa*
13:00–14:00	*Lunch break*
14:00–17:30	**Review presentations** (cont'd) • *Egypt* • *United States of America* • *Mexico* • *Additional presentations (delivered by national experts and/or observers)* **Open debate** Feedback and comments on the reviews presented. Summary of major issues and salient aspects identified
	Wednesday, 7 July 2010
09:00–12:30	**Working Session I** • *Elements for a targeted developmental programme* Drafting the "Desert and arid lands aquaculture development: the way forward" document
12:30–14:00	*Lunch break*
14:00–17:30	**Working Session I** (cont'd)
	Thursday, 8 July 2010
09:00–12:30	**Working Session II** • *Priority and targeted project proposals* Preparation of selected and targeted project proposal concept notes. Each expert is invited to prepare two or three (or more) project proposals concept notes for presentation and discussion at the workshop (see below recommended concept note template)
12:30–14:00	*Lunch break*
14:00–17:30	**Finalization of the first draft of the "*The way forward*" document** **Workshop follow-up actions** **Closing remarks**
	Friday, 9 July 2010
09:00–17:30	**Field trip** • *Visit to aquaculture facilities and the desert of Sonora* **Departure**

Annex 2 – **List of participants**

COUNTRY EXPERTS

Samuel APPELBAUM
Albert Katz Department of Dryland Biotechnologies
The Bengis Center for Desert Aquaculture
Jacob Blaustein Institute for Desert Research
BGU, Sede Boqer Campus
Midreshet Ben-Gurion 84990
Israel
Tel.: +972 8 6596812
Fax: +972 8 6596810
E-mail: sappl@bgu.ac.il

Silvia GOMEZ JIMENEZ
Centro de Investigacion en Alimentación y Desarrollo
Km. 0.6 Carretera a la Victoria
Apdo. Postal 1735
Hermosillo, Sonora
C.P. 83000
Mexico
Tel.: +52 662 2892400 ext. 334
Fax: +52 662 2800421
E-mail: s.gomez@ciad.mx

Bakhtiyor KARIMOV
Institute of Zoology
Uzbekistan Academy of Sciences
1 Niyazov Street
Tashkent 100095
Uzbekistan
Tel.: +998 71 2460718; 2460900
Fax: +998 71 1206791; 2460900
E-mail: Karimov@sarkor.uz

Hiroshi KITANI
Senior Advisor (Fisheries)
Japan International Cooperation Agency
Senmonin Tokyo-to, Shinjuku-ku, Ichigaya Honmuracho 10-5
162-8433
Japan
Tel.: +81 3 52269398
E-mail: hkmat@sta.att.ne.jp

Sagiv KOLKOVSKI
Principal Research Scientist
Marine Aquaculture
Department of Fisheries, Western Australia
PO Box 20 Northbeach
WA 6920
Australia
Tel.: +61 8 92030220
Mob.: +61 0417940498
Fax: +61 8 92030199
E-mail: Sagiv.Kolkovski@fish.wa.gov.au

Blessing MAPFUMO
Regional Aquaculture Advisor
INFOSA
No. 89 John Meinert Street
PO Box 23523
Windhoek
Namibia
Tel.: +264 61 279436/430
Fax: +264 61 279434
Mob.: +264 81 2099042
E-mail: blessing@infosa.org.na

Sherif SADEK
Aquaculture Consultant Office
12 B (House No. 9), Street No. 256
11435 New Maadi, Cairo
Egypt
Tel.: +202 25215065
Fax: +202 25215063
Mob.: +201 23492423
E-mail: sadek_egypt35@hotmail.com

Manuel SEGOVIA QUINTERO
Diseño y Desarrollo de Tecnologia Acuícola
Departamento de Acuicultura
Centro de Investigación Científica y de Educación Superior de Ensenada
Mexico
Tel.: +52 646 1750500 ext. 24601
Fax: +52 646 1750534
E-mail: msegovia@cicese.mx

Granvil TREECE
Aquaculture Specialist
Texas A&M University
Sea Grant College Program
2700 Earl Rudder Freeway South, Suite 1800
College Station, Texas 77845
United States of America
Tel.: +1 979 8457527
Fax: +1 979 8457525
E-mail: g-treece@tamu.edu

FAO AQUACULTURE OFFICERS

Valerio CRESPI
Aquaculture Officer
Aquaculture Service (FIRA)
Fishery and Aquaculture Resources Use and Conservation Division
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla 00153
Rome
Italy
Tel.: +39 06 57052009
Fax: +39 06 57053020
E-mail: valerio.crespi@fao.org

Alessandro LOVATELLI
Aquaculture Officer
Aquaculture Service (FIRA)
Fishery and Aquaculture Resources Use and Conservation Division
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla 00153
Rome
Italy
Tel.: +39 06 57056448
Fax: +39 06 57053020
E-mail: alessandro.lovatelli@fao.org

Annex 3 – **Expert profiles**

APPELBAUM, Samuel – Professor Samuel Appelbaum obtained his B.Sc. at the Hebrew University, Jerusalem, Israel, and his M.Sc. and Ph.D. at the University of Hamburg, Germany. He has been the head of the Bengis Center for Desert Aquaculture at Ben-Gurion University of the Negev for the last 16 years. He is an eminent leader in the field of brackish water aquaculture and desert aquaculture research and development. Working closely with local collectives (Kibbutzim) and Negev fish farmers, he is responsible for the introduction and expansion of brackish water fish farming in the Negev Desert in southern Israel and is currently researching the efficient and economical aquacultural use of this desert brackish water and its application to the "Integrated aqua/agricultural" farming model. This research includes the introduction of two suitable species (Barramundi, *Lates calcarifer* and gilthead seabream, *Sparus aurata*) for desert aquaculture and the studying of the suitability of the brackish water at different locations in the Negev Desert for the cultivation of gilthead seabream. His current research also includes utilization of brine from desalination plants for aquaculture and the reproduction of marine and freshwater species for cultivation in the desert. Evaluating the potential use of decapsulated *Artemia salina* cysts and the use of various enrichments for *Artemia* nauplii as a nutrient in aquaculture is another aspect of his research. His activities include training and instruction of foreign visitors, teaching students and post-doctorate researchers, and participation in courses and seminars. He has published numerous articles in international scientific journals and chapters in related books.

CRESPI, Valerio – Valerio Crespi graduated from the "La Sapienza" University of Rome, Italy, in biological sciences with a specialization in fisheries and aquaculture. He has undertaken a three-year advanced post-graduate course (Master equivalent) at IFREMER (French Research Institute for Exploitation of the Sea) at the laboratory of Sète (France), funded by the European Union (EU). Up to 1999, he was actively involved in research activities related to inland fisheries and aquaculture in Africa, Guinea and Uganda within the framework of EU cooperation projects. In 2000, he joined the FAO Fisheries and Aquaculture Department in Rome, working as a consultant for two years and collaborating on the development, support and management of the Fisheries Global Information System (FIGIS) and for the FAO-COPEMED project on the analysis of the inventory of the artisanal fisheries in the Western and Central Mediterranean Sea. In 2002, he was appointed Aquaculture Officer (Information) in the Aquaculture Service of FAO, and he has conducted extensive normative work dealing with aquaculture information dissemination through the Internet and other information technology (IT) tools. The main activities he is currently focused on are: technical assistance to field projects on freshwater aquaculture in a number of countries; and technical assistance to FAO regional fishery bodies through the establishment of Web-based regional aquaculture information systems. He is directly responsible for the management and maintenance of the FAO aquaculture gateway page (www.fao.org/fishery/aquaculture).

KARIMOV, Bakhtiyor – Dr Bakhtiyor Karimov is Head of the Laboratory of "Problems of intensive aquaculture and fisheries" of the Institute of Zoology of the Uzbekistan Academy of Sciences, Tashkent, Uzbekistan. He has a Candidate of Sciences (Ph.D.) degree in biology from the State Scientific Research Institute for River

and Lake Fisheries of the Fisheries Ministry of the Russian Federation, Saint Petersburg (1985) and holds a Doctor of Sciences degree in biology from Tashkent State University (1995). He has been working in the field of ichthyology, ecotoxicology, aquatic ecology, aquaculture and fisheries development on arid and desert areas of the Aral Sea Basin for the past 25 years. In particular, he has studied artificial desert lakes of irrigational origin, such as the Aydar-Arnasay Lake System, Lakes Sarikamysh, Kamishlibash and Shorkol, and the deltaic lakes of the Amudarya River. His scientific publications (more than 100) have been published in well-recognized journals of the former Soviet Union and of the Commonwealth of Independent States (CIS), as well as in peer-reviewed journals. He has edited international conference proceedings, an FAO aquaculture and fisheries review and a special issue of the scientific popular journal *Ecological bulletin* devoted to aquaculture and fisheries issues. He has research experience from Europe and Central Asia through a series of short- and longer-term joint research projects. In the period 1995–97, he worked at the Zoological Institute of the University of Hamburg as a fellow of the Alexander von Humboldt Foundation (Germany) on the project "The impact of water pollution on fisheries". He has coordinated two FAO technical cooperation projects on aquaculture and fisheries (in 2007–2008 and in 2009–2010) and a German-Uzbek project on sustainable aquaculture development in the Aral Sea Basin (2006–2007). He was a team leader of the EU–INTAS-funded Aral Sea project (2002–2004), and has participated in several other UNESCO and national projects on aquaculture, fisheries and sustainable use of water resources. He has been a member of the Committee on Coordination of Science and Technologies Development under the Cabinet of Ministers of the Republic of Uzbekistan: Section 4: Agriculture, Biology and Ecology since 2002, and he is also an active member of the Zoological Society and President of the Humboldt Society of Uzbekistan.

KOLKOVSKI, Sagiv – Mr Sagiv Kolkovski is Principal Research Scientist of the Aquaculture and Aquatic Health Unit at the Department of Fisheries, Western Australia, Australia. He is also Research and Development (R&D) Director at Nutrakol Pty. Ltd., a company specialized in nutrition and health solutions for the aquaculture industry. He has been working in the field of aquaculture for the past 25 years, undertaking R&D and consultancy work around the world including: Australia, Chile, Ecuador, France, Indonesia, Israel, Japan, Malaysia, Mexico, New Zealand, Portugal, Singapore, Spain, Thailand and the United States of America. In the past ten years, he has led the marine aquaculture research programme at the Department of Fisheries, Western Australia. Prior to this role, he was invited professor at Ohio University, the United States of America. He has diverse interests and expertise in marine aquaculture including marine organisms' nutrition and physiology and aquaculture engineering. He has developed techniques, systems and diets for a wide range of marine organisms, including finfish (groupers, seabream, seabass, mahi mahi, *Seriola* sp. ornamental fish and others), crustaceans (lobsters, shrimps), octopus and live food (rotifers, *Artemia*). His R&D projects, linked with industry, and his applied approach resulted in the establishment of the first large-scale commercial production of *Artemia* in closed-system, commercial (patented) feeding systems, maturation diets for crustaceans and many other "tailor-made" nutritional and health solutions. He is also specialized in site and species selection and "desert" aquaculture. He has published more than numerous papers in international science journals, several book chapters, and many scientific and professional reports to several government agencies around the world and commercial clients. He is on the editorial board of the journals *Aquaculture* and *Aquaculture Nutrition*.

LOVATELLI, Alessandro – A trained marine biologist and aquaculturist, he obtained his B.Sc. and M.Sc. degrees at the universities of Southampton and Plymouth (the United Kingdom of Great Britain and Northern Ireland), respectively. His first

experience with FAO dates back to 1987, working as the bivalve expert attached to an FAO/UNDP (United Nations Development Programme) regional project. His subsequent FAO assignment was in Mexico, working on a regional aquaculture development project (AQUILA) funded by the Italian Government. From 1993 to 1997, he worked in Viet Nam, Somalia and then again in Southeast Asia. In Viet Nam, he headed the aquaculture and fisheries component of a large EU project developing, among other activities, ten regional aquaculture demonstration, training and extension centres. In Somalia, he acted as the lead aquaculture and fisheries consultant for the European Commission. Following an additional year in Viet Nam as one of the team leaders under the Danish-funded Fisheries Master Plan Project, he was recruited by FAO as the Aquaculture Advisor attached to the FAO-EASTFISH project based in Denmark. In 2001, he once again joined the FAO Fisheries and Aquaculture Department in Rome. The main activities he is currently focusing on are marine/offshore aquaculture development, transfer of farming technologies and resources management. Mr Lovatelli has coordinated and co-authored a number of FAO technical reviews and papers, mainly focused on marine aquaculture development.

MAPFUMO, Blessing – A national of Zimbabwe, he is the Regional Aquaculture Advisor at INFOSA (the intergovernmental organization for marketing information and technical advisory services for the fisheries industry in Southern Africa), responsible for all technical matters pertaining to aquaculture development in Southern Africa (a regional block of 15 countries). He has nearly eight years of direct experience in fish farming, having worked as Production Administrator at Lake Harvest Aquaculture based in Zimbabwe (the largest freshwater aquaculture farm in Africa). He has been consulted by the Governments of Angola (Socio-Economic Study for Small-Scale Fisheries), Mozambique (Small-Scale Aquaculture Development Plan), Namibia (Study on Assessment of Markets for Namibian Aquaculture Products) and Zimbabwe (National Training Needs Assessment on Aquaculture). Furthermore, he has undertaken several consultancy projects on freshwater aquaculture development and trade aspects and has so far trained more than 100 aquaculturists in the region under INFOSA's capacity-building programme on aquaculture. On desert and arid land aquaculture, he has conducted two feasibility studies on the potential for freshwater aquaculture in dry eastern regions of Namibia. He is also an advisor to two large-scale pilot projects in desert/arid lands: CAMDEBOO Satellite Aquaculture Project (Eastern Cape, South Africa) and Tahal (Botswana) on both production and marketing issues. He also administers the regional Technical Information Centre (TIC), including INFOSA's Web site (www.infosa.org.na) for all inland fisheries and aquaculture activities in Southern Africa. This centre is also a regional dissemination hub for FAO technical information. He is also a guest lecturer at the University of Namibia and inland fisheries colleges in Zimbabwe on aquaculture and fish-trade-related subjects. He has written two case studies for the SARNISSA Web site (www.sarnissa.org) on both freshwater and mariculture in the region, some articles for the EUROFISH Africa Pages Magazine and several training manuals on freshwater aquaculture. He sits on the board of directors as a technical advisor for the Zimbabwe Aquaculture Trust and is also a key advisor to the Ministry of Fisheries and Marine Resources on aquaculture-related matters. He holds an MBA (Management College of South Africa), an Higher National Diploma (United Kingdom) in agricultural management (Zimbabwe), a diploma in fish farming (South Africa), a diploma in information technology (University of Zimbabwe) and several certificates on aquaculture, inland fisheries, project development and related fields.

SADEK, Sherif – An aquaculture specialist. In 1984, he obtained his Ph.D. (Doctor Engineer) from the Institut National Polytechnique (INP), Toulouse, France. He has evaluated the expected problems and solutions in earthen brackish water ponds in

Egypt, related to gilthead seabream, European seabass and mullet species. In the period 1986–1987, he undertook post-doctoral study and research at the Department of Fisheries and Allied Aquaculture at Auburn University, the United States of America. His topic was: development possibilities of freshwater prawn and marine shrimp culture in Egypt. In 1998, he obtained the degree of Docteur de l'INP from the Institut National Polytechnique, Toulouse, France. His research subject was: the different techniques of giant river prawn (*Macrobrachium rosenbergii*) during the last ten years in Egypt. In the period 1980–1991, he participated as a research assistant in the General Authority for Fish Resources Development (GAFRD), Egypt. Since 1991, he has been the creator and general manager of the firm Aquaculture Consultant Office. Dr Sadek has been nominated as a consultant for different projects in North African and Arab countries. His career history contains a long series of successful management of large projects: programming, budgeting, planning, supervision and monitoring of implementation, coordination and control of outside consulting experts and suppliers of specific equipment, elaboration of process schedules and execution rules and check-lists, recruitment, training and management of personnel. In the past five years, he has been involved in numerous efforts by the International Union for Conservation of Nature (IUCN) and FAO to apply the ecosystem approach to aquaculture and to establish guidelines to make aquaculture a more sustainable industry. He has published about 30 complete scientific papers in different international journals and also presented 35 short papers at various international aquaculture conferences. Dr Sadek's field expertise is more related to freshwater prawn breeding and culture, in addition to the culture of finfish (gilthead seabream, European seabass, mullet and meagre) and shrimp (*Penaeus semisulcatus*) in arid land, desert areas and costal zones.

SEGOVIA QUINTERO, Manuel – A researcher at the Center for Scientific Research and Higher Education at Ensenada (CICESE), Ensenada, Baja California, Mexico. He has a Ph.D. in aquaculture from Louisiana State University, the United States of America, and has been doing research in the field of aquaculture for the last eight years. His research expertise is in the design and development of modular recirculating aquaculture technology and the economic feasibility of such systems for commercial aquaculture in Mexico and Latin America. In arid lands, his ongoing research is focused in the study of mass transfer between high-density recirculating systems and aquaponics and the design of low-cost recirculating systems with commercial applications. He has been involved in research, consulting and transferring technology in Mexico and other countries such as Argentina, Bolivia, Chile, Costa Rica and Peru. As a result, he has developed recirculating technology for abalone production, oyster broodstock conditioning and maturation and spiny lobster larvae systems. He has published scientific publications in peer-reviewed journals on diverse aquaculture topics.

TREECE, Granvil – An aquaculture specialist at the Texas A&M University and the Sea Grant College Program since 1983, he received an M.Sc. from Texas A&M University, the United States of America, in 1977, and worked in the commercial aquaculture industry as a shrimp hatchery manager 32 years ago. He has worked in 44 countries over the years on various aquaculture projects, working with the United States Department of Agriculture's Foreign Agriculture Services, USAID and as a private consultant to build shrimp farms and hatcheries, as well as providing training. He has conducted marine shrimp culture courses throughout the world in the last 27 years and has conducted the Texas Shrimp Farming and Marine Finfish Farming Course at Texas A&M University for 24 years. He has been an Adjunct Associate Professor at the TAMU Wildlife and Fisheries Sciences Department since 1999. He has worked with most of the shrimp farms in the United States of America, including the desert farms in Arizona and West Texas. He has served for 21 years on the board

of directors of the Texas Aquaculture Association, and helps them maintain their Web site (www.texasaquaculture.org). He has numerous scientific publications on various aspects of aquaculture and related topics in peer-reviewed journals and books. He has also developed computer software to assist in aquaculture planning, feasibility and design. He has assisted Texas Parks and Wildlife with the rules and regulations for offshore aquaculture and assisted the Gulf of Mexico Fisheries Management Council in preparing their fisheries management plan to regulate offshore aquaculture in the Gulf of Mexico Exclusive Economic Zone.

Annex 4 – **Selected photographs**

Small-scale aquaculture in the desert and arid lands of Ouargla, Algeria

PHOTO 1
Pump station for pumping underground water

COURTESY OF V. CRESPI

PHOTO 2
Fish pond in the desert

COURTESY OF V. CRESPI

PHOTO 3
Stocking fingerlings

COURTESY OF V. CRESPI

PHOTO 4
Farm-made feed

COURTESY OF V. CRESPI

PHOTO 5
Feeding fish

COURTESY OF V. CRESPI

PHOTO 6
Discharge canals

COURTESY OF V. CRESPI

Small-scale aquaculture in the desert and arid lands of Ouargla, Algeria (continued)

PHOTO 7
Integration with agriculture (salad)

COURTESY OF V. CRESPI

PHOTO 8
Integration with agriculture (greenhouses)

COURTESY OF V. CRESPI

PHOTO 9
Fingerlings production in hapas

COURTESY OF V. CRESPI

PHOTO 10
Palm leaves used to protect hapas from the sun

COURTESY OF V. CRESPI

PHOTO 11
Harvesting a fish pond

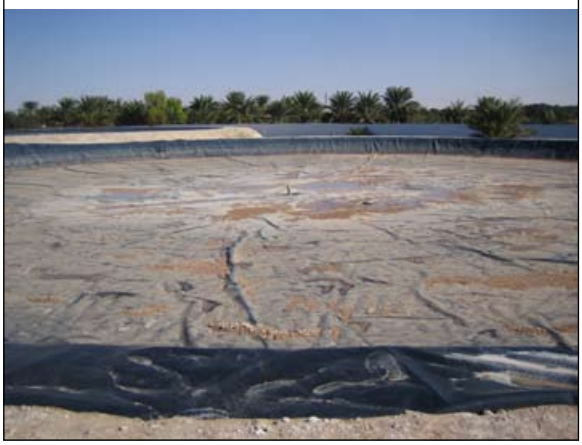
COURTESY OF V. CRESPI

PHOTO 12
Farmed Nile tilapia (*Oreochromis niloticus*)

COURTESY OF V. CRESPI

Commercial aquaculture farms in the desert and arid lands of Ouargla, Algeria

PHOTO 13
Bottom of earthen pond lined with PVC sheet



COURTESY OF V. CRESPI

PHOTO 14
Fish pond in a medium-sized commercial farm

COURTESY OF V. CRESPI

PHOTO 15
Concrete ponds used as hatchery

COURTESY OF V. CRESPI

PHOTO 16
Commercial fish farm "Pescado de la Duna"

COURTESY OF V. CRESPI

PHOTO 17
Ongrowing raceways

COURTESY OF V. CRESPI

PHOTO 18
Indoor nursery raceways

COURTESY OF V. CRESPI

Commercial aquaculture farms in the desert and arid lands of Ouargla, Algeria (continued)

PHOTO 19
Broodstock of red tilapia

COURTESY OF V. CRESPI

PHOTO 20
Feed processing plant on the farm

COURTESY OF V. CRESPI

PHOTO 21
Farmed red tilapia

COURTESY OF S. SADEK

PHOTO 22
Fish processing plant

COURTESY OF V. CRESPI

PHOTO 23
Fillets of red tilapia

COURTESY OF S. SADEK

PHOTO 24
Value-added products

COURTESY OF V. CRESPI

Commercial aquaculture farms in the desert of Sonora, Mexico

PHOTO 25
Shrimp farm

COURTESY OF V. CRESPI

PHOTO 26
Seawater inlet pumps

COURTESY OF V. CRESPI

PHOTO 27
Bottom PVC lining in an earthen pond

COURTESY OF V. CRESPI

PHOTO 28
Earthen ponds for shrimp culture

COURTESY OF V. CRESPI

PHOTO 29
Manual feeding of shrimp

COURTESY OF V. CRESPI

PHOTO 30
Manual feeding of shrimp

COURTESY OF V. CRESPI

Commercial aquaculture farms in Mexico

PHOTO 31
Circular earthen ponds in Sonora

COURTESY OF M. SEGOVIA

PHOTO 32
Rectangular stonemasonry tanks in Sonora

COURTESY OF M. SEGOVIA

PHOTO 33
Hatchery and tanks covered with liners to avoid sand contamination in Baja California

COURTESY OF R. MALONE

PHOTO 34
Rectangular tanks covered with PVC in Baja California

COURTESY OF R. MALONE

PHOTO 35
Concrete tanks covered with PVC against solar radiations

COURTESY OF M. SEGOVIA

PHOTO 36
Nursery tanks

COURTESY OF M. SEGOVIA