An overview on desert aquaculture in Central Asia (Aral Sea Drainage Basin)

Bakhtiyor Karimov
Institute of Zoology of Uzbekistan Academy of Sciences
Tashkent, Uzbekistan
E-mail: Karimov@sarkor.uz

Karimov, B. 2011. An overview on desert aquaculture in Central Asia (Aral Sea Drainage Basin). *In* V. Crespi & A. Lovatelli, eds. *Aquaculture in desert and arid lands: development constraints and opportunities. FAO Technical Workshop. 6–9 July 2010, Hermosillo, Mexico*. FAO Fisheries and Aquaculture Proceedings No. 20. Rome, FAO. 2011. pp. 61–84.

SUMMARY

Central Asian countries are bounded in the northwest by the Aral Sea, a basin which dominates the whole region. The climate is extremely continental and arid. The average annual precipitation is about 100–200 mm in the plains; 30–50 percent of the total rainfall is in the spring, 25–40 percent in winter, 10–20 percent in autumn and 1–6 percent in summer. There are three main climatic zones in the Republic of Kazakhstan, Republic of Turkmenistan and the Republic of Uzbekistan: (sand) deserts and dry semi-deserts (steppes); foothills (piedmont areas); and mountains. The history and present status, traditions, main production systems, technologies, cultured fish species, etc., in desert and arid lands aquaculture development in all former Soviet Republics/Central Asian countries have very common characteristics. The end of commercial fishery in the Aral Sea in 1983 due to desiccation has had a significant impact on the aquaculture development of this region. Uzbekistan can be considered as a model for this review as it has typical characteristics for the region. The aquaculture sector in the Aral Sea Drainage Basin (ASDB) countries was established under Soviet rule. Before 1961, the only fish available on the market originated from capture fisheries, mainly originating from the Aral Sea. Fisheries managers already knew that the Aral Sea was drying up and that fisheries in reservoirs and lakes could not produce enough fish to meet the demand of the rapidly growing population of Central Asia. The attention of policy makers, therefore, shifted slowly to aquaculture development. In the early 1960s, local governments, in cooperation with the All-Union Ministry for Fisheries, managed a large-scale programme of aquaculture development, establishing >30 farms with a total pond area of ~31 000 hectares in Central Asia, including the southern part of Kazakhstan. Most were in Uzbekistan. This programme included the development of new technologies and the establishment of research and education facilities. The technology mainly promoted was extensive and semi-intensive cyprinid polyculture in earthen ponds. The species reared were common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*H. nobilis*) and grass carp (*Ctenopharyngodon idellus*). As a result, the fish farms of Central Asia produced ~38 000 tonnes in the 1980s. By the beginning of the 1990s, ~21 000 tonnes of pond fish were produced annually in Uzbekistan alone.

Currently, pond culture of cyprinids is still prevalent in all Central Asian countries. Silver carp became the most cultured species and constitutes 70–85 percent of total production. However, the total area of ponds in the desert and arid lands of the ASDB has decreased considerably and is estimated to be ~15 000 hectares; this has been caused by economic difficulties and permanent water deficit, which makes filling the huge fattening ponds difficult. As in all other countries, consumer demand for fish is increasing in Central Asia, along with general development and increasing incomes. Generally, the consumption of fish in the 1980s was ten times what it is today. The current demand is, therefore, at least ten times more than existing annual fish production.

RÉSUMÉ

Les pays d'Asie centrale sont bordés au nord-ouest par la mer d'Aral, un bassin qui domine l'ensemble de la région. Le climat y est extrêmement continental et aride. Les précipitations annuelles y sont en moyenne comprises entre 100 et 200 mm dans les plaines, avec 30 à 50 pour cent des précipitations au cours du printemps, 25 à 40 pour cent pendant l'hiver, 10 à 20 pour cent durant l'automne et seulement 1 à 6 pour cent en été. On relève trois grandes zones géographiques et climatiques dans cette région formée par la République du Kazakhstan, le Turkménistan et la République d'Ouzbékistan : les déserts (de sable) et semi-déserts secs (steppes), les contreforts montagneux (zones au pied des montagnes) et les montagnes. En matière de développement de l'aquaculture en milieu aride ou désertique, l'histoire comme la situation actuelle, les traditions, les principaux systèmes de production, les technologies, les espèces de poissons élevées, etc. ont des caractéristiques communes dans toutes les anciennes républiques soviétiques et dans tous les pays d'Asie centrale. La fin de la pêche commerciale dans la mer d'Aral en 1983, due à son assèchement, a eu des effets importants sur le développement de l'aquaculture dans la région. Dans le cadre de cette étude, l'Ouzbékistan peut être considéré comme un modèle car il représente des caractéristiques typiques pour la région. Le secteur aquacole a été créé dans les pays du bassin de la mer d'Aral conformément à la législation soviétique alors en vigueur. Avant 1961, les seuls poissons disponibles sur le marché provenaient de la pêche de capture, principalement dans la mer d'Aral. Les responsables du secteur savaient déjà que la mer d'Aral allait disparaître et que la pêche pratiquée dans les réservoirs et dans les lacs ne pourrait pas produire suffisamment de poissons pour satisfaire la demande d'une population croissant rapidement dans la région. L'attention des décideurs politiques s'est donc lentement déplacée vers le développement de l'aquaculture. Au début des années 1960, en coopération avec le ministère soviétique de la Pêche, les autorités locales ont lancé un programme de développement de l'aquaculture à grande échelle, avec la création de plus de trente exploitations dont les étangs couvraient une superficie totale d'environ 31 000 hectares en Asie centrale, y compris dans la région sud du Kazakhstan. La majorité de ces fermes piscicoles ont été créées en Ouzbékistan. Le programme comprenait la mise au point de nouvelles technologies et la création de structures de recherche et de formation. Les technologies encouragées visaient essentiellement la polyculture extensive ou semi-intensive de cyprinidés en étang. Les espèces cultivées étaient la carpe commune (*Cyprinus carpio*), la carpe argentée (*Hypophthalmichthys molitrix*), la carpe à grosse tête (*H. nobilis*) et la carpe herbivore (*Ctenopharyngodon idellus*). Dans les années 1980, la production des exploitations piscicoles d'Asie centrale s'élevait à environ 38 000 tonnes. Au début des années 1990, la production de poissons élevés en étang atteignait environ 21 000 tonnes seulement en Ouzbékistan. Actuellement, l'élevage de cyprinidés en étang domine toujours la production piscicole en d'Asie centrale. La carpe argentée est devenue la principale espèce élevée. Elle représente entre 70 et 85 pour cent de la production totale. Cependant, à cause des difficultés économiques rencontrées et d'un déficit permanent en eau qui rend difficile le remplissage des immenses étangs d'engraissement, la superficie totale des étangs a considérablement baissé dans les zones

désertiques et arides du bassin de la mer d'Aral. On estime qu'ils couvrent aujourd'hui environ 15 000 hectares. En Asie centrale comme partout ailleurs dans le monde, la demande en poissons ne cesse d'augmenter. Elle accompagne le développement global et l'augmentation des revenus. De façon générale, la consommation de poissons était dans les années 1980 dix fois supérieure à celle d'aujourd'hui. La demande actuelle est donc au moins dix fois supérieure à la production.

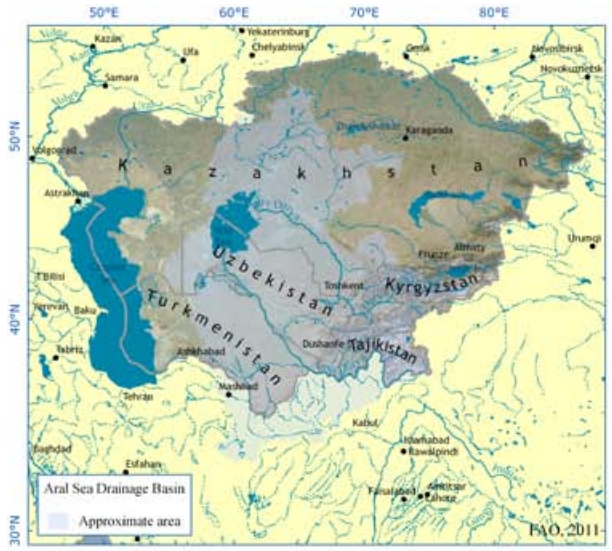
ملخص

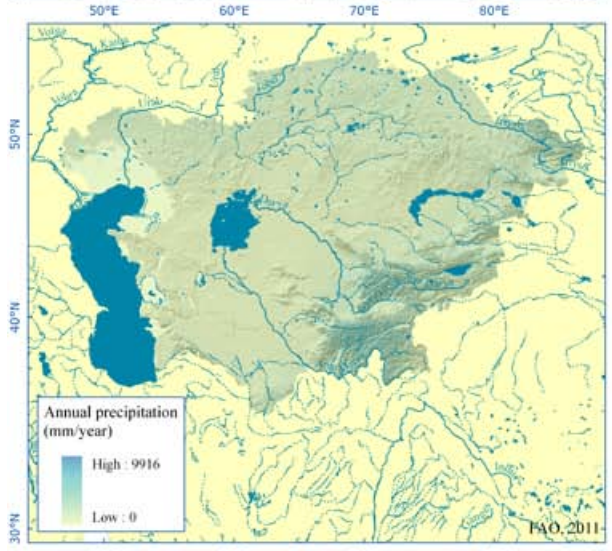
يحد بحر الاورال بلدان آسيا الوسطى من الجانب الشمالي الغربي، وهو بمثابة حوض يسيطر على المنطقة بأكملها. والمناخ هو قاري وجاف جدا. ويصل متوسط المعدل السنوي لسقوط الأمطار الى 100 200 ملم في السهول؛ و30 50 في المائة من إجمالي كمية الأمطار تسقط في فصل الربيع، و25 40 في المائة في فصل الشتاء، 10و 20 في المائة في الخريف و 1 6 في المائة في فصل الصيف. هناك ثلاثة مناطق مناخية رئيسية في جمهورية كازخستان، وجمهورية تركمنستان وجمهورية اوزبكستان: الصحاري (الرمل) وشبه الصحاري القاحلة (السهول)؛ التلال (مناطق سفوح الجبال)؛ والجبال. ان تاريخ والحالة الحالية، والتقاليد، وأنظمة الإنتاج الرئيسية، والتقنيات، والأنواع السمكية المستزرعة، الخ. في تنمية تربية الأحياء المائية الأرضية الصحراوية/الجافة في جميع بلدان آسيا الوسطى/الجمهوريات السوفيتية السابقة لديها صفات عامة مشتركة. ان نهاية الصيد التجاري في بحر الاورال في عام 1983 بسبب الجفاف كان له تأثير مهم على تنمية تربية الأحياء المائية في هذه المنطقة. ويمكن اعتبار اوزبكستان نموذجا لهذه الدراسة وذلك لكونها تتميز بصفات مثالية في المنطقة. وقد تم تأسيس قطاع تربية الأحياء المائية في بلدان حوض تصريف بحر الاورال (ASDB) وذلك في ظل الحكم السوفيتي. وقبل عام 1961، فان السمك المتوفر في الأسواق كان مصدره قطاع المصايد التقليدية، وبشكل أساسي كان مصدره بحر الاورال. ويعلم مدراء المصايد السمكية الآن ان بحر الاورال يموت وان المصايد في البحيرات والخزانات المائية لايمكن ان توفر كميات كافية من الأسماك للوفاء بالطلب المتزايد بشكل مضطرد للسكان في آسيا الوسطى. وبالتالي، فإن اهتمام صانعي السياسة قد تحول بشكل بطئ الى تنمية تربية الأحياء المائية. وفي بدايات الستينات من القرن الماضي، قامت الحكومات المحلية بالتعاون مع جميع وزارات الثروة السمكية في بلدان الاتحاد بإدارة برنامج كبير لتنمية تربية الأحياء المائية وذلك بتأسيس أكثر من ثلاثين مزرعة بمساحة إجمالية للأحواض وصلت الى 31000 هكتار في آسيا الوسطى، وتتضمن الجزء الجنوبي من كازخستان. ومعظمها كان في اوزبكستان. ويتضمن هذا البرنامج تطوير تقنيات جديدة وتأسيس تسهيلات للبحوث والتعليم. والتقنية التي طبقت بشكل أساسي كانت هي الاستزراع المتعدد الموسع وشبه المكثف للشبوطيات في الأحواض الترابية. والأنواع المستزرعة كانت الكارب الشائع اوما يسمى بالشبوط (*Cyprinus carpio*)، والكارب الفضي او الشبوط الفضي (*Hypophthalmichthys molitrix*) والكارب ذو الرأس الكبير او الشبوط كبير الرأس (*H. nobilis*) والكارب العشبي او الشبوط العشبي (*Ctenopharyngodon idellus*). وكنتيجة لذلك، فان مزارع الأسماك في آسيا الوسطى أنتجت 000 38 طن في الثمانينات من القرن الماضي. ومع بداية التسعينات من نفس القرن، يتم إنتاج 000 21 طن سنويا من أسماك الأحواض في اوزبكستان وحدها. وحاليا، فان استزراع الأحواض للشبوطيات مايزال هو السائد في جميع بلدان آسيا الوسطى. وقد أصبح الشبوط الفضي أكثر الأنواع المستزرعة ويمثل 70 85 في المائة من الإنتاج الكلي. ومع ذلك، فان المساحة الإجمالية للأحواض في الصحراء والأراضي الجافة في منطقة حوض تصريف بحر الاورال (ASDB) قد انخفضت بشكل كبير وتم تقديرها تقريبا ب000 15 هكتار؛ وذلك بسبب الصعوبات الاقتصادية والنقص الدائم في المياه، والذي جعل من الصعوبة ملء أحواض التسمين الكبيرة. وكما هو الحال في جميع البلدان الأخرى، فان طلب المستهلكين على الأسماك قد ازداد في آسيا الوسطى، سوية مع التنمية العامة وزيادة الدخل. وبشكل عام، فان استهلاك الأسماك في الثمانينات من القرن الماضي كان أكثر بعشر مرات عن معدل الاستهلاك الحالي.وبالتالي فان الطلب الحالي أكثر على الأقل بعشر مرات عن الإنتاج السنوي الحالي للأسماك.

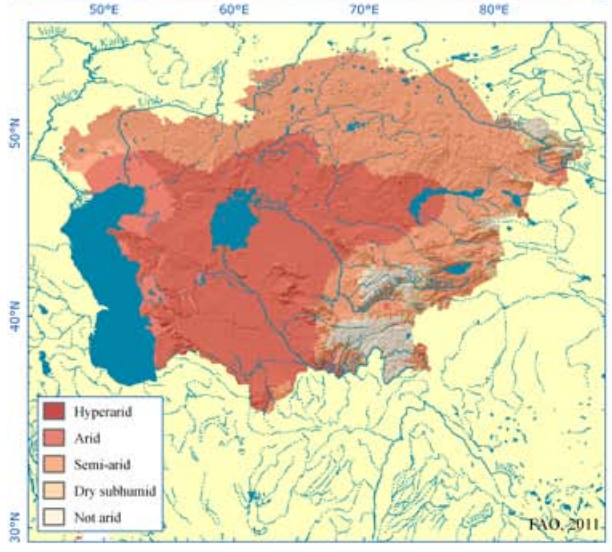
GENERAL OVERVIEW OF DESERT AND ARID LANDS AQUACULTURE DEVELOPMENT

Central Asia (CA) covers an area of 3 994 300 km² (Figure 1), about two-thirds of which are drylands and include some of the most sparsely populated regions in the world. CA is bounded on the northwest by the Aral Sea, a basin which dominates the whole region. The Aral Sea Drainage Basin (ASDB), which is situated within CA and covers an area of 2.2 million km² and is home to around 50 million people, comprises

FIGURE 1
Maps of Central Asia countries around the Aral Sea Drainage Basin







Central Asia
(Aral Sea Drainage Basin)

Countries area: approx. 400000 (1000 Ha)
Source: FAOSTAT. Estimated, 2007

Land area: aprox. 393000 (1000 Ha)
Source: FAOSTAT. Estimated, 2007

Agricultural area: approx. 284000 (1000 Ha)
Source: FAOSTAT. Official data, 2007

Aquaculture Production Average 2004-2008: 3771 tonnes
Source: FISHSTAT. Official data

Aridity:
Approx. areas of hyperarid regime: 0 (1000 Ha)
Approx. areas of arid regime: 203400 (1000 Ha)

A typical landscape of an arid region in Central Asia.

COURTESY OF B. KARIMOV

the drainage area of two major rivers – the Amudarya and the Syrdarya – and the Aral Sea itself.

The climate is extremely continental and arid. January is generally the coldest month (with a mean temperature of –2 to 0 °C in the south and –12 to –8 °C in the northwest) and July is the warmest (mean temperatures of 25 to 30 °C in the plains and 20 to 25 °C in the mountains). The average annual precipitation is about 100–200 mm in the plains, which is lower than the rate of evaporation. Downstream Amudarya and desert zones are the areas with the lowest precipitation, having an average rainfall of <100 mm (UNDP, 2008). Thirty to 50 percent of the total rain falls in the spring, 25–40 percent in winter, 10–20 percent in autumn and 1–6 percent in summer. Most rivers and lakes freeze over from late December until early January/mid-February. The waters supported the development of economically and culturally rich civilizations around oases based on the development of irrigated agriculture, which has been continuously and sustainably practised in the region for thousands of years.

The development of agriculture, including aquaculture and capture fisheries, in arid and desert lands within the ASDB has a common problem – a deficit of river water because of its irrational and inefficient use for irrigation. The distribution of water resources is extremely unfavourable in the vast plain areas occupied by deserts and semi-deserts. During the Soviet period, irrigation activities in Central Asia were directed mainly to the growing of cotton. The production of other agricultural goods, especially the production of meat and fish, was widely neglected. This situation was aggravated by the drying of the Aral Sea itself; now the protein supply for the population can only be met through the import of meat and fish (Karimov, 2003; Karimov, Keyser and Kurambaeva, 2002; Karimov *et al*., 2004, 2005).

The historical and current development of aquaculture has many similarities in all the arid and desert areas of the ASDB. Five newly independent states appeared in the ASDB after the breakdown of the Soviet Union in 1991 (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan). These countries have embarked upon independent and regional approaches to nature conservation, including fisheries issues.

The Aral Sea is the world's fourth largest lake, but it was only recently that the scientific community of the region was allowed to talk about the catastrophic ecological changes in it and its river deltas. As a direct result of Aral Sea desiccation, about 500 000 hectares of spawning areas and fish migratory patterns have been totally destroyed.

The history, traditions, main production systems, technologies, species, etc., in desert and arid lands aquaculture development in all countries of the former Soviet Republics/Central Asian countries have the same characteristics. Uzbekistan can be considered as a model country having most of the typical characteristics of these countries; this review, therefore, concentrates on this country.

The per capita consumption of fish in Uzbekistan is very low (estimated to be 0.4 kg/year). This situation is typical of other CA countries, except Kazakhstan, where is it ~8 kg/year. Enhancing per capita fish consumption at levels recommended by health specialists would have social and economic importance. It is therefore, a priority of the governments in Uzbekistan, Tajikistan, Turkmenistan and Kazakhstan to improve the yield of fish from small and large water bodies. More attention should also be paid to the development of aquaculture, for which climatic conditions are highly suitable. Some preliminary experience in the development of aquaculture in small fish ponds exists.

Traditions in desert aquaculture development in the region

The fisheries sector in ASDB countries was established under Soviet rule. In Uzbekistan and Kazakhstan before 1961, the only fish available on the market was from the capture fisheries, mainly from the Aral Sea and the deltaic water bodies of the Amudarya and

Syrdarya rivers. The landlocked Aral Sea was rich in fish species, and Uzbekistan captured an average of 25 000 tonnes of valuable fish per year and another 20 000 tonnes was captured by Kazakhstan (Tleuov, 1981, Karimov and Razakov, 1990). By the 1960s and 1970s, fish yields had decreased sharply in the Aral Sea, and in 1983 the last catch officially recorded was only 50 tonnes (Kamilov, Karimov and Keyser, 2004). The fishing industry in Uzbekistan had to find new sources to supply fresh fish to the market. Up to 6 000 tonnes of fish were caught annually in the reservoirs and lakes of Uzbekistan in the 1970s and 1980s. However, the fisheries managers of the former USSR already understood in the 1960s that capture fisheries could not produce enough fish to meet the demand of the rapidly expanding population of the CA Republics.

The attention of scientists and policy makers moved slowly towards aquaculture development. In the early 1960s, the governments in cooperation with All-Union Ministry for Fisheries managed a large-scale programme of aquaculture development including the establishment of more than 30 fish farms (totalling ~31 000 ha) in the CA. Most were established within Uzbekistan. The development of new technologies and the establishment of research and education centres for fisheries and fish culture were other key components of that programme. The main technology promoted was extensive and semi-intensive cyprinid polyculture. As a result, fish farms in Uzbekistan alone produced 20–25 000 tonnes/year in the 1960s and 1970s; productivity was the highest of all the regions of the former USSR, averaging 3 to 3.5 tonnes/hectare in Uzbekistan and as much as 4 tonnes/hectare in the Tashkent region.

In Tajikistan, the first hatchery was established in 1951 (Thorpe and van Anrooy, 2009). Originally covering 72 ha, the farm expanded within 20 years to >200 hectares and produced 14 million larvae for domestic and export purposes. Between 1970 and 1990, new ponds with an area of 2 500 hectares were established in Tajikistan, including a spawning-nursery pond in the Kayrakkum fish farm in the arid north of the republic. In 1988, a fish reproduction complex of regional significance, with a capacity of 250 million larvae of carp and phytophagous fish species, was created at the foot of the Djami Fish Farm. This complex was unique in the CA and included semi-intensive culture and extensive polyculture of carps in earthen ponds. The species cultured were *Cyprinus carpio, Hypophthalmichthys molitrix, H. nobilis* and *Ctenopharyngodon idellus*. Aquaculture provided 3 298 tonnes of fish or 70–80 percent of the marketed fish before its independence in 1991 (Thorpe and van Anrooy, 2009). However, after independence, aquaculture production sharply decreased; by 2006, only 210 tonnes were produced – only 20 percent of that were reared before independence (Thorpe and van Anrooy, 2009). According to A. Khaitov (personal communication, 2008), this decline is attributed to institutional failure following the deterioration of economic relations with the former USSR (especially with Uzbekistan, Kazakhstan and the Russian Federation); this led to sharp increases in the market price of fish feeds, petroleum, oil and lubricants and a lack of spare parts to repair fish culture equipment and hatcheries; in addition, the civil war damaged the economic and social life in Tajikistan.

In Kazakhstan, aquaculture began in 1970 and by the end of 1980s there were 12 farms with a total area of 5 041 hectares (3 313 hectares of fattening ponds and 728 hectares of fingerling ponds). By the beginning of the 1990s, the number of fish farms had risen to 47. During the period from 1970 until 1990, the volume of fish production through aquaculture increased from 692 tonnes to 9 883 tonnes (Timirkhanov, Chaikin and Makhambetova, 2007). In the desert and arid regions of Kazakhstan – the so-called Aral-Syrdarya basin (the Syrdarya, Shardara and Shymkent fish farms [South-Kazakhstan] and Kosjar [Kamyshlybas] fish farm in Kosjar Village at Lake Kamyslybas [Kyzylorda region]) mainly produced fish seeds and reared common carp, silver carp and grass carp in polyculture and functioned successfully until the beginning of the 1990s. However, by the year 2004, most of the 17 fish farms had already ceased operations. By 2006, only 175 tonnes of fish were produced in the

remaining 12 fish farms (Timirkhanov, Chaikin and Makhambetova, 2007). Today, the situation in these enterprises is very poor for many reasons, including the absence of broodstock or fish breeding programmes, new technologies, low quality of feeds, lack of specialists, etc. This has been exacerbated by a sharp increase in fish imports (herring, salmonids, etc.) which has made farming fish uneconomic (Timirkhanov, Chaikin and Makhambetova, 2007). The development of aquaculture in Kyrgyzstan started in the late 1950s with the establishment of the Chui state fish farm (now the joint-stock company Balyk) as a regional fish hatchery with a total pond area of 370 ha. In addition to the production of table fish, various carp species were also provided for stocking. The main cultured species in arid and desert land aquaculture were similar to the other republics: silver carp, common carp and grass carp. The Uzgen fish farm (Osh region), with an annual capacity of 500 tonnes, started in 1968. The Talass fish farm existed in 1975; at best it produced ~300 tonnes of common carp and Chinese carps per year. At the end of the 1980s, there were about 1 310 hectares of ponds, but after its independence in 1991, these farms were practically closed because of well-known economic problems. Aquaculture production fell from ~1 500 tonnes in 1989 to about 30 tonnes in 2006 (Niyozov *et al*., 2007).

The Republic of Turkmenistan possesses one of the largest sandy deserts in the world – the Karakum Desert. The total production of fish in 2006 was ~15 000 tonnes. Pond aquaculture with a total surface area of about 1 400 hectares was practised in the Ashgabat (Gerens), Tedzhan and Karamat-Niyaz fish farms, which were constructed during the Soviet period. Between 1991 and 1995, aquaculture production declined by 50 percent (from 2 100 to 1 050 tonnes) and by 1997 it had decreased further to 342 tonnes. This was largely attributed to the lack of domestically produced fishmeal and other feed components and the rapidly progressing deterioration of ponds, mainly due to siltation. Currently, aquaculture and inland capture fishery production is insignificant. At present, the only active fish hatchery facility in the country is Biotilsimat, which provides fingerlings and fry to the state for restocking activities and to two private small-scale fish farmers (Thorpe and van Anrooy, 2009). Neither inland capture fisheries nor aquaculture is considered to be a priority by the government.

In Uzbekistan, aquaculture has been the main fish producing sector since 1985, but the proportion decreased from a peak of 85 percent in 1983 to a trough of 52 percent in 2008, as the proportion from capture fisheries increased. Recognizing the collapse of the Aral Sea Fishery, two fish farms were constructed in the lower reaches of the Amudarya River in Karakalpakstan, mainly to produce fish for restocking. However, both the Nukus and the Muynak fish farms are now abandoned. Rehabilitation of these facilities and the development of fish farming provide opportunities to use limited water resources in the lower reaches of rivers to produce more marketable fish. The present potential productivity in fish farms in Uzbekistan is ~3 000 kg/ha, as opposed to 5–10 kg/hectare (or 30 kg/hectare in the case of restocking of common carp and Chinese carps) in natural water bodies. The Muynak fish farm alone, with its 500 hectares of fish fattening ponds, could produce at least 1 500 tonnes of fish/year (Karimov *et al*., 2005). The rehabilitation and intensification of aquaculture in the Nukus fish farm (which has not functioned for the last 20 years, but in 2007, the newly established Karakalpak-Russian joint venture Nukusbalik Ltd. began rehabilitation measures) provides the potential to produce at least 3 000 tonnes/year of valuable fish. These may be used to supply the Muynak canning factory. There are also other possibilities to develop small fish farms, e.g. cage culture in irrigation canals and drainage water collectors.

A modern motto for fisheries development in the desert and arid areas of the Aral Sea Region could be: "*Move from unpredictable capture fisheries in unstable water bodies to intensive fish farming that provides constant fish yields and jobs for the local population*".

FIGURE 2
Fish harvest from a large fish pond in the Khorezm Fish Farm

COURTESY OF B. KARIMOV

The main farmed fish production unit in the northwestern part of Uzbekistan since 1974 has been the Khorezm fish farm, constructed on a non-conventional desert land area on the periphery of an agricultural oasis. Until the early 1990s, the Khorezm fish farm (with 1 484 hectares of ponds) produced about 3 000 tonnes/year, mainly of silver, common, bighead and grass carps (Figure 2). However, during recent years, it has produced only about 1 000 tonnes of fish/year, due to economic difficulties, water scarcity and the absence of formulated (balanced) fish feed.

Main production systems, technologies and species

The prevalent type of aquaculture in the desert and arid areas of the CA is the polyculture of cyprinids in large earthen ponds. The species cultured are common carp, silver carp, bighead carp, and grass carp. Crucian carp (*Carassius auratus*), wels (*Silurus glamis*) and snakehead (*Channa argus*) are cultured as additional or accidental species in some fish farms. The growing season lasts from late March/April to October/November. Market-size fish are produced within a two-year production system: during the first year, small fry are raised in fingerling ponds (10–50 ha) to at least 25 g; after the winter season, they are transferred to fattening ponds – grow-out ponds – (70–150 ha) where they grow to marketable sizes of 500 g to 1 kg. The total duration of this full production system is ~540 days. Where farms only operate part of the production cycle, fattening takes ~270 days and the rearing of fingerlings takes 180 days.

Historical review

Uzbekistan (and other CA countries) had a relatively good production of fish from desert and arid land aquaculture before and immediately after its independence in 1991 (Table 1). The average pond productivity was 3.0 to 3.3 tonnes/hectare in the 1970s and 1980s, which was high compared to the average of 1.5 to 1.7 tonnes/hectare in the former USSR during the same period. At that time, aquaculture produced about 20 000–21 000 tonnes/year (Kamilov, Karimov and Keyser, 2004).

During the Soviet era and in the early 1990s, liming and fertilization were common practices in pond management. These activities stimulated the development of plankton in the water body as natural feed for silver carp and bighead carp and of plants for grass carp. Supplementary feeds were given to common carp and, partly for grass carp. Good quality commercial fish feeds were available; these had protein levels of 28–32 percent for fry and early fingerlings and 24–28 percent for grow-out. All farms had well equipped laboratories, with good management and well educated experts. Broodstock were available and larvae from several hatcheries were transported to all regions of the Republics of Central Asia. Fish production and reproduction technology was well documented and financing for fish farms was available. Successful results of research work were applied. Generally, the support for aquaculture development was considered effective. Cyprinid culture was well developed in Uzbekistan and other republics. In addition, there was one small trout farm called Tavaqsay that produced 20–50 tonnes per year (1970s and 1980s) in Uzbekistan and another – the Turgenev trout farm – in Kazakhstan. There were also some experimental intensive aquaculture projects, including the introduction of new species, such as channel catfish (*Ictalurus punctatus*),

TABLE 1
Fish production in Uzbekistan, 1980–2009 ('000 tonnes)

Year	Total fish production	Fish production	
		Fish pond farms	Natural water bodies
1980	16.7	11.5	5.2
1990	26.5	20.4	6.1
1991	27.2	20.3	6.9
1992	28.1	20.9	7.2
1993	23.4	16.8	6.6
1994	15.3	12.2	3.1
1995	12.5	8.9	3.6
1996	8.0	5.8	2.2
1997	8.4	5.3	3.1
1998	8.8	6.1	2.7
1999	8.2	5.5	2.7
2000	8.7	5.3	3.4
2001	8.8	5.4	3.4
2002	7.8	5.2	2.6
2003	5.4	3.3	2.1
2004	4.3	2.4	1.9
2005	6.1	3.2	2.9
2006	7.2	3.8	3.4
2007	7.1	4.0	3.1
2008	7.9	4.1	3.8
2009	9.2	5.1	4.1

Siberian sturgeon (*Acipenser baieri*), three species of buffalo fish (*Ictiobus cyprinellus*, *I. bubalus* and *I. niger*), some strains of rainbow trout (*Oncorhynchus mykiss*), etc. However, even when research projects proved to be successful, the centrally planned economy maintained the emphasis on carp culture (Uzbekistan was one of the biggest carp producers in the former USSR).

FIGURE 3
Use of cattle manure in the Khorezm Fish Farm

COURTESY OF B. KARIMOV

Present status

The pond culture of cyprinids remains prevalent in Uzbekistan and other CA countries. No improvements have occurred because of the lack of investment after the cessation of the USSR. As inorganic fertilizers are much cheaper than fish feeds, most attention is paid to liming and fertilization in order to stimulate phytoplankton development. Commonly used fertilizers are urea, ammonium nitrate and ammonium phosphate, in addition to cattle manure (Figure 3). For this reason, silver carp became the main cultured species and now represents 70 to 85 percent of total aquaculture production. Common carp, together with grass carp and bighead carp, are now considered additional fishes. Some farmers use supplementary feeds (mainly bran, cottonseed husk, wheat) for common carp feeding, while other farmers do not provide supplementary feeds. Occasionally, grass carp are fed with freshly cut plants (mainly reeds).

FIGURE 4
Carp eggs incubation in the Balikchy Fish Farm

COURTESY OF B. KARIMOV

Artificial reproduction, using hormonal or pituitary injections, incubation (Figure 4), and larvae and fry rearing to fingerlings (so-called summerlings) are commonplace. Over-wintering is generally carried out in smaller ponds than in former times. Large ponds (50–100 hectares or more) are filled with fresh river water every year in spring and stocked with the yearlings. This requires considerable expense and labour to ensure forage reserves are available (to make the water fertile). Stocking densities for yearlings of 15–25 g are between 1 500 and 2 000/ha; these are cultured until autumn. Forage is added to the ponds in the summer season (in well-managed ponds, 5 kg of forage produces 1 kg of fish).

According to our observations, most ponds (~93 percent) are used for fish production. The rest (usually small enterprises) combine the cultivation of fish with rice (paddy-cum-fish farming) and ducks.

In autumn, the water, with its accumulated fertility, is discharged from the ponds and all the fish have to be sold within a few days. Then the ponds remain empty from autumn to spring. In the spring, they are refilled with fresh "infertile" water. Under the planned economy, fish farmers were mainly concerned to meet their production targets, not to consider commercial aspects. Currently, private farmers are seeking ways to reduce costs and increase productivity. In large fish farms (e.g. Khorezmbalikmakhsulotlari), aquaculturists have started to market table fish gradually, keeping them until January in deep wintering ponds.

Some large fish farms stock at higher densities (up to 3 000–4 000 fish/ha), resulting in the need to raise the fish for a third year. These farms aim to produce more valuable fish weighing 1.5–3.0 kg. This practice is profitable because there is still no real competition and taxes on land and water use are low.

There are problems with fish diseases, the most widespread being saprolegniosis. *Ichthyophthiriosis*, *diplostomosis*, *lerneosis* and krasnucha (spring viraemia of carps or roseola) are also frequent. Frequently damaged species are common carp and grass carp (Sidorov, 2005). In some cases, water quality problems are accepted as the main cause of fish diseases and mass mortality. Fish diseases may become more important as more intensive methods become utilized.

During 1991–2007, there were no attempts to modernise aquaculture production systems. The only new private fish farm oriented towards intensive fish culture is the NT Fish Farm (Tashkent Region), which was established at the end of 2007. Flow-through tanks for trout were constructed and operations began in 2008. This farm was based on the results of the German Uzbek Research Project funded by the German Federal Foundation for Environment (Wecker *et al.*, 2007). However, this farm is situated in the foothills with high rainfall.

Potentially, the fish ponds of Uzbekistan have the capacity to produce 26 000 tonnes of fish annually. However, for over 15 years, they have not been well maintained,

as funds were generally lacking. Thus, total aquaculture production gradually decreased from about 20 000 tonnes at the beginning of the 1990s to not more than 4 000–5 000 tonnes in 2007–2009 (see Table 1). The combined nursery ponds in the country can produce as many as 93 million yearlings annually. However, due to poor financing and management, actual production is much lower (estimated to be not more than 10 million/year).

The German-Uzbek Research project was followed in 2007 with support from the FAO TCP/UZB/3103(D) Project, which developed a working plan for the development of aquaculture and fisheries in Uzbekistan for 2008–2016. This document has gained government attention, but the resultant programme is primarily concerned with the rehabilitation of existing fish farms. Despite this, several hundred new small private fisheries enterprises have appeared, but most are concerned with capture fisheries; only a few started to cultivate carps in ponds using old production systems, technologies and species. Modern technologies will only be introduced when the government makes financial resources and other necessary facilities available.

HUMAN RESOURCES

Since ancient times, fisheries have been one of main sources of food for local people. During Soviet times, the fishing industry was a main branch of the economy of the whole Karakalpakstan autonomous republic. Traditionally, fish and fisheries meant everything for the people of the Amudarya River delta. They used to catch fish and process them in the Muynak Fish Canning Factory (MFCF). Muynak traditionally had three main types of employment: fishermen, fish cannery workers and cattle breeders. According to Tleuov (1981), there were about 1 200 fishermen involved in 12 capture fishery collective farms. They had 113 fishing boats and caught about 75 percent of total fish in the country.

The MFCF was a significant employer and was equipped with modern fish processing equipment imported from Germany in the 1933–1941 era. It included five other smaller fish processing plants situated on the southern and southwestern coastlines of the Aral Sea. During the years of favourable ecohydrological conditions, MFCF was a major producer of canned fish and other fish products in the ASDB. However, by 1974, production had been cut by half and other plants had ceased to exist at the end of the 1970s. The supply of frozen oceanic fish imports from Russia dried up and the factory became unprofitable, but it continued to function on a reduced scale using locally produced silver carp. Today, the factory is practically out of operation.

In those days, many people worked in ship maintenance plants, the Aral shipping company or in other branches of local industry engaged in fishing or fish processing. A few were also involved in the coastal tourism industry.

It is not possible to differentiate employment data between aquaculture and capture fisheries. In the 1980s, more than 70 farms and enterprises were active in the fisheries sector (capture fisheries and aquaculture) and 5 600 to 5 800 people were employed by the enterprises of the republican Fisheries Committee, Uzbekribvod (the Commission for the protection of fish resources) and Ribsbit (Fish trade). Under the planned economy, all of them worked as full-time employees. In addition, about 100–150 specialists worked at the Central Asian Branch of Gidroribproekt (Institute for the promotion of fisheries projects) and the Central Asian ichthyo-pathological laboratory (both situated in Tashkent).

During the independence, in the period 1994–2003, significant changes took place in the sector, job security and salaries were low and there were no new entrants. At the start of the privatization process, the trading companies left the sector. Other enterprises followed suit and only a few fish farms and capture fisheries enterprises remained active. As a consequence, the number of people employed in the sector decreased significantly, particularly in the early years of the privatization process.

When the full privatization of fisheries was permitted, the number of enterprises increased as existing enterprises were split into several smaller units and new enterprises were created. The number of people employed in the sector also slightly increased (Karimov *et al*., 2009). It is estimated that about 5 700 people were employed in 2007 in fisheries activities. Of these, more than 2 000 worked in 21 fish farms. Total employment in fisheries in Uzbekistan, including all the support services, is much higher, being estimated at ~10 000 (Karimov *et al*., 2009). Most of those with diplomas in fisheries, fish breeders, mechanics, technical and engineering employees can be found in Tashkent (44 percent of total workers), while the rest are spread between the remaining four provinces (Ferghana, Navoi, Andijan and Karakalpakstan). Currently there is a lack of qualified personnel in the aquaculture sector.

In 2008–2009, there were 2 022 people employed ful-time in fish farming in Uzbekistan (FCDC MAWR, unpublished data), of which 1 693 were men. There were also 337 employed part-time (301 men).

FARMING SYSTEMS DISTRIBUTION AND CHARACTERISTICS

At present, the total pond surface area of all fish farms in desert and arid ASDB has considerably decreased compared to the early years of independence, due to economic difficulties and permanent water deficit for filling the unmanageable gigantic fattening ponds. While there were 18 fish farms in Uzbekistan in 1991 with a total pond surface of more than 20 000 ha, by 2007 there were 21 farms with a total pond surface area estimated at 10 237 hectares (Karimov *et al*., 2009), i.e. only 49 percent of ponds were in use. After the issuance of the State Programme on measurements of fisheries sector development in the republic in 2009–2011 in 2009, which created favourable conditions for the establishment of new fish farms in all parts of the country, the number of fish aquaculture farms started to increase rapidly. By the middle of 2009, the total number of new farmers registered as culturing fish in ponds and other artificial water bodies in Uzbekistan reached 700 (FCDC MAWR, unpublished data). The total pond surface area was 12 630 ha, including 10 932 hectares of fattening/grow-out ponds and 1 698 hectares of nursery ponds (see Table 2 for more details). Most of them were created in the Tashkent, Samarkand and Andijan regions. The expected total production of fish from aquaculture was 5 550 tonnes but the actual production in 2009 was 5 162 tonnes. Most of this total production came from large-scale aquaculture enterprises that were established already in Soviet times. According to our analyses, only 107 fish farms produce fish today in quantities of more than one tonne/year. Most of the newly established enterprises actually capture fish or are involved in culture-based fisheries, introducing Chinese carps and common carp fingerlings.

Current estimates are that the total area of fish ponds in desert and arid ASDB is presently is not more than 15 000 ha.

CULTURED SPECIES

The fish species contributing most of the aquaculture production are the following, in descending order of value:

- silver carp (*Hypophthalmichtys molitrix*);
- common carp (*Cyprinus carpio*);
- bighead carp (*Hypophthalmichtys nobilis*);
- grass carp (*Ctenopharyngodon idellus*);
- crucian carp (*Carassius auratus*).

PRODUCTION

According to FCDC MAWR (Karimov *et al*., 2009) it is mainly phytophagous fish that are being reared in the large fish farms (Table 3) – mainly silver carp, grass carp and bighead carp, which constitute about 88.5 percent of total production. Common

TABLE 2
Details of fish farms in the Central Asia countries

No.	Province	Town/village	District	Names of the farm	Year of foundation	Pond area. ha			Full-time employees	Fish production 2009, tonnes
						Total	Fattening	Nursery		
KAZAKHSTAN (Kyzylorda and south Kazakhstan regions)										
1	Kyzylorda Region	Kosjar	Aralsk	Kosjar fish farm	1966	176	0	176	103	**
2	South-Kazakhstan Region	Shardara	Shardara	Shahdara fish nursery	–	–	–	–	–	**
KYRGYZSTAN (only southern part)										
1	Osh region	Uzgen	Uzgen	Uzgen fish farm	1968	290	224	66	–	7.7 (in 2007)
2	Talass region	Bakai-Atin	Bakai-Atin	Talass fish farm	1975	364	296	68	–	15 (in 2007)
TAJIKISTAN (only northern part)										
1	Sogd region	Kayrakkum	Khodjand	Shukufon	1992	–	0	–	–	–
TURKMENISTAN										
1	–	–	–	Biotilsimat	–	–	0	–	–	**
UZBEKISTAN										
1	Karakalpakstan	Nukus	Nukus	Nukusbalyk Ltd.	1974	46	0	46	36	2
2		Turtkol	Turtkol	Antika fish	2008	10	9	1	–	10
3		–	Chimboy	Khudaybergen Guldaga	2009	9.8	–	–	–	5.3*
4		–	Konlikul	Atabek	2009	2	–	–	–	2*
5	Andijan	Balikchi	Ulugnor	Olimp Koshonasi Lmtd.	2008	84	74	10	–	40
6				Andijanbalyk JS	1975	986	894	92	–	362
7		–	Andijan	Zh.Kabilov sahovati	2009	2	–	–	–	4*
8		–		U.Mashrabjon	2009	3	–	–	–	6*
9		–	Asaka	Asaka sazan	2009	1.4	–	–	–	4*
10		–	Balikchi	Abad yurt fayzi	2009	5	–	–	–	10*
11		–	Boz	O. Toshboev	2009	3	–	–	–	6*
12		–	Jalakuduk	Ok amur karp	2009	2	–	–	–	4*
13		–	Izboskan	Mukarramhon umidlari	2009	3.3	–	–	–	7*
14		–	Hojabad	Kora amur	2009	3	–	–	–	5*
15		–	Shahrihon	R.Razakov	2009	18.3	–	–	–	20*
16		–	Altinkul	F.Vohidov	2009	4	–	–	–	8*
17	Bukhara	–	Bukhara	Bukharabalyk Ltd.	–	574	428	146	–	–
18	Kashkadarya	–	Nishan	Sof Khavzalar Ltd.	2004	90	–	–	7	80
19		–	Karshi	Kashkadaryabalyk Ltd.	1980	409	359	50	32	200
20		–	Mirishkor	Olim ogli Sherzod	2009	6	–	–	–	4*
21		Mirishkor	Mirishkor	Achin baliklari Ltd.	2008	–	–	–	–	7.5
22	Namangan	Pap	Pap	Namanganbalyk Ltd.	1976	800	600	200	–	226
23		Pap	Pap	Madaminjon Ota Ltd.	–	90	90	0	–	–
24		–	Mingbulok	Altin zamin barakasi	2008	30	–	–	–	14.3*
25		–		Mashrab Kadir	2008	12	–	–	–	10.8*
26		–		M.Parpiev	2008	65	–	–	–	70*
27		–	Narin	K. Mingboev	2009	3.5	–	–	–	4*
28		–	Uychi	Nodirbek	2009	4.5	–	–	–	2*
29		–	Ichkurgan	Ok amur royasi	2009	1.5	–	–	–	1.5*
30	Navoi	M. Troynik	Kiziltepa	Beliy amur	2004	22	–	–	2	–
31		Kiziltepa		Aqua-Todakul	2003	128	80	48	120	**
32		Shogolon	Hatirchi	Turkumbalik plus	2009	15	–	–	3	–

TABLE 2 (continued)

No.	Province	Town/village	District	Names of the farm	Year of foundation	Pond area. ha			Full-time employees	Fish production 2009, tonnes
						Total	Fattening	Nursery		
33	Samarkand	Payarik	Payarik	Ashurota farm	2008	93.3	68.7	24.6	–	73
34		Payarik		Sherali farm	–	116.3	59	57.3	–	20
35		Balikchi		Taidyl AV farm	2003	93.4	70	23.1	–	50
36		U-Yangi Kurgancha	Katakurgan	Navruz fish farm	1998	10	7	3	13	48.5
37		–		O. Dostov	2009	5	–	–	–	5*
38		–	Bulungur	Abdikadir polvon	2009	2	–	–	–	2*
39		–		Ismoilov ata	2009	2	–	–	–	1.2*
40		–	Akdarya	Jarkishlok elita baliklari	2008	7	–	–	–	5*
41		–		D. Gozikhanov	2009	2	–	–	–	1.5*
42		–	Pastdargam	Akhun	2009	2	–	–	–	2.5*
43		–	Pakhtachi	Churgan	2009	2	–	–	–	2.5*
44		–	Samarkand	Ok amur balik	2008	2	–	–	–	2*
45		–	Urgut	S.K. Amriddin	2009	2.1	–	–	–	2.5*
46		–	Nurobod	Khakim bobo	2009	35	–	–	–	8*
47	Surkhandarya	Uzun	Uzun	Azizbobo farm	2008	34	34	0	–	8*
48		Uzun		At-Termizij farm	2008	34	34	0	–	8*
49		Uzun		Abu-Hurairo farm	2008	32	32	0	–	8*
50		–		Jorakul Hasan	2009	17	–	–	–	8*
51		Gur-gur	Jarlurgan	Oktepa Golden fish Farm	2009	15	–	–	2	11*
52		Termez	Termez	Surkhonbalik Lmtd.	2010	18	–	18	5	–
53		–		Chegara koshin otryadi	2008	105	–	–	–	5*
54		–	Sariosiyo	Undina Gulmohi	2009	50	–	–	–	7*
55	Syrdarya	Sardoba	Mirzaobod	Syrdaryabalyk Ltd.	1985	980	980	0	–	100
56		58 Railway station		Yangierbalyk Ltd.	2003	400	400	0	15	140
57		SFU		Durgoyakhor farm	2001	160	–	–	5	5
58		Shirin	Shirin	Sirdarya IES	2009	4	–	–	–	2*

TABLE 2 (continued)

No.	Province	Town/village	District	Names of the farm	Year of foundation	Pond area. ha			Full-time employees	Fish production 2009, tonnes
						Total	Fattening	Nursery		
59	Tashkent	Balikchi	Kuyi Chirchik	Balykchi JSC	1950	2 573	2 351	222	–	2 200
60		–		Ogonek Lmtd.	2008	301	–	–	–	450
61		–		Olim Saidhodja	2009	19	–	–	–	3*
62		–		I. Shokir balikchi	2009	4.7	–	–	–	3*
63		–		Barakali hovuz Ltd.	2009	34	–	–	–	3*
64		–		Beijing Kaoya	2009	2	–	–	–	3*
65		Damachi	Zangiata	Damachi Balyk Ltd.	1940	275	275	0	–	300
66		Chinoz	Chinoz	T.Mirahmedova	2009	151	–	–	–	20*
67		–		Intexnol Ltd.	2009	150	–	–	–	15
68		–		Ummon sahovati	2009	5	–	–	–	5*
69		Kush yogoch	Yangiyul	"MBP" ShK	1975	258	0	258	30	38
70		–		Cof balik baraka	2009	3.3	–	–	–	3*
71		–		K.Dicimboev	2009	10	–	–	–	3*
72		–		U.Mirahmedova	2009	20	–	–	–	4*
73		Uzbekistan	Pskent	Toshkentbalyk Ltd.	–	133	133	0	–	16
74				IIV GUIN	2008	63	–	–	–	10*
75		Yukori Chirchik	Yukori Chirchik	Balik tayyorlash business Ltd.	2009	53	–	–	16	17
76		–		Delfin	2009	10.4	–	–	–	12
77		Boka	Boka	Jahongir-Sevara	2009	6.6	–	–	–	4*
78		–		Tilanboy Bobur	2009	11.2	–	–	–	5*
79		–		Kaldirgoch	2009	4.8	–	–	–	3*
80		–	Ahangaran	Ahang Abad Pilat Diyor	2009	16	–	–	–	3*
81		–	Tashkent	Agro-Omad	2009	8.1	–	–	–	4*
82		–		Eshonhodja ota	2009	20	–	–	–	3*
83		–	Akkurgan	Saodat kamolot sari	2009	11	–	–	–	3*
84		–		Afgan urush katnashcisi	2009	2	–	–	–	1*
85		–	OrtaChircik	Islam Global Business	2009	22	–	–	–	15
86		–		Toytepa hovuzi	2009	41	–	–	–	10
87		Madaniyat	Kibray	NT Fish farm	2008	2	–	–	–	25
88		–		Gulistan tanga	2009	2	–	–	–	2*
89		Tavaksay	Bostanlik	Forel Ltd.	2008	4	–	–	–	4*
90		–		R. Saidahmedov	2009	1	–	–	–	2
91		–		Kh. Akmal baraka	2009	12.3	–	–	–	1*
92	Ferghana	Besharyk	Besharyk	Besharykbalyk Ltd.	–	503	385	118	–	145
93		–		R.Abdullajonovns	2009	3.5	–	–	–	6*
94		–		U.Kambarov kelajagi	2009	21	–	–	–	20*
95		–		I. Rakhimov	2009	10.4	–	–	–	12*
96		–		S. Norbutaev	2009	20	–	–	–	17*
97		Dangara	Dangara	Urai Ltd.	2008	334	314	20	–	30
98		Kuvasay	Kuvasay	M.Joraev Omad	2009	4.5	–	–	–	7*
99		–	Toshlok	Sotvoldi bobo	2009	15.7	–	–	–	20*
100	Khorazm	Kattabag	Yangarik	Horazmbalykmahsulot JS	1975	1 473	1 112	361	130	570
101		Tashkent	Bagat	Sh. Karimboboe ogli	2009	10	–	–	–	14.4*
102		Dehkonabad	Gurlan	Shaykh bobo	2009	2.9	–	–	–	5.4*
103		Ovshar	Khazarasp	Rozmat Davlat	2009	1.5	–	–	–	2.9*
104		Beshta		Kenja Yakutjon	2009	14	–	–	–	8.1*
105		Pichokchi		Hodji Saidmurod	2009	35	–	–	–	11.5*
106		Pichokchi		Matmurod bobo	2009	4.7	–	–	–	5.8*
107		Pitnak		Masharip Davron	2009	22.3	–	–	–	8.6*
TOTAL UZBEKISTAN						**12 630**	**10 932**	**1 698**	**–**	**5 552**

carp production is equivalent to ~11 percent (range: 3.9 to 27.23 percent). Average data for all fish farms in Uzbekistan for the year 2009 show similar results; the share of phytophagous fish and common carp is about 80 and 17 percent, respectively (Table 4).

According to surveys conducted in 2009, the average wholesale price per kilogram of: silver carp was UZS2 750, common carp and grass carp UZS5 000, trout UZS18 000 and crucian carp UZS2 000 (USD1 = UZS1 550). Based on actual wholesale domestic market prices, the total value of the fish produced by aquaculture in 2009 was equivalent to USD11 332 859.

TABLE 3
Major fish species reared in three large farms in Uzbekistan (in tonnes)

Species	Balikchi		Khorezm		Yangierbalik		Average %
	2006	%	2009	%	2009	%	
Common carp	86	5.5	186	27.2	3.9	5.0	11.3
Silver carp	1 375	88.3	453	66.4	74	95.0	84.6
Bighead carp	7	0.4	-	-	-	-	-
Grass carp	49	3.2	44	6.4	-	-	4.1
Crucian carp	41	2.6	-	-	-	-	-
Total	**1 558**	**100.0**	**683**	**100.0**	**77.9**	**100.0**	**100.0**

TABLE 4
Total aquaculture production and value by species in Uzbekistan in 2009

Species	Production		Total value (USD)
	tonnes	%	
Common carp	854.8	16.5	2 761 004
Grass carp	618.3	12.0	1 997 109
Silver carp	3 503.7	67.9	6 201 549
Trout	13.0	0.3	150 930
Others (crucian carp, snakehead)	172.3	3.3	222 267
Total	**5 162.1**	**100**	**11 332 859**

MARKET

Both before the independence in 1991 and at present, fish (low value cyprinids: silver carp, grass carp and common carp) from farms situated on desert and arid lands are mainly produced for the domestic market. Due to the limited quantities of fish available in recent years, fish is currently mainly sold fresh, with very small volumes sold smoked or salted. During the Soviet era, some of the large fish farms, such as Khorezmbalikmakhsulotlari, Balikchy JSC, etc., had their own fish processing and storage facilities. This enabled them to store part of their fish production for sale later or to process them by smoking or salting. After the independence, processing and storage facilities have commonly deteriorated and do not now operate throughout the country. This has been caused partly by the limited supply of fish, resulting in most fish being distributed in live and fresh forms and also the lack of investment in this subsector.

Fish farms are often situated near urban populations, which harvest and market their fish production in the autumn. Part of the harvested fish is sold to wholesalers and retailers in small lots (up to 200 kg) at the farm gate, for which contracts are generally concluded during the growing season. Another part of the production is sold by the farmers in nearby markets and to local retail shops. However, aquaculturists from provincial fish farms intending to earn high profits may transport their cultivated fish themselves to the Chinaz wholesale market. From this market, fish are transported on a daily base to Tashkent, which is about 70 km distant. Most of the fish originating from this market comes from natural lakes (Aydar-Arnasay lake system in Uzbekistan and Shardara reservoir situated in Kazakhstan). The transportation of fish and other aquatic products officially has to be accompanied by a copy of the declaration of origin

and a veterinary certificate. The major cultured fish species sold are common, silver, bighead and grass carps. Large fish are popular among consumers and are, therefore, about twice as expensive as small fish.

Despite the decline in processing facilities, some enterprises are slowly becoming interested again in fish processing in the past 2–5 years. They have also begun to open their own private fish shops and restaurants in large cities. For example, frozen silver carp products (gutted, free of scales and decapitated) are available at Balykchi JSC situated in Tashkent Province.

FIGURE 5
Fish section of the market in the city of Tashkent

COURTESY OF B. KARIMOV

Fish retailing can only be performed in places allocated by the local authorities of cities and districts (hokimiyats). Fish sales are only allowed if the retailer has documents confirming the legality of the catch or can show evidence of purchase of the products, and if he has a certificate confirming the quality and safety of the products on sale. There are special sections in the markets for the sale of fish, which are generally equipped with tanks for live fish and have access to tap water (Figure 5). The markets also possess refrigerators or power outlets to which refrigerators/freezers can be connected. Each retailer has its own table. The fish retail sections have special containers for waste, which is frequently removed. Generally, there are also open sewerage systems, with covering grids, which are used for the waste water. Upon consumer demand, the purchased fish can be gutted, decapitated and cleaned.

All fish wholesalers and retailers are licensed. The marketing of fish is highly seasonal; therefore, there are only a few enterprises specialized in this activity. The middlemen active in fish marketing have a marketing margin of 10 to 20 percent.

Most fish (60 percent) are sold in markets; more than 15 percent are sold through shops and supermarkets; and about 25 percent (mainly frozen and processed) are sold from warehouses to special consumers and wholesale buyers.

CONTRIBUTION TO THE ECONOMY

As Uzbekistan develops, priorities are changing. In recent years, the government has started to pay attention to the development of the fisheries sector, recognizing the necessity to market fish as the most valuable food. It has definitively identified the development of the fisheries sector as a social-economically important trend in the agrarian sector of this state. Primarily, the government has used its available administrative resources for the rehabilitation of available capacities.

The fisheries sector in Uzbekistan, composed of inland capture fisheries and aquaculture subsectors, has a potentially important role in the development of the rural economy of the country. However, in recent years the contribution of the sector to gross domestic product (GDP) was less than 0.1 percent. In spite of the vast water resources available for fisheries sector development (ponds, reservoirs, lakes, rivers, irrigation canals, etc.), total fish production declined significantly from 27 200 tonnes in 1991 to 7 200 tonnes in 2006 (Umarov, 2003; FAO, 2003; Karimov *et al.*, 2005; Karimov, Lieth and Kamilov, 2006). Of the production in 2006, the contribution of aquaculture was only 3 800 tonnes (Karimov *et al.*, 2009). Imports of fish and fisheries products also decreased during this period. As a consequence, per capita consumption decreased to less than 500 g/year in 2006, which means a reduction of over 90 percent

compared to the 4.5 to 5 kg annual per capita consumption of fish and fisheries products in the late 1980s.

In 2007, with the support of the FAO (TCP/UZB/3103(D), leading specialists of the sector, concerned ministries and agencies organized two national participatory workshops and developed a Draft Conception of the Development of Aquaculture and Fisheries in Uzbekistan for the years 2008–2016, which was approved by the Resolution of the Committee for Agrarian, the Water-Management and Ecological Issues of the Legislative Chamber of Oliy Madjlis (Parliament) of the Republic of Uzbekistan on 18 December 2008. The most pleasing symbolic event that followed was that in 2008–2009 the government paid attention to the fisheries sector, confirming its social and economic importance and the necessity to develop it as a priority. After the issuance of the programme on measurements of fisheries sector development in the republic in 2009–2011, signed by the Prime Minister of the Republic of Uzbekistan on three march 2009, No. 03/1–348, the volume of fish production from aquaculture started to increase slightly. In 2009, it reached about 5 000 tonnes. Most of the increase came from large-scale aquaculture enterprises such as Balikchi JSC, Khorazmbalikmahsulot, Damachi, etc. Based on this programme, about 200 new fisheries and aquaculture enterprises were established in various provinces of Uzbekistan. However, they only capture fish and have not yet started aquaculture activities.

The results from surveys of 30 large, medium and small fish farms in Uzbekistan during 2009–2010 have revealed that 90 percent of respondents stated that aquaculture was their main activity (FCDC MAWR, unpublished data). The main factor that influenced them to commence fish farming was its high profitability (80 percent). About 7 percent of farmers stated that the availability of technology was an important factor, and 13 percent gave other reasons. These results show the elevated role and potential of desert and arid land aquaculture in food security, employment, and poverty alleviation in rural areas.

As stated above, about 2 400 people are employed directly in aquaculture enterprises. If support services such as transport, processing, retailing (mainly women) and wholesaling, ice suppliers, etc., are included, total employment increases to 5 000. Aquaculture development and its intensification will contribute to increased sustainable production of fish in Uzbekistan and other CA countries, generating alternative new employment and increasing income in rural areas.

INSTITUTIONAL FRAMEWORK

In the ex-USSR, fisheries in Uzbekistan and in other CA Republics were a part of the All-Union Ministry of Fisheries and each republic had its own State Committee of Fisheries. For the first four years of independence in Uzbekistan, the company Uzbalyk functioned as the state agency responsible for fisheries development and sector management. In 2003, the management of the fishery sector was entrusted to the Ministry of Agriculture and Water Resources (MAWR).

The Main Administration for Development of Animal Husbandry, Poultry Farming and Fishery, consisting of 12 officers, was established in 2003 to manage the sector but only one of them has an educational background in aquaculture.

As part of this development, the Uzbek Research centre of Fish Culture Development (FCDC) was established under the control of MAWR. The main objectives of the centre are:

- developing scientific and methodological recommendations on the fish industry and its forage reserve development;
- carrying out research on fish breeding, capture fisheries, developing fish disease treatment and preventive measures, and improving the brood fish quality and acclimatization of new species;
- providing fisheries and fish breeding farms with high quality selective materials;

- organizing training and raising the qualification and skills of fish industry personnel.

Departments for the development of animal husbandry, poultry farming and fisheries have also been established in regional departments for agriculture and water management. Non-governmental associations of fisherfolk and fish-breeders were set up in the Provinces of Karakalpakstan (2006), Bukhara (2007) and Samarkand (2008). The main task of these associations is the protection of the interests of fish farms at a regional level. There is no fisherfolk association at the national level.

GOVERNING REGULATIONS

Since independence, the management of farms, including fish farms, is regulated by codes, laws and decrees of the President of Uzbekistan and enactments of the Cabinet of Ministers (Karimov *et al*., 2009), namely:

- The Law "On Protection of Nature" of 9 December 1992.
- The Law "On Water" of 6 May 1993.
- The Law "On Farm" of 30 April 1998.
- Decree of the President of Uzbekistan No.VII–2086 of 10 October 1998 "On introduction of a single land tax for agricultural producers".
- Enactment No. 350 "On measures to intensification of de-monopolization and privatization in the fishery sector" of 13 August 2003.
- Enactment No. 1292 registered by the Ministry of Justice of 20 December 2003 "On the approval of the regulation of the calculation and levying of rent payment for the use of natural water bodies by fish farms".
- Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 508 of 28 October 2004: "Enhancement of Oversight over the rational use of biological resources, and their imports and exports in the Republic of Uzbekistan".
- The Hunting and Fish Catching Regulations on the Territory of Uzbekistan, No. 1569, registered at the Ministry of Justice on 2 May 2006.
- The "programme on measurements of fisheries sector development in the republic in 2009–2011" signed by the Prime Minister of the Republic of Uzbekistan of 3 March 2009, No. 03/1–348.

APPLIED RESEARCH, EDUCATION AND TRAINING

The collapse of the Soviet Union had an extremely negative impact on aquaculture research in all CA post-soviet republics. Research laboratories previously staffed by highly qualified and trained scientists have seen a significant exodus of staff due to the shortage of research funds and low salaries. Many research institutions need urgent upgrading of laboratory facilities and skilled young scientists.

Research on fish breeding is conducted under the umbrella of the Coordination Committee on Science and Technologies Development under the Cabinet of Ministers of the Republic of Uzbekistan, created on the resolution of the President of the Republic of Uzbekistan of 7 August 2006 "On measures to improve the coordination and management of science and technology development".

- There is one research institute solely devoted to aquaculture and fisheries (FCDC MAWR), but there are another four research institutions with departments conducting research in the fields of ichthyology, hydrobiology, fisheries and aquaculture: Laboratory for the Problems of Intensive Aquaculture and Fisheries.
- Laboratory for Ichthyology and Hydrobiology at the Institute of Zoology of Uzbekistan Academy of Sciences (UzAS).
- Institute of Bioecology of the Karakalpak Branch of UzAS (located in Nukus).
- Department of Ecology, National University of Uzbekistan.

There is a fund for the development of fish breeding, to which part of the funds realized by the privatization of the state share of property in fish farms was allocated,

as well as part of the funds for the use of rented water bodies. This fund is used for the functioning of FCDC MAWR, but it is insufficient for large-scale studies on up-to-date technologies.

In order to render real support to state goals and objectives for the development of the fisheries sector from 2009 to 2011, as well as for the development of the recommendations of the FAO Project TCP/UZB/3103(D) in Uzbekistan and the "Conception of the development of aquaculture and fisheries in Uzbekistan until the year 2016", the administration of the Institute of Zoology of the UzAS supported the initiative of the leading scientists of this sector to establish a new specialized Laboratory for the Problems of Intensive Aquaculture and Fishery, as noted above. This laboratory commenced its activities on 1 April 2009 and currently consists of a Head of Laboratory and two associates (one Doctorate in Biology and two Candidates of Biology), as well as three assistants. In the past three years, the staff of this laboratory has published a number of important methodical guidelines and monographs on the development of the fisheries sector in the basin of the Aral Sea, with support from the FAO Subregional Office for Central Asia. This laboratory could become a scientific and applied research centre for the introduction of advanced technologies and experience from developed countries, taking into account the natural climatic and socio-economic conditions in Uzbekistan and adjoining states.

All the higher educational institutions are under the authority of the Ministry of Higher and Secondary Specialized Education of the Republic of Uzbekistan. This ministry determines the number of places in the masters and bachelor courses for each specific specialty. The Ministry of Agriculture and Water Resources, as well as other concerned agencies, can submit their proposals to the Ministry of Higher and Secondary Specialized Education about the number of students to be admitted to the institutions for higher studies.

In the past, higher education in aquaculture and fisheries was supplied by central All-Union Fisheries Institutes in the actual Russian Federation and the Ukraine and at Tashkent State University. In the Department of Hydrobiology and Ichthyology in the Biology Faculty of Tashkent State University (now the National University of Uzbekistan), 8–20 students graduated each year. However, in 2003 that department was transformed into the Department of Ecology; now there is no national centre for higher education for the fishery sector. This means that neither researchers nor lecturers and technologists with specialization in aquaculture are entering the sector. Currently, those that work in the sector as specialists were trained in subjects related to fisheries at the National University (biologists), Agro University (agriculture experts), Technical University (engineers, food industry experts). Today, vocational training and other practical training opportunities for fish farmers are non-existent in the country.

TRENDS, ISSUES AND DEVELOPMENT

The reasons why per capita fish consumption in Uzbekistan remains low (~0.5 kg/year compared to 4.5–5.0 kg/year in 1991) have been stated earlier in this review.

Until 2007, aquaculture development was not regarded as a priority in Uzbekistan, causing major constraints in technology, management, extension, access to credit, etc. A special (and perhaps unique) feature of the aquaculture and fisheries sector of Uzbekistan and other desert and arid CA countries is that it is a secondary user of already relatively scarce freshwater. In addition, it can sometimes unwittingly receive water that comes from residual irrigation discharges, i.e. water that may be contaminated with chemicals from crop run-offs. This raises problems of fish health and food safety. It will be necessary to tackle this issue by interagency and intersectorial cooperation, which is facilitated by the fact that fisheries are also under the Ministry of Agriculture and Water Resources. In this sense, water is not a sectorial issue.

Taking these factors into account, prominent scientists and experts in Uzbekistan drew attention to the necessity for the comprehensive development of the fisheries sector in the early 2000s (Karimov *et al*., 2004; Kamilov, Karimov and Keyser, 2004), as noted earlier in this review. As a result, the government began to pay attention to this sector in 2008–2009 and confirmed its social and economic importance and the necessity to include it among state development priorities. However, the programme that emerged primarily envisaged the rehabilitation of the available capacities of fish farms with extensive and slightly semi-extensive technologies. So far, the improvement of education, training and research in this sector has not yet been activated.

At present, all fisherfolk and people in rural areas are involved only in informal/artisanal, small-scale capture fisheries; this is neither economically feasible nor ecologically sustainable. There are many cases of unregistered, unregulated and illegal fisheries, which make it extremely difficult to get real statistical data and to develop scientifically based recommendations for the improvement of capture fisheries. At the same time, the country has very convenient natural and socio-economic conditions for aquaculture development that have been neglected until recently.

Various regional and national initiatives in recent years have shown that one of the main constraints to development of the aquaculture sector is the lack of availability of and access to high quality fish feeds. No high quality fish feeds are being produced in the region and this hampers development. This resulted in the initiation of the FAO TCP/RER/3205 project "Advice to Central Asian Governments on the feasibility of commercial fish and livestock feed production".

A strengths, weaknesses, opportunities and threats (SWOT) analysis, prepared by a regional workshop conducted in Antalya, Turkey in 2007 (van Anrooy, Marmulla and Celebi, 2008), showed the following weaknesses:

- There are generally no national fishery sector policies or regulatory frameworks in place that assist the sector in its development in a sustainable manner.
- Fisheries were not a priority sector for government development planning (now some countries like Uzbekistan since 2009 have started to pay attention to the sector).
- There are generally no fisheries departments, and financial means available for the administration/management of the sector are insufficient (fisheries administrations should be equipped with highly qualified staff and modern means of communication and transport).
- Lack of extension services at regional and country level.
- Diversity in fish species culture is limited. Culture practices are based on the culture of silver carp, common carp, grass carp and bighead.
- The fishery sector research institutes in the region do not have the technical and financial capacity to undertake the necessary research to assess fisheries resources and support the development and management of fisheries.
- No high quality fish feeds for aquaculture are being produced in the region.
- There are no hatchery facilities in some countries for restocking inland waters and aquaculture ponds with fish seed (where such facilities exist they are functioning at low levels of efficiency or are underutilized).
- The collection of fisheries statistics is not coordinated properly and data collection and analysis is not done in a scientific and systematic manner (which affects decision making processes negatively).
- There is a general lack of access to credit facilities from banks and incentives (subsidy) from the government in support of fisheries sector development.
- Insurance facilities are not extended to the fisheries sector (in contrast to insurance for the agriculture sector).
- There is a generally low level of training and education of human resources in the sector.
- Limited access to knowledge and technology from elsewhere (limited contacts with other regions).

- Poor and inappropriate fishery resources management is common in the region.
- The lack of marketing facilities for fisheries products reduces profitability (a supply chain approach is missing and means of transport for fish are generally not available).
- Lack of public awareness on fishery sector aspects and low interest in solving fishery sector problematic.

SUCCESS STORIES

Considering the period after independence (1991), there are no real success stories in desert and arid land aquaculture in countries in the CA region to report. Private entrepreneurs are only now beginning to show some interest in increasing fish production as profitable ventures. As the privatization process in the sector finished in 2003–2004, there were no positive developments for some time (up to 2006). However, some new fish farm owners (investors from outside the sector) have purchased and tried to implement semi-intensive technology recently. A few of these private ventures have shown good progress. For example, Asia Agro Alliance became the owner of the Damachi fish farm in 2005 and had an initial fish production of 75 tonnes. The enterprise restored the old soviet technology that was already in place and financed fish feed and fertilizers. The enterprise harvested 400 tonnes in 2005 and 490 tonnes in 2006. As no commercial high quality fish feeds are available in the country, the enterprise uses farm-made feeds comprised of wheat and bran. The enterprise markets its production at the following sizes: silver carp 1 200–1 500 g; common carp 800–1 500 g; and grass carp 1 000–1 500 g. In recent years, its productivity has been 2.1 tonnes/hectare and net profitability is estimated at 30–40 percent.

WAY FORWARD

The Uzbek population has increased rapidly, from 8.4 million in 1960 to 26.9 million in 2007 (UN, 2010). Consumer demand for fisheries and aquaculture products in CA is rising with increasing incomes. Generally, the consumption of fish in the 1980s was ten times what it is today; there is a big demand and especially older people still have a tradition of eating fish. Profit margins of producers on species like trout and grass carp are considerable at present; there is also potential to increase profitability through the introduction of modern technologies, augmenting species diversity and improving product quality and safety.

In Uzbekistan, since its independence, the per capita supply of many types of food has either considerably increased or remained at about the same level. However, at the same time, the consumption of fish has been drastically reduced to 0.5 kg/year, as stated earlier in this review. Aquaculture productivity is low: <2 tonnes/hectare or <130 g/m^3 of water used (about 75 g/m^3 taking into account high evaporation losses). Meanwhile, according to FAO (2007), global aquaculture productivity is typically 50–200 kg/m^3 and the average consumption has reached 16.6 kg per capita/year, while the minimum level recommended by regional medicine authorities in the CA is 12 kg per capita/year. This implies that Uzbekistan needs at least ~270 000 tonnes of additional fish per year in the domestic market.

It is impossible to achieve a significant increase in fish production based on the available technologies and cultured species alone (Karimov *et al.*, 2009). They are outdated, fall short of market relations, require significant land and water resources and show a low productivity. Alpeisov (2005) suggests the inclusion of additional high value species such as sturgeons, paddlefish (*Polyodon spathula*) and striped bass (*Morone saxatilis*) in Kazakhstan aquaculture. However, the technology for their cultivation in the natural conditions of CA is not yet developed.

TABLE 5
Main strategies for desert and arid land aquaculture development in the Central Asia region

Aquaculture systems	Flow-through systems alongside irrigation and drainage canals, cage-culture on all suitable water bodies, small earthen ponds, integrated and recirculating aquaculture systems
Main fish species for aquaculture	Common carp, grass carp, silver carp, channel catfish, wels, tilapia, pike-perch*
Water bodies and watercourses for aquaculture development	Ponds in fish farms, water reservoirs, irrigation and drainage canals, rivers, peripheral lakes of irrigational origin, etc.
Fish-productivity	An average of 40–50 kg/m³ in all stated systems with possible further increase

* i.e. warmwater species, although it is possible to culture coldwater fish such as trout during the cold period from October to April.

The development of the aquaculture sector must be based only on modern intensive technologies (Table 5). The main emphasis in desert and arid land aquaculture development should be placed on the following:

- aquaculture in order to increase fish yields;
- aquaculture using available water resources;
- aquaculture using water and resource saving technologies;
- culture-based fisheries;
- recreational fisheries and ecotourism;
- development of recirculating aquaculture systems; and
- international cooperation and transfer of advanced intensive aquaculture technologies.

The development of new technologies requires that new fishery policies, strategies and programmes be adopted by the Governments of CA. For example, Uzbekistan, with its centuries-old experience in agriculture, can significantly improve the production of fish by using a small quantity of water so that it will not only provide the local market with this valuable food, but also significantly develop its export potential.

At a regional level, all ASDB countries have developed their "Policy and strategy of aquaculture and capture fisheries development" for the coming decades under the guidance of the FAO Subregional Office for Central Asia in Ankara, Turkey. The proposed strategies have the goal to adapt world-wide expertise to ASDB conditions during the next ten years, creating the necessary infrastructure, research and educational potential and equipping private entrepreneurs with attractive technologies that will stimulate their involvement in the sector (aquaculture is one of the most beneficial types of rural businesses in all regions of the world). In modern economic conditions, highly profitable technologies are in demand, both for private individual small-sized family farms and for large enterprises. The Governments of ASDB countries should approve policies and strategies that are designed to stimulate the development of the sector.

REFERENCES

Alpeisov, S.A. 2005. The ways of rational use of aquaculture objects in Kazakhstan. *In Fisheries investigations in the Republic of Kazakhstan: history and present situation*, pp. 279–280. Almaty, Bastau. (in Russian)

FAO. 2003 The use of irrigation systems for sustainable fish production Uzbekistan. *In Fisheries in irrigation systems of arid Asia*, pp. 115–124. FAO Fisheries Technical Paper No. 430. Rome. 150 pp.

FAO. 2007. *The State of World Fisheries and Aquaculture 2006*. Rome. 162 pp.

Kamilov, B., Karimov, B. & Keyser, D. 2004. The modern state of fisheries in the Republic of Uzbekistan and its perspectives. *World Aquaculture*, 35(1): 8–13, 71.

Karimov, B. 2003. Saving the Aral Sea. *Humboldt-Cosmos*, 82: 24–25.

Karimov, B.K. & Razakov, R.M. 1990. The evaluation of toxicological situation on example of Central Asian region. *In* V.A. Lvov & A.K. Kuzin, eds. *The fundamentals of water protection*, pp. 26–34. Kharkov. (in Russian).

Karimov, B., Keyser, D. & Kurambaeva, M. 2002. Impact of agriculture on deltaic hydroecosystems of the Aral Sea basin: ecotoxicological studies. *In Advances in Ethology No. 37: Contributions to the 4th International Symposium on Physiology and Behaviour of Wild and Zoo Animals, 29 September – 2 October 2002, Berlin, Germany*, p. 183.

Karimov, B., Lieth, H. & Kamilov, B. 2006. The state of fishery and aquaculture and hydroecological-economical conditions for their development in the Republic of Uzbekistan, Central Asia. *In Abstracts of the World Water Week in Stockholm, August 20–26, 2006*, pp. 173–174. Stockholm, Stockholm International Water Institute.

Karimov, B., Lieth, H., Kurambaeva, M. & Matsapaeva, I. 2005. The problems of fishermen in the southern Aral Sea region. *In* J.C.J. Nihoul, N. Aladin & M. Glantz, eds. *Journal of Marine Science/Special Issue: Mitigation and Adaptation Strategies for Global Change*, 10: 87–103.

Karimov, B., Joldasova, I., Blanchoud, H., Kurambaeva, M., Mullaboev, N. & Chevreuil, M. 2004. Problems of sustainable fishery and aquaculture in the southern Aral Sea region under anthropogenic impact. *In Abstracts of the 14th Stockholm Water Symposium, 16–20 August 2004*, pp. 72–273. Stockholm, Stockholm International Water Institute.

Karimov, B., Kamilov, B., Upare, M., van Anrooy, R., Bueno, P. & Shohimardonov, D. 2009. *Inland capture fisheries and aquaculture in the Republic of Uzbekistan: current status and planning*. FAO Fisheries and Aquaculture Circular No. 1030/1. Rome, FAO. 124 pp.

Niyozov, B.N., Alpiev, M.N., Sarieva, M.K. & Niyozov, E.B. 2007. Fishery and aquaculture in Kyrgyzstan. Bishkek. 31 pp.

Sidorov, E.G. 2005. The history of ichthyo-parasytological investigations in Kazakhstan. *In Fisheries investigations in the republic of Kazakhstan: history and present situation*, pp. 221–236. Almaty, Bastau. (in Russian)

Thorpe, A. & van Anrooy, R. 2009. *Inland fisheries livelihoods in Central Asia: policy interventions and opportunities*. FAO Fisheries and Aquaculture Technical Paper No. 526. Rome, FAO. 62 pp.

Timirkhanov, S., Chaikin, B. & Makhambetova, Z. 2007. Analysis of fishing industry in the Republic of Kazakhstan. Draft 8 October 2007. FAO. 65 pp.

Tleuov, R.T. 1981. The new regime of the Aral Sea and its influence on the ichthyofauna. Tashkent, Fan Press. 190 pp. (in Russian)

Umarov, P. 2003. Uzbekistan irrigation systems and their management potential for fisheries in regional context. *In Fisheries in irrigation systems of arid Asia*, pp. 125–150. FAO Fisheries Technical Paper No. 430. Rome, FAO. 150 pp.

United Nations (UN). 2010. *Uzbekistan Second Review*. Environmental Performance Reviews Series No. 29. New York and Geneva. 201 pp.

United Nations Development Programme (UNDP). 2008. Environmental profile of Uzbekistan based on indicators. Uzbekistan. 88 pp.

Van Anrooy, R.; Marmulla, G.; Çelebi, R. (eds). Report of the Regional Workshop on Inland Fisheries and Aquaculture in Central Asia: Status and Development Prospects. Beymelek, Turkey, 11–14 December 2007. FAO Fisheries Report No. 862. Rome, FAO. 2008. 58p.

Wecker, B., Karimov, B., Kamilov, B., Waller, U., Matthies, M. & Lieth, H. 2007. *Sustainable aquaculture in recirculating systems – feasibility study for the catchment area of the Aral Sea*. Project report. Germany, USF University of Osnabrueck, DBU. 74 pp.