ABSTRACT

In the countries of Central Asia (Kazakhstan, Tajikistan, Kyrgyzstan, Uzbekistan and Turkmenistan) there are over 50 reservoirs that serve irrigation and hydropower production. In the basin of the Syr-Darya there are 19 reservoirs and in the Amu-Darya 36 reservoirs. The irrigation demand is so high that only rarely does any water reach the Aral Sea, resulting in the rapid desiccation of this sea. Irrigation systems require a novel approach to fisheries, as many economically important river fish species are unable to establish themselves in the reservoirs and many perish in the uptakes to irrigation canals. Until the end of the era
of the Soviet Union, in which the countries of Central Asia were included, fisheries management in reservoirs was effective, largely based on introduction of fish species and fish food organisms to the new irrigation systems. Interconnecting river basins with canals led to mixing of fish faunas of the major rivers, such as Amu-Darya and Syr-Darya. Fish faunas became dominated by introduced and immigrant fish species, which also dominated fish catches. With the diversion of water for irrigation, the delta lakes in the Amu-Darya and Syr-Darya also became important fish producing water bodies and the new water bodies established from drainage waters temporarily produced commercial quantities of fish. Since the independence of the countries of Central Asia in 1990, the former centralized management of fisheries has become fragmented, each country being dependent on its own human and material resources. Combined with the effort to dismantle the centrally planned economic system and introduce free market economy, the result has been a rapid decline in both fisheries management and control over fisheries resources. Fisheries law and regulations, dating from the former Soviet Union period, need to be updated and enforced, as today much of the fishing is uncontrolled. As a consequence of the changes, fish have become less available to the broader communities. This presentation concentrates on the fishery problems in two countries of the region: Kazakhstan and Uzbekistan.

INTRODUCTION

Irrigated farming is essential for food production in the countries of Central Asia. In Kazakhstan, prior to transition to the market economy in the last decade of the twentieth century, approximately one third of agricultural products came from irrigated lands, although this represented only 5-6 percent of the farmed area. At the end of the twentieth century in southern Kazakhstan the produce from irrigated farming often represented 2/3 of the total produced in Kazakhstan while over 70 percent of water is used for irrigation.

Uzbekistan, where about 73 percent of the irrigated land is set aside for cotton production, is the fourth largest cotton producer in the world. Uzbekistan has developed a sophisticated irrigation system, which includes reservoirs, irrigation canals, drainage canals and lakes for residual/drainage water.

The large-scale manipulation of the two major rivers, Amu-Darya and Syr-Darya forms the main base of the economy of the five countries of Central Asia. These rivers, situated in the basin of the Aral Sea, are used for irrigation and hydropower production, which have had considerable impact on the aquatic biotic resources, especially on the indigenous fish fauna (e.g. Petr (ed.) 1995; Petr and Mitrofanov1998; Petr (ed.) (2003). With the development of fisheries, the highly manipulated water resource environment consisting of reservoirs, canals and water bodies storing drainage water, requires a unique approach to maintain and improve fish production. While in the second half of the twentieth century fisheries management concentrated on enhancing fish stocks through introductions and translocations of fish species and on stocking juveniles produced in hatcheries constructed near most of the reservoirs (Petr and Mitrofanov 1998), the political and economic changes in the 1990s virtually halted this management work. There was a decline in fish production, which only recently is being slowly reversed. This paper reviews the past and present situation and puts forward some measures required for the rehabilitation of fisheries in water bodies serving irrigation in the countries of Central Asia.
GEOGRAPHICAL AREA

Central Asia occupies an area of about 2 million km² situated deep in Eurasia. Five countries form this region: Kyrgyzstan (198 500 km²), Tajikistan (143 100 km²), Turkmenistan (448 100 km²), Uzbekistan (447 000 km²) and the southern part of Kazakhstan. About 70 percent of Central Asia is covered by steppes and deserts and 30 percent by mountains. The basin of the Aral Sea occupies the central part of the region (Figure 1).

Due to the landlocked location of the region and it being open to the north, the climate is extremely continental, with high aridity; about 20 percent of the region receives less than 100 mm precipitation per year, 90 percent less than 300 mm. Large seasonal and daily fluctuations in temperature are characteristic.

The two large rivers of the Aral Sea basin, the Amu-Darya and Syr-Darya, can only exist because of the presence of high mountains, from which they receive predominantly snow- and ice-melt water. Their catchments constitute a major part of the Aral Sea catchment. Before reaching the sea their water is stored in numerous reservoirs from where it is distributed for irrigation and also used for hydropower production.

The Amu-Darya, 1 440 km long, has an annual water runoff of about 78 km³. The Syr-Darya has a runoff of 36 km³ and is 2 140 km long. The rivers receive water largely from the mountains located in

![Figure 1. Location of the Aral Sea Basin](image-url)
in Turkmenistan: in 1900, there were 5,530 km² of irrigated land, requiring 3.68 km³ of water, by 1986 this had risen to 17,830 km², which required 16.50 km³ of water.

Micklin (1991) produced a map of the major irrigation zones in Kazakhstan and Central Asia (Figure 2).

![Figure 2. Major irrigated areas in Central Asia and Kazakhstan (based on Micklin 1991)](image)

The irrigation infrastructure comprises an interconnected system of canals and drainage collectors, with freshwater and drainage (return) water flows. In Uzbekistan there are 28,000 km of main and inter-farm irrigation canals and 168,000 km of on-farm irrigation

### Table 1: Catchment areas in the Aral Sea basin (km²/year)

<table>
<thead>
<tr>
<th>State</th>
<th>River basin</th>
<th>Aral Sea basin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Syr-Darya</td>
<td>Amu-Darya Km</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>2,624</td>
<td>2,626</td>
</tr>
<tr>
<td>Kyrgyzstan</td>
<td>27,605</td>
<td>29,209</td>
</tr>
<tr>
<td>Tajikistan</td>
<td>1,005</td>
<td>60,583</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>-</td>
<td>1,549</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>6,167</td>
<td>11,223</td>
</tr>
<tr>
<td>Afghanistan and Iran</td>
<td>-</td>
<td>11,593</td>
</tr>
<tr>
<td>Total Aral Sea Basin</td>
<td>37,203</td>
<td>116,483</td>
</tr>
</tbody>
</table>

### Table 2: Distribution of population in the Aral Sea basin (1998)

<table>
<thead>
<tr>
<th>Country</th>
<th>Total</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>inhabitants</td>
<td>% of total</td>
<td>% inhab/ km²</td>
</tr>
<tr>
<td>Kazakhstan*</td>
<td>2,710,000</td>
<td>6.8</td>
<td>7.9</td>
</tr>
<tr>
<td>Kyrgyzstan*</td>
<td>2,540,000</td>
<td>6.4</td>
<td>19.9</td>
</tr>
<tr>
<td>Tajikistan</td>
<td>6,066,600</td>
<td>15.2</td>
<td>42.0</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>4,686,800</td>
<td>11.8</td>
<td>9.7</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>23,867,400</td>
<td>59.8</td>
<td>53.2</td>
</tr>
<tr>
<td>Aral Sea basin</td>
<td>39,870,800</td>
<td>100</td>
<td>25.7</td>
</tr>
</tbody>
</table>

* Only provinces in the Aral Sea basin are included
canals. Only 5-6 large main canals, with a length of 100-350 km and each with a capacity of 100-300 m³ s⁻¹, are at present of fishery significance. In most canals water flows by gravitation, but pumping is used in two canals, the Karshi main canal and Amu (Darya)-Bukhara main canal. For fisheries only large main drainage collectors with more than 100 km length and water flow rates of 40-100 m³ s⁻¹ each are important. The canals and collectors are not efficient and water losses from irrigation networks are estimated at about 40 km³ annually. This amount of water would be enough to stabilise the Aral Sea at its current level (Kamilov 2003). Intensive development of irrigation and drainage in the Aral Sea basin has had two major impacts on water quantity and quality in the rivers: a major freshwater uptake for irrigation and generation of polluted return water of elevated salinity. If the salt concentration is too high, the water may be discharged into lakes, some of which have been formed entirely from such water.

Fresh water of less than 1 g L⁻¹ is present only in the upper catchments of the rivers and tributary streams and in the upper parts of the middle courses of major rivers. Further downstream all rivers and associated lakes receive return waters. During the last decades water salinities in rivers ranged from 0.5 to 2.0 g L⁻¹, in reservoirs from 0.5 to 2.5 g L⁻¹ and in lakes formed from residual waters and in natural lakes receiving such waters then were from 3 to 20 g L⁻¹.

The shortage of water resources leads to the use of return waters for irrigation. This has resulted in degradation of flora and fauna and in pollution of surface water resources as they contain elevated concentrations of salts, fertilizers, herbicides, other harmful chemicals and bacteria than water present in unpolluted rivers.

During the last decades, all natural lakes have been impacted by large-scale irrigation development. Some lakes have dried up; others have been used for residual water storage. In the middle and lower courses of Uzbekistan rivers there are practically no natural lakes left whose water quality and quantity would not be affected by salinity and by the irregular discharges of drainage water.

In Uzbekistan all four major rivers, Syr-Darya, Zarafshan, Kashka-Darya and Amu-Darya and their tributaries have been regulated and have storage reservoirs (Kamilov and Urchinov 1995) the major purpose of which is to keep sufficient amount of water of required quality for irrigation use. Only these large rivers and some of their tributaries have fisheries importance. Inter-connecting a number of river systems by canals has formed one vast network through which fish species formerly specific for one catchment now disperse into other catchments.

The major impact of water diversion for irrigated agriculture has been well documented for the Aral Sea. While during the first half of the twentieth century water uptake for irrigation did not upset the water balance of the Aral Sea, since the 1960s the flow redistribution has caused irreparable damage to the whole ecosystem. Irrigation has changed the water regime in the whole of the Aral Sea basin and the Aral Sea itself. Uzbekistan shares the Aral Sea with Kazakhstan. In 1960, the Aral Sea had an area of about 68 000 km² and a volume of 1 061 km³ (Micklin 1988). Before 1960, the Syr-Darya and Amu-Darya rivers annually discharged into the Aral Sea about 56 km³ of water and a further 8 km³ came in the form of precipitation and as ground water flow. The mean annual evaporation from the sea surface was 63 km³. The water level of the Aral Sea was about 53 m above sea level (a.s.l.). As a result of the intensive uptake of water for irrigation until the 1990s, the annual water runoff reaching the Amu-Darya and Syr-Darya river deltas was reduced to 5 km³ and in some years the rivers virtually stopped flowing into the sea. By 1992 the Aral Sea water level had dropped to 37 m a.s.l., the surface area was reduced to 34 100 km², salinity reached 34-37 g L⁻¹ as compared with 9-10 g L⁻¹ in the 1960s. Today the seacoast is 60-80 km from the original coastline (Kamilov 2003). The changes in the Aral Sea over the period 1960 – 1985 are shown in Figure 3.
There are about 60 reservoirs with a total volume of 61.6 km³ in the countries of Central Asia, constructed in the basins of all large rivers. In the basins of the two major rivers, Amu-Darya and Syr-Darya, there are 55 reservoirs, of which 36 in the Amu-Darya basin and 19 in the Syr-Darya basin. There are 22 reservoirs in Uzbekistan, 13 in Turkmenistan, 8 in Tajikistan, 6 in Kyrgyzstan and two in Kazakhstan. The total water surface of reservoirs with fisheries importance is 3 310 km² (Table 3) (Nikitin 1991).

Under the arid conditions of Central Asia the average evaporation rate is twice that of precipitation. This leads to salinization of water and soils. The long-term average salinities of reservoirs in the montane and foothill zones above 500 m altitude range from 223 to 527 mg L⁻¹, with maximum salinities reached during winter and spring, before floods. In lowland reservoirs the salt concentration ranges from 550 to 1 200 mg L⁻¹, with a maximum of 1 700 mg L⁻¹ reached during the autumn-winter period (Nikolaenko 1988). Nikolaenko (1988) compiled information on average salinities of 13 reservoirs of Central Asia (Table 4) that shows that by the mid-1980s, salinities exceeded the value of 1 g L⁻¹ in four out of 13 reservoirs. Water quality in the reservoirs of Central Asia started deteriorating in 1974 when drainage waters with high concentrations of sulphates, chlorides, manganese and sodium were diverted back into rivers.

Table 3: Reservoirs of fisheries importance in the Aral Sea basin

<table>
<thead>
<tr>
<th>River basin</th>
<th>Number of reservoirs</th>
<th>Area (km²)</th>
<th>Volume (km³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syr-Darya</td>
<td>22</td>
<td>1 850</td>
<td>34.5</td>
</tr>
<tr>
<td>Amu-Darya</td>
<td>17</td>
<td>1 460</td>
<td>23.3</td>
</tr>
</tbody>
</table>

Table 4: Mean salinity values (mg/L) in 13 reservoirs situated in Central Asia (from Nikolaenko 1988)

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Years</th>
<th>Salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charvak</td>
<td>1917-1980</td>
<td>223.1</td>
</tr>
<tr>
<td>Ortotokai</td>
<td>1958-1961</td>
<td>291.8</td>
</tr>
<tr>
<td>Tuyabuguz</td>
<td>1968-1980</td>
<td>304.8</td>
</tr>
<tr>
<td>Kattakurgan</td>
<td>1970-1980</td>
<td>417.4</td>
</tr>
<tr>
<td>Jizak</td>
<td>1969-1970</td>
<td>527.4</td>
</tr>
<tr>
<td>Yuzhno-Surkhan</td>
<td>1970-1980</td>
<td>551.2</td>
</tr>
<tr>
<td>Chimgurgan</td>
<td>1974-1980</td>
<td>581.2</td>
</tr>
<tr>
<td>Pachkamar</td>
<td>1969-1976</td>
<td>866.2</td>
</tr>
<tr>
<td>Uchikyzyl</td>
<td>1973-1980</td>
<td>908.8</td>
</tr>
<tr>
<td>Kairakkun</td>
<td>1968-1980</td>
<td>1062.5</td>
</tr>
<tr>
<td>Tyuyamuyun</td>
<td>1983</td>
<td>1069.5</td>
</tr>
<tr>
<td>Kuyumazar</td>
<td>1973-1980</td>
<td>1135.6</td>
</tr>
<tr>
<td>Chardara</td>
<td>1966-1976</td>
<td>1202.0</td>
</tr>
</tbody>
</table>
While water with salinity over 1 mg L$^{-1}$ is considered unsuitable for the usual crops, less is known about salinity levels that are harmful to the native fish of arid and semiarid climates and especially to the young. Antagonistic interactions between the agriculture and fisheries sectors arise from the application of pesticides and herbicides, which can be harmful to aquatic living organisms. Agrochemicals used against pests or for defoliation, such as in cotton production, contribute to serious water quality problems and represent a hazard to fish and the end consumers – birds and man. Where drainage and wash waters are diverted in desert depressions without an outflow, or into swamps, salinity and agrochemical concentrations may gradually reach unacceptable levels, making the fish unsuitable for human consumption. Many large lakes with saline water, such as Sarykamysh (3 300 km$^2$) and Dengizkul (260 km$^2$), formed along the Amu-Darya.

A number of natural lakes and of those artificially created for residual water storage have been important for fisheries. Those of importance for fisheries cover about 7 000 km$^2$, a surface area of about twice that of all reservoirs. Most of the lakes function for many years. They do not experience major seasonal changes. After the demise of fisheries in the Aral Sea, the Aydar-Arnasai lake system and the lakes of the Amu-Darya delta are the major water bodies in this category supporting fisheries in Uzbekistan. Due to the current problem of harmonizing the use of the Syr-Darya among the riparian countries, the Aydar-Arnasai system is now receiving large volumes of water and as a result of that it now covers more than 4 000 km$^2$, which makes it the largest artificial lake in the region.

In the 1960s, the delta of the Amu-Darya had some 40 lakes with a total water surface of 1 000 km$^2$, now there are only some 20 lakes, but they have a total water surface of 1 150 km$^2$. The increase in area is a direct result of the restoration of the main lakes and appearance of new isolated ones on the dried Aral seabed. These water bodies are maintained almost completely by collector-drainage waters.

**FISH FAUNA**

Prior to large-scale irrigation efforts the indigenous fish fauna in the Aral Sea catchment rivers and lakes was little affected by human activities. Kamilov and Urchinov (1995) listed 84 species of fish for Uzbekistan, including those that were rare and those that were introduced. The ichthyofauna has undergone major changes as a result of water regulation and introductions of fish species from outside the Aral Sea basin (Kamilov 1973; Kamilov et al. 1994). By blocking the migratory path of fish, dams have a major impact on fish species that require suitable spawning and/or nursery and feeding grounds. Dams on the Amu-Darya and Syr-Darya have blocked the migratory path of fish, such as Aral barbel (*Barbus brachycephalus* (Kessler)), shovelnose (*Pseudosca-phinynchus kaufmanni* Bogdanow), spiny sturgeon (*Acipenser nudiventris* Lovetzky), Aral trout (*Salmo trutta aralensis* Berg) and pike asp (*Aspiolucius esocinus* (Kessler)), which are all now threatened with extinction (Pavlovskaya 1995).

The most recent information on the fish fauna is provided by Kamilov (2003). Species considered extinct or rare because they have been unable to adapt to the new environment include the endemic shovelnoses (*Pseudoscaphirynchus kaufmani*, Bogd.), *P. hermani* (Kessler), *P. fedtschenkoi* (Kessler), ostroluchka (*Capoetobrama kuschakewitschi*, Kessler), minnows (*Alburnoides bipunctatus* (Filippi), *A. taeniatus* (Kessler), *A. oblongus* (Bulgakov) and Zarafshan dace *Leuciscus lehmanni* (Brandt). Spiny sturgeon and Aral barbel disappeared because dams blocked their spawning migrations. Some species such as gudgeons (*Neogobius fluviatilis* (Pallas)), *N. melanostomus* (Pallas), *Proterorhinus marmoratus* (Pallas) and Baltic herring (*Clupea harengus membras* L.), introduced in the Aral Sea became established for a while, but later on disappeared as a result of increasing salinity and other changes in the Aral Sea environment. During the period 1960-1990 a number of fish species from outside the region were introduced in a number of irrigation water bodies of Central Asia. Pikeperch and bream were released into reservoirs and
lakes of the rivers Zarafshan, Kashka-Darya and the middle courses of the Syr-Darya and Amu-Darya. Silver carp (*Hypophthalmichthys molitrix* (Valenciennes)), grass carp (*Ctenopharyngodon idella* (Valenciennes)), bighead carp (*Aristichthys nobilis* (Richardson)) and snakehead (*Channa argus warpacchowskii* (Berg)), introduced from the Far East, were stocked in fish farms in the Tashkent area and from there the hatchery-produced stocking material was regularly stocked into lakes and reservoirs. Three species of buffalo (*Ictiobus cyprinellus* (Valenciennes), *I. bubalis* (Rafinesque), *I. niger* (Rafinesque)) and channel catfish (*Ictalurus punctatus* (Rafinesque)) were also introduced into fish farms but they did not enter rivers, except the last species which entered the Syr-Darya. Rainbow trout (*Oncorhynchus mykiss* (Richardson)), Sevan trout (*Salmo ischchan issykogegarkuni* Kessler), peled (*Coregonus peled* (Gmelin)) and lake herring (*Coregonus sardinella* Val.) were released into Charvak reservoir in the Tashkent area where they are now established.

Many species spread throughout the basin via the connecting major canals. Some species started to breed in both the irrigation and drainage canals. Fish stocks in canals were not managed. In the 1970s-1980s management concentrated on stocking fingerlings and one-year-old marketable fish, the stocking material for which was produced in fish farms. Silver carp, grass carp, common carp and bighead carp were regularly stocked in reservoirs and lakes for residual water storage. This resulted in fish yields increasing by 5-15 kg ha⁻¹. After 1991 stocking continued only in the Aydar-Arnasai lake system and several other large water bodies.

**FISHERIES**

Until 1960 the fishing concentrated on the inshore waters of the Aral Sea and the deltas of the major inflowing rivers. In 1958 fish catches reached a maximum close to 50 000 tonnes (Figure 4). The major fish species captured were common carp (*Cyprinus carpio* L.), bream (*Abramis brama* Berg), barbel (*Barbus brachycephalus* (Kessler)), roach (*Rutilus rutilus aralensis* Berg) and shemaya (*Chalcalburnus chalcoides aralensis* Berg). Less common were wels (*Silurus glanis* L.), pike (*Esox lucius* L.), asp (*Aspius aspius* Kessler), sturgeon (*Acipenser nudiventris* Lovetzky), and pikeperch (*Stizostedon lucioperca* (L.)). In the 1960s only one small fish farm and one hatchery existed near Tashkent. In those days the fisheries were government-owned, but several fisheries cooperatives also operated on the Aral Sea. During the 1960s-1970s, fish catches decreased sharply. In 1983, the last year of the Aral Sea fishery, only 53 tonnes were caught. As a result of the Aral Sea desiccation and increased salinity to 14 g L⁻¹ (the salinity in 1983), there has been no fishing in the Aral Sea since 1983. Today’s fish yields in lakes and reservoirs in the Aral Sea catchment range from 1.2 to 209 kg ha⁻¹ (Anon. 1990, 1998, 2001).

Fisheries in Uzbekistan had to find new sources of fresh fish. During the 1970s fishing fleets were transferred from the Aral Sea to Lake Sarykamysh and the Aydar-Arnasai lake system. During this period up to 6 000 tonnes of fish were caught annually in these lakes. While in 1964 the catch in Aydar-Arnasai lakes was only 26 tonnes, in 1971 it was 512 tonnes and a maximum of 4 200 tonnes was captured in 1988, corresponding to a yield of approximately 25 kg ha⁻¹. Sarykamysh eventually lost its fishery value due to an increase in salinity, which now reaches 20 g L⁻¹ in some areas.

While most irrigation reservoirs have good water quality, they also have some limitations, such as unseasonal water level drawdown which conflicts with fish reproduction. This requires regular stocking of hatchery-produced juvenile fish. Another problem is the absence of any structures, which would prevent fish from entering irrigation canals and fields where they perish. Thus, in the lower Amu-Darya up to 90 percent of larvae and fry entering canals die on irrigated fields (Pavlovskaya 1995). But large connecting canals can be beneficial for fish distribution. For example fish larvae and fry of the middle course of the Amu-Darya migrate through the Amu-Bukhara Main Canal into Tudakul reservoir where they contribute to maintaining fish stocks in this reservoir.
By the end of the 1980s, the annual volume of drainage water in the basin of the Aral Sea reached about 33 km³, which was about 60 percent of the total river discharge into the Aral Sea. This volume included 17 km³ in the basin of the Amu-Darya, 13 km³ in the Syr-Darya and 3 km³ in the Zarafshan and Kashkadarya. Part of the 33 km³ was returned into rivers and 10-13 km³ was diverted into depressions where this water eventually created Lake Sarykamysh (3 000 km²), the Aydar-Arnasai lake system (at present more then 4 000 km²) and a number of smaller lakes. For a while lakes for residual water storage were more preferred for capture fishery than reservoirs as they behaved like lakes, i.e. their water level was not affected by drawdowns.

Reservoir capture fisheries and those established in water bodies which have formed from drainage and wash water could not replace the quantity of fish lost from the Aral Sea. The Uzbekistan Ministry of Fisheries had to do the best possible to develop fisheries in the new water bodies, whatever the constraints to fish production arising from their management for irrigated agriculture. The Government of Uzbekistan and the former All-union Ministry of Fisheries developed a large-scale development programme of pond fish culture and fisheries in inland water bodies. That programme included creation of new fish farms and fishing enterprises in all regions of Uzbekistan, testing and implementation of new technologies, establishment of research centres, specialist training, etc. The well-managed fish farms all functioned well between 1970 and 1990. The total annual fish production in Uzbekistan ranged from 24 to 33 thousand tonnes per year. From this 7-8 thousand tonnes came from capture fisheries and 18-23 thousand tonnes from fishpond culture. Besides the capture and culture, the fisheries organisations also dealt with fish transport, storage and marketing of about 60-70 thousand tons of marine fish imported from other regions of the former USSR. This comprehensive fishery programme was possible under the very centralized system, where the fisheries were under the USSR Ministry of Fisheries, which was assisted by the appropriate Uzbekistan authorities.

IMPACT OF INDEPENDENCE ON FISHERIES IN WATER BODIES OF IRRIGATION SYSTEMS

After the countries of Central Asia gained independence at the beginning of the 1990s, there has been a decline in agriculture production. For example in Kazakhstan, over a period of five years the cultivated irrigated lands were reduced by 880 000 ha, i.e. 43.4 percent. The existing structures have been deteriorating due to the almost complete absence of government financial support. This reflects the deterioration of the overall economic situation in agriculture. Almost one million hectares of irrigated land are now out of production, there has been an increase in poor practices of water use and construction and rehabilitation have
been suspended. The deterioration of irrigation systems has had also a negative impact on fish production from water bodies serving irrigation.

Prior to independence, Uzbekistan was implementing a large-scale comprehensive programme of fish production for all types of inland water bodies. Special attention was paid to education, research, planning, water and fish quality monitoring and other issues. State-owned fishing companies were established at all large reservoirs and lakes for return water storage. Hatcheries for producing stocking material were constructed in all parts of Uzbekistan. By the 1980s up to 7 000 tonnes of fish per year were harvested from reservoirs and lakes. All fish farms were state owned, financed by the government and functioned within the structure of the Ministry of Fisheries. They regularly reported on their fish production. The positive aspect of the former centrally planned economies of some countries in the Region was that they had well-organized research and collection of statistics obtained through regular monitoring of fish stocks, so that the impacts of introductions, stocking and catches could be evaluated and management strategies adjusted. Centralised statistics provided the longest series of data for a number of irrigation reservoirs in the former Soviet Union, including Central Asia (Karpova, Petr and Isaev 1996) and these were used for further assessment, evaluation and as examples of the level of efficiency of the applied enhancement measures. They also showed the failures resulting from some introductions.

Independence resulted in fragmentation of the formerly regional system of water resource management in the Aral Sea basin. For example, the government of Uzbekistan privatised all state-owned fish farms and capture fisheries enterprises and starting in 1994 it stopped providing financial support. Fishers found themselves in the new and unfamiliar conditions of a market economy. The overall economic crisis and the loss of economic links with producers of equipment in the former USSR have also adversely affected fisheries.

At present water resources in the basin of the Aral Sea are regulated from five centres, one in each country of Central Asia. This has already caused a number of problems. For example, during the period 1991-2001 huge amounts of Syr-Darya water had to be discharged from the Chardara reservoir in Kazakhstan into the Aydar-Arnasai lake system in Uzbekistan. Aydar-Arnasai has no outflow, therefore the water cannot be reused and accumulates in this depression and has become a water body of fisheries importance.

Over the last ten years fishing equipment in Uzbekistan has much deteriorated. The number of fishing boats, nets and seines dropped. By the end of the 1990s there were only 20 fishing boats with 130 horsepower engines, 40 boats with 20 to 60 horsepower engines and 250 other types of motorised boats. All fisheries companies together had only 5 000 gillnets and 36 beach seines, which were worn out. Tables 5 and 6 give information on reservoir lake and river capture fisheries for selected years. After a major decline in catches, which reached the lowest value in 1996, there has been a slow recovery. Nevertheless, fish production dropped to one third and large-scale fishing in Uzbekistan reservoirs such as Charvak, Chimkurgan and several others virtually stopped or was significantly reduced, as for example in Tudakul reservoir, where the reported fish catches dropped from 700 tonnes in the early 1990s to 250 tonnes in the late 1990s.

Fish production in ponds in Uzbekistan decreased on the average from 3 000 kg to 850 kg per ha. Education and training of specialists also stopped and the research network came to an almost complete standstill (Kamilov 2003). The main limitation in aquaculture has been the absence of formulated fish feed. In 1995, the total fish production was 5 600 tonnes. Table 5 shows aquaculture production in Uzbekistan prior to and after gaining independence, with the lowest production being in 1996. The trend is the same as for the capture fisheries. This has been followed by a slow recovery. Of the 20 existing fish farms established along the irrigation network in Uzbekistan, 12 have fresh water and 8 contain drainage water with a salinity of 5-6 g L\(^{-1}\) (Table 6).
Today, Uzbekistan has no national programme or specific fishery development projects supported by the government or international assistance. Private initiative focuses only on exploitation of rich fish stocks in the Aydar-Arnasai system using small fishing teams. The fishery potential of water bodies of the irrigation system of Uzbekistan is largely unexploited.

An example of problems facing fisheries managers of irrigation reservoirs is reported from Chardara reservoir in Kazakhstan by Ismukhanov and Mukhamedzhanov (2003). This reservoir was constructed for irrigation and hydropower production in 1965 on the middle course of the Syr-Darya. Like a majority of irrigation reservoirs in southern Kazakhstan, Chardara is filled in the autumn-winter period (October-March) and drawdown takes place in spring and summer (April-September). Seasonal fluctuations of the water level reach up to 11 m. During the spring and summer the drawdown reduces the reservoir surface to only 15 000-20 000 ha, which is a quarter or less of the water surface area of the full reservoir. At the same time the water volume is reduced 10-12 times. Such considerable seasonal changes in the volume and the surface area are mainly due to the irrigation water uptake. Water for irrigation enters Kyzylkum Canal, but some water is also used for power generation.

The most important factors influencing fish stock formation in Chardara reservoir is the hydrological regime, which is determined by water uses other than fisheries. Reduction of the surface area and depth leads to the reduction in the number of spawning areas and to a high mortality of the spawn during the spring breeding period (1 April – 20 May). In summer months fish may die due to low concentrations of dissolved oxygen resulting from cyanobacteria blooms. Reservoir drawdown also considerably reduces the habitat of benthic organisms and changes their species representation. Benthic invertebrates are an important food source for some fish species. By autumn, with the drop in water temperature, the situation worsens, especially for plankton. There is also a loss of valuable fish species such as zander, roach and bream due to the fry being carried out into the Kyzylkum Canal. In May the

<table>
<thead>
<tr>
<th>Year</th>
<th>Capture fisheries</th>
<th>Aquaculture</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lakes#</td>
<td>Reservoirs</td>
<td>Rivers</td>
</tr>
<tr>
<td>1980s##</td>
<td>5.5</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>1994</td>
<td>2.0</td>
<td>0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>1996</td>
<td>1.2</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>1999</td>
<td>3.1</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>2.7</td>
<td>0.3</td>
<td>0</td>
</tr>
</tbody>
</table>

# - lakes used for residual water storage
## - average for a decade

<table>
<thead>
<tr>
<th>Year</th>
<th>Fish farms with fresh water</th>
<th>Fish farms with saline water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>13.2</td>
<td>7.6</td>
<td>20.8</td>
</tr>
<tr>
<td>1993</td>
<td>12.8</td>
<td>6.1</td>
<td>18.9</td>
</tr>
<tr>
<td>1996</td>
<td>3.8</td>
<td>1.2</td>
<td>5.0</td>
</tr>
<tr>
<td>1999</td>
<td>4.1</td>
<td>1.5</td>
<td>5.6</td>
</tr>
</tbody>
</table>
maximum number of fish fry are washed out, with an estimated loss of 1 million per day.

Following the independence of Kazakhstan in 1992, there was a change in the pattern of use of the reservoir. The upper part of Chardara reservoir was now located in Uzbekistan. In 1992-2000 high discharges of the Syr-Darya from February to April led to water spilling over the Chardara spillway as well as over the Arnasai emergency spillway. Large quantities of fish fry and fish of all age groups were washed out. The outflow of 800-1 600 m³ s⁻¹ over the emergency spillway resulted in great losses of fish. It is estimated that during those two months, from 1992 to 2000, annual losses of fry of valuable fish species reached 18 to 64 billion. Taking into consideration that the commercial fishing pressure has not changed during the last ten years and the impact of other factors has not changed either, one can assume that the loss of fry and larger fish during floods was responsible for the sharp drop in catches of commercial fish species, from 2 040 tonnes in 1992, to 216 tonnes in 1999. Another problem has been caused by pollution with pesticides, causing fish mortalities. More recently concentrations of pesticides and herbicides have been declining as a result of the reduced use of these agrochemicals.

Measures to reduce the rate of fish loss and increase the stocks of valuable commercial fish species in Chardara include: reconstruction of the Kyzylkum sluice of the Kyzylkum irrigation canal uptake and construction of a fish protection device on the Arnasai emergency spillway. A new reservoir (Koksarai) is being constructed 120 km distant from Chardara reservoir to store floodwaters which now end in the Arnasai depression. Other measures include limits on the catch or even closing of the fishery and intensive stocking of the reservoir with fish species of high value. An attempt to protect common carp by closing the carp fishery during the period 1997-2000 failed because of lack of enforcement. Low value fish species need to be controlled by intensive fishing to reduce the pressure on fish food organisms. This would make them available for higher value fish species. To increase the stocks of silver carp it is recommended to stock reservoirs every year with 250 000 two-year-old fish, which is 3-4 times the current stocking rate. This should result in a sustainable annual harvest of 100-120 tonnes of silver carp.

**FISH PRODUCTION POTENTIAL IN THE AMU-DARYA AND SYR-DARYA CATCHMENTS**

There is good development potential for both capture fisheries and aquaculture, especially in Uzbekistan, Kazakhstan and Turkmenistan. However, successful development will depend on a number of conditions, which at present still need to be established. Between 1996 and 2001, with the help of foreign assistance, in Uzbekistan two project proposals were formulated for the development of fisheries on fish farms: a project for a model aquaculture farm using semi-intensive technology and a fish farm sturgeon production project. Both projects are pending, mainly because of lack of funds on the Uzbek side and because of insufficient experience of Uzbek fishery specialists in implementing such projects (Umarov 2003).

There has also been lack of continuity in some successful projects, such as one for using irrigation systems for fish production in the Golodnaya and Karshy steppes.

Many fish hatcheries in Uzbekistan and Kazakhstan are still functioning, including the breeding and production of fish fry and fingerlings of cyprinids. They have sufficient capacity to provide potential farmers with the required quantities of fry, fingerlings and yearlings for increasing fish production (Kamilov 2003; Ismukhanov and Mukhamedzhanov 2003). The major constraint is the high cost of fish feed.

Uzbekistan has a good transportation and industrial infrastructure, large rural population and diversified agriculture. This creates favourable social and economic conditions for development of fish production in irrigation water bodies. There is no reason why the current shortage of fish in Central Asian countries couldn’t be overcome by intensified fish produc-
tion. All countries in the Aral Sea basin have favourable climates and abundant water resources. In Uzbekistan there is also an optimal density of population and available labour force and good access to markets, especially in larger towns. The lowland water bodies are suitable for the development of fisheries based on warmwater Chinese carps, i.e. silver, bighead and grass carp and common carp. The mountain and foothill storage reservoirs could produce cold-water fish such as rainbow trout, Issyk-Kul (Sevan) salmon and whitefish (Coregonus spp). It would be profitable to use the existing ponds, now in private ownership, for creation of fish farms. With a model of a profitable small fish farm, farmers of Uzbekistan could then combine pond fish culture with the traditional farm crop production. This would appear to be an efficient way of boosting the fish production in the country.

While a new management approach is required, some of the knowledge on reservoir fish and fisheries can be adapted from similar situations where a river was dammed for hydropower electricity production. In addition to introductions, some reservoirs have been regularly stocked with fingerlings produced in hatcheries. This, in the past, resulted in a sustainable fish production in a number of reservoirs in Uzbekistan, Turkmenistan and Kazakhstan, with the highest yield of 30.9 kg ha⁻¹ achieved in one reservoir, where the potential sustainable yield was estimated at 78 kg ha⁻¹, if regularly stocked with silver, grass and common carps.

Fisheries managers have a number of options for fishery development in irrigation systems. Most options are a response to the impacts caused by the manipulation of the water resource for purposes other than fisheries. Irrigation systems are subject not only to rainfall and evaporation rates, but also ambient air temperature, which determines the amount of snow- and ice-melt from glaciers. Agriculture practices such as selection of crops are not static and may change from year to year and with them the amount of water and timing of the demand required for achieving the best crop. Furthermore, there is the use of agrochemicals, which may differ from year to year. Thus, fisheries managers, while having an overall master plan, may also need contingency plans, as fisheries in irrigation systems are subordinated to other demands for water. An example is when there is a sudden release of water from an upper reservoir. In the Kazakhstan Chardara reservoir on the Syr-Darya, fish fry, fingerlings and young fish are sometimes washed out due to a sudden surge of water released from a neighbouring country; there is a need for installing fish protection devices to prevent such losses. As the government usually underfunds the fishery sector in countries of Central Asia, this may place a limit on what fisheries managers can do.

Long-term research on several reservoirs has indicated that the major reasons for the low fish production in some reservoirs are: poor utilisation of the natural fish food, poor spawning conditions and nursery habitats and vacant niches not yet occupied by economically important fish species. In some reservoirs aquatic plants are under used, or benthos is used by fish species of low value.

Let’s now have a look at fisheries management options for irrigation canals and lakes established from drainage/return waters.

**IRRIGATION CANALS**

The rate of water flow in the major irrigation canals usually ranges from 40 to 300 m³ s⁻¹, with a water velocity between 0.4 to 2.0 m s⁻¹. A minimum flow of 5 m³ s⁻¹ in some major canals may be maintained even when the canal is not in use. Where rivers carry a high sediment load, a sedimentation reservoir may be constructed at the head of the canal. While the average concentration of sediments at the intake of water from the Amu-Darya into Karakum canal is 3.7 mg L⁻¹, corresponding to a transparency of less than 40 cm, after the water leaves the sedimentation reservoir its transparency is much higher. But as the distance from the reservoir increases, the transparency gets gradually reduced due to the erosion of the canal sides. Apart from current velocity and water transparency, water salinity is also important for fish. In the Amu-Darya irrigation canals salinity ranges from 118 to 1
304 mg L⁻¹ (Ergashev 1989), increasing towards the canal tail reach and final distributaries.

Fish with pelagic eggs, such as Aral barbel, razor fish, the introduced Chinese carps and white Amur bream (Parabramis pekinensis Basilewsky) have been doing well in slow flowing large canals and side storage reservoirs, such as those alongside the Karakum canal in Turkmenistan. Introduced fish are well established in the Karakum canal and breed there. In a number of irrigation canals grass carp has greatly assisted in controlling aquatic plants. Grass carp is also known to contribute to the eutrophication of those irrigation canals with dual purpose, i.e. irrigation and as a source of drinking water. Its use for control of aquatic macrophytes, therefore, has to be carefully planned, especially in deserts, where other sources of water are not available.

**Lakes established from or receiving drainage waters**

Where drains collecting residual irrigation water and wash water do not re-enter a river and/or a terminal lake, as required when the salinity of the drainage water exceeds 1 mg/L, the water may be diverted to a depression, where it creates a new water body. Pavlovskaya (1995) estimated the number of drainage collecting depressions in the Aral Sea catchment at 2,341, covering 7,066 km² surface area. More than one third of drainage water collecting depressions and water bodies are in the Syr-Darya River basin. Twenty-four percent of such water bodies, with a total area of 52 percent of the total are concentrated in the Amu-Darya River basin. Kamilov and Urchinov (1995) and Pavlovskaya (1995) provided figures for fish catches for five drainage lakes.

In Sarykamysh the fishery started in 1966 and the maximum annual catch of 2,500 tonnes was recorded during the 1981-5 period, with yields ranging from 4 to 8 kg/ha. The fishery virtually stopped in 1988 as fishing became unprofitable due to the large distance between the water body and the fish processing plant and also because of the poor quality of fish (Pavlovskaya 1995, Figure 3). The fishery focused on Aral barbel and common carp and due to the lack of enforcement of regulatory measures, the stocks of these two species became overexploited. This was accompanied by an increase in the less valuable pikeperch and razorfish, but even those species could not tolerate salinities over 10 g/L.

The Lake Sarykamysh experience has provided a number of lessons on the impact of a rapidly changing aquatic environment on indigenous and introduced fish and their fisheries. Sarykamysh shows the instability of lakes established by drainage water from irrigated agriculture in desert conditions with a high evaporation rate. Instability of especially the limnological environment is inherent in such lakes, which are subject to a gradual increase in salinity. Freshwater fish are stressed as the salinity affects the fertilisation and hatching of eggs and retards growth of fish. Studies have shown that the ratio of predatory to prey fish increases, largely due to the increase in the number of pikeperch, which is the most salinity-resistant commercial fish species in the Aral Sea catchment. In Sarykamysh bream, pikeperch and razorfish were the most adaptable and productive fish under the increasing water salinity. Eventually, pikeperch represented 27 percent of the total fish stocks (Sanin and Shaporenko 1991) but this was followed by their decline.

The experience with Sarykamysh has shown that water bodies with increasing salinity need a dynamic approach to environmental and fishery management if they are to continue producing fish. Breeding fish in hatcheries and stocking fingerlings may perhaps compensate the deteriorating spawning conditions resulting from increasing salinity. Other species, such as those of estuarine character, which tolerate large water salinity differences, could also be tested. A major problem is the increasing load of pesticides and other toxic substances applied in agriculture. Alternative solutions should be found that would lower agrochemical application levels and biological control should be introduced where possible (Petr and
DISCUSSION

The arid zone of Asia extends from the Mediterranean to the Pacific, including the following countries: Turkey, Syria, Iraq, Iran, Southern Russia, Afghanistan, five countries of Central Asia, i.e. Turkmenistan, Uzbekistan, Kazakhstan, Kyrgyzstan and Tajikistan, Outer Mongolia, Pakistan, India and China. In all of them most food crops are produced using irrigated agriculture and many of the water bodies used for irrigation have harvestable fish stocks. In Central Asia, over 80 percent of the total water use is for irrigated agriculture. In Pakistan 78 percent of the arable land depends on irrigation as compared with 100 percent in Egypt, 33 percent in all Asia, 21 percent in the Near East and Northern Africa, 8.5 percent in Latin America and 2.7 percent in Sub-Saharan Africa. In 1987, in 93 developing countries of the world, a total of 164.7 million ha of land was irrigated. This was expected to increase to 220 million ha by year 2000. In developing countries over 70 percent of water used is for irrigation. It is estimated that in the year 2010, 45 percent of the total global food production will come from irrigated lands. The irrigation demand ranges from the extreme of the total diversion of water of some rivers for irrigation, to partial diversions and use, with the consequence of various degrees of flow diminution downstream of water abstraction.

Storing water for irrigation and hydropower production requires construction of dams. The impact on fish stocks of damming rivers is well known: in reservoirs the number of riverine fish species diminishes and are replaced by fish species with a preference for standing waters, subject to their presence in the catchment. The retention time of water in irrigation canals is often a limiting factor on their use by fish. Residual water bodies have a high rate of evaporation under desert and semi-desert conditions and fish there face elevated salinity levels, as well as high concentrations of agrochemicals which may be used in the irrigated crop production. While all this represents formidable obstacles for the fish, careful management of some irrigation water bodies is capable of replacing the losses in fish production due to damming rivers.
In the Aral Sea basin, government policy for the near future should first of all concentrate on the rehabilitation of irrigation systems, but at the same time decisions should be made on how to optimally use water and land resources. This would allow the maintenance of the existing lands under irrigation.

In Central Asia, Uzbekistan is the largest water user with the least potential to generate water resources. It faces water deficit and therefore is applying much effort to solving the problems of transboundary water resources management. Old principles of water management, which were applied to the whole region prior to independence and gave priority to irrigated agriculture are no longer valid, as power generation has become the priority in the now independent countries located in the upper watershed area (Kyrgyzstan and Tajikistan). This leads to a conflict of interests between upstream and downstream countries.

To replace the loss of the Aral Sea fish through a better use of the existing water bodies of irrigation systems is a major task. Without close collaboration among the countries of the region, including consultations and transfer of experience, it will be difficult to achieve such a goal.

With the rising demand for fish in arid countries of Asia the need for a better management of water resources in irrigation systems is evident. Co-management and community-based management of irrigation water bodies could be applied under the new privatisation policy and market-oriented economies emerging in Central Asia. Maintaining and monitoring the fishery by a small group would facilitate exclusion of outsiders, often illegal fishers. Government policy makers may consider delegating the management responsibility to collective or private groups, which then should receive government support through credit, training, scientific and extension assistance.

Due to lack of access to oceans, as well as the demise of the Aral Sea fisheries, Kamilov (2003) believes that the future of Uzbekistan’s fisheries lies in aquaculture and enhanced capture fisheries. Extensive pond aquaculture is the most important sector of the fisheries industry, providing 60 percent of today’s total fish production. About 20 companies own hatcheries, which induce-breed and farm fish, mainly silver carp, bighead carp and grass carp, with common carp reproduced both artificially and naturally. The fish are grown to market size on farms. In the 1990s the total area of ponds reached 10,400 ha, with sizes of the individual ponds ranging from 10 to 150 ha. Small-scale aquaculture could be developed in reservoirs, canals and lakes, with participation of villagers and local administration. Once the credit mechanism is fully understood, with the help of the local administration the new small-scale aquaculture ventures should be easy to implement.

**Constraints**

Umarov (2003) identified a number of constraints in using water bodies of irrigation systems for fish production. These do not necessarily apply to all countries sharing the river catchments as Umarov based this account on the experience from Uzbekistan where these include:

**Institutional constraints**: Absence of governmental and non-governmental institutional structures to promote the use of irrigation systems for fish production. Legislation ensuring the rights of private fish farmers to a guaranteed water supply within special limits and to trade in fish may be lacking.

**Economic constraints**: Lack of or minimal government financial support and private investments into fisheries. No special credit lines.

**Technical constraints**: Priorities for water use, i.e. irrigation demand and hydropower production, often do not allow maintaining optimal water supply for fish spawning and in nursery grounds. Lack of protecting devices preventing young fish from being discharged with irrigation water onto irrigated fields; lack of corridors between water bodies including floodplains, river reaches and canals, to make possible the migration of fish and fish fry from and to places of spawn-
ing, reproduction and other types of existence; unsuit-
ability or absence of fish passes.

**Ecological constraints**: water pollution in irrigation 
systems, including increased salinities and toxicity.

**Social and cultural constraints**: Low level of public 
awareness that the irrigation network can be used for 
fish production. Shortage of fisheries experts and of 
fisheries training programmes.

The following constraints may be difficult to 
address, at least initially. These constraints may also 
apply to other countries of Central Asia in the Aral Sea 
basin, especially in Amu-Darya and Syr-Darya catch-
ments:

- Lack of economic and technological models for the 
development of private fisheries in irrigation sys-
tems;
- Lack of financial support for scientific and applied 
research in this direction;
- Lack of experience in obtaining credits for estab-
ishment of fish farms and in attracting foreign par-
ticipation for private ventures;
- Lack of international assistance for the develop-
ment of fish production.

**Fisheries development perspectives**

Fisheries development in the Amu-Darya and 
Syr-Darya river basins has a good potential, given the 
favourable climatic conditions prevailing in this geo-
ographical area. The socio-economic frame also sup-
ports this, with abundance of labour. The rapid popula-
tion growth also means increasing demand for food 
and the further development and expansion of fisheries 
is one of the ways to go. In Central Asia and mainly in 
the catchments of the Syr-Darya and Amu-Darya 
Rivers, it is estimated that the fish yield potential of 
lakes, rivers and reservoirs is about 100 kg ha⁻¹ year⁻¹. 
This could provide 200 000 tonnes of fish annually to 
the markets. Uzbekistan of all countries in the region 
has the greatest potential for using irrigation systems 
for fish production (Umarov 2003). The development 
of fisheries in reservoirs serving irrigation will provide 
employment and contribute to the diversification of 
food supply. Development of aquaculture in irrigation 
systems would further increase fish supply to markets.

The transition from the centrally planed econo-
my to market economy has not been a smooth one. 
Even after more than 10 years fisheries face great dif-
ficulties, especially in form of easy credits without 
which the industry cannot be kick-started. Even main-
tenance of the existing facilities has proved to be cost-
ly, as much of the former government support has 
evaporated. The decline now seems to have been halt-
ed, but the recovery process is extremely slow. With 
shortage of private funds a valuable resource is being 
wasted.

Due to the regional interdependence of all five 
countries on the same water resources, there is also a 
need for regional cooperation. At present no regional 
network exists to deal specifically with the use of irri-
gation systems for fish production. The Interstate 
Coordination Water Commission (ICWC), based in 
Tashkent, Uzbekistan, could take this up. This 
Commission already deals with other aspects of 
regional cooperation of water resources of the Aral Sea 
basin (Umarov 2003). The top level management 
organisations from the five countries of the Aral Sea 
basin are represented by the ministers at the quarterly 
meetings of the ICWC which discuss the current situa-
tion related to water distribution and use and formulate 
water strategy for the forthcoming period. The ICWC 
consists of three permanent executive bodies: Basin 
Water Organizations (BWO), Amu-Darya and Syr-
Darya and the Scientific Information Centre (SIC) of 
ICWC. BWOs Amu-Darya and Syr-Darya are in 
charge of the operational monitoring of the water lim-
its set by ICWC and operation of interstate reservoirs 
and hydrostructures. The SIC ICWC is in charge of 
technical policy and manages a regional information 
database on regional water resources.

The ICWC is now also paying attention to the 
interests of other water resource users including fish-
eries. It aims at overcoming administrative barriers and 
tries to involve the general public and private sector, 
non-governmental organizations and water users in the
integrated water resources management both at national and regional levels (Dukhovny and Kindler 1999). Umarov (2003) believes that the available institutional framework for water management at the regional level and the possibility of regular contacts with governments, related ministries and the general public make ICWC the most suitable structure for information support and development of a regional network involving the use of irrigation systems for fish production.

Umarov (2003) formulated a number of recommendations for better use of irrigation systems for fish production in Uzbekistan, a country that is using water resources of both the Amu-Darya and Syr-Darya rivers. He has grouped the measures needed for the rehabilitation of fisheries and further progress in this direction as follows:

### Institutional aspects

- Taking into account the institutional integrity of agriculture and water management, there is a need to establish within the Ministry of Agriculture and Water Resources of Uzbekistan a department for the use of irrigation systems for fish production;
- Favourable conditions should be created for involving the personnel operating and maintaining irrigation systems in fish production; this would provide them with additional income and also solve the problem of rapid employee turnover;
- A system of public awareness through mass media needs to be established;
- A legislative base, setting out the rights and duties of fish producers and protecting their interests, needs to be established.

The following institutional framework for fish production is proposed:
- Department of Fisheries under the aegis of the Ministry of Agriculture and Water Resources;
- Agricultural research organisation;
- Aquaculture associations.

### Economic aspects

The on-going reforms in agriculture and water management are gradually establishing favourable conditions for private small-scale pond aquaculture. Private fish farmers could be then incorporated in the Associations of Farmers and Water-users.

### Technical, training and research aspects

Regular releases of water are needed to prevent salinisation of water bodies with good water quality and to prevent increase in salinity of water bodies which are already saline.

- Fish protection devices need to be constructed on intake structures;
- Subsequent or simultaneous water use for several purposes should be encouraged, for instance combining irrigation and drainage with fisheries;
- Irregular and untimely water releases and flood waters should be harvested in the best possible way for fish production; fish producers should be provided with seasonal flows required for biological functioning of fish;
- An experimental research centre for development of fishery technologies for use in irrigation systems should be established; the centre would also monitor global development and trends, identify the most appropriate technologies and adapt them for the local geographical, social and economic conditions;
- Selected technologies should be tested in pilot projects, with the objective of applying them throughout Uzbekistan and in other countries of Central Asia;
- Regular training courses in aquaculture are needed. The ICWC Training Centre, Tashkent, Uzbekistan, could run these.

Many of the above recommendations are relevant to the other countries of Central Asia where freshwater fisheries need to be rehabilitated and developed in irrigation water bodies.
REFERENCES


