Feasibility of stocking and culture-based fisheries in Central Asia

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Karagandy region, Kazakhstan. Photo by S. Timirkhanov
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Lower right: Ton Hatchery, Issyk Kul, Kyrgzystan. Photo by A. Thorpe

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Preparation of this document

This study was conducted in 2010/2011 by the FAO Subregional Office for Central Asia in response to the regional priorities set by those involved in the establishment process of the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (CACFish).

Experts involved in this desk study were Professors Andy Thorpe and David Whitmarsh, and Drs Ben Drakeford and Chris Reid of the University of Portsmouth (United Kingdom); Dr Bakhtiyor Karimov, Institute of Zoology, Academy of Science (Uzbekistan); Dr Serik Timirkhanov, Kazakh Scientific Research Institute of Fisheries (Kazakhstan); Kuanych Satybekov (Kyrgyzstan) and Raymon van Anrooy (FAO). This document was made possible with regular programme funding of the FAO Subregional Office for Central Asia, based in Ankara, Turkey, was edited by Richard Arthur and Robin Welcomme and was technically reviewed by Devin Bartley and Mohammad Hasan (FAO Fisheries and Aquaculture Department, Rome, Italy). The authors would like to acknowledge with thanks the contributions by Tina Farmer, Marianne Guyonnet and Cana Salur of FAO in the finalization of this document for publication.

The desk study makes use of case studies drawn from Kazakhstan, Kyrgyzstan and Uzbekistan; case studies that provide a good insight into the current situation in the region as a whole.

Abstract

Culture-based fisheries have been successfully developed across the world in order to increase productivity of capture fisheries, with five to tenfold increases in productivity per hectare not uncommon. Fish farming too has shown to be an important contributor to national food security, rural employment and income generation.

Unfortunately, political upheaval, the disruption of historic fish supply chains and limited state budgets have combined to halt many of the stocking and culture-based fisheries programmes in the Central Asian and Caucasus region during the 1990s. This is unfortunate, as a number of important waterbodies in the region offer great potential for such activities. As a consequence, this study was tasked with providing an overview of regional waterbodies and historic and contemporary culture-based fisheries and stocking experiences – using case studies from Kazakhstan, Kyrgyzstan and Uzbekistan – with a view to suggesting potential ways in which national governments and the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (CACFish) might support the rehabilitation of culture (and, by extension, capture) fisheries in the region.

Seven overarching principles are identified (i.e. ecosystem compatibility, compatibility with other uses, best available science and information, social and economic benefits, collaboration with the culture production sector, the regulatory process, public information) and accompanying recommendations are made to guide culture-based activity and stocking in the region.

The Fourth Intergovernmental Meeting on the Establishment of the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (Cholpon Ata, Kyrgyzstan, 22–24 June 2011) discussed and adopted the conclusions and recommendations of this regional study and requested the FAO Secretariat to CACFish to pass them forward to the Inaugural Meeting of the Commission for endorsement by the same Commission.

Thorpe, A.; Whitmarsh, D.; Drakeford, B.; Reid, C.; Karimov, B.; Timirkhanov, S.; Satybekov, K.; Van Anrooy, R. *Feasibility of restocking and culture-based fisheries in Central Asia.* FAO Fisheries and Aquaculture Technical Paper. No. 565, Ankara, FAO, 2011. 106 pp.

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In Memoriam
David Whitmarsh, 1950–2010

David Whitmarsh, Professor of Marine Resource Economics at the University of Portsmouth, passed away in the early hours of 28 August 2010 after losing his battle with cancer.

Born in Plymouth on 17 February 1950, David completed his education at King's College in Taunton and the University of Exeter, where he graduated in Economics in 1971. A brief stint as Assistant Master at Hurstpierpoint College in Sussex was followed by a move to Edinburgh to undertake a Diploma in Rural Science, and then a return to the West Country as Non-Executive Company Director of Capital Securities Ltd (Plymouth).

Appointed at the princely salary of £1 120 *per annum* as a Research Assistant in the small (two staff, four researchers) Marine Resource Research Unit (MRRU) in the Department of Economics at the then Portsmouth Polytechnic, David's career would henceforth be indelibly linked with research on the economics and management of marine resources. An MA by research on *Technological Change in the UK Fishing Industry* at Exeter in 1975 facilitated his appointment as a Lecturer in Economics at the Polytechnic in 1977. In 1984, David took charge of MRRU, and co-authored (with Mike Dunn and Steve Cunningham) *Fisheries Economics* (1985), recognized by many as a seminal text in the field. He was also a driving force in introducing the Postgraduate Certificate in Fisheries Economics (subsequently the MSc in Fisheries Economics), a programme that provided invaluable exposure to economic and social aspects of fisheries and aquaculture to many up and coming fisheries postgraduates from across the developing world. Rewarded for his endeavours with a Principal Lectureship in 1991, it was only natural to convert his growing portfolio of publications on technology, fishing effort and management into a doctoral degree on *The Role of Economics in the Management and Development of Marine Fisheries* in 1995. In "impact" terms, David's growing reputation saw him either lead or be a key participant in fisheries research commissioned by the Organisation for Economic Co-operation and Development (OECD), Food and Agriculture Organization of the United Nations (FAO), the European Commission, the Department of Trade and Industry (DTI), HM Treasury, the United Kingdom's (UK) Environment Agency and the UK House of Commons Agriculture Committee, the Economic and Social Research Council (ESRC), the Ministry of Agriculture, Fisheries and Food (MAFF) and the Canadian High Commission, among others.

Although he stepped down as Head of the Centre for the Economics and Management of Aquatic Resources (CEMARE, MRRU's successor) in 1991, his research and teaching remained in the realm of fisheries – latterly embracing aquaculture and emerging multidisciplinary themes such as coastal zone management and the valuation of unpriced resources. He was also a valued member of international organizations such as the International Institute of Fisheries Economics and Trade (IIFET) and the European Association of Fisheries Economists (EAFE), and served on the editorial boards of the *Marine Pollution Bulletin* and *Fisheries Research.* Nevertheless, despite the acknowledged quality of his research during this period, his international profile was less than it might have been given his reluctance to trade-off being with his young and growing family with international conference networking and field research. Appointed a Reader (2001) and thence a Professor in Marine Resource Management (2004), and with a grown up family, David was now able to apply his expertise internationally, contributing to a Department for International Development (DfiD) funded study examining the *Social and Economic Valuation of the Aquatic Resources of the Lower Mekong Delta* and delivering short-courses in fisheries economics in Cambodia, Greece, Turkey, Spain and Korea. Shortly before his death he had delivered a similar course – competing admirably with a 6 000 Watt generator immediately outside the teaching room – at the University of Sierra Leone, and was also involved in the formulation of projects that would have seen him give courses in Kyrgyzstan and Mexico later this year.

David will be remembered with great affection at Portsmouth. At the time of his death he was completing the final edits to a monograph on *Marine Resource Economics* (to be published by Earthscan in early 2011) – a fitting epitaph for a man who will be sorely missed by colleagues at Portsmouth and in the wider aquatic research community.

Abbreviations and acronyms

ALS	Arnasay Lake System
AMA	Association Marocaine de l'Aquaculture
APA	Aquaculture Producers Association
ASDB	Aral Sea drainage basin
BMPs	best management practices
BOWs	Basin Water Organizations
CACFish	Central Asian and Caucasus Regional Fisheries and Aquaculture Commission
CAPA	Commercial Aquaculture Producers Association
CAPAS	Central Asian Production and Acclimatization Station
CEMARE	Centre for the Economics and Management of Aquatic Resources
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CPAA	Central Production and Acclimatization Authority
DDT	Dichloro-diphenyl-trichloroethane
DfID	Department for International Development (United Kingdom)
DSP	diarrhetic shellfish poisoning
DTI	Department of Trade and Industry (United Kingdom)
EAFE	European Association of Fisheries Economists
EIA	environmental impact assessment
ESRC	Economic and Social Research Council (United Kingdom)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAO-FIGIS	FAO Fisheries Global Information System
FCDC	Fish Culture Development Center (Uzbekistan)
FFDA	Fish Farmers Development Agency (India)
GEF	Global Environment Facility
HACCP	Hazard analysis critical control points
HFA	Hunter and Fishers Association
ICWC	Central Asian Interstate Commission for Water Coordination
IIFET	International Institute of Fisheries Economics and Trade
IRR	internal rate of return
KRIF	Kazakh Research Institute of Fisheries
LLP	limited liability partnership
MAC	maximum allowable concentration
MAFF	Ministry of Agriculture, Fisheries and Food (United Kingdom)
MAWPRI	Ministry of Agriculture, Water Resources and Processing Industry (Kyrgyzstan)
MAWR	Ministry of Agriculture and Water Resources (Uzbekistan)
MRRU	Marine Resource Research Unit
NACA	Network of Aquaculture Centres in Asia-Pacific
NOAA	National Oceanic and Atmospheric Administration (United States of America)
NPV	net present value
OECD	Organisation for Economic Co-operation and Development
PSP	paralytic shellfish poisoning
RENAPIB	Réseau National des Pisciculteurs du Bénin

R&D	research and development
SGP	Small Grants Programme (of GEF)
SSR	Socialist Soviet Republic
SYNAS	Syr Darya and Northern Aral Sea Project
TICA	Turkish International Cooperation Agency
USSR	Union of Socialist Soviet Republics
VAT	value added tax
WHO	World Health Organization
WSSD	World Summit on Sustainable Development
WTO	World Trade Organization

1. Introduction

The inland capture fisheries and aquaculture sectors in the Central Asian region have suffered a calamitous decline in production over the last few decades. For example, Thorpe and van Anrooy (2009a) note that, while aggregate output in the countries comprising the old Soviet Union declined 61percent from 9.6 million tonnes to 3.8 million tonnes between 1989 and 2006, the most acute falls in output were experienced in Central Asia. Thorpe and van Anrooy (2009b) and the World Bank (2004) – specifically in the case of Kazakhstan – also noted that data collection suffered as a consequence of the break-up of the Soviet Union, and actual catches are likely to be in excess of reported catch in all five of the republics. Nevertheless, reported catches in Kazakhstan dropped by around 35percent and those of Turkmenistan and Uzbekistan by almost 75percent during the same period, while Tajikistan's and Kyrgyzstan's catches dropped by more than 90percent (Table 1).

TABLE 1
Fish production in the Central Asian republics

Republic	1989	2008	2008 production (as percent of 1989 output)
Kazakhstan	89 508	55 902	62.5
Kyrgyzstan	1 447	100	6.9
Tajikistan	3 547	172	4.9
Turkmenistan	52 974	15 016	28.3
Uzbekistan	25 526	6 218	24.3
Total	173 002	77408	44.7

Source: FAO-FIGIS (2010–2011).

This collapse had a profound effect upon fisher livelihoods across the region (Thorpe and van Anrooy, 2009b), most notably in the Aral Sea region (Paivina, 2011), and prompted a discourse as to the most effective way to rehabilitate the sector. At the regional level, these concerns have led to moves to establish a Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (CACFish), whose first meeting took place in Dushanbe in Tajikistan in November 2008. At the national level, governments are taking action to: resolve the lack of legislative clarity regarding the governance of the sector; reduce the conflicts between the fishery sector and the agricultural (irrigation needs) and energy (hydro-power generation) sectors over the use of the region's scarce water resources and remove impediments (i.e. tariffs, the leasing of waterbodies) that have militated against fisheries growth in the post-independence era.

The production statistics in Table 1 show the continuation of a trend that was already evident in the pre-independence period – namely the demise of the region's capture fisheries. Historically, the early focus of Soviet scientists was directed towards interventions that merely sought to enhance the value of regional capture fisheries – most notably by introducing the starry sturgeon into the waters of the Aral Sea (to boost sturgeon landings) and the Sevan trout into Issyk Kul (to create a new high-value fishery alongside the existing low-value dace-based fishery). As specialist culture and research institutions were set-up (i.e. the Central Asian Production and Acclimatisation Station (CAPAS) in Bishkek, the Kazakh Research Institute of Fisheries (KRIF), Uzbek Commission of Fish Resources and Fish Reproduction Protection (Uzbekribvod)), and it became apparent that the state would need to play an active and continuing role in the stocking of regional waterbodies if capture levels were to be maintained, the number of species considered for possible release into Central Asian waters increased. Deliberately introduced species included the Atlantic herring (into the Aral basin, 1957), pike-perch (Issyk Kul, 1958), and Lake Sevan trout, common carp, naked osman, tench, European whitefish, Tibetan stone loach and gray loach (into Son Kul lake system, 1959).

The Union of Socialist Soviet Republics (USSR) Ministry of Fish Industry authorized the construction of around 20 hatcheries/nurseries across the region during the 1960s and 1970s to facilitate the growing stocking programme. Although pond culture had always been prominent in Tajikistan since the opening of the Luchobka (1936) and Kuybyshev (1951) hatcheries (Khaitov, 2008), it was largely the ecological disaster of the desiccation of the Aral Sea (Micklin,1988) and the sharp decline in the Issyk Kul landings during the 1970s that highlighted the limited future for capture fisheries in the region. While regional production levels were sustained in the 1980s by the growth of a largely cyprinid-based aquaculture/pond culture, these endeavours, – based as they were on imported feed and equipment and central subsidies – proved particularly vulnerable in the post-independence era. A diminution in the status accorded to the sector in the post-Soviet era (with many fisheries institutions either being wound-up or subsumed within an agriculture/environment ministry) did not help, and production collapsed (Table 1).

As the Central Asian republics proceed through the twenty-first century, it is clear, that any future attempt to rehabilitate the fisheries sector must focus upon culture as opposed to capture. Capture fisheries in the larger waterbodies will continue to provide a living for local fishing brigades, as Thorpe and van Anrooy (2009b) and Paivina (2011) have indicated and there remains the need to ensure their continued stocking. However, the major contribution to growth in the sector for exports and/or domestic nutrition will be derived from future culture production. As a consequence, this technical paper is intended not only to complement the national fisheries reviews published by the Food and Agriculture Organization of the United Nations (FAO) over the period 2008–2010 and research examining fisheries livelihoods (e.g. Thorpe and van Anrooy, 2009b), but to focus more explicitly on aquaculture and its prospects in the region. The intention of this technical paper is thus fivefold. First we provide a general overview of global culture production and its growth over time. Second, we highlight the environmental, economic and social aspects of culture-based production, drawing upon evidence from across the globe as to the environmental consequences of encouraging such production, the standard techniques employed to measure returns to the enterprise and the myriad social benefits culture-based production may bring. The third part of the report introduces the reader to the waterbodies and rivers of the region, while the fourth section examines the institutional framework for fisheries/culture production, past and contemporary stocking/culture experiences and the problems currently encountered by those pursuing such activities in three of the Central Asian economies (Kazakhstan, Kyrgyzstan and Uzbekistan). A final section offers a series of conclusions and recommendations based upon the preceding research and analyses its capacity to respond to the four research questions.

1.1 Definitions.

Capture fisheries as defined by the FAO as referring to: "The sum (or range) of all activities to harvest a given fish resource. It may refer to the location (e.g. Morocco, Georges Bank), the target resource (e.g. hake), the technology used (e.g. trawl or beach seine), the social characteristics (e.g. artisanal, industrial), the purpose (e.g. (commercial, subsistence, or recreational) as well as the season (e.g. winter)." (FAO Fisheries Glossary).

Aquaculture is defined as "The farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production. Farming also implies individual or corporate ownership of the stock being cultivated" (FAO, 2011a).

Culture-based fisheries are defined as " Activities aimed at supplementing or sustaining the recruitment of one or more aquatic species and raising the total production or the production of selected elements of a fishery beyond a level, which is sustainable through natural processes. In this sense culture-based fisheries include enhancement measures, which may take the form of: introduction of new species; stocking natural and artificial water bodies, including with material originating from aquaculture installations; fertilization; environmental engineering including habitat improvements and modification of water bodies; altering species composition including elimination of undesirable species or constituting an artificial fauna of selected species; genetic modification of introduced species." (FAO, 2011b). Culture based fisheries consist of two phases - a farmed phase for the provision of stocking material, and a wild phase where the onward growth of the fish stocked depends on natural processes.

Stocking is the release of fish, usually as fry or juveniles, into a water body to improve the fish stock and the fishery. Stocking material (seed) is usually obtained from aquaculture although stocking with seed captured form other water bodies is also common in some areas. Stocking is usually a repeated exercise.

Introductions are the release of species new to an environment, usually to introduce a new element into the fish community. Introductions are intentionally self-sustaining and are thus only made once.

The Latin names of the fish species mentioned in this paper are given in Appendix I.

2. Culture-based fisheries and world inland fisheries and aquaculture production

Culture-based fisheries are capture fisheries which are mostly or entirely maintained by the regular stocking of seed fish. Culture-based fisheries rely entirely on the natural productivity of the water body for growth and on artificial stocking for recruitment (Lorenzen, 1995). This means that they lie somewhere between pure capture fisheries and aquaculture in the range on management techniques for inland and, in some cases, marine waters. They are one of a range of tools to increase yields of natural populations of fish molluscs and crustacea (Welcomme and Bartley 1998). Culture-based fisheries are not reported separately in the fishery statistics reported to FAO. They are usually included with capture fisheries but in some countries and some types of fisheries they are included under aquaculture. Stocked fisheries are a common means of managing reservoir and small lake fisheries and are prominent in Thailand, Viet Nam, India, Mexico, and Cuba among others. Given the widespread nature of the practice they undoubtedly make a significant contribution to the global capture fisheries landings but probably make less of a contribution to aquaculture production.

In 1987, the last year in which the USSR reported fish catches as a block, the total landing of fish products from capture fisheries reached 85.6 million tonnes (The Soviet union continued reporting some catches until 1991 albeit at a much reduced quantity). In 1987 the Soviet Union was second only to Japan with total catches (inland and marine) of 12percent of the total. Since 1987, landings from capture fisheries have fluctuated around 90 million tonnes (FAO, FishStatJ). Many of the world's marine fisheries are now considered to be overexploited (FAO, 2007a) and, since the 1970s, there has been a consistent downward trend in the proportion of stocks offering potential for development, coupled with an increase in the number of species that are fished to capacity or overfished. Under current management strategies, capture fisheries seem to have reached their potential with regard to the number of fish that can be produced each year for either direct or non-direct (largely fishmeal) human consumption. In 2002, the World Summit on Sustainable Development (WSSD) in its Plan of Implementation called for immediate action to maintain or restore (fisheries) stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015. The world catch from inland fisheries was about 6 million tonnes in 1987 of which 654 thousand tonnes (11percent) came from the waters of the USSR. Since 1987 world inland fish catches have been reported as increasing to their 2009 value of 10.3 million tonnes However, there have been considerable variations in the growth of the sector between various parts of the world and the inland fish catch from the countries of the former Soviet Union and Central Asia in particular have declined (FAO in press)

Overfishing is an international problem, with stocks expected by some commentators to become more depleted and damage ever more widespread (Naylor *et al.*, 2000, 2009; Worm *et al.*, 2009). Worm *et al.* (2006) predict the collapse of all species of sea fish by 2048 if steep declines of stocks are allowed to continue at current rates. Sustainability (in one form or another) has been a goal in the fishing and aquaculture industry for a long time. There are many definitions of sustainability and sustainable development, but the one used here is that employed by Bruntland (1987): "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". It contains within it two key concepts: the concept of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs. Under this philosophy it is possible that some increases in catches from marine and inland fisheries might be achieved by improved management.

In contrast to fisheries, global production from aquaculture has grown rapidly over the past 20 years or so. Aquaculture is becoming an increasingly important source of fish for human consumption and continues to grow more rapidly than all other food-producing industries, with an average annual growth rate of 9.2 percent per year since 1970 (FAO, 2008a). Over the last 35 years, aquaculture's contribution to total fish production has increased from 5.3 percent by weight in 1970 to 36 percent in 2009 (FishStatJ - [http://www.fao.org/fishery/statistics/software/fishstatj/en] accessed august 2011), with per capita supply increasing from 0.7 kg in 1970 to 7.8 kg in 2008. According to FAO, 2010, 46percent of fish directly consumed by humans (excluding fish used in feed production) are farmed and fish from this source may well overtake capture fisheries as a source of food.

Production by aquaculture of the six FAO FishStat major groups classified by weight is given in Figure 1. Finfish contribute 49 percent of the catch, aquatic plants (mainly seaweeds) 24 percent, mollusca 19 percent, crustacea 7 percent and invertebrates and amphibians about 0.5 percent each In terms of value, the 2009 production was worth $110 million (Table 1). Finfish were the most valuable commodity at $1.81/kg, followed by crustacea at $1.39/kg. Forty three taxonomic species of cyprinids were the most abundant cultured inland species at 64 percent of production (with seven species making up nearly 90 percent of production). Eleven species of cichlid made up a further 9 percent (with Nile tilapia contributing 82 percent of this) and salmonids making up a further 7 percent. Prices per kilo were cyprinids $1.3, cichlids $1.6 and salmonids $4.7.

Figure 1
World aquaculture production by main species-group (source FishStat)

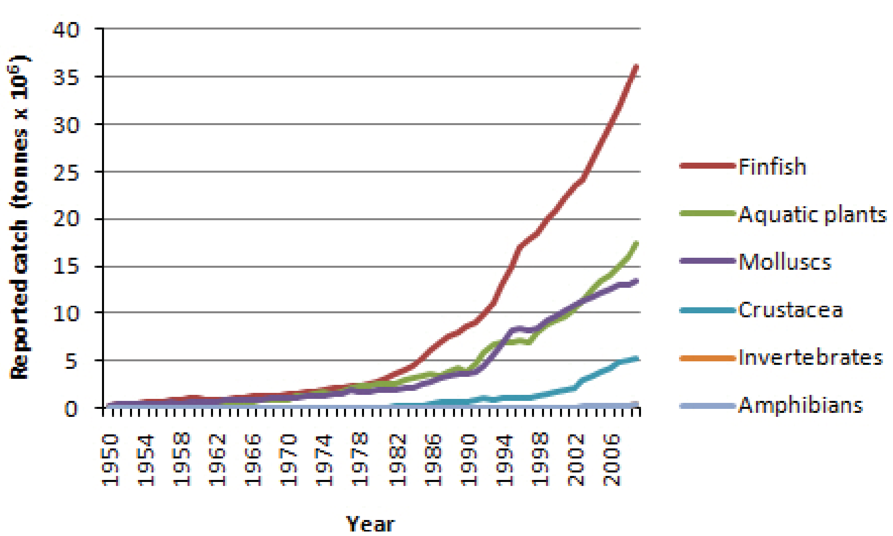

TABLE 1
Value of aquaculture output by main category in 2009

Major category	Value ($)	percent of total	Value $/kg
Finfish	65 284 908	59.27	1.81
Crustacea	24 133 782	21.91	1.39
Molluscs	13 160 091	11.95	0.97
Aquatic plants	4 815 465	4.37	0.91
Amphibia	1 827 637	1.66	4.82
Invertebrates	927 162	0.84	2.63
Total	11 0149 046	100.00	

The vast water bodies of Central Asia have the potential to increase regional culture production – a culture-based fishery being essentially a wild fishery that is supplemented by stocking. Stocking of water bodies in the region is an old practice, and was historically undertaken to rejuvenate fisheries that had been overexploited, to supplement stocks that had been wiped out through environmental degradation or to bias the species mix of the fish community in favour of a particularly desirable species. Stocking in culture-based fisheries is generally undertaken to increase productivity beyond the level sustainable through natural processes.

Several species are favoured for stocking, usually based on their commercial value or their social acceptability. Many of these have been introduced around the world for this purpose. Tilapia and common carp, in particular, can be cultured in a variety of environments and are remarkably tolerant to changes in water quality and temperature. However, in many areas of Central Asia, where water bodies may freeze to the bottom during the winter, fish population cannot be maintained throughout the year and species have to be used that grow to sufficient size during the season where the water bodies remain unfrozen. In this tilapias are particularly valuable because of their very high growth rates, even in extensively farmed systems. Some species of carp also grow quite rapidly and have the additional advantage that they are more tolerant of low temperatures and also survive well at low oxygen concentrations.

3. Environmental, economic and social aspects of culture-based fisheries

This section of the report sets out to identify the various environmental, economic and social aspects associated with the development of culture-based fisheries in Central Asia.

ENVIRONMENTAL ASPECTS

The main environmental problems associated with culture based fisheries arise mainly from the aquaculture practices needed to supply fish for stocking but the stocked wild fishery may also have some problems (Table 2). Two main effects can be noted, effects of the environment on the fishery and effects of the fishery/culture practice on the environment.

The environmental impacts of aquaculture have been well documented over the last two decades or so (see e.g. Naylor and Burke, 2005; Asche, *et al.*, 2009) (Table 2).

TABLE 2
Some environmental problems associated with aquaculture and intensive culture-based systems

Problem area	Problem results from:
Waste and nutrient loadings	Outputs of solids, nitrogen, phosphorous, vitamins, minerals, husbandry/diseases, chemicals, antibiotics, impacts of waste material on the adjacent benthos and the water column; on species community diversity, quality indices, stimulation of blooms
Water exchange	Flushing through freshwater or marine cage or enclosure, quantities required, effects of abstraction, dilution with "low grade" wastes, at concentrations sufficient to diminish measured quality but too low for sample treatment
Degradation of terrestrial environments	In coastal areas – salinization of soils affecting adjacent agricultural practices, excessive clearance of mangroves and protective cover
Fish escapes	Damaged culture systems, flooding, damaged or ineffective discharge screens, risks of competition with genetic contamination of local stocks, disease transmission, directly or indirectly reduced biodiversity
Predation by conservation-sensitive species	Damage, loss, stress-related disease in farmed stocks
Social amenity disturbance	Visual, noise, activity disruptions

Source: Magdy et al. (2001).

Because the stocked fish communities are in natural water bodies many of the environmental issues that impact on these will also affect the fishery. Thus incidents of pollution or nutrient enrichment within the basin may well cause changes in the survival and growth of the fish in water bodies downstream. Similarly, water abstractions for irrigation or urban supply in the affluent streams could well cause the water body to lose area or depth to a degree that it freezes completely in the winter. Natural water bodies are also very susceptible to climatic conditions particularly periods of drought or long and unusually cold winters. In this respect many inland water habitats are especially vulnerable to global warming.

Ecosystem aspects

Each water body, whether it is a river, reservoir or lake, has a biological carrying capacity depending on its nutrient status and morphological characteristics. Biological carrying capacity can be defined as the population size of a species that the environment can sustain given the food and other necessities available in the environment. Stocking can only be effective in increasing yields where production by naturally stocked fish is below the carrying capacity of the water body. For stocking programmes to be efficient the carrying capacity of the resource must be known, otherwise the water body may be overstocked and productivity may be decreased, with detrimental effects for the naturally occurring fauna. One mechanism whereby higher levels of yield can be maintained is in water bodies where overfishing reduces the spawning stock and stocking is used to re-establish the population structure over that possible by the self-recruiting resident stocks (Lorenzen, 1995).

Maximizing the effectiveness of culture based fisheries is highly dependent on ecosystem productivity and optimizing management regimes so that a water body's production potential is managed effectively (Lorenzen *et al.*, 2001). On the one hand, there are many examples of successful culture-based fisheries, especially in China, where productivity can be raised from 150 kg/ha to 750 ka/ha by stocking carps (Huang, Lui and Hu, 2001). On the other hand, there are numerous examples where culture-based fisheries have failed. The reasons for failure are not always clear, although in some cases mortality of stocked juveniles appears to be higher than seen in wild populations (Lorenzen *et al.,* 2001). Accurate stock enhancements are sadly lacking in many countries, in particular quantitative information on density dependent population processes is not available. In Kazakhstan, Kyrgyzstan and Uzbekistan[1] records of stocking experiences from before 1990 are generally not available, and data can only be obtained through experimental management when the water bodies are newly stocked. However, because the ecosystem interactions of the current fauna are not known, many stocking programmes fail to increase productivity. Some synthesis of this experimental data, however, may provide useful information to aid future stocking programmes.

Clearly, if the biology and characteristics of stocked species are not fully known, a species may be stocked that is not compatible with the current fauna of the lake, leading to competition with other species and overall declines in productivity, for example, as when trout and pike perch were stocked into Lake Issyk Kul in Kyrgyzstan.

Introduction issues

The introduction of non-indigenous species (also known as alien, exotic or non-native species) has had a chequered history throughout the World. In many cases introductions

1 While full records were kept during the Soviet period, institutional re-organization and the downgrading of the sector in terms of its economic importance and the support offered ensured many records were subsequently lost or destroyed.

have formed the basis of important fisheries, and the major introductions, common carp, Nile tilapia and rainbow trout have all contributed to aquaculture and capture fisheries in their adoptive countries. Many other introductions have proved neutral but some have proved detrimental by transforming the structure and species composition of ecosystems, either directly (by out-competing native species for resources) or indirectly (by changing the way nutrients are cycled through the system). Non-indigenous species may also compete with other animals in the ecosystem, as food webs become distorted.

There are many examples where the introduction of non-indigenous fish has caused the decline of indigenous populations (see Cook, Ashton and Campbell, 2008). Tilapia is a very good example, because if tilapia are stocked either purposely or accidently (i.e. escapees), they can very quickly outcompete indigenous species (for food, habitat, mates, etc.), permanently altering the species composition of the water body in some cases. Nevertheless, tilapias, and *Oreochromis niloticus* in particular has contributed to the success of many reservoir fisheries in Asia and Latin America where local species have been unable to adapt to the new lacustrine conditions(see De Silva *et al*. 2004). There have been similar cases in some Central Asian fisheries, where stocking different species of fish to those naturally found has decreased overall productivity. In Kyrgyzstan, stocking of Sevan trout from Lake Sevan in Armenia in the 1930s and pike-perch in the 1950s into Lake Issyk Kul led to a precipitous decline in stocks of the indigenous Issyk Kul dace, naked osman, the Issyk-Kul marinka and Schmidt's dace. Overfishing was also implicated in this decline but while overfishing and poaching are serious problems in Lake Issyk Kul, species introductions have nonetheless had a significant impact on biodiversity and stock abundance (Konurbaev and Timirkhanov, 2003).

These difficulties show that if culture-based fisheries are to be successful, understanding the biology and characteristics of any species propose for introductions is crucial so that increases in productivity are not linked with increased environmental damage. Moreover, while some environmental problems such as disease and poor water quality can be dealt with to some extent, there is little that can be done to remove invasive, introduced species, especially given the immense size of some of the water bodies in Central Asia. For this reason FAO advises that utmost care be taken in introducing new species to a watershed by first evaluating social/economic need for the introduction which, if positive, should be accompanied by a careful biological and ecological assessment of the risks associated with such an introduction (FAO, 1996).

Stocking issues

Stocking in culture-based fisheries may also cause problems. Stocking may unbalance the fish community structure, disrupting food chains and causing competition with established stocks. Furthermore, much of the seed used originates in hatcheries, often from stock of limited genetic diversity, and if the stocked fish then breed with native wild fish the gene pool may be altered and the strength of natural populations weakened. For this reason material for stocking should be derived from brood stock taken from the water body to be stocked and should be sufficiently diversified to ensure good genetic diversity.

There are frequent problems with disease in hatcheries and a real risk of introducing diseased material. To avoid this risk fish seed should only be taken from carefully controlled hatcheries that are regularly inspected for the commoner fish diseases and its health carefully checked before it is stocked into the receiving water.

If stocking programmes are proposed for water bodies that have high populations of predatory fish, careful consideration needs to be given to the species that are to be stocked and also to their size. An easy solution of course may seem to be the removal of predators from the water body, but predator removal may be difficult and may also cause environmental impacts. For example, if chemicals are used to kill predatory fish, they have to be selective, otherwise loss of other fish and organisms can offset any increased productivity from the stocking programme. Predator removal has also raised serious concerns among environmentalists, as predators form an important part of biodiversity and constitute a valuable part of the catch, providing a critical source of income for subsistence fishers in some countries (Valbo-Jørgensen and Thompson, 2007).

Because stocked fisheries are economic enterprises requiring a, sometimes substantial, investment in seed, financial and social considerations assume equal importance to the ecological ones. Investment implies an investor, and if this is to be by the private sector, ways of protecting the financial outlay have to be found. This usually takes the form of transferring ownership of previously open access resources to private individuals or groups of individuals. Many of the water bodies used to produce fish in Central Asia have not been not properly managed since independence, if they have been managed at all. Giving ownership to communities via some form of culture-based activity may provide a solution to increasing fish production in some of the poorest places in Central Asia. This cannot be achieved only through extensive research into the biology of species, but also by using experimental facilities to monitor species interaction and by

BOX 1

The impact of stocked fish on ecosystem interactions and biodiversity

When a waterbody is stocked, other management measures (especially access restrictions) need to be implemented if those investing are to earn a return on that investment. The reduced access lowers fishing pressure and, with everything else being equal, will lead to higher fish biomass and a high catch per unit effort, but not necessarily a higher overall level of production (Lorenzen *et al*., 1998).

To determine the profitability of stocking, it is essential to know the production potential of the indigenous species already present in the waterbody (Thompson, 2005). In some instances the value of this production may be higher than the value harvested after stocking, which may occur if the mixture of wild indigenous fish comprise a key component of local diets and command relatively high prices.

As financial and ecological impacts depend on the interactions between stocked species and the species already present in the waterbody, it is crucial that the composition of fish species in the waterbody is known in advance if any prediction is to be made of the outcome. This allows the right species to be stocked, (to minimize competition and profitability) and the best size of fingerlings to be selected, taking into account the presence and nature of predators (stocking large fingerlings in such waters will reduce mortality – but large fingerlings are also much more expensive).

careful analysis of the cost benefit ratios to be expected. Government should play an important role in facilitating planning and policy development to ensure that stocking programmes increase the productivity and financial yield of the water body. However, in some cases, the choice of species to be stocked may depend primarily on the price and availability of fingerlings. As noted by Valbo-Jørgensen and Thompson (2007), species should ideally be chosen for their suitability to the local environment and the needs and benefits of the stakeholders, as the stocking of any species (whether it is indigenous or exotic) will impact on the biodiversity and ecology of the system (see Box 1).

Some interactions can be unexpected. For example, stocked carp have competed with several indigenous species in Bangladesh. Black carp have competed with people (as well as other species), as they feed on snails that local folk catch to sell or feed to their ducks. Stocked fish may not only interact with other fish, but also other fauna and flora, which, as discussed earlier, are important themselves for the functioning of water bodies.

Pollution

Pollution may be an issue for two reasons. Firstly inflowing waters feeding a water body may be of such low quality that existing fisheries may be damaged. In such case, clearly further stocking of fish is only going to make the situation worse and the only measure is to ensure that the quality of the inflowing water is improved.

Secondly there are problems arising from within the fishery itself. Natural wetland functions support a wide array of environmental goods and services that sustain economic and societal systems (Burbridge, 1994). Any form of fisheries development, be it the highly intensive farming of species like salmon and shrimp or extensive forms of fish production such as culture-based fisheries, can damage the functionality of water bodies and disrupt the supply of environmental goods and services (Bunting, 2006).

The development of aquaculture (whether marine or freshwater) has been marred by concerns relating to pollution, from extensive pond culture to intensive shrimp farms. Although they pose less of a risk, culture-based fisheries must ensure, through research and planning, that they do not pollute in the same way as intensive forms of aquaculture. By doing so, conflict among stakeholders, especially environmentalists and local folk, should be minimized.

Shrimp aquaculture in Asia probably best exemplifies the impacts of aquaculture development on the environment. Since the 1980s, there has been an unprecedented growth in shrimp aquaculture in the region, as shrimp farming became very profitable. The environmental impacts of shrimp farming can be divided into two main groups: those derived from mangrove destruction and those arising from the day to day operation of the industry. Mangroves provide a range of environmental benefits, such as flood buffering, habitats for small fry, juvenile fish and other marine organisms, and acting as a buffer for run off sediments. These ecosystem benefits have been lost or severely reduced in Asia (principally in China and Thailand), largely as a result of thousands of hectares of mangroves being cleared for shrimp farming. Moreover, the highly intensive farming techniques employed were also responsible for deteriorating water quality, and even complaints of skin disease due to contamination of drinking water (Corea *et al.*, 1998). Several advances have been made to reduce the environmental impact of this form of aquaculture production, such as integrated systems, reducing reliance on artificial feeds and moves toward less intensive (organic) production techniques. The mistake of emphasizing short-term economic gains over long-term sustainable yields must not be repeated in Central Asia through the development of culture-based fisheries as the environmental impact of doing so may be irreversible.

Extensive forms of culture-based fisheries are unlikely to cause the same level of pollution as those that results from intensive aquaculture operations. However, there is a potential for pollution if additional forms of enhancement, such as feeding or fertilization of lakes are planned. In such cases, there may be pollution from biological waste and chemicals (such as inorganic fertilizers), in the water body concerned and in discharges from it into rivers. In more intensive systems there is also a possibility of transmission of disease. Any water body that is fed by or feeds into a river system has potential to cause environmental damage through escapees, although this is only a risk when non-native introductions are involved. However, enrichment by artificial feeds or fertilization is developed to increase productivity, care must be taken as many of the water bodies that appear to offer potential for culture-based production are located near irrigation water sources and close to agricultural land (see Figure 2), and thus can themselves be polluted.

FIGURE 2
Drainage channels running alongside fish production ponds in Uzbekistan

Most fish production facilities in Central Asia are not well developed and are not fully contained. Many smaller ponds and lakes are highly influenced by pollution from agriculture, as they are often situated close to agricultural land. Only fully contained fish production units such as recirculating aquaculture systems, can prevent damage to fish. While this solution sounds appealing, such systems are very capital intensive. Given the low investment in fisheries in Central Asia since independence, it is unlikely that these highly sophisticated methods of fish production will be seen in the short to medium term.

Habitat modification and enhancement

If culture-based fisheries are truly extensive, then habitat modifications and enhancements (other than the ecosystem modifications made by stocking fish) should not be required, as only species suitable to the natural environment should be stocked. However, if the fishery is not generating sufficiently high yields, then there are a number of ways to increase productivity. The main methods tend to be fertilization and artificial feeding. Waterbodies tend to be fertilized, although not exclusively, during the dry season after the previous crop has been harvested (many fertilizers are slow release, rendering additional fertilization during the production cycle unnecessary). In China, there are examples where fertilization has increased yields by tenfold (Potuzak, Huda and Pechar, 2007). Artificial feeding is often used in combination with fertilization. If the stock density is below the carrying capacity of the water body, then the need for artificial feeding tends to imply that the system is being farmed more intensively. However, as production becomes more intensive, water quality needs to be monitored stringently. This may be achieved by installing aerators or by removing the bottom anoxic substrate. There are many examples where these techniques have been used to increase productivity as fish production becomes more intensive.

Modifications to the aquatic habitat may be necessary as part of stocking programmes. The most evident of these is the creation of the water body itself, although it is rare for dams and reservoirs to be constructed only for fisheries. Rather the fishery interest is secondary to other needs such as irrigation, drinking water or power generation Habitat modification may be necessary if natural conditions within the water body are not wholly suited to the needs of the species selected for introduction or stocking . Typically modifications to the environment may be needed to prevent valuable stocked fish escaping, to provide supplementary spawning and nursery areas and shelter to protect against predators, poachers, etc. However, if the modifications interfere with ecology of the native species they may not be in the best interest of the fishery in terms of total productivity (Valbo-Jørgensen and Thompson, 2007). Artificial habitats for stocked and native species are particularly needed where environmental degradation has occurred and such habitats have been destroyed. However, adding additional habitats to the water body may displace habitats of wild species and may have potential impacts on their breeding grounds. Adding artificial habitats should not pose a problem providing the ecosystem of the water body is fully understood and problems only tend to arise when a good understanding of the aquatic ecosystem is lacking.

Normally culture-based fisheries are undertaken as a simple addition of seed to supplement natural populations of fish. In such cases habitat modifications and enhancements should not be required, as only species suitable to the natural environment should be stocked. However, if the fishery is not generating sufficiently high yields, there are a number of ways to increase productivity. The main methods tend to be fertilization and artificial feeding. Water bodies tend to be fertilized, although not exclusively, during the dry season after the previous crop has been harvested (many fertilizers are slow release, rendering additional fertilization during the production cycle unnecessary). In China, there are examples where fertilization has increased yields by tenfold (Potuzak, Huda and Pechar, 2007). Artificial feeding is often used in combination with fertilization. If the stock density is below the carrying capacity of the water body, then the need for artificial feeding tends to imply that the system is being farmed more intensively. However, as production becomes more intensive, water quality needs to be monitored stringently. This may be achieved by installing aerators or by removing the bottom anoxic substrate. Such intensification of the fishery means that what were simple enhanced capture fisheries fall increasingly under the purview of aquaculture.

Impact of vegetation

Vegetation satisfies many functions within an ecosystem, such as sediment retention, oxygenation, nursery habitat, protection from predators, etc. The level of vegetation impacts upon the diversity and composition of fish species within a water body and can affect the predator-prey balance, as the ecology of the lake is changed. The level of vegetation can also be too high or too low. For example, floating vegetation that covers much of the water body's surface will impact on levels of primary production by shading out phytoplankton, which will affect the food chain. Abundant emergent vegetation can provide areas of habitat where small fish can hide from predators, and may prevent the biomass of predator from increasing to unmanageable levels. Submersed vegetation may be needed as spawning grounds and nurseries for larvae and juveniles, and support for their food The degree to which the various categories of vegetation are needed to support the native and stocked fish needs to be fully understood in developing a culture-based fishery,.

This section has shown that stocking additional fish in water bodies where populations have become depleted for one reason or another is only one requirement for a successful culture-based fishery. The reasons why stock levels of native fish are low need to be fully understood in the first place, as overfishing or illegal fishing may not be the only factor that led to the depletion of the stocks. Where the cause of the depletion is environmental, stocking alone will not suffice to increase productivity and should be used in combination with other mitigation and enhancement measures. Lakes and reservoirs, for example, can be modified in ways that enhance fishery production that stocking alone cannot achieve. Many Central Asian water bodies, for one reason or another, are no longer in their pristine state and are therefore not sustaining their maximum potential production. In these, mitigation of ongoing environmental damage or rehabilitation of degraded habitats may also be necessary. Projects which aim to restore a system to as near pristine conditions as possible through physical and biotic modifications should be based on the ecosystems approach – whereby key ecologic processes are indentified, re-established and maintained (Petr, 2001). However, a full understanding of the habitat, environment, current flora and fauna is needed in order to do this successfully.

Culture-based fisheries, which have been promoted by some as a method of augmenting natural yields (see De Silva, 2003), will need to address some of the above issues if they are to be successful. In Central Asia, in particular in Uzbekistan, Kazakhstan and Kyrgyzstan, there are a number of water bodies that have potential to be used for culture-based fisheries but which are not currently used for this purpose. Greater understanding of the environmental aspects and impacts of culture-based fishery production is thus required to prevent this form of production suffering some of the same problems as traditional capture fisheries and aquaculture.

ECONOMIC ASPECTS

In contrast to subsistence and artisanal fisheries most commercial operations are conducted by enterprises dependent on long-term profitability. Capital and labour must be remunerated to avoid their diversion to alternative uses. Costs of fuel, gear and other inputs may be accommodated in the short term, but not the long run. These costs are in turn defined by prevailing economic conditions, such as borrowing and wage costs and the exchange rate. In examining culture-based fisheries development, we distinguish between impact and efficiency approaches. The impacts of fisheries development upon employment, incomes and welfare are considered below (See following section on social aspects). With regard to economic efficiency, factors that affect the returns on culture-based fisheries investment projects relative to their costs are the most relevant considerations for agencies and entrepreneurs considering participation in the sector.

The appraisal of fisheries projects

Investment projects are expected to generate a stream of economic benefits that exceed costs over their expected duration. Acknowledging the time value of money, costs and benefits are discounted at an appropriate rate so that the difference between project costs and benefits is considered in present value terms.[2]

(1) $$NPV = \sum_{t=1}^{T} \frac{R_t - C_t}{(1+r)^t} + \frac{S_t}{(1+r)^t} + [S_x] - I$$

Where:

$NPV =$	Net present value
$R =$	Revenue
$C =$	Costs
$r =$	Discount rate
$S =$	Salvage value of project upon completion
$S_x =$	Salvage value of existing capital
$I =$	Initial investment cost

Equation (1) represents a stylized investment decision that might represent an aquaculture development, stock enhancement project or commercial fishery infrastructure such as a boat or a cold store. This project will generate revenues (R_t) and costs (C_t) in each period of its duration. The present value of accumulated revenues and costs are compared to initial investment (I) costs. If the net present value (NPV) of net revenues exceeds initial investment costs, then the project is viable. Because investors may consider several different projects, perhaps differing in capital and labour intensity, we anticipate that they will rank them in order of the net benefits realized. A project's internal rate of return

2 The discounted cash flow approach to project appraisal is central to most business investment analysis and has been used extensively in considering fisheries projects (see Sumaila, 2001; Strehlow, 2004; Whitmarsh, 2011, Chapter 4).

(*IRR*), a measure realized by solving Equation (1) for the discount rate *r* when the *NPV* is zero, offers a measure of the return on resources employed that can be ranked in this fashion.[3] In addition, projects may realize a salvage value (S_t) upon completion, such as the disposal of vessels involved in fish capture or stocking activities, which should be set against investment costs after discounting. Similarly, if investors are incumbent to the sector, then disposing of or scrapping existing capital – such as older hatchery facilities – may generate a payment S_x that also offsets investment costs *I*.[4]

Such appraisals are conducted *ex ante*. While certain variables, such as investment costs, may be known with reasonable certainty in advance, expected future values of revenues and costs are necessarily estimates. Consequently, single figure valuations of *NPV* and *IRR* may be potentially misleading, suggesting that projects are uniquely profitable or unprofitable. Investors are more likely to face a range of possible outcomes contingent on the distribution of these expected values. Sensitivity and risk analyses evaluate how changes in key variables influence a project's *NPV* or *IRR* and hence its feasibility. In the remainder of this section, we consider the factors to which investments in culture-based fisheries within Central Asia might be sensitive.

Understanding costs and benefits

Central Asian fisheries are insignificant compared to total economic activity and are likely to remain so irrespective of the level of fisheries development. Consequently, they exert no influence upon the prevailing economic conditions that govern the employment of capital and labour. Their relative insignificance raises the probability that there will be more efficient uses for resources than in the fisheries sector, a key factor in explaining the inadequate resources attracted to Kyrgyzstan fisheries identified by Thorpe *et al*. (2009).

Economic viability is conditional upon a project's technical characteristics, which are in turn contingent upon the scale of operations. The feasibility of hatchery/nursery operations for stocking a designated environment is predicated upon assumptions regarding the numbers of fish to be stocked, time taken to raise juveniles, the age at which they are released, expected survival rates, time to harvesting, the productivity of the environment and so on. While there is extensive scientific and technical information on these parameters to guide projects in Central Asia, the considerable challenges such projects present should not be underestimated. Moreover, all projects embody the potential for catastrophic failure. It requires little imagination to conceive that investments in culture-based fisheries could be seriously jeopardized or wiped out by disease, harsh subzero temperature winters or environmental pollution. Some of these risks may be predictable and insurable, adding to the project's costs, but others may be more erratic. In any case, during the project formulation phase it is important to consider measures that could be taken to reduce risks as these are likely to affect the economic viability of the project. The relative underdevelopment of indigenous expertise, attributable to the sector's size and limited funding of fisheries research in post-Soviet republics, do little to ameliorate these challenges and ferment uncertainty in appraising such projects in the region. Hence, access to expertise and training is an essential precondition for successful project development, as considered in the following section.

The size of the fisheries sector in Central Asia and the underdevelopment of supporting industries and services raise the possibility that its extension through culture-based

3 Most spreadsheet programs, such as Microsoft Excel, include formulae for calculating *NPV* and *IRR*: the use of Excel for appraising fisheries investment projects for, example, is demonstrated in Whitmarsh (2011, Chapter 4).

4 Allowances for depreciation are not included.

projects will require resources unavailable within the domestic economies of Central Asia. This may relate to both dedicated capital for the establishment of facilities and to inputs required throughout the project's duration, possibly including commercial fish feeds, broodstock, fertilized fish eggs or larvae and, in the case of stocking projects, fishing gear. In such circumstances, the domestic price of these inputs will depend upon the prevailing exchange rate, its expected movements over the duration of the project, and the state of supply and demand in relevant international markets. It is also the case that international economics affects a range of non-specific costs within the sector, particularly fuel and energy. The extent to which projects are exposed to exchange rate risks varies from one proposal to another. While the costs of using imported capital goods in the initial investment can be computed with relative certainty, those projects that utilize imported resources throughout their duration face a persistent threat from real exchange rate depreciation that raises costs and reduces margins, especially if producers are unable to fully pass these additional costs on to consumers. Thorpe *et al.* (2009) observe that the post-independence sharp increase in the cost of fishmeal, together with the imposition of tariffs and other trade barriers, was a profound shock to Kyrgyz fish farms and hatcheries from which they are only now recovering. Movements in the exchange rate will also affect the viability of establishing export markets in the future.

The capacity to manage resources significantly affects the likelihood of a project's economic success. It is likely that little will be gained from meeting the challenges of a given environment if this in turn attracts new and unsustainable levels of harvesting effort that dissipate any expected economic benefits (see Thorpe *et al.* 2009) for an analysis of the failure of stocking projects in Lake Issyk Kul for example). It is thus essential that culture-based fisheries projects in the region be accompanied by management strategies that address property rights to the stock and the harvest. Management costs are expected to be positive over the course of the project's duration, contributing to the magnitude of costs C_t. These costs have obvious implications for project viability: other things being equal, higher management costs reduce the probability of profitability. The implications of this dimension of project development for education and training, for building institutions and social relations within the sector are addressed in the following section of this report.

Culture-based fishery developments in Central Asia will effectively be price takers in the markets for capital, labour and other necessary inputs. While successful projects may ultimately yield an increase in the stock of financial capital within the sector, capital is also required for project commencement/development. The opportunity cost of renting capital is effectively reflected in Equation (1) through the discount rate. Both *NPV* and *IRR* are sensitive to the choice of discount rate, with higher rates associated with lower values. Three key questions are significant with respect to the discount rate:

First, to what extent can access to finance through national governments or multilateral donor organizations provide finance at rates below those available through conventional borrowing? Preferential terms will clearly enhance the likelihood of a project's profitability, as would production subsidies (which affect the project's cost structure).

Second, to what extent are the costs of servicing capital investment volatile? Significant fluctuations in capital costs may undermine a project's profitability and its capacity to meet the opportunity costs of borrowed funds.

Finally, to what extent will donors or lenders demand a risk premium be attached to returns? Culture fisheries projects are typically more complex than (say) arable or pastoral agriculture developments that might compete for scarce finance. Hence, it may be necessary to pay higher rates of interest or other inducements to attract capital to fisheries enterprises. Ordinarily, a risk premium negatively affects measures of the project's feasibility.[5]

Any assessment of the potential for culture-based fisheries in the Central Asian region is predicated upon the fisheries capacity to generate future benefits through finding markets. As van Anrooy *et al.* (2004) observe, fish makes an extremely modest contribution to per capita daily consumption of animal proteins in the Central Asian republics. It is conceivable that an increase in the supply of fish will create its own additional demand, possibly offsetting the tendency for an increase in quantity supplied to create a decrease in price. Alternatively, if the market's capacity to absorb additional supplies is limited, then expanding supply may offer limited additional revenues. FAO (2007a) suggest that the extensive import of fish into Kyrgyzstan reveals that effective demand is not satisfied from domestic supplies and that higher income urban consumers wish to consume high-value species such as trout. In Uzbekistan, while demand fell in the post-independence era, there also remains a significant market for imported fish (FAO, 2008b). Overall, it may be that the general pattern of post-independence decline in fisheries production creates opportunities for expanding production and import substitution that will enhance revenues. However, strong buoyant markets for highly esteemed imported fisheries commodities can leave little scope for domestic producers to expand domestic markets. A recent simple FAO survey of import tariffs, custom clearance fees and excise taxes applied for fish, fisheries products and inputs and equipment used in fish production and processing in the Central Asian republics showed large variations between these countries. World Trade Organization (WTO) membership of Kyrgyzstan seemed to have a reducing effect on the tariffs applied, compared to those in the other republics.

Cost dynamics of stocked fisheries

The basic assumption of culture based fisheries is that the value of the catch derived from a certain number of fry stocked into a water body will exceed the cost of the fry. This implies that there is a net benefit from the natural environment in growth less mortalities that ensures sufficient profit to run the fishery.

This situation is very complex. The relationship between growth and mortality of one cohort of stocked fish can be expressed by the standard stock assessment formulae:

$$B_t = N_t \cdot \overline{W_t}$$

Where B_t is the biomass at time t: N_t is the number of fish still alive after time t, N_o is the number of fish at time zero, i.e. number stocked, according to the formula

$$N_t = N_o e^{-Mt}$$

where M is the instantaneous natural mortality rate

$\overline{W_t}$ is the mean weight of fish at time t,and is derived formula

$$W_t = Q * L_\infty^3 \, [1 - exp(-K\ (t - t_0))]^3$$

Time t is usually expressed in years or fractions of years and represents the elapsed time form stocking to harvesting.

5 We can consider the discount rate as the risk-free rate and the risk premium. Consequently, projects for which future outcomes are known with less certainty will attract a higher risk premium, and hence a higher discount rate, which ordinarily lowers the expected *NPV*.

The correct use of these formulae depends on knowledge of the basic life history parameters for the fish concerned (see Sparre and Venema 1998)

Two main variables influence the viability and profitability of stocking in any water body:-

M the mortality rate, which is regulated by conditions in the water body stocked including the numbers of native, naturally reproduced fish. Interactions can include competition between the stocked and native fish and effects of pollution or other adverse environmental conditions. excessive numbers stocked or stocking into lakes where healthy native populations exist can result in high mortalities among the stocked fish.

K the growth rate, which is regulated by the support capacity of the environment in the form of its primary and secondary productivity. Again excessive stocking means that there is insufficient food for all fish and growth rates will be lowered. Growth is also dependant on temperature and unseasonal cold periods may also slow the rate of growth. Limitations to growth through poor productivity may be overcome by supplementary feeding or raising the nutrient status of the water body by fertilization. In such case the cost of the feed and fertilizer have to be added to the costs of stocking.

$$W_t = Q * L_\infty^3 [1 - exp(-K (t - t_0))]^3$$

$$B_t = N_t \cdot \overline{W_t}$$

$$N_t = N_o e^{-Mt}$$

$$B_t , N_t N_o \cdot \overline{W_t}$$

In general where stocking is well established local authorities or private managers have developed rules of thumb on the numbers to be stocked, often using measures of the nutrient state of the host water body.

The cost of seed is also critical. Here the trade-off is between the size of the material stocked and the cost. In general, the larger the size at stocking the better the survival of the fish seed but the greater the cost because of the longer period spent under culture. At the same time less seed is required if larger fish are stocked. Thus precise biological and financial judgement is needed to choose the optimum strategy to determine number and size of seed to be stocked. Welcomme and Bartley (1998) give details of the effects of stocking in water bodies of different areas. In general stocking appears more efficient, with greater yields per hectare, in smaller rather than larger water bodies and the numbers of seed stocked are also higher. This is possibly because more control can be exercised over the smaller water bodies. Furthermore, the productivity of lakes is generally strongly correlated with their depth, shallower lakes and reservoirs being more productive. As a result, stocking programmes in large lakes are relatively rare, whereas the smaller ones are often intensively stocked.

The various parameters make the cost effectiveness of culture-based fisheries extremely sensitive. An analysis of current government led practices forced Desilva and Funge-Smith (2005) to conclude that stock enhancement in South East Asia has not been successful, precipitating the need to search for new approaches. Similarly the government led stocked reservoir fisheries in Cuba, which were the basis of a highly productive fishery, have decline in recent years due to failures in government funding.

SOCIAL ASPECTS

Identifying the social aspects of culture-based fisheries presents a number of problems. First, many studies fail to distinguish the social aspects/costs/issues, etc. from the economic, and treat them jointly (see, for example, FAO, 1987; Harrison, 1994; Shang *et al.,* 1994; Perez Sanchez, Muir and Ross, 2000; Tisdell and Poirine, 2000; Wafula, 2000). In this study we interpret "economic" in a narrow sense as referring merely to the immediate production process (in terms of inputs and technologies used for farming the different species – and the returns so generated). Second, in policy terms there is less interest in the social aspects *per se* – and rather more preoccupation with the social impacts relating to culture-based fisheries (conversely, much of the academic literature focuses on the former rather than the latter). Third, quantifying the importance of social aspects to stakeholders is no easy task and analysts customarily recourse to a series of assessment techniques to address this. Finally, consideration of the social aspects should also generally embrace a consideration of the governance mechanisms associated with the endeavour – with co-management and community participation initiatives preferred to more top-down, hierarchical management in social terms. However, as the majority of culture-based fisheries across both the developed and the developing world is driven by government investment, the governance issue aims at both defining the appropriate regulatory framework (and channels for opinions/concerns to be aired and addressed) and soliciting greater community or civil society involvement in the location/production decision.

This section of the report therefore identifies the various social impacts associated with the development of culture-based fisheries, although it does not suggest ways of quantifying/evaluating these. It does not dwell upon particular Central Asian regulatory frameworks, as these are very much state-specific and will be discussed in more detail in the national contexts within the following sections of this report. Instead we follow the lead of FAO (2008a) in grouping potential social impacts within the "capitals" categorization found within the livelihoods framework advocated by DfID (1999), among others.

Natural capital and social impacts

The development of culture-based fisheries can impact (positively or negatively) upon three types of natural capital – land (and land-based habitats), water and wild fish stocks. Culture-based fish production can have manifold social impacts upon land and terrestrial habitats. Establishing the aquaculture facilities and associated infrastructure in support of stocking can create local land shortages and push up land purchase/rental prices. It can also lead to the destruction and/or degradation of terrestrial habitats, wetlands, lagoons and mangroves through land clearance and/or salinization (the latter having potentially detrimental impacts upon agricultural productivity in adjacent land areas). Conversely, such production may also deliver social benefits by allowing previously un- or underutilized land to be brought into full production, with a consequent increase in employment, or may complement existing production systems (i.e. fish-rice culture as practiced extensively in South and East Asia). In Central Asia, the culture-based systems under consideration impose limited land demands –save for supporting culture and/or processing units onshore – and consequently are likely to have only a marginal social impact in land and terrestrial habitat terms.

Not only do culture-based fisheries impact on water resources, but can exacerbate competition for same. Over extraction of water from underground aquifers and riverine sources for culture fisheries can impact upon the quantity and quality of water available for agricultural and household use. Equally, the proliferation of coastal, lake or reservoir-based culture activities can conflict with other uses of the water bodies for bathing, diving and other recreational activities. In Central Asia, three factors combine to indicate that current (and future) social impacts on the water resources of culture fisheries are likely to be minimal. First, the prevalent form of aquaculture production –

carp culture in ponds – poses only insignificant additional demands for water. Second, fisheries production (including culture-based fisheries) in other water bodies presently ranks well below agriculture and energy generation in terms of water allocation priorities and it is more likely that such demands will disrupt water availability for fisheries rather than the reverse. Finally, the water-based recreational activities are little developed in the region, except for limited instances on the northern shores of Lake Issyk Kul.

The social impacts of culture-based fisheries on wild fish stocks are limited. Some changes in wild fish stock levels have direct – and often immediate – consequences for the livelihoods of fishers who target such species. For example, sturgeon from the Caspian and trout from Issyk Kul are netted for the extraction of eggs for culture In the case of Issyk Kul the numbers of fish removed for this purpose is unknown (Sarieva et al., 2008) as are the effects of this activity upon wild fish stock levels.

Culture-based fisheries may increase opportunities for recreational fisheries (in terms of enhancing species diversity, building up target stocks for recreational fisheries) – as practiced by the Kyrgyz Hunter and Fishers Association across the water bodies it leases in the Chui-Bishkek oblast- (see Thorpe and van Anrooy, 2009b) and may enhance the social and economic value attached to recreational fisheries (see also Parkkila *et al* 2010).

Physical capital and social impacts

FAO (2008a) identifies three avenues through which culture-based fisheries development can influence the quantity of physical capital.

First, it can affect household food security[6] by either influencing the supply of or access to fish, smoothing fish consumption over the year, and/or by impacting upon food safety/quality. Access_to fish protein is improved if the increased volumes of fish available result in lower prices – and hence a greater uptake of fish products by poor consumers. However, such expansion may be at the expense of the natural capture fisheries output favoured by the poor, because of limitation of access to them (Prein and Ahmed, 2000).

While inland fisheries can contribute to consumption smoothing – either by acting as a “bank in the water” (= natural capital) as Béné *et al.* (2009) acknowledge, or through its transformation into a processed, storable product, such as dried fish (= physical capital).

A second physical capital effect relates to its impact upon infrastructure and related facilities. The expansion of culture-based production globally has been accompanied by investment in processing and hatchery facilities (government funded in most countries), complemented by state investment in supporting infrastructure in the form of roads, power, telecommunications and water. There has been a surge in new fisheries infrastructure investment in Aralsk, notably the construction of the Atamekenrybprom Processing Plant, which is in support of the capture fishery. By and large, culture-based fisheries infrastructure – such as hatcheries – have been inherited from the old Soviet system and, while these have been privatized in a number of instances (i.e. Aralrybprom in Kazakhstan, Karakol Balygy and Balykchylar in Kyrgyzstan), there has been limited new investment to date. Elsewhere, new private enterprises sourced their seed/brood stock from state entities under contract (e.g. the case of Ekos International and the

6 Physical capital, in the conventional livelihoods framework (see Livelihoods Connect, undated, for example), encompasses basic infrastructure (such as roads, water and sanitation facilities, schools and hospitals, Information and Communications Technology (ICT), etc.) and producer goods (including tools and equipment) alone. FAO (2008b) extends this to include "household food security" so as to capture physical accumulation (inventory) of the product.

Ton hatchery in Kyrgyzstan), while the self-consumptive nature of much carp pond culture militates against the development of substantive infrastructural facilities. As a consequence associated infrastructural investment (road, water, electricity provision, etc.) remains negligible.

The third and final avenue relates to the way culture-based fisheries development can impact upon other industries. Besides impacting upon other industries via competition for land and water resources (natural capital), the expansion of aquaculture infrastructure can be pivotal in the development of physical capital of other industries. The most evident beneficiary is the feed sector –for example the strong growth of aquaculture production in Viet Nam, some of which is in support of the culture -based sector, has seen local feed companies actively seek to source new cost-effective feed ingredients internationally (Canada Agri-Food Trade Service, 2009). There is no feed manufacturer in the region (feed being imported from the Russian Federation and/or Europe) alternatively, inorganic fertilizers are used to stimulate phytoplankton growth as a cheaper cost alternative.

While illegal fishers and poachers may have earned sizeable incomes from the catch of sturgeon and the illegal sale of caviar and sturgeon meat, the international illicit trade (sometimes in the hands of organized crime) in these products generated much larger proceeds, at the expense of an endangered species[7].

The successful implementation of capture and culture-based fisheries in reservoirs also implies the maintenance of reasonable water regimes. Too rapid a change in water level, or excessive drawdown cause by extractions for irrigation or power generation can impact negatively on the fish stock. While the primary purpose of dam creation is usually other than fisheries some attempts need to be made to negotiate favourable water conditions with the prime users of the water body.

Human capital and social impacts

Culture-based fisheries development can add value to human capital in three ways. First, in terms of increased employment – either within the sector, or through support industries (input suppliers plus infrastructure provision/construction) and/or forward (processing/distribution) multiplier effects. This is mainly through the creation of jobs in the supporting aquaculture systems as fishermen are usually drawn from the existing community. It is only where new reservoirs and fisheries are created that there is an increase in the employment of fishermen.

Evidence on the employment-generating contribution of culture-based fisheries in Central Asia is limited (and what there is, is not disaggregated in any meaningful sense by gender). However, there is a consensus that employment within the sector fell following the demise of the USSR, as many state hatcheries and reproduction/processing facilities fell into disuse. This downward trend was only reversed in the last decade as economic liberalization has allowed new private entrepreneurs to enter the field (see following sections of the report). In Uzbekistan, for example, direct employment in aquaculture and culture-based fisheries provides an estimated 2 000 jobs, with a further 2 000 employed in other parts of the culture supply chain (FAO, 2008a*)*.

Human capital can also be compromised or enhanced if culture-based production feeds through to impact upon human health and activity levels. Culture-based production can

7 Detailed information on the case of sturgeon and caviar trade can be found on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Web site: www.cites.org.

foment the desire/demand for education and training. Training courses and workshops on identifying health issues, disease control, fish species nutrition requirements, developing and implementing feed plans and stock handling practices, stocking strategies, as well as equipment maintenance classes and more generalized training in record keeping, operations management and budgetary control do not only contribute to increased corporate competitiveness but also augment the human capital qualities of the recipients. The World Bank (2007) details, for example, how, in Asia, companies and producer groups invested in staff training, and “private demand for technical and scientific skills complemented external support for capacity building. With public support, formal, vocational and informal training *built human capacity* [the italics are ours].” Moreover, many of these skills acquired are transferable and can be redeployed elsewhere if the sector expands and/or labour markets permit.

The Central Asian experience has not been a happy one on the training front over the last two decades. The collapse of the USSR was mirrored by the collapse of training and extension facilities in culture production across the region, and the emigration or retirement of many accomplished experts in the field. In 2008, FAO noted “On-farm participatory research in aquaculture is not practised in Uzbekistan. There are no technical schools offering aquaculture training. There are no specialized educational organizations that prepare specialists for the fisheries sector as well as there are no researchers, lecturers or technologists .... support for training fish farmers is lacking in the country” (FAO, 2008a)[8]. The same scenario is evident across many of the other countries in the region (FAO, 2011c), and the situation is not much better on the human capital (health front) – with no studies conducted in Central Asia, to the best of our knowledge, linking health (or ill-health) to fish consumption.

Financial capital and social impacts

The linkage between financial capital and culture-based production takes two forms[9]. First, culture-based production can enhance the stock of financial capital for employers and own-account aquaculturists (increased revenues/profits) and employees (greater employment opportunity – as discussed in the preceding subsection – translates into improved incomes).

Second, the availability of financial capital can, in turn, affect the level of culture-based production and its rate of growth**.**

Social capital and social impacts

Social capital is probably the most amorphous of the five types of capital, the term being variously used to describe networks/connections underpinned by norms – such as reciprocity and trustworthiness – between individuals (Putnam, 2000), intra-firm organizational relationships based on such norms (Cohen and Prusack, 2001), and even in relation to “...the institutions, relationships, and norms that shape the quality and quantity of a society’s social interactions” (World Bank, 1999). In this particular context, we view social capital in terms of the societal – national and local – (legal and customary) institutions and relationships, in conjunction with the accepted norms (i.e.

8 The same report does, however, note that the Centre for Fisheries Development had recently constructed and opened a training centre for fish farmers at Yangiyul Fish Farm in 2008.

9 The FAO analytical framework proposed (2008a:52) in fact suggests four linkages. However, we contend the "investment" (as opposed to the "credit") linkage refers to actual destination of funds – and is thus more appropriately discussed under the physical capital banner. Similarly, "fiscal policies" are dictated by the legal and regulatory framework operative – and so are dealt with within the context of the "social capital" subsection that follows.

attitudes towards corruption, or more particularly in the fisheries instance – towards poaching) as the "cement or glue" that holds society together.

In formal institutional terms, the prevailing regulatory framework – or changes thereto – can have important social impacts**,** although the actual impact is likely to be mediated through one of the other capitals. Regulations can remove existing and/or create new terrestrial and marine property rights (impacting on natural capital access). Fiscal, regulatory and extension policies that affect credit modalities (financial capital), offer/affect training activities (human capital) and/or influence input costs (physical capital) have social implications (see too, Halwart, Soto and Arthur (2007) for different regional experiences). Customary rights are much less in evidence in aquaculture[10] than in either the marine or inland capture fisheries arena, although where customary rights to the foreshore, seabed or inland waterways exist, they can affect aquacultural activities. In culture-based fisheries there is usually the need to transfer control of the fishery to the investors responsible for stocking. These may be individuals or groupings of investors (usually the fishers themselves acting as a co-operative). This is necessary where private interests pay for the fish seed and, in intensified systems, the fertilizer and feed, and wish to protect their investment from exploitation by external groupings. This means that access to the fishery becomes controlled in what were previously open access resources. Socially this is often divisive creating have and have-not sections of previously homogenous communities. In some countries, however, the State acts as the stocking agency to support fishermen in general to reduce the impacts of such effects.

In Central Asia, Thorpe *et al.* (2009) comment how independence saw the erosion of social capital as factory-based networks collapsed following plant closure, and local social networks and cooperation mechanisms disintegrated (Kuehnast and Dudwick, 2004). In their stead, new producer associations have emerged as the aquaculture sector has grown (see Section 5 of this report), although – as in the case of Uzbekistan (FAO, 2008a) – these may be provincially as opposed to nationally based. The regulatory environment has also altered markedly, with new Fisheries and Aquaculture Laws having been (in the process of being) approved across the region. This framework now embraces private (as opposed to collectivist) property rights and has laid the grounds for devolution of ponds and reservoirs to private aquaculturists and culture-based fisheries firms under long-term leases – most notably in Kazakhstan – although the scheme is still in its infancy.

10 New Zealand is perhaps an exception in this instance, although even here the relevant legislation (Aquaculture Reform Act 2004) only allows customary rights in the case of non-commercial aquaculture.

4. Major water bodies in Kazakhstan, Kyrgyzstan and Uzbekistan and their ecological suitability for culture-based fisheries

The demand for water for irrigation continues to rise. In some developing countries, rivers now have a cascade of reservoirs, with little free-flowing water between them, to feed the growing demand of water for agriculture (Petr, 2001). In Central Asia, over 80 percent of the total water use is for irrigated agriculture. By the end of the Soviet period, over 40 reservoirs had been constructed, with their primary uses being water storage for irrigation and hydropower production (Petr, 2001).

According to Karimov (1995) the water bodies of the Central Asian region can be grouped, into:

- natural water bodies (rivers and streams, lakes);
- primary, artificial freshwater water bodies (irrigation canals, reservoirs, ponds); and
- secondary, artificial brackish water bodies (drainage canals, lakes for residual water storage).

Since independence in 1990, fisheries in Central Asia have been in decline. Part of the problem undoubtedly lies with the conflicting objectives of the departments that are responsible for water management and fisheries management and, as cooperation between the two departments is often lacking (FAO, 2008c), the schedule for water abstraction continues not to take into account the needs of reservoirs and other water bodies for fishery production.

THE WATERBODIES IN KAZAKHSTAN[11]

Kazakhstan has large and diverse water resources. As well as being the largest landlocked country in the world, part of Kazakhstan's international borders traverse major regional water bodies. Of these, the Caspian Sea is the largest (371 000 km^2). Fishing rights in the Caspian Sea Basin are shared with Azerbaijan, Iran, the Russian Federation and Turkmenistan. The Aral Sea was also important in fisheries terms, although historic fishing rights were shared with Uzbekistan. There are also the large lakes such as Balkhash and Alakol, hundreds of reservoirs (the largest, Bukhtarma, extends over 5 000 km^2, tens of thousands of small and medium lakes and rivers including the Irtysh, Ural, Syr-darya and lli. According to regional akimats[12], there are 1 290 water bodies that can potentially be used for fishery production.

11 This section is largely based on Timirkhanov *et al.* (2010).

12 An akimat is the governmental representative at the local level (equivalent to the chair of a local authority).

Rivers in Kazakhstan

The arid and semi-arid nature of most of Kazakhstan accounts for its relatively low number of rivers (Table 3). There are eight large river basins in the country that, combined, discharge over 100 km³ of water per year, (of which 56 km³ originates in the country itself). Glacial runoff from the large mountain ranges in the country provides the main water resource for most of Kazakhstan's rivers, with over 70 percent of the usable water from these river systems used for irrigation, largely for cotton culture. The large demand for irrigation means that many of the rivers have to be regulated by dams to ensure water availability throughout the year.

TABLE 3
Main river systems in Kazakhstan

Major rivers	Average annual discharge (km³)		Available water resources under different levels of supply (percent)		Current volume of water used annually (km³)
	Total	From neighbouring countries	75	95	
Total in Kazakhstan, of which:	110.9	43.9	26	26	36.6
Syr-darya	17.9	14.2	9.3	9.3	12
Ile	17.8	11.1	3.4	3.4	5.2
Karatal, Lepsy, Ayaguz	10	0.3	2	2	3.6
Irtysh	33.8	7.8	8.4	8.4	5.4
Ischim	2.3	–	0.1	0.1	1
Nura	0.8	–	–	–	1.1
Sarysu	0.4	–	–	–	0.4
Tobol	0.6	–	–	–	0.5
Torga	1.4	–	–	–	0.5
Shu	2.3	–	1.6	1.6	2.7
Talas-Assa	1.4	0.7	0.7	0.7	1.4
Ural	9.5	6.5	0.3	0.3	2
Emba, Sagiz	0.8	–	–	–	0.2

Source: WRC-K (2002).

There are around 8 500 rivers, and several of these (the Ural, Emba, Syr-darya, Irtysh, Ischim, Tobyl and lli) are over 1 000 km in length. With the exception of the Irtysh, Ischim and Tobyl rivers, all other rivers form are national and do not traverse borders. Despite the immense size of Kazakhstan, the utilization of rivers for fishery production is low. This is largely related to the lack of water during months of low glacial melt and the increasing demand for water for irrigation, which means that some of the lakes and reservoirs created by damming rivers dry up completely during parts of the year. While some of the rivers are of seasonal importance for recreational fishing, rivers are considered of limited importance for fishery development. This is largely because the limited supply of water causes droughts in some parts of the country, due to exhaustion of flow by irrigation. In short, until there is sufficient water to satisfy irrigation needs in the country, the use of water for fish production will remain limited.

Lakes in Kazakhstan

It is estimated that there are around 48 000 lakes in Kazakhstan, the most important in fishery terms are Lake Balkhash, Lake Alakol and Lake Tengiz. In total, there are over 3 000 water bodies larger than 100 ha, which account for around 90 percent of total lake resources in Kazakhstan. However, only 60 percent of these lakes can be used for year round production, as 40 percent dry out during parts of the year.

Lake Balkhash, the largest of the lakes found in Kazakhstan, is 605 km long and 9–19 km wide (giving a surface area of 17 000 km^2) and varies in depth between 5.8 and 25.6 m. Lake Balkhash is found east of Almaty, the former capital of the country, and holds 112 km^3 of water when full. As with most river-fed lakes in the country, Lake Balkhash has variable salinity levels throughout the year.

The Alakol lake system, found on the Balkhash-Alakol plain, between the border of Almaty and the southern Kazakhstan oblasts, consists of four large lakes (Sasykkol, Koshkarkol, Alakol and Zhalanashkol). *Lake Alakol* has a surface area of 2 696 km^2 and a drainage basin of 6 520 km^2 and holds 58.6 km^3 of water. The lake is around 104 km long and 52 km wide, with a maximum depth of 54 m, although the average depth is 22 m. The lake is fed by around 15–20 rivers. By comparison, *Lake Sasykkol* is much smaller and has a surface area which varies between 600 and 736 km^2 during flooding, is 50 km long and 15 km wide, with a maximum depth of 4.7 m (average 3.3 m). The lake is fed mainly by the River Ili, which provides around 80 percent of water inflow. The next lake in the Alakol lake system, *Lake Koshkarol*, is smaller still – covering only 120 km^2, with depths up to 5.8 m. During flooding, the lake becomes one with Lake Sasykkol and Lake Alakol. The smallest of the three main lakes in Kazakhstan, *Lake Tengiz*, covers an area of 1 382 km^2 and has limited potential for fishery development, given that the lake is already on the Ramsar List[13] of Wetlands of International Importance.

Reservoirs in Kazakhstan

Reservoirs play an important role in fisheries. There are many small reservoirs, ranging in size from several hundred to several thousand hectares. These smaller reservoirs, however, are not currently used for fish production, as their primary functions are irrigation, domestic and industrial water supply (only a few are multipurpose). The most important of the 475 reservoirs in the country are found in the south. The 75 reservoirs located here have a combined capacity of 95.5 km^3 and a surface area in excess of 10 000 km^2. As in Kyrgyzstan, the reservoirs are of primary importance for irrigation and power generation, although they can represent important sources of fish production and are currently exploited by commercial fishers. The characteristics of the main reservoirs are given in Table 4.

TABLE 4

Characteristics of the major reservoirs of Kazakhstan

Economic regions	Storage reservoirs	River	In operation since	Volume (Million m^3)	Area (km^2)	Salinity (g/l)
Southern	Chardara	Syr-darya	1965	5 700	900	1.3–1.7
	Kapshagay	Lli	1970	23 100	1 847	0.4–0.6
	Tashutkul	Shu	1974	620	78	0.6
Eastern	Ustkamenogorsk	Irtysh	1952	600	37	0.13–0.16
	Bukhtarma	Irtysh	1960	49 600	5 500	0.12–0.14
Northern	Verkhneusol	Tobol	1971	816	87	0.6–0.11

Source: WRC-K (2002).

13 Lake Tengiz is a Ramsar area primarily because of the habitat it provides for over 200 species of birds, some of which are endangered.

Hydroelectric power stations have been constructed on some of the larger reservoirs, (Bukhtarma, Chardara, Kapshagay, Shulbin and Ust-Kamenorgorsk), While they are used primarily for power production, they also have potential for fisheries development.

The Bukhtarma Reservoir was constructed on the Irtysh River in 1960 and at 5 490 km^2 is the fifth largest reservoir (by area) in the world. Over 500 km in length, with a maximum width of 35 km and an average depth of 9.6 m, the Bukhtarma Reservoir contains around 49 600 million m^3 of water. As the reservoir is not used intensively for irrigation, seasonal drawdown is negligible, and only in spring for 15–20 days is there a high water discharge (up to 2.5–3.0 km^3) for irrigation. This stability in water levels promotes successful spawning of fish – and fish are currently being produced in the reservoir.

The Chardarya Reservoir was constructed in 1965 for irrigation and hydropower production. The reservoir is situated at an altitude of 252 m on the Syr-darya, on the border between Uzbekistan and Kazakhstan. Drawdown is significantly higher than the Bukhtarma Reservoir, when, during the drawdown period (April–September), water level can decrease by 11 m. During the maximum drawdown period the reservoir diminishes to 11 000 ha, compared to 90 000 ha when full. The majority of water is abstracted for irrigation, although water is also used from this reservoir for domestic and industrial water supply.

Fisheries in Kazakhstan have been in decline since independence. Despite the size of the country, river systems are not particularly suitable for fishery development, primarily because the majority of water is abstracted for irrigation. While there are many lakes in the country, only 60 percent are useable for the whole year; competition for water with agriculture is presently a barrier to fisheries development in the lake systems.

THE WATERBODIES OF KYRGYZSTAN

The potential for culture-based fishery production in Kyrgyzstan, based on the number of rivers, reservoirs and lakes, is considerable. Most potential, however, lies in the large water bodies of Lake Issyk Kul, Son Kul and Chatyr Kul. Reservoirs and rivers (in particular) offer limited potential for increasing fish production in Kyrgyzstan due to their characteristics, which are described below.

Rivers in Kyrgyzstan

The river system in Kyrgyzstan is less significant for fish production than in Kazakhstan, Uzbekistan and other areas of Central Asia. The river system is small by comparison and because most rivers originate from the mountains and, while water quality is very good it is characterized as being of low nutritive value. The water flow is largely dictated by snow melt in the mountains, which provides for little or no water in the summer and harsh and fast currents in the winter. As the natural water flow of these rivers is so variable, the potential for using river resources is limited in Kyrgyzstan, although these rivers offer some potential for the highly profitable trout farming, which is probably more suited to the rivers of Kyrgyzstan than the other water resources found in the country.

Lakes in Kyrgyzstan

The main lake systems found in the Kyrgyz Republic are Issyk Kul, Chatyr Kul and the Son Kul. ***Issyk Kul Lake***, located 1 609 m above sea level, is one of the deepest mountainous lakes in the world. The lake occupies a significant part of the Issyk Kul trough, which is one of the largest depressions of tectonic origin. The trough lies between two mountain ranges, the Kungley Ala-Too in the north and the Terskey Ala-

Too in the south. Although there are no outlets from Issyk Kul, the lake is fed annually with around 3 720 million m^3 of glacial water by more than 80 rivers. The lake is 178 km long and 60 km wide, giving a surface area of 6 236 km^2, and as much as 668 m deep, although an average depth of 280 m is observed. The majority of the lake (63 percent) is over 100 m deep, and these parts of the lake have low nutritive value, supporting a fish capacity of only 1.5–2.0 kg/ha. The remainder of the lake, where depth is less than 100 m, is rich in phytoplankton (if slightly saline) and has been dedicated a wetland area of international importance under the RAMSAR Convention[14] (Thorpe *et al.*, 2009). Overfishing led to a moratorium on all fishing activity in the lake in 2003, a prohibition that remains in force.

Other lakes of significance, in terms of culture-based fishery development in Kyrgyzstan, are Son Kul and Chatyr Kul. Both of these lakes are much smaller than Issyk Kul, the second largest lake, Son Kul (Naryn region), being just 275 km^2. Situated high in the mountains at an altitude of over 3 600 m, ***Son Kul*** is the largest freshwater body in the country and are 28 km long and 18 km wide. The maximum depth is reported to be 22 m, and it is generally as productive as the shallower areas of Lake Issyk Kul.

Son Kul Lake, unlike Issyk Kul, has an outlet (the Kokdjerty River) as well as several small inlet rivers. Water quality is very high, although in winter the lake is fully covered with ice, often from the end of November until June. There are no naturally occurring fish species in the lake, and the lake was devoid of fish until 1959. Since then, larval peled and other larval and brood whitefish have been introduced into the lake, and by the late 1970s around 140 tonnes of fish were caught each year, as many of the stocked fish formed breeding populations. However, high levels of predation by the newly introduced species, in particular pike-perch, allied to the release of pesticide residues into the lake in 1979 caused production to slump. Fishing was banned on the lake at the end of 2004. There are many lakes with the same characteristics as Son Kul, however, as they are found high in the mountains (generally at altitudes over 3 000 m), their size and oligotrophic nature ensures that the potential for fish production remains low and what stocks are there can be easily overfished (Thorpe *et al.*, 2009). Coupled with the unforgiving climate in many Central Asian countries and infrastructure shortcomings, most of these lakes are not considered suitable for fishery development of any kind.

Chatyr Kul Lake is the third largest lake in Kyrgyzstan. It is located in the Naryn region in south Tien Shan and is found 3 500 m above sea level. The lake is around two-thirds the size of Son Kul, with a surface area of around 170 m^2. The lake is 23 km in length, with a maximum width of 11 km. The depth of the lake varies from as little as 1.5 m to as much as 19 m. Similarly to Issyk Kul, there are around 50 small rivers and brooks that feed Chatyr Kul, but the lake has no outlets. The water feeding the lake is saline and in general, mineralization is around 2 g/l. In the north-western area of the lake, the substrate is limestone and water is hard, with a high content of calcium carbonate. From the end of October, the lake is completely frozen with ice as thick as 1.5 m, thus the shallow parts of the lake freeze solid. Melting starts at the beginning of May and by the end of June, the lake is ice free. The biomass of zooplankton in the summer is between 4.7 and 7.1 g/m^3. Coupled with the availability of amphipods in the lake, there appears potential to produce fish in Chatyr Kul, although at present the lake is not used for fish production, and there are currently no fish found in the lake. However, the caveat here is that the surface of the lake is almost completely frozen for 7–8 months of the year. Therefore, in order to determine the suitability of this resource for culture-based fishery

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14 Lake Issyk Kul was designated for the Ramsar List by the former Soviet Union in 1976 and added to the Montreux Record in 1990. The site was designated in 2002 by the Kyrgyz Republic, and discussions are presently under way with the Kyrgyz authorities about its present status vis-à-vis the Montreux Record (Baetov, 2006).

production, analysis of both feed availability during winter months and information on the availability of dissolved oxygen is required to ensure stocked populations can survive the harsh winter conditions that are found in the Tien Shan Mountains.

Thus in the short-term, fishery development in Kyrgyzstan is likely to focus upon already identified resources, such as Lake Issyk Kul.

Reservoirs in Kyrgyzstan

The potential for trout and other coldwater species is considerable in the many reservoirs in Kyrgyzstan, which are typically characterized by high water quality and high oxygen content,. The Toktogul, Kurpsai and Tashkumyr reservoirs in particular are considered important resources for fishery development.

Toktogul Reservoir was constructed in 1974 and was purpose built for irrigation and the production of hydropower[15]. The reservoir is located on the Naryn River in the Jahal Abad region in the Ketemen Tyube depression, the lowest depression of the inner Tien Shan. Around 10 rivers flow into the reservoir, which covers 265 km^2 and contains 19.5 km^3 of water. The most important of these are the Chichkan, Uzun Akhmat, Torkent and the Uch Terek. The Naryn River (the main river supplying Toktogul Reservoir) brings turbid, cool water into the reservoir. The maximum river temperature reaches only 15^o C in the summer months, and the level of mineralization is between 200–250 mg/litre. The oxygen content ranges from 98 percent in early spring to 78 percent during the winter. During the winter, water temperature in the shallow zones can be as low as -20^o C.

There are 47 species of phytoplankton and 13 species of zooplankton within the reservoir, and the abundance of both is suitable to support increased fishery production. Although Toktogul Reservoir is currently used for fish production and can be used year round, as the reservoir does not freeze during winter months, it is necessary to increase enforcement of existing fishery rules and prevent poaching, which often occurs during the spawning season (thus impacting on future recruitment and productivity). However, as Toktogul was not purpose built for fisheries, it was not constructed in a way that is particularly conducive to fish production. As its primary purpose is irrigation, which results in significant decreases in water level during the summer months, thereby reducing the potential for fish production.

Kurpsai Reservoir is also located in the Jalal Abad region on the Naryn River and was constructed in 1981, primarily for irrigation but also for power supply. The reservoir covers 12 km^2, is 40 km in length, between 300 and 400 m wide (although up to 1 000 m in places), up to 95 m deep, and (when full) holds around 354 million m^3. The reservoir is served by the Naryn River, and water levels increase from the end of May until the end of July, and then decline until the end of October. Fluctuations in draw down rates range between 0 and 1 000 m^3/s dependent on extraction rates for irrigation and power generation. In terms of primary productivity, the Kurpsai Reservoir is poor compared to Toktogul. Zoobenthos biomass is between 5–7 g m^{-2}, and the density of zooplankton is between 3.5–4 g m^{-3} The Kurpsai Reservoir is not currently used for fish production, but could potentially be used all year round, as the reservoir does not freeze during the winter months. However, while the reservoir has been classified as suitable for fishery development and is currently inhabited by similar species to those found in Toktogul Reservoir, fisheries development is limited due to its poor zoobenthos biomass and zooplankton density.

15 Hydroelectricity refers to electricity generated by hydropower by means of the gravitational force of falling or flowing water and is the most widely used form of renewable energy in the region.

Tashkumyr Reservoir, located in the same region, was commissioned in 1988 for the same purposes as the Toktogul and Kurpsai reservoirs. Tashkumyr is the smallest of the three, with a surface area of 7.8 km^2, a length of 18.8 km and a width ranging from 100 to 850 m. In places depth reaches 65 m, but on average the water body is 18.5 m deep. At full capacity, the volume of the reservoir is 144 million m^3. This reservoir has probably the least potential for culture-based fishery development, as there are significant daily fluctuations in water level, which can fluctuate as much as 2.5 m per day, (and if required, the reservoir can be completely drained in 11 days). The reservoir has some potential for the development of trout fisheries, but the potential for this is higher in the river systems that feed the reservoirs.

These reservoirs, like most of the reservoirs in Kyrgyzstan, were purpose built for, and are therefore of most importance to irrigation and hydropower generation. Given that the demand for irrigation is so high, primarily for use in cotton culture, most of the reservoirs in the country, including the larger ones, are emptied to the dead horizon[16] at times throughout the year. As the reservoirs were not constructed for fish production, they would require significant modification, both in design and decreased exploitation for other uses, to be suitable for fish cultivation. Such modifications might include altering outlets to prevent fish escaping and altering inlets to prevent predators or unwanted species from entering the reservoir. Significant investment would also be required to create an ecosystem that is suitable for larvae, fry, fingerlings and mature fish. The reliance on these reservoirs for irrigation, in particular, would need to be reduced to prevent excessive abstraction during those months when water does not flow into the reservoirs. However, these modifications would require significant investment and funding for a sector that has been in decline since independence in 1990.

The water quality in the Naryn-fed reservoirs is undoubtedly suitable for fishery activity, including culture-based fishery development. The water is rich in oxygen, and unlike some lakes and other water bodies in mountainous locations, the water in these reservoirs does not freeze in winter, thereby allowing for year-round production. In some of the reservoirs, work is being undertaken to try to protect fish stocks, even those where water is abstracted to the dead horizon, and work is also being undertaken to culture some species of fish in cages in Issyk Kul Lake. River systems in Kyrgyzstan have not been well utilized since independence, and it appears that the potential for raceway trout farming in the majority of river basins is underutilized.

THE WATERBODIES OF UZBEKISTAN

The climate in Uzbekistan is characterized by considerable temperature changes, low humidity and precipitation with moderate wind speeds. The least precipitation, less than 100 mm per year, falls on the plains, while the higher levels of precipitation are found over the mountainous lakes, where rainfall is normally over 1 000 mm per year.

Fisheries in Uzbekistan are centred primarily in two river basins, the Amu-Darya and the Syr-Darya (including the Aydar-Arnasay lake system) flowing into the Aral Sea. Of the 3 000 lakes in the Aral Sea Basin, 770 are located within Uzbekistan territory, with 500 of these in the basin of Amu-Darya and the remainder in the Syr-Darya basin. While the irrigated area of the Aral Sea Basin has increased steadily from 2.0 million ha to 7.2 million ha between 1925 and 1980, the total utilizable area of inland water bodies (excluding the Aral Sea) is more than 800 000 ha (Karimov *et al.*, 2009).

16 The point at which no further water can be abstracted.

Rivers and irrigation canals in Uzbekistan

There are over 600 rivers in Uzbekistan, and only a few of them are not affected by irrigation. The Amu-darya River is 1 440 km long and the Syr-darya is over 2 140 km long. The highest annual discharges are 78 km^3 and 36 km^3, respectively. There is little or no management of the river systems in Uzbekistan, and most of the middle and lower courses of the Uzbek rivers, and the lakes found there, have poor water quality due to salinity and discharge of drainage water (Karimov and Razakov, 1990; Joldasova *et al.*, 2004; Karimov, Lieth and Kamilov, 2006).

There are more than 1 200 irrigation canals that extend over 170 000 km in Uzbekistan. However, only the large irrigation canals (those that extend for 100–350 km and have a capacity of 100–300 m^3/s) are of significance for fisheries development – including culture-based fisheries. These include the South Golodnaya Steppe Canal, the main Karshi Canal and Amu-Bukhara canals, and others in the Amu-darya and Syr-darya river basins (Table 5). In most canals, water flows by gravitation, but in the Karshi and Amu-Bukhara canals the water flows by means of pumping.

TABLE 5
Main irrigation canals in the Amu-darya and Syr-darya river basins

Canal	Water source	Initial water runoff (m^3/s)	Length (km)	Year constructed
Savay	Karadarya River	20	53	1930
Andijansay	Karadarya River	54	69	Before 1900
Shahrikhansay	Karadarya River	150	105	Before 1900
South-Ferghana	Karadarya River	70	120	1940
Main Ferghana	Naryn/Karadarya	200	249	1940
North-Ferghana	Naryn River	110	166	N/K
Main Namangan	Naryn River	62	162	1940
Main Andijan	Naryn River	200/300	109	1973
Bozsuv	Chirchik River	200	140	1970
Zakh	Chirchik River	65	74	Before 1900
Left side Karasu	Chirchik River	26	45	Before 1900
Parkent	Chirchik River	57	69	1930
Tashkent	Chirchik River	87	61	1985
Akhunbabaev	Syr-darya River	50	50	1941
South Golodnaya Steppe	Syr-darya River	230	113	1949
Zang	Amu-darya River		29	1915
Main Karshi	Amu-darya River	300	N/K	1912
Main Amu-Bukhara	Amu-darya River	300	197	1965
Tashsaka	Amu-darya River	220	165	1940
Pakhtaarna	Amu-darya River		58	1931

N/K – Not Known

There are also around 100 000 km of collector-drainage canals in Uzbekistan, although only the large collectors (those that are more than 100 km in length with flow rates of 40–100m^3/s) are of interest for fisheries development. Some of the main collectors are extremely large, with annual discharges similar to that of some rivers (Table 6).

TABLE 6
Main drainage collectors in Uzbekistan

Main collectors	Average flow rate in 1999 (m^3/s)	Mineralization (g/litre)	Annual discharge (million m^3)	Discharged into
Amu-darya River Basin				
KS-1	12.6	4	400	Jiltirbas Bay
KS-3	5.3	4.1	168	Jiltirbas Bay
KS-4	4.3	2.65	138	Lake Eastern Karateren
KKS	18.4	5.4	581	Sudoche Lake
Beruny	10.1	3.9	321	Amu-darya River
Ayazkala	12.4	4	392	Ayazkala Lake
Ustyurt	6.6	4	209	Sudoche Lake
Ozerny	73.1	4.1	2 ,308	Sarikamish Lake
Divankul	31.1	2.7	981	Sichankol Lake
Parsankul	28.1	3	884	Amu-darya River
Dengizkul	14.3	4.9	451	Dengizkol Lake
Central Bukhara Canal	15.5	3.05	490	Solyonoe Lake
Zalodno-Romiton	2.5	2.4	79	Solyonoe Lake
Agitma	5.5	2.1	174	Ayak-Agitma Lake
Severny	22.6	2.9	713	Korakir Lake
Yuzhny	74.2	7.1	2, 339	Sultandag Lake
Syr-darya River Basin				
Central Golodnaya Steppe Collector (CGC)	43.1	4.2	2,100	Arnasay Lake system
Shuruzak	12.7	2.8	400	Syr-darya River
DGK	11.2	3.5	354	Kly Collector
Ok-Bulok	3.9	3.9	122	Tuzkan Lake
Pogranichny	1.8	4.5	58	Tuzkan Lake
Kly	3.23	4.7	102	Tuzkan Lake
Achikkul	49.5	2.65	1,560	Syr-darya River
Korakalpak	9.6	1.57	302	Syr-darya River
Sari-Suv	65.8	1.5	2,074	Syr-darya River
Urtukly	20.6	1.3	650	Syr-darya River
Chilisay	11.2	1.27	350	Syr-darya River

Note: In 2004, total annual discharge, including other small collectors was 23.5 km^3.

The 150 km long main collector Ozerny, which begins in the Khazarasp District of Khorazm and, after collecting drainage waters from 50 collector tributaries, enters the Tashauz region of Turkmenistan is one of the most important in fisheries terms. The canal then connects with the Daryalik main collector and flows into Sarikamish Lake, discharging 2.3 km^3/y. Other smaller, although nonetheless significant collectors, enter other lakes (some in Uzbekistan and some in neighbouring Kazakhstan) after receiving drainage water from irrigated land.

Lakes in Uzbekistan

The majority of the 3 000 lakes in the Aral Sea drainage basin are less that 1 km^2 in size and are mainly located in mountainous areas at altitudes of 2 000–3 000 m. Within Uzbekistan, almost all of the lake systems have been impacted by irrigation; some have completely dried, while others have been used for residual water storage. Table 7 provides a general overview of the hydrological characteristics of the main Uzbek lakes and their potential for culture-based fisheries development.

TABLE 7
Hydrological characteristics of the main Uzbek lakes and their potential for culture-based fishery development

Name	Hydrological characteristics					CBF use
	Water surface (ha)	Volume (km^3)	Depth (m) max/mean	Water source	Mineralization (g/l)	
Arnasay Lake system (ALS)	370 000	40	34/N/K[1]	Collectors CGC, Kli, Akbulak, etc.; Chardara Reservoir	1.5–8	B
Sarykamysh	347 000	48	39.5/10	Main Collector Daryalik	10–12	B
ALS-Lake Aydar	300 000	N/K*	34/16.1	Chardara Reservoir, CGC, Lake Tuzkan	3.4–8	B
Tuzkan	64 000	N/K	15.2/11.7	Collectors CGC, Kli, Akbulak	4.9–6.3	B
Sudochye	52 000	0.880	2/0.9	KKS and Ustyurt collectors	3–3.35	A
Jiltirbas Bay	28 500	0.130	N/K	KS 1-3	5–7	C
Dengizkol	26 700	2.3	11/5.1	Collector Dengizkol	11.5–12.2	B
Karakyr	26 175	0.740	4.5/2.25	Collector Severny	5.4–12.8	B
Khojakol-Karajar	24 000	0.033	4.3/0.4	Ustyurt collectors	3–3.5	C
Ayazkala	8 000	0.4	4/2.5	Collector Ayazkala	6.5–7	B
ALS-Eastern Arnasay Lake	6 000	N/K	3.5/1.5	Chardara Reservoir	1.0–5.8	B
Akhcha-Kol	5 000	0.257-8	14/1.5	Collector Beruni	7–8	B
Solyonoye	4 150	0.072	3.5/1.9	Central Bukhara Canal and Zalodno-Romiton Collector	3.7–4.3	C
Mashan-Kol	4 000	0.250	N/K	Ustyurt collectors	2–2.5	C
Ullushorkol	2 600	2–2.5	9/2.5	Main Collector Ozerniy	3–5	B
Eastern Karateren	2 000	0.150	16.5/5.5	Collector KS-4	4–6	C
Ayak-Agitma	N/K	3.34	N/K	Collector Agitma	2.5–3.5	B

**N/K – not known.*

Note: CBF (culture-based fishery) use: A = currently being used for CBF; B = historically used for CBF, but currently not in use; C = suitable for CBF use, but not used.

Smaller lakes are widespread in the deltas of the Amu-darya and Syr-darya rivers. Historically, these deltaic water bodies were particularly important for fishery development, as they provided excellent spawning areas for indigenous and introduced species. However, most of these deltaic lakes have been subject to large-scale irrigation water abstraction and dry up completely during peak periods. Most of the lakes in the territories of the middle and lower reaches of the Amu-darya and the Syr-darya rivers are fed mainly by sewage and collector-drainage waters, although groundwater input is also an important source of water, especially as increased extraction of river water is undertaken for irrigation purposes.

The water temperature regime in many Uzbek lakes is similar to that of shallow water bodies that are characterized by rapid warming and cooling (see Lake Sarikamish, for example in Table 8). Although wind speed is generally moderate, it is quite consistent, causing mixing of water. In Lake Sarikamish, for example, the average water temperature in mid March is 4^{o} C, yet by early April the water temperature rises to over 10^{o} C. The harsh winter conditions in Central Asian countries mean that fish tend not to feed throughout the winter months. What is more problematic, however, is the early feeding patterns observed when water temperature increases rapidly, leading to water quality problems in early spring months in some pond culture systems.

TABLE 8
Average long-term (1976–1986) meteorological characteristics of Lake Sarikamish

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Air temperature	N/K*	N/K	4	14	20	25	28	26	21	12	5.9	1.9	12.8
Humidity %	4.9	5.2	5.8	9.8	13	15	17	16	13	9.4	6.9	5.8	10.2
Water temperature %	0.6	0.5	2	11	18	22	24	23	19	13	6.9	3.7	12

** N/K – not known.*
Source: Gorelkin and Maksimov (1990).

Evaporation in the larger lakes can be significant, with water loss of around 2 600 mm per year not uncommon, although generally evaporation ranges from 400–2 000 mm per year[17]. Mountainous lakes tend to suffer from ice cover as early as late September. The water bodies found in the plains are characterized by high levels of mineralization, but are only covered with ice during parts of the winter (and sometimes only during the harshest winter days). The duration of ice cover depends on the climate, but generally varies between 10–100 days on the plains to 60–180 days in the mountain areas, and in these mountain areas ice depth can be as much as 30 cm. In water bodies of the Amu-darya's lower reaches, ice tends to form in the second half of January and is established by early February, although the ice here tends to be much thicker, and has been known to reach depths of 50 cm. In these lower reaches, ice lasts between 40–100 days. All water bodies tend to be ice free by early March when waters warm rapidly and fish begin to feed.

The oxygen content in most lakes varies during daytime hours between 9.1–12.3 mg/litre, and falls as low as 4 mg/litre during night hours. The oxygen content also varies during the winter months when lakes are completely covered with ice. In the large, deep lakes oxygen levels remain within tolerable limits for fish during this period, however, the smaller or shallower lakes can become depleted of oxygen, resulting in mass fish deaths. The pH of most lakes tends to remain within tolerable limits for the current commercial fauna.

In lakes that are subject to high levels of evaporation and reduced river inflows, excessive levels of mineralization can be a problem, with salinity levels increasing

17 In comparison with pond systems, evaporation in lakes and reservoirs tends to be lower due to lower average water temperatures (ponds are generally shallower than the lakes and reservoirs used for culture-based fisheries).

beyond the levels tolerated by the main commercial species. Finally, the biogenous elements in the lakes of Uzbekistan are, for the most part, within limits suitable for the main commercial species.

One of the largest, and perhaps most suitable, areas for fishery development is the ***Arnasay lake system*** found in the middle reach of the Syr-darya River. The Arnasay lake system is unique in the sense that it is the largest man-made water body in Central Asia. Originally a series of three natural depressions fed by groundwater and precipitation, the depressions were filled in 1969 when emergency floodwater was discharged from the Syr-darya River during a devastating flood season. In total, 22 km^3 of water was diverted from the Syr-darya, which filled and connected the three depressions, resulting in the Arnasay lake system. While subsequent flooding of the Syr-darya increased the surface area of the Arnasay lake system to 2 700 m^2, over the next decade the lake reduced in size, as no further water was discharged into the lake and with around 100 cm^2 of water level lost each year through evaporation, the surface area reduced to 1 750 km^2.

The ground water and drainage water inflow (around 2.5 km^3 per year) is thought to be sufficient to sustain the system's surface area at 1 750 m^2 (as, combined, they compensate for water loss through evaporation). During the 1980s, the salinity of the water in the three depressions ranged from 3–9 g/litre in Lake Eastern Arnasay, from 4–12 g/litre in Lake Tuzkan and from 6–19 g/litre in Lake Aydar (Karimov, 1995). In addition to the fluctuating salinity levels, the lake experienced high levels of pollution, mainly of agricultural origin, during the 1980s. Since the collapse of the USSR, water discharge from the Syr-darya River was largely unregulated, and remains poorly regulated today. There is also tension between the countries that the Syr-darya flows through regarding the use and abstraction of water that remains unresolved to date.

The Arnasay lake system is now considered a single water body that is around 340 000 ha in size. The water quality is considered to have improved in recent years, with salinity levels stabilizing between 1.5–8 g/litre. Generally, the water level increases each year due to increased water discharge from rivers, and in the last decade the waters have risen around 7 m. The lake presently has a surface area of 3 400 km^2, with a maximum depth of 27 m, and it is not uncommon for the entire lake system to be covered with ice during winter months.

The system has stabilized biologically and is holds considerable potential for fish production and related economic improvements in the local and surrounding communities. The original flora and fauna were introduced to the lake via the Shardara Reservoir (which is fed by the Syr-darya). More recently Fish have been introduced as part of stocking programmes. Species composition in the Arnasay lake system has changed in the last 30–40 years, due to changing hydrological conditions and changes in water quality. Until the late 1970s, stocks predominantly consisted of common carp and pike-perch. Pike, however, are not tolerant of high levels of mineralization, and the pike population decreased as levels of mineralization increased in the 1980s. Species that are tolerant of higher levels of mineralization, such as roach, became the dominant species in the 1990s. The current species with most commercial value in the lake are mainly benthophagous (common carp and freshwater bream), detritophagous (Crucian carp and roach), phytophagous (silver carp) and grass carp and predators (wels, asp, pike-perch, and the Amur snakehead).

Reservoirs in Uzbekistan

During the 1970s, catches from the Aral Sea had declined to such an extent that fishers were relocating to inland waters, including lakes and reservoirs that were intended for residual water storage for irrigation purposes (Table 9). However, natural productivity is low, only 5–10 kg/ha in mountain reservoirs and 10–20 kg/ha in the plains.

TABLE 9
Main Reservoirs in Uzbekistan

Name	Year constructed	Water surface (km^2)	Total capacity (million m^3)	Source of water inflow	Depth (m) max/mean
Amu-darya River Basin					
Tuyamuyun	1980	650	7.800	Amu-darya River	20/7.7
Mejdurechye	1978	387	800	Amu-darya River	9.3/1.0
Kattakurgan	1941	80.5	900	Zerafshan River	25/11.3
Talimarzhan	1978	77.35	1.525	Karshi Main Canal	40/20
South Surhan	1962	65	800	Surkhandarya River	27/12
Dautkol	N/K	50	N/K	Amu-darya River	2/1.5
Chimkurgan	1964	45.1	425	Kashkadarya River	28/9.8
Sarbasskoe	1990	38.7	2.71	Amu-darya River	3.0/0.5
Shorkol	1978	30	170	Zerafshan River	17/10
Tudakol	1986	22.5	875	Amu-Bukhara Main Canal	12/3.9
Muynakskoe	1983	21.5	1.93	Amu-darya River	2.5/0.5
Kuyu- Mazar	1957	18	350	Amu-Bukhara Main Canal	24.6/19.5
Pachkamar	1967	12.4	260	Guzardarya	62/17
Uchkyzyl	1959	10.5	160	Zang Canal	40/16
Gissarak	1982	4.7	170	Aksu	134/80.5
Kamashi	1957	3.82	29.5	Yakkabagdarya	14.9/6.2
Degrez	1958	2.3	12.8	Canal Hazarbag from Topalang River	11/5.6
Dehkanabad	1983	1.48	18.4	Kichik-Uradarya	32.2/10
Karabag	N/K	0.75	7.5	Kizildarya River	28.5/10.9
Langar	N/K	0.7	7.2	Langar River	27/16
Yangikurgan	N/K	0.7	3.3	Karasu River	16/4.7
Shurab-sayskoe	1977	0.38	2	River Shurabsay	9/4
Karatepe	1987	1.9	24	Zerafshan River	34/10
Akdarya	1989	N/K	130	Akdarya River	N/K
Topalang	1985	N/K	500	Topalang River	N/K
Total	**25**	**1,526.2**	**14.975**		
Syr-darya River Basin					
Andijan	1970	60	1.750	Karadarya River	100/29.2
Charvak	1966	40.1	2 000	Chirchik River	148/50
Tuyabuguz	1959	20	250	Ahangaran River	36.5/12.5
Arnasay	2000	20	605	Chardara Reservoir	10/3
Dzhizak	1969	13.8	100	Sanzar River	21.9/7.1
Karkidon	1964	9.5	218	Kuvasai and South Ferghana Canal	66/22.9
Ahangaran	1971	8.1	399	Ahangaran River	95.5/49.3
Kassansai	1954	7.6	160	Kassansai	55/21
Zaamin	1987	5.5	51	Zaaminsu	N/K
Uchkurgan	1961	3.7	54	Naryn River	33.4/14.6
Total	**10**	**188.3**	**5.587**		

N/K – Not Known

As the majority of water in Uzbekistan is used for cotton culture and often results in most reservoirs being fully emptied, the use of reservoirs for fish production is currently low. Given the demand for water in cotton production, the suitability of Uzbek reservoirs for culture-based fishery production is governed by several factors:

- Agreement to guarantee that water will not be abstracted during the cotton-growing season beyond the quantity required to maintain the reservoir for fish production.
- Assessment to ensure that the hydrophysical and hydrochemical conditions are suitable for fish production.
- There is both local demand for fish and infrastructure in place.

Assessments of the hydrophysical and hydrochemical conditions of the main reservoirs in Uzbekistan suggest that there is potential for fish production (Kamilov and Urchinov, 1995; Karimov, 1995; Karimov, Leith and Kamilov, 2006). However, analysis of the hydrological parameters of the main reservoirs suggests that only seven are suitable for fishery development (see Table 10).

TABLE 10
Hydrological parameters of water reservoirs most suitable for culture-based fisheries

Water reservoir	Height above sea level (Baltic system) (m)		Volume (million m^3)			Water surface (km^2)		Depth (m)	
	At project volume	At dead volume	Full	Usable	Dead*	At project volume	At dead volume	Max.	Ave.
Kuyumazar	240.5	217.7	350	303	47	18	9	24.6	19.5
Talimarjan	**400.5**	**373**	**1 525**	**1 400**	**125**	**77.35**	N/K*	**40**	**20**
Surkhon	415	399	800	710	90	65	23	27	12
Uchkizil	321.5	312.5	160	80	80	10.5	8.3	40	16
Todakul	**222**	N/K	**875**	**555**	**325**	**225**	N/K	**12**	**3.9**
Ahangaran	**1 100**	**1 060**	**399**	**319**	**80**	**8.1**	N/K	**95.5**	**49.3**
Uchkurgan	539	N/K	54	37.6	16	3.7	N/K	33.4	14.6

**N/K – not known.*
Note: Dead volume is the level at which water cannot be abstracted for irrigation.

The reservoirs Talimarjan, Todakul and Ahangaran (bold in Table 10) appear to offer the most potential for fish production and the development of culture-based fisheries. Ahangaran is suitable for the production of cold water fish, such as trout, and Talimarjan and Todakul for the production of warm water species like carp.

5. Culture-based fisheries in selected Central Asian countries: the historic and contemporary experiences

The first instances of introducing new species into the waters of Central Asia date from the late 1920s and early 1930s when Soviet scientists introduced the starry sturgeon and the Caspian shad into the Aral Sea and the Sevan trout into Lake Issyk Kul in order to enhance the value of local capture fisheries (see Box 2). Subsequent planned introductions[18] into the region's main water bodies included pike-perch, European whitefish, peled, freshwater bream, and various members of the carp family. Some were successful, others less so. However, the initial emphasis of culture-based fisheries in Central Asia was oriented to the stocking of regional water bodies of national and international importance with a view to underpinning the livelihoods of local fishing communities. Karimov *et al.* (2009) thus suggest that before 1961 the fish available on the regional market was only from the capture fishery, mainly from the Aral Sea where annual landings of 25 000 tonnes/y were commonplace.

Desiccation and salinization of the Aral Sea and its deltas, accompanied by concerns over the overfishing of other water bodies, led the All-Union Ministry of Fisheries to announce a large-scale fish culture development strategy in the 1960s. This presaged the establishment of a score of fish culture farms covering over 25 000 ha across the republics, farms that were supplied with all the latest technologies, techniques, feed and funding to meet centrally set production targets. While some of these farms focused on sturgeon (Atryau in the Socialist Soviet Republic (SSR) of Kazakhstan and Nukus in the USSR of Uzbekistan), the majority focused on cyprinid culture using large on-site earthen ponds. While stocking remained important, the dispersion of cyprinid fry, fingerlings and young fish into smaller water bodies fostered the emergence of pond culture in the region. This strategy proved highly successful, and culture farm production from Uzbekistan alone reached 20 000–25 000 tonnes by the late 1970s.

The traumas of independence and the cut-off in institutional support saw farm production decline precipitously in the 1990s (Thorpe and van Anrooy, 2009b) as many enterprises were forced to curtail – or even cease – operations due to a shortage of funds, feed, advice or equipment. Privatization proved not to be a palliative, as many of the privatized culture establishments found it difficult to prosper, because the economic policies pursued in the decade after independence extended few favours to the sector. This began to change in the first decade of the current century as the emergence of a new group of committed entrepreneurs (i.e. Ekos International in Kyrgyzstan), a reformulation of sectoral legislation – triggered by international institutions (such as FAO and the World Bank) and embraced by the national governments, and the gradual removal of structural obstacles militating against a resurgence of the sector have been removed. The following subsections thus trace the evolution of and the current situation facing culture-based fisheries in three of the regional republics.

18 Unplanned introductions included the stone moroko and eleotris (discussed in more detail in the following respective country analyses).

KAZAKHSTAN

Historical background

In the former SSR of Kazakhstan, the responsibilities for water body stocking and species introductions fell under the remit of the Kazakh Research Institute of Fisheries (KRIF). The research institute produced five-year stocking plans which were subsequently approved by the USSR Ministry of Fish Industry in Moscow. In institutional terms, the KRIF subsequently answered to the Ministry of Fishing Industry of Kazakhstan, following its creation in 1966[19]. The ministry was entrusted with developing both capture and culture fisheries in the republic, and was given full jurisdictional authority over local fishing and fish processing associations[20], the Union of Fishing Collective Farms (Kazakhrybbakkolkhozsoyuz), KRIF, the Institute for Fisheries Facilities Design (Kazgidrorybproekt), laboratories for Ichthyopathological Control and Hydrochemical/ Hydrobiological Control, and all (fishing) port, processing and aquaculture facilities (ponds, hatcheries, and fish farms) in the republic.

This coincided with the intensive development of the sector, with production growing exponentially to peak at over 100 000 tonnes in 1975 (Thorpe and van Anrooy, 2009b). Increased fish harvesting from the Aral and Caspian seas and Lake Balkhash was augmented by the growth in aquaculture production. While acclimatization schemes date back to 1933– 1934, when starry sturgeon was introduced into the Aral Sea, and culture operations to 1937, when one of the first pond fisheries was opened on the outskirts of Almaty[21], aquaculture activities really only developed following the construction of 13 state hatcheries in the late 1960s and early 1970s. While some of these focused upon cyprinid-based culture, others were located near major reservoirs and other water bodies so as to facilitate the introduction of high-value species (most notably pike-perch, freshwater bream and vendace or European cisco). In the latter case, the acclimatization of these new species proved so successful that, by the 1990s, the fisheries of Lake Balkhash, the North Aral Sea, and the reservoirs of Bukhtarma, Zaisan, Kapchagay and Shardara were based almost exclusively on these introduced species (Ismukhanov and Mukhamedzhanov, 2003).

The Ministry of Fishing Industry of Kazakhstan promulgated specific legislation governing fishing in the republic in June 1969 (*Rules for Fishing in the Water Basins of the Republic of Kazakhstan*) which detailed the rights and responsibilities of the respective fishing industry bodies, laid down total allowable catch for certain species in designated water bodies, identified minimum permitted mesh sizes for fishing gear

19 Prior to 1966, fisheries activities in the republic were organized on basin lines, with the basin administrations of Uralkasrybvod (Ural-Caspian basin) and Kazakhrybvod (Kazakh basin) responsible for the protection, reproduction and regulation of fishing within their respective geographic confines. These administrations reported directly to Glavrybvod (whole USSR basin) of the USSR Ministry of Fish Industry.

20 The most important of these were Aralrybprom (established in the Aral-Syrdarya basin in 1925), Balkhashrybprom (Balkhash-Alakol basin, 1929), Zaisanrybprom (Irtysh-Zaisan basin, 1933), Atyraurybprom and Mangystaurybholodflot (Ural-Caspian basin).These associations were responsible for around 90 percent (in volume terms) of the republic's catch (Timirkhanov *et al.*, 2010:58).

21 These facilities now form part of the Bent JSC, a network of industrial and agricultural enterprises. It is involved in both poultry farming (poultry breeding, production of hatching eggs, production of commercial eggs and poultry meat and sausage products of poultry meat) and fish farming (production and selling of live fish, mainly silver carp). As a private enterprise, its production output is not reported to the Committee of Fisheries.

deployed, and established regulations governing amateur and sport fishing[22]. The regulations were reinforced in April of the following year by legislation (*Measures for Strengthening Protection of Fish Resources in the Water Basins of the Kazakh SSR*) that took a tougher line on poaching and the violation of fishing regulations and outlined institutional remits within the sector for regional councils, ministries and other administrative bodies.

The growth of culture-based production also saw a series of scientific studies undertaken in the early/mid-1970s with a view to providing detailed fishery-technological specifications for pond-based aquaculture in the republic. These specifications, which still informed culture policies in the republic 30 years later, divided the country using isolines (based on the number of days in which the air temperature exceeds 15^{o} C) into seven regions. These isolines informed pond capacity figures used for planning and fish farm management purposes in each of the regions (Table 11).

TABLE 11

Average pond capacity figures, by region, for cyprinids(in 100 kg ha/y)

Isoline Regions	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
Region of country	None in Kazakhstan	N. Kazakhstan + N. Akmola	E. Kazakhstan, S. Akmola, N. Karaganda & Kostany, Pavlodar	N. Akyubinsk, S. Karaganda and Kostany	W. Kazakhstan, Atyrau + S. Akyubinsk	Almaty, Zhambyl, Kyzlorda, Mangistau	S. Kazakhstan
No. of days with temp. 15 ^{o}C or above	>76	76–90	91–105	106–120	121–135	136–150	151+
Grow-out Ponds	8	14	16	19	22	24	26
Common carp	8	11	12	13	13	14	15
Grass carp & Silver carp	–	3	4	6	9	10	11
Nursery Ponds	8.5	15	17	20	25	26	28
Common carp	8.5	12	13	14	15	15	16
Grass carp & Silver carp	–	3	4	6	10	11	12

Source: Adapted from Timirkhanov et al. (2010) – figures for peled capacities (Regions I–II) are also available from the same source.

The mid-seventies too saw a restructuring of the sector, with post-harvest operations – for both capture and culture subsectors – assigned to the newly created Kazakhrybpromsbyt (Decree No. 547, December 1976). Kazakhrybpromsbyt opened fish processing and/or trade centres ("Okean") in the country's 19 oblasts and, with its main focal areas in the towns of Balkhash, Rudniy, Ekibastuz and Tekeli, at its peak had a refrigeration

22 These regulations allowed all citizens to fish – without first acquiring licences – in any waterbody in the republic which was not designated as a protected area or where commercial fishing was being pursued. In the latter instance, separate regulations applied. These regulations still largely govern sport and amateur fishing in the independent republic (see Timirkhanov *et al*. (2010:20ff) for a review of the recreational fisheries sector in Kazakhstan).

capacity of almost 720 000 t. The activities of Kazakhrybpromsbyt were complemented by the Ministry of Food Manufacturing Industry, the Consumers Union Association (Kazpotrebsoyuz) and the Ministry of Defence (trading branch), and annual domestic fish trade in the latter years of the Soviet period was estimated to include 120 000 tonnes (including 12 000 tonnes of herring) and 94 million tins of canned fish (Timirkhanov *et al.*, 2010). Sectoral re-organization subsequently saw the Ministry of Fishing Industry and all its attendant functions subsumed within Gosagroprom in 1988 following the Decree of the Presidium of the Supreme Council of the Kazakh SSR.

By the end of the 1980s, culture and culture-based production had expanded sharply and was also now taking place on some of the republic's major lakes and reservoirs, particularly in Almaty and Kyzylorda oblasts. By 1990, 9 722 tonnes was being produced, compared to 672 tonnes two decades earlier (Table 12). Statistics suggest 47 enterprises were active at this time, their operations extending across 50 reservoirs and 12 commercial pond farms (the latter covering 5 041 ha). The subsector provided employment for 1 200 people, and productivity was high – with yields reaching 1 500 –1 800 kg/ha (Timirkhanov *et al.*, 2010).

TABLE 12

Culture and culture-based production by oblast (t), 1970–1990

	1970	1990			
	Total – Lake[1]	Pond	Lake	Reservoir	Total
Akmola	30	57	397	75	**529**
Atyrau	–	–	–	–	**–**
Almaty	258	2177	82	115	**2 374**
Aktubinsk	–	89	–	–	**89**
East Kazakhstan	102	529	–	–	**529**
Zhambyl	–	620	–	20	**640**
West Kazakhstan	15	545	–	92	**637**
Karaganda	–	260	–	117	**377**
Kyzylorda	33	987	993	573	**2 553**
Kostany	–	–	154	47	**201**
Pavlodar	17	240	–	–	**240**
North Kazakhstan	–	–	174	–	**174**
South Kazakhstan	217	1 292	–	87	**1 379**
Total	**672**	**6 796**	**1 800**	**1 126**	**9 722**

Note: Hatchery output aggregated with pond production.

Source: Adapted from Timirkhanov et al. (2010).

Independence had a profound impact upon institutional organization of the sector. Two years after independence Gosagroprom was wound up and replaced by a Fisheries Committee located within the Ministry of Agriculture (Decree No. 159 of February 1992). Exactly three years later the Fisheries Committee was merged with the Committee on Forestry and Hunting and relocated to the Ministry of Natural Resources and Environment Protection (Decree No. 157 of February 1995). The merger was not a success, and in June 2003 (Decree 714) a Fisheries Committee was recreated under the aegis of the Ministry of Agriculture. The regulatory framework has also evolved, with Law No. 593-II (July 2004 – subsequently amended in 2010) *Regulating Protection, Reproduction and Use of Fauna*, providing the legal framework for future fisheries management in the country. While the law did not deal directly with the issue of user rights or tackle enforcement issues (to name two shortcomings), subsequent ordinances have sought to redress this by making operational concepts and management practices within the sector (i.e. Order No. 963 *Regarding Adoption of the RoK Fisheries Sector*

Development Concept, 2007–2015, October 2006)[23]. One of the most important of these was the *Rules of Fishery* approved by governmental decree (No. 1456) in December 2004 which requires lessees to develop a fisheries plan[24] (including the stocking thereof) for the water body in question for the duration of the lease (5–49 years). Catch quotas are determined annually by government decree. To aid in the management process, given the enormity of the country, the Fisheries Committee also established interregional basin and district territorial departments in April 2005 (Decree 310).

Tentative steps were taken to establish clear goals for the culture-based fisheries and to support its modernization. Fishery-technological specifications and procedures were reviewed and new *Instructions on the Procedure for the Acclimatization of Fish and Aquatic Animals and the Stocking of National Water bodies* were issued by the Fisheries Committee in January 2004 (Decree 12-p). In 2007, the *Republic Strategy of Acclimatization and Fish Stocking* was approved by the Government of Kazakhstan (Decree 57) and laid down a series of goals and objectives for the sector (Box 3).

While to date all the goals of the new strategy have not been met (i.e. the introductions of fingerlings of Aral barbel, fringebarbel sturgeon and paddlefis) to form new fish populations have not yet been carried out), there is some emerging evidence to suggest that such measures have not only managed to halt, but to partially reverse, the sharp decline in reported culture production seen since independence (Table 13).

23 These are emitted either by the Government of Kazakhstan (case of Ordinance No. 963), the Ministry of Agriculture (case of Ordinance No. 462 – *Relating to the Labelling of Sturgeon Caviar for Retail on the Domestic and International Markets, August 2004*), or the Fisheries Committee (Ordinance No. 56-π – *Regarding Fishing Gear Restrictions, May 2004*). Further examples can be found in Timirkhanov *et al*. (2010:64–65).

24 The lessee can subcontract any recognized research organization to produce this mandatory plan. In the case of waterbodies deemed to be of international or national importance whose control falls under regional akimat (on behalf of the national Fisheries Committee), feasibility studies are funded at the state's expense.

BOX 3

The Republic Strategy of Acclimatisation and Fish Stocking (2007)

The strategy proposed the development of whitefish farms in Northern Kazakhstan, sturgeon farms (mainly) in Western and Eastern Kazakhstan and carp farms in Southern and South-Eastern Kazakhstan. The goals outlined in the strategy were to:

- increase fish output;
- improve and preserve biodiversity (sturgeons);
- promote fish stocking so as to preserve the genetic pool (Ural River sturgeons);
- restore broodstock levels;
- support the growth of broodstock (ciscos);
- develop intensive farming methods;
- form new fish populations; and
- exert biological control over aquatic plant growth.

As the declared goals were predicated on increasing fish stocking volumes, aquaculture was of crucial importance. To this end a number of incentives were offered to the sector to accompany the legislative changes occurring. Two main paths were favoured:

- lake fish farms (as this allowed increased fish output from natural water basins without the need for large investments); and
- growth of sturgeon and pike-perch in recirculating systems (this was favoured by exporters, as it ensured a constancy of supply given that number of valuable fish species in natural waterbodies had dramatically fallen over time).

In 2008, *Recommendations for the Development of Sturgeon Farming in the Republic of Kazakhstan* was published. While the recommendations were for the internal use of the Fisheries Committee and were of an advisory nature, the document proposed creating a Selection and Genetic Centre of Sturgeon Farming. Four reproductive complexes were identified – Ural and Caspian, Aral and Syrdarya, Ili and Balkhash, and Irtysh and Zaysan – and estimated broodstock abundance was calculated and regionally appropriate sturgeon growing techniques were proposed for each reproductive complex.

TABLE 13
Culture and culture-based production by oblast (t), 1990–2009

	1990				2004	2006	2009
	Pond	Lake	Reservoir	Total	Pond culture		
Akmola	57	397	75	**529**	–	–	12.5
Atyrau	–	–	–	**–**	–	–	–
Almaty	2 177	82	115	**2 374**	110	150	95.4
Aktubinsk	89	–	–	**89**	25	15–30	0.9
East Kazakhstan	529	–	–	**529**	–	–	22
Zhambyl	620	–	20	**640**	–	–	–
West Kazakhstan	545	–	92	**637**	10–15	10	43.8
Karaganda	260	–	117	**377**	–	–	25
Kyzylorda	987	993	573	**2 553**	–	–	–
Kostanay	–	154	47	**201**	–	–	9.7
Pavlodar	240	–	–	**240**	–	–	4
North Kazakhstan	–	174	–	**174**	–	–	76.5
South Kazakhstan	1 292	–	87	**1 379**	–	–	14.8
Total	**6 796**	**1 800**	**1 126**	**9 722**	**145–150**	**175–190**	**304.6**

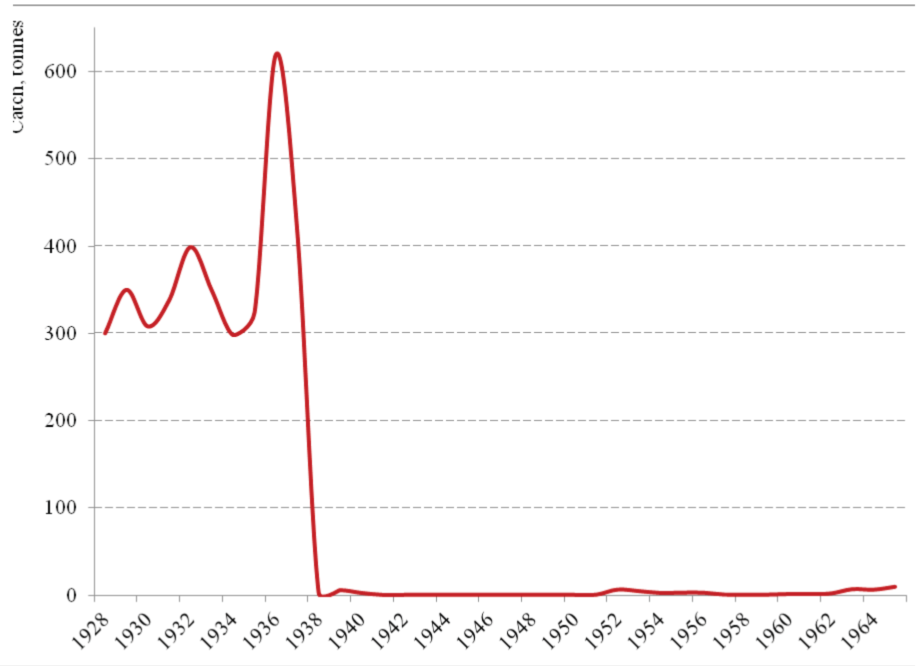
Source: Fishery Committee of the Republic of Kazakhstan.

The most dramatic collapses in cultured output were in the oblasts of Kyzylorda and Almaty and South Kazakhstan, which historically accounted for just over 64 percent of national culture production in 1990 (The following subsections of this report cast more light upon these regional production shortfalls). Since 2004, however, output has begun to rise, although Timirkhanov *et al.* (2010) suggest that a major impediment to the resurrection of the sector remains a lack of funding – with less than 10 percent of the funding assigned to the sector being directed to the financing of fish farming and supporting the introduction of new technologies into the sector.

Past stocking experiences

The most widely stocked fish were common carp, grass carp, and silver carp – which had been introduced to water bodies all over Kazakhstan 0151 – and ciscos (Coregonidae). However, the first introduction into the small steppe lakes in northern Kazakhstan, involved a member of the sturgeon family, the starry sturgeon. This exercise was one of the least successful. While the Aral Sea already hosted one indigenous sturgeon species – the fringebarbel sturgeon, the decision was taken to introduce starry surgeon from the Caspian Sea into Aral waters as a population enhancement measure. To this end, 330 000 fingerlings were released in 1933, and 90 broodstock in 1934. Unfortunately, the capsalid monogenean *Nitzschia sturionis* – a parasite affecting the skin and gills of members of the sturgeon family (Whittington, 2004) – was present in the introduced stock, and had a devastating effect upon the native fringebarbel sturgeon. While 300–400 tonnes of fringebarbel sturgeon had been landed annually by the Aral fleet in the early 1930s, landings peaked in 1936/1937 (Figure 3) as the infection spread and the fleet landed large numbers of ill specimens. The consequences of the epidemic were all too plain to see the following years, as catches dwindled to near zero, with the catching of fringebarbel sturgeon being banned by government edict on 1 June 1940. Although there were incidental catches of fringebarbel sturgeon by the Aral fleet in subsequent years (though never more than 4–10 tonnes/y), by the late 1970s statistics show only occasional specimens were landed.

FIGURE 3
Catches of fringebarbel sturgeon in the Aral Sea (1928–1969)



Paradoxically, although the starry sturgeon had been introduced into the Aral Sea to enhance commercial catches, no starry sturgeon was caught until 1948. Thereafter, records show single specimens of up to 1 m in length and 6 - 8 kg in weight were infrequently landed. This did not deter further stocking, however, and over the period 1948 - 1957 fertilized starry sturgeon eggs were flown across from the lower reaches of the Ural River to the Syr-darya, where they were incubated, prior to the fingerlings/young sturgeon being released into the Aral waters. Statistics suggest the volumes transported amounted to around 41 million eggs in this period, with 4.7 million fingerlings and 7.4 million young sturgeon subsequently liberated into the sea.

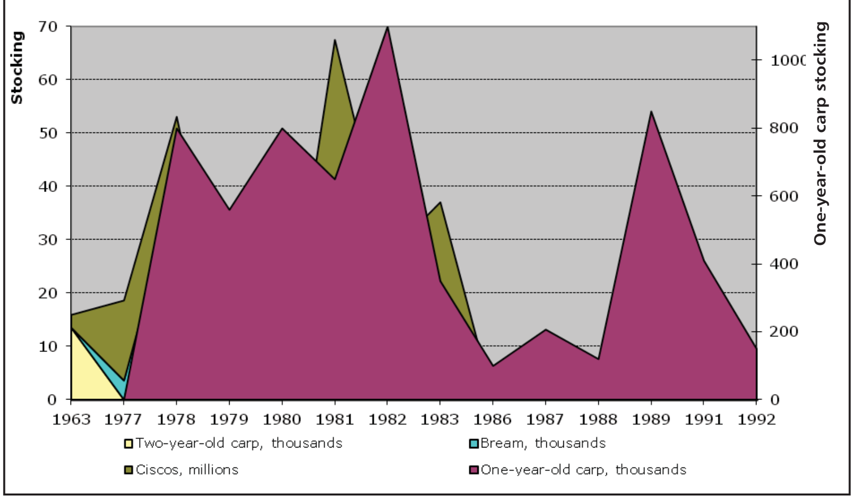
Renewed stocking took place between 1960 and 1963 when 12.1 million fertilized starry sturgeon eggs were transported to the Aral region, with a further 5.5 million (fringebarbel and starry) sturgeon eggs making the same journey between 1963 and 1975 (no records exist of the numbers of fingerlings/young sturgeon introduced over these periods). A further attempt was made to turn the Aral Sea into a sturgeon water body in the late 1990s as part of the *Regulating the Syr Darya River and saving the northern part of the Aral Sea Project* (SYNAS – Syr Darya North Aral Sea - I), funded by the International Bank for Reconstruction and Development project – a project which constructed a dam across the Berg Strait so as to restore the level and salinity of the Small (North) Aral Sea. The project proposed the yearly stocking of the water body with the expectation that catches of up to 10 000 tonnes/y could be achieved, and oversaw the reconstruction of the Tastak Fish Hatchery.

All attempts to acclimatize starry sturgeon in the Aral Sea failed. Early attempts were unsuccessful due to the immaturity of the introduced fingerlings (five day old), which resulted in high mortality rates, while the juvenile sturgeons released failed to prosper due to the environmental/ecologic changes occurring in the sea. Stocking in the 1960s also met with little success, as the profound changes in water inflows and the hydrological regime following the abstraction of water and the damming of the two feeder rivers meant natural reproduction of anadromous fish was impossible.

Latter attempts also ended in failure, despite improved information being available on the sea's post-1990 hydrologic regime and recognition that natural reproduction of the species was impossible in the Syr Darya Delta. Overoptimistic estimates of the potential broodstock base – the Tastak Hatchery project, for example, proposed to use broodstock from the Aral Sea, despite few starry specimens having been landed in the intervening years – contributed to the project's shortcomings. Moreover, even if the stocking programme was truly successful, starry landings were only ever likely to be around 50 percent of historic fringebarbel sturgeon catches[25].

A second example of a failed stocking programme concerned the introduction of common carp and ciscos into the lakes of north Kazakhstan. Indigenous ichthyofauna in these steppe lakes included Crucian carp, roach, European perch and ruffe. In the 1960s, freshwater bream were introduced, and specimens of carp and ciscos were then stocked. Ciscos appeared well-suited to the cold waters of the lakes in the region as they can thrive better than trout in less oxygenated water (typical of the northern lakes), and their forage spectrum is zooplankton – which meant they would not compete for feed with the indigenous (carnivorous) benthophagic species. Moreover, the rapid growth of zooplankton biomass in the summer appeared conducive to the raising of cultured species in the lake's confines. One such example was the Imantau Lake Fish Farm, formed in the mid-1970s, which linked Imantau (4 500 ha), Zhaksy-Zhangistau (4 300 ha), White (1 200 ha), Lobanovo (300 ha) and Baisary (300 ha) lakes, which supplied the Petropavlovsk fish processing plant.

FIGURE 4
Fish stocking, Imantau Lake Fish Farm (1963–1992)



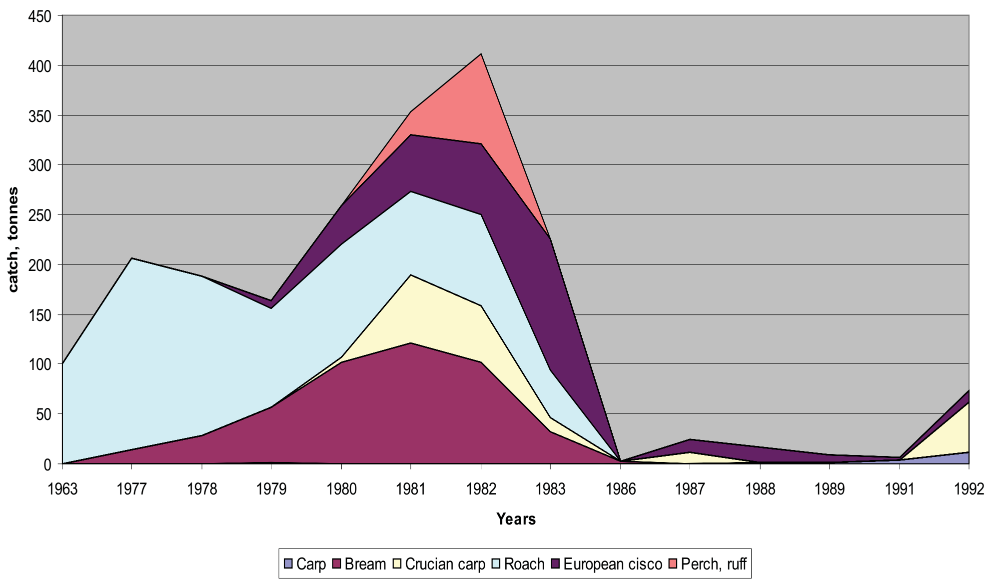
Catches, recorded at 100 tonnes in 1963, began to climb as the stocking programme developed. The early focus on two-year-old carp had given way to a preference for one-year-old carp by 1977, numbers peaking in 1982 when one million fingerlings were released into the lakes. Cisco releases peaked a year earlier, when around 700 000 young were stocked (Figure 4).

While catches almost quadrupled between 1963 and 1983, disaggregation of catch statistics by species suggests the stocking programme was not as successful as the aggregate figures suggest. First, as not only were the lakes' water temperatures too

25 The authors' estimate maximum yields were likely to be of the order of 235 t y^{-1}. This figure is generated by taking into consideration the catches (25 000 t y^{-1}) in the Northern Caspian Sea, an aquatic area 106 times the size of the North Aral Sea.

low for carp reproduction, but the water bodies were already populated with carp competitors – specifically Crucian carp, freshwater bream and roach – who cover the same forage spectrum, and facultative predators such as European perch and ruffe, who feed on benthic organisms in the absence of their normal prey. Research by the authors suggests carp stocking may have produced net losses once the cost of fingerlings was factored into the equation. Although cisco catches did rise after the stocking programme commenced (Figure 5), landings never reached the predicted 130 tonnes/y and perch and ruffe stocks and catches grew instead, as these predatory species feasted upon the young ciscos. The introduction of bream in the lakes proved to be a mistake too. While bream landings from the Imantau lakes grew steadily from the late 1970s, it was never a popular food fish in the local market.

FIGURE 5
Catches in the lakes controlled by the Imantau Lake Fish Farm



As noted in the preceding section, culture production dropped sharply in the wake of independence as state support for the sector was sharply cut back. Timirkhanov *et al.* (2010) complements the above (specific) examples of failed stocking experiences with both the identification of, and commentary upon, the experiences of the major fish hatcheries situated in the Republic of Kazakhstan (Table 14).

Sturgeon reproduction for stocking was entrusted to the Atyrau and Ural Atyrau hatcheries sited on the Ural River. These captured wild broodstock on an annual basis during the species spawning runs on the lower reaches of the river[26]. Although three hatcheries were established in East Kazakhstan Oblast, two (Semipalatinsk and Ust-Kamenogorsk) were sold to private investors following independence – with only Bukhtarma Hatchery, based on the reservoir of the same name, still operative. Almaty was home to five aquaculture operations, three of these (Almaty, Chilik and Turgen) being sold-off to private investors in the independence period. Kapchagay has historically faced problems in reaching its peak production capacity due to recurrent water shortages which have frequently only permitted one-fifth of its pond area to be used, while KazPAS is one of the smaller state hatcheries to function in the republic. The one culture enterprise in Aktyubinsk Oblast, Karagaly Pond Fish Farm, situated on the banks of the Zhaksy-Kargaly River, was also privatized, but rising costs saw the 12 pond complex cease operations in 2003.

26 The two state enterprises were merged in 2007 (Decree No.144) to become the Atyrau Sturgeon Hatchery Erkin Kala.

TABLE 14
Major fish hatcheries in Kazakhstan

Name	Oblast	Year	Area (ha)	Peak capacity (t or *pieces*)	Species cultured
Almaty Pond Farm (Bent)	Almaty	1939	279.6	452 t	Common carp, silver carp
Ardagym Pond Farm	Aktyubinsk	1978	227	N/K	Common carp, sturgeon, Chinese carps
Atyrau Sturgeon Hatchery	Atyrau	1998	33	*3.5 million*	Sturgeon
Bukhtarma hatchery	E.Kazakhstan	1964	680	*32.3 million*	Common carp, vendace
Chilik Pond Farm (Aidyn)	Almaty	1964	1 500	1 337 t	Common carp, Chinese carps
Kapchagay hatchery	Almaty	1982	720	1.9 t	Common carp, Chinese carps
Karaganda hatchery	Karaganda	1975	506.4	*80–100 million*	Common carp
Kachir hatchery	Pavlodar	1966	123	2.5 t	Common carp
Kamyshlybash hatchery	Kyzylorda	1966	266.4	*15 million*	Common carp, Chinese carps
Maybalyk hatchery	Akmola	1964	365	*70.8 million*	Common carp, ciscos and whitefish
KazPAS hatchery	Almaty	1961	25.9	*0.8 million*	Common carp, Chinese carps
Petropavlovsk hatchery	N.Kazakhstan	1964	52.7	*130.8 million*	Common carp, ciscos
Shardara hatchery	S.Kazakhstan	1987	210	*0.9 million*	Common carp, Chinese carps
Shidertinksy hatchery	Pavlodar	1977	80	*1.1 million*	Common carp, cisco
Shuiskoe (LLP DSU85)	Zhambyl	1985	830	*85 million*	Common carp, Chinese carps
Shymkent Pond Farm	S.Kazakhstan	1963	277	600 t	Common carp
Syr Darya Pond Farm	S.Kazakhstan	1975	824	*6.06 million*	Common carp, Chinese carps
Tastak hatchery[8]	Kyzylorda	1967	53	*50 million*	Sturgeon/ Common carp
Turgen Trout Farm (LLP Technoimport)	Almaty	1967	4.2	100 t	Trout
Upper (Verkhne) Tobol	Kostani	1991	203.6	*2.2 million*	Common carp, cisco
Ural Atyrau Sturgeon Hatchery	Atyrau	1998	51.4	*3.5 million*	Sturgeon
Uralskoye Pond Farm (Zhivoye Serebro** LLC)	W.Kazakhstan	–	287	600 t/*24 million*	Common carp, sturgeon, Chinese carps
Ust-Kamenogorsk Cage Farm	E. Kazakhstan	1985	–	–N/K	Trout
Ust-Kamenogorsk Pond Farm	E. Kazakhstan	1964	643	–N/K	Common carp, Chinese carps
Zerendy hatchery	Akmola	1967	224.4	*81.3 million*	Whitefish, Common carp
Zhezkazgan Pond Farm	Karaganda	1974	106.4	*2 million*	Common carp

**Tastak Sturgeon Hatchery forms part of the larger Kamyshlybash Hatchery for organizational/ management purposes.*
***Uralskoye Pond Farm never commenced operations during the Soviet period.*
Note: Those denoted in bold are still active.

Source: Timirkhanov et al. (2010: Table 8 and authors' research).

While Maybalyk Fish Hatchery in Akmola remains one of the country's biggest culture operations, the Zerendy Pond Farm complex – located within the Kokshetau National Park – is capable of producing over 80 million fry (50 million whitefish, 30 million carp) and 1.3 million carp fingerlings. The aquaculture operations in Karaganda Oblast (Karaganda Fish Hatchery and Zhezkazgan Pond Farm) both continue to operate in the guise of a merged Karaganda complex (created in 2003), although output remains well below projected peak capacity. The Kachir Fish Hatchery in Pavlodar was an important carp culture centre in the 1960s, producing over 2.2 million fingerlings annually, while the Shidertinsky Spawning and Breeding Farm (which also focused on carp) continues to operate across its 80 ha. In Kyzylorda, the Tastak Hatchery, set-up in the 1970s to rear sturgeon, subsequently switched to the culture of carp for local reservoirs, an activity also undertaken by the much larger Kamyshlybash Fish Hatchery following its creation in 1967.

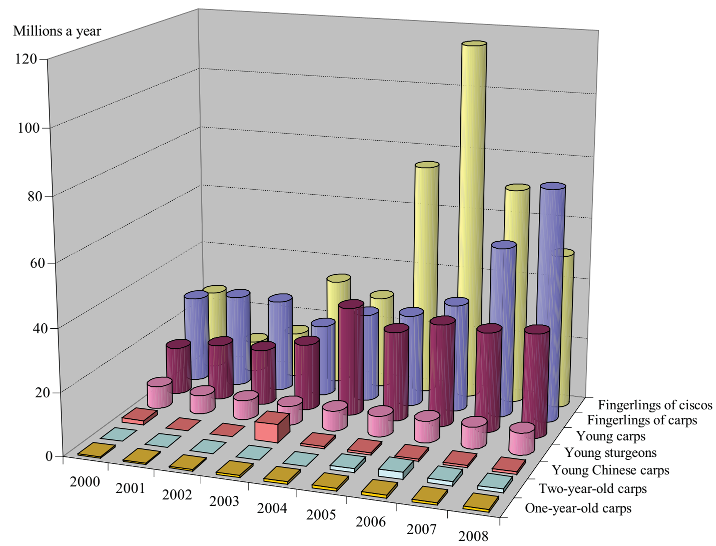
The Petropavlov Fish Hatchery in northern Kazakhstan has operated for almost half a century, its profile growing in recent years (see following section), while the Verkhne-Tobol Fish Hatchery, sited on the upper reaches of the Tobol River in Kostanay, like the Petropavlov Hatchery, historically focused on carp culture. At the other end of the country, the Shardara Fish Hatchery, constructed below the dam of the same name on the Syr Darya River, is now the only aquaculture enterprise operating in the oblast following the demise of the Syr Darya and Shymkent pond farms (the latter being split into the Limited liability partnership (LLP) Komesh-Balyk and Kamyshbalyk Meirhan at the end of the 1990s). In western Kazakhstan, the 287 ha Uralskoye Pond Fish Farm was converted into the private enterprise Zhivoye Serebro LLP in 2003. While it produces carp, sturgeon and Chinese carps, production data are not presently supplied to the Committee of Fisheries, although research suggests the enterprise produced 43 tonnes of fish in 2010 (personal communication from Oleg Lazarenko Director of "Zhivoye Serebro LLP"). In Zhambyl Oblast, the Shuiskoe Pond Farm became LLP DSU85 which, while still functional, does not currently produce fish for the market.

Recent stocking experiences

Although stocking has continued in the post-Soviet era (as we discuss below), recorded catches declined, stabilizing at low levels, notwithstanding high levels of stocking activity in the early 1990s. One positive example of stocking in recent years relates to the decision to introduce one million European cisco fingerlings *per annum* into Lake Yakush (previously characterized by an absence of fish) from 2004. By 2005, seven tonnes of cisco was being landed, this rising to ten tonnes by 2009 as the lake's biomass ascended to 14.7 kg/ha. The success of the Yakush cisco programme can principally be attributed to the fact that the lake was not populated prior to the fingerlings being released – hence there was no predation or shortage of feed – and stocking has remained a single species-centred activity.

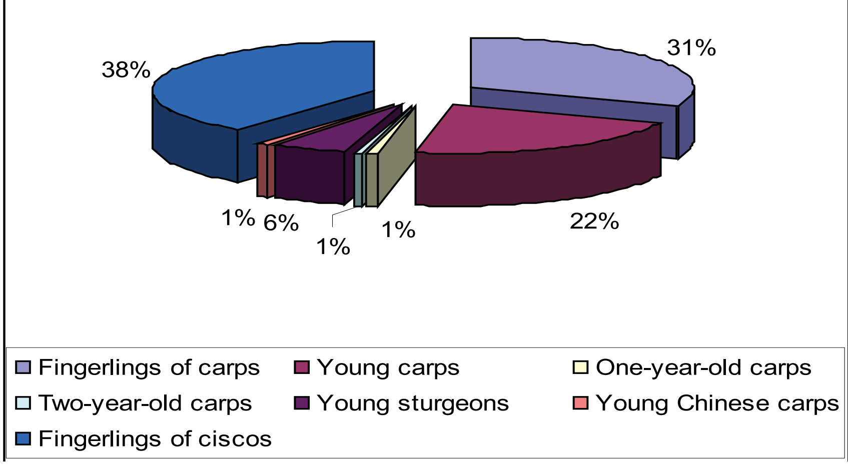
The current culture emphasis in Kazakhstani fish hatcheries focuses upon the breeding of ciscos (larvae), common carp (larvae, juveniles, one-year and two-year-old fish), herbivorous fish (one-year-old grass carp and silver carp), in particular, the raising of carp and cisco fingerlings and, to a lesser extent, young carp and sturgeon (Figure 6).

FIGURE 6
Fish stocking volume in Kazakhstan, 2000–2008



There is a limited focus on the culture of one and two-year-old carps – as was common during the period when Kazakhstan was part of the USSR – due to a combination of the unavailability of funding for such activities on the one hand, and the shortage of sufficient pond space in hatchery installations on the other (Figure 7).

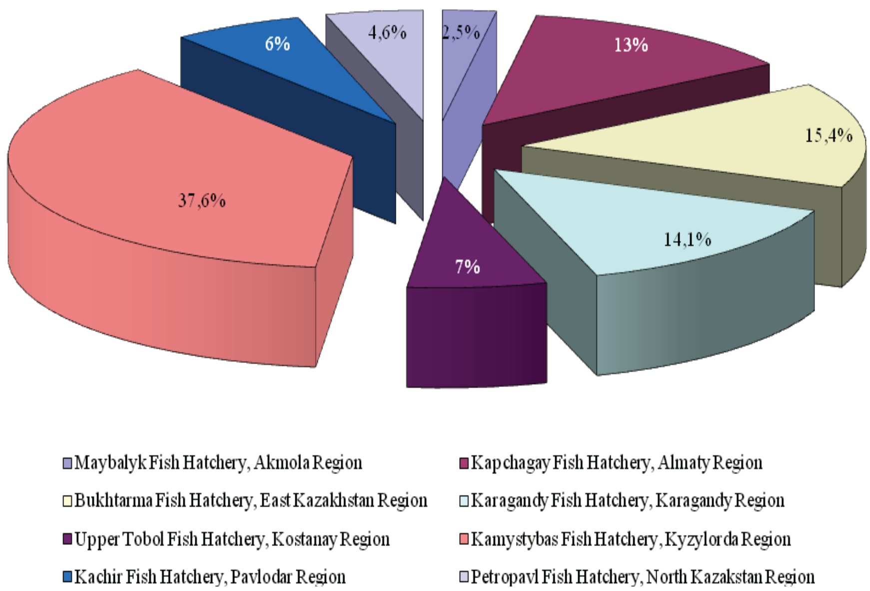
FIGURE 7
Species structure of fish stocking in Kazakhstan (average 2000–2008)



There is also a degree of specialization among the hatcheries. Petropavlovsk Fish Hatchery in north Kazakhstan Oblast, for example, is responsible for almost 100 percent of the country's cisco larvae production. While Maybalyk Fish Hatchery (Akmola Oblast) produced almost 100 percent of carp larvae prior to 2006; nowadays carp larvae are produced fifty-fifty in Kamyshlybash and Maybalyk. Production of one-year-old carp is more widely distributed, although a significant portion (37 percent) originates from the Kamyshlybash Fish Hatchery in Kyzylorda Oblast (Figure 8). The majority (70 percent) of two-year-old carp are raised at Bukhtarma Hatchery, while all young sturgeons are raised at Atyau Sturgeon Hatchery.

FIGURE 8

Young carp (one year) production in Kazakhstan, by fish hatchery (average 2000–2008)



There has been a recovery in hatchery output since the last decade of the twentieth century (Table 13). Maybalyk Hatchery in Akmola was very much the dominant – and most efficient – supplier in 2003, accounting for 44 percent of the fry output and absorbing just 3.2percent of the sector's operating expenses. In contrast, the Kamyshly production unit in Kyzylorda produced 15.7percent of the fry but accounted for 27percent of the operating expenses. In the intervening years, as Table 16 shows, while fry output has more than doubled (up 122percent by 2008), operating costs have risen rather faster (up 200percent over the same period), one reason why the government has taken recent steps to help more effectively rehabilitate the sector[27]. At the same time, increased concentration is also evident within the sector. The 2006 decision to re-assign part of the responsibility for carp larvae production to Petropavlovsk Hatchery has seen this hatchery assume a greater significance in the local aquaculture sector, producing 51.1percent of sectoral output in 2008 (Maybalyk's share dropping to 24.3percent) at a cost of Kazakh tenge (KZT) 25,300 (just under six percent of the sector's total operating costs). Detailed operational costs of the Petropavlovsk Hatchery are given below (Table 15). While juvenile output to date has not fluctuated particularly, expansion of fingerling capacity incurs incremental operating costs (up from KZT5–8 a piece). Cisco juveniles/fingerlings are also produced at the installation.

The larger hatcheries identified in Table 16 are also complemented by a number of other private hatcheries[28] (which culture fish as well as either stocking fish in adjacent local water bodies or selling fry/fingerlings to local pond culturalists); however, no

27 These include the provision of subsidies (the state covering 50 percent of both forage and fry costs and 100 percent of costs for maintaining genetically pure lines), partial tax exemption (tax rates for aquaculture enterprises are reduced by up to 70 percent), leasing of equipment at favourable rates to the enterprises and special legislation recognizing "lake fish farms" as a management enterprise.

28 This includes the Besagash complex in Almaty and the Kolos Hatchery in Zhambyl Oblast. While, in the case of the former, plans suggest it could cultivate up to 20 million fry on around 150 ha of ponds; it presently remains inoperative, as the ponds have not yet been built. Kolos, which began operations in 2002, covers 71 ha and has a capacity of 5–10 million carp fry and up to one million carp fingerlings, but is also currently inactive.

detailed records of these enterprises are available. Research suggests, however, that the privatization experience – at least in so far as it involves culture fisheries – has been less than successful to date, as either production levels have fallen in the newly privatized enterprise or production has ceased altogether as the new owners have chosen to pursue non-culture projects on the newly acquired land and installations.

Nevertheless, Kazakhstan has a significant lake area on which to develop lake fish farms. As most of these are located far from large settlements, in areas with high numbers of unemployed, developing fish farming on these (small) lakes will help to improve employment opportunities. For example, the proposed Kyzylorda 2010–2020 Fish Industry Development Programme is expected to create 1 000 new jobs, thereby swelling the incomes of the local population. Legislation in this regard (creation of lake fish farms) is presently expected.

TABLE 15
Operating performance of Petropavlovsk Fish Hatchery (in a normal year)

Ciscos	Units	Approximate Range of Values	
		Lowest	Highest
Fingerlings reared	Number (million)	10.2	100
Market price of fish sold	KZT per kg	350	600
Cost of juveniles/fingerlings	KZT per 1 million	250 000	300 000
Operating costs	KZT per piece	0.16	0.17
Carp – system 1 – stocking at juvenile size (one year)			
Juvenile carps reared	Number (million)	0.86	0.994
Market price of fish sold	KZT per kg	600	900
Cost of juveniles	KTZ per 1 million	100 000	120 000
Operating costs	KTZ per piece	0.05	0.06
Carp – system 2 (stocking in same year of fingerling size fish)			
Fingerlings reared	Number (million)	15.0	38.0
Market price of fish sold	KZT per kg	600	900
Cost of fingerlings	KZT per 1 million	–	–
Operating costs	KTZ per piece	5.0*	8.0*
Capital costs	*KZT per facility*	*23.80*	*55.95*

**Price in northern Kazakhstan (in southern Kazakhstan price per piece is KZT10–20; usual price is 15 KZT per piece).*

TABLE 16

Output volume of fish fry and total operating expenses (TOC) in Kazakh tenge of Kazakhstan's fish hatcheries, 2003–2009

	Name of hatchery	2003		2004		2005		2006	
		Number (millions)	TOC	Number (millions)	TOC	Number (millions)	TOC	Number (millions)	TOC
1	Atyrau Sturgeon	3.00	19 570	3.25	43 000	3.35	47 731	3.50	49 731
2	Bukhtarma	6.00	7 794	10.00	18 000	1.00	19 212	1.50	21 212
3	Upper Tobol	1.20	7 893	2.00	14 000	2.20	15 979	2.20	15 979
4	Kapchagay	1.90	10 181	2.80	16 200	4.00	26 644	6.00	34 000
5	Karaganda	2.00	8 691	3.40	19 200	4,60	35 479	5.80	40 900
6	Kachir	1.00	4 638	1.90	13 000	2.20	15 890	2.20	15 890
7	Kamyshly-Bash	12.00	38 138	13.40	43 000	14.60	62 631	15.22	70 223
8	Maybalyk	33.90	4 626	44.40	8 159	45.80	9 293	50.80	10 443
9	KazPAS	0.50	3 000	0.80	6 192	0.80	11 618	0.80	12 818
10	Petropavel	10.80	5 098	16.00	9 348	61.30	20 038	101.60	26 800
11	Shardara	0.70	8,527	0.80	12 624	0.85	14 417	0.90	15 300
12	Ural Atyrau Sturgeon	3.00	22 660	3.25	43 762	3.35	47 756	3.50	49 756
Total:		76.00	140 816	102.00	246 485	144.05	326 688	194.02	363 052

	Name of hatchery	2007		2008		2009	
		Number (millions)	TOC	Number (millions)	TOC	Number (millions)	TOC
1	Atyrau sturgeon	7.00	114 352	7.00	115 352	7.00	125 000
2	Bukhtarma	1.00	20 487	0.80	11 333	N/K	N/K
3	Upper Tobol	2.00	16 100	2.20	18 500	N/K	N/K
4	Kapchagay	6.00	39 690	5.50	47 390	6.00	76 112
5	Karaganda	5.00	39 590	5.50	41 490	N/K	N/K
6	Kachir	2.00	16 097	2.20	17 497	N/K	N/K
7	Kamyshly-Bash	15.22	89 311	16.72	93 312	13.20	121 000
8	Maybalyk	41.00	13 600	41.00	14 900	41.00	24 926
9	KazPAS	0.80	12 818	0.80	14 418	0.80	20 124
10	Petropavl	86.40	23 800	86.40	25 300	88.40	55 950
11	Shardara	0.80	20 520	0.90	23 620	N/K	N/K
Total:		167.22	406 365	169.02	423 112	156.40	423 112

Note: The operations at Bukhtarma, Upper Tobol, Karaganda, Kachir and Shardara were transferred into private hands, and since this transfer production data are not reported to the Committee of Fisheries. As the Atyrau and Ural Atyrau sturgeon hatcheries were merged in 2007 (Decree No. 144) – becoming the Atyrau Sturgeon Hatchery Erkin Kala – only data for the new enterprise are shown in the bottom half of the table.

Problems facing culture-based fisheries production in Kazakhstan

Culture-based fisheries production in Kazakhstan has, at the national level, favoured the culture and release of carp and herbivorous fish into the nation's water bodies, with local hatcheries concentrating on sturgeon (Aral region) and ciscos (north Kazakhstan region). These activities were underpinned by a series of studies in the early/mid-1970s which produced detailed fishery-technological stocking specifications for pond-based aquaculture across the republic (See Table 11). Although these specifications and state support delivered a growing culture production output over the following two decades, this growth was not sustained in the post-independence era – when recorded output collapsed. A number of factors have been identified as contributing to this decline; they include:

A. Outdated technical specifications

The 2007 *Republic Strategy of Acclimatization and Fish Stocking* was formulated based upon the original technical reports developed in the 1970s. The failure to critically analyze the water body stocking experiences that followed – their shortcomings and their successes – has ensured policy is based upon a moribund set of specifications that have not evolved in the light of experience. The need for technical studies of current (and recent past) stocking activities is paramount – as is the need for external advice on the best/most effective contemporary aquacultural practices relevant to the nation's water bodies.

B. Regulation/monitoring

It is acknowledged that current fish stocks in Kazakhstan – with the exception of bream, which is not overly preferred by the majority of national consumers – are depleted. At the same time, while capture activities on the republic's largest water bodies (Aral and Caspian seas, Kapshagay, Balkhash and Alakol lakes, and the Bukhtarma, Shulba and Shardarya reservoirs) are monitored, this is largely limited to the recording of catch volumes. Elsewhere, not even catches are monitored. More detailed monitoring of stocking and capture activities on the nation's water bodies thus seems a prerequisite for enhancing the contribution of the sector to national development.

C. A coherent development strategy for the sector

While the 2007 *Republic Strategy of Acclimatization and Fish Stocking* outlines a series of goals/targets for the sector and the government has made welcome attempts to deliver these goals by offering a series of incentives to stimulate the sector, there is still a degree of policy incoherence which militates against enhancing output from the sector. Examples of this incoherence include:

- The transfer/leasing of water bodies to multiple owners. Experience has shown that this approach has, in a number of instances, induced conflict and "free-riding" among lessees. A case in point was the Global Environment Facility Small Grants Program (GEF/SGP) project which assigned Koshkarkol Lake to four users. However, when one of the parties subsequently reneged upon the agreement, the full cost of stocking the lake fell upon the remaining lessees (one solution in this instance is to limit the number of users to whom a water body is assigned and/or stipulate the maximum size of water body that can be assigned to one lessee).

- Stocking of water bodies of national and international importance within the republic is the responsibility of the state, a responsibility fulfilled by the contracting of state enterprises to culture and subsequently liberate the fry/

fingerlings into the designated water body (as legislation presently prohibits the state from contracting private aquacultural operations to undertake such stocking, the potential for (small) private fish farm expansion is circumscribed).

- The introduction of land use fees for aquacultural enterprises, but on differential terms to those applied to agricultural enterprises (thus distorting investment/attention to agrarian rather than aquatic endeavour).

- The 2007 strategy, focusing as it does on the "mechanics" of stocking, overlooks the need for financing to support the rehabilitation of the sector. Timirkhanov et al. (2010), for example, suggest that aquaculture only receives between 8–10 percent of the sectoral budget.

- Although certain culture production enterprises have independent access to a water supply (i.e. Almaty, Chilik and Shymkent farms), the operating costs of others have risen due to the sharp hike in water use fees, rendering such activities unprofitable.

- The operation of nearly all fish farms in the republic is critically dependent upon power supply. Not only has the sector been adversely affected by rises in power charges in recent years (as with water), but the uncertainty of supply in winter – when supply has been cut off due to excessive aggregate demand – has caused high mortality rates across a number of nursery farms and dampened risk-taking behaviour.

- Timirkhanov et al. (2010) note how customs policies and tariffs currently impede the import of larvae and roe (fertilized), fish feed, veterinary drugs and chemical reagents, and culture equipment to the detriment of the sector, suggesting a thorough analysis of trade-based impediments to growth may prove conducive to culture-based production growth in the coming years.

D. Greater diligence with respect to the introduction and propagation of new and invasive species

The history of culture fisheries in Kazakhstan has shown that fish farms have been the main conduit for the introduction of invasive species into national waters. The endemic presence of undesirable species such as Balkhash marinka, Balkhash perch, spotted thicklip loach and Seven River's minnow in the water bodies of south-eastern and south Kazakhstan can be traced to their importation, along with the importation of desired species of herbivorous fish such as silver carp and grass carp from the Far East, and their subsequent culture and (unintentional) release by fish farms in the waters of the republic. One possible solution to future occurrences of this problem is to re-orientate stocking procedures towards the release of one-year-old fish (albeit the costs are higher), as this will reduce the likelihood of propagating the spread of invasive species. Concerns have also been expressed as to the impact of introduced species on native fish, most particularly in mountainous areas, prompting a call for certain mountainous water bodies to be designated as habitats solely for native species. Presently, given the low returns from carp and herbivorous stocking, there is a proposal to investigate the potential benefit of introducing fry of the predatory pike-perch into Kapchagay Reservoir in Almaty Oblast and sterlet sturgeon into the Irtysh River, although such introductions should be made with caution.

E. A lack of fish feed

Historically, one obstacle to trout and sturgeon culture was the non-availability of feed. While options existed to import the requisite feed from Chinaz (Uzbekistan) or Dnepropetrovsk (Russia), the former was deemed to be of too poor a quality, while the latter was expensive given the transportation distance involved. A similar shortfall existed with regard to carp feed following independence. Although there was a local supplier, the Semipalatinsk Feed Plant in east Kazakhstan, its principal market was the poultry and livestock markets rather than aquaculture. While the Semipalatinsk plant was willing to supply the sector, the terms of supply, whereby only large quantity orders were accepted and as delivery would often only be possible two to three months before the feed was actually required the feed deteriorating due to extended storage time, were not coincident with the sector's specific needs.

KYRGYZSTAN

Historical Background

In the former SSR of Kyrgyzstan, stocking and species introduction responsibilities fell under the remit of the Central Asian Production and Acclimatization Station (CAPAS), located in the capital, Frunze (now Bishkek). Funding for CAPAS came directly from the All-Union Ministry of Fisheries in Moscow, channelled via the Central Production and Acclimatization Authority (CPAA) based in the same city[29]. The task of fisheries development in the republic was entrusted to the Office of Fishery of the Ministry Council of the Republic, this metamorphosing into the State Fisheries Department. The office/state department was responsible for organizing the capture fisheries based on Lake Issyk Kul, the second largest mountainous lake in the world (after Lake Titicaca on the border between Peru and Bolivia), and opened a fish processing factory at Grigorievka village on the lake in 1931 to process the catches of Issyk Kul dace[30]. However, the low value of such catches prompted early consideration as to the benefits of stocking the lake with more highly valued species.

Following the recommendations of L.S. Berg, around 755 000 fry of the Sevan trout were released into the lake in 1931 (Berg, 1930). In 1936, a further 800 000 fry were released into the lake. Acclimatization proved successful – fecundity increased five-fold and growth rates four to six-fold – and specimens reached sizes of 89 cm and 17 kg (Thorpe *et al.*, 2009). Moreover, the abundance of Issyk Kul dace (and to a lesser extent of Schmidt's dace) and Issyk Kul marinka, despite the sharp increase in fishing effort following the establishment of the Grigorievka Fish Processing Factory, meant predation was not a problem. More problematic was the lack of suitable breeding rivers adjoining the lake. As a consequence, the fisheries authorities constructed a hatchery on the Ton River (Ton Hatchery) on the lake's southern shores in 1956, which trapped brood fish entering the river and other adjacent tributaries. Eggs were extracted, and fry/fingerlings were raised before being released into the lake. The hatchery had the capacity to produce 10 million trout and carp fingerlings annually (Sarieva *et al.,* 2008); although there is no evidence to show that these levels were ever reached. A further

29 The CPAA funded local employee's wages, transport and all other expenses. The qualified fish breeders who formed the CAPAS staff – based on the premises of the East Central Asian Fish and Water Resources Authority – Vostrsredneazrybvod – had no equipment, save isothermal boxes (transportation of eggs), plastic bags (transportation of fry and full-grown fish) and oxygen cylinders.

30 This prompted a sharp intensification of fishing activity, with annual catches generally exceeding 1 000 tonnes (90–95 percent Issyk Kul dace) over the next 30–40 years.

hatchery (Karakol) was constructed at the village of Beru-Bash on the Karakol River estuary on the eastern shoreline in 1969, and Borisov (1981) suggests the two hatcheries released 145.5 million fry and 79 million fingerlings into the lake during the 1970s.

The success of the introduction of Lake Sevan trout also prompted the introduction of pike-perch into the lake between 1954–1956, and subsequently freshwater bream, common carp, tench, Seven khramulya and Baikal omul. Other species – including the stone moroko, striped bystryanka and eleotris – were also introduced accidentally during this period. Not all survived, as Konurbaev *et al.* (2005) make clear. The decision taken in the early 1970s to turn Issyk Kul into a trout-whitefish waterbody – at the expense of the local populations of marinka, Issyk Kul dace and Schmidt's dace – presaged the introduction of European whitefish from Lake Sevan and the peled from the Novosibirsky Fish Farm (Novosibirsk Province in the western Siberian region). Unfortunately, this rapidly depleted the indigenous fish fauna of the lake and aggregate catches fell sharply (Table 17).

TABLE 17
Lake Issyk Kul, fish landings (1965–1990)

Year	Species landings (t)							Total production
	Schmidt's dace	Issyk Kul dace	Pike-perch	Trout	Whitefish	Bream	Other	
1965	32	1 275	20	–	–	–	26	**1 335**
1968	23	1 010	38	4.5	–	2	12.5	**1 090**
1975	77	686	112	47	–	2	5	**927**
1980	36	224	36	40	5	1.5	2	**344**
1985	14	86	22	13	23	7	1	**174**
1990	32	163	32	18	21	15	5	**278**

Source: Thorpe et al. (2009).

The state also promoted cyprinid-based aquaculture in the second half of the last century so as to take advantage of the myriad of small ponds scattered across the republic. A fish hatchery/nursery was established with around 50 ponds covering 370 ha at Chui in the 1950s, across 290 ha at Uzgen in Osh Province in the south of the country in 1968, and in Talas (364 ha) in 1975. By the end of the 1980s, production from the grow-out ponds at these three culture-based facilities alone (Table 18) dwarfed landings of capture fisheries – which remained centred on Lake Issyk Kul. Elsewhere, attempts were also made to commence fisheries production at Lake Son Kul, the country's second-largest natural waterbody (although barely one-twentieth the size of Issyk Kul) and at Toktogul Reservoir[31] but output levels were only minor relative to aggregate national production in the last few years of Soviet rule.

TABLE 18
Culture production (t) in Kyrgyzstan (1985–1990)

Farm	1985	1986	1987	1988	1989	1990
Chui	241	274	200.2	415.2	390.4	316.4
Talas	26.7	120	132.3	152	270	274
Uzgen	271.1	411	408	431	497.3	380
Total	**538.8**	**805**	**740.5**	**998.2**	**1 157.7**	**970.4**

Source: Adapted from Sarieva et al. (2008:Table 3).

31 Toktogul Reservoir (about the same size of Son Kul Lake – at 270 km^2), completed in 1976, was seeded with Sevan trout and Amu-Darya trout in 1977, various cyprinids in 1978 and the Siberian sturgeon in 1982. Although fishing commenced in 1978, output levels were of the order of 25 tonnes annually throughout the 1980s. The principal problem affecting capture and culture fisheries in the lake is that water levels are dictated by the needs of the agricultural and energy sectors – rather than the fisheries sector.

Independence saw the State Fisheries Department subsumed within the Republican Industrial Association "Kyrgyzrybhoz" (subsequently becoming Kyrgyzbalygy in 1997[32]) located within the Agro-industrial Committee. As centralized funding from CPAA ceased, the local acclimatization authority – CAPAS – closed, and its historic records on seeding programmes and their financing were largely lost.

The newly independent republic produced its first fisheries legislation (*Law of the Kyrgyz Republic on Fish Industry*) in June 1997. This gave Kyrgyzbalygy the responsibility for coordinating fish farming and establishing biological norms for the conduct thereof in Kyrgyzstan, the government of the republic took charge of fish stocks (and their capture) in the nation's main lakes and reservoirs, while the Ministry of Environmental Protection was entrusted to oversee fish stocks in other (non-private) reservoirs. Nevertheless, problems with making operational the statute prevented Article 7 – the granting of use and access rights to reservoirs and other waterbodies to private entities – from being exercised for fully a decade. Equally, Article 18 – the designation of a fund for financing fish farm development – was never created, given the imprecise wording of the legislation[33]. The law did, however, trigger the establishment of a new Department of Fisheries (which assumed responsibility for fish stocks in the major waterbodies on behalf of the government of the republic)[34] later the same year, although this was subsequently swallowed up within the Ministry of Agriculture, Water Resources and Processing Industry (MAWPRI) in 2000, becoming a Fisheries Industry Sectoral Unit, which was then upgraded into a Fisheries Inspectorate the following year. Although the inspectorate prohibited whitefish and trout fishing on Issyk Kul in 2003, the lack of effective enforcement resulted in reduced lake stocks of these species, while the few powers the inspectorate had were diluted further the following year when the State Agency for Environmental Protection and Forestry assumed responsibility for the issuance of commercial fishing licences and collection of the related fees[35].

Following the collapse of the country's two major capture fisheries at Issyk Kul (a fishing moratorium was introduced at the end of 2003) and Son Kul (moratorium introduced in 2005) and the parlous status of the country's culture-based installations, the government recreated a Department of Fisheries, housed within MAWPRI in 2006. Twelve staff were entrusted with collating capture and culture production data, managing and implementing state policy within the sector. A Fisheries Board comprised of key private, public (local and national authorities) and educational (National Academy of Sciences, other research institutes) stakeholders was also formed to offer advice on policy and strategy in the sector. This board determines and assigns catch quotas on the major waterbodies under its jurisdiction, while permitted catches in around 40 waterbodies leased to the Kyrgyzohotrybolovsouz (the hunters and fishers association)[36] are determined by the Kyrgyzohotrybolovsouz Community Board.

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32 In 2000, Kyrgyzbalygy was privatized, becoming Serebryanyi Proliv Ltd (Current Director – E. Niyazov). Although the enterprise is active in various fields, it is presently not involved in culture or capture fisheries.

33 Article 18 simply stated that a fund *may* be set up (the italics are ours).

34 It also assumed responsibility for stocking (or granting permits to restock) and the acclimatization of new fish species in Kyrgyz waters. Such decisions, as stipulated in the laws on fishery (1997), fauna (1999) and environmental protection (1999) are taken collectively in conjunction with the Ministry for Environmental Protection.

35 Recreational fishing permit fees are paid over to either the Kyrgyzohotrybolovsouz or the leasors of the waterbody concerned.

36 The Kyrgyzohotrybolovsouz, established in 1963, has around 25 000 members (about half being fishers or hunter-fishers), has an office in each oblast, and employs around 300 staff. It is also active in stocking those reservoirs in which it has fishing rights, releasing around 1.5 million tonnes of fingerlings per annum over the last decade (Thorpe *et al*., 2009:39).

The first steps towards remedying the managerial and strategic vacuum that existed were the belated authorization of the leasing out of waterbodies (20 in the first year) under Article 7 of the 1997 Law in March 2007. The following year the government approved Decree No. 7 *On Measures for the Preservation of Fish Stocks in Issyk Kul and Son-Kul*

BOX 4

The future of culture-based fisheries in Kyrgyzstan

The *2008-2012 Strategy for Fisheries and Aquaculture Sector Development and Management in the Kyrgyz Republic* makes a number of commitments relating to culture-based fisheries. Besides general commitments to undertake scientific research, extend credit, and promote training, use of best practices and international cooperation in this area (as well as capture fisheries), the most important culture-specific objectives are:

- 1.3 Introduce changes in fisheries-related legislation to avoid uncertainty over property or water rights in pond aquaculture.
- 1.5 Develop the regulations for establishing, licensing and registration of aquaculture activities.
- 3.1 Review and amend as necessary the current stocking programme (in terms of reach, species, economic feasibility and financial resources) based on scientific grounds.
- 3.2 Optimize the operations of state-owned hatcheries and research facilities.
- 3.3 Provide support to private-sector stakeholders involved in the stocking programme.
- 3.4 Improve the quality of stocking material (private and state), through improved selection/better broodstock strains.
- 4.1 Facilitate the establishment of aquaculture farms and the production capacity of existing farms.
- 4.5 Introduce low-cost technologies for the local production of locally suitable feeds.
- 4.6 Increase diversification of species cultured in line with market demands.
- 4.7 Ensure that aquaculture farms meet environmental standards and avoid pollution from their operations.
- 5.4 Promote the supply of aquaculture products to guest houses, hotels, cafeterias, and restaurants.

Lakes and Other Waterbodies in the Kyrgyz Republic (January 2008). A new proactive Departmental Director ushered in the *Strategy for Fisheries and Aquaculture Sector Development and Management in the Kyrgyz Republic 2008–2012*, a Kyrgyzstan som (KGS) 50 million (US$1.4 million) strategy which was embodied in Decree No. 161*,* which entered into law on 22 April 2008. While this decree placed specific emphasis upon developing culture-based fisheries in the republic (see Box 4), it also outlined measures for the overall development of the fisheries sector and introduced regulations to govern the operations of the Fisheries Department and recreational fishing in the country.

Subsequently, a number of further resolutions and decrees affecting the sector were approved:

- Resolution No. 162 – *Creation of a Fisheries Development Fund – and Regulations Upon its Use* (10/3/2009).
- Resolution No. 509 – *Establishing the Normative-Legal Framework for Entrepreneurial Activity* (11/9/2009).

- Resolution No. 561 – *Utilization of Natural and Artificial Fish Ponds for Fish Culture in the Kyrgyz Republic* (7/9/2009).
- Decree 98 – *Sustainable Development of the Issyk Kul Ecological and Economic System* (10/2/2009).
- Decree No. 241 – *On Normative-Legal Acts of the Kyrgyz Republic – Clarifying Property Rights Over Water and Terrestrial Areas* (20/7/2009).
- Decree No. 270 – *Licensing of Enterprises – Including Fisheries Enterprises* (13/10/2009).

Although it is relatively early to judge the success of these policies in rehabilitating the fisheries sector in the country, the scenario is promising. Uncertainty over property rights (Box 4 – Objective 1.3) has been tackled by Decree 241, while Decree 270 has introduced a regulatory framework for the aquaculture sector (Objective 1.5). Moderate success is also apparent in terms of rehabilitating culture-based establishments (Objective 3.2), as the state/sponsors have funded the purchase of modern fish breeding equipment and the equipping of a small unit to produce fish feed at Ton (Objective 4.5), the only functioning state hatchery at present. In contrast, the farms at Talas and Uzgen – which remain in state hands – have been unable to obtain investment funding. While the state does assist on the legislative requirements of farm creation and offers training courses in aquacultural techniques, the lack of funding prevents any more meaningful support being offered (Objective 4.1).

Less progress has been made in reorienting the stocking programme (Objective 3.1) due to a lack of financial resources, with the same shortcoming preventing state support to private-sector stakeholders (Objective 3.3), and the import purebred high-productive broodstock (Objectives 3.4 and 4.6) – rainbow trout excepted. State involvement in fish promotion activities to the services sector (restaurants, hotels, etc.) is conspicuous by its absence (Objective 5.4), while currently there is also an absence of explicit environmental regulations pertaining to the creation and operation of culture-based production activities.

Past stocking experiences

The primary emphasis of introduction and stocking programmes was to acclimatize new, higher value, species in the waterbodies of the republic. Karpevich (1975), however, suggests that as this occurred on a trial and error basis rather than based on underlying scientific studies of the waterbody in question, these introductions risked irreparably disrupting the local ecosystem and the ichthyological fauna therein. This was the case in both the country's largest lakes.

In 1958, 500 000 pike-perch eggs were transferred from Lake Zhizhitskoye (Pskov region, North-East Russia), incubated in-country, and then released as larvae into Tyup Bay in the north-eastern part of Lake Issyk Kul. A further 1 400 fingerlings from the Ural River mouth were also released into Rybachye Bay in the western end of the lake. The newcomers were introduced in the expectation that they would predate upon non-commercial fish species such as the Issyk-kul naked loach, Issyk-kul' minnow and gudgeon. However, its numbers swiftly multiplied because of the ready supply of food and favourable reproductive conditions, and landings of pike-perch passing 100 tonnes/y in the 1970s. Its growing presence in the lake led to a decline in indigenous Schmidt's dace and the young Issyk Kul dace stocks and landings (Table 17). Trapped between a voracious coastal predator, the pike-perch, and the deeper-water predation of the now acclimatized Sevan trout, the shoals of dace that had historically inhabited Tyup Bay were wiped out.

A year after pike-perch was introduced into Issyk Kul, the decision was made to introduce Sevan trout, naked osman, tench, broad whitefish, European whitefish, Tibetan stone loach and gray loach– among other species – into the pristine waters of Lake Son Kul, waters which, until that time, had lacked any indigenous fish species. Fingerlings of tench (1 050) and common carp (450) were transferred from the CAPAS facilities at Bishkek/Frunze, and supplemented with 130 scaley osman from the Tyulek River and 70 naked osman[37] from the Kara-Kudjur River. These released fishes were of different ages and sizes. The following year, a further 4 950 naked osman fingerlings were dispatched to the lake from the Ton Hatchery. Although historic research suggests that most species successfully acclimatized and survived their first winter, due to the coldness of the water only the Tibetan stone loach and the gray loach of these early introductions successfully reproduced. A decade later, in 1968, the lake was seeded with 121 million peled and 232 million European whitefish larvae from the Tobolsk Fish Farm in Siberia, and 3.04 million peled larvae and an unknown quantity of whitefish larvae from the Onega (northern Russia) and Velikoluksky (Pskov region, northeast Russia) fish farms (Pivnev, 1990).

These latter introductions proved more successful, the fish growing to sizes of 2–3 kg, and the lake was seeded with a further 592 000 peled larvae in 1972. Nikitin (1976) reports landings of around 140 tonnes/y in the 1970s[38], and the lake was also an important source for the trade in fish eggs[39], although concrete data on the latter activity is not available. Harvesting of the fast-growing peled during the summer period was problematic though, as the nets deployed also captured a significant quantity of the slower growing immature whitefish biomass (estimates suggest as much as 30 percent of the year cohorts). The capture fisheries potential of the lake was compromised, however, by the now acclimatized Tibetan stone loach and gray loach, which actively competed with the new introductions for food and also consumed substantive quantities of the peled and whitefish eggs released during the spawning period. This was exacerbated in 1979 when pesticides used to combat a local locust infestation leached into the lake. The consequent destruction of the lake's biota caused a further slump in fisheries production (down to around 40 t) and, with the waterbody's food webs taking a decade to return to their historic levels, compromised further activities on the lake. Overfishing, due to a combination of the indiscriminate issue of fishing licenses, weak enforcement and growing levels of poaching, did not help matters in the post-independence period, and all fishing has been banned on the lake since 2004. Nevertheless, fishing does still take place, albeit illegally, as evidenced by the DOF (2007) revealing that 188 nets were found being used in the lake's waters in 2006 over a ten-day period.

Although the Chui Fish Hatchery was established in the late 1950s, the major impulse to pond culture came in 1962 when the hatchery (known in Soviet times as the Frunze State Fish Farm) received a consignment of grass carp and silver carp from Uzbekistan. The successful propagation of these species in the state facilities at Frunze and their subsequent dispatch to reservoirs, ponds and other waterbodies in the republic

37 Despite Goncharov and Pavlova (1961) recommending the introduction of the naked osman to the lake, it is unclear whether this was ever a realistic economic proposition given that the species only reaches a weight of 1–1.5 kg after 17 years (maturity), and maturity times were likely to be even further extended in the Son Kul case given the extreme weather conditions encountered.

38 Field research suggests postharvest losses could reach as much as 30 percent of the catch due to the relative inaccessibility of the lake, the nature of the catching techniques and the non-availability of ice.

39 Field research suggests as many as 80–100 million peled and common whitefish eggs may have been harvested and smuggled into Kazakhstan and Russia.

revolutionized pond culture[40]. Historically, the dominant farmed species had been the common carp, supplemented by other benthophages, most notably the freshwater bream and the Prussian carp *Carassius gibelio*. However, as these other benthophages competed for the same feedstuffs, pond productivity was constrained. While the third historic cultured fish of choice, the tench did target different plants, it matured slowly and consumer demand was low. These two new phytophagous introductions not only consumed the phytoplankton ignored by the common carp but, because grass carp is a biological ameliorator, helped to enrich the pond environment through its voracious consumption of excess vegetation. Revised local stocking recommendations now envisaged a culture-mix comprising 20 percent silver carp and 10 percent grass carp, in the expectation that pond productivity could be increased by as much as 25–30 percent. Indeed, field research suggests that, in the case of ponds, productivity rose from around 17–20 kg/ha to 30+ kg/ha, with lower recorded increases in reservoirs (0.8–1.2 kg/ha to 2.0+ kg/ha) due to the nature of these waterbodies and the demands placed upon them by irrigation and hydro-electrical power.

Pond culture remained critically dependent upon the scientific support of CAPAS and, by extension, CPAA in Moscow, and funding (subsidies) from the All-Union Ministry of Fisheries for the operation of the local hatcheries, nursery and grow-out or fattening ponds at Chui, Uzgen and Talas. Independence ruptured these links, and as the newly independent state reduced expenditures on fish reproduction and the control of fish diseases, reduced revenues at the local level saw the more irregular disinfection of equipment, a generalized deterioration in facilities and a sharp decline in production (Table 19).

TABLE 19
Post-independence culture output (t) in Kyrgyzstan

Hatchery	1990	1991	1992	1993	1994	1995	1996	1997
Chui	316.4	545.1	326.1	96.2	54.1	66.9	21.5	27.7
Talas	274	153.8	66.3	74	16	0	0	0
Uzgen	380	270	200	31	0	5.8	5.2	4.7
Total	**970.4**	**968.9**	**592.4**	**201.2**	**70.1**	**72.7**	**26.7**	**32.4**

Source: Thorpe et al. (2009).

The Chui/Frunze facilities were consolidated (by merging some of the 50+ ponds) and sold off to private investors in 1993. The main beneficiary was Balykchy (Director: K. Ryspaev), which acquired 40 ponds covering around 300 ha – comprising 13 nursery ponds, 4 ponds of broodstock, 12 ponds for rearing/spawning and 11 commercial ponds – and the hatchery facilities. It remains wedded to producing common, grass and silver carp and has an incubation capacity of 10 million fish eggs of each species. In 2009, it employed 24 people, supplemented by an extra 8–10 employees during the peak season, and produced 6 million common carp eggs and 5 million eggs of grass and silver carp apiece. Production in 2009 was of the order of 18 tonnes of consumption-size fish, with revenues further supplemented by the sale of fingerlings at the farm gate to local pond culturalists.

The Talas facilities remained in public hands (Director: O. Dyushebaev) but suffered severely from a lack of investment and a break-down in marketing channels post-

40 One problem with the seeding/stocking strategies, as practiced locally, was that the imprecision of the release process also led to more harmful invasive species – such as the stone mooko, the eleotris, the sawbelly, the bitterling and the Amur goby – being inadvertently released into the targeted waterbody at the same time.

independence, production dwindling to near zero by the millennium. A lack of investment capital to renovate the farm equipment and repair the ponds persists and, while the enterprise has produced growing commercial quantities of fish in recent years (29.5 tonnes harvested in 2007), the majority of its pond area (61 percent; 220 of 360 ha) is rented out to private pond culturalists. Employment is similarly low, with three fulltime and six seasonal staff employed in the last production cycle.

Uzgen, which also remains in state hands (Director: A. Ershatov) has completely forsaken fish production in recent years in favour of rice production. In 2008/09, 90 of its 290 ha of ponds were dedicated to producing (350 t) of rice, given its greater per hectare profitability. Research suggests that only with greater state financial support – in particular, the construction of a feed plant – will cyprinid production become commercially viable. Presently the enterprise employs three fulltime and seven seasonal workers.

The Karakol and Grigorievka facilities on Lake Issyk Kul were both privatized. Karakol became Karakolbalygy Ltd (Director: E. Alamanov), and production activities are now purely centred round the village of Beru-Bash. Here 16 ponds encompassing 50 ha have been constructed for carp culture. A nearby hatchery incubates carp, peled and European whitefish eggs, with the peled and whitefish fingerlings raised being released into Issyk Kul, Son Kul and the Orto-Tokoi Reservoir, and carp fingerlings either being sold to farms in the region or destined for the company's fattening ponds. In the 2009/10 reproduction cycle, 3 million carp and 7.5 million whitefish were incubated (1.3 million whitefish fingerlings were subsequently released into Orto-Tokoi and 2.63 million into Issyk Kul). The operation is much reduced from its Soviet heyday, as the second historic site of Karakol's operations, a large hatchery capable of incubating 20 million whitefish eggs based upstream on the Karakol River, was sold off to investors in 2004 and subsequently ceased culture-based operations. Grigorievka Fish Factory became Balykchylar Ltd (Director: D. Kabataev), and although historically more oriented to fish processing, does have some culture facilities. The enterprise currently employs five people, and its hatchery capacity is around 500 000 eggs. Historically, around 300 000 fingerlings of Issyk Kul trout were introduced annually into Lake Issyk Kul, although this species has not been cultured in the last two years. For 2010, however, the plan is to incubate 200 000 Issyk Kul trout eggs for subsequent re-introduction as fingerlings into the lake, and to this end the company was granted a permit to capture 130 female (spawning) and 36 male broodstock from the lake between 20 September and 31 December 2010[41]. The enterprise has also branched out, importing rainbow trout eggs from Denmark (the fishmeal is imported from Finland and Holland) which have been incubated, fattened in ponds and then sold to a number of local trout farms with whom the company has recently signed contractual agreements (including Restbase Trout Farm – see following Section).

41 Both these enterprises, along with four other private enterprises (Dolon Ltd, Elemena-Kol, Telim Ltd and Darkhan Ltd) and the biological research station at Chopon Alta were licensed to capture broodstock from the lake. However, while none of these other enterprises presently exercise this option, Dolon Ltd (Director: T. Chukunov) has rented a reservoir in Tyup for the purpose of carp pond culture.

BOX 2

INTRODUCTION AND STOCKING IN THE USSR

The history of stocking practices in the former USSR was closely connected with the development of fish acclimatization activities. This work was coordinated by the Central Board of Acclimatization and Production of the Central Fisheries Directorate of the Ministry for Fisheries of the USSR, with biological work relating to introductions carried out under the aegis of the Consultation Council on acclimatization of the Ichthyologic Commission of the All-Union Ministry of Fisheries. Under Soviet law (*On the Rules of Implementation of Acclimatization and Stocking of Fishes and Other Aquatic Organisms in Waterbodies in the Russian Federation*, see www.lawrussia.ru), the acclimatization of aquatic organisms is viewed as:

"*a biological and biotechnological process which includes transmission of species from one group of waterbodies, regions and countries to another group, where earlier they were not present [or had fully disappeared] in order to ensure their full or part naturalization, and/or to enhance a fisheries importance and/or fish productivity [whether it be for commercial capture, recreational, or culture based]".*

Introductions were viewed as successful if the introduced species formed self-reproducing populations and by the late 1970s, annual USSR production of introduced fishes was on the order of 35 000 tonnes – with the share of introduced fish in the total catch being high in most cases. In contrast, partial introduction (i.e. the introduction of Chinese carps into the ASDB) referred to those instances where reproduction required continued cultivation of the species in artificial conditions in hatcheries. In such cases, stocking was:

"*.. a particular case of partial acclimatization, consisting of the regular release of young fish into a particular waterbody for fattening (and subsequent capture)"*

Thus, in the Soviet period, stocking was often conducted together with introductions, and saw the introduction of either larvae, fingerlings or yearlings of one or more fish species into a waterbody where they had existed historically but had disappeared due to anthropogenic or natural reasons or had never been present.

In Central Asia (zone 5 of the five culture-based fisheries zones identified by the Soviet authorities), the main species recommended for stocking – based upon the duration of the growing period (i.e. number of days with water temperature above 10 °C and the sum of average daily temperatures) were: cyprinids (common carp and herbivorous Chinese carps), coregonids – (*Coregonus peled*, *C. nasus*, *C. muksun*, and *C. albula*) and salmonids (rainbow and Sevan trout).

Ton Hatchery (Director: S. Imanaliev) remained in state hands, and unlike both Talas and Uzgen, wages, fuel and other production costs are funded directly from the state budget. Employment increases to around 33 workers during the spawning season, with the employment of around 20 temporary workers augmenting the permanent staff of 13 (including three fisheries specialists). The hatchery has six ponds stretching across 15 ha. While its activities have been severely circumscribed in recent times it released 1.9 million fingerlings into Lake Issyk Kul in the middle of the last decade, barely 20 percent of the numbers released in the period immediately prior to independence. More recently, it has been supplying rainbow trout on a contractual basis to the newly established cage-aquaculture firm Ekos International (See Section 3), based on the southern shores of the lake. In 2009 the hatchery was upgraded with the help of the Turkish International Cooperation Agency (TICA), receiving new incubation facilities for carp, European whitefish, peled and trout, a standby generator and associated equipment, while technical staff benefitted from attending a training workshop in Turkey the same year. In the same year, 102 000 Issyk Kul trout fingerlings were released into the lake of the same name, and 840 000 carp fingerlings were deposited into the enterprise's own fattening ponds.

The 2010 reproduction cycle saw 900 000 Issyk Kul trout, 600 000 European whitefish and 500 000 rainbow trout eggs (the latter under contract to Abyl peasantry group – see next section) incubated in the hatchery's installations.

Recent stocking experiences

Although recent legislation (most particularly, the *2008–2012 Fisheries and Aquaculture Development and Management Strategy*) and the reduction of tariffs on fish-breeding equipment and commercial fish feed imports[42] have provided a conducive environment for the restoration of culture-based fisheries, the private nature of much of this enterprise, allied to a state that can only weakly monitor production activities, ensures that there is only limited information available on ongoing stocking experiences.

One positive example of contemporary stocking for which information is available relates to Kara-Suu Lake, a waterbody of 3.82 km^2 located close to Toktogul Reservoir (Jalal Abad District) in the river valley of the same name. The endemic species in the lake include the Sattar snowtrout, the Severtsov osman and the grey and Tibetan stone loaches. However, as the adult osman, the dominant species, was susceptible to ligulosis (a metazoan parasitic disease), the waterbody's commercial fishery was limited to Sattar snowtrout catches averaging around 2 tonnes per annum. This prompted CAPAS to introduce peled fingerlings into the lake in the 1980s. A total of 510 000 fingerlings were purchased at a total cost of 153 000 Kyrgyz soms (US$3 272) from incubation nurseries at Karakol and Ton at prices ranging from 500–800 Kyrgyz soms (US$10.6–17.1) per thousand fingerlings and transported to the lake (at an estimated cost of 10 000 Kyrgyz soms), where they were then released. The mature peled were harvested by contracted fishers over a period of five months (at a cost of 45 000 Kyrgyz soms), and the 10 tonnes landed was sold at a price of 60 soms a kg (US$1.3). After covering rental costs of the lake (15 000 soms), the lessee was left with a pretax operating profit of 377 000 Kyrgyz soms (around 200 000 soms [about US$4 278] after deducting taxes, amortization of boats and nets used in the enterprise, and other incidental expenses). The project provided an employment/income source (not full-time) for 20 persons over the year, contributing to local food security in Kara Kul and Toktugul, as the fish was sold locally in markets, cafes and canteens.

Profitable opportunities for new private culture fisheries based on internal market demand have also emerged in the last decade. In 2000, the Restbase Trout Farm (Director: A. Kutushev) opened on the outskirts of Bishkek. The farm consists of 10 raceways – eight for breeding fish of a commercial value and two for breeding fingerlings – and three water storage ponds. Using raceway farming techniques, the farm grew steadily to produce around 20 tonnes *per annum* (around 2 tonnes of fish per chute) over a five year period. Imported eggs from Denmark are incubated under contract at Balykchylar Ltd and transported back to the farm in special containers as fingerlings. Fed with imported feed by six permanent staff, the mature fish are either caught under licence by visitors (and are then prepared, cooked and served on site according to the visitors wishes – at around KGS400/kg), sold wholesale to cafes and restaurants in Bishkek or exported to Kazakhstan. Research suggests that, given the pristine, fast-flowing river waters across much of Kyrgyzstan, there is currently further unexploited potential for expanded raceway production of trout and related species in the republic. There is, however, a

42 Imported fishmeal with certificated "origin of goods" documentation is liable to incur taxes of 12.15 percent (12 percent Value Added Tax (VAT), 0.15 percent customs charges) upon import – as opposed to 47.15 percent (including 35 percent customs duty) when the feed lacks such certification. This measure was welcomed, as Kyrgyz aquaculturalists have remained cautious about using locally produced feeds after a feed mix containing cotton oil that was experimentally applied in a number of fattening ponds resulted in a high incidence of fish mortality (Thorpe *et al*., 2009:11).

question as to the buoyancy of local demand for the product. While the fish was retailing at around KGS500 Kyrgyz soms per kg (US$10.6) across Bishkek in the middle of the last decade, current prices – following the establishment of Restbase, Ecos International (see below) and other enterprises – are less than half that (250 soms – about US$5.30).

The most significant new culture production enterprise to emerge in the last few years is Ecos International (Director: O. Beishembaev). Based at Koltsovka Bay on the southern shore of Lake Issyk Kul, the company imports eggs from Denmark, and latterly, Finland, the United Kingdom and the United States of America (feed is Royal a brand for rainbow trout produced by the Finnish company Raisio Feed Ltd. In its first year of operations (2006), a six-month contract was signed with the state hatchery at Ton for incubation and hatching of the eggs. After the fry had grown into fingerlings of around 7 g, the company then transferred the fish into four newly constructed cages on the southern shores of Issyk Kul. Expansion was rapid. The company has increased the number of cages to eight (two for nursing its own fingerlings) and harvested 21.3 tonnes in the first six months of 2010. Output is sold in Bishkek, at cafes and tourist complexes in the Issyk Kul region, and part of the output is purchased by the gold-mining company for distribution to its workforce.

The success of Ecos encouraged other companies to start raising trout on the southern shores of the lake. These included Aqua-Da Ltd (Director: U. Mamyrov), which has two cages sited in Ton Bay; Aquafond-K Ltd (Director: O. Dosaev), with eight cages in Ordok-Uchpas Bay; GoldFish Ltd (Director: Ch. Jumaliev), one cage in Pokrovka Bay; and Abyl Peasantry (Director: D. Dyusheev), with four cages. Although lake production has risen sharply (Table 20) since Ecos opened its facilities in 2006, there is some question over the reliability of the statistical data reported to the Fisheries Department[43].

TABLE 20
Rainbow trout production on Issyk Kul Lake (t), 2006–2010

	2006	2007	2008	2009	2010 (first six months)
Output	3.1	53.0	22.6	33.5	24.1

Source: National consultant's field research.

Problems facing culture-based fisheries in Kyrgyzstan

Capture fisheries in Issyk Kul ensured Kyrgyzstan was one of the major fish-producing countries in the Central Asian region until the 1970s. After this, lake capture fisheries were displaced – in output terms – by a growing cyprinid pond culture centred on a handful of state institutions. Critically, these were funded by the All Union Ministry of Fisheries in Moscow. When funding ceased, so did much of the production, recorded production collapsing to just 48 tonnes in the middle of the last decade. Rehabilitation of the fisheries will be no easy task, however, and many of the problems confronting Krygyz culture-based fisheries are found elsewhere in the region too. These include:

A. The water deficit

In Kyrgyzstan, the majority of reservoirs were constructed for either energy supply and/ or irrigation needs and the demands of these sectors dictate when, and how much, waters

43 As the cages commonly employed in Kyrgyz aquaculture are capable of producing between 30–70 tonne of rainbow trout each year, if all the above identified companies were working at just 80 percent of production capacity and were using the smaller-size cage (30 tonne production capacity each), then expected production levels would be on the order of 500 tonne *per annum*.

are released. In the summer, many reservoirs run low due to agricultural demands; with potentially fatal consequences for any meaningful culture-based fisheries production in the waterbody, as fish, released larvae and food sources are swept downstream. Although the Fisheries Department and the Water Resources Department are housed in the same ministry (MAWPRI), concordance on a water release strategy has not always been forthcoming.

B. Limited natural food reserves

Research shows that the food requirements of a relatively intensive programme of culture-based production are likely to exceed the natural fish "food reserves" in the majority of the country's waterbodies. This is especially true in the case of the higher altitude waterbodies, where the colder climate tends to prolong maturation (particularly for thermophilic fish) and restrict phytoplankton growth. While this can be ameliorated by importing/production of supplementary feeds in-country (notwithstanding the local concerns we have noted) and/or modifying stocking strategies (as occurred post-1962 with the introduction of grass carp), a concerted effort to increase production is likely to require that due consideration be given to commercial feed supply.

C. Dilapidated/poor quality production equipment

The lack of maintenance of state culture facilities in the immediate post-independence period was not rectified following the sale of many of these installations to private investors. Private investment in the sector, with limited exceptions, has remained negligible until very recently and, where it has occurred, concerns have been raised about the quality of the materials/equipment introduced, notwithstanding the tariff/taxation changes designed to help the sector. Sarieva *et al.* (2008) suggest that an annual investment of some 2 million Kyrgyz soms (US$55 500) is required to build capacity for fish breeding/biology (and allied to this, that fish stock assessments should be conducted in national waterbodies). In the mid-term, increased investment in the sector is also likely to trigger a demand for training and capacity building that will also need to be addressed.

D. The ability of stocked species to form breeding populations

Scientific research has shown that Kyrgyz waters are generally not conducive for the reproduction of either the silver or grass carp, and so there is a need to maintain broodstock, hatch eggs and raise larvae in captive conditions. Equally, past stocking experiences have shown (as in the case of Son Kul and the stocking of osman and carp therein) that certain species are unable to reproduce or thrive in particular waterbodies, so repeated seeding/stocking is necessary if production levels are to be maintained.

E. Information and statistical shortcomings

Much of the historical data/statistics on culture and capture production in the country were lost during the eight institutional reorganizations affecting the sector and its operations in the immediate post-independence period. While the institutional situation has been stabilized and thence consolidated in recent years under the aegis of the current Director of Fisheries (D. Dogochiev) and his predecessor (B. Baitemirov), there are still marked statistical shortcomings. These relate specifically to the nature of much private culture-based activity and the fear that tax liabilities and commercial competition would be increased were commercial data on catches, stocking activities, revenues, input costs and the like be disclosed.

F. *Regulation of activities*

Presently there is little regulation of the activities of new private entrants into the culture-based fisheries sector, although this failing is slated for rectification under the *2008–2012 Strategy for Fisheries and Aquaculture Sector Development and Management in the Kyrgyz Republic* (see Box 4, Objective 1.5). The current regulatory vacuum permitted the uncontrolled expansion of cage- culture activity on Lake Issyk Kul and led to inferior equipment being used in such cage-construction (point C above). This prompted the consequent escape of rainbow trout into the lake[44]. Effective support mechanisms for the sector in terms of credit, stocking programme guidelines, Environmental Impact Assessments (EIA) for aquaculture and training programmes are also currently conspicuous by their absence.

UZBEKISTAN

Historical Background

In the former SSR of Uzbekistan, two institutionally independent branches of the All-Union Ministry of Fisheries were created to deal with fisheries issues in the early 1960s: local fish production matters were dealt with by the State Committee of Fisheries, while fisheries resource protection was the remit of Uzbekribvod. The State Committee of Fisheries of Uzbekistan[45] was responsible for fish production and the processing of fish produced in the republic. All waterbodies and their fish stocks belonged to the state, and all enterprises involved in fishing, aquaculture, processing, trade, production of equipment, commercial feeds, research, engineering and construction were the responsibility of the State Committee. The committee in turn reported to the All-Union Ministry for Fisheries – a move that meant financing the establishment of new enterprises (both fish capture and culture) and their respective budgets were determined within the framework of the budget of the All-Union Fisheries Ministry. Uzbekribvod (the Uzbek Commission of Fish Resources and Fish Reproduction Protection) had separate divisions for fish inspection, fish reproduction and fish stocks monitoring, and water quality monitoring, and had offices across the country. It was a powerful organization that could fine or even close any factory or enterprise which polluted water and/or undertook any activity that negatively impacted upon fish reproduction and fish stocks. Uzbekribvod was responsible for enforcing all-union standards on fish protection ("regulations on fish capture") in the Aral Sea basin, and all stocking programmes had to be agreed with this organization in advance.

Prior to 1961, the only fish available on the internal market was caught, mainly from the Aral Sea where state and private fisheries units/cooperatives were operating. The landlocked Aral Sea was rich in fish species, and Uzbekistan captured on average around 25 000 tonnes of fish annually, with another 20 000 tonnes captured in the neighbouring SSR of Kazakhstan (Tleuov, 1981; Karimov and Razakov, 1990).

44 Accidental escapes have decimated local indigenous fish populations along the southern shore and caused the Biologic-Soil Institute of the National Academy of Sciences of the Kyrgyz Republic to recommend that only culture production of local indigenous species (including carp and European whitefish) be permitted on the lake. A meeting on 15 July 2010 in Bishkek, attended by government and agricultural ministry staff, agreed to conduct a comprehensive review of the effect of cage escapees upon the lake fauna – and to prohibit commercial cage breeding if evidence suggested the effect was prejudicial to the local ecosystem.

45 The State Committee was established following the upgrading of the State Fisheries Department (housed within the Ministry of Agriculture).

However, the desiccation of the Aral Sea and its deltas (see Thorpe and Van Anrooy, 2009b) significantly diminished the area of lakes and wetlands. Between 1960 and 1980, the area of lakes in the Amu-darya Delta fell from 49 000 to 8 000 km^2, with the area of reed beds shrinking from 500 000 ha to around 1 000 ha over the period 1965–1986 (Micklin*,* 2004). As a result, about 500 000 ha of spawning areas and fish migratory routes were destroyed, and fish yields from the sea decreased sharply. The last recorded catch, in 1983, was just 50 tonnes (Kamilov, Karimov and Keyser, 2004).

Over the same period, a number of large waterbodies appeared (see Table 9) fed by the discharge of highly mineralized collector-drainage waters from the cotton fields; the gigantic Arnasay Lake System (ALS) in the middle reaches of the Syr-darya, Lake Sarykamish (to the southwest of the Aral Sea), and Lakes Dengiskul, Ayak-agitma and Karakir, among others, in the middle and lower reaches of the Amu-darya (Tleuov, 1981; Letolle and Mainguet, 1993; Karimov and Razakov, 1990; Kamilov, Marimov and Keyser*,* 2004) . While these waterbodies delivered catches of up to 6 000 tonnes of fish in the 1970s and 1980s, it had already been clear to fisheries managers and specialists of the former USSR a decade earlier that the Aral Sea was dying, and fish capture from these new reservoirs and lakes could not produce enough fish to meet the demands of a rapidly growing population in the Central Asian republics.

The attention of the policy-makers therefore shifted slowly to aquaculture development. In the early 1960s, local governments in cooperation with the All-Union Ministry for Fisheries announced a large-scale fish culture development strategy and proposed the establishment of more than 20 fish culture farms (with a total pond area of about 25 000 ha) in Central Asia. Most of these farms were established in Uzbekistan and were supported by the introduction of new culture technologies, the creation of local research centres and capacity-building in fisheries education and fish culture techniques[46] – all as part of the same programme. The main emphasis was on the polyculture of cyprinids in large earthen ponds under semi-intensive production conditions, with lime and fertilization liberally applied to promote plankton and plant growth (Karimov *et al*., 2009). By the late 1970s, fish farms in the SSR of Uzbekistan were annually producing 20 000 –25 000 t, local productivity (at 3–3.5 t/ha, up to 4 t/ha in the Tashkent region) was the highest of all the Soviet republics and regular stocking of the republic's waterbodies was an integral part of the programme (see Box 5). Stocking of the ALS with fingerlings, yearlings and two-year-old common and silver carp commenced in 1977 (Igamberdiev *et al.*, 1983) and, by the end of the 1980s, 10–15 million fry and fingerlings of cultured fish (mainly silver, grass and common carp) were being stocked annually into the nation's waterbodies (Aripdjanov, 2006). Almost 50 percent of the total was stocked into the ALS, with a concomitant increase in fish yields (in 1964, 26 tonnes were landed in the ALS; by 1971 this had risen to 512 tonnes and, after the stocking programme commenced (Table 21), fish yields peaked in 1985 at 4 321 tonnes – about 25 kg/ha).

46 The Uzbek Research Institute for Fisheries in Inland Waterbodies was created in the early 1970s as a local counterpart to the All-Union Institute of Pond Fish Culture, and subcontracted culture research to local research institutes in Uzbekistan. Capacity building principally took the form of providing specialist education at the Hydrobiology and Ichthyology Department at Tashkent State University and seconding one or two students a year from Tashkent State University and other institutes to study aquaculture at Moscow research institutes (the students returning to take up posts in the State Committee on Fisheries of Uzbekistan) and special missions from Moscow State University, which collaborated with staff at the Balikchy Fish Farm and other centres (Karimov *et al.,* 2009). Most of the scientists working in the Uzbek fisheries sector had studied at research institutes in either Moscow or Leningrad (St. Petersburg).

Research by Igamberdiev *et al.* (1983[47] calculated that a comprehensive stocking of the republic's waterbodies (Table 22) would increase fish catches (within four years) by up to 11 400 tonnes annually (368 tonnes from water reservoirs, 10 430 tonnes from the ALS and 340 tonnes from other waterbodies), with the share of stocked fish in total fish catches being 6 707 t. However, these recommendations were not fully followed by fisheries managers at the time, and the above hypothesized volumes of fish catches were never achieved.

BOX 5

Extraction of broodstock in Uzbekistan

The Fisheries Board (whose members include representatives from the Fisheries Department, the State Agency for Environmental Protection and Forestry, and the Academy of Sciences) meets annually to identify the stocking volumes needed for the republic's main waterbodies. This in turn determines the volume of permits emitted for broodstock extraction.

In 2007, for example, the board decided to release 3.3 million European whitefish fingerlings into the lake. This required the incubation – allowing for losses – of 5 million eggs. Based on an average whitefish spawning fertility of 10 000 eggs per spawner (in the case of trout, the level is much lower – at 2 000 eggs), this required the extraction of 500 spawners – and 1 000 ml of milt for fertilization – necessitating a total broodstock of 1 500 fish. Fishermen are employed to catch the permitted broodstock and, while four two-man boats could capture the 1 500 broodstock within 20 days in the past, overfishing now means that fishing effort, either by greater fishing capacity (more boats) or fishing time (more days) has to be increased.

Permits (to catch a specified number of broodfish – and to introduce a specified number of fingerlings into a designated waterbody) are assigned to one or more enterprises, and must be exercised during an identified spawning period. In the case of European whitefish, this is generally around November-December. No currency changes hands; the companies are reimbursed for incubation and stocking by being allowed to keep (and sell) the broodstock caught.

TABLE 21

Annual catches from the Arnasay Lake System, 1981–2004

Years	Total fish catch (tonnes/y)	Common carp (percent of catch)	Silver carp (percent of catch)
1981–1985	3 263–4 321	51.2	1.2
1986–1990	2 558–4 300	42.1	1.4
1991–1995	302–2 431	26.9	3.3
1996–2000	1 200–2 984	37.2	0.6
2001–2004	1 245–1 600	18.6	0.0

Source: State Nature Protection Committee of Uzbekistan.

47 They recommended stocking with various sized fingerlings and fry of the main commercial fish species, estimating the commercial returns likely if no stocked fish were caught in the first year, 10 percent of stocked fish were caught after one year, 10 percent (plus 55 percent of fish stocked the preceding year) were harvested in the second year and, after three years, 10 percent (plus 55 percent of the second year stocked fish plus 25 percent of the first year stocked fish) were to be caught.

TABLE 22
Recommended stocking measures for the waterbodies of Uzbekistan

Fish Species	Amount of young fish to be stocked annually, thousands					
	With body mass 40 g	With body mass 100 g	With body mass 25 g	With body mass 10 g	With body mass 0.02 g	Total
Silver carp	1 711	5 880				**7 591**
Bighead carp	1 564	927				**2 491**
Common carp			6 291			**6 291**
Sevan Trout				800		**800**
Peled					500	**500**
Buffalo			7 665			**7 665**
Total	**3 275**	**6 807**	**13 956**	**800**	**500**	**25 338**

Source: Igamberdiev et al. (1983).

A number of fish species from outside the region were introduced into the irrigation water systems of Central Asia during the period 1960–1990. Pike-perch 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, bighead carp, grass carp, and Amur snakehead from the Far East (Box 6) were stocked in fish farms in the Tashkent area, and the hatchery-produced stocking material from there was regularly released into lakes and reservoirs of the Aral Sea drainage basin (ASDB) (Salikhov and Vundzettel, 1986). Three species of buffalo fish, were also introduced into the country by fish farms, but were not released into the river systems. In contrast, the introduced channel catfish entered the Syr-darya basin, and rainbow trout, Sevan trout peled and sardine cisco were subsequently released into the Charvak Reservoir in the Tashkent region, where they are now established[48]. Phytophagous fishes (Chinese carps) from the Far East were also introduced into the inland waters of the ASDB about this time (see Box 6). A number of accidental introductions displaced indigenous species (e.g. sharpbelly, which displaced the indigenous Tashkent riffle bleak, which can now only be found in mountainous waterbodies like Charvak Reservoir – although even in these mountain lakes it is under threat from the sharpbelly (Khurshut, 2006a).

48 Although Karimov *et al.* (2009) note that experimental work suggested that certain areas of Uzbekistan were suitable for the culture of channel catfish, sturgeon and trout during the 1980s, these opportunities, save for the establishment of the small Tavaqsay Trout Farm which has operated since the 1970s and the development of cage culture, were ignored by the central authorities in favour of expanded cyprinid culture.

BOX 6

Chinese carps in Central Asia

During the late 1960s, Soviet scientists suggested that the ecological niche for herbivorous fishes in the ASDB and other waterways in the region was not fully occupied. As a result, artificially reproduced fry of Chinese herbivorous carps (silver carp, bighead carp and grass carp) were introduced (often on an annual basis) in lakes used for residual water storage, reservoirs and drainage channels in the Central Asian region.

The cycle between stocking and capture of Chinese carps is generally two to three years. During the first year, small fry would be raised from late March to October-November in fingerling ponds (10–50 ha in size) to a size of around 25 g. After wintering in these ponds, they would be transferred to fattening ponds (70–150 ha) the following spring, growing to a marketable size of 0.5–1 kg. Stocking densities of yearlings are between 1500–2 000 fish/ha. Some farms stock at higher densities (3 000–4 000 fish ha^{-1}), a procedure that extends the reproduction cycle to three years but produces heavier fish (1.5–3 kg). Forage (or inorganic fertilizers), as necessary, is added to ponds in the summer (5 kg of forage producing around 1 kg of fish).

In Uzbekistan, Chinese carps have proved to be very adaptive, especially in major irrigation canals (Karakum) and reservoirs, and in some main canals and lakes, and even in the Syrdarya and Amu-darya rivers self-reproducing stocks were established (Petr, 1995; Kamilov and Urchinov, 1995). As a result, in the main capture waterbodies housing these species, productivity increased from 10–15 to 20–27 kg ha^{-1}.

The development of a capture and culture-based fishery with stocking practices was stimulated after the Central Committee of the Communist Party of the Uzbek SSR enacted Decree No.928 in 1982 designed to increase fish capture volumes in the Zhizak region. Here, a special culture-based fisheries enterprise – Fisheries Production Agglomerate Zhizak – had been created on the shores of lakes Aydar and Tuzkan in 1976. Research undertaken by the Institute of Zoology and the Uzbek Fisheries Research Institute discovered the existence of large underexploited volumes of fish food resources in the ALS, and this led them to recommend the annual stocking of the ALS with fingerlings of silver carp (2.5–3 million), grass carp (1.5–2 million), common carp (3–4 million) and bighead carp (1 million). According to the institute's prognosis, these stocking measures could, after three to four years, increase fish yields to around 12 000 tonnes annually. Although these recommendations were accepted by the State Committee on Fisheries of Uzbekistan (and subsequently, its successor, Uzryba), they did not follow them fully.

BOX 7

The Yangiyul State Fish Hatchery

The Yangiyul State Fish Hatchery, located in Tashkent Province southeast of Yangiyul town, was established in 1975. The hatchery has 370 ha, 248 ha of which are given over to 84 ponds (72 nursery and 12 broodstock ponds). Breeding and rearing are undertaken mainly for three species (common, silver and grass carp), and the farm also conducted research on fish pathogens/fish health. While the production potential is 15 million yearlings, present production is only about 2 million yearlings and 50 million larvae. The yearlings, ranging in size from 6 to 12 cm and in weight from 20 to 70 g, are sold for UZS10 000 (around US$6.7) per kg for silver carp and UZS12 500 (US$8.33) per kg for common carp and grass carp. Larvae are sold in bags of 100 000 larvae for UZS100 000 (US$66.67) per bag, including the price of the bag. Following independence, the hatchery fell under the operational remit of the Fish Culture and Development Center (FCDC) of the Ministry of Agriculture and Water Resources (MAWR). However, as it was unable to produce to capacity during this period, in 2010 it was leased to the Balikchy farm company (owned by Tashinvest) for a period of 49 years.

Fry, and sometimes fingerlings, of silver carp, bighead carp, grass carp and common carp were also produced in the Yangiyul State Hatchery (see Box 7) and Balikchy Fish Farm (both located in the Tashkent region) and some other regional fish farms – and these provided larvae for aquaculture programmes developed in many of the other Soviet republics. Norms for stocking were recommended by the state research institutes (the activity was financed from the state budget) and commercial returns – in terms of caught fish over several years[49] – were established. As we have seen, the stocking activities were rather successful in the Aydar-Arnasay Lake system and the lakes in the Lower Amu-darya, where special culture-based enterprises were created. Some stocking activities were less successful in Russia (commercial returns < 0.1 percent), particularly in the Tsimlyanskoe and Kakhovskoe water reservoirs, due to pike-perch predation. In the latter cases, it was therefore recommended to instead stock with two-year-old fishes (body mass of 200–400 g), so as to raise returns to 4–4.5 percent (Negonovskaya *et al*., 1980).

After Uzbekistan proclaimed independence in 1991, there was significant structural change in the sector. One of the first changes was the closure of Uzbekribvod. Fisheries protection functions were transferred to the newly organized State Committee of Nature Protection and its Special Commission of Biologic Resources Control – GosBioKontrol. Following Decree No. 427 of 18.08.1994 (*On the Establishment of the Corporation Uzryb*a), partial privatization of the sector occurred. Enterprises could now be legally established within the sector as joint-stock companies, with 30 percent of shares destined for a state holding company (Uzryba), 55 percent held under the collective ownership of the employees and the remaining 15 percent by private investors.

As state funding to the sector ceased after 1993, stocking activities were cut back sharply. During the peak years of the 1980s, about 10–15 million larvae, fry and fingerlings had been stocked annually – half of these into the ALS lakes (Aripdjanov, 2006). Stocking volumes were now much less than during soviet times (Table 23), with from 3.9 to 5.48 million fry stocked annually over the period 2004–2009, more than half of which was introduced into the Todakol Reservoir by the private company JV Aqua-Todakul. In 2009, only 1 million fry were released into the waterbodies of the Bukhara region and Karakalpakstan, and just 228 000 fingerlings into the ALS[50].

49 These were: 0.1 percent from larvae stocked, 1–2 percent from fry, 2–5 percent from fingerlings and 5–8 percent from yearlings. For sturgeon, the commercial norm was 3 percent, and for salmonids, 4–10 percent.

50 The species structure of the stocked fish over this period is unknown.

TABLE 23
Stocking volumes in Uzbekistan, 1992–2009 (millions of fry)

	Fish species		
Year	Common carp	Silver and bighead carps	Total
1992	5.1	4.9	10
1993	4.3	3.2	7.5
1994	2.0	0	2.0
1995	N/K	N/K	N/K
1996	6 (larvae)	1.7	7.7
1997	2.7	2.0	4.7
1998	1.7	2.8	4.5
1999	0.6	2.0	2.6
2000	N/K	N/K	N/K
2001	1.0	1.5	2.5
2002	1.6	4.9	6.5
2003	N/K	N/K	N/K
2004	N/K	N/K	3.9 (3.8)
2005	N/K	N/K	N/K
2006	N/K	N/K	3.4 (3.19)
2007	N/K	N/K	2.3 (1.32)
2008	N/K	N/K	N/K (2.49)
2009	N/K	N/K	5.5 (1.6)

**N/K – Not Known.*

Note: Figures in parentheses (total column) refer to the number of fish stocked into Todakul Reservoir by JV Aqua-Todakul.

Source: Uzryba and GosBioKontrol.

On 6 July 2001, under Decree No. 289 (*On the Improvement of the System of the Fishery Sector Management*), the state holding company Uzryba became Uzbalyck. Uzbalyck had 28 enterprises under its wings, including Karakalpakbalyk (an association of 27 small capture fisheries farms in the Autonomous Republic of Karakalpakstan), although trade union participation, present in Uzryba, was absent from the new company. The new law also saw Uzbalyck's share in joint-venture operations scaled-back to 25 percent (in comparison, private entrepreneurs could now hold 65 percent of the stock, and employees just 10 percent). Barely two years later, direct state involvement in culture-fisheries production effectively ended as Decree No. 350 of 13.08.2003 (*On Measures to Remove Monopolies and Privatize the Fisheries Sector*) saw Uzbalyk and Karakalpakbalyk liquidated, and fish-breeding and fish-capture enterprises completely privatized (Karimov *et al.,* 2009). Under this decree, natural waterbodies can be assigned to fishery enterprises on the basis of rental/lease contracts for a period of a minimum of 10 and a maximum of 49 years. This regulation places the onus upon the tenant fish farmer/fishery enterprise to not only commercially exploit the leased waterbody by catching and selling fish at their own discretion, but also to undertake annual stocking of the waterbody, along with any other measures necessary to ensure the integrity and reproduction of fishery resources. These regulations helped inform the more wide-ranging *Programme on Measurements of Fisheries Sector Development in the Republic in 2009–2011* (Decree No. 03/1-348 of 03.03.2009).

The decree also established the Development of Animal Husbandry, Poultry and Fisheries Unit, housed within the Ministry of Agriculture and Water Resources (MAWR), which was entrusted with the responsibility for the further development of fisheries in the country (local offices of the unit being set-up in each of the 12 regional administrations and in Karakalpakstan autonomous territory). However, while the main administrative staff of the Development of Animal Husbandry, Poultry Farming and Fishery unit total 12 officers, just five work on poultry and fisheries – with two persons presently assigned to work on fisheries issues. The development of a Fisheries and Research Centre for Fish Culture Development (FCDC) within the Uzbek Research-Production Centre for Agriculture based in the MAWR was supported by monies received from the sell-off of Uzbalyk's shareholdings under the terms of the decree, while the funds obtained from the rental of natural waterbodies were allocated to supplement the local oblast budget (60 percent of funds realized) or destined for the FCDC (25 percent) or the State Committee on Nature Protection (15 percent).

Although the state, via Decree No. 508 of 28.10.2004 (*Enhancement of Oversight Over the Rational Use of Biological Resources, and their Imports and Exports in the Republic of Uzbekistan*) oversees introduction and stocking practices in the country, since 2003 the stocking of waterbodies is expected to be carried out by the private sector. Yet, to date, private entrepreneurs have not carried out many stocking activities, as fry and fingerlings are either not available or the costs are considered too high (Karimov *et al.,* 2009). The exception to this rule is the joint venture Aqua-Tudakul working at Tudakul Reservoir.

Further legislation affecting the sector includes the self-explanatory Decree No. 1292 of 20.12.2003 *(On the Approval of the Regulation of the Calculation and Levying of Rent Payment for the Use of Natural Waterbodies by Fish Farm*), and Degree No. 1569 of 2.05.2006 *(Hunting and Fish Catching Regulations on the Territory of Uzbekistan).* The latter prohibits commercial fishing on both the Amu-darya and Syr-darya and also in irrigation and overflow channels up to 200 m from fish hatcheries, ponds or other aquaculture areas. The decree also details regulations relating to the extraction of fish from the waterbodies of the republic (e.g. prohibition of fishing in specified waterbodies, mesh-size limits, rules regarding the use of various fishing gears, quotas on the extraction of different types of fish, the prohibition of non-ecological fish-capture methods, etc.) rather than their stocking, however.

Past stocking experiences

Although stocking activities largely date from the last two decades of Soviet rule, efforts to introduce new exotic species into the ASDB date from the end of the 1920s when Caspian shad and starry sturgeon were introduced from the Caspian Sea. These introductions were unsuccessful, as not only did these fishes not naturalize (Karpevich, 1976), but parasites of starry sturgeon roe *Polypodium hydriforme* and gills *Nitzschia sturionis* were passed on to the indigenous fringebarbel sturgeon and caused strong epizootic diseases[51]. Starry sturgeon from the Caspian Sea was again introduced in 1948–1963, but again acclimatization efforts proved unsuccessful (Karpevich, 1975). Other acclimatization experiments also failed, as a series of authors have noted (Tleuov, 1981; Kamilov and Urchinov, 1995; Aladin, Plotnikov and Letolle, 2004; Kamilov, Karimov and Keyser*,* 2004).

One notable success, however, was the introduction (1954–1959) and subsequent acclimatization of Atlantic herring, and by the beginning of 1957 this exotic planktophage appeared in large numbers in local catches. However, a number of non-commercial species, most notably the Caucasian dwarf goby, the Caspian sand goby, the round goby and the big-scale sand smelt, were also introduced accidentally and this increased

51 Indigenous sturgeon did not suffer from these parasites prior to the introduction of the starry sturgeon (Dogiel and Lutta, 1937; Aladin, Plotnikov and Letolle, 2004).

pressure on the zooplankton, causing the number of herring landed to reduce drastically. By the 1960s, the Atlantic herring had largely disappeared from the Aral Sea (Aladin *et al.*, 2004 ; Karimov *et al.,* 2009). The most successful acclimatization was undoubtedly the introduction of Chinese carps (silver carp, bighead carp and grass carp) as mentioned earlier, along with the accidental introduction of two other related species, the black carp and Amur snakehead which became of commercial value in the ASDB (Aladin *et al.,* 2004). These introductions were also ecologically beneficial, as the herbivores removed a large part of the fast-growing aquatic plant biomass, especially reeds from irrigation canals, reducing the need for applying environmentally dangerous (and expensive) herbicides. As a result of intended and accidental acclimatization efforts, the number of fish species in the ASDB increased from 43 to 51, and today there are 73 fish species registered (Kamilov, 1973; Kamilov, Karimov and Keyser*,* 2004; FAO, 2009).

The need to stock waterbodies in the ASDB were first advanced in the mid- 1960s by construction of two artificial hatcheries–one in the Syr-darya Delta[52] and one (Nukus) in the Amu-darya Delta – to compensate for the reduced stock biotas in the basin. The Nukus Fish Hatchery was established in 1974, a decade after Volodkin's recommendations, close to the city of that name in the Karakalpakstan Autonomous Republic. It was equipped with a powerful pumping station and good quality large and deep fish ponds for breeding Spiny sturgeon and Aral barbel. However, these migratory fish species were never bred at this farm, which was instead turned over to the production of cyprinid fishes for stocking lakes. Unfortunately, the hatchery only functioned for a few years before being closed down. The principal problem was that the bottoms of the ponds were never lined, and consisted of very permeable sandy soil, which resulted in the fast filtration of water entering the ponds into the underground water table. This was compounded by low water levels in the hatchery's sole water source – the Kyzketgen Irrigation Canal, resulting in very high pumping costs. These two factors saw the farm ultimately declared uneconomic, and shut-down. By 2008, the pumping station was in ruins and 95 percent of the ponds were silted up (Figures 9 and 10).

FIGURE 9
Ruins of water pumping station
Photo by B. Karimov

52 Kambasbalyk Fish Farm and the Kosjar Fish Hatchery were established in response to Volodkin's recommendations in 1966 on Lake Kamyshlybas in the Syrdarya Delta in what is now Western Kazakhstan. Covering an area of 176 ha, it released common, silver and grass carp fingerlings into the lake and other waterbodies in the region.

FIGURE 10

Old fish pond fed by groundwater in the territory of Nukus Fish Farm in 2008

Photo by B. Karimov

The Muynak Fish Farm was established in 1979 at Porlatau village in the Amu-darya Delta and tasked with breeding and acclimatizing common and Chinese carps for use as stocking material in the lakes of the Amu-darya Delta. The only fully operative fishery enterprise in Karakalpakstan, it produced both stocking material and marketable table fish from its broodstock and nursery ponds of about 150 ha. A small part of the produced fish was destined for use in the Muynak Fish Canning Factory.

A number of factors conspired to ensure the farm never reached the capacity intended (50 million fry/larvae/y). First, the shortage of water in the Amu-darya only permitted part of the hatchery and its fattening ponds to be used. Second, the large size of the fattening ponds attracted flocks of cormorants which consumed a large portion of the fish cultivated. Other factors included the low quality of aquaculture activities (due to the poor education of the workforce in cultivation techniques) and the lack of modern fishery equipment. As a consequence, productivity in the ponds was only on the order of about 1 000 kg/ha (compared to 2 760–3 730 kg/ha in other fish farms across the Republic of Uzbekistan) and, by 1990, just 459 tonnes of table fish were produced. In 1996, the farm ceased production, principally due to the sharp water deficit, and a decade later, the fish farm and its offices and laboratories had been reduced to ruins (see Figure 11).

FIGURE 11

Ruins of the Muynak Fish Farm in the village of Porlatau on the Amu-darya River Delta in Karakalpakstan

Photo by B. Karimov

A more recent project was the 1999 Lake Sudochye Wetlands Restoration Project funded by the Global Environment Facility (GEF)/World Bank. Intended to restore the Lake Sudochye Wetlands area (water surface 52 000 ha) in the north-western part of the Amu-darya Delta, the emphasis was on conserving important and highly endangered biodiversity, improving socio-economic conditions in the area (by supporting grazing, fishing, muskrat and other wildlife harvesting, and through the improved drainage of farm lands), and improving the regulation of drainage water discharges by installing a major collector canal. One component of the project was to rehabilitate the wetlands fish population's structure and productivity, and to this end (urgent) stocking with common carp, grass carp and silver carp was recommended. Young fish were collected from neighbouring waterbodies and rice fields, and feed organisms (*Caspiohydrobia, Theodoxus* and *Cerastoderma*) from Lake Sarykamish for release into the wetlands, as the development of local culture-based fisheries was planned. However, as further research suggested that the project could not create a sustainable and economically feasible culture-based fishery in the wetlands of Sudochye, these plans were shelved and fish stocking into the wetland has ceased, despite fish yields in the lake system remaining very low.

Even more recent (unsuccessful) culture-based production experiences date from 2006–2007, when a number of private companies conducted small-scale stocking activities on the Talimardjan (Kashkadarya region) and Kattakurgan (Samarkand region) reservoirs. Small hatcheries were established in 2006 and stocking with fry of common, silver, and grass carp commenced in 2007. One of these enterprises, the 920 ha Navruz Fish Farm at Kattakurgan, introduced about 10 million fry of common carp in 2008 (and about 2 million in 2007) into the Kattakurgan Reservoir. However, in both years the return to the company was minimal, as the reservoir's waters were almost fully exploited for irrigation, and so the local population caught/collected the majority of the fingerlings from the almost dried-out waterbody to feed to their chickens and other domestic animals (Mr Muhammadiev, Proprietor of the Navruz Fish Farm, personal communication).

Current stocking activities

Recent revitalization of the sector can be traced to the 2007/8 FAO TCP/UZB/3103(D)[53] Project which convened stakeholders from across the sector to produce a *Draft Concept for the Development of Aquaculture and Fisheries in Uzbekistan (2008–2016)*, a draft which was approved by the Committee for Agrarian, Water-Management and Ecological Issues of the Legislative Chamber of Oliy Majlis (Parliament) of the Republic of Uzbekistan on 18 December 2008. This confirmed the potential social and economic importance of the sector and prompted the Cabinet of Ministers of the Republic of Uzbekistan to develop Decree No. 03/1-348 (*The Program on Measurements of Fisheries Sector Development in the Republic in 2009–2011*) which was signed into law by the Prime Minister of the Republic on 3 March 2009. The immediate target was to increase production of fish to 3 000 tonnes by 2011, primarily through the rehabilitation of existing capacities of fish farms (Table 24), although the decree was silent on improving education and research in the aquaculture sector.

This new legislation, recognizing as it did the commercial attractiveness of the sector, encouraged the formation/registration of new culture farms across the republic. At the time of independence in 1991, statistics suggest the sector covered 20 000 ha of ponds split across 18 farms. Although the number had increased slightly (to 21) by 2007, the corresponding pond area in use had shrunk by 49 percent to 10 237 ha (Karimov *et al.,* 2009). Just two years later (mid-2009), the stimulus of the new legislation led to the number of registered fish farmers rising to 700 (data of FCDC MAWR), although the majority of these enterprises are small and produce less than one tonne *per annum*. Moreover, most of these newly established farms either only catch fish or practice culture-based fisheries by introducing Chinese carps and common carp fingerlings into their ponds and have not yet started to culture fish.

53 This FAO Technical Cooperation Programme (TCP) project was entitled *Development of Strategic Partnerships in Support of Responsible Fisheries and Aquaculture Development in Uzbekistan.*

Research by Karimov *et al.* (2009) identifies 107 farms (Table 24) each currently producing more than one tonne annually. These cover a surface area of 12 630 ha (1 698 ha of nursery and 10 392 ha of fattening/grow-out ponds) and employ 416 full-time staff, with the majority of the farms located in the provinces of Tashkent, Samarqand and Andijan. Aquaculture production in 2009 was 5 162 t, slightly less than the expected projected production of 5 550 t, with 3 858 tonnes (74.7 percent) of this coming from six establishments set-up in the Soviet era (Balykchi, Khorezmbalykmahsot, Andijanbalyk, Damachi Balyk, Namanganbalyk and Kashkadaryabalyk).

TABLE 24
Fish culture farms in Uzbekistan in 2009

No.	Province	Name	Year begun	Pond area (ha)			Full time workers	2009 Production (t)
				Total	Grow-out	Nursery		
1	Karakalpakstan	Nukusbalyk Ltd	1974	46	0	46	36	2**
2		Antika Fish	2008	10	9	1		10
3		Khudaybergen Guldaga	2009	9.8				5.3*
4		Atabek	2009	2				2*
5	Andijan	Olimp Koshonasi Ltd	2008	84	74	10		40
6		Andijanbalyk JS	1975	986	894	92		362
7		Zh. Kabilov Sahovati	2009	2				4*
8		U. Mashrabjon	2009	3				6*
9		Asaka Sazan	2009	1.4				4*
10		Abad Yurt Fayzi	2009	5				10*
11		O. Toshboev	2009	3				6*
12		Ok Amur Karp	2009	2				4*
13		Mukarramhon Umidlari	2009	3.3				7*
14		Kora Amur	2009	3				5*
15		R. Razakov	2009	18.3				20*
16		F. Vohidov	2009	4				8*
17	Bukhara	Bukharabalyk Ltd		574	428	146		
18	Kashkadarya	Sof Khavzalar Ltd	2004	90			7	80
19		Kashkadaryabalyk Ltd	1980	409	359	50	32	200
20		Olim Ogli Sherzod	2009	6				4*
21		Achin Baliklari Ltd	2008					7.5
22	Namangan	Namanganbalyk Ltd	1976	800	600	200		226
23		Madaminjon Ota Ltd		90	90	0		
24		Altin aZmin Barakasi	2008	30				14.3*
25		Mashrab Kadir	2008	12				10.8*
26		M. Parpiev	2008	65				70*
27		K. Mingboev	2009	3.5				4*
28		Nodirbek	2009	4,5				2*
29		Ok Amur Royasi	2009	1.5				1.5*
30	Navoi	Beliy Amur	2004	22			2	
31		Aqua-Todakul	2003	128	80	48	120	***/**
32		Turkumbalik Plus	2009	15			3	

33	Samarqand	Ashurota Farm	2008	93.3	68.7	24.6		73
34		Sherali Farm		116.3	59	57.3		20
35		Taidyl AV Farm	2003	93.4	70	23.1	–	50
36		Navruz Fish Farm	1998	10	7	3	13	48.5**
37		O. Dostov	2009	5				5*
38		Abdikadir Polvon	2009	2				2*
39		Ismoilov Ata	2009	2				1.2*
40		Jarkishlok Elita Baliklari	2008	7				5*
41		D. Gozikhanov	2009	2				1.5*
42		Akhun	2009	2				2.5*
43		Churgan	2009	2				2.5*
44		Ok amur Balik	2008	2				2*
45		S.K. Amriddin	2009	2.1				2.5*
46		Khakim Bobo	2009	35				8*
47	Surkhandarya	Azizbobo Farm	2008	34	34	0		8*
48		At-Termizij Farm	2008	34	34	0		8*
49		Abu-Hurairo Farm	2008	32	32	0		8*
50		Jorakul Hasan	2009	17				8*
51		Oktepa Golden Fish Farm	2009	15			2	11*
52		Surkhonbalik Ltd	2010	18	0	18	5	–
53		Chegara Koshin Otryadi	2008	105				5*
54		Undina Gulmohi	2009	50				7*
55	Syr-darya	Syr-daryabalyk Ltd	1985	980	980	0		100
56		Yangierbalyk Ltd	2003	400	400	0	15	140
57		Durgoyakhor Farm	2001	160			5	5
58		Sirdarya IES	2009	4				2*

59	Tashkent	Balykchi JSC	1950	2 573	2351	222		2 200**
60		Ogonek Ltd	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 Balyk Ltd	1940	275	275	0		300
66		T. Mirahmedova	2009	151				20*
67		Intexnol Ltd	2009	150				15
68		Ummon Sahovati	2009	5				5*
69		Yangiyul Fish Nursery	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		Toshkentbalyk Ltd.		133	133	0		16
74		IIV GUIN	2008	63				10*
75		Balik Tayyorlash Business Ltd	2009	53			16	17
76		Delfin	2009	10.4				12
77		Jahongir-Sevara	2009	6.6				4*
78		Tilanboy Bobur	2009	11.2				5*
79		Kaldirgoch	2009	4.8				3*
80		Ahang Abad Pilat Diyor	2009	16				3*
81		Agro-Omad	2009	8.1				4*
82		Eshonhodja Ota	2009	20				3*
83		Saodat Kamolot Sari	2009	11				3*
84		Afgan Urush Katnashcisi	2009	2				1*
85		Islam Global Business	2009	22				15
86		Toytepa Hovuzi	2009	41				10
87		NT Fish Farm	2008	2				25
88		Gulistan Tanga	2009	2				2*
89		Forel Ltd	2008	4				4*
90		R. Saidahmedov	2009	1				2
91		Kh. Akmal Baraka	2009	12.3				1*
92	Ferghana	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		Urai Ltd	2008	334	314	20		30
98		M. Joraev Omad	2009	4.5				7*
99		Sotvoldi Bobo	2009	15.7				20*
100	Khorezm	Khorezmbalykmahsot JSC	1975	1 473	1 112	361	130	570**
101		Sh. Karimboboe Ogli	2009	10				14.4*
102		Shaykh Bobo	2009	2.9				5.4*
103		Rozmat Davlat	2009	1.5				2.9*
104		Kenja Yakutjon	2009	14				8.1*
105		Hodji Saidmurod	2009	35				11.5*
106		Matmurod Bobo	2009	4.7				5.8*
107		Masharip Davron	2009	22.3				8.6*
		TOTAL		**12 630**	**10 932**	**1 698**	**416**	**5 552**

* Planned production volumes (newly established farm).

** These fish farms also/only raise stocking material for waterbodies.

***Fish landings of Aqua-Todakul from Todakul Reservoir are considered to be a "capture" fishery by the authorities and therefore are not included in this table.

Source: FCDC MAWR.

The most successful new aquaculture enterprise in the country is presently Aqua-Todakul, which built a fish nursery on the coast of Tudakul Reservoir in the Zarafshan River Basin (Navoi Oblast)[54], cultivates yearlings of cyprinid fishes, stocks the reservoir and then catches the stocks a few years later.

The company, a joint Uzbek-US[55] venture, dates from 1999 when five small ponds, each with an area of about 5–12 ha (total area 48 ha), were built for the cultivation of grass carp, silver carp and common carp at a cost of around UZS26 million. The operation proved successful, and in 2001 the company built three large fattening ponds (covering 80 ha in area). Currently the company has 14 earthen ponds, five for fry, six for fingerlings and three for table fish (raised table fish had an average weight of about 1–1.3 kg), with a total water surface area of 125 ha. At the start, young fish for stocking purposes were obtained by the natural spawning of common carp in the company's ponds. However, in 2004 the company constructed a modern fish hatchery boasting contemporary Israeli and Russian technologies, and now produces its own seed of common, grass and silver carp. Seed are raised to fingerling size in the ponds, and then the fingerlings are stocked into the reservoir from early August to December (on average about 45 000–55 000 fingerlings of common and silver carp *per annum*)[56]. More recently, the company has purchased a 'closed aquaculture system' (i.e. a recirculation aquaculture system) which allows the early reproduction of silver carp and common carp (8 million larvae per annum) and grass carp (5–6 million *per annum*).

The reason for this significant investment/expansion is almost certainly attributable to the fact that the company received a State Licence in January 2003 granting it a lease over Tudakul Reservoir (21 637 ha) for the next 20 years. That year, reported corporate production was 170 tonnes However, as the growth rate of stocked fish is high (introduced silver carp reaches a body weight of 2.5–4 kg by the end of the second year and grows to reach 5–10 kg by the end of the third), catches have climbed sharply (356 tonnes in 2004, 502 tonnes in 2005 and currently around 1 000 t). This has not only supplied an increased level of fish products to the local population – important for a country with an annual per capita consumption level of 0.5 kg per annum (down sharply from 4.5–5 kg per annum in 1991) – but also provides full-time employment for 120 workers[57]. However, the company has reported problems with poaching on the reservoir. Unlicensed fishers using cheap prohibited nets (the net cost is equivalent to the price of one 4–5 kg fish) catch an unknown quantity of fish of all sizes (the company itself returns fish caught of less than 1 kg).

In the last few years a number of new private enterprises have also emerged, acquiring assets and installations of the state, although few details are available upon the nature and scope of their present activities. In 2005, Asia Agro Alliance purchased the assets of the Damachi Fish Farm, rehabilitated the old Soviet physical capital (ponds, hatcheries and the like) and provided working capital in the form of feed (a bran-wheat mix produced

54 Tudakul was constructed in 1953 (Kamilov, 1973), and commercial fish capture in the reservoir started the same year. Until 1994 the reservoir was regularly restocked with Chinese carps, and fish yields were on the order of about 300–400 tonnes per year (13–30 kg ha^{-1}). Stocking ceased in 1994, and fish yields fell to 150 tonnes/year, the 2003 quota for the reservoir being exactly equivalent to this amount.

55 US funds are provided by the Small Enterprise Assistance Fund, a global investment firm focused on providing growth capital and operational support to businesses in emerging markets based in Washington D.C. (see http://www.seaf.com/fund_a_casef.htm). Aqua-Tudakul also holds 26 percent of the shares in Navoiybalicchilik, a joint-stock company that undertakes culture and capture operations in the western part of Lake Aydar.

56 Khurshut (2006b) suggests that in 2004 the estimated total biomass of stocked carp was 679 tonnes.

57 Official data (FCDC MAWR) suggests about 3 200 people are employed within the fisheries sector. However, as Table 23 suggests, there are just 416 full-time workers in the sector.

in-house), fertilizer and finance for raising common, grass and silver carp. In its first year of operation, it harvested 400 tonnes and thence 490 tonnes in 2006. Productivity levels of 2.1 tonnes/ha and a 30–40 percent net profitability rate have been reported, although the new owners to whom the enterprise was sold in the last few years have not been so forthcoming with information on catches and other aspects of the operation. Balikchy Fish Farm, taken over by Tashinvest, has switched from a two-year to a three-year harvesting cycle, to take advantage of the higher prices paid for heavier silver carp on the local market. Karimov *et al.* (2009) also report that the Namangan Fish Farm in the Fergana Valley has adopted similar techniques to that introduced by the Asia Agro Alliance to increase fish production.

More recently, in 2007, the Karakalpak-Russian joint venture Nukusbalik Ltd was established (57.72 percent equity share held by Nukusbalik, 42.28 percent share by Intraflex Ltd), after the Uzbek partner (K. Primbetov) purchased the locale of the old Nukus Fish Hatchery from the state. Using funds supplied by the Russian partner, the hatchery was reconstructed and seed production from their own 300 strong broodstock of common, silver, and grass carp commenced, with the expectation of producing 500 000 fingerlings annually. To this end, the company leased 4 390 ha of Sarykamish Lake and the whole of Dautkol Water Reservoir (a total of around 6 000 ha) for culture-based fishery production. However, stocking the Dautkol Reservoir proved impractical in 2007 and 2008, as a lack of water inflow from the irrigation canal linked to the Amu-darya River saw the waterbody drying out completely. In 2009, there was sufficient water – about 50 million m^3 water accumulated in the reservoir – and the waterbody was stocked with 500 000 fingerlings of common carp (they did not stock silver carp because their broodstock died out due to water shortages in the hatchery's ponds). This was remedied in 2010 by the purchase of silver carp broodstock from the Khorezmbalik Fish Farm at a cost of UZS10 500 per kg (about US$7). One million fry were produced and subsequently introduced into the company's leased waterbodies in 2010, and there is an expectation that the company will commence capturing stocked fish from the reservoir in autumn 2010. This improved production scenario has also led the company to commence construction of a 200–240 tonne *per annum* processing facility in the vicinity.

The NT Fish Farm was formed in 2007 following the conclusion of a joint German-Uzbek research project which had examined the local feasibility of employing recirculating system techniques. Following the feasibility report, the NT Fish Farm constructed a flow-through (raceway system) farm not far from Tashkent for the cultivation of rainbow trout at an expected productivity of 30 kg m^{-3}.[58]

However, despite the growth in the number of fish farms in the last few years, current stocking activity is a pale shadow of the past. While in the 1980s about 10–15 million larvae, fry and fingerlings of valuable fishes were stocked annually, the volumes stocked into the country's natural waterbodies slumped after independence. Although Decree 350 of 2003 was expected to reverse this trend, allowing companies to take over and

58 Financing was a particular problem, as local financial institutions were loathe to risk investing in new production techniques which were locally unproven. As a consequence, the enterprise was obliged to self-fund the investment required. However, in 2010 the farm was contracted by the State Committee for Nature Protection to produce stocking material for the newly established fish farms under the 2009–2011 Programme (Decree No.03/1-348), receiving about 100 million Uzbel soms for pond construction and equipment purchase. The large electric power station Syrdarya also provided finance for this purpose. The farm is also the site selected for the construction of a small demonstrative recirculation aquaculture system by the Uzbek Institute of Zoology, using monies granted under the GEF Small Grants Programme (US$50 000). Production of stocking material is planned to commence in autumn 2010.

exploit state culture-based production assets (while regulations permitting the formation of new companies were simplified and taxes on both land and water use remained low), the reality to date, Aqua-Todakul excepted, has been rather different. In 2009, only 1 million fry were released into the waterbodies of the Bukhara and Karakalpakstan regions by private farmers, and only 228 000 fingerlings were dispatched into the ALS. The following subsection therefore seeks to identify the particular problems facing the growth of culture-based fisheries in the country.

Problems Facing Culture-Based Fisheries Production in Uzbekistan

Historically, culture-based fisheries development in Uzbekistan, like in other countries within the ASDB, was largely based on the introduction and stocking of common and Chinese carps (silver, grass, and bighead). While these introductions were grounded in large-scale ichthyological investigations which identified empty ecological niches within the waterbodies of the ASDB into which these species could slot, the failure of past, and the problems facing contemporary, culture-based fisheries production and stocking programmes in Uzbekistan largely originate from one common problem:

A. The acute water deficit:

Most of the waterbodies in the deltaic region of the Amu-darya (in Karakalpakstan) largely dry out because of natural drought and the diversion of large volumes of water for irrigation purposes; and in some low-water years (e.g. 2001–2002), cause the total elimination of fish populations in these waterbodies. For this reason, most water reservoir stocking activities and culture-based production will have limited potential unless the detrimental effects of the discharge of accumulated waters upon aquacultural and capture-based fisheries activities are taken into account.

Other problems inhibiting the development of Culture-based fisheries production in Uzbekistan include:

B. Deterioration of water quality: elevated mineralization.

When the composition of dissolved salts (and pollutants) in the water exceeds maximum tolerable levels, the structure of the fish fauna changes depending on the comparative resistance of various fish species. In the case of most freshwater fish populations, reproductive success and commercial productivity decrease with increasing concentrations of mineral salts (Karimov and Keyser, 1998). Salinization of surface waters resulting from the reintroduction of drainage water from irrigated fields is now a common problem in Uzbekistan. In 1913, for example, average water mineralization in the Amu-darya at Nukus (200 km from the delta) was within the range 0.41–0.57 g/litre (maximum of 0.67) – but by 2001, it lay within the range 1.05–1.30 g/litre (maximum of 2.77). Equally, while the total volume of salts brought down the Amu-darya into the delta in the 1960s was equal to about 21 million t, in 2003 it was about 50 million tonnes (Shermatov et al., 2004).

While water with a salinity of over 1 g l-1 is considered unsuitable for most regional crops, less is known about the precise harm such salinity levels have upon the reproduction of the native fishes of the ASDB (Karimov and Keyser, 1998). However, Salikhov and Vundzettel (1989), Sanin, Kostjukovski and Shaporenko (1991) and Karimov (1990) report unsuccessful fish spawning in lakes Sarykamish and Arnasay, where water mineralization levels varied between 5 and 15 g/l (Kamilov, Karimov and Hakberdiev, 1994). Pond culture is particularly liable to mineralization due to high evaporation rates. Wecker et al. (2007) reported mineralization levels in fingerling ponds of 1.3–1.8 g/litre and in fattening ponds of 1.5–3/g/litre at Khorazmbalik Fish Farm, although much lower mineralization levels were encountered at Damachi, Namangan and Balikchi fish farms due to the regular inflow of freshwater; the same occurred at Tavaqsay Trout Farm on the upper reaches of the Chirchiq River. The FAO Central Asia Regional Programme for Fisheries and Aquaculture Development (FishDev Central Asia – GCP/RER/031/TUR), jointly with the Institute of Zoology of the Uzbekistan Academy of Science, initiated a water quality monitoring system in support of sustainable aquaculture development in Uzbekistan in 2011.

C. Deterioration of water quality: pollution with biocides

Agricultural production in Uzbekistan was heavily dependent upon pesticide use, with 80 000 –85 000 tonnes applied annually – at levels of 20–25 kg/ha of irrigated land (up to 40 kg/ha in some instances) – in the pre-independence period. According to Soviet water quality criteria, more than 25 percent of freshwater resources in Uzbekistan were not suitable for drinking and were dangerous for irrigation at the beginning of the 1990s (Khamraev, 1992). Although pesticide usage has dropped around 75percent since 1995, 24 pesticides are still used in large quantities, particularly in the provinces of Karakalpakstan and Khorazm, where there are large rice plantations. The volume of industrial sewage water remains high, 6.0 km^3 in 2002–2004, as compared to 6.2 km^3 in the 1990s, while pesticide residues from past applications remain in the ground/silt.

The effect of pesticide accumulation in the various organs of fish was thoroughly investigated across more than 27 waterbodies of various origin and categories in the ASDB (including the ALS and Mejdurechye Reservoir) over the period 1987–1994 by Karimov (1990; 1995). Fortunately, he found that only in the fat tissue of predatory fish such as pike-perch did pesticide levels exceed the maximum allowable concentration (MAC) established by the Health Ministry of the Former Soviet Union, while more recent research in 2002–2006 confirmed that contamination of water, sediment and fish by persistent organochlorine pesticides (mainly dichloro-diphenyl-trichloroethane (DDT) and hexachlorane) has now fallen below detectable limits.

D. The integrated irrigation and drainage structure

The development of irrigation and drainage systems connecting the various river basins has seen, for example, the Syr-darya connected with the Sanzar River, and the Sanzar River in turn connected with the Zarafshan River. This river is linked by the Eski Angar Canal to the Kashkadarya River, and thence via the Karshi Main Canal to the Amu-darya. Thus the irrigation/drainage network ties together the different river basins into one Central Asian water system. While this integration allows freshwater species to migrate from one river basin to another, it does inhibit the stocking of certain waterbodies, as the benefits of stocking programmes are potentially dissipated across the entire regional water system.

E. Genetic diversity

All stocking material to date is largely produced in one hatchery – the state fish hatchery Yangiyul. The culture and subsequent release of fish from this sole source has compromised the genetic variability of indigenous commercial species such as the wild form of common carp, and it is now very difficult to find a pure wild form of common carp in the ASDB. Therefore, to protect genetic diversity across important commercial species, special culture-based stocking and rehabilitation programmes and zonal reproduction are perhaps required.

F. The ability of stocked species to form breeding populations

In economic terms, stocking costs are minimized in those instances where the introduced species successfully acclimatizes. While early sturgeon stocking programmes proved unsuccessful in this regard, the more recent emphasis on carp culture has seen the introduced species form successful breeding populations in the Amu-darya, the Syr-darya, the Karakum Canal and other large irrigation canals. However, in those instances – or waterbodies – where ecological conditions are unfavourable vis-à-vis the introduced species, the benefits of stocking programmes are more open to question.

G. Relative feed prices

The current price differential between inorganic fertilizers (Uzbekistan produces all types of inorganic fertilizers) and fish feed has seen an increased emphasis of liming and fertilization of ponds to stimulate phytoplankton development, and this in turn has lead to an (over) emphasis on silver carp (70–85 percent of culture production) production at the expense of other cyprinids. As a consequence of this bias towards fertilization – allied to the use of supplementary feeds (such as wheat and bran) – the sector does not currently source feed from the Chinaz plant (although this was established in the 1980s to specifically supply the culture sector).

H. Technology and techniques of production

Karimov *et al.* (2009) note that not only is there an emphasis on extensive – as opposed to intensive – culture practices in Uzbekistan, but “extension and training facilities in support of aquaculture and culture based fisheries development and management are non-existent”. Moreover, international market access for fish products is circumscribed, as no national producers and processors are compliant with international health, product quality and safety (i.e. HACCP) requirements[59]. Obtaining financing has also historically been problematic for the sector, and there is a dearth of specialist suppliers (inputs, veterinary services, etc.) underpinning the sector.

I. Information and statistics on national culture-based fisheries

Fisheries data and statistics relating to the natural waterbodies of Uzbekistan are very inaccurate, especially concerning the number of stocked young fish and the annual catches of individual fish species taken from each waterbody. This lacuna contributes to the poor understanding of the economic and social contribution of stocking practices in the republic. Historically, the centralized nature of the Soviet system ensured the meticulous recording of such data. However, independence not only saw this practice largely discontinued (while the sectoral re-organization of production led to much historic data being lost), but the market-oriented nature of current production activities militates against the widespread dissemination of much key statistical information on the grounds of its perceived commercial value.

59 GTZ (2010:9), moreover, note that only the NukusBalyk enterprise in Karakalpakstan is likely to be able to process fish in sufficient quantities to cover the cost of bringing the establishment up to international requirements in the near future.

6. Conclusions and Recommendations

The Central Asian region is characterized by low levels of annual precipitation[60], average annual summer temperatures that range from 30° C (Kazakhstan) up to 40° C in the Fergana Valley of Kyrgyzstan, and winter temperatures that can fall as low as -20° C. This already precarious natural environment has been substantively modified by human activity, most notably the Soviet drive for self-sufficiency in cotton which converted the region into a "huge cotton plantation in the 1960s and 1970s" (Karaev, 2005). This was most apparent in what is now Uzbekistan, where seed cotton production grew from 300 000 tonnes in the 1950s to peak at over 3 million tonnes in the mid-1980s (Abdullaev, Giordano and Rasulov, 2005). As natural precipitation was insufficient to satisfy crop water requirements, water was abstracted from the two main regional rivers (the Amu-Darya and the Syr-Darya) and their tributaries and an extensive system of irrigation and feeder canals emerged. In Kazakhstan, 3.3 million ha of land was supplied by 96 400 km of irrigation and 14 900 km of drainage canals, a network that absorbed over 70 percent of the country's national water resources (FAO, 2002). In Uzbekistan, the irrigated area ascended to 4.3 million ha (Umarov, 2003). Water management became a must, and to facilitate production a whole series of reservoirs were built on the region's rivers – Nurek in Tajikistan, Kapchagay in Kazakhstan, Toktogul in Kyrgyzstan and Tuyamuyun, Tudakul, etc. in Uzbekistan – stockpiling the glacial meltwater for the time when it was needed to irrigate the ever expanding cotton fields[61].

The main ecological casualty of this expansion was the Aral Sea, whose surface area fell 70 percent (to 17 382 km^2), whose volume declined 90 percent, and whose salinity increased ten-fold between 1960 and 2006 (Micklin, 2007). This had a devastating effect upon local livelihoods, as communities now found themselves (proverbially) "high and dry". The Aral Sea's main fishing port, Aralsk, found itself almost 100 km from the Aral's waters. GEF (2002) suggests lower water tables and increased soil salinity have cost the immediate region US$1 754 million in crop losses annually. Human health in the vicinity has deteriorated markedly too due to the ingestion of heavily mineralized water (leading to increased kidney and liver diseases), dust storms sweeping up the pesticide residues that became exposed as the sea dried up (causing increased respiratory problems) and a quadrupling of the infant mortality rate since the 1960s as poverty and malnutrition have become endemic features of the communities that remain (Whish-Wilson, 2002). Regional fish resources were decimated, as the increased salinity wiped out the indigenous Aral species and, despite the best efforts of Soviet scientists to introduce salt-water species into the lake, only the European flounder prospered. The fate of the fringebarbel sturgeon and the Aral barbel was symptomatic of a wider malaise that affected the fisheries sector of the region. Dams blocked spawning migrations, deliberately and accidentally introduced species had devastating effects upon local

60 These range from under 150 mm (6 inches) a year in Western Uzbekistan and East Turkmenistan, to 300–400 mm (12–16 inches) in East Uzbekistan, Kyrgyzstan and Western Tajikistan, while Kazakhstan receives an average of 581 mm (23 inches) *per annum*. Precipitation, however, tends to be more concentrated in the mountainous regions, while the drier valley regions are the center of agricultural production (USDA, undated).

61 This expansion was checked in the post-independence period, as grain self-sufficiency (most notably in Turkmenstan and Uzbekistan) became a priority for the new republican governments.

fish populations (as indicated earlier in this report), and overfishing by an increasingly impoverished population in the post-independence period decimated remaining capture stocks on the majority of the region's waterbodies. If lakes, seas, rivers and reservoirs are to be replenished, fisheries to be resurrected and the livelihoods of those living alongside waterbodies to be (partially) restored, then stocking and the development of culture-based fisheries will be necessary. Past attempts have met with limited success across the region. These attempts have not only served to illustrate the difficulties of stocking regional waterbodies (where fisheries are of secondary importance to agriculture and hydro-power needs and, post-independence, open access has tended to prevail) and designing effective culture-based interventions (Research Question 1 (RQ1) below) but have also provided useful insights into the feasibility of culture-based fisheries in the region given local environmental, economic, social and cultural constraints (RQ2 and RQ3). On this basis, this technical paper offers some recommendations as to how governments can best support the development of an effective, ecosystem-appropriate culture-based fisheries policy in the region (RQ4).

RQ1: What are the lessons to be learned from failed and successful examples of culture-based fisheries in the past?

In Central Asia, the first examples of stocking date back to the 1920s and 1930s. Trout from Lake Sevan in Armenia were introduced into Lake Issyk Kul in 1931 and starry sturgeon into the Aral Sea in 1933. As capture fisheries production rose over the following decades, the All-Union Ministry of Fisheries sought to complement capture production by announcing a large-scale fish culture development strategy in the 1960s. Production expanded rapidly, with culture farm output across the region reaching 25 000 tonnes within a decade, although not every planned introduction was successful. Culture production continued to rise in the 1980s, the production of fish in some of the most notable waterbodies in Central Asia[62] being almost exclusively based on these introduced species by the time independence dawned. However, the removal of a centralized system of support to the sector saw many installations decay and sectoral output collapse (Thorpe and van Anrooy, 2009a).

In Kazakhstan, the growth of culture-based production saw a number of scientific studies undertaken in the 1970s with a view to providing detailed fishery-technological specifications for pond-based aquaculture. Carps, in particular grass carp and silver carp, along with ciscos were the main species stocked into waterbodies in Kazakhstan. Many of these early stocking attempts were not successful for a variety of reasons, but largely related to a lack of understanding of either the biology of the species stocked or the ecosystem interactions within the waterbody into which fish were stocked. A good example is the stocking of carp and ciscos into the lakes of north Kazakhstan. The main problem was one of competition between species – and this could have easily been avoided with a better understanding of the ecosystem interactions. While the environmental characteristics of the lakes appeared to be suitable, the population of competitor species (in terms of feed), and predators (in terms of recruitment), meant that the stocking of carp and ciscos may have actually decreased overall production. Bream were also introduced into the lakes, and while catches grew steadily from the late 1970s, there was little local market demand.

There have been other unfortunate examples of failed stocking programmes, such as the stocking of starry sturgeon into Aral waters in 1933, an introduction that almost caused the local eradication of the fringebarbel sturgeon (through an introduced disease), a naturally occurring indigenous species. Despite this, several further attempts were made

62 The fisheries of Lake Balkhash, the North Aral Sea and the reservoirs of Bukhtarma, Zaisan, Kapchagay and Shardara.

to form breeding populations of the starry sturgeon, all of which have been unsuccessful for a number of reasons, but again largely related to either poor understanding of the species stocked or a poor understanding of the waterbody into which the fish were stocked.

Since 2004, Lake Yakush has been stocked with one million cisco fingerlings annually. By 2005, seven tonnes of cisco were landed, this rising to ten tonnes in 2009. However, the principal factor attributed to the success of stocking cisco in Lake Yakush was the fact that the lake was not populated prior to the fingerlings being released; hence ecosystem interactions (such as predation, etc.) were not an issue in this instance.

It is therefore clear that in Kazakhstan a better understanding of the environmental characteristics of waterbodies and ecosystem interactions was, and is, required to promote the success of future stocking programmes. This, in part, can be achieved by keeping accurate records of current stocking programmes so as to provide guidance on best practice for future stocking efforts.

In Kyrgyzstan, the primary emphasis of culture-based production was to acclimatize high-value species, in the first instance Sevan trout, into major waterbodies such as lakes Issyk Kul and Son Kul. The higher-value species were introduced largely on a trial and error basis, given the lack of underlying scientific studies, and in some cases caused irreparable damage to the ecosystem and natural fauna of the lakes. As evidenced by the intentional stocking of pike-perch in Lake Zhizhitskoye so as to prey on the non-commercial species found in the lake, the introduction of predators to waterbodies can cause irreversible damage if the populations formed affect the predator-prey relationship in the waterbody.

Later introductions of pike-perch, peled and European whitefish into Issyk Kul were more successful and during the 1970s catches were reported to be healthy for a number of the stocked species. This brought new problems, however, because a successful culture-based activity (in terms of increased production) becomes economically interesting to other parties and, if these fisheries are not well managed – as was the case with Issyk Kul – then overfishing/illegal fishing can significantly impact on future production. Furthermore, it also appears that breeding populations were not formed in many of the waterbodies into which carp were stocked. As a consequence, it was necessary to establish fish breeding facilities and extract broodstock from waterbodies where they had become established.

Although recent legislation has provided a more conducive environment for the restoration of culture-based fisheries, the private nature of much of this enterprise – allied to a state that can only weakly monitor production activities – ensures there is only limited information available on ongoing stocking experiences and hence what lessons can be learnt.

Similarly to Kazakhstan and Kyrgyzstan, early stocking programmes in Uzbekistan were generally not successful. The failure to follow stocking recommendations when releasing silver carp fry and fingerlings into the Arnasay Lake System (ALS) during the late 1970s and 1980s, for example, led to decreased catches in the late 1980s. One notable success, however, was the introduction of the Atlantic herring into the Aral Sea in the mid 1950s, this species quickly appearing in large numbers in local catches. However, a number of accidental stockings of other species increased pressure on natural food resources and, only a few years after stocking, Atlantic herring had largely disappeared from the sea. The intended and accidental stocking of carp species has also been successful in the region and has increased species numbers in some waterbodies. This is largely because there is little competition for food between the stocked fish and naturally occurring species. The development of fish hatcheries to produce fry and fingerlings for stocking in Uzbekistan was limited during the 1970s and 1980s, largely because of water shortages (either because of high pumping costs or the priority accorded to irrigation and power generation). More recent culture experiences saw a number of private companies conduct small-scale carp stocking in Talimardjan and Kattakurgan reservoirs. However, as the reservoirs were exploited for irrigation to the point of drying, the stocked fish perished.

Recent revitalization of the sector can be traced to 2007/08 when an FAO-led project convened stakeholders from across the sector to produce a *Draft Concept for the Development of Aquaculture and Fisheries in Uzbekistan (2008–2016)*. To increase fish production in Central Asia is probably not that difficult, if facilities and funding are provided to do so**.** What has proven to be the main challenge in Central Asian fisheries, both pre and post-independence, has been the lack of understanding of the waterbodies in the region. In many cases, fish farms have produced fish for stocking programmes that have had dismal results. Production volumes in the targeted waterbodies have often remained stagnant and have sometimes even been reduced through introduction of disease, competition with indigenous species, etc. Without investing in education and research and development, simply increasing the production of fry and fingerlings from fish farm facilities is almost pointless. While the potential for culture-based fisheries in Uzbekistan appears to be higher than in Kazakhstan and Kyrgyzstan (at the current time), there remain numerous obstacles to overcome in order to achieve sustainable and profitable culture-based production.

RQ2: What are the possibilities for culture-based fisheries in each country based on the current environmental, economic and social situation?

The vast waterbodies in Central Asia offer considerable potential to increase fish output to levels seen during the old Soviet era and perhaps beyond. However, production since independence has decreased significantly in the Central Asian countries of Kazakhstan, Kyrgyzstan and Uzbekistan due to a decrease in funding for fisheries development, a lack of clarity over strategies for the sector and weak oversight of the fisheries that are currently in production. However, there are a number of issues that demand consideration.

Any attempt to rehabilitate the sector must primarily focus on the environmental aspects of production*;* otherwise the externalities associated with increased production may actually offset the benefits of stocking programmes. Our research suggests that despite substantive research on a number of regional waterbodies being undertaken during the Soviet period, a full understanding of the complete ecosystem of the various waterbodies in Central Asia is still lacking. Equally, the various interactions between the stocked fish and the indigenous species were either not fully understood and/or considered, as evidenced by the examples of failed stocking experiences in the three countries. To gather a full understanding of the ecosystem interactions within a waterbody requires significant effort, however, because, as Lorenzen *et al.* (2001) note, the reasons for failed attempts are not always immediately clear. Accurate data on stock enhancements and stocking experiences are sadly lacking (or have been lost) in many Central Asian countries, and can only be obtained through experimental management when waterbodies are newly stocked. The first step, therefore, is to gain an understanding of the ecosystem interactions when waterbodies are newly stocked and synthesize the data across the three countries so as to inform future stocking programmes.

Assuming an understanding of the ecosystem interactions, the success of stocking programmes is determined by the species stocked. The introduction of non-indigenous species has caused problems around the world and has been highly detrimental to the functioning of many lake and river systems. A pitfall of previous regional stocking programmes would appear to be a bias in viewing the potential rewards of stocking species on the basis of short-term economic gains rather than long-term sustainable yields. Given the harsh environmental condition in Central Asian countries, where many waterbodies cannot feasibly be used to produce fish, a full understanding of the biology of the current fauna and flora is critical to ensure that any attempt to increase productivity through stocking does not compromise native stocks. Ultimately, as stocking decisions are irreversible, serious consideration needs to be given to the species stocked.

Any culture-based activity must be designed to promote long-term sustainability and profitability. Thorough e*x ante* appraisals should therefore be undertaken so investors can see the likelihood of their investment returning long-term profit. An understanding of the full costs and benefits is also needed. This is particularly true in Central Asian culture-based fisheries, as they presently do not benefit from state funding or subsidy. The limited funding available for fisheries in Central Asian countries means that access to expertise and training, which can also be considered essential preconditions for successful project development, are lacking. The lack of available data on the regional fisheries sector is equally problematic, as appraisals (such as cost-benefit analysis) rely on the use of data from past experiences (in terms of costs, etc.). If these data are not available or are inaccurate, then the feasibility of projects may be in doubt incorrectly.

Since independence, national fisheries management capacity has declined (and ceased to exist in some cases) across the region. Moreover, the nature of the command economy inhibited the development of an entrepreneurial culture and, while private commercial activity has grown in the wake of independence, culture-based fisheries was never going to be an attractive proposition for many emergent entrepreneurs given the limited incentives on offer. Yet it is this entrepreneurial or management capacity that is critical in determining the likelihood of a project's economic success. It is therefore essential that culture-based fisheries projects in the region also be underpinned by clear and transparent regulations regarding property rights to the stock (or waterbody) and the harvest. Further attention must be paid to researching and developing markets for the products produced (both currently, and in the future). While fish consumption presently makes only a modest contribution to daily consumption of animal protein in the Central Asian region, there appears to be a significant market for imported fish in both Kyrgyzstan and Uzbekistan – suggesting that with the right marketing support culture production of new and existing species could help close this deficit.

In social terms, the development of culture-based fisheries can impact upon three types of natural capital – *land, water and wild fish stocks*. On the one hand, the development of culture-based fisheries can, through the installation of aquaculture facilities, for example, create local land shortages and/or damage the environment. On the other hand, such production may also deliver social benefits by allowing previously underutilized land or water resources to be brought into full production. In Central Asia, the development of culture-based fisheries under consideration largely focuses on cage culture in lakes/ reservoirs and pond culture, and therefore the social effects of these developments are likely to have only a limited impact in land and terrestrial habitat terms. While culture-based fisheries could in theory lead to increased competition for *water* resources between different stakeholder groupings, this is unlikely in the Central Asian context for two reasons. First, the prevalent form of production – carp culture in ponds – poses no additional demands for water. Second, fisheries production in these countries is likely to continue to rank well below agriculture and energy generation in terms of water allocation priorities. In terms of the social impacts of culture-based fisheries on *wild fish stocks*, culture production is likely to increase fish supply without harming wild populations (albeit subject to the several caveats discussed concerning environmental aspects). The development of culture-based fisheries may also bring several social benefits to the region. While investment in the fisheries sector since independence has been minimal, if increases in fisheries output are complemented by the provision of improved infrastructure (such as roads), other industries may also derive benefits and see levels of employment increase.

RQ3: What is the overall feasibility of culture-based fisheries in the defined countries of Central Asia?

The vast waterbodies of Central Asia offer considerable potential to increase output through culture-based activity. However, current and future stocking programmes are likely to fail unless the following problems are addressed:

1. The research available that documents past stocking programmes in Kazakhstan, Kyrgyzstan and Uzbekistan clearly shows that there is a poor understanding of the ecosystem interactions of the waterbodies, and also a limited understanding of the species chosen for stocking (in particular in terms of how the species stocked will impact upon the ecosystem). As this report has shown, many stocking activities have failed because either the stocked species out-competed the indigenous species (for food, habitat, etc.) or because the stocked fish itself could not form breeding populations (through lack of food or predation, for example).

2. To date there are few examples of stocking activities in the region that have increased total fish output without impacting on the waterbody in some negative way. One exception was the stocking of bream (in Kazakhstan), which subsequently formed breeding populations without impacting on the already existent flora and fauna of the waterbody. However, this gain was nullified, as there is no local market for bream. Therefore, culturists need to be sure that any fish they choose for culture is either already in demand in the local markets or is likely to be demanded in the future (as export markets are not well developed in the region).

3. While there have also been instances where stocking activities have increased overall fish production and provided fish for important markets in the region, little detailed data exist documenting these activities. The only way of obtaining new data then is from new stocking experiences. The collection and subsequent synthesis of this new production data could therefore provide vital information for future stocking ventures, allowing culturists to understand why previous attempts have failed (or been successful), and perhaps allow the production of some "best practice" guidelines.

4. Any feasible culture strategy is critically dependent upon management – both at the enterprise and the sectoral level, and culture-based fisheries will only develop effectively in the region if attention is paid to research and development (R&D) and education. Funding will also be required in the short term to revitalize the facilities that are needed to produce the fry and fingerlings that form the basis of stocking programmes.

5. The selection of waterbodies to culture fish is critical, given that the use of water for irrigation and energy production will likely remain a higher priority than fish production. As the most suitable artificial waterbodies identified in this report for fish production are primarily already used for irrigation and energy production, further research into the characteristics of other waterbodies is required to identify those that do not have a primary use by those sectors.

Any stocking activity needs to consider the economic, environmental and social dimensions if stocking is to lead to higher production. The problems outlined above are common to all three of the countries that are the focus of this report. For a feasible culture-based fishery to emerge in the region, the primary task would appear to be education – to ensure that the correct fish are stocked in the most suitable waterbody. To some extent, the way forward will still be one of trial and error, as information regarding past experiences tends not to be available, but the long-term success of culture-based activity will depend upon increasing the level of education and R&D in culture-based fisheries development. The waterbodies of Central Asia offer potential for culture-based activity, but unless the above issues are given serious consideration, future culture activity is likely to suffer the same fate as past attempts.

RQ4: What advice/guidance can be given to governments in Central Asia in supporting the development of culture-based fisheries?

It is recommended that the Central Asian governments, through the medium of the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (CACFish), develop a set of overarching principles to guide culture-based fisheries and stocking activity in the region. These principles should include[63]:

A. **Ecosystem compatibility**

Culture-based fisheries development in the region should be compatible with the functioning of healthy, productive and resilient natural (lakes and rivers) and man-made (reservoirs) aquatic eco-systems. Past research, however, shows that certain species are unable to reproduce or thrive in particular waterbodies (e.g. osman and carp in Lake Son Kul, silver and grass carp more generally in Kyrgyzstan) – so repeated reseeding/ stocking is required, while limited natural food reserves in many waterbodies across the region preclude the development of an intensive programme of culture-based fisheries in the absence of employing supplementary feed sources (see also point E. below). Moreover, other introductions, both planned and accidental, have had profound effects on the local aquatic ecosystem, e.g. the Balkhash marinka and perch and the Eurasian minnow becoming endemic in the waters of south and south-eastern Kazakhstan following their accidental release into local waterbodies. The introduction of carp cultured at the state fish hatchery of Yangiyul into Uzbek waters, for example, has also compromised the genetic fingerprint of the wild form of common carp previously found in the region. **It is therefore recommended that:**

- **National governments** take a lead in developing, implementing, and enforcing ecosystem-based conservation and management measures for culture-based fisheries, with **CACFish** helping to coordinate the integration of such measures at a regional level[64].
- **National governments** support the stocking of only native – or currently naturalized – species in national waterbodies unless best available science shows that the introduction of new species (tilapia say) does not cause undue harm to wild species, habitats, or ecosystems in the event of an escape (NOAA, 2011).

63 These principles are based upon the set of criteria derived to guide aquacultural development by the United States National Oceanographic and Atmospheric Administration (NOAA, 2011).

64 Our experience suggests there is limited knowledge of ecosystem approaches to aquaculture and its management presently in the region, a lacuna that can be addressed within the training proposed under point C (see below.)

- **National governments** develop, implement and enforce conservation and management measures (where they do not presently exist) to maintain the health, genetics, habitats and populations of native species; to maintain water quality; and to prevent escapes and the accidental introduction of cultured species into local environments.

- **CACFish** should, in line with its "5-Year Regional Work Programme (2011–2015)" prepare a *Strategy for Responsible Fish Introductions and Translocations in Aquaculture in Central Asia and the Caucasus* and support its implementation in the region.

- **CACFish** should, in line with its "5-Year Regional Work Programme (2011–2015)" develop regional best-practice approaches for rehabilitation of waterbodies (including spawning and nursery habitats in rivers and lakes).

- **CACFish** be of assistance in promoting ecosystem compatibility of aquaculture establishments (including those involved in culture-based fisheries) through the *Development of Environmental Impact Assessment (EIA) Methods for Aquaculture in Central Asia*, as stipulated in its "5-Year Regional Work Programme (2011–2015)"

B. Compatibility with other uses

A particular problem in designing a Central Asian capture and culture fisheries programme relates to the multiple demands placed upon the region's scarce water resources. As noted, the majority of reservoirs in the region were constructed for either energy supply and/or irrigation needs, and the demands of these sectors dictate when – and how much – waters are released. While reservoirs such as Todakul and Talimarjan in Uzbekistan, for example, offer significant potential for culture-based fisheries due to the relatively high volumes (325 and 125 million m^3, respectively) of water that remain once water abstraction for irrigation purposes is exhausted (the "dead" level), others such as Uchkurgan and Kuymazar have much lower dead levels (16 and 47 million m^3, respectively). It is not just the levels of residual water that impacts upon fisheries in the regional waterbodies, as water release during the summer (for irrigation) or winter (for hydro-power) can sweep fish (native and restocked), released larvae and fingerlings, and food sources, downstream.

A similar problem prevails when irrigation and drainage systems are prioritized – as with the Syr-darya-Sanzar-Zarafshan-Eski Angar – Kashkadarya-Karshi-Amu-darya link – as the development of such networks can inhibit stocking/stocking of certain waterbodies as the benefits of such stocking programmes are dissipated across a much wider regional water system. Agriculture further exacerbates the development of regional culture-based fisheries through its impact upon water quality. Salinization (mineralization) of surface waters resulting from the reintroduction of drainage water from irrigated fields is a common problem in the region, affecting reproduction success, and with it, commercial productivity. The heavy historic use of pesticides also resulted in a deterioration in water quality, with research by Karimov and others (1990 and 1995) documenting the extent of pesticide accumulation in fish tissue. In Kazakhstan and Tajikistan, fish farms, which are almost all dependent upon supplied energy, have also suffered due to the uncertainty of power supply in the winter months – with sudden, unannounced, cuts in energy supply causing high mortality and a consequent reduced profitability. **It is therefore recommended that:**

- **National governments** take steps to promote greater coordination between their respective national fisheries departments and those other agencies/ departments that have a stake in how the country's aquatic resources are used.

This coordination should not just discuss optimal methods of water release, but also focus on how to improve water quality (i.e. by reduced mineralization and biocide presence) by modifying production techniques.

- **CACFish**, on behalf of the member governments, should represent fisheries interests at the regional level, liaising and advising the Central Asian Interstate Commission for Water Coordination (ICWC) and the respective Basin Water Organizations (BWOs) among others, so as to ensure that the objectives and needs of the fisheries sector are both recognized and streamlined into the developmental activities of these other organizations.

- **CACFish** should also, on the basis of stated national preferences regarding aquaculture development in the region, draw up a "Regional Plan for the Support of Aquaculture", so that both funds and technical support can be targeted more effectively to the sector. This would be in line with the "5-Year Regional Work Programme (2011–2015)" of CACFish, which gives importance to the *Provision of Advice on the Formulation of Aquaculture Policies and Strategies at National Level in Specific CACFish Member Countries.*

C. Best available science and information

Management decisions for culture-based fisheries should be based upon the best available science and information. Unfortunately, the tremendous strides made by scientists during the Soviet period in undertaking technical studies on regional fish culture have not been maintained in the independence period. In Kazakhstan, for example, the *2007 Republic Strategy of Acclimatization and Fish Stocking* was formulated based upon original technical reports prepared in the 1970s. Equally, the national consultants involved in the preparation of this report have highlighted that much of the technical and quantitative data (including data on the specific stocking programmes – in terms of costs, fingerlings cultured and released – and the annual catches from the various national waterbodies) have either been lost, are inaccurate or do not exist. The scenario is further hampered, as Karimov *et al.* (2009) report, due to the severe educational and training deficit that now exists in some of the republics, with "extension and training facilities in support of aquaculture development and management non-existent". **It is therefore recommended that:**

- **National governments,** via their respective fisheries departments, undertake a "gap" analysis to identify just what technical and statistical data on culture (and capture) production currently exist, and – on the basis of national development strategies for the sector – what technical studies, extension support and the like are needed.

- **National governments**, on the basis of this gap analysis, support scientific studies which examine culture-based production technologies, practices, benefits, costs and risks, so as to develop "best practices" which can inform the attainment of sectoral strategy goals.

- **CACFish** should synthesize and deliver information in a timely manner to the member countries on the current state of scientific understanding about the observed and potential impacts and benefits of culture-based production of the species selected for national aquaculture strategies. This would include monitoring, evaluating and perhaps maintaining a regional database on the impacts of aquaculture on predator-prey relationships, biodiversity and other factors integral to the maintenance of healthy and productive ecosystems.

- **CACFish** should work with member governments to improve scientific understanding of the effects of culture-based technologies and practices, and ensure the restitution of national (and/or perhaps regional) specialisms in extension techniques and training programmes necessary to attain sectoral strategy goals, and to solicit international funds (where necessary) to help in this.

- **CACFish** should also take the lead in ensuring the regional dissemination of international health, quality and safety requirements (i.e. HACCP), so as to enable regional producers – with national government and CACFish support – to enter the more lucrative international markets[65].

- **CACFish, together with national governments,** should collect and disseminate information on best practices in stocking and culture-based fisheries from other regions.

D. Social and economic benefits

As intimated in the study, culture-based fisheries production has the potential to deliver a number of economic (to the producer) and social (to the wider community) benefits, and it is thus imperative that investment in the sector is channelled in such a way as to provide a net benefit to the nation, the local community arraigned around the waterbodies, and consumers of the products produced. **It is therefore recommended that:**

- **National governments** undertake an *ex-ante* baseline analysis of all proposals for new and/or expanded culture production activities, assessing the likely positive and negative social, economic and cultural impacts of the activity on all stakeholders in the immediate and longer-term before approving the activity.

- **National governments** (once the baseline study is concluded) actively support the establishment of new culture enterprises that not only create jobs but could also provide associated employment and revenue-generating opportunities upstream (e.g. fish processing companies) and downstream (e.g. local input suppliers), expanded product choice on the local market and reduced fish imports.

E. Collaboration with the aquaculture sector

It is important that local operators of aquaculture facilities, whether state or private, be held accountable for protecting the environment, wild species and human safety and, moreover, such operators should be obliged to report regularly to the national authorities on the nature and extent of the activities undertaken. This has been particularly problematic in the Central Asian region in the post-independence period. The lack of guidelines or regulations led to the uncontrolled expansion of cage-culture activity on Issyk Kul using inferior cage construction and a consequent escape of rainbow trout into the waterbody. In Kazakhstan, the assignation of rights – with few responsibilities – of waterbodies to multiple owners has triggered conflict and “free- riding”.

Equally, however, state support to the sector has fallen short. Timirkhanov *et al.* (2010), for example, have noted how customs policies and tariffs have deterred the

65 This is based on the premise that production for export does not displace production for the domestic market, but rather complements it.

import of larvae, roe, feed, veterinary drugs, chemical reagents and culture equipment and, allied with the decision to sharply increase water use fees and a general lack of financial support to the sector in Kazakhstan, have been strong brakes on its rate of growth. Feed is a particular problem, with the high cost of imported feed and the lack of a domestic feed industry that could supply the quantities required[66] causing producers to seek alternative, less effective, home-grown remedies. While this disconnect, which is in large part attributable to a combination of the transition from command to market economy and the relative lack of interest by both the private and public sectors (until recently) in the sector, is slowly being remedied (see Kyrgyzstan's *2008–2012 Strategy for Fisheries and Aquaculture Sector Development and Management in the Kyrgyz Republic*, and the *Policy and Strategy for Fisheries and Aquaculture Development for Poverty Alleviation in Tajikistan for 2010 – 2025,* for example), a further pro-active strategy is necessary in order to ensure that an effective management framework is established where rights and responsibilities of sectoral stakeholders are clearly enunciated. **It is therefore recommended that:**

- **National governments** work with aquaculture and fisheries operators to: (i) prepare and implement (where necessary) broodstock management plans, aquatic animal health plans and a contingency plan for responding to emergencies; (ii) adopt recognized best management practices (BMPs) (in terms of husbandry, biosecurity, etc.); and (iii) incorporate environmentally efficient and responsible management practices (to reduce input usage and waste discharge).

- **National governments** undertake regular inspections of all installations and establish, in partnership with private-sector aquaculturists and fishers, national codes of practice to guide the operations of the sector. In addition, consideration should be given to setting national monitoring and reporting requirements for all operators (these should include, inter alia, reporting annual volumes produced, escapes, disease outbreaks, nutrient discharges, and drug and chemical usage).

- **CACFish** should help in this regard by collating (and distributing) information on BMPs and codes of practice from both within and outside the region[67], and coordinating regional training programmes on the preparation of broodstock and aquatic animal health plans, and other salient culture, environment or management practices.

F. The regulatory process

It is equally incumbent on the state to ensure sectoral management decisions are taken in a timely, impartial, efficient and transparent manner. In Kazakhstan, for example, current legislation prohibits the state from contracting private aquacultural operations to undertake stocking activities on its behalf – a bias that severely circumscribes the opportunities for private-sector expansion. **It is therefore recommended that:**

- **National governments** constantly review all regulations pertaining to the sector with a view to ensuring policy coherence, reducing regulatory uncertainty and minimizing unnecessary regulatory burden on all aquaculture and fisheries operators. This includes the vetting of applications for new culture-based operations and providing public notice of the same.

66 While there is a feed plant (Semipalatinsk) in East Kazakhstan, its main custom is with poultry producers and, while not averse to supplying culture fisheries, the terms of supply were not coincident with the needs of local culture producers.

67 A first task perhaps is to see the extent to which *the FAO Technical Guidelines for Responsible Fisheries: Aquaculture Development* (FAO, 1997) and the associated supplements both apply, and have been applied, in the region.

- **CACFish** should play a major role in supporting modification and harmonization of legal frameworks in the region through offering technical advice on the modernization of laws and regulations governing fisheries and aquaculture.

G. Public information

Poaching is endemic across the region, as a number of reports have indicated (see World Bank, 2004; Sareiva *et al*., 2008). This epidemic is attributable to three factors: (i) the collapse in livelihood opportunities in the post-independence era, placing increased pressure on the harvesting of natural resource stocks (Thorpe and van Anrooy, 2009b); (ii) the regulatory vacuum that ensued[68]; and (iii) ignorance over the ownership of stocked species. The latter two causal factors have been obviated in the case of private culture activities in Uzbekistan, where *the Programme on Measurements of Fisheries Sector Development in the Republic in 2009–2011* promoted the formation/registration of new fish farms and, as a consequence, the newly registered fish farmers have taken active steps to police and protect their newly assigned waterbodies. However, in the case of larger waterbodies in the region – particularly those which the state continues to restock – the ownership of stocked species is either unclear and/or poorly understood. **It is therefore recommended that:**

- **National governments** take action to communicate to the public the changes that are occurring/have occurred in legislative and policy terms, and how these changes impact upon fishing rights in the national waterbodies.

- **National governments** increase awareness among the population on the importance of fish consumption as part of a healthy diet – and inform the public on the state of the fish resources (and the role of the fishery and aquaculture sector at large) in terms of its contribution to aquatic biodiversity, fish production, employment, income and poverty alleviation.

The Fourth Intergovernmental Meeting on the Establishment of the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission, which was held in Cholpon Ata, on the shores of Lake Issyk Kul, Kyrgzystan, 22 -24 June 2011, discussed and adopted the above conclusions and recommendations of the regional study and requested the FAO Secretariat to CACFish to pass them forward to the Inaugural Meeting of the Commission for endorsement by the same Commission.

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68 Sarieva *et al.* (2008:17) suggest "poachers" may have been able to extract as much as 250 tonnes *per annum* from Lake Issyk Kul in Krygyzstan due to the inability to police the fishing moratorium imposed there in 2005.

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Culture-based fisheries have been successfully developed across the world in order to increase productivity of capture fisheries. Unfortunately, political upheaval, the disruption of historic fish supply chains and limited state budgets combined halted many of the stocking and culture-based fisheries programmes in the Central Asian region during the 1990s. This publication provides an overview of regional waterbodies and historic and contemporary culture-based fisheries and stocking experiences using case studies from Kazakhstan, Kyrgyzstan and Uzbekistan – with a view to suggesting potential ways in which national governments and the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission might support the rehabilitation of culture based (and, by extension, capture) fisheries in the region. The conclusions and recommendations made in this document have been presented to and were formally adopted by the Fourth Intergovernmental Meeting on the Establishment of the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (Cholpon Ata, Kyrgyzstan, 22–24 June 2011).

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