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Annotated Bibliography of Grass Carp (*Ctenopharyngodon idella*) from Russian-language Literature

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

This annotated bibliography has been prepared to summarize the available information pertaining to the distribution, migration, spawning, development, feeding, bioenergetics and physiological limits of Grass Carp (*Ctenopharyngodon idella*) from Russian-language literature. Grass Carp is native to large rivers of eastern Asia, including the Amur River basin which borders Russia, and has been introduced into Russian waters. As a result, a considerable portion of Grass Carp research conducted in the native range has been published in the Russian language. With the increasing risk of invasion by Grass Carp into the Great Lakes region, a translation and compilation of Russian literature will help to educate scientists and managers, and will inform a binational ecological Grass Carp risk assessment for the Great Lakes basin.

Bibliographie commentée fournissant un résumé de l'information disponible sur la carpe de roseau (*Ctenopharyngodon idella*) dans la littérature russe

RÉSUMÉ

La présente bibliographie commentée a été préparée dans le but de résumer l'information disponible concernant la répartition, la migration, le frai, le développement, l'alimentation, la bioénergétique et les limites physiologiques de la carpe de roseau (*Ctenopharyngodon idella*) dans la littérature russe. La carpe de roseau est originaire de grandes rivières de l'est de l'Asie, y compris le bassin du fleuve Amour qui borde la Russie, et a été introduite dans les eaux russes. Par conséquent, une grande partie des recherches sur la carpe de roseau menées dans l'aire de répartition indigène a été publiée en russe. Avec l'augmentation du risque d'invasion de la carpe de roseau dans la région des Grands Lacs, la traduction et la compilation de la littérature russe sur la carpe de roseau permettront d'informer les scientifiques et les gestionnaires et d'éclairer une évaluation binationale des risques écologiques de la carpe de roseau dans le bassin des Grands Lacs.

INTRODUCTION

Considerable scientific information on the biology of Grass Carp (*Ctenophayrngodon idella*) has been generated from research conducted within their native and introduced ranges. Part of the native range of Grass Carp includes the Amur River basin, which borders southeastern Russia and northeastern China. As such, there is a substantial amount of primary literature that exists in the Russian language that has been inaccessible to scientists not familiar with the language.

Russian language peer-reviewed journal sources, books, government publications and additional literature were reviewed and translated individually into an annotated bibliography that summarizes key findings and conclusions from research conducted on Grass Carp. This review revealed that there has been little published research on Grass Carp within the last 20 years. Data from 68 Russian-language sources published before 1983 were cited in an earlier synopsis of biological data on the Grass Carp (Shireman and Smith 1983). These papers were not included in the annotated list except for a few of the most important ones which are summarized here in more detail. In addition, a translated species account for Grass Carp from the Fishes of Kazakhstan (Mitrofanov et al. 1992) is included in an appendix (Appendix 1).

ANNONATED BIBLIOGRAPHY

Abdullayev [Abdullaev], M.A., and Khakberdiyev [Khakberdiev], B. 1980. Perspectives of the use of phytophagous fish for fisheries in natural and artificial water bodies of Middle and Lower Amu Darya. [Perspektivy rastitel'noyadnykh ryb v razvitii rybolovstva v estestvennykh i iskusstvennykh vodoyomakh srednego i nizhnego techeniya Amudar'i]. *In* Phytophagous fishes in industrial fish culture. Edited by G.K. Kamilov. Book of Abstracts of the 9th All-Union Conference. [Rastitel’noyadnye ryby v promyshlennom rybovodstve. Tezisy dokladov IX Vsesoyuznogo Soveshchaniya.] Izdatel’stvo AN UzSSR, Tashkent. p. 94–45.

and

Abdullayev [Abdullaev],M.A., and Khakberdiyev [Khakberdiev], B. 1989. Problems of biology and ecology of Grass Carp and Silver Carp from collecting-drainage waters of middle and lower reaches of Syr Darya. [Voprosy biologii i ekologii belogo amura i obyknovennogo tolstolobika kollektorno-drenazhnykh vod srednego i nizhnego techeniya Amudar’i.] *In* Phytophagous fish in water bodies of different types. [Rastitel’noyadnye ryby v vodoyemakh raznogo tipa.]. Edited by I.T. Negonovskaya. Sbornik Nauchnykh Trudov GosNIORKh. [Collected Scientific Articles of State Research Institute of Lake and River Fisheries]. No. 301. p. 113–129.

Morphological features and ecological characteristics of Grass Carp (*Ctenopharyngodon idella*) distributed in different water bodies of the Middle and Lower Amu Darya River in Uzbekistan and Turkmenistan were examined. The study area has been heavily altered by the construction of a large number of artificial channels and dammed lakes, forming an extensive channel drainage system used for irrigation. Channels and dammed lakes varied in depth, water quality, current and width; however, Grass Carp inhabited all of them. Grass Carp has a considerable commercial value in the region, composing up to 29.4% of total catch. Grass Carp were first introduced to the lakes and channels of the Lower and Middle Amu Darya River in 1960–1961, having been intentionally released from fish farms. Individuals examined during the study were 15–74 cm long, and weighed up to 4,500 g. In some dammed lakes, Grass Carp weighing 22–33 kg were recorded. The most abundant age classes were 2+ to 4+ and the maximum age recorded was 8+.

Larvae and juveniles (up to 15–20 mm long) fed on zooplankton and benthos, with algae comprising the dominant component of the diet. Adult Grass Carp fed primarily on macrophytes (up to 64–89% by weight), with almost 50 plant species represented in the diet. However, adult Grass Carp also consumed benthos, zooplankton, detritus (up to 20% of weight in autumn), and algae (especially in spring). The Fulton Condition Factor (Fcf) for Grass Carp was 1.12–3.75, averaging 1.52–2.55 for 1+ to 8+ age classes. Index of fullness varied between 100 and 110 $^{0}/_{000}$. In general, feeding intensity was very high, and in some waterbodies Grass Carp consumed all macrophytes, thus destroying spawning grounds for a number of phytophilous fishes (e.g., pike, wild carp).

Grass Carp males attained maturity at age 5+ (minimum of 70 cm length) and females at 7+ (minimum of 73 cm length), and a weight of 3400–7500 g. Males attained maturity at an earlier age class. Spawning occurred in irrigation channels below dams between May and July when water temperatures were between 17–23 °C. Two females (73 and 84 cm) with ripe ovaries were examined. Absolute fecundity was 1,207,800 and 199,920 eggs and relative fecundity was 213.8 and 26.7 eggs g^{-1} of fish weight, respectively. For both females, oocyte diameter varied, indicating Grass Carp in these waterbodies are batch-spawners, with eggs released more than once during a spawning season.

Abdusamadov, A.S. 1986. Biology of Grass Carp *Ctenopharyngodon idella* (Val.), Silver Carp *Hypophthalmichthys molitrix* (Val.) and Bighead Carp *Aristichthys nobilis* (Rich.) introduced in the Terek River region of the Caspian Basin. [Biologiya belogo amura *Ctenopharyngodon idella* (Val.), belogo tolstolobika *Hypophthalmichthys molitrix* (Val.) i pestrogo tolstolobika *Aristichthys nobilis* (Rich.), akklimatizirovannogo v Terskom rayone Kaspiyskogo basseyna.] Voprosy Ikhtiologii [Journal of Ichthyology, Moscow]. 26(3): 425−433.

Based on studies of spawning runs and migration (eggs and fingerlings), major spawning characteristics were defined for the following phytophagous fish species: Grass Carp (*Ctenopharyngodon idella*), Silver Carp (*Hypophthalmichthys molitrix*), and Bighead Carp (*Hypophthalmichthys nobilis*). These species have been introduced into the Terek River watershed, part of the Caspian Sea basin. Larvae and fingerlings of these species migrated downstream to coastal areas of the Caspian Sea (water salinity of 6−12‰) and remained there until maturation. Spawning occurred in upstream reaches of the Terek River; approximately 125–260 km from the river mouth. Sexual maturation varied by species and sex, with Grass Carp attaining maturation at 4+ (males) and 5+ (females) years. Spawning populations among all species were dominated by fishes aged 5−6 years. Average absolute individual fecundity also varied by species: Grass Carp (756,000); Silver Carp (812,000); and Bighead Carp (930,000). Spawning occurred from April to July, with temporal variation by species. Mass spawning runs of Grass Carp occurred in early May. These spawning runs coincided with flooding of the Terek River and water temperatures reaching 18 °C.

Abdusamadov, A.S. 1989. Biology of perspectives of the commercial use of phytophagous fish introduced in the Daghestan Region of the Caspian Basin. [Biologiya I perspektivy rtbokhozya'stvennogo ispol'zovaniya rastitel'noyadnykh ryb, akklimatizirovannykh d dagestanskom ray'one Kaspiyskogo basseyna]. Abstracts of Candidate of Sciences Dissertation. VNIRO, Moscow. 24 p.

Between 1982–1988, a total of 2,388 Grass Carp were collected for examination from the middle and lower reaches of the Terek River; a deltaic system in the coastal area of the Caspian Sea, from Kizlyar Bay in the north, to the Sulak River in the south.

Sexually mature Grass Carp migrated upstream in the spring, apparently overcoming the Kargalinsk Dam on the Terek River. Spawning sites were located 125–300 km from the river mouth. Eggs and larvae drifted downstream along the main deltaic branches and artificial channels to rice fields of the delta and its lake-like waterbodies and further into the Agrakhanskiy Bay and other coastal areas adjacent to the Terek delta. Larvae remained in these coastal areas (water salinity 6−7‰) until maturation. Both adults and juveniles overwintered in the main course of the Terek delta and in the northern Agrakhanskiy Bay.

Grass Carp reached an average weight of 1.7 kg in 2 years, 7 kg by the end of the fifth year, and 11 kg by the end of the eighth year. Grass Carp attained sexual maturity by the age of 4 (male) and 5 (females) years. No abnormalities in Grass Carp gametogenesis were found. In contrast to populations from the native range or southern basins where it is believed to be a batch-spawner, Grass Carp in this system was considered to be a fractional spawner. Absolute fecundity of Grass Carp varied from 186,000 to 2,090,000 eggs, with an average of 945,000 eggs. Relative fecundity was 38–226 eggs g^{-1} of fish weight, with an average of 130 eggs g^{-1} of fish weight. Upstream migration started mid-April, when water temperatures reached 15−16 °C, with mass migration occurring between 1 and 20 May. Spawning occurred during the last ten days of May, once water temperatures reached 18–19 °C, and flow velocity and water levels had risen abruptly. During the spawning period, flow velocities fluctuated from 0.9–2 m/sec. Within a given year, individuals that spawned during high water levels laid more eggs than those that spawned after water levels decreased and stabilized at a lower water level. Natural reproduction was considered to have occurred between 1983 and 1987.

Abrosov, V.N., and Bauer, O.N. 1955. On stocking of Grass Carp in the USSR. [O razvedenii belogo amura v SSSR]. Voprosy Ikhtiologii [Journal of Ichthyology, Moscow]. 3: 129−134.

The paper reviewed one of the first introductions of Grass Carp to European Russia. In May 1949, 73 individuals of Grass Carp (0.5–0.7kg to 2–3 kg of weight) caught in the Amur River at the village of Golovino, were transported live to fish farms in the Velikiye Luki, Moscow and Novgorod provinces. All Grass Carp survived transport and of these, 46 individuals survived to the following summer and winter despite water temperatures as low as 1–1.5 °C. Some individuals examined for parasitological purposes revealed skin, gills and fins that were heavily infected by protists (*Ichtyophirius multifiliis* and a Trichodina), monogeneans (*Dactylogyrus ctenopharyrngodoni*s and *D. amellatus*), as well as a crustacean (*Pseudergasilus major*).

Aliyev [Aliev], D.S. 1967. Morphology of young-of-the-year hybrids of phytophagous fish. [Morfologia segoletkov gibridov rastitel'noyadnykh ryb]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 7(1): 191−194.

Two hybrid progenies from a crossbreeding of a female Grass Carp (*Ctenopharyngodon idella*) and a male Bighead Carp (*Hypophthalmichthys nobilis*) were described. The predominantly matroclinous young deviated from Bighead Carp significantly toward the parental phenotype except they possessed one less caudal vertebra and were pale bluish-grey in colour. Hybrid offspring from a female Silver Carp (*Hypophthalmichthys molitrix*) crossed with a male Grass Carp were patroclinous and lacked the abdominal keel; pectoral fin position and length of the anal-fin base were intermediate between the parental character states. Hybrid fingerlings were also obtained by crossing a female Grass Carp with a male Black Bream (*Acanthopagrus butcheri*). Character states tending toward the paternal phenotype were: long ante-dorsal and pectoral-pelvic distances; a deep dorsal fin; long pectoral and ventral fins; and, a long anal-fin base. Character states in common with the Black Bream were: anterior dorsal fin position; presence of a keel between the pelvic fin and the anus; and, a small terminal mouth. Some characters approached the Grass Carp, such as the head measurements and the distance between the pelvic fins and anus. The number of anal-fin branched rays (n=17) was in between those of the parents.

Aliyev [Aliev], D.S., and Bessmertnaya, R.E. 1968. Using Grass Carp [*Ctenopharyngodon idella* (Val.)] in the fight against larvae of mosquitoes. [Ispol'zovaniye belogo amura [*Ctenopharyngodon idella* (Val.)] v bor'be s lichinkami krovososuschikh komarov]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 8(2): 395−397.

From 1961–1963, the effectiveness of Grass Carp to control mosquitoes was examined in one of the poorly drained lakes of the Karakum Canal system. During the warm season, ~90% of the lake area was covered by aquatic plants. The majority of plants were Eurasian watermilfoil *Myriophyllum spicatum* (82% of water surface), but perfoliate pondweed *Potamogeton perfoliatus* also occurred (9% of water surface). Depth of the lake did not exceed 1 m. White anopheles (*Anopheles pulcherrimus*) larvae at different stages of development were very abundant among surface vegetation, with up to 306 individuals m^{-2} (estimated as 4.5 million in total lake). In May 1961, 375 Grass Carp, ranging in length from18–22 cm and weighing between110−200 g, were released. By the end of the warm season (November), no aquatic vegetation remained in the lake. The lake was then drained and Grass Carp removed. In 1962, the lake was filled up with water again but Grass Carp were not introduced. Aquatic vegetation was minimal and did not reach the water surface, and no mosquito larvae were observed. In 1963, the aquatic vegetation continued to increase and once again covered the majority of the water surface; mosquito larvae were numerous. It was concluded that Grass Carp could effectively alter the abundance of blood-sucking mosquitoes through their consumption of aquatic macrophytes.

Aliyev [Aliev], D.S., and Sukhanova, A.I. 1977. Influence of water temperature on the maturation of gametes and spawning. [Vliyaniye temperatury vody na sozrevaniye polovykh produktov i nerest rastitel'noyadnykh ryb v Karakumskom kanale]. *In* Results and perspectives of phytophagous fish. [Itogi i perspektivy rybokhozya'stvennogo ispol'zovaniya rastitel'noyadnykh ryb]. Edited by B.D. Verigin et al. Book of Abstracts of the 9th All-Union Conference. Naukova Dumka, Kiyev. p. 17−18.

From 1969 to 1973, observations on thermal spawning conditions of phytophagous fishes in the Karakum Kanal were carried out. In 1969 and 1973, spawning of Grass Carp and Silver Carp began when water temperatures reached 18.5 °C (on 3 May and 25 April, respectively). However, in 1972 spawning started when water temperatures reached 20.4 °C. For Grass Carp, the calculated minimum required accumulated heat (from 1of January until the start of spawning) was 800 degree-days (°d). However, even though the value of accumulated heat was over 957 °d by that time, Grass Carp did not start spawning because of the low water temperature (15.3–18 °C). Thus, the amount of accumulated heat, together with water temperature, is important in determining spawning activity.

Aliyev [Aliev], D.S., and Sukhanova, A.I. 1977. Observations of the dynamics of phytophagous fish egg drifting in the Karakum Canal. [Nablyudeniya za dinamikoy skata ikry rastetel'noyadnykh ryb v Karakumskom kanale]. *In* Results and perspectives of phytophagous fish. [Itogi i perspektivy rybokhozya'stvennogo ispol'zovaniya rastitel'noyadnykh ryb]. Edited by B.D. Verigin et al. Book of Abstracts of the 9th All-Union Conference. Naukova Dumka, Kiyev. p. 9-11.

Natural reproduction along a 20 km head stretch of the Karakum Canal was studied in four species of introduced phytophagous fishes, including the Grass Carp. Stationary observations revealed the first case of natural reproduction of these four species in the Karakum Canal. Spawning sites of all four introduced phytophagous fishes were located in the upper stretch of the canal. Depending on water temperature, spawning began between April and May and ended in late July. Intensive spawning, estimated by the number of drifting eggs, occurred during the first 25–30 days of the spawning period. Maximal drifting intensity (number of eggs per time unit per net) occurred at the beginning of the spawning period, and decreased during the middle and end of the spawning period by a factor of 3 and 10, respectively. During the first 3–4 to 7–7.5 days of intense spawning, continuous drifting occurred with 4.6–130.5 thousand eggs per minute. Two daily spawning peaks occurred; one in late evening/night and one in the early morning. Drifting intensity subsequently declined to 1.5–3 days of continuous drifting, to hours to 4–5 days of interrupted drift (i.e., no egg drift). At the end of the spawning season, egg drifting was episodic, lasting only 0.5-2 h. Spawning interruptions commonly occurred during the daytime. At the end of the spawning season, eggs were only present in late evening-night.

Exact spawning site locations were calculated based on the presence of embryos at the morula-gastrula stage of development within the drifting eggs and by taking into account water temperature and flow velocity. Location of main spawning sites were calculated to be between the 2nd and 5th kilometre of the head stretch of the Karakum Kanal (close to its exit from the Amu Darya River), with fewer fishes spawning up to 10 km downstream of there. Between 1969 and 1975, Grass Carp eggs were the most abundant compared to the other three species; comprising 51–61% of all pelagic eggs collected during the survey.

Baltadzhi, R.A. 1972. Feeding of phytophagous fish young-of-the-year in ponds constructed on the base of Mironovsjaya Thermal Electric Station. [Pitaniye segoletok rastitel'noyadnykh ryb v prudah, postroennykh na baze tioplykh vod Mironovskoy GRES]. *In* Acclimatization of phytophagous fish in water bodies of the USSR. [Akklimatizatsiya rastitel'noyadnykh ryb v vodoyomakh SSSR]. Editd by M.F. Yaroshenko et al. Book of Abstracts of the 7th All-Union Conference. Shtiintsa, Kishenev. p. 23−26.

Young-of the-year (1–2 g) Grass Carp (aquaculture raised) were released into warm-water ponds of the Mironovsjaya Thermal Electric Station for three months (until September). In contrast to natural conditions, Grass Carp primarily consumed aquatic plants represented mainly by duckweed and field grass, as well as detritus, while algae and large zooplankton (*Cyclops*, *Daphnia*, and *Bosmina*) were only consumed at the beginning of summer. Indices of gut fullness varied from 70–1,540 $^{0}/_{000}$, with peaks in July and August.

Belotserkovskiy,Yu.B. 1980. Commercial use of Far Eastern phytophagous fish in the Volga-Akhtuba flood plain and Volga Delta. [Rybokhozya'stvennoye ispol'zovaniye rastitel'noyadnykh ryb lal'nevostochnogo kompleksa v volgo-akhtubinskoy poyme i del'te Volgi]. *In* Phytophagous fishes in industrial fish culture. Edited by G.K. Kamilov. Book of Abstracts of the 9th All-Union Conference. [Rastitel’noyadnye ryby v promyshlennom rybovodstve. Tezisy dokladov IX Vsesoyuznogo Soveshchaniya.] Izdatel’stvo AN UzSSR, Tashkent. p. 65−67.

Results of Grass Carp introductions to waters of the Lower Volga (Volgo-Akhtuba flood plain and delta), primarily through repeated release of aquaculture-raised larvae and juveniles, were reviewed. Although spawning, as well as the presence of eggs and larvae, was regularly observed, a self-sustaining population had not established. Adult Grass Carp had a high growth rate and fatness; fish attained a maximum weight of 24 kg.

Bessmertnaya, L.E. 1968. Some aspects of feeding of Grass Carp fry. [Voprosy pitaniya lichinok belogo amura.] *In* New research on ecology and stocking of phytophagous fishes. [Novye issledovaniya po ekologii i razvedeniyu rastitel'noyadnykh ryb.]. Edited by G.V. Nikol'skiy. Nauka, Moscow. p. 164−168.

Feeding of Grass Carp larvae at different development stages, as well as the daily mode of larval feeding during the D2 ontogenetic stage (according to Vasnetsov 1953) was examined. Effects of long-term starvation on larvae were also experimentally assessed. Results indicated that at water temperatures of approximately 26 °C, 97 to 99% of larvae survived starvation for 3 to 6 days and were able to restart feeding. Appearance of abnormalities and disease occurred on the seventh day of starvation; some larvae survived and began to feed after 11 days of starvation.

Bezrukov, V.F., and Berdyshev, G.D. 1983. The variability of muscle proteins in Grass Carp *Ctenopharyngodon idella* (Val.), Silver Carp *Hypophthalmichthys molitrix* (Val.) and Bighead Carp *Aristichthys nobilis* (Rich.) (Cyprinidae). [Izmenchivost' myshechnykh belkov belogo amura *Ctenopharyngodon idella* (Val.), tolstolobika *Hypophthalmichthys molitrix* (Val.) i pestrogo tolstolobika *Aristichthys nobilis* (Rich.) (Cyprnidae).] Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 23(3): 502−507.

Using an electrophoretic method, myogenic activity was studied in three species of phytophagous fishes: Bighead Carp, Grass Carp, and Silver Carp. Myogens were identified as species-specific by their electrophoretic spectra. Hybrids between two species maintained protein fractions from both parents. In Grass Carp, two types of myogenic patterns were revealed: A-type, and B-type. Observed variability of fast myogenic fractions was related to different ages of the studied individuals. Grass Carp at age 1+ possessed the A-type, while age 2+ individuals possessed the B-type. Results indicate that in addition to genetically determined polymorphism, protein fractions of myogens in Grass and Silver carps also demonstrate epigenetic variability defined by age factors.

Bizyayev [Bizyaev], I.N. 1966. Results of introduction of Black Amur, Grass Carp, Silver Carp and Bighead to open waters of the Azov-Kuban' Region. [Rezul'taty vseleniya amurov i tolstolobikov v otkrytyye vodoiomy Azovsko-Kubanskogo rayona]. *In* Fisheris development of phytophagous fish. [Rybokhozya'stvennoye osvoyenie rastitel'noyadnykh ryb.]. Edited by E.N. Pavlovskiy. Materials of 4th All-Union Conference, Moscow, 1963. Moscow, Nauka. p. 49−51.

and

Bizyayev [Bizyaev], I.N. 1968. Some features of acclimatization of phytophagous fish in the Northern Caucasus. [Nekotoryye osobennosti akklimatizatsii rastitel'noyadnykh ryb na Severnom Kavkaze]. *In* Acclimatization of fish and invertebrates in water bodies of the USSR. [Akklimatizatsiya ryb i bespozvonochnykh v vodoyemakh SSSR]. Edited by A.F. Karpevich. Nauka, Moscow. p. 112–115.

In 1958, 4050 young-of-the year Grass Carp, weighing between 5–10 g, were transported to fish farm ponds in the Krasnodar Krai (Kuban' region). By 1960, only 23% of Grass Carp fry had survived and by autumn of 1960, at an age of 27–28 months, weighed on average 1,239 g. Surviving Grass Carp were subsequently released into natural waterbodies of the Lower Kuban' system. In 1963, three juvenile Grass Carp aged 1+ (length: 36–45 cm, weight: 730–1,500 g) were caught, indicating successful spawning had occurred in 1962.

In following years, spawning in the Kuban River occurred at water temperatures of 20–23 °C; feeding behaviour occurred between 5–35 °C. Each year, juveniles and post-spawning adults migrated to the Azov Sea estuarine zone, where salinity reached 11.5‰. Aside from temperature, stream characteristics largely influenced spawning success in the Kuban River. Unlike the majority of cyprinids, carps in the Far East preferred spawning in turbid waters, which enabled eggs to be suspended in the water column during the entire period of embryonic development. Investigations of reproduction in phytophagous fishes in the Kuban River indicated that spawning was not influenced by water level, but rather by turbidity. The relative egg density decreased through a hydration process in the perivitelline space and approached the relative density of turbid water. Under natural conditions, reproduction of carps in the Far East occurred where water turbidity parameters reach 1.2 kg sediment/m^3 of water during the spawning period and include the Amu Darya, Terek, Kura and Kuban rivers. In contrast, in rivers with low turbidity, such as the Don, Volga, and Dnieper, as well as in many lakes, reservoirs and ponds, natural spawning of phytophagous fishes was improbable. Spawning of phytophagous fishes in the Kuban River took place in the main course, along a river section between villages Tbilisskaya and Temizhbeckskaya, at channel bars with small gravel substrate and having flow velocities higher than in silted, broad, and deeper sectors of the river. Hydrological conditions at the bars (high flow velocity, rough pebbly riverbed, and numerous vertical vortices) maintained suspension in the water column of the released eggs until the hydration process had finished.

Bogeruk, A.K. 1984. Thermal adaptations of Grass Carp *Ctenopharyngodon idella* (Val.) during introductions to water bodies at different latitudes. [Temperaturnyye adaptatsii belogo amura *Ctenopharyngodon idella* (Val.) pri introduktsii v vodoiomy razlichnykh shirot.] *In* Biological fundamentals of intensification of fisheries in water bodies of the Volgograd Province. [Biologicheskiye osnovy intensifikatsii rybnogo khozyastva v vodoemakh Volgogradskoy oblasti.]. Edited by V.N. Nefedova, and M.P. Miroshnichenko. Sbornik Nauchnykh Trudov GosNIORKh. [Collected Scientific Articles of State Research Institute of Lake and River Fisheries]. 218: 123−133.

Thermal adaptations were investigated in over 1,000 individuals of second and third generation Grass Carp stocked in four non-native ranges located in different climatic zones: Moscow Province (56–57°N); Republic of Daghestan (southern Russia) (43–44°N); Iran (33–34°N); and, Cuba (22–23°N). The degree of temperature acclimation was estimated by the body mass growth rate coefficient (K) described by the equation: $K=[3(M_1^{1/3}-M_0^{1/3})]/T$, where M_0 and M_1 represent the initial and final body masses, respectively, and T is the growth period (in days). The influence of temperatuare on growth for Grass Carp populations from different latitudes was estimated by the ratio of accumulated heat (degree days) to body mass gain (one mass unit). This coefficient demonstrated how much accumulated heat was necessary to gain one mass unit. Results indicated that Grass Carp populations from each location were thermally acclimated; thermal threshold for the start of feeding (after the cold season), thermal optimum for vital functions, and the rate of growth were specific for each location. Water temperature of each climatic zone was highly correlated with the acclimation temperature and growth rate of Grass Carp from that location. Moscow populations at low temperatures required the least amount of degree days to gain 1 g of body mass, while populations from Cuba at high temperatures required the lowest number of degree days to gain 1 g of body mass. Growth rate differed for climatic zones at the same water temperature. At water temperatures between 15–25 °C, growth rates were highest for Grass Carp from northern populations (Moscow and Daghestan), while at water temperatures between 27–32 °C, southern populations (Iran and Cuba) had the highest growth rates. Thermal optimums also varied by location: 26–28 °C (Daghestan); 28–30 °C (Iran); and, 28–31 °C (Cuba).

Borutskiy, E.V. 1952. Data on feeding of Grass Carp *Ctenopharyngodon idella* (Val.) and *Plagiognathops microlepis* (Bl.) in the Amur River. [Materialy po pitaniyu belogo amura *Ctenopharyngodon idella* (Val.) and melkocheshuychatogo zheltopiora Plagiognathops microlapis (Bl.) v basseyne Amura]. *In* Proceedings of the Amur Ichthyological Expedition in 1945−1949. [Trudy Amurskoy Ikhtiologicheskoy Ekspeditsii 1945-1949 godov.]. Edited by G.V. Nikol'skiy. 3: 505−510.

Feeding and dietary compositon of 18 Grass Carp individuals (33–58 cm body length) collected between June and September of 1949 and 1959 from the Amur River were examined. Digestive tract length was 222–298% of the body length; fish size was not correlated to gut length. The majority (except for two) of examined digestive tracts contained crushed leaves and sedge stems; other dietary components (e.g., algae and invertebrates) were likely consumed as epiphytes. During a period of low water level, gut content analysis of two specimens revealed the presence of only water moss *Fontinalis*. This was likely due to the lack of availability of other macrophytes for Grass Carp to feed on during the low water level. Feeding did not vary with age or size, but some seasonal differences were found, as Grass Carp feeding decreased in the autumn (in September, the gut fullness was a seventh as much as in July) and completely ceased in the winter. Gut content was similar in all three gut sections (anterior, middle, and posterior); however, nutrient absorption (calculated by level of nitrogen absorption) in Grass Carp was higher than in Silver Carp: 65% vs 38.4%.

Burdiyan, B.G., and Razmashkin, D.A. 1972. Farming of Grass Carp in Chebach'e Lake, Tyumen' Province. [Vyrashchivaniye belogo amura v pitomnom ozere Chebach'e Tyumenskoy oblasti]. *In* Acclimatization of phytophagous fish in water bodies of the USSR. [Akklimatizatsiya rastitel'noyadnykh ryb v vodoyomakh SSSR]. Edited by M.F. Yaroshenko et al. Book of Abstracts of the 7th All-Union Conference. Shtiintsa, Kishenev. p. 23−26.

In 1970 and 1971, approximately 3,000 parasite-free, 17-day-old individuals/hectare were introduced into Chebach'e Lake in the Tyumen' Province (southern Siberia). This is one of the most north-eastern Grass Carp introductions in the former USSR. Lake area was 90 ha, maximal depth was 3.5 m, average depth was 2.5 m and the lake was classified as eutrophic. Macrophyte presence was minimal; comprised mainly of pondweeds (*Potamogeton pectinatus* and *P. pusillus*), and the common reed. Zooplankton biomass reached 1.5–5 g/m^3 and phytoplankton was comprised primarily of diatoms. Water temperature at the time of introduction was 18−20 °C.

Following introduction, Grass Carp became infected; mainly with *Tripartiella bulbosa* (100% infection, up to 35 parasites in microscope field of view) and *Diplostomum spathaceum* (93% infection, up to 24 metacercariae in microscope field of view). By the end of the warm season (October), average fry weight was 11.5 g (1970) and 14.5 g (1971). Grass Carp aged 1+, weighed 30–125 g by June and 150–300 g two months later. Thus, the average annual weight increment was 202 g. The diet of young-of-the-year Grass Carp during the first months consisted of zooplankton and phytoplankton (60% of food weight), hironomid and caddisfly larvae, as well as gammarids. By September, the diet shifted to mostly phytoplankton (67–90%) and by late autumn the primary dietary components were ephippial cladoceran and copepod eggs (up to 78% of total food weight). The following summer, 1+-old fry started to consume pondweeds and their seeds, as well as pondweed-associated diatoms (>25 species) and caddisfly (*Limnophilus*) larvae.

Charyyev, R. 1984. About some of the consequences of introductions and naturalization of Grass Carp *Ctenopharyngodon idella* (Val.) (Cyprinidae) in the Karakum Canal. [O nekotorykh posledstviyakh vseleniya i akklimatizatsii belogo amura *Ctenopharyngodon idella* (Val.) (Cyprnidae) v Karakumskom kanale.] Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 24(3): 385−892.

After nearly 20 years since Grass Carp were first introduced to the artificial and natural waterbodies of the Karakum Canal and adjacent lake and river systems, the introduction history, biology and impacts of introduced Grass Carp were reviewed. Grass Carp reduced overabundant aquatic macrophytes in artificial waterbodies. In some natural or semi-natural ponds, reservoirs or river sections, Grass Carp removed most submerged and floating macrophytes (e.g., *Phragmites communis*, reedmace *Typha angustata*, water buttercup) resulting in the loss of spawning grounds of local phytophilous fish (e.g., *Cyprinus carpio*) as well as the areas used by larvae and juveniles for foraging and growth during the first summer after hatching. Grass Carp diet varied significantly in intensity and selectivity depending on season, and/or habitat and locality.

Doroshev, S.I. 1963. On survival of Grass Carp and Silver Carp fry in Aral and Azov sea water of different salinity. [Vyzhuvaniye molodi belogo amura i tolstolobika v azovskoy i aral'skoy vode raznoy solionosti.] *In* Problems of industrial use of phytophagous fishes in waterbodies of the USSR. [Problemy rybokhozya'stvennogo ispol'zovaniya rastitel'noyadnykh ryb v vodoyemakh SSSR.]. Edited by A.O. Tashliyev. Izdate'lstvo AN Turkmenskoy SSR, Ashkhabad. p. 144−149.

and

Doroshev, S.I. 1964. Salinity tolerance of some species of fish recommended for introductions to the Sea of Azov. [Soleusto'chivost nekotorykh vidov ryb, rekomendovannykh dlya vseleniya v Azovskoye more]. *In* Acclimatization of fish and food organisms in seas of the USSR. [Akklimatizatsiya ryb i kormovykh organizmov v moryakh SSSR.]. Edited by A.F. Karpevich. Trudy VNIRO. [Proceedings of All-Union Institute for Fisheries and Oceanography]. 55(2): 97–107.

The effect of salinity on the survival rate of Grass and Silver carps fry was examined. For this study, 40-day-old Grass Carp fry (length: 125–140 mm, weight: 150–400 mg) were imported from China and exposed to natural marine waters of varying salinity levels from the Sea of Azov (2.5, 5, 7.5, 9, 10, 11, 12, and 12.5‰) and from the Aral Sea (3.5, 7, 10.5, 12, and 14.5‰). The average daily mortality rate in the control tank (freshwater) accounted for 1% of total mortality. Rapid exposure to the 2.5, 5 and 5.5‰ Azov sea water resulted in zero mortality level (all individuals survived until the end of the experiment). At 10‰ salinity, the average daily mortality increased to 1.6% as compared with the control group and most fry died before the end of the experiment. Sea of Azov salinity levels of 12.5‰ resulted in complete fish mortality within 3 days, with an average daily mortality of 33%. However, gradual exposure to Azov sea water of the same salinity resulted in twice as low mortality (e.g., in water of 12.5‰ fry survived for 6 days, with an average daily mortality of 16%). Gradual exposure to the 3.5, 7, 10.5, and 12‰ Aral Sea water resulted in zero mortality. In 14.5‰ Aral Sea water, the average daily mortality increased to 1% and growth rate of surviving individuals decreased considerably. The upper salinity threshold for Grass Carp fry was estimated at 9–10‰ (Azov Sea) and 13–14‰ (Aral Sea), which corresponds to a chloride concentration of approximately 5‰.

Duvarova, A.S. 1980. Dependence of embryonic development rate on temperature regime of incubation. [Zavisimost' skorosti embrional'nogo razvitiya belogo amura ot temperaturnogo rezhima inkubatsii]. *In* Phytophagous fishes in industrial fish culture. Edited by G.K. Kamilov. Book of Abstracts of the 9th All-Union Conference. [Rastitel'noyadnye ryby v promyshlennom rybovodstve. Tezisy dokladov IX Vsesoyuznogo Soveshchaniya.] Izdatel'stvo AN UzSSR, Tashkent. 162 p.

Effects of water temperature on the duration of Grass Carp embryonic development were studied. Following hypophysal injections to six female Grass Carp, 300 to 500 eggs were collected and incubated at 24, 26, 28, 30, 32, or 34 °C. Normal embryo development was highest at water temperatures of 24 and 26 °C, and the duration of embryogenesis at these temperatures was 19 hours and 50 minutes and 18 hours, respectively. At 28 °C, embryonic development was quicker and took on average, 16 hours and 54 minutes. At 30 °C, 50% of embryos died after 8–9 hours of incubation. Of the surviving individuals, most died before hatching and for those embryos that hatched, 0.5–1% were abnormal and died. Temperatures of 32 and 34 °C were lethal as all embryos died within 5–9 hours and 20–30 minutes, respectively. Duration of development from egg hydration to blastodisc formation was similar for all temperatures – taking approximately 20 minutes. Duration of cleavage differed by treatment: 7 h 38 m at 24 °C; 5 h 37 m at 26 °C; 5 h 7 m at 28 °C; and, 4 h 49 m at 30 °C. Duration of organogenesis was similar at 24, 26 and 28 °C, averaging 5 h 20 m to 5 h 40 m, but at 30 °C it was considerably shorter at 4 h 19 m.

Faryshev, N.I., and Bashunov, V.S. 1980. [Estestvennoye razmnozheniye belogo amura v reke Ili]. *In* Phytophagous fishes in industrial fish culture. Edited by G.K. Kamilov. Book of Abstracts of the 9th All-Union Conference. [Rastitel'noyadnye ryby v promyshlennom rybovodstve. Tezisy dokladov IX Vsesoyuznogo Soveshchaniya.] Izdatel'stvo AN UzSSR, Tashkent. 197 p.

The Ili River flows into Balkhash Lake and is characterized by a spring-summer water level rise associated with increased turbidity and relatively fast current. In 1978 and 1979, Grass Carp introduced into Balkhash Lake spawned in the Ili River. Fish entered the deltaic Ili River branches (e.g., Ir, Kugaly, Dzhideli, and Topar) and moved approximately 170–250 km upstream from the lake. Spawning sites were located along an 80 km section of the Ili River (upstream from the village of Bakanas) characterized by shallow and wide riffles, sandy spits and islands. Current velocities at spawning sites were 0.6–1 m•s^{-1}. Spawning occurred in June when water temperature reached 18 °C and the water level rose sharply. Spawning adults were aged 4+ to 8+years, had an average length of 55.8 cm (males) and 62.7 cm (females), and an average weight of 3 kg (males) and 4.4 kg (females). The ratio of females to males was 1:1.5. A single spawning peak was recorded, with up to 10,000 eggs collected in 5 minutes (trap opening=0.25 cm^2). Embryos hatched while drifting 15–20 km downstream from the village of Araltyube; however, spawning success was low, as only one juvenile (age 2+ years) was later collected. See also Nezdoliy and Mitrofanov (1975) for a review of the Grass Carp population in the Kapchagay Reservoir (upper reaches of the Ili River) and its spawning upstream from the Kapchagay Reservoir.

Gannokha, E.N. 1972. Rearing of Grass Carp larvae in ponds with irrigation water with increased mineralization. [Podrashchivaniye lichinok belogo amura v prudakh na irrigatsionnom stoke s povyshennoy mineralizatsiey vody]. *In* Acclimatization of phytophagous fish in waterbodies of the USSR. [Akklimatizatsiya rastitel'noyadnykh ryb v vodoyomakh SSSR]. Edited by M.F. Yaroshenko et al. Book of Abstracts of the 7th All-Union Conference. Shtiintsa, Kishenev. p. 33−34.

Effects of mineral concentration on the growth of 3-day-old Grass Carp larvae were examined. Larvae were held in two pond types:

1. two ponds with flow water and average mineral concentration of 2943 mg•l^{-1}; and,
2. two ponds without water input and with increasing mineral concentration (up to 9,766 mg•l^{-1}).

The experiment lasted for 20 days, from 11–30 June, at water temperatures 14−27 °C. Larvae exhibited variable weight gain and survival rates when exposed to different mineral concentrations. After 20 days, in the pond with flow water (average mineral concentration of 2,943 mg•l^{-1}), larvae weighed 89.9–95.5 mg, and survival rate was 64–66%. However, in a pond with a final mineral concentration of 5,800 mg•l^{-1}, larvae weighed up to only 65 mg and survival rate was 40%. All larvae died in a pond with a final mineral concentration of 9,766 mg•l^{-1} by the 7th day following introduction.

Gorbach, E.I. 1961. Age composition, growth and age of sexual maturity in *Ctenopharyngodon idella* (Val.) and *Mylopharyngodon piceus* (Rich.) in Amur River drainage. [Vozrastnoy sostav, rost i vozrast nastupleniya polovoy zrelosti belogo *Ctenopharyngodon idella* (Val.) i chornogo *Mylopharyngodon piceus* (Rich.) amurov v basseyne r.] Amura. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 1(1): 119−126.

From 1957–1960, observations on Grass Carp biology were made in the lower section of the Middle Amur River (between the villages of Ventselevo and Golovino), where approximately 70% (1,100 metric centners annually) of commercially fished Grass Carp in the Amur River (Russian section) were caught. Compared with catch data from 1933–1949, the age and size composition of Grass Carp has changed due to intensive fishing. In the1930s, the most abundant age classes were between 6+ to 14+, with 10–13-year-old fish most abundant. In 1957–1959, fish aged 4+ to 6+ and 6+ to 8+ (depending on locality) were most abundant and fishes aged >9+ were rare; although a 21-year-old individual was collected.

The most rapid linear growth occurred duing the first 4–5 years of life (9–10 cm). Annual growth subsequently decreased with age: 6–7 cm during 5–8 years of life; and, 2.5–5 cm at 8–9 years of life. In contrast to linear growth, annual weight gain was greatest in fishes older than 5–7 years. Annual weight gain increased with age: 480 g (4-year-old fish); 675 g (5-year-old fish); 680 g (6-year-old fish); 1,250 g (7-year-old fish); 2,700 g (8-year-old fish); 1,012 g (9-year-old fish); and, 1,180 g (10-year-old fish).

Stage of gonad development was determined by direct examination or using histological methods. Non-mature individuals (I and II gonad developmental stages) were up to 80 cm long and aged up to 10+ years, but most (70%) individuals were 50–65 cm long and aged 5+ to 7+ years. Non-mature individuals did not participate in spawning in the current year (i.e., year of examination). Mature individuals (III to VI-II gonad developmental stages) were 54–94 cm long at an age of 6+ to 14+ years; however, most individuals (52%) were 70–78 cm long at an age of 9+ to 11+ years, and fish 54–69 cm long comprised only 5.5%.

Gorbach, E.I. 1965. Maturation and spawning of Grass Carp *Ctenopharyngodon idella* (Val.) in the Middle Amur. [Sozrevaniye i razmnozheniye belogo amura *Ctenopharyngodon idella* (Val.) v Srednem Amure]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 5(3): 426−441.

Histology of female and male Grass Carp gonads from the Middle Amur was examined. Individual females could spawn repeatedly (two or three times) within one spawning season but the number of eggs was greatest at first spawning. Ovaries of most females were completely spent by the end of July. In females with partially spent ovaries (second and/or third portion of eggs unlaid), eggs were resorbed. Egg resorption time varied based on spawning. If spawning occurred before early August, egg resorption was completed by winter (late September–October) and females could spawn during the following spawning season. However, for females that did not spawn or only partially spawned, egg resorption took longer due to low water temperatures that last until early May. These females, which were mostly older, did not develop new oocytes and thus did not spawn the following spawning season. Mature males were observed to contain two generations of spermatozoids released in several portions.

Gorbach, E.I. 1972. Fecundity of Grass Carp *Ctenopharyngodon idella* (Val.) in the Amur drainage. [Plodovitost' belogo amura *Ctenopharyngodon idella* (Val.) v basseyne Amura]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 12(4): 674−683.

Between1963–1969, the fecundity of female Grass Carp (n=190; length: 66–96 cm, weight: 5,050–16,400 g, age: 7+ to 15+) collected from the Middle Amur River, (between the villages of Ventselovo and Petrovskoye) were examined. Absolute fecundity (number of eggs per fish) ranged from 237,000 (7-year-old, length=67.5 cm), to 1,687,000 eggs (15-year-old, length=96 cm), and averaged 820,000 eggs. Approximately 90% of females had between 600,000 and 1,150,000 eggs. Absolute fecundity was positively correlated with body size, weight and age. For example, average absolute fecundity increased by 4 times with size; from 454,000 eggs in ~66 cm long females to 1,634,000 eggs in ~96 cm long females. Significant correlations were found between absolute fecundity and weight (r=+0.73), Fulton's (r=−0.25) and Clark's (r=+0.20) condition factors, and Tester's fat content factor (ratio of weight of an individual fish in the air to that in water) (r=+0.32) but not with the fat content index (r=−0.04). Absolute fecundity was also positively correlated with environmental conditions and food availability during the warm season before spawning. Relative fecundity ranged from 48–177 per gram weight of the body without viscera, with an average value of 110. Relative fecundity was also correlated positively with length, weight, and age but inreased only slightly in old or large females. Fecundity was also affected by condition, fat content, pre-spawning feeding, and fishing pressure. No correlations were found between relative fecundity and condition factors (Fulton's and Clark's), but there was a weak correlation with Tester's content factor (r=−0.18) and the fat content index (r=−0.17).

Gorbach, E.I., and Krykhtin, M.L. 1980. Optimal parameters of the main factors determining maturation and reproduction of Grass Carp and Silver Carp in the Amur. [Optimal'nye parametry osnovnykh factorov, opredelyayushchie sozrevanie i razmnozhenie belogo amura i tolstolobika v Amure]. *In* Phytophagous fishes in industrial fish culture. Edited by G.K. Kamilov. Book of Abstracts of the 9th All-Union Conference. [Rastitel'noyadnye ryby v promyshlennom rybovodstve. Tezisy dokladov IX Vsesoyuznogo Soveshchaniya.] Izdatel'stvo AN UzSSR, Tashkent. p. 152–154.

To attain sexual maturity in the Amur River region, Silver Carp and Grass Carp required an annual accumulated heat of 2,655–3,111 degree-days (°d) (mean 2865 °d). Of these, 565 °d must immediately precede the pre-spawning period (before 15 June). During years with a low water level, the pre-spawning accumulated heat value increased to 650 °d and there were approximately 20 days of water temperatures between 15–20 °C, an estimated 50% of adult Grass Carp reached maturity at the age of 6+ to 7+ years (males) and 7+ to 8+ years (females). In colder years, with only ~10 days when water temperatures reached 15–20 °C before 15 June and the amount of accumulated heat reached only ~500 °d, most Grass Carp delayed spawning for 3 (males) or 4 (females) years. Spawning began when water temperatures rose above 17 °C. Below this threshold, spawning activity stopped and eggs that had already been laid perished. The period of most intensive spawning took place in late June and early July, when water temperatures ranged from 21–26 °C. However, the dates and intensity of spawning were highly correlated to fluctuations in water level; even if favourable water temperatures were reached, spawning only occurred when water levels were high and ceased if levels dropped. Spawning was most successful when there were 2–3 periods of rising water levels (increases of 1–2 metres) each maintained for a period of 1 to 2 weeks. Under unfavourable conditions (i.e., only one or two short periods of rising water level), 25–30% of Grass Carp females had unlaid and then resorbed eggs. Among other hydrological requirements for successful spawning, water velocities of 0.7–1.4 $m \cdot s^{-1}$ (not less than 0.3 $m \cdot s^{-1}$) and a 100–600 km length of river stretch between spawning sites and nursery areas were necessary. This distance may differ in other rivers depending on water temperatures and velocities, but there must be enough time for bathypelagic eggs and embryos to reach the stage of active feeding and swimming. Otherwise, eggs and embryos thicken and die on the substrate before they reach the active stage.

Gorbach, E.I., and Krykhtin, M.L. 1981. Rate of maturation in Grass Carp *Ctenopharyngodon idella* (Val.) and Silver Carp *Hypophthalmichthys molitrix* (Val.) in Amur River. [Temp sozrevaniya belogo amura *Ctenopharyngodon idella* (Val.) i tolstolobika *Hypophthalmichthys molitrix* (Val.) v reke Amur.] Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 21(5): 835–843.

Variation in age, length, and weight at first maturity was described for Grass Carp and Silver Carp in the Amur River. Male Grass Carp matured at 6–12 (5+ to 11+) years (majority at 7–9 years at minimal length and weight of 55 cm and 3 kg, respectively), females at 7–14 years (majority at 9–11 years at minimal length and weight of 56 cm and 3.1 kg, respectively). Rate of maturation was dependant upon annual water supply and flood volume. In high water years

(1958–1964), first maturation occurred in both males and females at an age of 8 (7+) years. In low-water years (1967–1970 and 1974–1978), first maturation occurred at 7 years in males (56–60 cm long) and at 8 years in females (61–65 cm long). In lower-water years, the majority of matured adults, both first-time and repeated spawners, were 3–4 years younger (males 7–8 years, females 8–10 years) than those from high-water years. Changes in maturation rate over years were related to differences in the thermal constant (accumulated heat degree-days) during the pre-spawning period and accumulated fat stores in individual fishes. In high-water years, water temperatures were lower in general and the development of gonads slowed down. Mass (weight) maturation in the Amur River was dependant on the average pre-spawning thermal constant of 919 ± 29 degree days and exposure to warm water for 29 ± 2 days.

Gorbach, E.I., and Krykhtin, M.L. 1988. Migration of Grass Carp, *Ctenopharyngodon idella*, and Silver Carp, *Hypophthalmichthys molitrix* in the Amur basin. [Migratsii belogo amura *Ctenopharyngodon idella* i belogo tolstolobika *Hypophthalmichthys molitrix* v basseyne Amura. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 28(4): 619–625.

Spawning grounds for Grass Carp were located in the Middle Amur River (~500 km stretch) between the villages of Pashkovo (585 km upstream from the town of Khabarovsk) and Lugovoye (95 km upstream from the town of Khabarovsk), and in the Songhua (Sungari) and Ussuri rivers. Main spawning sites were located in the lower lowland section of the Songhua River (approximately 200 km upstream from its confluence with the Amur River) and in a 100 km stretch of the Amur River below the Ussuri River mouth. Eggs and pre-larvae drifted over 500 km downstream from spawning sites. Pre-larvae and actively feeding larvae were present in the Middle Amur River 100 km and 265 km downstream of Khabarovsk; however, Grass Carp larvae were not present 540–930 km downstream of Khabarovsk or in the Khanka Lake basin. Thus, the majority of larval and post-larval Grass Carp resided in the Middle Amur lowland where the floodplain is well-developed. Young-of-the-year and 1-year-old Grass Carp were located up to 475 km downstream of Khabarovsk, but never further downstream. Fish gradually dispersed further downstream in the Amur River as they grew; with >3+-year-old fish regularly caught in the Lower Amur River, but were least abundant in the lowest section of the river. At an age of 4−5 years and length >70 cm, maturing adults began the 500 km upstream migration (from Bogorodskoye to Malmyzh), approaching Malmyzh in approximately 2 years. Further migration from Malmyzh to the main spawning sites also took at least 2 years. Maturing adults over-wintered in deepwater pockets located in sections of the river close to spawning sites. A large number of mature individuals moved in late May–June into the warmer waters of the Sungari River. During the second half of July, post-spawn fishes gradually returned to the main Amur course to feed (mainly along left-hand waterbodies connected to the main Amur in water temperatures between 20–26 °C), and overwinter.

Karpov, V.E., Bayekeshev, A.Sh., Glukhovtsev, I.V., Shapovalov, M.V., and Pichkily, L.O. 1989. Characteristics of self-sustaining stocks of Grass Carp and Silver Carp in the Balkhash-Ili basin. [Kharakteristika samovosproizvodyashchikhsya stad belogo amura i belogo tolstolobika Balkhash-Iliyskogo basseyna.] *In* . Phytophagous fish in waterbodies of different types. [Rastitel'noyadnye ryby v vodoyemakh raznogo tipa.]. Edited by Negonovskaya I.TSbornik Nauchnykh Trudov GosNIORKh. [Collected Scientific Articles of State Research Institute of Lake and River Fisheries]. 301: 86–112.

Grass Carp populations in the Ili River, including Balkash Lake and the Kapchagay Reservoir, were examined. In 1958, Grass Carp larvae from China were introduced into Alma-Ata Pond Farm located in the Balkhash Lake basin. From 1963–1964, larvae were cultivated in Chilik Pond Farm and Alma-Ata Fish Hatchery. Since 1963, intentional releases and known cases of fish escapes have occurred into Balkhash Lake. Since the late 1970s, two self-sustaining populations, physically separated by the Kapchagay HEPS dam, existed in the region; one in

Kapchagay Reservoir and the other in Balkhash Lake. In the 1970s, the Kapchagay population (located upstream of the Kapchagay Dam completed in 1970) used to spawn in the Ili River. The estimated distance (80 km or less) from the reservoir to the major spawning sites of Grass Carp was identified based on age (stage of development) in water samples and the average flow velocity (0.6 m•s^{-1}). By the mid-1980s, the migratory distance considerably increased. An analysis of the total number of drifting embryos and pre-larvae, as well as their ratio (larger proportion of pre-larvae in catches further downstream) against the temporal pattern of downstream migration and hydrological conditions suggested that major spawning sites of the Kapchagay population were 120−200 km upstream from the reservoir, a shift of 40–120 km.

During the first decade following introduction, spawning migration of the Kapchagay Grass Carp started in April (in late March in some years) when water temperature attained 10–12 °C and terminated by early or mid-July, with peak migration in late April-early May when water temperature reached 21.5 °C. In general, the number of migrating fishes depends on water level rather than temperature. Maximal drift densities were 5,300 (1986) and 6,000 (1987) eggs and larvae sec^{-1}, which corresponds to high water years In the upper Ili River, three peaks of downstream migration (free embryos and larvae) occurred, indicating both single- and multiple-batch spawning patterns occur in this area and corresponds to a long spawning period (longer than 3 months, from April to July). However, the authors supposed that the peaks more likely indicated the existence of several groups of adults reaching spawning sites at different times rather than a multiple-batch spawning pattern. Absolute individual Grass Carp fecundity was similar in the Kapchagay population and Amur River and varied between 220,000–1,630,000 (averaging 635,000) eggs; relative individual fecundity was between 41.5–163.7 (averaging 91.4) eggs.

The Balkhash Lake population spawned in the Ili River, up to 300 km upstream of the lake (downstream of the Kapchagay Dam). Hydrological conditions for Grass Carp spawning downstream of Kapchagay Reservoir were less favourable than those unsptream of the dam. The volume and timing of water releases downstream from the reservoir, which influenced water level and temperature, decreased the spawning period and shifted spawning sites (downstream to the lower reaches of the Ili River). Spawning success was highly dependent on the temperature of discharged water; cold water discharged from the reservoir ceased spawning. Although this population was established, natural reproduction was limited and likely hindered due to unsuitable conditions for larval development (requires a short distance for downstream drift and sufficient zooplankton and phytoplankton abundance for feeding). However, in some years with a pronounced high-water period (for example, 1987) during the peak of downstream migration, intensity of the drift was 50,000 eggs and larvae sec^{-1}. In the lower Ili River, data indicated a pattern of single-batch spawning in Grass Carp with a total spawning period of less than 1.5 months. Absolute female fecundity in the Balkhash population (1970−1973) was 161,000–1,239,000 (averaging 533,000) eggs, and relative fecundity was 30–187 (averaging 88) eggs g^{-1}. Females caught in the Ili delta in May 1988 had absolute fecundity of 2,320,000–2,648,800 eggs and relative fecundity of 170–296 eggs g^{-1}. This is, on average, three times higher than that of equal-sized females from the upper Kapchagay Reservoir.

First successful spawning likely occurred in 1967, 9 years after Grass Carp were first introduced. In the lower Ili River (Balkhash Lake population), females attained maturity at 4–6 years (average length: 62.7 cm, average weight: 4.4 kg), most often at 5 years of age, whereas males matured a year earlier at an average body length of 55.8 cm and weight of 3 kg. Data from literature indicate that females could mature earlier at 3–5 years (average length: 50 cm). In the upper Ili River (Kapchagay population), age at first maturity (determined by spawning marks on scales) was 3–6 years at a length of 30–60 cm, with the majority (50–70%) attaining maturity at 4 years, at a length of 35–50 cm. The sex ratio in spawning groups of Grass Carp in both sections of the Ili River was approximately 1:1. However, within the Kapchagay Reservoir annual experimental catches (1971–1987) revealed a persistent average prevalence of females ranging from 1.1:1 to 1.6:1, with an overall average of 1.3:1 for the entire period (n=191).

From 1965–1986, length (total length without caudal length) and weight of Grass Carp young-of-the-year in the Balkhash-Ili system were: 1.5–10 g in September (Balkhash); 62–95 mm in August (Ili River); 32 mm and 0.65 g in August (Kapchagay Reservoir); 26–40 mm and 0.75 g in the last 10 days of July (Ili River at Ayakkalkan); and, on average 54 mm in early September (Kapchagay backwater). From 1986–1988, the length of yearlings in the Kapchagay population (6.3 to 18.9 cm) was similar to Grass Carp yearlings in the Amur River drainage (6–12 cm). However, 5-year-old Kapchagay fish were generally 10–16 cm longer compared to fish of the same age class from the Amur River. From 1986–1988, growth rate (average length) of Grass Carp from the Kapchagay population was as follows (age in full years given in brackets): (1) 10.1–10.7 cm, (2) 17.4–20.3 cm, (3) 24.9–31.9 cm, (4) 33.4–45.3 cm, (5) 41.8–54.4, (6) 48.8–61.7 cm, (7) 55.5–68.4 cm, (8) 57.5–73.6 cm, (9) 63.1–67.5 cm, (10) 64.7 cm, (11) 70.9 cm. From 1986–1987, the average weight of Grass Carp upstream of Kapchagay Reservoir was 141 g (76–210 g) for two-year-old fishes.

In Balkhash Lake and the Ili delta, Grass Carp growth rate (average length) from 1987–1988 was similar to that in Grass Carp upstream of Kapchagay Reservoir: (1) 11.4 cm, (2) 18.2 cm, (3) 27.4 cm, (4) 36.6 cm, (5) 44.2, (6) 50.7 cm, (7) 57.5 cm, (8) 62.8 cm, (9) 71.9 cm, (10) 72.9 cm, (11) 80.2 cm, (12) 88.7. However, in the early 1970s, growth rate of Balkhash Grass Carp was much higher − reaching an average length of 37 cm and weight of 1.2 kg at two years of age (1+); 40.3 cm and 1.5 kg at three years of age; and, 56.8 cm and 3.6 kg at 4 years of age.

Following establishment in Kapchagay Reservoir, yearlings foraged in floodplain water bodies 8–10 km upstream from the reservoir, feeding on animals (crustacean *Diaphonostoma* and *Acanthocyclops*, water beetle imagos, and chironomid larvae, up to 34.8% by weight), macrophytes (mostly *Potamogeton pectinalis*, 12.3% by weight), algae (195 different species), and detritus (39.8% by weight). The diet of adult Grass Carp was initially limited to a few food items: common reed (up to 100% by frequency and weight of food bolus); filamentous algae *Cladophora* (21.2% by frequency); and, in rare cases, the remains of terrestrial plants and phytoplankton, chironomid larvae (the only animal food item), and bryozoan statoblasts. The index of gut fullness was of medium value but annual average values decreased over years: 317–937$^{0}/_{000}$, 519–559$^{0}/_{000}$in 1970; 162–781$^{0}/_{000}$, 330−376$^{0}/_{000}$in 1971; 235$^{0}/_{000}$in 1972; and, 205$^{0}/_{000}$in 1973. The highest feeding intensity occurred in spring and autumn but in summer >50% of guts were empty and the average index of gut fullness decreased from 350 $^{0}/_{000}$in spring to 82$^{0}/_{000}$in summer. In subsequent years, adult Grass Carp diet in Kapchagay was comprised mainly of algae, pondweed and reed; however, Grass Carp diet expanded to include more food items. Non-specific food components such as mysids (in juvenile Grass Carp) and bivalves (in 6 to 9-year-old adults, in May, up to 48.1% by weight), were included as they were present in the reservoir at a high density when, especially in spring, plant food items were lacking. Grass Carp diet in Balkhash Lake and the Ili River delta consisted of stonewort and other *Chara* algae. At spring-flooded river sections of the Ili River, Grass Carp fry diet consisted primarily of various algae (majority *Spirogyra*), pondweed and pupae of chironomids, as well as detritus. During the first years of establishment, Fulton's condition factor reached 2.8 (2.0–2.4 on average), but decreased over time throughout all waterbodies. In Kapchagay Reservoir, Fulton's condition factor fluctuated over the years, following the changes in feeding conditions, while the mid-term average condition values for the 18-year observation period remained low but stable: 1.7–1.9 (Fulton's) and 1.46–1.59 (Clark's). Individual values of the condition factors varied significantly (Fulton's:1.1–2.8, Clark's: 0.99–2.28) in Kapachagay.

Khalmatov, N. 1974. Changes of morphological features of the blood in fish depending on seasons and conditions of rearing. [Izmeneniye morphologicheskikh pokazateley krovi ryb v zavisimosti ot sezonov goda i usloviy vyrashchivaniya.] *In* Biological fundamentals of fish industry in waterbodies of Central Asia and Kazakhstan. [Biologicheskiye osnovy rybnogo khozyaistva vodoyemov Srednei Azii i Kazakhstana]. Edited by O. Nichay. 2. Ylym, Ashkhavad. p. 91−92.

Blood chemistry (numbers of erythrocytes, leucocytes, hemoglobin and hematocrit levels, and total protein) was examined in Common Carp (*Cyprinus carpio*), Gibel or Prussian Carp (*Carassius gibelo*), Grass Carp (*Ctenopharyngodon idella*), and Silver Carp (Hypophthalmichthys molitrix) from an artificial pond in the Ferghana Province (Uzbekistan). Grass Carp blood chemistry varied with seasons: erythrocyte number ranged from 1.4 million per mm^{-3} (spring) to 2.2 million per mm^{-3} (autumn); leucocyte number fluctuated from 20,200–24,000 per mm^{-3}; and, erythrocyte sedimentation rate was 4.0–3.5 mm/hour. Variation in blood chemistry was also observed in other fishes.

Kim, E.D. 1977. Amino acid composition of eggs and embryos of phytophagous fish. [Aminokislotnyy sostav ikry i embrionov rastitel'noyadnykh ryb]. *In* Results and perspectives of phytophagous fish. [Itogi i perspektivy rybokhozya'stvennogo ispol'zovaniya rastitel'noyadnykh ryb]. Edited by B.D. Verigin et al. Book of Abstracts of the 9th All-Union Conference. Naukova Dumka, Kiyev. p. 62−64.

and

Kim, E.D. 1980. Changes in amino acid content in larvae of Grass Carp during the critical periods of their development. [Izmeneniye aminokislot v lichinkakh belogo amura v kriticheskiye periody ikh razvitiya]. *In* Phytophagous fishes in industrial fish culture. Edited by *G.K.* Kamilov. Book of Abstracts of the 9th All-Union Conference. [Rastitel’noyadnye ryby v promyshlennom rybovodstve. Tezisy dokladov IX Vsesoyuznogo Soveshchaniya.] Izdatel’stvo AN UzSSR, Tashkent. p. 170−171.

During embryonic development of Grass Carp and Silver Carp eggs and embryos (from morula to 7-day-old larva), 16 protein-related and free amino acids were identified: isoleucine, leucine, valine, phenilalanine, tyrosine, alanine, glutamic acid, glicin, threonine, serine, asparagine, histidine, arginine, lysine, cysteine, and, as traces only, methionine and proline. During the first 2 days after hatching and during the start of exogenous feeeding (5–6 days after hatching when yolk resorption was completed), survival rates of Grass Carp larvae have been found to decrease (Vovk 1974, Vladimirova 1975). The present study demonstrated that during hatching and for the following two days, the total amount of protein-related amino acids significantly increased (increase of 22.4% compared to previous periods); however, the amount of valine and phenilalanine gradually decreased (18–19% less than during the previous periods). The majority of free amino acids also increased during hatching and for the following two or three days. Upon completion of yolk resorption (5–6 days after hatching), amounts of individual amino acids (necessary for metabolic processes) declined rapidly by factors of 1.4–14.8. Loss of this amino acid resource was then renewed by exogenous feeding. Thus the most critical period during embryonic development occurs immediately following the transition to exogenous feeding.

Koblitskaya, A.F. 1981. Key to young of freshwater fishes [Opredelitel' molodi presnovodnykh ryb]. Moscow, Liogkaya i pischevaya promyshlennost'. 208 p.

A key based on stages of ontogenetic development as identified by Vasnetsov (1953) is presented to identify pre-larval, larval and juvenile stages of common freshwater fishes of the Volga basin including introduced Grass Carp (*Ctenopharyngodon idella*) and, Silver Carp

(*Hypophthalmichthys molitrix*). Characteristics used to distinguish pre-larval Grass Carp from Silver Carp include: trunk myomeres (30–32 in Grass Carp, 26 or less in Silver Carp); length of caudal region of the Grass Carp body is 2.5 times the body length of the abdominal region (two times the abdominal length in Silver Carp); and, pigmentation of the pre-anal fold is absent in Grass Carp but well developed in Silver Carp.

Pre-larval Grass Carp hatch at 5.0–5.7 mm body length have no pigmententation (Figure 1a). Two days post-hatch, pigmentation appears on the anterior part of the yolk sac as an oblique line. The yolk sac is cigar-like, the caudal region is short (12–14 segments), there are 24–26 abdominal segments, the head is small, the snout is stout, and the mouth is inferior. The yolk sac is completely dissolved in individuals 7–7.5 mm long. Pigmentation subsequently becomes more prominent in developing larvae, particularly on the dorsal surface of the bladder, which becomes dark. The primordial dorsal fin appears and is located at the 11th–12th myomere anterior to the anus and extends over two segments. By the end of the stage, both dorsal and anal fins extend over 4–5 segments. Caudal fin rays appear, and, at 7–7.2 mm, a pigment line has developed along the side of the body and the mouth has become terminal (Figure 1b, c). At 10–10.5 mm, the primordial pectoral fin lacks rays, but are present in the dorsal and anal fins. Pigment is scattered over the body, especially on the back, and is not concentrated in clear lines along the body; the swim bladder is two-chambered (Fig. 1d). At the end of the larval period (at a length 14–15 mm), pelvic fin rays are present, dorsal and anal fins are completely developed and have separated from the caudal fin.

Scales are present once juvenile fish reach approximately 20 mm in length. The head is large and retains a terminal mouth. Juvenile fish at 40–45 mm are similar to adults and are characterized by having 7 dorsal fin branched rays; 8 anal fin branched rays; and, a lateral line with 43–45 scales (Figure 1e).

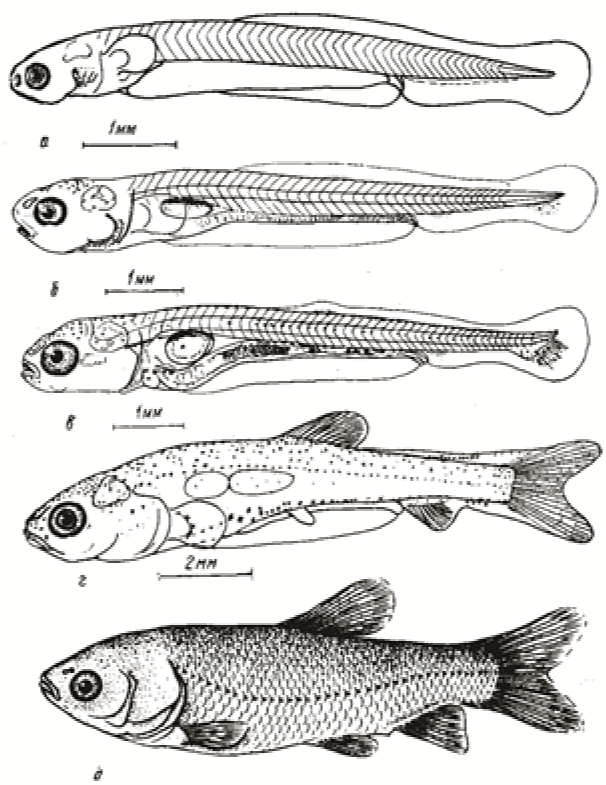

Figure 1. Developmental stages of C. idella *(from Koblitskaya 1981).*

Krykhtin, M.L., and Gorbach, E.I. 1981. Ecology of reproduction of the Grass Carp *Ctenopharyngodon idella* (Val.) and Silver Carp *Hypophthalmichthys molitrix* (Val.) in the Amur River basin. [Ekologiya razmnozheniya belogo amura *Ctenopharyngodon idella* (Val.) i belogo tolstolobika *Hypophthalmichthys molitrix* (Val.) v basseyne Amura.] Voprosy Ikhtiologii [Journal of Ichthyology, Moscow]. 21(2): 317−330.

Spawning conditions of Grass and Silver carps in the Amur River were examined in a long-term study. Distribution of Grass Carp eggs and pre-larvae (>10,000 samples), as well as the stage of maturity and gonadal development of adults (> 9,000 individuals), were assessed. Pre- and post-spawn female Grass Carp were found primarily in the Amur River between Ventselevo and Lugovoye and rarely in the Ussuri River. Downstream-migrant eggs and pre-larvae first appeared in samples from the Leninskoye and Golovino districts (downstream of the Sungari River mouth) in the Sungrari water stream in early June, and lasted until late July. In the Amur water stream, eggs and pre-larvae were present 2 weeks later and their migration lasted until August. Grass Carp pre-larvae reached Khabarovsk and Sarapul'skoye in 2–4.5 days and were not found downstream of these areas. The time frame of 4.5 days corresponds to the necessary time to reach the active feeding stage when water temperatures are between 21 and 26 °C. The majority of eggs were carried in the surface water layer, where flow velocity reached 0.7–1.4 m•sec^{-1}. In the nearshore sites, where the flow velocity slows to 0.3–0.4 m•sec^{-1}, eggs occurred more frequently in the bottom layer. Eggs represented many age classes, from 1 hour post-fertilization to over 1.5 days of age. The stage of embryonic development ranged from blastodisc cleavage to rotating embryo (just prior to hatching). Eggs at early stages of development were located close to spawning grounds, primarily in the morning (6:00–9:00) and in the evening (20.00–22.00). Under optimal water temperatures (over 17 °C) two or three peaks of spawning activity occurred and subsequent increases in migrant egg abundance occurred downstream during periods of water level increase. In favourable conditions, when water levels rose to 1–2 m and remained as such for 1–2 weeks, the number of successfully spent females was over 90%. In less favourable conditions, more than 30% of females did not spawn.

Kryzhanovskiy, S.G., Smirnov, A.I., Soin S.G. 1951. Data on development of fishes in the Amur River. [Materialy po razvitiyu ryb v reke Amur]. *In* Proceedings of the Amur Ichthyological Expedition in 1945–1949. [Trudy Amurskoy Ikhtiologicheskoy Ekspeditsii 1945–1949 godov.]. Edited by G.V. Nikol'skiy. Vol. 2. p. 5–233 [*Ctenopharyngodon idella*, p. 73–78].

Embryological development in Grass Carp was described from samples collected in the Amur River during the Amur Ichthyological Expedition (1945–1949). Grass Carp spawned from upstream of the mouth of the Sungari down to Leninskoye, but did not spawn in the Khabarovsk area or at Elabuga. Eggs and larvae were collected from the main Amur River stream and floodplain lakes and were then held in aquaria. Here, Grass Carp reached a length of 15 mm at an age of three weeks, which is a faster growth rate compared to other pelagophilous fish. Grass Carp eggs were typically pelagic, with a large hydrated space under the egg membrane. Eggs were large, with an egg shell diameter between 4.2–5 mm in hydrated eggs. The yolk sack was roundish (diameter of aproximately 1.25 mm) at fertilization but became pear-shaped by the end of the first day of development at water temperatures 18−19 °C when 26 body segments had developed. At this stage, Grass Carp embryos were easily distinguishable from other fish embryos by large eye precursors.

Hatching occurred approximately 3 days post-fertilization, at which stage embryos were relatively large (6.85 mm); segmentation was complete, the caudal region was short with only 12–16 (commonly 13) segments, the body was straight, and there were inchoate pectoral fins present. Blood circulation was very intense, the Cuvier ducts were broad and oblique, and the caudal vein was sinuate but only slightly penetrating into the anal fin fold. Eyes were very large, with a pigment dot in the lower area, while the body was non-pigmented. Pigmentation appeared at 6 days post-hatch (in embryos up to 8.25 mm long) and was especially intense along the body cavity and caudal vein. Embryos were sedentary in aquaria and drifting in the river current. Although morphologically very similar, Grass Carp embryos had a larger eye and different numbers of abdominal and caudal segments than did Silver Carp (Grass Carp: 28–32 abdominal and 12–16 caudal segments; Silver Carp: 24–26 and 14–17, respectively), and had no pigment on the ventral surface of the yolk sac (present in Silver Carp).

The larval period started at approximately 7 days of age and at a length of 7.75 mm or larger. Air bubbles appeared in the swim-bladder, the yolk sac was considerably reduced. Gills were considerably enlarged but were not completely covered by the gill cover; larvae were breathing only by the use of the gills. Larvae were able to swim and catch food objects. Larvae at this stage fed on zooplankton and algae but digestion was incomplete. By the 22nd day, larvae reached 14.75 mm in length and were nearly fully developed (protrusive upper jaw, two-chambered swim bladder, inferior mouth), though a rudiment of the pre-anal fin fold was still present in some larvae.

Makeyeva [Makeeva], A.P. 1963. On maturation of females of Grass Carp and Silver Carp and reproduction of these fishes in the Amur basin. [O sozrevanii samok belogo amura i tolstolobika i razmnozhenii etikh vidov v basseyne Amura.] *In* Problems of industrial use of phytophagous fishes in waterbodies of the USSR. [Problemy rybokhozya'stvennogo ispol'zovaniya rastitel'noyadnykh ryb v vodoyemakh SSSR.]. Edited by A.O. Tashliyev. Izdate'lstvo AN Turkmenskoy SSR, Ashkhabad. p. 76–83.

Grass Carp females (n=329), 30–91 cm in length, were examined. According to literature, Grass Carp in the Amur River attain sexual maturity at a minimum age of 6+ years and at a length of at least 63 cm. The majority of adult Grass Carp from the Amur River at Leninskoye Village were 9+ to 10+-years-old and 68–75 cm long (all females were longer than 80 cm). Spawning occurred once per year as evidenced by most post-spawning females having only pre-vitellogenetic oocytes (stage VI-II; Sakun and Butskaya 1968). However, histological examination revealed some asynchronicity of oocyte maturation in a few individuals and the presence of a second generation of vitellogenetic ocytes. This may indicate repeat spawning activity; however, it is more likely that some females did not spawn annually or that the development of vitellogenic oocytes may take more than one year. There was also a considerable portion of Grass Carp females that likely matured for the first time at an older age. Females containing eggs were collected in June and July; in August and later, in females that did not spawn, eggs were resorbed. Spawning occurred at water temperatures between 17.5–25.5 °C.

Makeyeva [Makeeva], A.P. 1968. On maturation of females of phytophagous fish in Turkmenia and some observations on their eggs development. [O sozrevanii samok rastitel'noyadnykh ryb v Turkmenii i nekotorye nablyudeniya za razvitiyem ikh ikry.] *In* New research on ecology and stocking of phytophagous fishes. [Novye issledovaniya po ekologii i razvedeniyu rastitel'noyadnykh ryb.]. Edited by G.V. Nikol'skiy. Nauka, Moscow. p. 160−165.

Grass Carp females of two origins attained maturity at age 3+ to 4+ (from Russian Amur River) and at age 4+ to 5 (from China, originally from Yangtze River), at a length of approximately 67 cm and weight of 5,000 g. In both places, males matured earlier than females. Gonadal development and ontogenetic development were studied in offspring from the artificial spawning. Oocyte degeneration occurred in females that attained maturity for the first time but did not spawn, but these females reached maturity again the next year without any visible abnormalities. Females with the highest growth rates before the spawning season were the most fecund. The outer membrane of Grass Carp eggs separates from the yolk 40 to 60 sec after water contact. Fertilization takes place during this period and not later. Fertilized eggs absorb water and swell rapidly, reaching maximum size between 1.5–2 hours and 3 hours. In increased salinity (1.7‰), the diameter of swollen eggs was two times less than the diameter of eggs fertilized in fresh water, though development was normal in both cases. Morula and blastula stages were most sensitive to mechanical stress.

Makeyeva [Makeeva], A.P., and Soin, S.G. 1963. Importance of the Middle and Upper Amur for the reproduction of commercial pelagophilous fishes. [Znacheniye srednego i verkhnego Amura v vosproizvodstve promyslovykh pelagofil'nykh ryb.] Voprosy Ikhtiologii [Journal of Ichthyology, Moscow]. 3(4): 688–697.

Downstream migration of eggs of pelagophilous fish was studied in the Middle Amur River and a key to the pelagic fish eggs in the Amur River system was developed. The following characteristics were used to identify Grass Carp eggs: 4.2–6.0 mm eggshell diameter; 1.2–1.3 mm yolk sac diameter; 28–32 trunk myotomes; and, 12–14 caudal myotomes. Bighead Carp eggs were distinguished by: 4.0–5.0 mm eggshell diameter; 1.1–1.2 mm yolk sac diameter; embryos had 24–26 trunk myotomes; and, 14–17 caudal myotomes.

Makeyeva, A.P., and Verigin, B.V. 1974. Hybridization of Carp *Cyprinus cario* L. with Grass Carp *Ctenopharyngodon idella* (Val.). [Gibridizatsiya karpa *Cyprinus cario* L. s belym amurom *Ctenopharyngodon idella* (Val.)]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 12(2): 290−296.

Offspring from crosses between Grass Carp (male) and Common Carp (female) had very low survival. Hybrid embryos were very similar to Common Carp as they had a highly developed vascular system and pronounced pigmentation; features that are considerably less developed in Grass Carp at this development stage. Most hybrid individuals died soon after hatching due to major malformations, especially in the structure of the branchial apparatus and the jaws. Several hybrid individuals (78–126 mm long) that survived until the end of summer (age two–three months) were morphologically examined using a modification of the Hybrid Index of Hubbs and Kurinuma (1942). By most character states (20 meristic and morphometric characters were used for comparison), hybrid individuals were much closer to the Common Carp than to the Grass Carp. Except for pectoral fin length, two offspring (approximately 20 cm body length) were almost entirely within the ranges typical for Common Carp. Shape, number, and location of pharyngeal teeth were also very similar to those in Common Carp, although some differences still occurred. For example, the presence of a hook at the apex of the tooth was a feature absent in both parental species. The prominent genetic influence of Common Carp may be due to its polyploidy (100–104 chromosomes in contrast to 48 in Grass Carp).

Makeyeva, A.P., and Verigin, B.V. 1992. Morphological characteristics of young-of-the-year reciprocal hybrids between Grass Carp *Ctenopharyngodon idella* and Black Carp *Mylopharyngodon piceus* [Morfologicheskaya kharakteristika segoletok belogo *Ctenopharyngodon idella* i chornogo *Mylopharyngodon piceus* amurov]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 32(6): 41−48.

Reciprocal hybrids between Grass Carp (GC) and Black Carp (BC) were examined at the age of 3 months. GC (female) x BC (male) hybrids were much smaller than BCxGC hybrids though both combinations were between BC (smallest size at this age) and GC (largest size at this age). Hybrids of BCxGC and GCxBC had intermediate colouration of the two parental species but most morphometric characters demonstrated a clear shift to BC character states. In BCxGC hybrids, the structure of the pharyngeal teeth were similar to those in BC, while in GCxBC hybrids, teeth were rather broad and hooked and did not resemble either GC or BC.

Martino, K.V. 1974. Natural spawning of Grass Carp in the lower Volga system [Estestvennoye razmnozheniye belogo amura v vodoemakh Nizhney Volgi]. Gidrobiologisheskiy Zhurnal. [Hydrobiological Journal, Kiyev]. 11(1): 91−93.

Since 1964, Grass Carp individuals aged 1+ to 3+ years were introduced in the Lower Volga system. In 1971–1972, natural spawning of introduced Grass Carp in the Lower Volga River was studied. Gonads of these introduced Grass Carp individuals (n=102) were examined. Spawning fishes were aged 5+ to 8+ years; however, 17% of 6+-old fish were immature individuals and 5% of 7+-old fish were immature. Only 8% of Grass Carp were mature at the age of 5+ years (males were 5% and females were 3%).

First spent adults were recorded in late May, when water temperatures in the river were only 12–13 °C. Some Grass Carp may have started spawning in shallow, flooded areas where water temperature was much higher; however, water velocities in the flooded areas were 0.2–0.5 m•sec^{-1}, which is much lower than velocities at spawning sites in the native range of Grass Carp. Spawning success was probably very low, as only one Grass Carp larva was found in 1971 and 15 larvae were found in 1972. The spawning period was prolonged, lasting until August. Gonad development and maturation were asynchronous, without any clear peak of spawning activity. In many females, the development of different parts of gonads was non-simultaneous. For example, in 17% of females, the caudal part of the gonad was spent while the cranial part was still at the IV (pre-spawning) maturity stage.

Miroshnichenko, L.M., and Kamenetskaya, I.L. 1978. An observation on maturation and spawning migration of phytophagous fishes in Syr Darya. [Nablyudeniye za sozrevaniyem i nerestovoy migratsiye' rastitel'noyadnykh ryb v Syrdar'e. *In* Biological fundamentals of fish industry in the republics of Central Asia and Kazakhstan. [Biologicheskiye osnovy rybnogo khozya'stva respublik Sredney Azii i Kazakhstana.]. Edited by A.O. Konurbaev. Ilim, Frunze. p. 367–368.

From May to July 1977, observations of spawning migrations were made in the Syr Darya River in Uzbekistan (in the Chardara Reservoir and upstream of the reservoir). The spawning run of Grass Carp started on May 20, and was associated with an abrupt rise in water level when water temperature reached 20 °C. One peak was observed in the downstream drift of Grass Carp eggs (May 23–24) at a water temperature of 20 °C. Ripe males (80 cm long, 6 kg weight) were observed on May 23 at Chinaz, 35–40 km upstream from the reservoir. Sex ratios were approximately 1:2, which was confirmed by fishermen at the spawning site, where a single female being followed by two males was observed. A second spawning site was located at the Dshidali Peninsula at a confluence of two riverine branches. The site was located 110 km upstream from the Chardarinskoye (Chardara) Reservoir, at a depth of 2 m with a sandy-pebble substrate. Significant differences in the values of gonadosomatic index were recorded, although this could be attributed to the concurrent presence of individuals at the II, III, and IV stages of maturity in the spawning stock. Some females did not take part in spawning activity due to disturbance or rapid changes in the river water level, and later demonstrated resorption of eggs; histological examination did not reveal any disorders of gametogenesis. This study confirms the occurrence of natural spawning of Grass Carp in the Syr Darya River and suggests offspring may also develop in the river.

Mukhamedova, A.F. 1963. Observations on the youth of Grass Carp and Silver Carp during the quarantine period before the release into the Tsymlyansk Reservoir. [Nablyudeniye za molod'yu tolstolobika i belogo amura d period karantinizatsii i podraschivaniya pered vypuskom v Tsimlyanskoye vodokhranilische.] *In* Problems of industrial use of phytophagous fishes in waterbodies of the USSR. [Problemy rybokhozya’stvennogo ispol’zovaniya rastitel’noyadnykh ryb v vodoyemakh SSSR.]. Edited by A.O. Tashliyev. Izdate’lstvo AN Turkmenskoy SSR, Ashkhabad. p. 84–88.

Feeding habits, growth and parasites of 1+-old aquaculture-raised fry of Grass and Silver carps imported directly from China were examined in ponds of the Tsimlyansk experimental fish farm. These one-year-old individuals spent 4 months in the ponds and were measured on several occasions (Table 1). Grass carp were released into the ponds on 18–23 July. Average initial weight of Grass Carp was 0.29 g and average length 30 mm.

Table 1. Measurement of Grass Carp released into ponds.

Date	n	Average weight (g)	Average Length (mm)
28 July	12	0.44	28
8 August	75	3.00	51
29 August	78	3.21	54
11–14 September	117	15.90	851
13–14 November	89	8.20	100

Due to the lack of macrophytes in the experimental ponds, Grass Carp actively consumed benthic organisms, especially tendipedid larvae; and in late August-early autumn, larvae of beetles (*Berosus*). Growth rate varied from 26 to 132 mm (length), average 100 mm, and from 0.28 to 43.3 g (weight), average 18.2 g, per year during the second warm season. The majority of Grass Carp (91%) were infected with *Dactylogyrus* (Monogenea) (up to 16 parasites per fish), and up to 48% were infected with a cestode, *Bothriocephalus gowkongensis*.

Negonovskaya, I.T., and Rudenko, G.P. 1974. Oxygen threshold and features of respiration exchange of the young phytophagous fish – Grass Carp *Ctenopharyngodon idella (*Val.) and Bighead Carp *Aristichthys nobilis* (Rich.). [Kislorodnyy porog i osobennosti dykhatel’nogo obmena molodi rastitel’noyadnykh ryb - belogo amura *Ctenopharyngodon idella* (Val.) i pestrogo tolstolobika *Aristichthys nobilis* (Rich.).] Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 14(6):1111–1117.

Fry of phytophagous fishes (70–100 mg, age of 1–1.5 month) had a very low oxygen threshold. At a water temperature between 20–24 °C, Grass Carp showed respiratory distress at 0.59 mg•l^{-1}, and the lethal oxygen concentration for the most viable Grass Carp individuals was 0.44 mg•l^{-1}.Grass Carp oxygen consumption differed considerably depending on the initial oxygen concentration of the water: 0.75–0.76 mg O_2 per 1 g of fish weight per hour when initial oxygen concentration was approximately 9 mg •l^{-1}; and, 0.25–0.53 mg O_2 per 1 g of fish weight per hour when initial oxygen concentration was 1.28–2.56 mg •l^{-1}. The authors concluded that phytophagous fishes, which lived in extensively overgrown ponds with an unstable gaseous regime, were characterized by an extended lability in respiration metabolism in comparison with fish species from a more stable oxygen environment. Respiration lability in phytophagous fishes was expressed as a reduction in the respiration rate in response to deteriorating oxygen conditions and a decline in oxygen threshold.

Nezdoliy, V.K., and Mitrofanov, V.P. 1975. On natural reproduction of Grass Carp *Ctenopharyngodon idella* (Val.) in the Ili River. [O estestvennom razmnozhenii belogo amura *Ctenopharyngodon idella* (Val.) v reke Ili.] Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 15(6): 1039−1045.

The Ili River is similar to rivers of East Asia where Grass Carp is a native inhabitant and is characterized by a spring-summer rise in water level, with increased turbidity, and a relatively fast current. Grass Carp likely first spawned in the Ili River in 1964; in 1966, two-year-old fish were present along a 600+ km section of the Ili River up to the Charyn River mouth. In 1972 (April 20–October 15) and 1973 (March 20–July 1), eggs, embryos and larvae moving downstream were regularly present in samples from a river section located upstream from the Kapchagay Reservoir. In 1972, 344 eggs and 54 pre-larvae were collected, and in 1973, 61 eggs and 86 pre-larvae were collected. Stages of development ranged from gastrulation to newly hatched pre-larvae. In 1972, Grass Carp eggs and larvae were present from the 11th of May at water temperatures of 18.5 °C and were absent in samples taken in the third decade (10 day period) of May when water temperatures were 23 °C. In 1973, eggs and larvae were present from the 19th of May at temperatures of 18.7 °C and were absent by the third decade (10 day period) of June when water temperatures were 23.5 °C. Migration peaks occurred at water temperatures between 19.5–19.9 °C, and immediately following a rise in water level, with increases in both current velocity (up to 1.8 m $\bullet sec^{-1}$) and turbidity. Although mature or spawning adults were not observed, it is likely that Grass Carp from Kapchagay Reservoir entered the Ili River and migrated upstream. Based on the age (developmental stage) of eggs and pre-larvae, spawning spawning grounds are likely located 8 to 80 km upstream from the reservoir. See also Faryshev and Bashunov (1980).

Nuriyev [Nuriev], K.H. 1969. On biology of Grass and Silver carps in the Tudakul' Reservoir. [K biologii belogo amura i obyknovennogo tolstolobika v Tudakul'skom vodokhranilische.] Uzbekskiy Biologicheskiy Zhurnal. [Uzbek Biological Journal]. 6: 37−39.

Growth and nutritional status (Fulton condition factor, F_{cf}) of Grass Carp were studied in the Tudakul' Reservoir of Uzbekistan (lower reaches of the Zervshan River). Fish entered into the reservoir through the Amu-Bukharsky Canal. In the reservoir, characterized by high water temperatures and a long vegetation growth season, fish grew faster than in their native range in the Amur River. For Grass Carp in the Tudakul' Reservoir, the average growth rate (linear growth during a warm season based on back-calculated growth of scales) was 24.7 cm in fish at age of 1+ (second warm season; n=23) and 29.7 and 19.8 cm at age of 2+ (second and third warm season respectively; n=7). Grass Carp in the Tudakul'Reservoir, thus, grew fast reaching, on average, 27.2 and 47.0 cm by the end of the second and third warm seasons, respectively, as compared to 8.4 cm, and 16.5 cm in the Amur River, and 8.8 cm and 16.4 in the Aral Sea. Average measurements for Grass Carp at the end of warm season were: body length 35.7 cm, weight 1003 g, F_{cf}=2.12 at age 1+ (n=23); and body length 52.4 cm, weight 2,309 g, F_{cf}=1.87 (1.56–2.08) at age 2+ (n=7). These parameters considerably exceeded those found for Silver Carp.

Pavlov, D.S., Aliyev, D.S., Shakirova, F.M., Nezdoliy, V.K., Ostrovskiy, M.P., Dzhemileva, T.G., Malakhova, T.V., Nikolayev, A.A., and Sukhanova, A.I. 1994. Biology of fishes of the Saryyazyn Reservoir. [Biologiya ryb Saryyazynskogo vodokhranilishcha]. Gidroproekt, Moscow. 150 p.

The Saryyazyn Reservoir supported self-sustaining populations of introduced Chinese carps (i.e., phytophagous fishes). Before its construction, Grass Carp spawning first occurred in 1976 in the Murghab River. By July 1977, yearlings had reached an average length of 32 cm and an average weight of 875 g, while young-of-the-year Grass Carp were 2.9–15.0 cm long (average 5.1 cm) and weighed between 0.45–77.4 g. Spawning Grass Carp migrated upstream in the Murghab River and spawned 20–100 km upstream of the Tashkeprin Dam and, in some years, below the dam.

Grass Carp spawning, diet and growth were examined in 1981, 1984, 1986, and 1988. Spawning occurred in late April–May at water temperatures above 20 °C, and peaked at water temperatures between 20.7–23.3 °C. On one occasion, drifting embryos were present at a low temperature of 16.9 °C; however, egg abundance was very low and spawning ceased and restarted at 19.6 °C. Grass Carp eggs comprised from 30% (1981) to 1% (1988) of all eggs of Chinese carps sampled. Males matured at an age of 2+ to 3+ years, at a length of 54–59 cm; females matured at an age of 3+ (33%) and 4+ years, at a length >63.5 cm. This age is considerably lower than the age of maturity of Grass Carp in the native range (4–5 years in southern China, 7–8 years in the Amur River). Researchers found some heterogeneity of oocytes in the ovaries; both larger oocytes, which measured 1–1.4 mm in diameter (accounted for 80–88% of total number), as well as smaller oocytes which measured 0.6–1 mm in diameter, were present. Observed heterogeneity may indicate that Grass Carp were a portion spawner in this reservoir which is also typical for the fish in its native range; however, other possible explanations include egg heterogeneity that reflects unsatisfactory environmental conditions, such as limited food resources, in the reservoir. Absolute fecundity ranged from 233,600 to 511,200 eggs in fish 62.0–80.5 cm (4.0–8.4 kg).

Grass Carp fed on small zooplankton until they reached a length of 19 cm and an age of 10–12 days; after which they switched to primarily aquatic vegetation. Examination of the digestive tracts of 26 specimens revealed the following plants: common reed *Phragmites australis*, Eurasian watermilfoil *Myriophyllum spicatum*, and young leaves of flooded *Tamarix* bushes. In Saryyazyn Reservoir, Grass Carp growth rates were high, especially before sexual maturity. By late October, young-of-the-year reached an average of 9.2 cm and 18.4 g. Average lengths and weights of Grass Carp at subsequent ages were: 45.3 cm and 1.65 kg for 2-year-old (1+) fishes; 55.5 cm and 3.37 kg for 3-year-old (2+) fishes; 65.7 cm and 4.53 kg for 4-year-old (3+) fishes; and, up to 72 cm and 5.36 kg for 5-year-old (4+) fishes.

Payusova, A.N., and Tselikova, T.N. 1981. The differences and differentiation between stocks of different origin of Grass Carp, *Ctenopharyngodon idella* (Val.), Silver Carp, *Hypophthalmichthys molitrix* (Val.) and Bighead Carp, *Aristichthys nobilis* (Rich.) carps based on electrophoretic spectra of miogens. [Razlichiya i differentsiatsiya stad raznogo proiskhozhdeniya belogo amura *Ctenopharyngodon idella* (Val.), belogo *Hypophthalmichthys molitrix* (Val.) i pestrogo *Aristichthys nobilis* (Rich.) tolstolobikov po elektroforeticheskim spectram miogenov.] Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 21(4): 608–615.

An electrophoretic study of water-soluble muscle proteins revealed differences in the myogenic spectra of Bighead Carp, Grass Carp, and Silver Carp originating from different stocks (based on fish introduced either from the Yangtze River or the Amur River) and native locality (the Amur River). Results indicated that the myogenic spectra of the three species that came from the

Yangtze River were monomorphic and species-specific. Examination found no individual or interpopulation differences in myogenic spectra in Yangtze River carps introduced over broad geographic areas, ranging from the Moscow region to waterbodies of Central Asia, which confirmed strong inheritance of this physiological attribute. However, geographic variation in myogenic spectra in fish from the Yangtze and Amur rivers were established for Grass Carp and Silver Carp. Grass Carp samples from the two rivers differed in parvalbumin electrophoretic patterns.

Ryabov, I.N. 1973. Features of embryonic and larval development of hybrids of Silver Carp, *Hypophthalmichthys molitrix* (Val.), and Grass Carp, *Ctenopharyngodon idella* (Val.), with Eastern Bream, *Abramis brama orientalis* Berg. [Osobennosti embrional'no-lichinochnogo razvitiya gibridov belogo tolstolobika *Hypophthalmichthys molitrix* (Val.) i belogo amura *Ctenopharyngodon idella* (Val.) s vostochnym leschiom *Abramis brama orientalis* Berg.] Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 13(6): 842−857.

Early developmental stages of hybrids (female *Ctenopharyngodon idella* x male *Abramis brama*) were examined. Hybrid individuals had fewer abdominal mesodermal segments (4–10, commonly 6–9) compared to Grass Carp (12–15, commonly 14–15). Yolk shape was highly variable, and individuals with a pear-shaped yolk died earlier than those with a cigar-shaped yolk. Hybrid individuals had poorly developed gas bladders that did not fill with air and all hybrids died before or during the start of active feeding.

Rykova, T.I. 1964. On the salt tolerance of the Chinese phytophagous fish during early developmental stages. [O soleustoychivosti kitayskikh rastital'noyadnykh ryb na rannikh stadiyakh razvitiya.] *In* Acclimatization of fish and food organisms in seas of the USSR. [Akklimatizatsiya ryb i kormovykh organizmov v moryakh SSSR.]. Edited by A.F. Karpevich. Trudy VNIRO. [Proceedings of All-Union Institute for Fisheries and Oceanography]. 55(2): 195–196.

Salt tolerance of sperm, eggs and larvae of Grass Carp was tested in water of varying salinities from the Black and Caspian seas. Egg development in water from the Black Sea (1.9–4.9‰ salinity) was relatively normal; however, in water of 6.3‰ salinity or higher, egg development ceased at the blastodisc stage of cell division. Embryos successfully hatched at 3.2–4.9‰ salinity in water from the Black Sea and these embryos together with those reared in fresh water, survived until the end of the experiment (4 to 9 days post-hatch). Eggs reared at 6.3‰ salinity had limited hatching success and all hatched embryos died within a few hours. Eggs reared at 9.4‰ salinity died at the gastrula stage. Hatched Grass Carp larvae survived without visible abnormalities in Black Sea water up to 3.2‰ salinity; however, a considerable number of larvae survived until the end of the experiment in water of up to 7.6‰ salinity. In water from the Caspian Sea, a greater range of tolerance was observed. Normal development and hatching of eggs was observed at 4.2–5.9‰ salinity. Higher saline concentrations resulted in developmental abnormalities and, at 11.5‰ salinity, resulted in complete mortality of all embryos (either at the moment of hatching or within 24 hours).

The process of absorption of water by the membrane was also examined. Results indicated that the volume of the perivitelline space increased from 0 to 20–30 mm^3 in freshwater at a temperature of 19.4–20.6 °C in 60–90 minutes after fertilization. Eggs that developed in a more saline environment had a lower water volume in the perivitelline space. After incubation for 3.5 hours, Grass Carp eggs exhibited a perivitelline space volume of 16.403 mm^3 in freshwater, 2.053 mm^3 in Black Sea water (9.0‰ salinity), and 0.718 mm^3 in Caspian Sea water (11.7‰ salinity). Results also indicate the egg membrane was permeable to ions of sea water as the density of eggs swollen to maximum size in freshwater increased from 1.03 g per cm^3 to 1.04 g per cm^3 at 3.2‰ salinity, to 1.05 g per cm^3 at 6.3‰ salinity, and to 1.07 g per cm^3 at 9.4‰ salinity.

Rykova, T.I. 1972. Consumption of water by eggs of Grass Carp, Silver Carp and Bighead Carp during their development. [Potrebleniye vody yaitsami belogo amura, belogo i pestrogo tolstolobikov vo vremya razvitiya]. *In* Acclimatization of phytophagous fish in waterbodies of the USSR. [Akklimatizatsiya rastitel'noyadnykh ryb v vodoyomakh SSSR]. Edited by M.F. Yaroshenko et al. Book of Abstracts of the 7th All-Union Conference. Shtiintsa, Kishenev. p. 104−106.

Before fertilization, water content of mature Grass Carp eggs was 70.6% by weight. After hydration, or absorption of water, water content reached 99%. The egg membrane is very elastic, and in constrast to most cyprinids, has a corrugated surface which increases the surface area exposed to surrounding water. The egg membrane is highly permeable to water. Formation of the perivitelline space in eggs of these fish was prolonged compared to other fish, lasting 3–3.5 hours at a water temperature of 20–23 °C. Accordingly, the increase in egg shell strength took longer compared to other fish and never completely finished, and the shells remained comparatively weak. Density of hydrated eggs attained 1.015–1.02 g per cm^3 and did not change during development until hatching.

Rykova, T.I. 1977. Hydration of eggs of Grass Carp, Silver Carp and Bighead Carp in high salinity environment. [Obvodneniye yaits belogo amura, belogo i pestrogo tolstolobikov v srede c povyshennym soderzhaniem soley]. *In* Results and perspectives of phytophagous fish. [Itogi i perspektivy rybokhozya'stvennogo ispol'zovaniya rastitel'noyadnykh ryb]. Edited by B.D Verigin et al. Book of Abstracts of the 9th All-Union Conference. Naukova Dumka, Kiyev. p. 113−114.

Buoyancy in the water column of Grass Carp eggs containing embryos, attained by hydration of the oocyte and the egg just after fertilization, is critical for their survival and dispersion in the river. Buoyancy is established by an increased absorption of water through the membrane, which increases the perivitelline space. In saline water the degree of hydration is directly dependent on the concentration of salts as the membrane also absorbs salts, which slows the hydration process. Egg diameter decreased by 2% to 16–54% in extreme salinities of Black Sea water (9.4‰), Caspian Sea water (11.7‰), and Aral Sea water (14.6‰). This decrease in the extent of hydration was caused by the breakdown of osmoregulated cortical alveoli and the inhibitory effect of divalent cations, especially calcium, whose concentration is higher in the Caspian Sea water.

Rykova, T.I. 1980. The influence of water salinity on the development of eggs of Grass Carp, Silver Carp, and Bighead Carp. [Vliyanie solenosti vody na razvitie ikry belogo amura i tolstolobikov]. In Phytophagous fishes in industrial fish culture. Book of Abstracts of the 9th All-Union Conference. [Rastitel'noyadnye ryby v promyshlennom rybovodstve. Tezisy dokladov IX Vsesoyuznogo Soveshchaniya.]. Edited by G.K. Kamilov. Izdatel'stvo AN UzSSR, Tashkent. p. 191–192.

Fertilization of Grass Carp occurred both in fresh and brackish water, at a salinity threshold of 7.5‰. In water of a higher salinity, a delayed cortical reaction, increased sperm activity, and feasible polyspermy were observed which prevented normal fertilization and subsequent development. Normal larval and egg development occurred below 5‰. Increased salinity resulted in decelerated embryonic development and delayed hatching attributed to an increase in membrane density. Increased salinity during egg incubation resulted in various morphological defects and developmental abnormalities including decreased body length of hatchlings. In brackish water environments (salinity ≥5‰), embryos of the Far-East carps developed under strained osmotic conditions as a result of high membrane permeability to water and salt ions.

Level of egg hydration was not the most significant factor in embryonic development; instead, the concentration of monovalent chlorine and sodium ions and their subsequent impacts were more critical. Embryonic defects in embryos of the Far-East carps that occurred during exposure to seawater were attributed to the effects of sodium (the dominant seawater cation) and associated osmotic forces.

Shakirova, F.M. 1985. On growth of Silver Carp and Grass Carp in Saryyazyn Reservoir. [Rost belogo tolstolobika i belogo amura v Saryyazynskom vodokhranilische.] Izvestiya AN Turkmenskoy SSR. Seriya Biologicheskiykh Nauk. [Proceedings of the Academy of Sciences of the Turkmenskaya SSR, Biological Series.] 4: 22−25.

Natural spawning of Grass Carp was first recorded in the Saryyazyn Resevoir (Murghab River, Turkmenistan) in 1976. Growth data were collected from 1978–1980. Presence of young-of-the-year and 1+-old fish confirmed subsequent spawning. By early August, young-of-the-year fish attained an average length of 5.1 mm (ranging between 0.29–15 mm) and an average weight of 4.1 g (ranging between 0.45–7 g). Growth rates varied significantly among individuals and were likely correlated to environmental conditions in the reservoir, especially the low amount of zooplankton, which is the main food of Grass Carp until the D2 stage of development (10–12 days old and average weight of 19 mg).

Sobolev, Y.A. 1970. Feeding interactions of the young of Grass Carp, Silver Carp and Bighead Carp during the joint rearing in ponds in Belorussia. [Pishchevyye vzaimootnosheniya molodi belogo amura, obyknovennogo tolstolobika i karpa pri sovmestnom vyrashchivanii v prudakh Belorussii]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 10(4): 711–718.

Feeding of young-of-the-year Grass Carp and Silver Carp in polyculture with Common Carp were investigated. Stocking densities were 30–50,000 individuals $\bullet ha^{-1}$ for Grass Carp, and 20–30,000 individuals $\bullet ha^{-1}$ for Silver Carp. Stocked densities resulted in insignificant food competition and low strain on food resources between species during feeding activities. Reduced resource competition for food and a transition to species-specific food items were thought to promote growth among fishes. Grass Carp fry displayed distinct food preferences, selecting for *Daphnia longispina*, *Poliphemus pediculus*, *Bosmina longirostris*, and *Scapholeberis mucronata* while selecting against *Copepoda*, *Chydorus* and *Ceriodaphnia*. Using the similarity coefficient of Shorygin (1952), diet similarity between Grass Carp and Silver Carp was estimated to be only 21.2. Silver Carp began consuming phytoplankton 18 days post-hatch but Grass Carp switched to macrophytes much later. At the age of 26 days (length of 26–30 mm), macrophytes comprised 50% of the Grass Carp diet; and at the age of 36 days (length of 35–40 mm) macrophytes comprised 85% of the diet. In cold weather, Grass Carp started to consume only macrophytes at the age of 46 days (length of 45–52 mm), and in comparatively warm summer at the age of 36–40 days (length of 50 mm).

Soin, S.G. 1963. Morpho-ecological features of the Grass Carp and Silver Carp development. [Morfo-ekologicheskiye osobennosti razvitiya belogo amura i tolstolobika.] *In* Problems of industrial use of phytophagous fishes in waterbodies of the USSR. [Problemy rybokhozya’stvennogo ispol’zovaniya rastitel’noyadnykh ryb v vodoyemakh SSSR.]. Edited by A.O. Tashliyev A.O. Izdat. AN Turkmenskoy SSR, Ashkhabad. p. 100-137.

A detailed description of embryonic and larval development of Grass and Silver Carp from the Amur River and from a fish farm in the Moscow Region was provided. This report provided a preliminary introduction to the subject area and an enhanced understanding of terminology used on the subject and in subsequent publications. Good quality drawings were provided that was useful for identification of embryos and larvae of Grass Carp and Silver Carp.

Developmental processes of Grass Carp and Silver Carp were divided into periods, further divided into stages, and each stage subdivided into phases. 30 phases of development were described, beginning at fertilization and proceeding to development at 45 mm in length (age of 1.5 month). Morphological differences between Grass Carp (GC) and Silver Carp (SC) were described. Yolk sac diameter: 1.2–1.3 mm (GC), 1.1–1.2 mm (SC). Egg diameter is similar in both species (4–5 mm). In free embryos and larvae, ratio of body length to caudal length: 2.5 (GC), 2 (SC); number of abdominal myotomes: 28–30 (GC), 24–26 (SC); number of caudal myotomes:12–14 (GC), 14–17 (SC); pigmentation of yolk sac: in anterior part of the sac only (GC), in anterior part and on the ventral part of the sac (SC); pigmentation of pre-anal fin-fold: absent (GC), densely developed (SC). In young juveniles, scales: large and well visible (GC), scales small and poorly visible (SC); number of anal-fin rays: 8 (GC), 11–14 (SC); transformation of the pre-anal fin-fold: completely dissolved comparatively early (GC), long-lasting and transforming into the ventral keel (SC).

Soin, S.G., and Sukhanova, A.I. 1972. A comparative morphological study of Grass Carp, Black Amur, Silver Carp, and Bighead Carp (family Cyprinidae). [Sravnitel’no-morfologicheskiy analiz belogo i chernogo amurov, belogo i pestrogo tolstolobikov (sem. Cyprinidae)]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. Vol. 12(1(72): 72–83.

Morphological features observed in the development of embryos, larvae, and fry of Grass, Bighead, Black and Silver carps were discussed. These pelagic species were characterized by early hatching, under-developed embryonic respiratory structures, delayed onset of pigmentation, and accelerated development. Additionally, a number of significant species-specific differences in size of eggs and embryos, number of myotomes, pattern and degree of pigmentation, ratio of jaw development, location of unpaired fins, development of keel and scales, as well as other morphological characters were presented.

Non-hydrated eggs differed in size, averaging 1.4–1.5 mm in Bighead Carp (BC), 1.24–1.44 mm in Black Amur (BA), 1.21–1.36 mm in Grass Carp (GC), and 1.1–1.2 mm in Silver Carp (SC). Following completion of mesoderm segmentation, the four species were easily differentiated by the number of total myotomes: 24–26 (BC, SC), 27–28 (BA), and 29–31 (GC); however, the number of caudal myotomes is similar for all species - between14–19 (the lowest, 14–16 in GC). Pre-larvae of the four species can be further distinguished by the pattern of pigmentation; both GC and BA lack pigment cells on most of the yolk sac surface. Larvae are also distinguished by the pigmentation pattern. For example only GC have a clear semi-circle of pigments cells located at the base of the pectoral fin. By the end of this developmental period, both GC and BA can be distinguished from either SC or BC by shorter dorsal and pectoral fins. Young juveniles differ by the definitive characters typical for adults of the species, namely scales are much larger in GC and BA than in SC and BC, number of anal-fin rays is 8–9 in GC and BA while it is 11–14 in SC and BC. GC and BA have a completely rounded belly while in SC and BC there is a pronounced ventral keel.

Stroganov, N.S. 1963. Selectivity of the diet of Grass Carp. [Izbiratel'naya sposobnost' amurov k pische.] *In* Problems of industrial use of phytophagous fishes in waterbodies of the USSR. [Problemy rybokhozya’stvennogo ispol’zovaniya rastitel’noyadnykh ryb v vodoyemakh SSSR.]. Edited by A.O. Tashliyev. Izdate’lstvo AN Turkmenskoy SSR, Ashkhabad. p. 181−191.

Feeding behaviour and food (macrophytes) preferences of Grass Carp were examined. In the Moscow area, in ponds, Grass Carp fed predominantly on calm days in the morning and evening hours at nearly all temperatures, but most intensely at temperatures above 16 °C. In cold water (3–6 °C), feeding intensity on forage plants was much lower and feeding was irregular, with non-feeding intervals of 5 to 7 days. The lower the temperature, the less food is consumed and the longer the breaks between feeding periods. Grass Carp stop feeding when abrupt drops of 4–5 °C in temperature occur, even at temperatures above 22 °C. Grass Carp demonstrated selective feeding between plants. In some experiments, Grass Carp fed on a single plant species although six to eight different plant species were offered. At elevated temperatures, selectivity decreased (Grass Carp consumed a wider range of plants) and at lower temperatures selectivity increased (food spectrum was narrowed). In all cases, Grass Carp preferred soft vegetation. Young Grass Carp consumed up to 8 kg of terrestrial plants per 1 kg of their body weight during the growing season. On average, the feed conversion ratio was 18 (14 to 21), but in the absence of preferred plants the ratio increased to 54. Grass Carp tore forage plants into 1–3 mm pieces, rarely up to 5–10 mm. Digestion efficiency varied between 60–80%. Over 70 plant species were offered to Grass Carp and divided into groups based on preferences and intensity of consumption: 1) plants better consumed at all different temperature regimes; 2) plants consumed less than those from group 1 and not always (not at all water conditions); 3) consumed rarely and only at high temperatures; and 4) plants not consumed (consumption not registered). Group 1 included: fineleaf (slender leaved) pondweed *Potamogeton filiformis*; sharp-leaved pondweed *Potamogeton acutifolius*; *Elodea*; red clover (young)*Trifolium pratense*; *Pisum sativum* (blooming); common vetch *Vicia sativa*; common silverweed *Potentilla anserina*; young cereals (leaves); dandelion (leaves), oats (grains and young leaves); corn (soft leaves); and cow vetch *Vicia cracca*.

Sukhanova, L.E. 1968. Morphological differences of phytophagous fishes at early stages of development and behaviour of their embryos and larvae. [Morfologicheskiye razlichiya rastitel'noyadnykh ryb na rannikh periodakh razvitiya i povedeniye ikh embrionov i lichinok] *In* New research on ecology and stocking of phytophagous fishes. [Novye issledovaniya po ekologii i razvedeniyu rastitel'noyadnykh ryb.]. Edited by G.V. Nikol'skiy. Nauka, Moscow. p. 194−200.

Morphology and motility of developing embryos and larvae of Grass Carp, Silver Carp and Bighead Carp (from artificial breeding in the Karamet-Niyaz Fish Farm in Turkmenistan) were examined. Morphological comparisons revealed some significant differences, and some features of early motility in embryos and behaviour of larvae were identified. Grass Carp eggs (average of 3.8 mm) were larger than Silver Carp eggs (average of 3.2 mm) but smaller than Bighead Carp eggs (average of 4.7 mm). Grass Carp embryos were easily distinguished at early stages of development by a long abdominal region, which contained 29–31 mesodermal segments in contrast to 24–26 in Silver Carp and Bighead Carp, and a short caudal region (12–14 in Grass Carp vs 14–16 in Silver Carp and Bighead Carp). Pre-larvae and larvae of Grass Carp can be further distinguished by a weakly pigmented body (markedly pigmented in both Silver Carp and Bighead Carp).

Embryos became motile at the stage of 20–25 myomeres with 40–42 movements per minute within the shell at a water temperature of 20.4 °C. Newly hatched pre-larvae actively moved, undulating and occassionally floating to the surface; in the wild, this behaviour promotes the downstream drift of larvae. The next stage, when larval respiratory organs (Cuvier's ducts and branches of the anal vein) appear, was characterized by reduced undulating movement, and larvae stayed on the bottom. Following development of the swim-bladder, larvae started to move to the surface again to swallow air to fill up the swim-bladder. Larvae were then able to begin active movement.

Verigin, B.V., Makeyeva, A.P., and Shubnikova, N.G. 1975. Morphology of young-of-the-year hybrids between Bighead *Aristichthys nobilis* (Rich.) and Grass Carp *Ctenopharyngodon idella* (Val.). [Morfologiya segoletkov gibrida pestrogo tolstolobika *Aristichthys nobilis* (Rich.) s belym amurom *Ctenopharyngodon idella* (Val.)]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 15(2): 253−258.

Morphology of 20 hybrid specimens (approximately 8 cm in body length), from 7 different artificial breeding events between a single female Bighead Carp and a single male Grass Carp, were examined and compared to the parental species (20 specimens each) of the same length. For comparison, a modification of the Hybrid Index of Hubbs and Kurinuma (1942) was used. The number of abdominal myotomes was 26–28, which is intermediate between numbers typical for Bighead Carp (24–26) and Grass Carp (28–31). The number of caudal myotomes found in the hybrid individuals was 17–19, which was similar to that in Bighead, but in contrast to Grass Carp which commonly have 14–16 caudal myotomes. In general, the most distinguishing characters in hybrid individuals demonstrated a clear intermediate state. Among 19 characters (three counts and 16 morphometric characters), 12 were statistically different from the characters of both parental species, four were statistically different from the father (Grass Carp), and three were statistically different from the mother (Bighead Carp). Pharyngeal teeth formula was 1.4–5.1 (rarely 1.5–4.1). Teeth were laterally compressed, with a small concave masticatory surface slightly serrated along the margins. Interestingly, the teeth were clearly hooked; a character not typical for either Bighead Carp or Grass Carp.

Verigin, B.V., Makeyeva, A.P., and Zaki Mohamed, M.I. 1978. Natural spawning of *Hypophthalmichthys molitrix* (Val.), *Aristichthys nobilis* (Rich.) and *Ctenopharyngodon idella* (Val.) in the Syr Darya River. [Estestvennyy nerest tolstolobikov - *Hypophthalmichthys molitrix* (Val.) i *Aristichthys nobilis* (Rich.) i belogo amura *Ctenopharyngodon idella* (Val.) v reke Syrdar'e]. Voprosy Ikhtiologii. [Journal of Ichthyology, Moscow]. 18(1): 160−163.

Grass Carp and Silver Carp were not intentionally introduced into the Syr Darya River but likely escaped form the Akkurgan Experimental Pond Station in Tashkent Province where stocking has occurred since 1961. Fish were transplanted to the Pond Station from the Yangtze River in China. In 1975 and 1976, eggs and larvae were collected from the Syr Darya River at the right bank 3 km upstream from the mouth of the Chirchik River (a tributary of Syr Darya). Current velocity was approximatley 1 km•sec^{-1}. In 1975, larvae were present in only one sample (May 30), of which Grass Carp comprised 20% (out of 100 sampled individuals); no Grass Carp larvae were found in further irregular sampling. In 1976, regular observations started on the 14th of May and finished on the 5th of July; larvae of Chinese carps were sampled from May 24–31. During this period two peaks of downstream larval migration were observed, separated by a one-day-long interruption. Maximal migration occurred on the 28th of May, when over 600 eggs and embryos were collected per standard sample. Spawning likely started following a rapid rise in water level due to discharge from the Kayrakkum Reservoir. The spawning interruption coincided with a decline in water temperature, from over 23 °C to 22 °C. Drifting eggs and larvae varied in age, from gastrula stage to just-hatched pre-larva which suggests spawning may have occurred in different sections of the river located at different distances from the point of observations. Among samples, there were a significant number of dead eggs - up to 35% in some samples; and 2–3% of embryos were abnormally developed.

Vinogradov, V.K., and Zolotova, Z.K. 1974. Impact of Grass Carp on water ecosystems. [Vliyaniye belogo amura na ekosistemy vodoiomov.] Gidrobiologisheskiy Zhurnal. [Hydrobiological Journal, Kiyev]. 10(2): 90−98.

Information on the biology, reproduction, and ecology of Grass Carp available prior to 1974 was reviewed in this article.

Fish pond farms:

Feeding habits of introduced Grass Carp were studied in aquaculture. Grass Carp are herbivorous fish known for their high consumption rate. However, this species demonstrates high trophic plasticity and under limited food supply will shift from macrophytes to other food items available in a waterbody. This shift often leads to increased food competition for local fish species and disruption of trophic links in pond ecosystems. Grass Carp diet may include zooplankton, benthos, detritus, and peat. One study reported younger fish feeding on feces of older Grass Carp. Production of phytophilous fauna typically decreased in waterbodies with introduced Grass Carp which had significant implications to aboriginal fish species (as food supply), benthic composition, etc. The impact of Grass Carp on water chemistry and its physical properties was poorly studied but Grass Carp may contribute to fish-kills (derived from oxygen deficit) and may alter salt regimes in Grass Carp ponds.

Canals and irrigation systems:

The effective use of Grass Carp to control aquatic vegetation was first demonstrated in Karakum Canal, Turkmenistan. According to available data, a total of 246,000 Grass Carp fingerlings were released in the canal between1960 and 1961. In subsequent years, the estimated consumption rate was 10–15 tons of macrophytes per vegetation season. By 1974, the entire 850 km long canal bed and reservoirs were free from submerged vegetation, which was previously extremely abundant.

Experimentally stocked Grass Carp in the Ukraine (the Dnieper-Krivoy Rog canals and Severny Donets-Donbass) and Krasnodar Krai (Chibiy irrigation system) completely eliminated floating and submerged plant aggregations, resulted in grass and sedge cenoses, as well as reduced areas and suppressed development of dense reed and cattail communities.

In Dagestan Lower Terek and Arakum drainages, the floristic composition and community phytomass changed sharply after two years of Grass Carp stocking (100 individuals per hectare, once a year of 2–3 year-old fish, 200–300g; Magomayev 1998). Diversity of aquatic vegetation declined from 71 species of flowering plants (22 associations) to 58 (10 associations). This was mainly attributable to the consumption of submerged macrophytes preferred by this fish. The area of reed aggregations declined 80% to 30% foliage cover and the biomass of reedbeds were reduced 5-10-fold.

Selective impact on phytocenoses was demonstrated by studies in irrigation systems and reservoirs in Krasnodar Krai. Generally, Grass Carp moved from one feeding ground to another following depletion of preferred food items. In a few years after introduction some plants disappeared (pondweed, hornwort, water milfoil, and duckweed) and others became more abundant (mostly, toxic plants and nuisance hydrophytes). This trend suggests negative changes in plant communities occur due to the introduction of this phytophagous fish species.

Feeding habits of Grass Carp can indirectly affect food supply, fish fauna composition, and fish abundance. Long-term cultivation of herbivorous fish, including Grass Carp, in the Octyabr and Shendzhi reservoirs (Krasnodar Krai) altered the commercial fish fauna: pike and perch disappeared in catches and the stocks of crucian carp and roach declined considerably. In the reservoirs of Karakum Canal (Turkmenistan), the decline in wild carp production coincided with the total elimination of vegetation.

Spread:

Extensive introduction of Grass Carp would undoubtedly cause great damage to aquatic ecosystems. Major threats include disrupted trophic links and lost spawning grounds of native fish species. Due to the high migratory ability of this species, these impacts may extend over large areas of natural waterbodies. By 1974, self-sustaining populations of herbivorous fish were registered in the Amu Darya and Kuban rivers; spawning of these fish occurred in the Ili and Terek drainages. The dispersal capacity of Grass Carp is demonstrated by numerous examples: in the Volga River delta Grass Carp spread from Astrakhan to the Volgograd HEPS dam (and perhaps even further upstream to the middle Volga at Kuibyshev); in the lower Ural River from the Volga River delta, via the North Caspian; in the Dniester River via Cuciurgan estuary in Moldova; in the Central Asian rivers, from the Karakum Canal, the Aral and Azov seas.

Vovk, P.S. 1972. Rate of development and growth of Grass Carp larvae depending on water temperatures. [Temp razvitiya i rosta lichinok belogo amura v zavisimosti ot temperatury]. *In* Acclimatization of phytophagous fish in waterbodies of the USSR. [Akklimatizatsiya rastitel'noyadnykh ryb v vodoyomakh SSSR]. Edited by M.F. Yaroshenko. Book of Abstracts of the 7th All-Union Conference. Shtiintsa, Kishenev. pp 28−30.

and

Vovk, P.S. 1974. Reaction of embryos and larvae of Grass Carp to temperature effects [Reaktsiya embrionov i lichinok belogo amura na temperaturnyye vozdeystviya.] *In* Diversification of early ontogenetic development in fish. [Raznokachestvennost' rannego ontogeneza u ryb.]. Edited by V.I. Vladimirov. Naukova Dumka, Kiyev. p. 191−226.

Lethal, sublethal and optimal temperature ranges during the development of eggs, embryos and larvae were examined. At constant temperatures, egg survival during incubation was limited to temperatures between 17 and 30 °C. The extreme values were lethal to sublethal for eggs; the optimal temperatures were between 22.5 and 25.5 °C. Exposure for 2 hours to water cooled to 17 °C during early developmental stages caused considerable elongation of the incubation time and hatching period, as well as increased both egg mortality and the number of abnormal embryos. However, free Grass Carp embryos were rather resistant to low water temperatures between 13–17 °C. Pre-larvae and larvae survived at high water temperatures ranging from 38–43 °C (average 40 °C). At a water temperature of 20–32 °C their development accelerated but at 34–36 °C development was depressed and growth slowed. In general, larval survival rate was maximal, 76−95%, at water temperatures from 24–32 °C (the highest survival rate was registered at 30–32 °C); at water temperatures at 20 °C and at 34−36 °C the survival rate was 38−48%. Rates of survival and growth in older young-of-the-year were tightly correlated with thermal conditions during larval development. Average weight 2 days after hatching was: 1.4 mg (20 °C), 3.3 mg at (24 °C), 15.0 mg (28 °C), 31.6 mg (32 °C). Average weight 16 days after hatching was: 290 mg (32 °C) and 196 mg (34 °C). The maximal growth rate (both in weight and length) occurred in fry that were kept at 32 °C during their larval development and the lowest growth rate occurred in fry that were kept at 20 °C during the earlier stages of development.

Vovk, P.S. 1981. Morphological and biological variations of phytophagous fish under the influence of environmental conditions. [Morpho-biologicheskaya izmenchivost' rastitel’noyadnykh ryb pod vozdeystviem vneshney sredy.] Gidrobiologisheskiy Zhurnal. [Hydrobiological Journal, Kiyev]. 17(2): 112−113.

Based on information from breeding phytophagous fish in the Ukraine, the author concluded that significant changes in many biological and morphological characteristics of introduced fish have occurred. Compared to the native range of the fish (Amur River), pond conditions in the Ukraine are characterized by a warmer and longer vegetation season, a wider spectrum of macrophytes and phytoplankton, and some different hydrological features (e.g., lack of flow). In these conditions, Grass Carp, as well as Silver Carp, attained sexual maturity at a smaller size and demonstrated a broader diet, an increased rate of maturation, as well as an increased fecundity and somatic productivity.

Some morphological features of Grass Carp were dependent on thermal conditions (within the range 24–36 °C) during early post-embryonic development. Water temperature was positively correlated with body depth, caudal peduncle length and depth, and the pre-anal distance, but was negatively correlated with the number of lateral line scales.

Zubareva, E.L. 1980. [Vliyaniye rezkogo perepada vody na vyzhivaemost' lichinok belogo amura]. *In* Phytophagous fishes in industrial fish culture. Book of Abstracts of the 9th All-Union Conference. [Rastitel’noyadnye ryby v promyshlennom rybovodstve. Tezisy dokladov IX Vsesoyuznogo Soveshchaniya.]. Edited by G.V Kamilov. Izdatel’stvo AN UzSSR, Tashkent. p. 162.

The effects of rapid and significant water temperature changes on general activity and feeding of 15-day-old Grass Carp larvae were investigated. A sharp decrease from 26 °C to 18 °C caused no visible effect; larvae continued to swim in middle layers of water and consume both natural and artificial food. Sharp decreases from 26 °C to 13 °C and from 20 °C to 12 °C caused no visible effect; larvae continued to actively swim but moved closer to the bottom and consumed only natural food. A sharp increase in water temperature from 20 °C to 28 °C caused no visible effect; larvae continued to swim in middle layers of water and consumed both natural and artificial food. Larvae survived sharp changes in water temperature (14 °C to 31 °C and 31 °C to 14 °C), but they stayed at the bottom and took some time before starting to consume natural food.

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Mitrofanov, V.P., Dukravets, G.M., Sidorova, A.F., et al. 1992. *In* Fishes of Kazakhstan. [Ryby Kazakhstana] Vol. 5. Introductions, fisheries. [Akklimatizatsiya, promysel] Gylym, Alma-Ata. p. 126−159.

Shireman, J.V., and Smith, C.R. 1983. Synopsis of biological data on the Grass Carp *Ctenopharygodon idella* (Cuvier and Valenciennes, 1844). FAO Fisheries Synopsis. 135: 86 p.

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APPENDIX 1

Annotated extracts on Grass Carp (*Ctenopharyngodon idella*) from: Mitrofanov V.P., Dukravets, G.M., Sidorova, A.F., et al. 1992. *In* Fishes of Kazakhstan. [Ryby Kazakhstana] Vol. 5. Introductions, fisheries. [Akklimatizatsiya, promysel] Gylym, Alma-Ata. p.126−159.

DISTRIBUTION

The native range of Grass Carp includes waterbodies of East Asia, up to the Amur River drainage in the north. Grass Carp have been introduced in Mongolia, numerous European countries, the USA, and in many waterbodies of the former USSR, in particular, Moldova, Ukraine, Krasnodar Krai, the lower Volga River, Central Asia and Kazakhstan. Self-sustaining populations of Grass Carp have established in river drainages of the Kuban, Volga, Amu Darya, Syr Darya, and Ili, and may also occur in the Ural River.

Grass Carp was first introduced into the Caspian basin in November 1955, when 2- and 3-year old juveniles were intentionally introduced into the lower reaches of the Volga River. The first Grass Carp captures were subsequently recorded in 1959; one specimen (weight between 4 and 5 kg) from the Ural River delta, and the other (mature female aged 6+, weight 6.2 kg) from the Volga River, 85 km upstream from Astrakhan (Tanasiychuk 1961). Grass Carp (larvae, fry and young-of-the-year) were repeatedly introduced into the Volga Delta from 1955–1957 (together with Silver Carp) and from 1964–1976 (Martino 1975, Karpevich et al. 1968, Negonovskaya 1980). Following establishment, the population dispersed along the Volga River up to the Volgograd HEPS, where spawning occurred (Martino 1975, Kazancheyev 1981). Grass Carp also migrated into the Ural River via the North Caspian.

Beginning in the late 1950s to early 1960s, Grass Carp was introduced into a number of Kazakhstan waterbodies. Early introductions were comprised of Grass Carp imported from China (Yangtze River). However, over the next few years, artificial breeding of Grass Carp was initiated at fish hatcheries of the former USSR (Karametniyaz in Turkmenistan, Tastak and Alma-Ata in Kazakhstan, Akkurgan in Uzbekistan), and by the mid-1960s intoductions of locally produced Grass Carp stock (larvae, fry, juvenile and adult fish) occurred.

In the Ural River drainage, Grass Carp larvae from Karametniyaz fish farm were released in the mid-1960s (Karpevich and Lukonina 1970). Grass Carp subsequently spread within the river system, including floodplain lakes (Dukravets 1971), and have been present in the wild since the late 1960s.

In the Syr Darya River drainage, Grass Carp larvae from China were first introduced in 1960 into the ponds of Tastak Fish Hatchery, located in the river delta (Samukha 1961). In 1965, first maturity was recorded in cultivated Grass Carp and since 1965–1966 hatchery-juveniles (young-of-the-year and yearlings) were released annually into the desalinated Karateren Bay of the Aral Sea (Bykov 1968, Karpevich 1975).

Grass Carp was first recorded in the north Aral Sea in the mid-1960s and natural spawning was first recorded in the lower Syr Darya River in 1966–1967, as evidenced by captures of drifting Grass Carp embryos and larvae in river samples (Lim 1968). Grass Carp dispersed into the mid-section of the Syr Darya River from ponds of two fish farms – Akkurgan in Uzbekistan and Karametniyaz in Turkmenistan (Verigin et al. 1978). From 1966–1969, Grass Carp were recorded in Chardara Reservoir and in the Syr Darya River backwaters (Ereshchenko 1970). Spawning of Grass Carp was recorded between 1975 and 1979 (Verigin et al. 1978, Miroshnichenko and Kamenetskaya 1978, Verigin and Makeyeva 1983), but first spawning in this area likely occurred earlier, in the preceding years.

Data on the total number of releases into the Aral Sea basin under the State introduction programme for the period 1960–1973 are often contradictory (Karpevich 1968, Mitrofanov 1973, Karpevich 1975, Markova 1975, Negonovskaya 1980)

In the Balkhash Lake basin, Grass Carp larvae from China were introduced in 1958 into Alma-Ata Pond Farm. Since 1963–1964, Grass Carp was cultivated in Chilik Pond Farm and Alma-Ata Fish Hatchery ("Kazakh production and acclimatization station"). In addition to intentional introductions, unintentional introductions also occurred within the basin; fish escaped from pond fish farms (Alma-Ata Hatchery into the Kaskelen River of the Ili River drainage in 1958) and due to hydraulic accidents (e.g., in 1963 into Balkhash Lake). Single captures of Grass Carp (as by-catch in commercial fishery) have occurred in this area since 1964, including within the strait that joins the eastern and western sides of Balkhash Lake. In 1972, Grass Carp by-catch amounted to 8,700 kg. In the early 1980s, Grass Carp occurred primarily in the lower reaches of the Ili River, its delta and the deltaic lake areas and rarely occurred in the open waters of western Balkhash Lake and were not recorded in the eastern part of Balkhash Lake, despite its presence in the Karatal River (Serov 1965, Dukravets 1967, 1975, Serov and Antsiferova 1968, Antsiferova 1970, 1974, 1976, Negonovskaya 1980).

Following the damming of the Ili River by Kapchagay HEPS dam in 1969–1970, Grass Carp was regularly introduced (from 1970–1988) into the newly-formed reservoir for the purpose of establishing a Grass Carp population. These introductions were reviewed in a number of papers (Dukravets 1975, 1982, Nezdolyi and Mitrofanov 1975, Ereshchenko and Melnikov 1982, Yakubowsky et al. 1985, Karpov et al. 1989). By the mid-1970s, spawning was recorded in the Ili River and the presence of two self-sustaining populations of Grass Carp (isolated by Kapchagay HEPS dam) in the Ili River drainage was confirmed.

In the Alakol lakes system, Grass Carp juveniles were first introduced in 1967 or 1968 (Karpevich and Lukonina 1971, Strelnikov 1976, Dikansky 1983). Grass Carp was introduced to both Sasykkol (more frequently) and Alakol lakes from 1968 to1988. In the early 1970s, the absence of mature fish in the lakes (Strelnikov 1976) indicated that the Grass Carp population in the Alakol system was not self-sustaining and was maintained entirely through introduction measures. A self-sustaining Grass Carp population did not establish because spawning conditions in the area were unfavourable.

In the Talas River lakes (Zhambyl Oblast), Grass Carp juveniles from Alma-Ata Hatchery were introduced from 1965 to 1979 into Akkol (more frequently) and Biylikol lakes (Pivnev and Bashunov 1970). In the late-1960s to early-1970s, Grass Carp occurred sporadically in landings from Akkol and Biylikol lakes but were eliminated in this area due to sharp changes in the hydrological regime.

In 1968, Grass Carp larvae and young-of-the-year from Alma-Ata Hatchery were introduced into the Bukhtarma Reservoir (Irtysh River). Stocked fish were transported from Alma-Ata, Tedjen, and Tastak farms and reared up to 10–20 g at the Bukhtarma Hatchery and Nursery Farm prior to their release into the lakes. Repeated releases of Grass Carp juveniles occurred from 1969 to 1975. Introduction success of these stockings was low; likely due to the poor food supply and unfavourable spawning conditions for Grass Carp reproduction (Ereshchenko 1975). In 1975, young-of-the-year Grass Carp from Alma-Ata Hatchery were introduced into reservoirs of the Irtysh−Karaganda Canal to control aquatic vegetation. Initially, the effect of Grass Carp was minimal due to extensive predation on Grass Carp and poor stock quality (Yakubowsky and Ereshchenko 1978). However, by the mid-1980s, Grass Carp abundance increased to commercial size.

In addition to these large-scale introductions to main Kazakhstan waterbodies, a number of sporadic releases into other reservoirs occurred; mostly as unsubstantiated experiments to control aquatic vegetation or to enhance sports and recreational fishing. In recent years, Grass Carp juveniles have been used by the Ministry of Agriculture and Ministry of Water Resources of the Kazakh SSR to populate state-owned small lakes, ponds and reservoirs. Pond farms, hatchery and nursery farms under the Ministry of Fisheries of the Kazakh SSR all include Grass Carp in their activities, as they were considered necessary for successful freshwater aquaculture practices. However, despite these extensive and costly introduction activities, Grass Carp did not develop commercially important populations in Kazakhstan waterbodies.

Commercial exploitation of Grass Carp was launched in the Syr Darya River drainage from 1966–1969 and was extended further in to the Ili-Balkhash basin and the Ural River; however, commercial catches of Grass Carp were not significant and declined throughout most areas in the 1980s.

The exact number of Grass Carp populations in the above reviewed waterbodies was difficult to estimate due to existing illegal, unreported and unregulated fishing (Ereshchenko et al. 1977, Lysenko 1977, Tinkovich et al. 1984, Vorobyeva 1987); thus the distribution and abundance of Grass Carp in this region may be underestimated.

DESCRIPTION

Compared with Grass Carp within its native range (Sterba 1987), fish from the Ili River display an increased variability for most meristic characteristics. However, both the mean and modal values for the number of fin rays and lateral line scale counts (43.7 in the Amur River drainage) remained the same or similar to values from the native range. Two meristic characteristics, number of scales below the lateral line and number of gill rakers, markedly increased. Changes in the latter character are common, as this character is strongly associated wth feeding conditions. No data on the number of vertebrae were available for comparison.

During growth and development, Grass Carp from the Ili River had lower measures for relative indices such as: depth of unpaired fins, length of paired fins, length of head and snout, and, most notably, eye diameter. In contrast, maximum body depth, antedorsal, pectoventral, ventroanal and postorbital distances increased. Size and age variability between the studied groups was considerable.

Compared to Grass Carp from its native range, plastic characteristics in fish of the Ili River population did not significantly change, except for the decreased (relative) dimensional parameters of fins, the head and its calculated proportions. The overall variability of characteristics in different groups of introduced Grass Carp in the Ili and Amu Darya watersheds was low, which was considered to be indicative of a weak biotopic variability.

Sexual dimorphism in Grass Carp was not yet fully studied. Generally, females were larger than males of the same age.

Within its native range, Grass Carp attained 120 cm in length and 32 kg in weight (Berg 1949, Lebedev et al. 1969). The maximum size of Grass Carp in the Syr Darya watershed was similar: 112 cm TL, up to 19.5 kg in weight and even up to 25 kg in Chardara Reservoir (Salikhov 1984, Yakubowsky and Melnikov 1984). According to Korotkova et al. (1980), Grass Carp reached 37 kg at 96 cm length. In the Ili River, Grass Carp was smaller: up to 91 cm in body length and up to 13.7 kg in weight. Fishermen reported individual fish weighing up to 80 kg. An increase in the average size and weight characteristics may occur through further establishment of the fish population in Kapchagay reservoir.

REPRODUCTION

Self-sustaining populations of Grass Carp in Kazakhstan were formed in the Syr Darya and Ili watersheds. Natural reproduction also occurred in the Karatal River, as evidenced by the presence of Grass Carp larvae in samples from its lower reaches (KazSU expedition, July 1989). Spawning also likely occurred inin the Ural River.

Grass Carp reach maturity at different ages in different climatic zones: as early as the first year in the tropics; 3–5 years of age in Turkmenistan waterbodies; and in 6–10 years (45–75 cm body length), or more often in 8–9 years (at approximately 70 cm in body length), in the Amur River drainage (northernmost native range). Males usually mature a year earlier than females (Gorbach 1965, Makeyeva 1974).

In the lower Volga reaches, Grass Carp matured at 6 years (Kazancheyev 1981). In the Syr Darya drainage,Grass Carp matured earlier (in 2–4 years); males attained maturity in 2–3 years (63–84 cm body length and 2.8-6.9 kg weight), and females reached maturity in 3–4 years (67–90 cm body length and 5.3–11.5 kg weight) (Salikhov 1984).

Two self-sustaining populations of Grass Carp, physically separated by the Kapchagay HEPS dam, were established in the Ili River watershed. In the lower Ili River (Balkhash) population, first maturity occured in females at 4+ to 6+ years of age (62.7 cm TL and 4.4 kg in weight), or earlier (3–5 years, 50 cm TL; Antsiferova 1974, 1976), whereas males matured a year earlier at an average body length of 55.8 cm, and weight of 3 kg (Faryshev and Bashunov 1980). Age at first maturity in the upper Ili River (Kapchagay) population of Grass Carp, as determined by spawning marks on scales, was 3–6 years at 30–60 cm SL, but the majority (50–70%) of Grass Carp reached maturity at the age of 4 years, at body lengths of 35–50 cm.

Spawning migration of Grass Carp was triggered by the spring flood. In the Syr Darya River, spawning migration lasted from March–April (water temperature 13–16 °C) until the end of May. During this period, several groups of adult fish approached the spawning grounds at different times, with larger fish (85–112 cm in length, 9.3–18.5 kg in weight) arriving first. However, the majority (59%) of the spawning population was composed of fish 57–91cm long, weighing 4.2–11.5 kg (Salikhov 1984). In the upper- and lower Ili River populations, spawning migration lasted from early April (water temperature 10–12 °C) until mid-July. The majority of spawning fishes were between the ages of 5–8 years at lengths of 40–88 cm and at weights up to 12 kg. The weight-length characteristics of spawning fishes in this area were similar to those in the Syr Darya River (Baekeshev et al. 1988b, Faryshev and Bashunov 1980).

The sex ratio in spawning groups of Grass Carp in both sections of the Ili River was approximately 1:1. However, the prevalence of males or females was not infrequent, both at the spawning grounds and in the long-term statistics data. Thus, males were predominant (71–75%) among the younger spawners (2+ to 3+) in the Syr Darya River (Salikhov 1984) and at the downstream spawning grounds in the Ili River (Faryshev and Bashunov 1980). In Kapchagay reservoir, the average-annual experimental catches (1971–1987) revealed a persistent prevalence of females, from 1.1:1 to 1.6:1, with an average of 1.3:1 for the entire period (n=191).

Available data on the sex ratio at native-range spawning grounds show the same variability: the predominance of females (60%) in the Amur drainage and males (75–80%) in the Yangtze and Sungari rivers (Makeyeva 1974).

Grass Carp spawn in rivers with expressed stream flow and lay pelagic eggs, which develop in the water column while drifting (passive downstream migration) a considerable distance. The latter condition is important to the spawning success of Grass Carp and other herbivorous fish as the water course length needs to be of sufficient length to ensure the development of drifting eggs and pre-larvae. In the Amur River, this distance is 500 km and should likely not be less than 100 km (Krykhtin and Gorbach 1981, Gorbach and Krykhtin 1988).

Spawning in the Ili and Syr Darya rivers usually occured at sites with sandbars and islands, at the confluence of two streams, where vertical currents form. The depth was 2–3 m and the bottom was covered by sand, silt and sand, or sand and pebble. Flow rate did not exceed 2 m •s^{-1} (Miroshnichenko and Kamenetskaya 1978, Faryshev and Bashunov 1980, Salikhov 1984, authors' (Mitrofanov et al.) data).

The total spawning period was rather extended in both systems. Spawning generally started when water temperature reached 17–18 °C and water levels in the spawning river rose. In both watersheds, but particularly in the Ili River, Grass Carp spawned at the same time and location as another pelagophilic species, the Aral barbel.

In Syr Darya River, upstream of Chardara Reservoir, Grass Carp spawned in the latter half of May and June (data for 1975–1982), at water temperatures of 17–22 °C. Spawning was triggered by a sharp rise in the water level, due to releases from the upstream reservoirs. Several spawning peaks were noted; the most intense peak occurred at the concurrent rise of water temperature and water level. Spawning took place in both the morning and evening, but less often at night. Downstream migration of embryos (eggs) peaked in late May (Miroshnichenko and Kamenetskaya 1978, Verigin and Makeyeva 1983, Salikhov 1984).

In the upper Ili River, Grass Carp spawned from early May to mid-August, predominantly through late May until the end of June. Developing embryos and larvae were first recorded in May–July 1972 (at Ayak-kalkan, upstream of Kapchagay Reservoir). As in the Syr Darya River, downstream migration in the upper Ili River was preceded by a rise in water level, water temperature (18.5–18.7 °C) and current velocity (up to 1.3 m •s^{-1}). Although water turbidity also increased, it likely did not affect spawning or downstream migration processes.

During mass migration of free embryos and pre-larvae (at 19–20 °C), no diurnal pattern was identified in the upper Ili River (the Kapchagay population). However, in experimental sampling, eggs were captured mainly in the evening (71%) when water levels increased and, conversely, larvae were more abundant in the night-time and morning samples when water levels were lowest. Embryos and pre-larvae migrated along the midstream (Korotkova et al. 1980), predominantly in the bottom layer (85.7%) and pre-larvae were equally distributed in the water column and in the surface layer (Nezdoliy and Mitrofanov 1975, Pavlov et al. 1981).

In the 1970s, the estimated distance between the major spawning sites of Grass Carp and the reservoir (80 km) was determined based on the age (stage of development) of Grass Carp in samples and the average flow velocity (0.6 m •s^{-1}). In the mid-1980s, conditions changed in the upper Ili River. Analysis of the total number of drifting embryos and pre-larvae, as well as the greater proportion of pre-larvae in experimental catches (Baekeshev et al. 1987, 1988a, b), against the temporal pattern of downstream migration and hydrological conditions suggested that the major spawning sites for Grass Carp had “shifted” by 40–120 km upstream from the former spawning localities. A shift in the location of spawning grounds was confirmed by KazNIIRKh field studies in the Ili River in 1986 and 1988.

Spawning success of Grass Carp in the upper Ili River improved due to the increased survival rate in free embryos and the overall annual yield. The cumulative number of Grass Carp produced in this area reached 4.584 billion individuals, or 92.6% of the total fish migration in 1986, and in 1988 it reached 3.123 billion individuals (85% of the total fish migration) (Dmitriev et al. 1988). The estimated number of mature adults in the upper Ili River for these years ranged between 10,000 and 15,000 individuals. This estimate was calculated based upon the total number of downstream migrants (embryos and larvae) throughout the spawning season and the average fecundity for the Kapchagay population (approximatley 800,000 eggs per female, see below for further discussion). Following the establishment of the upper Ili River population, the diurnal pattern of downstream migration became smoother in the subsequent years, and drifting embryos and pre-larvae became more evenly distributed across the river section, with a slightly increased concentration in the bottom layer and the mainstream.

The hydrological conditions for Grass Carp spawning in the Ili River downstream of Kapchagay Reservoir were strongly dependent on the volume and timing of water releases from the reservoir which produced unfavourable water level and temperature conditions. Apparently, these factors resulted in a reduced spawning period and shifted the spawning sites downstream, to the lower reaches of the Ili River. According to KazSU expedition data, the sites located ca. 70 km downstream of the reservoir (at Tasmurun) were excluded from Grass Carp spawning grounds by 1978, as demonstrated by the number of developing eggs in samples (in 1976 – 2.8 million individuals or 0.4% of total migrants; in 1977 – 7.8 million individuals or 3.3% of total migrants; in 1978 – 1.72 million individuals or 0.03% of total migrants).

Spawning grounds of Grass Carp in the lower Ili River were located mainly within a 70 km section between the settlements of Bakanas and Araltyube. The proximity of the upper spawning sites to the river delta was sufficient for the complete development of eggs and pre-larvae during their downstream migration; however, a certain portion of free embryos from the lower spawning sites drifted to the deltaic lake systems and were eliminated there. From 1985–1987, mass spawning of Grass Carp in the lower Ili River was registered at the river section between Bakanas village (150 km off the reservoir and around 210 km off the Balkhash) – Ushzharma village (170 km off the Balkhash) – Akkol village (200 km off the reservoir and 160 km off the Balkhash, the most productive area, with 6.5 billion individuals in 1987).

The most intense spawning in the lower Ili River occurred from morning until noon. The number of adults in the lower Ili River (1982) was estimated at 25,000–30,000 individuals and the average fecundity was three times greater than in the Kapchagay population. Based upon the relative increase in the number of large eggs in ovaries (from 55.2 to 94.5%) during transition to maturity stage IV, Grass Carp in the lower Ili River were single-batch spawners (Antsiferova 1974, Faryshev and Bashunov 1980) with a spawning period that did not exceed 1.5 months. In contrast, the spawning period in the upper Ili River exceeded 3 months, with several bouts of downstream migration (free embryos and larvae). Thus, both spawning patterns (single- and multiple-batch) occur in the Ili River. In general, the intensity of spawning processes in the lower Ili River are greatly affected by the natural hydrological conditions of a certain year (water discharge, i.e., low- or high-water year) and those resulting from regulation of the river stream (releases from Kapchagay Reservoir), where the optimum water temperature (no less than 17 °C) and flow velocity are crucial factors. These processes, as well as their determining factors are reviewed in further detail for the period 1978–1982 (Faryshev 1983, Bashunov and Tsoi 1983).

Data on the Grass Carp spawning process within its native range (rivers of China, the Amur River) were contradictory and included indications of both single- and multiple-batch spawning. In the Yangtze and Amur rivers, two separate groups (single- and multiple-batch spawners) were distinguished due to differences in the process of vitellogenesis. At the same time, asynchronous vitellogenesis can be smoothed out during maturity stage IV and thus result in a single-batch spawning event. Spawning periods within the native range were considerably extended, due to uneven maturation and prolonged arrival of mature fish to the spawning grounds, and not as a result of the spawning pattern which likely depended upon the hydrological regime and feeding conditions for Grass Carp (Gorbach 1965, 1972, Makeyeva 1974, Lebedev and Spanovskaya 1983).

The individual absolute fecundity (IAF) of Grass Carp in China and Japan ranged from 29,000 to 960,000 eggs and perhaps up to 2 million eggs. In the Amur River drainage, the estimated Grass Carp fecundity ranged from 237,000–1,687,000 eggs (190 females, 5+ to 7+, 66–96 cm in length, and 5.05–16.4 kg in weight), and averaged 820,000 eggs (Gorbach 1972). These fecundity values increased with fish age and body size (length and weight).

In the Ili and Syr Darya rivers, Grass Carp fecundity was higher, with a maximum value of 2.5 million eggs. Upstream of Chardara Reservoir (Uzbekistan territories), IAF ranged from 13,600 eggs at first maturity (3+) to 2,409,000 eggs in 8-year-old fish (Salikhov 1984), while in the Ili River it ranged from 161,000 to 2,548,000 eggs.

Grass Carp fecundity in the Kapchagay population was similar to that of Grass Carp in the Amur River. Fecundity of females collected in the Ili delta was three times higher, on average, than that of equi-sized females from the upper Kapchagay Reservoir, which may be related to differences in egg size and the age of the introduced Grass Carp population.

Mature ovarian eggs in Grass Carp from the Ili River were yellow-green or bluish-gray, and measured 1.05–1.34 mm in diameter, while fertilized hydrated eggs measured 4–6 mm in diameter. These values were similar to those for Grass Carp in its native range: 1.0–1.6 mm and 3.8–6.5 mm, respectively (Makeyeva 1974). Pre-spawning egg diameter was slightly larger in the upper Ili River population, as compared with Grass Carp from the lower Ili River (Nezdoliy and Mitrofanov 1975, Antsiferova 1974).

Embryonic development of Grass Carp in natural waterbodies within Kazakhstan was not yet studied. However, in Shymkent Pond Farm (1967–1968), under hatchery conditions for artificial reproduction (water temperatures of 23–25 °C, oxygen saturation 52–100%), Grass Carp embryonic development lasted 22–29 hours, and hatching lasted 4–18 hours. The size of newly-hatched larvae increased within this period, from an average of 5.3 mm (range of 4.5–6.5 mm) in the beginning of the hatching period to 6.3 mm (range of 5.5–6.9 mm) by the end of hatching (Goryunova 1972). Koblitskaya (1981) indicated a similar size range of hatchlings: 5.0–5.7 mm.

The optimal temperature for Grass Carp embryogenesis was 18–32 °C and a gradual increase of water temperature within this range improved survival of embryos, with the maximum survival rate (76–95%) at 24–32 °C. Water cooling to 15–16 °C slowed the rate of development and induced malformations in hatchlings (reviewed in Makeyeva 1974). In the lower Ili River, thermal instability (mainly, sharp drops in water temperature) reduced the efficiency of Grass Carp natural reproduction and regular releases from Kapchagay Reservoir (from bottom layers) in May–June often led to cooling of river water to the critical limit and even below.

The optimal salinity for survival of eggs and free embryos of Grass Carp is approximately 5‰; thus, successful spawning can occur in fresh or low-brackish water only. Embryonic development in Aral Sea water (3–5‰) is normal but takes a few more hours than in fresh water. Embryogenesis fails at approximately 7‰ salinity. Salinity tolerance of larvae is higher, at approximately 6–8‰ salinity; however, increased water salinity increased the number of larval malformations (Rykova 1966). Interestingly, Grass Carp fry survived in Aral Sea water up to 12‰ salinity for 1.5-2 months when water salinity was raised gradually (Doroshev 1963). This suggests that both juveniles and adults may be able to penetrate the desalinated areas of the Aral and Caspian seas.

Water contamination by industrial and agricultural pollutants has caused acute or chronic intoxication of Grass Carp. In Chardara Reservoir (1980–1984), acute poisoning led to mass fish mortality; over 300 tons of adult Silver and Bighead carps and 2 tons of Grass Carp were eliminated. Toxicological studies in the Syr Darya drainage (Yakubowsky et al. 1985, Gubanova and Semenova 1988) revealed high levels of water and bottom sediments contaminated with oil products, phenols, and nitrites exceeding MPC values up to 27 times. Persistent organochlorine pesticides, such as HCH, DDT, DDE, and others, accumulated in fish bodies, including gonads, and consequently led to chronic toxicosis, which affects reproductive quality. In the mid-1970s, developmental malformations (2–3%) in drifting embryos of Grass Carp were recorded in the Syr Darya Riverand were attributed to hatchery practice (hormone treatment of maturing fish) (Verigin et al. 1978). In the Ili River drainage, there were no cases of mass mortality; however, free embryos with developmental aberrations were observed from mid-1980, up to 9 to 18% per sample. Aberrations included blastodisk flattening, as well as abnormal cleavage, gastrulation, and organogenesis (Kolobayeva 1989) and were most likely due to pollution runoff from rice fields, especially pesticides, that cause internal organ dysfunction (primarily, hematopoietic and generative) and affect fish reproduction (Popov 1978, Shilenko 1988)

AGE AND GROWTH

According to Koblitskaya (1981), body length of Grass Carp larvae in the lower Volga River was between 7.5 and 14.5 mm. Grass Carp and Chub larvae are similar in shape of body and head. Scales appear when Grass Carp reach approximately 20 mm TL, and squamation is fully complete at 40–45 mm TL. By August, Grass Carp fry reached 45 mm TL and by late September they had reached 60–70 mm TL. According to Nikolsky (1956), Grass Carp from the Amur River drainage, reached 15–34 mm TL by the second half of July and in early September they were between 50 and 100 mm, with an average body length of 72 mm. Between 1965 and 1986, similar linear and weight growth rates were observed in the Balkhash-Ili watershed: in Balkhash Lake – 1.5–10 g by September (Serov 1975); in the Ili River – 62–95 mm by August (Antsiferova 1974); in Kapchagay Reservoir – 32 mm and 0.65 g by August (Seleznev 1975); in the Ili River (at Ayakkalkan) – 26–40 mm and 0.75 g by the last 10 days of July; and in Kapchagay backwater – average of 54 mm by early September. In the northern tropics (Florida, USA), under favourable thermal conditions and abundant food supply, the average annual growth increment during the first four years was 20 cm in length and 3.75 kg in weight (Shireman et al., 1980).

In Kazakhstan, Grass Carp growth rates were high in most areas during the initial introduction period (Serov 1975, Antsiferova 1976, Korotkova et al. 1980, Faryshev 1983, Salikhov and Golubenko 1984). In Balkhash Lake and the Ili River delta, 2-year-old (1+) Grass Carp reached an average of 37 cm and 1.2 kg, 3-year-old fish reached 40.3 cm and 1.5 kg, and 4-year-old Grass Carp reached 56.8 cm and 3.6 kg. In Chardara reservoir and the Irtysh-Karaganda reservoirs, growth rates were similar (3-year-old (2+) fish: 36–41 cm TL, 1–1.5 kg by August) (Yakubowsky and Ereshchenko 1978), whereas in the middle Syr Darya River a more rapid growth rate was reported starting from the second year of life (Salikhov and Golubenko 1984). Growth rate in Kapchagay, Bugun, and the Ili River delta populations was more uniform and less rapid, but exceeded growth rates in the Amur River drainage. The slowest growth rates occurred in the brackish Aral Sea and Sorkol Lake (the Ili River floodplain); however, it was similar to Grass Carp growth within its native range (the Amur River). According to Grass Carp growth data (collected by Karpov and Glukhovtsev) collected in the areas upstream of Kapchagay Reservoir (1986–1987), Grass Carp yearlings reached 8.3–11 cm in body length, with an average of 9 cm; and 1+-old Grass Carp (at the end of the second growth season; data for end of summer 1987) reached 14.5–21 cm, with an average of 18.5 cm at 76–210 g in weight (with an average of 141 g). The calculated length of 1+ individuals in the Ili River drainage between 1986 and 1988 ranged from 6.3 to 18.9 cm. Thus, the size of Grass Carp yearlings in this area did not considerably exceed that in the Amur River drainage (6–12 cm, according to Gorbach and Krykhtin (1988)). This pattern persisted in the subsequent years; however, 5-year-old individuals from introduced populations were generally larger by 10–16 cm, as compared with fish of the same age class from the Amur River.

With regard to the length variability within the same year classes, the following patterns should be mentioned. First, the lower size range of age classes observed during the early formation of Balkhash and Kapchagay populations may be attributable to increased population heterogeneity. Second, in contrast to the Balkhash Lake population, size variability in Grass Carp from the Kapchagay population increased and was persistent throughout the reviewed period; this was likely due to the spawning conditions, as well as the repeated introductions of Grass Carp to the reservoir.

In the lower Volga River, Grass Carp grew faster than in the Ili River but slower than in the Syr Darya River: 3-year-old fish reached 35–40 cm and 1.2 kg; 7-year-old fish reached 67–70 cm; and, 10-year-old fish reached 80–83 cm and 12.7 kg (Martino 1975, Kazancheyev 1981, Tinkovich et al. 1984). According to Kushnarenko et al. (1977), the weight increment in the Volga River delta was similar to that in the Ili River delta and Chardara Reservoir: 3-year-old (2+) – 1.8 kg; 4-year-old – 3.7 kg; 5-year-old – 6 kg; and, 6-year-old (5+) – 7 kg.

Sex-related differences in the growth rate of Grass Carp in Kazakhstan waterbodies were unclear. Back calculations for Grass Carp from the Kapchagay Reservoir (Dukravets 1975) indicated females reached slightly greater lengths than males: 2 cm greater length within the 3-year-old age class and 2.6 cm within the 5-year-old age class. According to Nikolsky (1956), no sex-related differences in growth rate of Grass Carp were identified in the Amur River.

Grass Carp has a relatively long lifespan. In the Amur River drainage, it reached 16 years (Gorbach 1972), but may reach up to 21 years (Gorbach 1961). In the Ili River, both up- and downstream of Kapchagay HEPS, 12- and 13-year-old fish were not uncommon in recent years. A similar pattern was reported in Chardara Reservoir (Yakubowsky and Melnikov 1984) and in the lower Volga River (Kazancheyev 1981). Commercial catches in Kazakhstan are dominated by 4–8-year-old Grass Carp.

FEEDING HABITS AND CONDITION FACTOR

Adult Grass Carp are phytophagous, feeding almost exclusively on aquatic and submerged terrestrial vegetation. Pharyngeal dentition (teeth structure) enables the biting off, and grinding of, coarse stems of plants and its long intestine (220–300% of body length, Amur River Grass Carp) can absorb various plants and accidental items (Charyev 1978). Under conditions of insufficient vegetation, Grass Carp can consume animal food, and according to Chinese studies, may even become omnivorous under pond farming (Nikolsky 1956).

Feeding habits in Kazakhstan waterbodies were not fully known. In the lower Volga River, adult Grass Carp fed on macrophytes, mainly hornwort (Kazancheyev 1981) and the index of gut fullness was 1,200-1,400 $^{0}/_{000}$ (Martino 1975). In Chardara Reservoir, the summer diet was primarily composed of young reeds (up to 100%, both by frequency of occurrence and weight of food bolus), with the addition of filamentous and green algae in larger fish. The index of gut fullness was high – 1,215 $^{0}/_{000}$ (Korotkova et al. 1980). The diet of Grass Carp in Balkhash Lake and the Ili River delta consisted of stonewort and *Chara* algae (Serov and Antsiferova 1968, Serov 1975). Fishermen reported catches of Grass Carp in the lower Ili River by using odd baits, such as cucumber and watermelon peels.

In Kapchagay Reservoir (during the initial establishment period), Grass Carp also fed on a narrow range of food items (Ereshchenko et al. 1973, Tan 1982); primarily the common reed (up to 100% by frequency and weight of food bolus), followed by the filamentous algae *Cladophora* (21.2% by frequency), and in rare cases, the remains of terrestrial plants and phytoplankton, chironomid larvae (the only animal food item), and bryozoan statoblasts. The average index of gut fullness in the reservoir had a medium value and declined over time: in 1970 – 317–937$^{0}/_{000}$, 519–559$^{0}/_{000}$; in 1971– 162–781$^{0}/_{000}$, 330–376 $^{0}/_{000}$; in 1972 – an average of 235$^{0}/_{000}$; and, in

1973 – $205^{0}/_{000}$. The highest feeding intensity was observed in spring and autumn. In the summer, more than 50% of guts were empty and the index of gut fullness decreased from 350 to $82^{0}/_{000}$, which may be explained by the high water temperature and rapid digestion. The diet spectrum of adult Grass Carp in Kapchagay expanded in subsequent years to consist primarily of algae, pondweed and reed, but non-specific food components (mysids in juvenile Grass Carp, bivalves in mature Grass Carp) were also registered, which was aparently due to the high density of these animals in the reservoir and the lack of plant food. Molluscs were found in guts only in May but occurred in large quantities. In 1986–1988, the index of gut fullness of Grass Carp in Kapchagay Reservoir was rather low ($44.8^{0}/_{000}$in October 1986, $257.4^{0}/_{000}$in May 1987).

Available data from the middle Syr Darya River, indicate that Grass Carp continue to feed during migration and spawning (Salikhov 1984). In the native range of Grass Carp, feeding was suspended in winter when fish aggregated in deep river pockets and were covered with thick mucus (Lebedev and Spanovskaya 1983). However, no data are known for wintering of Grass Carp in Kazakhstan.

Following transition to exogenous feeding and up to the age of one month, Grass Carp fry consumed mainly animal food, as demonstrated by studies in Alma-Ata Pond Farm (Linchevskaya 1966). Plants occurred rather frequently in guts but comprised a small portion of the food bolus. In 10-day-old fry (9–14 mm, 4–26 mg), the most frequent food items were *Brachionus mulleri* and juvenile copepods, followed by *B. quadridentata*, *Alonella*, and chironomid larvae. Algae included *Cosmarium*, *Scenedesmus*, *Pediastrum*, *Merismopedia*, *Gomphosphaeria lacustris*, and *Phaeotus lenticularis*. The proportion of plants in Grass Carp diet increased gradually with growth. Zooplankton still dominated the diet of 20-day-old fry (14–30 mm, 250–595 mg) but the number of phytoplankton (mainly, the above listed species) increased significantly. At approximately 1-month-old, Grass Carp shifted rather quickly to a plant diet first consisting of unicellular and colonial algae and then expanded to include filamentous algae. The latter served as a transition link to feeding on higher aquatic vegetation, which was the major food in yearlings aged 1.5 months (40–60 mm, 1.9–6 g).

Similar data were obtained by Stuge (1973) in ponds of Alma-Ata Hatchery from 1970 to 1971. The diet of 1–1.5-month-old fry (3.3–10.9 cm, 1–1.8 g) consisted of rotifers (*Brachionus*, *Keratella*), cladocerans (*Diaphanosoma*, *Moina*, *Alona*), copepods (*Mesocyclops*, *Acanthodiaptomus*), ostracods, chironomid larvae, higher aquatic plants, terrestrial plants (clover), and algae – green, gold, and blue-green (*Anabaena*, *Oscillatoria*, and *Microcystis*). The diet of younger Grass Carp fry (aged 1 month, 3.3–3.6 cm, 1–1.2 g) was dominated (by weight) by animal components, though green unicellular algae and blue-green algae (*Microcystis* – 75% frequency and 30% by weight ratio) were frequent. Older fry (aged 1.5 month, 6–10.9 cm, 6.6–18 g) consumed mostly plant food. Unicellular algae were replaced by filamentous algae; pondweed and young water plantain were included. An artificial diet of clover with crushed silkworm pupae was readily consumed. The value of dietary *Microcystis* decreased but still remained significant (50% frequency and 25% by weight ratio) and was properly digested.

At spring-flooded river sites in the Ili River, the diet of Grass Carp fry consisted primarily (by weight) of various algae (105 species, or varieties of six divisions, the main component – *Spirogyra*), pondweed and pupae of chironomids, as well as detritus. The latter, apparently, indicated the presence of an insufficient food supply for Grass Carp in this area.This was also confirmed by data on the condition factor in this area over time. During the early years of acclimatization, Fulton's condition factor for Grass Carp in southern West Balkhash Lake, Ili River delta, Sorkol Lake, and in Kapchagay Reservoir reached 2.8, with an average of 2.0–2.4, and was explained by the low population size during that period. The condition factor decreased throughout all areas in the subsequent years. In Kapchagay Reservoir, the condition factor fluctuated over the years as the feeding conditions changed but the mid-term average value for the 18-year observation period remained low and rather stable: 1.7–1.9 (Fulton's) and 1.46–1.59 (Clark's). However, the individual values of condition factor varied significantly (Fulton's:1.1–2.8, Clark's: 0.99–2.28) and some Grass Carp individuals were well-fed with plenty of abdominal fat.

No sex-related differences were identified in the condition factor of Grass Carp from the Ili River drainage; however, the value of the condition factor decreased gradually with age (Seleznev 1975). A similar pattern occurred in the Amur River, where the average Fulton's condition factor decreased from 2.1 (6-year-old) to 1.8 (13-year-old) (Nikolsky 1956).

Information on the condition factor of Grass Carp in Syr Darya was limited to brief communications that indicated values in the Chardara Reservoir were high; apparently, due to the long vegetation season and the abundance of plants there, and that values were lowest in Bugun Reservoir, with its poor food supply. However, Markova (1968) indicated an even lower Fulton's condition factor (1.5) for 5-year-old fish from the Aral Sea. In reservoirs of the Irtysh-Karaganda Canal, condition factor of 2–3-year-old Grass Carp averaged 2.1 (Fulton's) and 1.7 (Clark's) (Yakubowsky and Ereshchenko 1978). Available published data (Ereshchenko et al. 1977, Lysenko 1977, Melnikov and Yakubowsky 1984) on this subject are fragmentary but generally coincide with the above mentioned values.