RISK ASSESSMENT
ON BLACK CARP (PISCES: CYPRINIDAE)

ORGANISM:	Mylopharyngodon piceus
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DEDICATION

This work is dedicated to the memory of Joseph McCraren, National Aquaculture Association, Sheperdstown, West Virginia, and former member of the Risk Assessment and Management Committee.

RISK ASSESSMENT ON BLACK CARP (PISCES: CYPRINIDAE)

I. INTRODUCTION

The purpose of this assessment is to test the risk process developed by the Risk Assessment and Management (RAM) Committee. This committee was initiated by, and is under the auspices of, the Aquatic Nuisance Species Task Force (Task Force). The Task Force was created for the purpose of developing a strategy in which the appropriate government agencies could meet the goals of the Aquatic Nuisance Prevention and Control Act of 1990.

The RAM committee's risk process "Generic Nonindigenous Aquatic Organism Risk Analysis Review Process" was designed, in part, to: (1) evaluate recently established nonindigenous organisms; (2) evaluate nonindigenous organisms proposed for deliberate introduction; and (3) evaluate the risk associated with individual pathways (i.e., ballast water, aquaculture, aquarium trade, fish stocking, etc.) (Risk Assessment Management Committee 1996).

The black carp (Mylopharyngodon piceus) was chosen as the test organism for the Review Process because it demonstrated: (1) a real issue in which the potential for positive gain (biological control of yellow grub and zebra mussel) has to be balanced with the potential of becoming established and causing economic and/or environmental damage in a new environment; (2) a real issue in which political, economic, and environmental concern were already present (an assessment process must be able to withstand issues which are controversial); and (3) a situation in which there still exists time to correctly manage this issue to the benefit of the American people (the assessment would not have been done in vain).

This assessment is a specific organism assessment and does not attempt to evaluate the black carp as a pathway. Therefore, the potential for damage caused by the establishment of black carp in the river systems of North America is evaluated, but the impact caused by the establishment of organisms traveling with the black carp (i.e., in the water or as parasites/diseases) are not evaluated in this assessment. Since this assessment is focused on a single organism and not a pathway, its entry into the risk assessment process is at the "Organism Risk Assessment Section" page 10 of the "Generic Nonindigenous Aquatic Organisms Risk Analysis Review Process."

The coverage of the biology of the black carp may appear more extensive than what might have been needed for determining the risk of establishment and estimating its capability of having an adverse effect. However, a thorough coverage of the available information is necessary if the assessors are to determine what is, or is not, relevant to a risk assessment. Because much of the information on the black carp is so fragmented and difficult to locate, it was decided that presenting as complete a profile of the species as possible would be highly beneficial to aquaculturists, research scientists, risk assessors, and risk managers working in the future on the black carp.

It is beyond the purview of the RAM committee to determine or initiate regulatory or management action. The sole purpose of this assessment is to evaluate the risk process and to provide the insights needed to adjust or correct the risk assessment methodology. Additional test risk assessments are being planned. These future assessments will examine pathways as well as other organisms.

II. LITERATURE REVIEW AND BACKGROUND INFORMATION

The black carp (Mylopharyngodon piceus) is native to eastern Asia (Figures 1 and 2) and although it is one of several commercially important carp species in China, many aspects of its natural history, including many details of its reproduction in natural conditions, are unknown. Most information on black carp natural history are studies originally published in Russian and Chinese. There are two relatively comprehensive reviews on the biology of this species. The first is Evtushenko et al. (1994), an English translation of a 1993 Russian paper. The second is a Chinese work published in 1976 by the Institute of Hydrobiology, Academia Sinica (IHAS), on fishes from the Yangtze River. An unpublished mimeograph on the black carp is available that is a partial English translation of that Chinese book.

A. TAXONOMY, SYNONYMY, AND COMMON NAMES

TAXONOMY

Family: Cyprinidae
Subfamily: Cyprininae
Genus: Mylopharyngodon Peters 1873
Mylopharyngodon piceus (Richardson 1846)

The black carp (Figure 1) was originally described as Leuciscus piceus by Richardson (1846). Its description appeared in Report XV Meeting of the British Association for the Advancement of Science, 1845, Cambridge, London, 1846, p. 298. The paper was possibly presented or read before the association in 1845, but its official release or publication date was 1846 (the work was reprinted in 1972). The new species was referenced as being from the Canton (Guangzhou) area of China. Nichols (1943:89) suggested that the species was described "from an unidentifiable Chinese drawing."

After its original description in 1846, there was considerable confusion surrounding the exact identity of the black carp. As a result, black carp taken from several different localities in eastern Asia were erroneously described separately as new by no less than five researchers: Basilewski in 1855, Bleeker in 1864, Gunther in 1873, Garman in 1912, and Oshima in 1920.

It was not until after 1930 that the six named species were recognized as representing a single widely distributed form.

Currently, the black carp is considered the only known species in the genus Mylopharyngodon. That genus is one of about 210 different genera in the family Cyprinidae. According to most experts, the black carp belongs to the large subfamily Cyprininae, which also includes Ctenopharyngodon (grass carp), Carassius (crucian carp and goldfish), Cyprinus (e.g., common carp, koi), and many other genera (Howes 1993:12, Nelson 1994). All other large cyprinids introduced to the United States, including Hypophthalmichthys (bighead carp and silver carp), Scardinius (rudd), and Tinca (tench), are placed in the subfamily Leuciscinae and are therefore considered less closely related to Mylopharyngodon (Nelson 1994).

Within the subfamily Cyprininae, black carp are grouped in the Squaliobarbin lineage. According to Howes (1993:12), the squaliobarbine group is comprised of three monotypic genera, Mylopharyngodon, Ctenopharyngodon and Squaliobarbus. All three genera are entirely East Asiatic. They are characterized by several derived cranial osteological and myological features (e.g., enlarged subtemporal fossa, palatine articulating with lateral border of supraethmoid, enlarged intercalar, and divided levator posterior muscle) (Howes 1993:12,25). Howes (1981) regards this group as the sister group of all other cyprinines. In contrast to Howes (1981, 1993), Chen et al. (1984) and Chen (1987a, 1987b) placed this group in the subfamily Leuciscinae rather than the Cyprininae. Other Chinese researchers also include Mylopharyngodon in the Leuciscinae (e.g., Pearl River Fisheries Research Institute 1991).

SYNONYMY

The following synonymy listing for Mylopharyngodon piceus was compiled from Chu (1930), Berg (1949), and Eschmeyer (1990).

Leuciscus aethiops Basilewski, 1855, Nouv. Mem. Soc. Nat. Mosc. X, p. 233, P. 6, fig. 1 (Pekin).-Bleeker, 1871, Mem. Cypr. Chine, Amsterdam, p. 45, Tab. 14, Fig. 1 (Yangtzekiang).-Bleeker, 1872, Mem. Fau. Ichth. Chin., Amsterdam, p. 144 (Yangtzekian, Pekin).-Mollendorff, 1877, Joum. Roy. Asi. Soc., North China Branch, New ser. No. XI, p. 109 (Chihli=Hebei).

Leuciscus dubius Bleeker, 1864, Neder. Tijdschr. Dierk., Vol. 2, p. 19 (China).-Bleeker, 1871, Mem. Cypr. Chin., Amsterdam, p. 10 & 46.-Bleeker, 1872, Mem. Fau. Ichth. Chin., p. 144.

Myloleucus aethiops Gunther, 1873, Ann. Mag. Nat. Hist., Vol. 12, p. 239-250 (Shanghai).-Sauvage and Dabry de Thiersant, 1874, Ann. Sci. Nat., ser. 6, Zool. & Paleont., Vol. 1, Art. No. 5 (China).-Gunterh, 1889, Ann. Mag. Nat. Hist. 6 ser., Vol. 4, No. 21, p. 225 (Kiukiang).-Kryenberg & Pappenheim, 1908 & 1909, Sitz. Ber. Ges. Natf. Freunde, p. 102, Abh. Mus. Nat. Heimatk. Magdeburg, Bd. 2, p. 15 (Hankau).

Mylopharyngodon aethio s Peters, 1880, Monasber. Akad. Wiss. Berlin, p. 926 (Ningpo).-Rendahl, 1928, Arkiv For Zoologi, Bd. 20A., No. 1, p. 54-55 (Anhui, Tang-tu-hsien; Kiangsu, Kiang-ningj-hsein).

Myloleuciscus atripinnis Garman, 1912, Mem. Mus. Comp. Zool., Harv. Coll., Vol. LX, No. 4, p. 116 (Hupeh: Shansi).—Fowler & Bean, 1920, Proc. U.S. Nat. Mus., Vol. 58, p. 313 (Soochow).

Leucisculus fuscus Oshima, 1920, 129, Proc. Acad. Nat. Sci. Phila. v. 72, p. 129 (Taiwan).

Myloleuciscus aethiops Everman and Shaw, 1927, Proc. Calf. Acad. Sci., 4th ser., Vol. XVI, p. 104 (Shanghai and nanking).–Nichols, 1928, Bull. Amer. Mus. Nat. Hist. Vol. LVIII, Art. 1, p. 16 (Hungting Lake, Hunan).

Mylopharyngodon aethiops Chu, 1930, in Contributions to the Ichthyology of China (Part 1), reprinted from the China Journal XIII, No. 3, September 1930, pp. 141-146.

COMMON NAMES

English	black carp, snail carp, Chinese black carp, black amur, Chinese roach, black Chinese roach
French	carpe noire (CEC 1993)
Chinese	Hih hwan, hih wan, hak wan, Qing Hwan, Hei Hwan, Wu Hwan, Luo Si Qing, Gang Qing, Ch'ing-yü, He chin yü, Ho-ên-yü, Kouan-yü, Tsao-yü, He ching, Ching, Ching yü (Richardson 1846, Kimura 1934)
Danish	en art karpefisk (CEC 1993)
Dutch	zwarte karper (CEC 1993)
German	Schwarzer karp fen (CEC 1993)
Greek	May οχυπ υos (CEC 1993)
Italian	carpa nera (CEC 1993)
Japanese	Aouo [green carp], ao-ou (Okado 1960); kokuren (Kuronuma 1961)
Portuguese	carpa negra (CEC 1993)
Romanian	Crap-chinezesc-negru (Blanc et al. 1971)
Russian	Kitaiskaya plotva [Chinese roach], chernyi amur [black amur] (Berg 1949), Tschernyi Amur (Blanc et al. 1971)
Slavic (Yugoslavia)	Crnog amura(?), Crni amur (?) (Knezevic and Maric 1986)
Spanish	carpa negra de China, carpa negra (Arizmendi 1992, CEC 1993)
Vietnamese	Ca Châm Den (Kuronuma 1961)

B. DESCRIPTION AND DISTINGUISHING CHARACTERISTICS

COLORATION: Body black, all fins black (Berg 1949). From its original description its general color was described as: "...pitchy or blackish-brown, deepest on the back, and gradually changing on the belly to bluish-gray... .Head blackish gray above, beneath white. ...greenish tint on the breast and tinge of crimson along the edge of the belly. All the fins are blackish-gray, deepening to black towards the edges, and their rays are whitish at the base." Okada (1960) states "...general colour is dark brown, much darker than below." Ling (1977) states "black carp...so named for its dark coloration, especially the fins...". According to Chu (1930), "Ventral surface of head and abdomen whitish; the rest of the body and fins black. When the fish is alive or fresh, the black colour is impregnated with a violaceous tinge." Others report that the fish is blue gray, dark above, gray below, and with fins black (IHAS 1976). A color photograph of a fresh specimen is presented in Masuda et al. (1984).

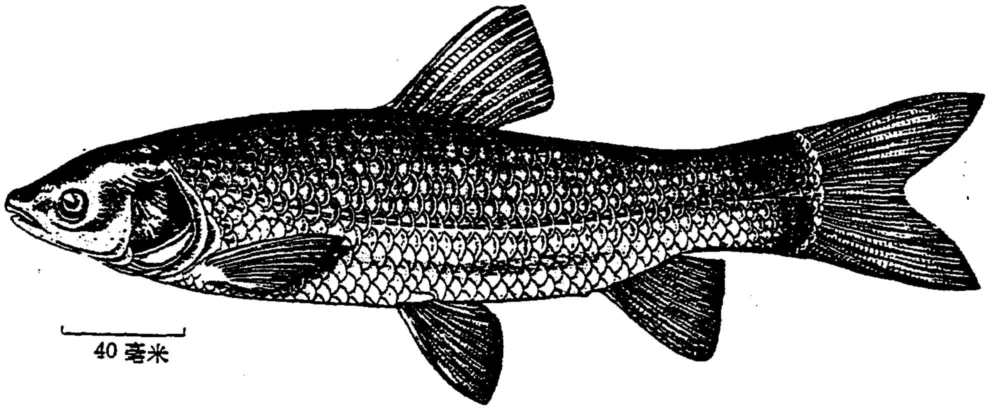

Figure la. Black Carp (Mylopharyngodon piceus) (source: IHAS 1976)

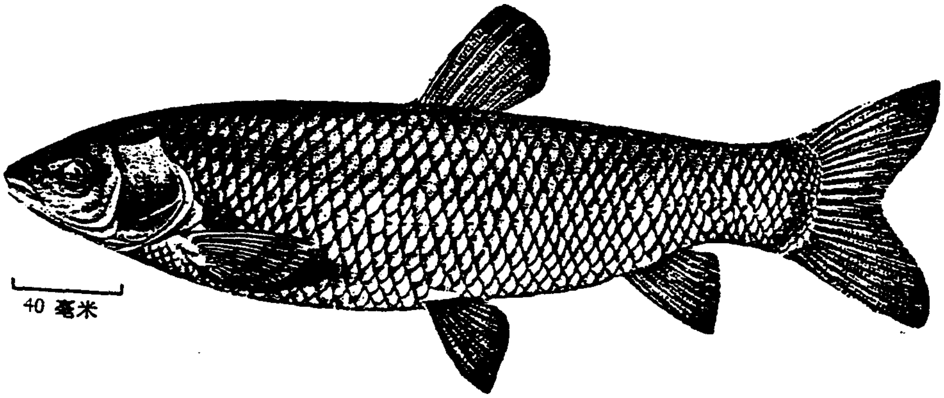

Figure lb. Grass Carp (Ctenopharyngodon idellus) (source: IHAS 1976)

SIZE: Black carp grow to more than 1 m [3.3 ft.] long. Bardach et al. (1972) states that it is the largest of the Chinese carps. Maximum size for the species given in the literature are as follows: over four feet long (Chu 1930); a length of four or five feet (Nichols 1943:90); total length up to 1 m [3.3 ft.] and over (Berg 1949); from 500 mm to 1 m [1.6-3.3 ft.] (Nakamura 1963); maximum of 120 cm [3.9 ft.] and 36 kg [79 lb.] (Atkinson 1977); up to 180 cm [5.9 ft.] (Bardach et al. 1972); to about 88 cm [2.9 ft.] (Welcomme 1988). A size range of 10.6 to 131.1 cm [4 in. to 4.3 ft.] was reported for a sample consisting of 1,090 specimens taken from Yangtze River in China (IHAS 1976). Evtushenko et al. (1994) reported that the average weight is about 15 kg [33 lb.] (at an age of 13-14 years), although the stated maximum weight was as much as 60 kg [132 lb.]. According to information provided by the IHAS (1976), large black carp harvested in the Yangtze River may weigh 15-40 kg [33-88 lb.], although individuals of more than 70 kg [154 lb.] have also been reported.

BODY SHAPE: Body elongated and laterally compressed (Masuda et al. 1984). The body is moderately compressed posteriorly (Okada 1960). Body elongate, moderately compressed; abdomen rounded (Chu 1930, Kimura 1934). U.S. fish farmers found that black carp from Israel were shorter and more stout than those imported from Taiwan (M. Freeze, pers. comm. 1994). Such shape differences may be genetic or simply diet related.

HEAD: Anterior part of head somewhat pointed (Masuda et al. 1984). The head is slightly depressed (Okada 1960). The head is flattened, with interorbital space wide and convex (Chu 1930). The top of head is also described as flat and broad (IHAS 1976). In a comparative study of Chinese cyprinids, Meng (1985) described and illustrated the neurocranium of the black carp. Kimura and Tao (1937) reported that male Mylopharyngodon develop breeding tubercles (pearl organs) in the interorbital region; although these may not always be observed (Bardach et al. 1972). Berg (1949) reported the head length, as a proportion of body length (standard length?), ranged from 4 to 4.5. Others indicated a slightly wider range in the head to body length proportion (e.g., 3.4-4.1 by Nakamura 1969; 1.7-5.0 by IHAS 1976).

EYES: The eyes are small with free orbital rims (Okada 1960). The eyes are also described as medium size and at the center of each side of head, with eye diameter, as a proportion of head length, reported as ranging from 3.4 to 4.5 by Berg (1949), 4.4 to 6.1 by Nakamura (1969), and 4.5-16.5 by IHAS (1976). The visual pigments of the black carp were discussed by Shi and Chen (1980).

TABLE 1. A literature review of selected morphological characteristics of the black carp (Mylopharyngodon piceus). (Most counts and measurements are given as presented by original authors. Note inconsistency among authors as to how counts and measurements were reported; modern convention is not followed in many cases. For instance, upper-case roman numbers are used in ray counts by some authors although these most certainly represent unbranched soft rays as opposed to spines.)

	Richard-son (1846)[a]	Chu (1930)	Kimura (1934)	Berg (1949)	Nikolsky (1954)	Okada (1960)	Nakamura (1963, 1969)	IHAS (1976)	Masuda et al. (1984)	Shakirova (1986)	Knezevic & Maric (1986)	Nakabo (1993)
Dorsal fin rays	9	3,7	3,7	III 7-8	7 to 8 branching	3 rays and 7 branched rays	8-9 or (111,7-8)	3/7-8	8-9	1117	II 7	iii+7-8
Anal fin rays	10	3,8	3,8	III 8	7 to 8 branching		8-9 or (111,7-8)	3/8	8-9	III8	III 8	iii+7-8
Ventral fin rays			1,8								II 8	
Pectoral fin rays			1,16								116	
Lateral line scales	43	41 or 42	43	39-43	39-42	40-43	41-44	41-44	39-45	40-43	42	39-45
Transverse scales	10 or 11 (in height?)	6/4.5	6/4	6/4			6-7/4-5					TRa 6-7 TRb 4-5
Gill rakers			4+14	19-21			14-18				16/22; 17/23	15-21
Pharyngeal teeth[b] (left to right)		one row, right 5; left 4	one row, 5 (right), 14 (left)	1.4-4.1 or 4-5; also 4-4.1	one or two rows	5 on right; 4 on left	4-4, 4-5 (1,4-4,1)	4/5			4.2-2.5	1, 5-5, 1
Vertebrae				38-41			38 (n=1)	36-37			38 (n=1)	
Body depth into SL		about 4	about 4	4		3.5-4	3.7 to 4.1				3.5; 4.2	
Comments	n=1	n=1						n=36? 13-96 cm		n=4	n=2, except as noted	

Notes: a-Original description, apparently based on a drawing of a single specimen. b-Pharyngeal teeth numbers and shapes are highly variable depending on age and size of fish (see Liu et al. 1990). Information on black carp morphology is also provided by Chu et al. (1)89:37-38), but that work has yet to be translated from the Chinese.

MOUTH AND ORAL CAVITY: Mouth terminal (Berg 1949, INHS 1976). The mouth is small and oblique (Okada 1960). No mouth barbels (Chu 1930, Masuda et al. 1984). Chu (1930) described the mouth as follows: "...cleft extending to a vertical from the anterior margin of the nostril; lower jaw slightly shorter; lower lip developed at angles and at lower sides." Upper jaw is reported as slightly longer than lower jaw, and corner of mouth is at vertical from anterior eye margin (IHAS 1976). The upper slightly projected and protractile (Kimura 1934). According to Shelton et al. (1995), black carp have a fairly small mouth, fish between 100 and 500 mm had gapes from 7 to 25 mm, respectively. Kimura (1934) gave additional head measurements and descriptions. All cyprinids have toothless jaws and toothless palatine (Sibbing 1991).

GILL RAKERS: The gill rakers are reported as short, with those in the lower portion of the arch being rudimentary and tubercle-like (Chu 1930, Kimura 1934). Kimura (1934) reported that the longest gill raker is 1/5 in proportion to the length of the gill filaments (gill filaments were 1 1/2 as a proportion of the eye diameter). Gill raker counts reported are given in Table 1.

FINS: Dorsal origin very slightly in advance of the vertical from the ventral origin (Berg 1949); dorsal origin closer to base of caudal than tip of snout (Chu 1930). The short dorsal fin is inserted above the pelvic fins; the pectoral fins are long and reach the pelvic fins; and the caudal fin is deeply emarginate (Okada 1960). Caudal fin is forked and the lobes are equal (Chu 1930, IHAS 1976). The dorsal and anal fins do not have spines (IHAS 1976). For fin ray counts see Table 1.

SCALES: The scales are cycloid (IHAS 1976), and are moderate size (Okada 1960) or very large (Evtushenko et al. 1994). Chu (1935:29) gave a detailed description of their scales. The number of lateral line scales range from 39 to 45 (Table 1).

LATERAL LINE: Lateral line is complete (Masuda et al. 1984), slightly decurved, extending along the middle of tail (Chu 1930).

PHARYNGEAL APPARATUS: Liu et al. (1990) discussed in detail and illustrated the post-larval development of the masticating apparatus of black carp. The pharyngeal apparatus, including the pharyngeal teeth and chewing pad, changes with black carp growth. These structural changes are associated with changes in diet and feeding patterns. illustrations of the pharyngeal teeth of black carp and grass carp are also given by Chu (1930, 1935), and Makeyeva and Verigin (1993). Makeyeva and Verigin (1993) provide information on the structure and formula of the pharyngeal teeth of reciprocal hybrids of the two species.

Pharyngeal Teeth: Berg (1964:16) reported that the teeth are molar-like and very strong, and not serrated. Evtushenko et al. (1994) described the pharyngeal teeth of black carp as being massive, smooth, not compressed, and as having wide masticatory surfaces. Unlike grass carp, the teeth of black carp do not have grooves or hooks of any kind (Maskeyeva and Verigin 1993). Chu (1935:117-118) discussed in detail the pharyngeals and teeth and includes photographs. The number, size, and shape of teeth change with age. The pharyngeal teeth are formed during postlarval development and grow on the pharyngeal bones on the lower part of the posterior pharyngeal cavity (Liu et al. 1990). Developmental changes in black carp pharyngeal teeth have also been studied by Yue and Nakajima (1995) and Nakajima and Yue (1995).

Liu et al. (1990) divided the development of black carp pharyngeal teeth into three separate stages:

(1) original teeth: fish from 6.7 -7.8 mm [0.26-0.31 in.] total length (TL) (5-6 days after hatching) with teeth characterized by a single generation and a dental formula of 1,2/2,1; the masticating apparatus is not capable of masticating food and the fish feeds mainly on zooplankton.

(2) transitional teeth: fish from 8.9-25.0 mm [0.35-1.0 in] TL (7-18 days after hatching), with teeth consisting of three generations and dental formulae of 3/3, 4/4, and 4/5, respectively; during this stage, the pharyngeal apparatus has a weak ability to masticate food and is not capable of grinding, the diet of the fish changes from zooplankton to benthos like chironomid larvae.

(3) fixed teeth: fish from 31-330 mm [1.2-13 in] TL (26-F days after hatching), characterized by several generations of teeth, each with a dental formula of 4/5. At the fixed teeth stage, the pharyngeal apparatus is capable of masticating and grinding benthic animals with shells, such as snails. The fixed teeth are composed of enamel, dentine, pulp, pulp-cavity, and cement.

Chewing Pad: The chewing pad (sometimes called the horny pad or callous pad) is located in the roof of the pharyngeal cavity opposite to the pharyngeal teeth. Similar to the pharyngeal teeth, the chewing pad is formed during postlarval development. It is composed of an outer layer of cuticle, a middle granular layer, and a germinal basal layer. Also somewhat similar to the pharyngeal teeth, the thickness and strength of the chewing pad increase with the growth of the fish (Liu et al. 1990).

INTESTINE: According to Chang (1966), the intestine of the black carp is relatively short, usually about 1.25 times the length of the body. Lee (1957) illustrated the coiled intestine and reported it as 1.44 times that of the body length. The membrane or lining of the body cavity is black (Lee 1957).

CHROMOSOME NUMBER: Based on research by Lou et al. (1983) and Zhang and Zeng (1993), the diploid chromosome number of black carp is 48 (i.e., 2N=48). According to Lou et al. (1983), the black carp karyotype consists of 8 metacentric chromosome pairs, 14 submetacentric chromosome pairs, and 2 subtelocentric chromosome pairs. In a slight variation, Zhang and Zeng (1993) reported the karyotype formula as 24 metacentric, 20 submetacentric, and 4 subtelocentric. The chromosome set morphology was characterized by very short homologous chromosome pairs ranging from 3.70-2.00 µm long; the total length of the chromosome set was 59.95 gm and there were 96 chromosome arms (Lou et al. 1983).

SIMILAR SPECIES: Black carp are superficially very similar to grass carp (Ctenopharyngodon idella) in terms of body size and shape, the position and size of fins, and the position and size of eyes (Figure 1). Juveniles, in particular, are difficult to distinguish from grass carp young. Both have a chromosome number of 2N=48 (Lou et al. 1983, Rothbard and Shelton 1993) although there are differences in the karyotype formula between the two species (Zhang and Zeng 1993).

Selected morphological characteristics of grass carp are as follows: barbels absent; lateral-line scales 34-45; 6-7 scale rows above the lateral line and 4-5 scale rows below the lateral line; dorsal fin rays i-iii, 7-11 (usually 8); anal fin rays iii, 7-11 (usually 8-9); pectoral fin rays 18-20; pelvic fin rays 8; gill rakers 12-16; pharyngeal teeth somewhat variable in number (2,5-4,1; 2,5-4,2; 2,4-4,2), the teeth with elongate, corrugated grinding surface; breast scaled; color olivaceous to silvery white (combined counts from Howells 1992 and Etnier and Starnes 1993). Maskeyeva and Verigin (1993) report that the pharyngeal teeth of grass carp are laterally compressed, serrated, with a longitudinal groove along the grinding surface, and that the teeth in the inner row are small and have small hooks.

Black carp adults (and probably larger juveniles) can be distinguished from grass carp in terms of body color (black, blue gray, or dark brown versus olivaceous or silvery white) and the morphology of the pharyngeal teeth. Chu (1930) indicated that the grass carp can be readily distinguished from the black carp externally by the color and the more cylindrical form of the body, and internally by the pharyngeal dentition. In his identification key, Nakoba (1993) distinguishes the two species based on scale pigmentation and snout tip differences. The relative length of the adult black carp intestine is shorter than that of the grass carp (about 1.25 versus 2.5) (Chang 1966). Color or black-and-white photographs of both species are given in Nakamura (1963, 1969), FAO (1983:14), Masuda et al. (1984), and Shen et al. (1995). Illustrations of the species are presented by Chu (1930), Nakamura (1969), IHAS (1976), Pearl River Fisheries Institute (1991), among others.

Maskeyeva and Verigin (1993) reported that there are major differences between these two species in terms of the structure of the digestive system corresponding to their typical diets (herbivore vs. molluscivore). They described the gastric mill, a muscular portion of the gut, of the black carp as having a "concave surface with a small rise posteriorly which juts into the convex part in the form of a corner"; in contrast, the gastric mill of the grass carp has a tubercular surface.

Lee (1957), Soin and Sukhanova (1972), and IHAS (1976) compared and contrasted the early developmental stages of black, grass, silver, and bighead carps. Bardach et al. (1972:84) provided a table listing few distinguishing morphological and behavioral characteristics of seven species of Chinese carp fry, including the black carp. Supposedly such traits are used by fry experts in Asia in the long tradition of visually sorting or estimating the numbers of different species of carp fry soon after the young fishes are captured from the river. In their table, Bardach et al. (1972) characterized black carp fry as having the following characteristics: swimming in the middle layer of water with occasional pauses; body long, eyes large; head depressed, triangular-shaped. Grass carp fry are described as swimming similar to that of black carp fry, but also having a dark color, medium eyes, small air bladder, roundish short body, and pointed tail. The black carp also reportedly has thicker mucous coating compared with that of grass or silver carp (M. Freeze, pers. comm. 1994; J. Malone, pers. comm. 1994).

IDENTIFICATION KEYS: Keys for the identification of the black carp, as well as illustrations of the species, are available in a number of publications, but these works are regional in scope and only selected works of Berg have been translated into English. The species appears in Berg's (1949) key to the cyprinid genera found in the boundaries of the former U.S.S.R. and adjacent countries and in the accompanying regional key to the cyprinid genera of the Amur River basin. It is included in regional identification keys published in Russian (Taranetz 1937, Borisov and Ovsyannikov 1951), in Japanese (Nakamura 1969, Nakabo 1993), and in Chinese (Whu et al. 1964, Chu et al. 1989:37, Pearl River Fisheries Research Institute 1991:80, Ding 1994, Shen et al. 1995), among others.

C. NATIVE DISTRIBUTION

Available literature indicates that the black carp's native range includes most major Pacific drainages of eastern Asia from about 22° N to about 51 N latitude (Figure 2). Its natural range includes the Amur (=Heilong Jiang), Yellow (=Huang He), Huai, Yangtze (=Chang Jiang), and Pearl (=Zhu Jiang) river basins, and possibly several smaller basins. Countries included in its range include China, parts of far eastern Russia, and possibly northern Vietnam. Berg (1949), IHAS (1976), Li and Fang (1990), and Evtushenko et al. (1994) provided the most detailed range account summaries for the species. However, there are some problems with each of these accounts (e.g., incomplete information, use of dated or unrecognizable site names, inclusion of non-native locations). Li and Fang (1990) is the only available work that included a map showing the natural distribution of the black carp. Unfortunately, their map is of poor quality.

Berg (1949) reported its distribution as Sungari at Harbin, Ussuri, Lake Khanka, Amur below Khabarovsk; China from Hebei (formerly Chihli) Province to Canton (=Kuang-Chou) in Kwangtung Province. Canton is located near the delta plain of the Pearl (=Zhu Jiang) River.

IHAS (1976) reported the black carp as widely distributed in the Yangtze River, from the upper main stream, such as Jinsa Jiang River, down to its estuary; rivers in the Sichuan Basin, such as the Ming Jiang and Tuo Jiang rivers; and lakes near the middle reaches of the Yangtze River, such as Dongtin Lake and Boyang Lake.

Based on the map given in Li and Fang (1990), the black carp's natural range includes (from north to south): the Heilong Jiang (=Amur River) (below about 51° N latitude) and its major tributaries the Songhua Jiang (=Sungari), Nen Jiang, and Wusuli Jiang (=Ussuri) rivers; the lower Yellow River and surrounding areas from near its mouth to its tributary the Wei He of Shaananxi Province; the Huai He River and surrounding areas; the Yangtze River upstream to about the Min Jiang River, as well as the lower Min Jiang and lower haling rivers, and the Gan Jiang and Xiang Jiang rivers; inland areas around Hangzhou Wan gulf and the lower Qiantang Jiang River; and the Zhu Jiang (=Pearl River) (which is the confluence of the Xi Jiang [=West River], Bei Jiang, and Dong Jiang rivers), and its western tributary the Xi Jiang (including surrounding areas) upstream to about 106° E longitude..

Evtushenko et al.(1994) reported that the black carp occurs in China and the far eastern part of Russia with a range that included the Amur river (=Heilong Jiang) and its two major southern tributaries the Sungari and Ussuri rivers, and Lake Khanka (=Hsing-k'ai Hu; a western tributary of the Ussuri on the Russian-Chinese border). In China, the black carp occurs from the Khubei (=Hubei) province to Canton (=Kuang-chou, Guangzhou), and includes the Khuankhe (the Russian to English translation for the Huang He or Yellow) and Yangtze rivers.

Several published records of black carp from outside of China likely represent introductions. Both Berg (1949) and Evtushenko et al. (1994) reported the species as occurring in Taiwan; however, Bardach et al. (1972) stated that the island has no large rivers to maintain reproducing populations. Fry are collected from the Song Hong (=Honghe or Red River) of northern Vietnam (Bardach et al. 1972:82 as Mylopharyngodon aethiops). Although the literature is somewhat vague on the issue, black carp may be reproducing in the Tone (=Tonegava) River in Japan (Kuronuma 1955, Masuda et al. 1984, Evtushenko et al. 1994, Bailey and Haller, no date, but see Kuronuma 1958 and Okada 1960). The origin of black carp populations in the Red River population in northern Vietnam are not clearly stated in the literature. Its presence there may be the result of past introductions; however, Li et al. (1985:391) showed the Honghe River as included in the natural distribution of both silver carp and grass carp. Although, the Chinese carps are not native to Japan, several species became established after their introduction during the 1800s and 1900s (Kuronuma 1955, Stanley 1976). Black carp were first introduced to that country some time between 1915 and 1945, probably after 1940 (Kuronuma 1955).

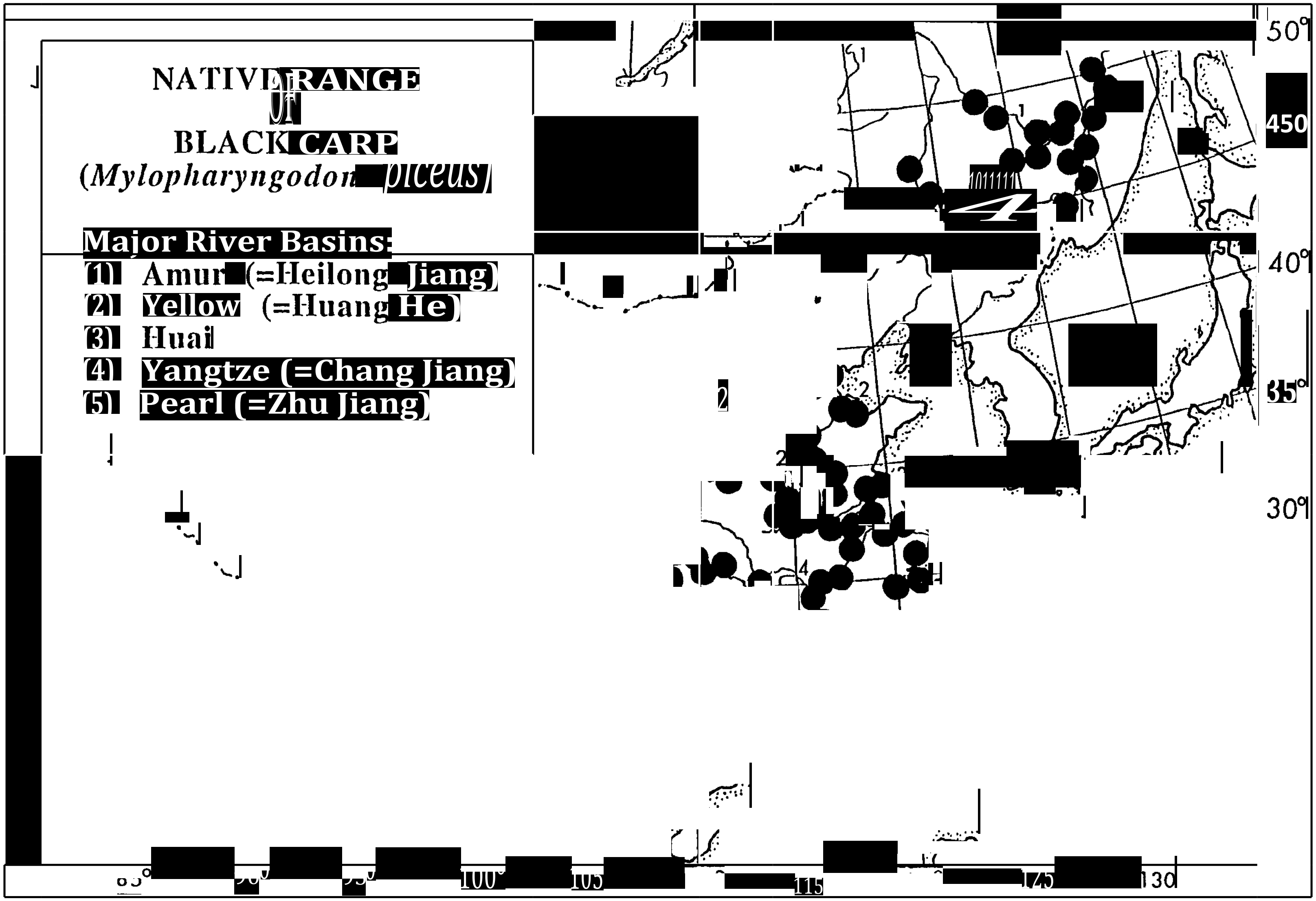

Figure 2. Native range of black carp (Eastern Asia) (modified from Li and Fang 1990)

In his table on the generic distribution of cyprinids of South East Asia, Rainboth (1993:197) listed Mylopharyngodon as occurring in the lower and upper sections of the Chiang Jiang River and the Hong River basin. In obvious error, he did not include either Mylopharyngodon nor Ctenopharyngodon as found in the Xi Chiang (Pearl) basin; neither did he include the Zhejiang-Fujian basin or Taiwan.

D. BIOLOGY AND NATURAL HISTORY

HABITAT: According to Li and Fang (1990), the black carp, grass carp, bighead carp, and silver carp together are typical lowland species, mostly found below 200 meters [656 ft.] above sea level, rarely above elevations of 500 meters [1,640 ft.]. Li and Fang considered all four species to be fishes of the northern warm temperate zone. The rivers and aquaculture areas where black carp are found in China range from areas with subtropical, hot climates (e.g., lower courses of the Chang Jiang, Xi Jiang, and Huang He rivers) to cold climate (e.g., Heilong Jiang middle course) (FAO 1983:11).

The black carp is a freshwater fish that inhabits lakes and lower reaches of rivers (Welcomme 1988). Chinese researchers (IHAS 1976) have investigated the habits of black carp, unfortunately the English translation is poor: "During the feeding season (April to October), often stay in river bends, lakes along the river and adjacent waters for nursery. Wintering in deep water above the river bed; spawning in rivers."

In the Yangtze River, spawning grounds are located along the main channel from Chongqing to Huangsi; spawning takes place in a smaller scale in several of its major tributaries including the Hanjiang and Xiangjiang rivers (IHAS 1976, Yu 1990). In that basin, black carp and other Chinese carps move between lake and river environments, although the construction of dams has blocked the traditional migratory paths of these fishes (Liu and Yu 1992). Additional information on habitat is provided in the section on spawning and reproduction.

ABUNDANCE: In likely reference to commercial catches, Berg (1949) reported that up to 300,000 centners (almost 15,000 metric tons [33,075,000 lb.]) of black carp a year were taken in China. Information on fish harvest from two locations in the middle and lower reaches of the Yangtze River in 1963 indicated that black carp accounted for 3% and 9%, respectively, of the total fish catch (apparently free-living populations). Flood prevention in China has possibly impacted black carp by preventing small juveniles from migrating from rivers into adjacent floodplain lakes. As a result, production of black carp in certain floodplain lakes where there is no intentional stocking of fingerlings (e.g., Honghu Lake, Hubei Province) has reportedly declined even though such lakes have mollusks that would serve as prey (IHAS 1976).

There has been a general decline in the catch of commercial fishes in the Pearl River since the 1960s (Liao and Xiao 1989). As one way to increase the native fish stocks and increase yields, the Chinese stocked young fish. For instance, in the early 1980s an area in the Pearl Delta was stocked with 47,100,000 fingerlings of several species. Of the total number of fish stocked, 9.4% (4,427,400 individuals) were black carp young.

Berg (1949) indicated that black carp were only taken in small quantities in what is now the former Soviet Union (i.e., the Amur River portion of its range). Similarly, Evtushenko et al. (1994) reported the species as rare in the Amur River. The black carp was included in the U.S.S.R. Red Book of rare animal species because of its apparent decline in the Russian reaches of the Amur River and in need of protection (Sokalov 1983, Krikhtin 1989).

According to recent FAO reports, aquaculture production of black carp in China during the period 1984-1992 totaled 530,103 metric tons (8.3 percent of grass carp production), with a low during that period of 36,090 metric tons in 1991 and a high of 117,100 metric tons in 1988 (FAO 1992, 1994). Based on the FAO information, average annual production for that 9-year period was 58,900 metric tons.

BEHAVIOR: Chinese researchers reported that black carp generally occur in the middle and lower water column, rarely coming to the surface (IHAS 1976). Chang (1966) reported that parent fish that have completed spawning return to the tributaries or lakes to feed. Those adults that are not sexually mature reportedly remain in the larger tributaries or lakes where there is an abundant supply of snails. During the winter, black carp stay near the bottom in the deeper tributaries of the main river (Chang 1966).

Researchers and fish farmers in the United States and China familiar with this species have observed that the fish prefers to stay near the bottom and can be kept in tanks without covers (W. Shelton, pers. comm. 1994, 1995; M. Freeze, pers. comm. 1994; J. Williams, pers. comm. 1994; Shelton et al. 1995). During efforts to net black carp in farm ponds, the fish attempt to escape capture by diving beneath seining nets; in contrast, U.S. fish farmers noted that grass carp typically try to escape by leaping over nets (B. Hopper and M. Freeze, pers. comm. 1994). In terms of taking hooks, it is known that grass carp will occasionally take baited hooks, but there is no mention in the literature of black carp being captured with hook and line.

Because black carp produce semipelagic eggs and spawn in open rivers, it can be concluded that they do not tend their eggs and that there is no parental care. Fish farmers in the United States familiar with black carp have observed that individuals placed together in large holding tanks tend to group or school; they reported that such behavior is similar to that of bighead carp but contrasts sharply with that of grass carp which typically disperse or spread apart from one another.

In reference to their behavior in Chinese fish ponds, Lin (1955) reported that both black carp and grass carp are active species that roam everywhere in the pond. He stated that the two species, if present in large numbers in the same pond, interfere with each others movements.

Bardach et al. (1972:84), in a list distinguishing morphological and behavioral characteristics of seven species of Chinese carp fry, indicated that both black carp and grass carp fry characteristically swim in the middle layer of water with occasional pauses.

DIET: Evtushenko et al. (1994), in their review of black carp biology, summarized the natural and artificial diets of black carp at different ages and sizes. During the larval stage of development, black carp feed mainly on microcrustaceans and rotifers. Early stage larvae take mainly copepod nauplii and cladocerans, especially Moina and Bosmina. Middle stage larvae (7-12 days old) prey on copepods, cladocerans (Cladocera), and larger rotifers such as Asplanchna and Branchionus. Chironomid larvae are also taken. Late stage black carp larvae feed heavily on ostracods and aquatic insects, mainly chironomid larvae, odonate nymphs, and ephemeroptera larvae. Black carp larvae also occasionally take phytoplankton.

Bardach et al. (1972:98) summarized the natural foods of black carp fry as follows: at size range of 7-9 mm [0.3-0.35 in.], fry feed on protozoa, rotifers, and nauplii; at 10-12 mm [0.4-0.5 in.] the diet includes protozoa, rotifers, nauplii, plus small daphnids and Cyclops; at 13-17 mm [0.5-0.7 in.] the diet consists of large daphnids and minute benthic animals; at 18-23 mm [0.7-0.9 in.] they feed on large daphnids, minute benthic animals, plus organic detritus; and at 24-30 mm [0.9-1.2 in.] the fry take minute benthic animals, insect larvae, and organic detritus.

In apparent reference to studies on pond fishes, Evtushenko et al. (1994) indicated that at the later stages of development (larval stage?) food items include cladocerans, copepods, other crustaceans, larval chironomids, and other insect larvae, aquatic hemipterans, staboblasts of bryozoans, crayfish shells, rotifers, mollusks, and food pellets. The major food items of young of the year in ponds are chironomid larvae. The diets of two-year old black carp included mollusks, oligochaetes, chironomids, aquatic macrophytes, larval insects, and zooplankton.

Based on the review by Evtushenko et al. (1994), adult black carp prey most heavily on mollusks. In the Amur River, adults take snails **Viviparus** and Melania amurensis. Bivalve mollusks recorded in adult diets include: Cardium (fingernail clam) and Dreissena (from Aral Sea region?), and Cristcaria plicata (from Amur River?). In pond culture, black carp have been found to take Dreissena polymorpha (zebra mussel); for instance, four-year-old black carp were reported as feeding on an average of 1.4-1.8 kg [3.1-4.0 lb.] of Dreissena per day (Evtushenko et al. 1994, and references therein). Cristaria plicata (Leach 1815) is a unionid species that superficially is very similar to many of our U.S. native species (e.g., heel splitters) and is characterized by having a very large, thick-walled shell, shell length to 230 mm [9.1 in.], height (with wing) 176 mm [6.9 in.]; it belongs to the subfamily Anodontinae (Zhadin 1952).

As discussed in an earlier section, Liu et al. (1990) reported that black carp feed on zooplankton when small. The diet of older juveniles changes to benthic organisms such as chironomid larvae. Larger fish feed on benthic organisms with shells, mainly snails. They report that the changes in diet are associated with changes in the masticating apparatus of the pharyngeal teeth. The powerful masticatory teeth permit the black carp to crush the thick shells of large mollusks. Nikolsky (1954) reported that the black carp feeds on gastropod mollusks, chiefly on Viviparus, crushing their shell with powerful pharyngeal teeth. Atkinson (1977) briefly reported on experimental studies in a fish farm near Shanghai where freshwater clams were being reared for freshwater pearl production and to supply food for eels and black carps.

Chang (1966) reported that black carp prey mainly on snails although they may also take other small mollusks; smaller black carp also feed on other benthic organisms such as dragonfly nymphs and other insect larvae, gonospores of bryozoa, and mollusk larvae.

According to the IHAS (1976), the major food of black carp larvae and fingerlings is zooplankton. Fish of about 15 cm [6 in.] length begin to feed on small spiral shells and clams. Associated with development of the lower pharyngeal teeth and the enhanced crushing ability, juvenile black carp feed primarily on mollusks such as clams, Corbicula, and spiral shells, although they also take shrimp, crabs, and insect larvae. The gut contents of black carp taken from Hoghu Lake in 1959 were found to consist almost entirely of mollusks.

Black carp and common carp (Cyprinus carpio) have been intentionally stocked into reservoirs in Israel for the purpose of controlling snails. Leventer (1979, 1981) reported that both species search for food on the reservoir bottom. Both species switch to feeding on insect larvae and shrimps once snail populations decrease to some low point.

Most reports on black carp diet are general and qualitative. Reports on black carp diet include benthic invertebrates (Liu and Yu 1992:364). Because the species commonly takes lymnaeid mollusks (intermediate hosts of Diplostomum), stocking black carp is considered one method of controlling the epizootiology of diplostomiasis on farms breeding carp and other fish (Denisov 1982). Okada (1960) stated that black carp feeds mostly on snails that live in small streams, pools and lakes, and sometimes takes crustaceans. According to Ling (1977), the black carp "is a bottom feeder, subsisting primarily on snails and clams, and sometimes on worms." Atkinson (1977) indicated that it feeds on shell animals (snails, mollusks, crustaceans, etc.).

According to Chu (1930), the black carp is a carnivorous fish, eating aquatic insects, snails, and shrimp. He reported that no plant material had been found in its stomach, but Chu did not indicate the number of specimens examined. Fish farmers in the United States reported that black carp can be raised on commercial feeds without mollusks as a supplement.

The feeding intensity of black carp is influenced by water temperature. Apparently in reference to young of the year, Evtushenko et al. (1994) reported that feeding drops sharply when water cools to 16°C [61°F] and that feedings stops almost completely at 3°C [37°F].

Cyprinids do not have jaw teeth and therefore must rely on their pharyngeal teeth and chewing pad to crush hard items such as snails and clams. W. Shelton (pers. comm. 1994, 1995), discussing his work with captive-bred black carp in Israel and Egypt, observed that the species was clearly gape limited in terms of the size of mollusks that could be eaten. He indicated that black carp crush food items (with their pharyngeal teeth) before swallowing. Because of the black carp's powerful pharyngeal apparatus, the fish can usually handle any food item that it can get into its mouth. With more difficult to handle snails, such as those with tight coils, the black carp has to work on the shell. Food items that can not be handled are spit out. In some instances, the fish is able to crack the edge of the shell, extract soft parts, and then spit out shell fragments. According to Shelton et al. (1995), the black carp has a fairly small mouth, fish between 100 and 500 mm had gapes from 7 to 25 mm. As such, black carp mouth size is an important limiting factor in terms of the size of mollusk that can be preyed on.

AGE AND SIZE AT MATURITY: According to most accounts, black carp reach maturity anywhere from 6 to 11 years of age (Atkinson 1977, Evtushenko et al. 1994 and references therein). Such late maturity contrasts with grass carp which mature at 3-4 years of age (Atkinson 1977). Male black carp from the southern Ukraine were found to mature at 9 years of age whereas females did not mature until age 11 (Evtushenko et al. 1994). Evtushenko et al. (1994) stated that the black carp from the Amur River and in northern China reach sexual maturity at 8-9 years of age. Rothbard and Shelton (1993) reported that the minimum age of maturity for black carp in subtropical climates was 8 years (and weight of 6-9 kg [13-20 lb.]) for females and 7 years for males. Bardach et al. (1972:88) reported that the age of maturity for black carp raised in central China and in Taiwan was somewhat less, 5 years (and 10-15 kg [22-33 lb.]) for females and 4 years for males.

Nevertheless, Chinese researchers have reported that black carp sometimes mature much younger, occasionally as early as 3 years (IHAS 1976). Their findings agreed, however, with others in that male black carp, on average, mature slightly earlier than females. According to data collected in the Hukou area of China (IHAS 1976), age classes of the reproductive population ranged from 3 to 15 years for females (82% were 5-9 years of age) and 3 to 10 years old for males (67.7% were 4-5 years of age). Their data also showed that 68% of 4-year-old males, and 47% of 4-year-old females were mature; whereas all 6-year-old males and most, but not all, 6-year-old females were mature. They found that females first reach maturity at about 100 cm [39 in.] long and about 15 kg [33 lb.]; the smallest female reportedly reaching first maturity was 88 cm [35 in.] long and 10 kg [22 lb.]. Males at first maturity were generally 90 cm [35 in.] long and 11 kg [24 lb.]; the smallest male reportedly reaching first maturity was 83 cm [33 in.] long and 8.5 kg [19 lb.].

Even though IHAS (1976) reported that black carp females reached maturity as early as 3 years of age, it should be noted that the smallest and presumably the youngest mature females that they studied weighed at least 10 kg [22 lb.]. In contrast, the youngest mature females reported by others were significantly older but weighed relatively less; the extreme being the 8-year old females, reported by Rothbard and Shelton (1993), that weighed in the range of 6 to 9 kg [13-20 lb .] .

REPRODUCTION AND SPAWNING: Like other Chinese carps (i.e., grass carp, silver carp, and bighead carp), black carp reproduce and spawn in rivers; and their eggs are pelagic or semipelagic and drift downstream (Banarescu and Coad 1993). In their natural habitat and in other temperate climates, the principal species of Chinese carps, including the black carp, are all annual spawners (Bardach et al. 1972). According to Chang (1966), black carp make annual migrations upstream to suitable habitats.

The annual migration and spawning by black carp in open waters begins as early as April and is completed in or before July; however, the literature indicates that the starting time and duration of spawning is variable (Change 1966, Evtushenko et al. 1994) and probably depends on the region and local habitat conditions. For instance, first spawning is reported as beginning from April to June or July (Evtushenko et al. 1994). In the Amur River, black carp spawning takes place during June and probably July; spawning occurs as torrential rains cause water levels to rise and at temperatures of 26-36°C [79-97°F]. In the Yangtze River, spawning begins in May, possibly late May (IHAS 1976, Evtushenko et al. 1994, references therein) and extends into July (IHAS 1976). This is somewhat later than the spawning period of grass carp and silver carp (IHAS 1976). It has also been reported that carp species raised in Chinese ponds spawn in May and June when water temperatures are increasing from 18 to 25°C [64-77°F] and that the black carp typically spawn later than either silver carp or bighead carp (Atkinson 1977).

In China, the main spawning sites for black carp and grass carp are located in the lower reaches of rivers with appropriate current and other characteristics (Atkinson 1977, Evtushenko et al. 1994). In the Yangtze River, spawning grounds are located along the main stream from Chongqing to Huangsi and, on a smaller scale, in the Hanjiang and Xiangjiang rivers (IHAS 1976, Yu 1990). Black carp taken in the Yichang spawning grounds during the reproductive season (and members of the reproductive populations migrating against current through the gorge) are reportedly all of about equal size (IHAS 1976).

Yu et al. (1985) and Liu et al. (1986) assessed the impact of the Gezhouba Dam, on the Yangtze River, on the spawning of four Chinese carp (black carp, silver carp, grass carp, and bighead carp) during the period 1981 to 1984. They reported that the spawning grounds of these fishes were still widely distributed in the upper and middle reaches of the river. Although the dam did prevent spawning adults from migrating to the upper reaches, it was concluded that the dam had not significantly impacted the spawning of these fishes apparently because the four species are highly adaptable and also because upstream populations still spawned above the dam (Yu et al. 1985, Liu et al. 1986, Dudgeon 1995). However, it was noted that the number of spawning fishes and total number of eggs spawned had diminished significantly since the 1960s. For instance, Liu et al. (1986) estimated that the four species spawned a total of 11-31 hundred million eggs each year; that estimate was less than 10% of total number of eggs recorded as spawned in the 1960s.

In a later work, Liu and Yu (1992) discussed the effects of the Danjiangkou Dam on the Hanjiang River, a major tributary of the Yangtze River, in Shanxi Province, China. The construction of dams in China blocked black carp migration paths and caused changes in spawning success. The numbers of eggs and fry upstream of the hydroelectric dam are markedly greater than downstream of the dam. For instance, egg production of the four major carp species (grass carp, black carp, silver carp and bighead carp) is 18.5 times greater above the dam than below. Their success is apparently due to the fact that fish above the dam are able to swim upstream to spawning sites in the upper reaches of the Hanjiang River. However, eggs drifting from spawning areas near the upstream sections of the reservoir sometimes settle prematurely and fail to develop in the still water of the reservoir (Liu and Yu 1992). Yu (1990) also reviewed dam impacts on fish spawning and provided a color map showing major spawning areas of the four major Chinese carp species (including the black carp) in the Yangtze (Changjiang) River.

In the Tone River (Japan) and in Kara Kum Canal (=Karakumskii Canal), spawning begins in April and May at temperatures of 18.6°C [65.5°F] with egg drifts reaching their highest numbers during the first 20-30 days; spawning is completed by the end of July (Evtushenko et al. 1994, references therein).

A brief mention of the actual act of spawning by black carp was given by Evtushenko et al. (1994). They reported that during spawning, the fish remain on the bottom and deposit one batch of eggs; the eggs are bathypelagic and carried by the current. According to Lin (1949) and Atkinson (1977), the spawning areas are known to professional fishermen who use special floating traps to collect the fry. In eastern Asia, the adults of riverine species (including black carp?), finish spawning and then migrate to their feedings grounds.

Nikolsky (1963:250) provided a general discussion on the reproduction of several riverine species, including the black carp, grass carp, and bighead, found in the former Soviet Union. He reported that the spawning of these Asian riverine fishes results in large numbers of pelagic eggs, embryos, and larvae that are then transported downstream from the spawning areas. The eggs develop and hatch as they float seaward. In eastern Asia, the spawning and the descent of the eggs and larvae coincide with the period of rising river levels. The eggs and larvae are carried by currents into floodplain lakes, smaller streams, and channels with little or no current, and such sites apparently then serve as feeding areas for the young fish. According to Nikolsky, if the drift of eggs and larvae occurs during falling river levels, then the larvae migrate actively to their feeding areas after absorbing the yolk sac.

According to Bardach et al. (1972:87), most Chinese carps from temperate areas are annual spawners. Spawning in their natural habitats seems to be triggered mainly by temperature, although rising water may play some role (Bardach et al. 1972). Except for common carp, there has been no indication that Chinese carp change from an annual to a perennial spawning cycle in tropical areas (Bardach et al. 1972:87).

Based on their literature review, Evtushenko et al. (1994) reported that the natural spawning requirements of black carp include water temperatures of 26-30°C [79-86°F] (although temperatures as low as 18.6°C [65.5°F] have been reported), rising water levels, and availability of mollusks (as a food source). Chinese research in the Yangtze River suggest that conditions required for spawning of black carp is less restricted compared with other domestic fishes. There, spawning can be stimulated in black carp by only a slight elevation of water level (IHAS 1976). In fact, black carp fry sometimes make up 40-50% of the total number of fry of domestic fishes collected from rivers during small scale floods. In comparison with the other river carp, information presented by the IHAS (1976) indicated that spawning activities of black carp are more scattered (less centralized), occur well below the water's surface, occur later in the season, and the spawning season is more prolonged.

Black carp introduced into open waters show mixed results in terms of their establishing reproducing populations. For example, although black carp are raised in Taiwan, the island has no large rivers to maintain reproductive populations (Bardach et al. 1972). Similarly, natural spawning is also not known among black carp introduced into Ukrainian waters (Evtushenko et al. 1994). In contrast, there may be a reproducing population, apparently descended from introduced individuals, in the Tone River, a large river on the eastern side of the island of Honshu, Japan (Kuronuma 1955, Masuda et al. 1984, Evtushenko et al. 1994, Bailey and Haller, no date).

SECONDARY SEXUAL CHARACTERISTICS AND INDICATORS OF RIPENESS: Mature males of black carp are known to develop finely serrated ridges on the pectoral fin rays (Bardach et al. 1972); the pectoral fin rays are described as harsh (Anonymous 1980). Mature males of both grass carp and black carp are reputed to develop nuptial tubercles or "pearl organs" prior to spawning (Kimura and Tao 1937, Bardach et al. 1972:89). Pearl organs are reported as occurring on the interorbital area of the head (Kimura and Tao 1937) and also on the operculum and the sides of the body (Anonymous 1980); however, Bardach et al. (1972:89) indicates that some culturists have not observed these structures. Ripe males of the black carp, as well as other Chinese carps, release milt when handled or gently pressed in the area of the testis (Bardach et al. 1972, Anonymous 1980).

In contrast to males, mature female black carp have smooth pectoral fin rays and do not have pearl organs. Ripeness in females may be indicated by a large, soft abdomen (Bardach et al. 1972, Anonymous 1980), although fish with large amounts of intestinal fat have the same appearance (Bardach et al. 1972). It has also been reported that the cloaca of ripe females is swollen and pinkish in front (Bardach et al. 1972), and the anus as being loose and reddish (Anonymous 1980); but such signs are apparently not always observable (Bardach et al. 1972).

FECUNDITY: Atkinson (1977) reported black carp fecundity as 400,000 or more eggs. In their review of black carp biology, Evtushenko et al. (1994) reported that total fecundity ranges from 129,000 (for a 119 cm [47 in.] fish from the Amur River) to 1.18 million eggs (for an 18.5 kg [41 lb.] fish from the Yangtze River basin). Chinese researchers of the IHAS (1976) reported that the absolute fecundity of black carps in the Yangtze River varied greatly, ranging from a low of about 260,000 to a high of 695,000 (n=88). They found that fecundity was closely related to body weight (correlation coefficient 0.75) and secondarily to body length (correlation coefficient 0.67). In Chinese ponds, the average fecundity of black carp is 1.5 million eggs and the relative fecundity is 662,500 eggs per kg of live weight (Evtushenko et al. 1994, references therein).

A report by the Pearl River Fisheries Research Institute provided the following information on the fecundity of pond cultured black carp: average weight of fish 23 kg [51 lb.]; average ovary weight 2,488 g [5.5 lb.]; average absolute number of eggs 1,500,000; average relative number of eggs 63; and average ovary coefficient (gonadosomatic index) 10.8 percent (Anonymous 1980). Based on the above information (i.e., from Anonymous 1980), the FAO (1983:37) calculated that the average number of ovocytes per kg of black carp weight was 65,000 and that the gonadosomatic ratio (i.e., weight of ovaries in proportion to total body weight) was 10.8 percent. The average number of ovules obtained through artificial propagation was calculated as 25,000 to 30,000 per kg of total body weight for the black carp; in contrast, an average of about 50,000 ovules per kg was calculated for grass carp, bighead carp, and silver carp (FAO 1983:37).

EGGS: Soin and Sukhanova (1972) compared the eggs and early development of black carp, grass carp, silver carp, and bighead. They reported that unswollen eggs of black carp range from 1.24 to 1.44 mm [0.05-0.06 in.] diameter (versus 1.21-1.36 mm for the grass carp). According to Evtushenko et al. (1994), egg size (probably mature or swollen eggs) diameter ranged from 4.30 to 5.59 mm [0.17-0.22 in.]. Information from IHAS (1976) indicated that fertilized eggs have a transparent membrane and that these eggs are 5.0 to 7.0 mm [0.2-0.3 in.] in diameter with a yolk diameter of 1.5 to 1.7 mm [0.06-0.07 in.]. Black carp eggs are nonadhesive, semipelagic, and drift with water currents (Atkinson 1977, Mikodina and Makeyeva 1980, Rothbard and Shelton 1993, Evtushenko et al. 1994). In general, black carp eggs are very similar in structure and size to that of the eggs of grass carp, silver carp, and bighead (Soin and Sukhanova 1972). Mikodina and Makeyeva (1980) discuss the ultrastructure of the egg membranes of black carp, and several other carp species with buoyant eggs. They reported that the egg membrane of these species is a 3-layered zone, with a thin chorion responsible for the slight stickiness of their eggs.

DEVELOPMENT: Information on black carp early development was provided by Soin and Sukhanova (1972), IHAS (1976), Wang (1982, 1985), and Evtushenko et al. (1994). Soin and Sukhanova (1972) also provided illustrations and a table comparing and contrasting the eggs, prolarvae, larvae, and fingerlings of black carp, grass carp, silver carp, and bighead. Black carp eggs reportedly hatch 35 hours after fertilization at water temperature of 21-24 °C [70-75 °F]; newly hatched fish are 6.4 to 7.4 mm [0.25-0.3 in.] long and have 27-28 trunk myotomes (less than that of grass carp) (IHAS 1976). Soin and Sukhanova (1972) described and illustrated the early developmental stages of captive-raised black carp, grass carp, silver carp, and bighead. All four species are characterized by early hatching from the egg, weak development of the embryonic respiratory organs, late appearance of pigment, and accelerated passage through the development stages. Differences in the developmental stages were also found. For example, the larval body of black carp was reported as being the most weakly pigmented of the four species examined.

The yolk sac is almost absorbed at 6-8 days after hatching and when the fish are 8.2 to 9.5 mm [0.32-0.37 in.] long. According to IHAS (1976), there is no melanotic pigment at the base of the pectoral fins, an obvious distinction from that of grass carp larvae. At three weeks after hatching, the fish are 18 to 24 mm [0.7-0.9 in.] long and scales have appeared. The paired and unpaired fins at this time are similar to those of adults (IHAS 1976).

The requirements of black carp are probably very similar to that of grass carp. Stanley et al. (1978) noted that grass carp eggs are semipelagic and currents are necessary to keep the eggs suspended. Based on their review of the literature and site visits to spawning areas in Europe and the former Soviet Union, they concluded that large, long rivers or canals with high volumes (>400 m^3/sec [524 yd^3/sec]) and fast flow rates (>0.8 m/sec [2.6 ft./sec]) were needed for successful spawning. Based on their research, Stanely et al. calculated that grass carp eggs are theoretically carried 50 to 180 km [31 to 112 miles], depending on water temperature and current speed, before hatching. As such, successful reproduction occurs only in rivers or very large canals. In very slow current the eggs drop to the bottom and in highly turbulent waters the chorion of the eggs is broken. In their review of the literature and discussion with experts, it was determined that any current above 0.8 m/sec was apparently sufficient to carry grass carp eggs. Their review indicated that eggs may drop to the bottom at flows of 0.6 m/sec [2 ft./sec] or less. However, based on a study using unfertilized eggs placed in a Florida stream, Leslie et al. (1982) found that grass carp eggs could be supported at flow rates down to 0.23 m/sec [0.75 ft./sec].

Optimal egg incubation for the grass carp was 22 to 26 °C [71.6-78.8 °F] although temperatures up to 30 °C [86 °F] are tolerated. Mortality of eggs is high below 20 °C [68 °F]. Stanley et al. (1978) also found that the length of river needed for carrying grass carp eggs before hatching depended on water temperature and velocity. Eggs drifting in rivers with lower water temperatures require more time to develop and thus a longer river is required. As is the case with black carp, grass carp were introduced to the Tone River in Japan and have become established. Because that river is relatively short, successful spawning of grass carp does not take place every year because very fast water carries the eggs beyond the nursery area and apparently out to sea. In addition, Stanley et al. (1978) reviewed the migration of adult grass carp and habitat requirements of larval and juvenile grass carp.

GROWTH: Atkinson (1977) provided the following data on black carp growth--age 1 (22-32 cm [8.7-12.6 in.]), age 2 (45-50 cm [17.7-19.7 in.]), and age 3 (5 kg [11 lb.]), with a maximum size of 120 cm [3.9 ft.] (36 kg [79 lb.]). Evtushenko et al. (1994) review of data on black carp growth rate indicated that fish weight is extremely variable, especially in their first year of life. Their information on black carp from several hatchery ponds as well as a cooling pool showed individual weight of first-year fish ranging from 1.1 to over 300 g [0.04-10.6 oz.]. It has been reported that the linear growth of black carp slows with age and decreases suddenly by the 8th or 9th year; however, weight gain increases with age, especially in the 5th-7th years (Evtushenko et al. 1994, and references therein).

Evtushenko et al. (1994) state that the growth rate of juvenile black carp is determined by the quantity and quality of its food and that individuals show large growth increases even after attaining sexual maturity. For example, black carp grow slowly if mollusks are not included in the diet. Growth rate is also influenced by temperature. They indicated that the black carp exhibit relatively high annual increases in length and weight even after reaching sexual maturity. Leventer (1979) reported that the growth rates of black carp stocked in Israel differed among reservoirs and depended on fish population density and the quality of food.

Liu (1955 as cited in Leventer 1979) reported on black carp grown in fish ponds in China. He found that black carp grew in weight at the rate of 1 to 63 (apparently the total weight of a group of fish increased by 2,122 kg [4,678 lb.] after feeding on a total of 134,650 kg [296,852 lb.] of mollusks). The high number of mollusks required for carp to increase weight was believed to be due to the fact that a disproportionate part of the weight of the mollusks is composed of shells that have no nutritional value.

Information from the IHAS (1976) also indicated that the growth of black carp is different under different ecological conditions and that the abundance of food and duration of feeding season are important determinants in their growth. They reported that black carp found in two areas, the

Yelabujia, Helilongjiang River and in Daihai, Inner Mongolia, require three years to attain the average length of one-year old black carp inhabiting the more suitable Yangtze River. Large black carp harvested in the Yangtze River may weigh 15-40 kg [33-88 lb.], although individuals of more than 70 kg [154 lb.] have also been reported (IHAS 1976).

Chen et al. (1965) examined 945 specimens of black carp from the Yangtze River in 1962 and 1963 to evaluate and compare different formulas used to back calculate the length of specimens from scale annulus measurements. Of four formulas, they concluded that the best predictors of body lengths of black carp were those of Monastyrsky ($L=4.785S^{\text{[illegible]}}$) and Vovk ($L = 0.481+4.761S$). Growth rate was found to be greatest at the age of 3-4 years and began to slow at 5 years of age, when maturity had set in.

According to the FAO (1983), growth rates of Chinese carps in ponds are greater in hot, subtropical conditions than in more temperate regions. Compared with grass carp, silver carp, and bighead carp, the black carp is a relatively slow grower (FAO 1983:52); however, it can grow rapidly if provided with a mollusk-rich diet (FAO 1983:56).

E. ASSOCIATED DISEASES AND PARASITES

A number of papers document the parasites and diseases of black carp. Evtushenko et al. (1994) provided a review of at least some of the literature dealing with black carp parasites. Because black carp feed heavily on mollusks, the species serves as a reservoir host to many mollusk parasites. Based on the available information, the black carp is a probable carrier of parasites and diseases that use mollusks as an intermediate host while frequently remaining immune from the effects of the disease itself. Several Russian papers indicated that black carp are highly resistant to certain parasites that are carried by snails (see papers by Zobel 1975; Denisov 1982).

Black carp in the Amur River carry the digenetic fluke, Aspidogaster conchicola, in their intestines. Black carp become infested after feeding on the fluke's primary host, the bivalve mollusk Cristcaria plicata. Amur River black carp also carry metacercaria of Metogonimus yokogawai. Infestation results from feeding heavily on the intermediate host, the mollusk Melania. Another diet-related parasite reported infecting black carp is Khawia sinensis. Oligochaetes that serve as intermediate hosts to "sea pink" (taxa?) are also preyed upon by black carp (Evtushenko et al. 1994, and references therein).

According to Evtushenko et al. (1994), the most serious parasitic problem of black carp in the Yangtze River basin is "inflammation of the viscera caused by parasitic fish lice." In the European portion of the former U.S.S.R., black carp were observed with a measles-like disease. Lee (1957) reported that gasteroenteritis (bacterial enteritis) is a common and serious disease of both black carp and grass carp; he also reported that gill rot disease occurred, mostly frequently among second and third-year black carp and grass carp. Other diseases recorded for black carp include ichthyophthiriosis, diplostomiasis, and metagonitiasis (Evtushenko et al. 1994, and references therein).

Bykhovskaya-Pavlovskaya et al. (1962) provided a list of 19 internal and external parasites known from the black carp: Trypanosoma mylopharyngodoni, Cryptobia branchialis, Eimeria mylopharyngodoni, E. cheni, Chloromyxum cyprini, Dermocystidium percae, Tripartiella bulbosa, Trichodina nasi, T. pediculus, Glossatella cylindriformis var. minuta, Trichophrya sinensis, Dactylogyrus magnihamatus*, Bothriocephalus gowkongensis*, Aspidogaster amurensis, Camallanus hypophthalmichthys (?), Sinergasilus major*, Neoergasilus longispinosus*, Paraergasilus longidigitus*, and P. brevidigitus* (those marked by an asterisk indicate parasites found in black carp from outside the limits of the former U.S.S.R., "T' indicated a questionable record).

Other recorded parasites for black carp include Dactylgyrus, Bothriocephalus, Argulus, and Lerea (Evtushenko et al. 1994, and references therein). Arizmendi (1992) reported the recovery of Centrocestus formosanus metacercariae from the gills of black carp that had been recently introduced into Mexico. These fish were being cultivated in a Federal Fish Farm at Tezontepec de Aldama, Hidalgo State (Arizmendi 1992).

Odening (1989) reviewed the trends seen with parasitic infections of cultured freshwater fishes during the 1980s. Infections reported for black carp included chloromyxosis caused by Chloromyxum cyprini and intestinal coccidioses caused by one or two unnamed species. Huang et al. (1983) reported on myxobacteria isolated from the fins, gills, and skin of different freshwater fishes including the black carp.

Although several papers indicated black carp are highly resistant to parasitism and diseases, Lin (1955) found that both black carp and grass carp succumb easily to bacterial diseases such as intestinal inflammation, dysentery, and gill rot. The two species also reportedly have a lower tolerance of foul water than other fishes. Lin reported that the mortality rate of these black carp and grass carp may reach 50% in congested ponds and therefore the two species are not stocked together in large numbers.

During the late 1980s and early 1990s, an extensive epizootiological study was carried out on the infectious diseases of cultured black carp in Taiwan (Chen et al. 1990). Results from 185 fish showed that Lernea, Trichodina, Dactylogyrus, Ichthyothirius, Chilodonella, Gyrodactylus, and Argulus were common in cultured black carp. Highest incidence rates of infection included Lernea (51%), Trichodina (37%), and Dactylogyrus (22%). It was also noted that diseased fish with parasites were infected with bacteria or infectious pancreatic necrosis virus (IPNN). The two most important bacteria isolated from infected black carp tissue included Flaxibactar columuaris and Aeromonas hydrophila. Pseudomonas fluorescens was also found.

Griffin (pers. comm. 1994) reported that there were rumors of a mysterious viral disease infecting black carp in China and that the Chinese had a vaccine. During the Taiwan study, only a single virus was detected, and that virus, found in tissues, seemed to cause no known problems (seemingly equivalent to an orphan human virus). However, the virus was not detected in a subsample of black carp from a fish farm in Arkansas (W. Griffin, pers. comm. 1994). Jiang and Ahne (1989) reported on a hemorrhagic disease of black carp and grass carp in China. That viral disease was first observed in China in the 1970s and was responsible for killing more than 80% of reared fingerlings and first-year fish. It was later reported that black carp artificially infected with grass carp hemorrhage virus (GCHV) were found to be positive for the GCHV antibody (Ding et al. 1991). Recently, Chen et al. (1993) identified an infectious pancreatic necrosis virus taken from the a black carp swim bladder.

F. HISTORY IN AQUACULTURE

In China, the black carp has long been considered one of the four most important domestic fishes; the other species being the grass carp, silver carp, and bighead carp (Gu San-Dun 1975, IHAS 1976, FAO 1983). Bardach et al. (1972:81, 106) and IHAS (1976) stated that the black carp is highly esteemed as a food fish in China. Chu (1930) reported that the black carp "...is one of the most esteemed fishes and its fins which are covered with thick adipose skin are especially regarded as a delicacy." He later added that the flesh of the black carp is superior in taste to that of the grass carp.

Chen et al. (1995) reported that the high-valued black carp represents 11% of stocking (by weight) in high-productivity Chinese provinces--areas where fish farming has a long and rich history (i.e., Jiangsu and Zhejiang), but the black carp is almost absent in Chinese fish farms located in low and medium productivity areas. Some of the differences in stocking densities among the different Chinese regions are simply the result of consumer demand. For example, common carp is preferred by consumers in northern China; in contrast, the more costly black carp (and silver carp) have become more desirable in such areas as Jiangsu province because the incomes of consumers have increased over time and shifted demand away from inexpensive, but less-desirable, fishes (Chen et al. 1995). Bardach et al. (1972) reported that there has not been much demand for this species outside China, such as in Taiwan, because persons in these areas do not highly prize it as a food fish. Welcomme (1988) reported that the species is "used in aquaculture but because of its particular food requirements has not been as widely transplanted as other Chinese carps."

The use of black carp in Chinese aquaculture dates back many centuries. During the Tang Dynasty (618 to 917 AD), China's royal family made the common carp a royal symbol and essentially prohibited the taking and selling of that species (Atkinson 1977:323). Because culture of common carp was no longer possible, growers in the Yangtze and Pearl rivers began growing other carps, mainly grass carp, black carp, and bighead. The combined use of these species during that early period was probably the beginning of polyculture in China (Atkinson 1977).

Traditional Chinese polyculture or multi-species culture involved stocking ponds with a combination of native fishes; typical species included a planktivore (e.g., Hypophthalmichthys or Aristichthys), an herbivore (e.g., Ctenopharyngodon or Megalobrama), a bottom-dwelling feeder (e.g., Mylopharyngodon, Cyprinus, or Cirrhinus), and occasionally a piscivore (e.g., native serranids, clariids, silurids, or channids) (Bardach et al. 1972). According to the FAO (1983), the total number of species used generally varies from four to eight, although the recent trend has been to use the greater number. The general practice of polyculture using Chinese carps was taken up throughout southeastern Asia and in other parts of the world (e.g., former U.S.S.R, Matena and Berka 1987:13).

Although somewhat regulated and based on past experience and experimentation, the numbers and sizes of each species used in polyculture stocking by the Chinese varies from region to region (FAO 1983:50, Chen et al. 1995). According to Atkinson (1977), the Chinese stock black carp in numbers ranging from 400-6,000 individuals per 100 m^2 with one or two other carp species (i.e., grass carp, silver carp, bighead carp).

Whereas other bottom-dwelling cyprinids, such as common carp, feed mainly on detritus and a mixture of small benthic organisms, Chinese fish culturists have long recognized that black carp prefer mollusks. Thus, Chinese fish culturists commonly provide black carp with snails and bivalves even though these fish require little supplemental feeding under the right conditions (Bardach et al. 1972). Hickling (1968:58) reported that black carp are stocked to feed on snails which occur in well-fertilized farm ponds and that wild snails and clams are collected by the basket-full in ditches for use as supplementary feeding. According to the IHAS (1976) the growth of captive black carp fingerlings in the Chinese provinces of Jiangsu and Zhijiang is enhanced by providing crushed spiral shells and clams supplemented with bean cake and silkworm chrysalis.

As is common in rearing other Chinese carp species, the Chinese also culture black carp fry in ponds that have been treated with manure; the manure supports the growth of small organisms that are used as prey by the young fish (Naiwei Wu et al., no date). Lin and Peter (1993) reported that black carp are often cultured together with the plankton-feeding silver carp and bighead carp. Black carp excreta increases the fertility of the pond water; as such, the growth rate and yield of silver carp and bighead in black carp ponds are similar to those in grass carp ponds (Lin and Peter 1993).

The early Chinese had little difficulty in spawning common carp in captivity. However, Chinese freshwater fish culturists were unable to spawn many of the larger river carps (black carp, grass carp, silver carp, bighead carp) and were forced to obtain the eggs and fry of these species directly from wild populations naturally spawning in rivers and lakes (Atkinson 1977). Based on the experience of many generations of collecting, professional fry collectors became very familiar with the spawning areas and typically set thousands of traps downstream of well-known spawning areas (Atkinson 1977). Bardach et al. (1972:82) and Atkinson (1977:331-332) described the methods used in collecting eggs and fry from rivers, including techniques used for hatching the eggs and sorting the fry.

Although it was later shown that these fish mature in pond conditions, spawning in captivity among these big river species almost never occurred (Bardach et al. 1972:77). Thus, the early spread of these carps was limited by the means available for maintaining and transporting live eggs and fry (Bardach et al. 1972). For instance, the Chinese fish farmers that settled in Taiwan several hundred years ago, had to annually import carp fry from the mainland because the island had no large rivers to maintain a reproductive population (Bardach et al. 1972). Historically, live carp fry were transported in water-tight containers made of bamboo. For transporting fish long distances, live fish were kept in the holds of boats or "live barges" (Atkinson 1977). More recently, live young and fry were transported in plastic bags containing water and oxygen (Atkinson 1977).

In addition to farming fish in ponds, the Chinese are also known to stock and harvest black carp and other carp species from rivers, natural lakes, and reservoirs (Atkinson 1977, FAO 1983:86, Lin and Peter 1993). Such "fish ranching" has been carried out in China for more than 100 years. This practice was particularly emphasized in China during the late 1950s and early 1960s when many irrigation projects and reservoirs were being constructed (Atkinson 1977). Atkinson (1977:339) reported that the recommended stocking rate was 100 to 150 fish (12 to 15 cm [4.7-5.9 in.] long) per 100 m^2 [1,076 ft^2]. The FAO (1983:48) reported that black carp fingerlings are reared in Bailianhe Reservoir, Hubei Province, in floating cages. These cages were stocked with 300 to 450 fingerlings (3 cm [1.2 in.] long and 0.5 g [0.02 oz.]) per square meter [per 10.8 ft^2] of silver carp (85%), bighead carp (10%), grass and black carp (4%), and Wuchang bream (1%). The young fish fed on natural food, escape and injuries accounted for 25-35% losses, and the rearing time was two months. In situations where black carp are raised for food, slightly larger black carp (13 cm [5.1 in.] and 25 g [0.9 oz.]) are stocked with other carp species in large floating cages (56-64 m^3 [43-49 ydˆ]) in Bailianhe Reservoir (FAO 1983:95).

Most available literature indicated that the black carp, at least in terms of relative numbers stocked, is not the most important fish in Chinese culture ponds. However, Lin and Peter (1993:595) indicated that the black carp is the principal species in the Yangtze basin. They reported that black carp comprised 42 percent of the total number of individual fish used in restocking polyculture ponds. Other species stocked in these ponds included grass carp (24%), silver carp (12-13%), bighead (7-8%), round head bream (7-8%), common carp (3-4%), and crucian carp (3-4%).

In a more modern treatment, Hagiwara and Mitsch (1994) included black carp as one of several species in their simulated ecosystem modeling of an aquaculture pond in south China.

ARTIFICIAL SPAWNING: According to Bardach et al. (1972:85), in the 1930s silver carp and grass carp were spawned in China by the practice of artificial insemination. Eggs and milt were obtained by hand stripping mature wild-caught fish. Using this technique, by the early 1950s fry specialists in China were supplying millions of artificially produced fry of silver carp, grass carp, and common carp to culturists. Bardach et al. (1972) did not specify if black carp were also produced in this way.

Significant changes in the Chinese culture of black carp occurred with the use of modern techniques using hormones to induce spawning; these have changed fish farming by stabilizing the supply of eggs and fry (Atkinson 1977). The practice of inducing spawning originated in 1934 by biologists in Brazil (Bardach et al. 1972). The use of hormones or pituitary extracts to induce spawning of Chinese carps began in the early 1950s. In 1954, researchers from the Institute of Hydrobiology, Academia Sinica were successful in inducing spawning of ripe wild-caught black carp and big head ahead of schedule (Bardach et al. 1972:85). Using these techniques, mass production of pond-reared silver carp, big head, and grass carp began in 1961; mass production of black carp began in 1963 (Bardach et al. 1972:85).

Bardach et al. (1972) reported that pituitary preparations from many different kinds of animals will induce spawning in Chinese carps, but the most commonly used are common carp pituitary and human chorionic gonadotropin. They indicated that the generally accepted dosages for black carp, big head, mud carp, and silver carp are "2 to 3 mg of dried cyprinid pituitary, 3 fresh pituitary glands, or 700 or 1000 IU of human chorionic gonadotropin per kilogram of spawner." With this technique, ripe individuals may be placed in the spawning pond as early as 12 hours prior to injection, although stocking of spawning ponds may be delayed until immediately after injection. Peter et al. (1988) and Lin and Peter (1993) summarized the traditional Chinese methods, and also the Linpe method, of inducing ovulation and spawning of cultured black carp (and other carp species). Zhange et al. (1991) and Zhang and Liu (1991, 1992) reported on the results of sperm cryopreservation with several cyprinids, including black carp. Fertilization rates of black carp sperm that had been cryopreserved for one to three years ranged from 70.3 to 78.5 percent.

Bardach et al (1972) stated that the recommended size of a spawning pond is 1.5 to 2.0 m [5-6.6 ft.] deep and 100 to 140 m^2 [1,080-1,512 ft2]. Atkinson (1977) reported that artificially-raised fish are injected in mid-afternoon with pituitary extract from common carp or a commercial preparation of gonadotropin to induce spawning; fish then spawn early the next morning (Atkinson 1977). For stocking of brood fish, the Pearl River Fisheries Research Institute recommended 8 to 10 individual fish, each more than 10 kg [22 lb.], per pond (Anonymous 1980).

Bardach et al. (1972:96) also reviewed the sample stocking and feeding rates for black carp fry and for fry of the other Chinese carps. An example program specific for black carp fry is as follows: black carp fry up to 20 mm [0.8 in.] long are stocked in ponds 0.5 to 1 m [20-39 in.] deep at the rate of one million per hectare and fed egg yolk paste or soybean milk, plus peanut cake after 10 days; black carp (age of 1 month to 1 year) are stocked in ponds 2.5 m [8.2 ft.] deep at the rate of 100-2,400 fish per hectare and fed barley, bean cake, and small snails.

Because snails are common in ponds and streams in Kiangsu Province in north China, black carp has been a recommended culture species, able to survive with or without supplementary feeding (Bardach et al. 1972:107). In this region, up to 2,000 black carp at sizes 150 to 180 mm [5.9-7.1 in.] long, are stocked in combination with other carps in ponds two to three meters deep (Bardach et al. 1972:108). In other northern areas of China, black carp fingerlings are stocked in ponds 1.3 to 1.5 m [4.3-4.9 ft.] deep to take advantage of the abundant benthic fauna; in these areas Chinese carps are stocked as fry or yearlings and left for three years before harvesting (Bardach et al. 1972:108). In successive years fish are moved to deeper ponds.

Bardach et al. (1972:109) reported that black carp are the principal food fish raised in the lower Yangtze River valley, accounting for as much as half of the stock at harvest time. In this region, black carp are given supplementary feedings of snails. In the West River drainage (Zhu Jiang basin) of southern China and northern Vietnam only a few black carp are stocked in ponds, as the species reportedly does not grow well in tropical climates. In that region, black carp may suffer high mortality due to very high temperatures and thus it is not stocked in shallow ponds (about 60 cm [2 ft.] deep) (Bardach et al. 1972:111).

HYBRIDIZATION: Evtushenko et al. (1994) briefly reviewed past experiments on hybridization of black carp. They reported that in the variant cross of black carp and silver carp (Hypophthalmichthys molitrix), the hybrid offspring died five days after hatching because of the development of embryonic hydroceles in the pericardial cavity (possibly caused by sharp fluctuations in water temperatures).

Makeyeva and Verigin (1993) studied the morphology of reciprocal grass carp-black carp hybrids. The proportion of fertilized hybrid eggs ranged from 57 to 100 percent, similar to that of nonhybrid eggs, but hybrid eggs had, on average, a somewhat higher mortality. Newly hatched larva of the parental species and hybrids were very similar morphologically and behaviorally, although there were differences in the number of trunk myotomes. Fish of about three months of age showed many characteristics intermediate between the parental species in terms of morphology, growth rate, and body coloration; however, the majority of morphometric characters among hybrids tended toward the black carp.

Makeyeva and Verigin (1993) reported that the structure of pharyngeal teeth and gastric mill of hybrids differed greatly from that of the parental species. In the hybrid black carp (female) x grass carp (male), pharyngeal teeth resembled those of black carp but the pharyngeal teeth formula of hybrids was highly variable (e.g., 5/5, 4/5, 4/4, 2.5/5.2, 1.4/4.1, 2.5/5.1, 1.5/5.1). The teeth of hybrid individuals from the grass carp (female) x black carp (male) cross differed significantly from those of both parents. In these fish, the teeth were broad like that of black carp, but there was a small hook on the crown. Because of the variation among the pharyngeal teeth, the investigators could not predict what the type of feeding behavior and diets the hybrids would have in nature or in fish culture.

Hybrids have also been produced by crossing black carp females with males of the cyprinid Megalobrama terminalis (Chen et al. 1987). Other hybrids reported include female black carp with male bighead carp (Hypophthalmichthys nobilis), common carp (Cyprinis carpio), and grass carp (Ctenopharyngodon idella) (Schwartz 1981).

TRIPLOIDY AND GYNOGENESIS: The creation of triploid fish is considered one way of preventing reproduction when fish are raised for food or stocked in the wild. Histological studies have also shown that the gonads of triploids are abnormal, and for management purposes can be considered to be sterile. As such, triploids are seen as a management tool to prevent reproduction and population increases of introduced fish stocks. Fish farmers in the United States have been successful in inducing triploidy in both black carp and grass carp.

There are four techniques commonly used to induce triploidy, all use newly fertilized eggs: treatment with chemicals, heat shock, cold shock, and hydrostatic pressure (Thorgaard and Allen 1987). As is the case with grass carp, triploid (sterile) black carp are indistinguishable in external morphology from normal (fertile) diploids. Triploidy can be confirmed by use of a Coulter counter with a channelyzer; such an instrument costs $25,490 or about $0.36/sample (Pauley et al. 1994).

Another chromosome manipulation technique is gynogenesis. This involves the production of diploid monosex individuals with both chromosome sets from the female parent. The technique is used for rapid inbreeding of fish and in the production of all-female populations (Thorgaard and Allen 1987). In laboratory experiments, Rothbard and Shelton (1993) induced gynogenesis in the black carp by activating black carp eggs with sperm of heterologous cyprinids with a different number of chromosomes. Similar to induced polyploidy, such crosses normally result in nonviable progeny. In their experiment, saline diluted and UV-radiated sperm of Japanese ornamental (koi) carp and Cyprinus carpio, and intact sperm of goldfish (Carassius auratus) were used to inseminate batches of black carp eggs. Diploidy was restored by retention of the second polar body by means of heat shock, applied at various biological ages. According to Shelton and Rothbard (1993), their work was the first published investigation on the developmental rate or ploidy manipulations for black carp.

G. HISTORY OF INTRODUCTION

INTRODUCTION OUTSIDE THE UNITED STATES: Table 2 provides a summary of black carp introductions. Bardach et al. (1972:81) reported that the black carp was used in polyculture outside China including Taiwan, Malaysia, and other nearby countries; however, they indicated that its arrival in these countries was the result of accidental introduction with fry of other species imported from China.

Welcomme (1988) stated that the black carp is used in aquaculture but the species has not been as widely introduced as other Chinese carps because of it particular food requirements. Zhadin and Gerd (1961) reported that certain species from the Amur basin, including the black carp, have commercial importance in addition to resistance to cold, thus making them suitable for introduction into lakes, artificial reservoirs, and ponds of the European part of the former U.S.S.R. and Siberia. Blanc et al. (1971) provide a map showing the occurrence of black carp in European and adjacent inland waters. Based on that map, black carp are known from regions in the Volga, Dnieper, Dniester, and Danube river basins.

Welcomme (1981) remarked that the black carp is widely used in Vietnam for stocking lakes and ponds. He indicated that it was unknown if the species is established, although Bardach et al. (1972:82 as Mylopharyngodon aethiops) indicated that reproducing populations are known from the Song Hong (=Honghe or Red River) of northern Vietnam since they reported that black carp fry, and possibly eggs, are collected in the river channel.

INTRODUCTION INTO THE UNITED STATES: Available information indicates that the black carp is currently being maintained in research and production facilities in six states (Table 3). This species originally entered the United States in the early 1970s as a "contaminant" in imported grass carp stocks. These fish came from Asia and were sent to a private fish farm in Arkansas. During the period shortly after its arrival, black carp was not produced commercially in the United States and the species probably was eliminated through attrition of handling and transfer (H. K. Dupree, pers. comm. with J. McCann, 1991). According to M. Freeze (pers. comm. 1995), in the late 1970's the Arkansas Game and Fish Commission attempted to spawn the original black carp introduced into the United States; however, state researchers were not successful because these fish were not old enough to be sexually mature.

The second introduction of black carp into the United States occurred in the early 1980s for yellow grub control (M. Freeze, pers. comm. 1994) and as a food fish (B. Hopper, pers. comm. 1994). Black carp were purposely brought into the United States by an Arkansas fish farmer and a Mississippi fish farmer during the early 1980s (M. Freeze, pers. comm. 1994) and by a fish farm

TABLE 2. Summary of international introductions of black carp (includes introductions into acivaculture facilities and/or open waters

Country	Source	Year	Reason	Reproduction	Reference
Thailand	China/Hong Kong	1913	aquaculture	no	Smith (1945:34); Welcomme (1981, 1988)
Malaysia	China	not stated	unintentional; polyculture	unknown	Bardach et al. (1972); Kottelat (1989)
Vietnam	China	unknown	aquaculture	natural and artificial	Bardach et al. (1972); Welcomme (1988)
Taiwan	China	not stated	unintentional; polyculture	artificial	Bardach et al. (1972)
Japan	China	between 1915 and 1945, probably after 1940	aquaculture	natural?	(Kuronuma 1955); Okada (1960); Masuda et al. (1984)
former U.S.S.R.	China	ca. 1950	aquaculture	natural and artificial	Huet (1986); Blanc et al. (1971); Evtushenko et al. (1994)
Ukraine	China	1961	aquaculture?	artificial	Evtushenko et al. (1994); As per map given by Blanc et al. (1971)
Albania	China	unknown	aquaculture	artificial	Welcomme (1988); Knezevic & Maric (1986)
Hungary(?)	not stated	not stated	not stated	natural?	As per map given by Blanc et al. (1971)
Romania	China or former U.S.S.R.	1959	aquaculture	artificial (natural?)	Blanc et al. (1971); Marcel (1980); Huet (1986); Vasilu & Manea (1987)
Turkmenistan			research/ aquaculture?	natural	Shakirova (1986)
Germany	China	1970	aquaculture	artificial	Welcomme (1988)
Israel	unknown	unknown	research/ mollusk control	artificial	Welcomme (1988)
Costa Rica	Taiwan P. China	1979	aquaculture	artificial	Welcomme (1988)
Cuba	former U.S.S.R.	1983	aquaculture	artificial	Welcomme (1988)
Panama	Taiwan P. China	1978	aquaculture	yes (artificial?)	Welcomme (1988)
former Yugoslavia	Albania(?)	1983	unknown/ possible escapes	unknown	Knezevic & Maric (1986)
South Africa	Israel	not stated	aquaculture/ research	no(?)	Prinsloo and Schoonbee (1985)
Mexico	China(?)	1979	aquaculture/ research	unknown	López-Jiménez (1987); Mújica-Cruz (1987; Arizmendi (1992); Arizmendi (pers. comm. 1995)
United States	China, Taiwan, Israel	1970s and 1980s	aquaculture/ research	artificial	Dupree (pers. comm. 1991; J. Malone, pers. comm. 1995)

TABLE 3. Summary of states known to have black carp in aquaculture (aquaculture farms and research facilities).

State	Counties	Drainage	Facility	Remarks
Arkansas	Lonoke, Craighead	Arkansas River/Mississippi Basin	several private farms	Diploids and triploids. Imported from China and Taiwan. Three farms (Lonoke Co.) currently with >100,000 black carp each; a fourth farm (Craighead Co.) once had diploids.
Louisiana	St. Martin Parrish	Atchafalaya River drainage?	one private farm	Triploids (approximately 1755 fish, 6-8 inch) imported from Arkansas in March 1996 for research to test use as a control of trematode infestations carried by snails.
Mississippi	Coahoma, possibly elsewhere	Mississippi Basin (possibly the Sunflower River drainage)	two private fish farms	Diploids and triploids imported from Arkansas (possibly for research purposes). One farm (Coahoma Co.) with <2,000 triploids; a second farm once had diploids.
Missouri	Camden/ Miller (?)	Missouri River/ Mississippi Basin	one private farm	Diploids and triploids, >100,000 fish.
North Carolina	Beaufort	Tar/Pamlico and Neuce river drainages.	one research facility and several private farms	5,000 triploids imported late 1993 or early 1994 from Arkansas by Sea Grant at North Carolina State University for research to test black carp potential use as a control of yellow grub.
Oklahoma	Cleveland	South Canadian River/ Mississippi Basin	one research facility (University of Oklahoma)	All fish maintained in laboratory setting including three gynogenetic fish from Israel and about 20 normal or diploid individuals.
Texas	Waller, Karnes	Brazos and San Antonio rivers drainages	a research facility (Texas A&M University) and a private farm	Apparently all diploids; about 92 or 93 fish were obtained from Arkansas by university researcher to evaluate their use as a control of apple snails (1989-1994); all surviving fish (about 30 fish) were later transferred to a private research/production facility. That facility currently has <200 individuals.

sources: Howells (1992); Trosclair (1993); He (1993); M. Freeze, J. Malone, and J. pers. comm. ; M. Freeze (pers. comm. 1995 via B. Collins and J. McCraren); W. Shelton (pers. comm. 1994, 1995); R. Hodson (pers. comm. 1995); J. Davis (pers. comm. 1995); D. Pooser (pers. comm., 1995); A P. Gaudé (pers. comm., 1996).

operation in Missouri during the period 1986-1988 (H. K. Dupree, pers. comm. with J. McCann, 1991; J. Kahr, pers. comm. 1994). An attempt was made to spawn the fish in 1990 for the production of triploids (H. K. Dupree, pers. comm. with J. McCann, 1991).

Many U.S. fish farmers believe that the black carp has considerable potential for aquaculture. It is considered one of the most, if not the most, desirable food fish of the Chinese carps in China. As such, fish farmers expect that sales would be highest in the ethnic markets, mainly among Asian Americans. Black carp are also cited as having potential in controlling snails found in U.S. culture ponds that carry yellow grub (Clinostemum margaritum) and possibly other snail-carried parasites (see section on biological control).

The first and only known record of an introduction of black carp into open waters of the United States occurred in Missouri in April 1994. Thirty or more black carp along with several thousand bighead carp escaped into the Osage River when high water flooded hatchery ponds at a aquaculture facility near Lake of the Ozarks. It was reported that the black carp may have been triploid and thus considered sterile (Anonymous 1994). As of June 1995, there have been no reports from Missouri of the escaped black carp being recaptured (S. Bruenderman, Missouri Department of Conservation, pers. comm 1995).

NATURAL REPRODUCTION OF BLACK CARP OUTSIDE ITS NATIVE RANGE: The published literature indicates that introduced black carp have established naturally reproducing populations in several areas outside of its native range (Table 4): the Kara Kum Canal in the Turkmen area of the former U.S.S.R. (Shakirova 1986, Evtushenko et al. 1994); the Red River in northern Vietnam (Bardach et al. 1972:82 as Mylopharyngodon aethiops) and possibly in the Tone River in Japan (Kuronuma 1955, Masuda et al. 1984, Bailey and Haller, no date).

TABLE 4: Open water bodies with introduced populations of black carp considered established (i.e., naturally reproducing) or possibly established.

Water Bodya	Country	Latitudeb
Kara-Kum Canal	former USSR (Turkmen region)	37°N (Missouri)
Tone River	Japan	36°N (Maryland)
Red (=Song Hong) River	Vietnam	22°N (south of Florida)

a= Tone River; 370 km, similar in latitude & climate to Potomac River; Kara Kum Canal, 650 km long in Amu-Darya basin, similar to All-American Canal of the Imperial Valley.
b=(State situated in same latitude).

The origin of black carp populations in the Red River population in northern Vietnam is not clearly stated in the literature. Bardach et al. (1977:82) stated that fry of black carp, along with that of other species, are commonly taken from the Red River. Its presence there may be the result of past introductions; however, Li et al. (1985:391) show Honghe (=Red) River as included in the natural distribution of both silver carp and grass carp. Black carp were first introduced to Japan some time between 1915 and 1945, probably after 1940 (Kuronuma 1955).

Except for the locations mentioned above, black carp have not become established in other areas where introduced for several reasons. In most countries the black carp was brought in only for brief experimental work and was kept in enclosed areas. As such, the species was never released or gained access to open waters. In some situations, the required habitat was not available for reproduction. For example, Bardach et al. (1972) stated that Taiwan has no large rivers to maintain reproducing populations of black carp.

There is little information available on the abundance of black carp in areas where it has become established. It was considered a relatively uncommon species in the Tone River of Japan where several Chinese carps were introduced and became established (Bailey and Haller, no date). Based on commercial catches and observations of adults, young of the year, and in egg collections, the Chinese carps spawning in 1955 in the Tone included about 70 percent grass carp and 30 percent silver carp, with insignificant numbers of bighead and black carp. In the middle 1970s, the carp community consisted of over 90 percent silver carp and less than 10 percent grass carp, with bighead and black carps still minor species (Bailey and Haller, no date).

H. USE AS A BIOLOGICAL CONTROL AGENT

In general, the black carp has been introduced for three, not necessarily mutually exclusive reasons. These include: (1) its use as an aquaculture food fish (e.g., Vietnam, Taiwan, Japan, South Africa); (2) for control of large populations of mollusks (i.e., snails in ponds; clams largely experimental) (e.g., Israel, USSR); and (3) for the control of fish and human parasites through direct predation on host snails (i.e., mostly in aquaculture ponds; e.g., China, United States)

It has been suggested that black carp could be used as biological controls against snail populations in ponds where snails might compete for food with herbivorous fishes (Bardach et al. 1972:81) or where snail populations serve as an intermediate host of dangerous human parasites (Ling 1977). Hickling (1968:58) reported that these snail-eating fish help to control snail fever, and are sometimes stocked for this purpose. To control snails in polyculture ponds, the Chinese add 75 to 100 black carp per hectare of pond (FAO 1983:50).

Zobel (1975) discussed the use of black carp to control fish disease through its predation on potentially disease-carrying mollusks. He presented the following equation to calculate the number of black carp required for stocking in different water bodies:

$$M = \quad (h\ 10{,}000)]/P)\ 0.023;$$

where: M = density of black carp to stock; a = the number of mollusks in the water per meter squared; h = surface area in hectares; 10,000 = number of meters squared in one hectare; P = daily consumption of black carp on mollusks; and 0.023 = a constant calculation coefficient.

In his table on stocking rates (number of fish of size classes per hectare), Zobel gives the following information:

Size range of black carp (in grams)	small pond	large ponds and rivers	reservoir
250 to 500	15 to 25	20 to 40	45 to 50
750 to 1000	10 to 20	15 to 30	35 to 40
1500 or more	10 to 15	15 to 20	25 to 30

The most commonly cited work on black carp as a biological control agent is that of Leventer (1979, 1981). He reported on experiments beginning in 1970 for integrated biological control in artificial reservoirs in Israel. Leventer's research involved the introduction of eight fish species, mostly large cyprinids, to control nuisance groups of aquatic organisms including algae, submerged plants, snails, and fishes that populated reservoirs in Israel. Black carp and common carp were used for the purpose of controlling snails that obstructed water meters and irrigation equipment. In an experimental reservoir at Pedaya, black carp reportedly eliminated three snail species (i.e., Lymnea auricularia, Bulinus truncatus, and Melania tuberculata). In a nearby reservoir, used as an experimental control, Lymnea was found at 198 units per square meter. Black carp did not reproduce in the Israeli reservoirs (propagation was carried out through artificial reproduction) and the stocking was discontinued since the snail populations had disappeared. Overall, Leventer found that black carp and common carp were useful in preventing the formation of large snail populations in Israel reservoirs. However, Leventer indicated that no biological control agent was found that could successfully combat populations of two snails (Melanopsis costata and Theodoxa jordani) inhabiting the open concrete canals that connected the various reservoirs. Unfortunately, Leventer (1979, 1981) failed to provide details of the experimental design, such as numbers of black carp used, their sizes, the number of reservoirs stocked, duration of experiments, etc..

Mochida (1991) recommended that black carp and common carp be used as control agents to combat the spread of the apple snail Pomacea canaliculata (family Pilidae). This freshwater snail was introduced as a human food from Argentina into Taiwan in 1979-1980. During the 1980s, the snail spread or was introduced from Taiwan to other Asian nations including Japan in 1981, the Philippines in 1982, China (Guangdon, Fuzhou, and Hangzhou) in 1985, Korea in 1987 or earlier, Malaysia in 1987 or earlier, and Indonesia and Thailand by 1989. Mochida also recommended a variety of other non-chemical methods for controlling the snail, such as hand picking, use of ducks, and use of metal screens.

Shelton et al. (1995) conducted laboratory experiments in both the United States and in Egypt to test various aspects of black carp feeding biology as a basis of predicting their potential as biological control agents. Experimental prey included snails (Physa, Heliosoma, Bellamya, Melanoides, Lanistes, Lymnaea, Bulinus, and Biomphilaris). The researchers found that mouth gape of black carp was a good estimator of the largest size snail that a particular fish could ingest, crush, and swallow.

In the United States, fish farmers consider the black carp as a potential control of yellow grub (Clinostomum marginatum), a digenetic trematode, or fluke. Becker (1983) provided a review of its life cycle and reported that the parasite appears as a small (about 6 mm [0.2 in.] long) whitish or yellowish cyst deep in the flesh of the fish, or sometimes just beneath the skin. According to U.S. fish farmers, main targets among cultured fish include fish species without scales (e.g., channel catfish) and certain species with small scales (e.g., striped bass). A fish carrying the parasite may be eaten by a heron; in the heron, the parasite crawls to the throat and mouth where it matures into an adult. The adult then releases eggs and the eggs are washed from the heron's mouth into the water as the bird is feeding. Free-swimming larvae hatch from the eggs and these larvae then penetrate certain snail species. In the snail, the larvae multiply and the progeny (cercaria) emerge from the snail and become free-swimming again. Upon contacting certain species of fish, the cercaria burrow into the flesh and metamorphose into yellow grubs. Becker (1983) stated that there is little danger of the yellow grub infecting man. Furthermore, the parasite is killed through cooking. Nevertheless, fish infested with the parasite are not marketable.

Arkansas fish farmers noted that stocking about five black carp per acre was sufficient to control snails in farm ponds, although this depended on the level of snail infestation (M. Freeze, pers. comm. 1994).

There have been very few experimental studies in the United States evaluating black carp as a control agent of snails. Because of large outbreaks of yellow grub in striped bass ponds in North Carolina, triploid black carp were imported into that state for research into the molluscivore's effectiveness in controlling the host snail. Research was carried out in 10 striped bass ponds of about 2.5-3 acres each. Although results were somewhat incomplete, the findings suggested that control of snails by black carp was highly dependent on the type of snail to be controlled and the amount of vegetation in the artificial pond. Black carp (about 25 per acre) could not control those snails (i.e., Physa sp., carrier of black grub and white grub) that burrow into the substrate; however, the fish did control ramshorn snails (Heliosoma sp., a carrier of yellow grub) but only in ponds with little or no vegetation. When vegetation was present in ponds, the snails were found to be less vulnerable and were not controlled (R. Hodson, pers. comm. 1995).

J. Davis (pers. comm. 1995) worked with black carp for 4 years (1989-1994) investigating their possible use as a control of the introduced apple snail (Pomacea sp.?). His results showed that the fish did suppress snail populations somewhat but were not sufficiently effective to be useful as a control agent. In that study, black carp were stocked as high as 25 fish per acre, but were still not able to control the rapidly reproducing apple snails. The fish were only useful in handling young snails; they could not handle adult apple snails, which grow to 3.5 to 5 in. [9-13 cm] in diameter. A. P. Gaudé (pers. comm. 1996) and colleagues from the University of Southwest Louisiana initiated a study in 1996 to examine the effectiveness of triploid black carp, among other methods, to control the snail Helisoma trivolvis in ponds at a commercial catfish center in southern Louisiana. The investigators reported that preliminary results indicated that black carp may be having an effect; however, differences observed were not statistically significant.

CONTROL OF THE ZEBRA MUSSEL (DREISSENA POLYMORPHA): Zebra mussels attach to hard surfaces such as rocks, floating and sunken logs, various debris, concrete structures, pipelines, and intake structures, as well as other living hard-shelled organisms (e.g., unionid mussels), by way of their byssal threads, typically forming huge, dense colonies of adults. Zebra mussels also attach to each other resulting in the formation of thick layers and clumps (Claudi and Mackie 1994). Ukrainian researchers have proposed the introduction of black carp into rivers, canals, reservoirs, and ponds to control zebra mussels (Dreissena polymorpha) (Evtushenko et al. 1994, and references therein). Evtushenko et al. (1994) indicated that zebra mussels in Ukrainian waters have no natural predators. They believe that use of black carp to feed on zebra mussels and other mollusks would improve fish production and also reduce mollusk-carried parasites. Based on pond experiments, four-year-old black carp reportedly fed on an average of 1.4-1.8 kg [3.1-4 lb.] of Dreissena per day (Evtushenko et al. 1994, and references therein). However, Evtushenko et al. (1994) did not provide details on the experiment designs; they also did not indicate whether or not fish were presented individual zebra mussels as opposed to natural large clusters or colonies of attached adults (i.e., rafts). It is likely that these fish were supplied with individual rather than clusters of zebra mussels (W. Shelton, pers. comm. 1995).

Black carp prey heavily on mollusks, primarily snails, in their natural range and also in areas where they have been introduced. Based on their mouth structure (i.e., toothless jaws) and what is known about their feeding behavior, it is unlikely that black carp would be capable of breaking apart zebra mussel rafts. Thus, their ability to control or reduce zebra mussel populations to any significant degree is questionable. Because black carp grow to a large size and they have large, crushing pharyngeal teeth, it is likely that black carp could easily masticate and eat zebra mussels if the mollusks could be eaten individually. However, experimental testing is required to determine whether or not black carp can pull apart and feed on zebra mussel rafts and whether they preferentially select zebra mussels over other types of food items (e.g., native mollusks). The available literature (e.g., Evtushenko et al. 1994) does not make clear if such testing has ever been done.

In the earlier section on diet, it was mentioned that the black carp is apparently a gape-limited predator because its mouth diameter, or gape, essentially determines the maximum size of mollusk it can take. Even though a single zebra mussel is relatively small and can likely be handled without difficulty by an adult black carp, black carp are probably not able to handle attached clusters or rafts of zebra mussels. Even if black carp are capable of feeding to some degree on zebra mussels, the high reproductive rate of zebra mussels suggests that "control" of zebra mussels will only be achieved if all zebra mussels are removed by the biological agent. This is because zebra mussels have a very high reproductive potential. For instance, a single female zebra mussel can produce as many as one million eggs in two years; larvae that are born typically mature in about one year, and some individuals reach sexual maturity in the year of birth (Claudi and Mackie 1994).

III. RISK ASSESSMENT PROCESS

This section uses the information gathered on the black carp (presented in previous sections) for purposes of providing a reasonable estimation of the overall risk associated with black carp introduction. As stated in the introduction, this assessment is a specific organism assessment and does not attempt to evaluate the black carp as a pathway. Therefore, the potential for damage caused by the establishment of black carp in the river systems of North America is evaluated, but the impact caused by the establishment of organisms traveling with the black carp (i.e., in the water or as parasites/diseases) are not evaluated in the assessment.

There are seven rating elements in the risk model (see Section A below). Each element is assigned an estimated level of risk, rated as high, medium, or low (definitions are given at end of Section Uncertainty codes after each element rating are as follows (with description): Very Certain (as certain as I am going to get); Reasonably Certain (reasonably certain); Moderately Certain (more certain than not); Reasonably Uncertain (reasonably uncertain); and Very Uncertain (a guess).

A. RATING ELEMENTS OF RISK MODEL

1) Estimate probability of the exotic organism being on, with, or in the pathway.

High - Very Certain

This species is already present in the United States Pathway is dependent on human transport (see INTRODUCTION INTO THE UNITED STATES, pp. 33-36).

2) Estimate probability of the organism surviving in transit. High - Very Certain

The black carp is present and survival in transit has been proven on at least several occasions (see (see HISTORY OF INTRODUCTION, pp. 33-37).

3) Estimate probability of the organism successfully colonizing and maintaining a population where introduced. Medium - Reasonably Certain

Appropriate habitats and climate are found throughout most of the United States (i.e., large rivers and canals). Preferred food (i.e., aquatic snails and mussels) are locally abundant. The black carp became established after it was introduced to several localities in Asia (e.g., Japan, possibly northern Vietnam), including at least one water body in the former Soviet Union (i.e., Kara Kum Canal) (Evtushenko et al. 1994). In addition, the grass carp (Ctenopharyngodon idella), a closely related species from Asia with similar spawning habitat requirements, has naturally reproducing populations in open waters of the United States (e.g., Conner et al. 1980, Brown and Coon 1991, Howells and Webb 1994, Webb et al. 1994, Raibley et al. 1995). That species seems to be firmly established in the Mississippi River basin. There is also evidence (i.e., the capture of young individuals) that another large-river Chinese cyprinid, the bighead carp (Hypophthalmichthys nobilis), has successfully spawned in the Missouri and Mississippi rivers (Pflieger, pers. comm. 1989; Burr et al. 1996). (See NATIVE DISTRIBUTION, pp. 11-14; HABITAT, pp. 14; NATURAL REPRODUCTION OF BLACK CARP OUTSIDE ITS NATIVE RANGE, pp. 36-37.)

4) Estimate probability of the organism to spread beyond the colonized area.

High - Reasonably Certain

Appropriate habitats (i.e., large lowland rivers and canals) and climate are available throughout most of the United States. Preferred foods (i.e., aquatic snails and mussels) are locally abundant in most U.S. rivers. The black carp is closely related to another east Asian cyprinid, the grass carp (Ctenopharyngodon idella); the native distributions of these two species are nearly identical and their reproductive requirements appear to be very similar. As such, if the black carp colonizes open water sites within the U.S., the species would likely spread beyond colonized areas as has been the case with the introduced grass carp. The grass carp was first introduced into the United States (Alabama and Arkansas) in 1963 and now occurs in more than 45 states. The broad distribution of grass carp throughout the country is the result of a combination of factors including dispersal of both diploids and triploids from original stocking sites, its wide use in research projects, stockings to control aquatic weeds, and interstate transport from private hatcheries (Guillory and Gasaway 1978). Many state records represent permitted introductions of certified triploids rather than the result of dispersal or spread from other localities. In terms of grass carp reproduction in the wild, there is evidence of natural reproduction (i.e., collection of grass carp eggs, larvae, and small juveniles) in several portions of the Mississippi River basin (Conner et al. 1980, Pflieger and Grace 1987, Brown and Coon 1991, Raibley et al. 1995) and from the Trinity River in Texas (Howells and Webb 1994, Webb et al. 1994). Another related Chinese cyprinid, the bighead, was first imported into the United States in 1972 and there is evidence that this species also has reproducing populations in the Missouri and Mississippi Rivers (Pflieger, pers. comm. 1989; Burr et al. 1996). Unless intentionally or incidentally spread into other areas by man, black carp spread in the United States would be expected to be limited to those river basins where introduced. Major river basins in the United States that appear to provide appropriate habitat include the Mississippi, the Snake, the Sacramento-San Joaquin, and the Colorado, among others. However, if the black carp is salt tolerant there is a risk that individuals could spread along coastal waters into adjacent basins or drainages. In a laboratory setting, the closely related grass carp have been shown to survive up to 24 days in 10.5 parts per thousand salinities (Cross 1970). Additionally, because of their similarity in appearance to grass carp, there is potential that black carp will be incorrectly identified as grass carp and be unintentionally introduced to some areas. Based on climate, black carp might be expected to occur over at least most of the continental United States as well as Hawaii. (See NATIVE DISTRIBUTION, pp. 11-14; HABITAT, pp. 14; HISTORY OF INTRODUCTION, pp. 33-37.)

5) Estimate economic impact if established. <u>Low - Moderately Certain</u>

There exists the possibility that the black carp would negatively impact the mussel industry by feeding on and reducing populations of native mussels. There is also potential that the black carp would directly compete for food (i.e., snails) with several native species (e.g., redear sunfish, pumpkinseed, certain catfishes and suckers, freshwater drum, several turtles). Because the black carp shows a preference for snails as food, it possesses the capacity to impact stream communities where snails play an important role as a grazer of attached algae. Black carp may directly and indirectly reduce aquatic insects. At present, no economically feasible control method is available to eliminate black carp in aquatic environments.

Possible benefits from introducing black carp include: (1) reduction of the number of yellow grub; (2) introduction of a valued food for humans in commercial aquaculture and for some segments of the American public.

Possible costs incurred from introducing black carp include: (1) reduction in the numbers and kinds of native mussels (many of which are important to the freshwater mussel industry); (2) competition with native fishes; (3) competition with waterfowl and other vertebrates that utilize mollusks for food; and (4) introduction of a probable carrier of parasites and diseases that utilize mussels as an intermediate host (while the carrier frequently remains immune from the effects of the disease itself).

Similar to other filter-feeding, benthic organisms, zebra mussels appear to bioaccumulate contaminants; although recent studies centered in the Great Lakes basin indicated that contaminant concentrations in whole mussels are low (Kreis 1995). While zebra mussels do not constitute "toxic waste" (by EPA standards), because of the potential for further bioaccumulation, animals that consume zebra mussels may accumulate high levels of contaminants. As such, if individual black carp do feed on zebra mussels, these fish may not be suitable for human consumption. In addition, there would be a potential hazard to other fish and wildlife that consume black carp burdened with contaminants. Also, black carp are not very likely to control zebra mussels.

The low rating is justified because none of the negative impacts described above would strongly impact the U.S. economy. The domestic freshwater mussel industry is likely to be most impacted, but it is unclear as to the extent of the damage. It is unlikely that black carp would be capable of feeding on the adults of the majority of the species utilized by the mussel industry; however, black carp would probably be able to take juveniles of these species. (See NATIVE DISTRIBUTION, pp. 11-14; HABITAT, pp. 14; ASSOCIATED DISEASES AND PARASITES, pp. 25-27; HISTORY OF INTRODUCTION, pp. 33-37).

6) Estimate environmental impact if established. **High - Very Certain**

There is high potential that the black carp would negatively impact native aquatic communities by feeding on and reducing populations of native mussels and snails. The black carp is known to feed on mussels that are similar in shape and size to some native mussels of the United States. The United States has a high diversity of gastropods and bivalves and many of these are endemic to relatively small regions of the country. For instance, the black carp would potentially threaten many of the imperiled mussels currently on the brink of extinction. Of the 297 native freshwater mussels, 213 taxa (71.7%) are considered endangered, threatened, or of special concern (Williams et al. 1992). There also exists potential that the black carp would directly compete for food (i.e., snails) with several native species (e.g., certain catfishes, sunfishes, and suckers, freshwater drum, as well as certain birds and mammals), including some native species listed as threatened or endangered. Because the black carp shows a preference for snails as food, there is potential for impacting stream communities where snails play an important role as a grazer of attached algae. Black carp may directly and indirectly reduce aquatic insects. (See BIOLOGY AND NATURAL HISTORY, pp. 14-25.)

7) Estimate impact from social and/or political influences.

Medium Moderately Certain

Certain groups and industries in the United States support introduction of the black carp. This includes many fish farmers, probably the Asian-American community, and also industries that have a problem with zebra mussels and perceive black carp as a potential solution.

Those against introduction of the black carp include various environmental groups and also persons involved with the mussel and freshwater pearl industry. The American Fisheries Society recently passed a resolution asking the governmental agencies to strictly prohibit the sale, possession and distribution of black carp, largely in part due to its potential to harm the native mussel fauna.

B. ORGANISM RISK POTENTIAL (ORP)

Probability of Establishment	Organism within Pathway (High)	Entry Potential (High)	Colonization Potential (Medium)	Spread Potential (High)	**= Medium**

Consequence of Establishment	Economic (Low)	Environmental (High)	Perceived (Medium)	**= High**

ORP RISK =	Probability of Establishment (Medium)	Consequence of Establishment (High)	**= High**

Definition of organism risk potential rating:

Low = acceptable risk - organism(s) of little concern (does not justify mitigation).

Medium = unacceptable risk - organism(s) of moderate concern (mitigation is justified).

High = unacceptable risk - organism(s) of major concern (mitigation is justified).

C. SPECIFIC MANAGEMENT QUESTIONS

1) In the absence of preferred prey, what foods are likely to be substituted in U.S. ecosystems? Based on the available literature, large juvenile and adult black carp preferentially prey on mollusks. In U.S. ecosystems the fish would most likely consume indigenous snails and mussels, and selected introduced mollusks (e.g., Asian clams). Because they are gape-limited predators, any hard items that black carp feed upon would, by necessity, have to be smaller than the fish's mouth width. Mouth width is less critical if the fish preys on soft items. In Israel, introduced black carp switched to feeding on insect larvae and shrimps once snail populations decreased (Leventer 1979, 1981). (see DIET, pp. 16-18; GROWTH, pp. 24-25.)

2) What are the anticipated impacts of black carp on aquatic organisms, particularly mollusk populations? Black carp would most likely cause a decline in the numbers and kinds of indigenous mussels and aquatic snails and possibly some nonindigenous species as well (e.g., Asian clam). Those likely to be most susceptible are small and medium-sized mussel and snail species. Even non-reproducing (triploid) black carp could consume large quantities of mollusks because of their size and age potentials (see DIET, pp. 16-18; USE AS A BIOLOGICAL CONTROL AGENT, pp. 37-41).

3) Is there compelling evidence to suggest that black carp will provide an effective means of controlling nuisance mollusks? Based on a few published and unpublished studies, there is scattered evidence that suggests black carp may be effective in controlling certain kinds of snails and possibly Asian clams. However, tests with black carp in aquaculture ponds demonstrated that black carp were not able to control adult apple snails or snails that burrowed into the substrate. Neither could the species effectively control snails in vegetated ponds. There is as yet no experimental evidence that indicates black carp would be effective in controlling zebra mussels. Black carp are gape-limited predators; in addition, they do not have jaw teeth and their mouths are relatively small. As such, these fish are not capable of feeding on hard items larger than their gape width and they are probably not capable of breaking apart zebra mussel rafts. However, there is disagreement in terms of the effectiveness of black carp to control zebra mussels (French 1993, Rubinstein 1994, Ricciardi 1994) (See USE AS A BIOLOGICAL CONTROL AGENT, pp. 37-41)

4) Is induced polyploidy likely to be a successful means for insuring that breeding populations of black carp do not become established in U.S. waters? Specifically, what do we know about "reploidization" of triploid black carp? Assuming that there are no escapes of diploid individuals from breeding stocks (and no unauthorized shipments and subsequent releases or stockings of diploids), it is unlikely that a breeding population of black carp would become established in open U.S. waters. Concerning "reploidization", there is no evidence in the literature of fish that are triploids reverting to diploids (Exotic Species Workgroup 1994). According to researchers (Exotic Species Workgroup 1994; W. Shelton, pers. comm. 1994), triploid grass carp can produce some viable gametes, but the proportion of such gametes is extremely low and the reproductive potential of triploids is essentially zero. In general with triploid fish, the triploid females never fully develop ovaries, but triploid males can sometimes have the "false appearance of being fully developed." (See TRIPLOIDY AND GYNOGENESIS, pp. 32.)

5) If breeding populations do become established, are black carp likely to compete with indigenous species? If so, which types (or species) of indigenous species are most likely to be affected? Established populations of black carp are likely to compete with certain indigenous species that feed on small mollusks, for instance redear sunfish (Lepomis microlophus), pumpkinseed (L. gibbosus), freshwater drum (Aplodinotus grunniens), several ictalurid catfishes (e.g., the snail bullhead, Ameiurus brunneus), copper redhorse (M. hubbsi), river redhorse (M. carinatum), as well as a recently recognized sucker, the robust redhorse, surviving only in the Altamaha River drainage in Georgia. Some North American fish species that specialize on mollusks appear to be very susceptible to extinction. For instance, the copper redhorse is listed as threatened (Williams et al. 1989) and the harelip sucker, Lagochila lacera, is now extinct (Miller et al. 1989). Several North American river and lake turtles, the sawbacks (Graptemys spp.) and musk turtles (Stemotherus spp.), also feed heavily on mollusks and could be impacted by black carp. These include several that are Federally listed as endangered or threatened (i.e., G. flavimaculata, G. oculifera, and S. depressus). Selected bird species also feed heavily on mollusks (e.g., some waterfowl, the limpkin, and the endangered snail kite). In addition, larval and young black carp feed on zooplankton and aquatic insects; as such, they could potentially compete for food with small native fishes and with juveniles of larger native species. (See DIET, pp. 16-18.)

6) Are there any known life-history traits of black carp that indicate it has a high probability to become a nuisance species if self-sustaining populations become established in U.S. waters (e.g., high reproductive output, broad habitat tolerances, long life, etc.)? The major life-history traits of black carp that indicate it has a high probability to become a nuisance species if populations become established include its broad climate tolerance, long life span (probably in excess of 14 years) and its preferred diet of mollusks. The black carp is closely related to the grass carp and its reproductive requirements are likely very similar. It is probably safe to assume (based on information on grass carp), that once the black carp is established, the fish would be very difficult or impossible to eradicate, particularly in larger lakes and in open river systems. The United States has a high diversity of native aquatic snails and native mussels; in addition, there is a high level of endemism and many of the species are considered threatened or endangered. Because the black carp is known to feed heavily on mollusks, it is likely that an established population of this fish would cause a local decline in mollusk populations. If the black carp were to become established in a watershed with an endemic mussel or aquatic snail, the black carp could very well threaten the continued survival of that species. (See SIZE, pp. 6; HABITAT, pp. 14; DIET, pp. 16-18; NATIVE DISTRIBUTION, pp. 11-14; HABITAT, pp. 14; REPRODUCTION AND SPAWNING, pp. 19-21.)

7) What are the basic physical and biological requirements of the black carp (e.g., thermal tolerances, salinity tolerances, spawning and rearing habitat needs, etc.)? Based on the literature and its close relatedness to the grass, it would appear that the basic requirements of the black carp include: large, freshwater rivers with relatively strong currents (greater than 0.6 m/sec) for use as spawning habitat. Thermal tolerances are fairly broad although the species in its native habitat seems to be most common in temperate regions. In open waters, the fish may also require large populations of mollusks as a food resource. Floodplain or other backwater areas may also be required by black carp for use as nursery areas (for their young). (See HABITAT, pp. 14; REPRODUCTION AND SPAWNING, pp. 19-21; DIET, pp. 16-18).

8) If triploidy is deemed sufficient mitigation, what types of production or rearing facilities would be needed as broodstock holding units? If triploidy is deemed sufficient mitigation, diploids would need to be used only as broodstock and not for stocking or as biological control agents. A priority of any facility would be the containment of broodstock and prevention of accidental release or escape. As such, facilities for holding broodstock would be needed that were secure and located outside the flood zone. The triploid certification program for grass carp is completely voluntary and the purpose of the program is to assure state agencies that within the limits of the program, no diploids will be shipped to these states. The grass carp inspection program does not act as a law enforcement agency, but simply provides the service to record, report, and observe. The separate state agencies are currently responsible for their own law enforcement as pertains to grass carp (Exotic Species Workgroup 1994).

9) What is the potential range of spread in open waters of the United States? Appropriate habitats (i.e., large lowland rivers and canals) and climate are available throughout most of the United States. Preferred prey (i.e., aquatic snails and mussels) are locally abundant in most U.S. rivers. Based on its native distribution (about 22° N to about 51 N latitude), the potential range of spread of black carp in U.S. open waters could include most of the lower 48 states. (See NATIVE DISTRIBUTION, pp. 11-14; HABITAT, pp. 14; HISTORY OF INTRODUCTION, pp. 33-37; RATING ELEMENTS OF RISK MODEL, pp. 42-45). The exact interval between introduction of any diploid black carp to open waters and when they might first reproduce probably depends on a combination of factors: the numbers of diploid fish introduced, the length of the growing season, and the time required to reach sexual maturity.

IV. RECOMMENDATIONS

1) All 100% black carp (exclusive of brood stock) must be certified triploids.

2) Brood stock must be restricted to and maintained in aquaculture facilities where the probability of escape or flooding is essentially zero.

3) Develop a mechanism for verifying the location and distribution of all live black carp (diploids and triploids).

4) Research to date suggests that black carp may not be particularly efficient in controlling snail populations in U.S. aquaculture facilities. Further use of black carp, experimental or otherwise, for testing their effectiveness in the control of disease-carrying snails, such as the yellow grub (Clinostomum sp.), must be restricted to triploid individuals.

5) Release of triploid black carp into any streams, lakes, or reservoirs should be prohibited until there is additional research demonstrating that any such introduction will be beneficial (i.e., be effective in controlling zebra mussels and Asian clams) and will not cause significant harm to native mussel and snail populations.

6) Black carp as a pathway for disease should be further investigated. Until this is done no additional stocks of black carp should be brought into the country unless additional precautions are taken (water changes; only healthy fish, inspected by veterinarian, etc.).

7) Produce an identification guide to distinguish black carp from native and other nonindigenous fishes to reduce any risk of misidentification (e.g., if black carp do become more common in U.S. aquaculture, there is a risk that the species would be unintentionally introduced as "grass carp" to some areas).

8) Establish a quality assurance and education program for the above recommendations.

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