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LITERATURE REVIEW AND FEASIBILITY ANALYSIS REPORT ON ICHTHYOFAUNAL RECONSTRUCTION AS A TECHNIQUE FOR RESTORING LAKE APOPKA

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EXECUTIVE SUMMARY

Lake Apopka is highly eutrophic and in need of sound restoration and management. Several restoration options are being considered by the St. Johns River Water Management District, including a relatively new approach called biomanipulation. Biomanipulation or ichthyofaunal reconstruction involves the removal or introduction of fish in order to alter the lake trophic structure and ultimately improve water quality.

The goals of this project are to review the available literature on biomanipulation, compile an annotated bibliography on candidate species and biomanipulation, propose candidate fish species for introduction, and design pilot studies to determine the applicability of the proposed introduction/manipulation to the Lake Apopka environment.

The literature review revealed that biomanipulation approaches to lake management are still largely experimental. The results of most studies have been inconclusive. Most of the reviewed studies were conducted in temperate lakes where fish and plankton communities differ from those in subtropical lakes. Variable conditions, settings, and research designs which characterized most studies made projections to the Lake Apopka environment difficult at best. These problems highlight the need for preliminary studies prior to any attempt at biomanipulation in Lake Apopka.

To date, fish populations have been manipulated in two basic ways in attempts to improve water quality. The first, and most prevalent in the literature, involves removal of visual feeding zooplanktivorous fishes, resulting in enhanced populations of herbivorous zooplankters, which in turn feed upon unwanted algae and consequently improve water quality. The second involves the introduction of a filter-feeding fish to graze directly upon unwanted algae. Removal has been achieved by introduction of predators or by poisoning and restocking with a higher ratio of predators to planktivores.

Despite limited support in the literature, it appears that control of unwanted algae by manipulating filter-feeding fishes may have some merit in subtropical lakes. Filter-feeding fish may suppress algal growth directly by grazing, or enhance phytoplankton biomass indirectly by suppressing herbivorous zooplankton and by increasing nutrient availability. If direct effects of algal grazing are not offset by indirect enhancement effects, filter-feeding fish can suppress total phytoplankton biomass.

In Florida, most eutrophic lakes are numerically dominated by filter-feeding gizzard shad. This fact indicates their ineffectiveness at reducing algal biomass through feeding activities. In fact, it has been suggested that gizzard shad populations may enhance phytoplankton growth, and therefore removal of gizzard shad may result in improved water quality. An alternative to gizzard shad removal would be the

introduction of another filter-feeding fish to consume suspended matter (phytoplankton, zooplankton, and detritus).

We recommended two filter-feeders, silver and bighead carp, as best suited for pilot studies. Both species have been used in water quality control programs in culture ponds, wastewater treatment, and reservoirs (See Appendix A). This recommendation is tempered by the fact that both species are exotic and the careless release of such animals could have unpredictable impacts on the entire Oklawaha system. This is why the pilot studies are such an important part of evaluating a proposed introduction. The studies were designed to provide direct information on the utility of silver and bighead carps as algal control agents, but will contribute salient information on ecological effects of the carps on the Lake Apopka environment.

Pilot studies design includes two sequential phases. Phase I involves in situ studies at the mesocosm level. Littoral enclosures are proposed as experimental units within which to evaluate the effects of various fish combinations on plankton populations and water chemistry. Preliminary studies will be needed to estimate appropriate stocking densities and number of replicate treatments needed to statistically resolve pertinent water chemistry and plankton questions. In the actual experiment, effects of various combinations of fish (bighead and silver carp, and gizzard shad) on water chemistry and plankton variables will be evaluated by comparison with fishless control enclosures. Weekly monitoring of plankton and chemical variables for the period of one year is recommended. If Phase I results prove positive, Phase II, a small lake level experiment, should follow. The proposed site for Phase II is Lake Carlton, a small lake in the Oklawaha chain with environmental characteristics similar to Lake Apopka. Lake Carlton would be stocked with the appropriate combination of fish, followed by weekly monitoring of water chemistry and plankton for one year.

In summary, as a lake restoration technique, biomanipulation is still experimental. Other, more proven restoration options should be considered before biomanipulation is attempted. If biomanipulation is chosen as a management strategy, then pilot studies should be conducted first to evaluate the likelihood of success. We identified filter-feeding silver and bighead carp as the best candidate species for experimentation. However, alternatives should be evaluated prior to the introduction of exotic fishes.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

BACKGROUND

Lake Apopka forms the headwaters of the Oklawaha Chain of Lakes, a series of eutrophic lakes located in Central Florida approximately 25 km northwest of Orlando. Once a popular resort area noted for its game fishing, Lake Apopka and its sister lakes have steadily become more eutrophic, largely because of poor sewage treatment practices and direct backpumping of nutrient-enriched irrigation water into Lake Apopka and the Apopka-Beauclair Canal from low-lying muck farms on the northern shores of the lake. Sewage discharges from Winter Garden on the south shore of Lake Apopka began ca. 1922 to 1927, followed by muck farm discharges starting in 1942 (Table 1). Although in all likelihood, Lake Apopka has always been quite productive (D. Canfield, 1988, personal communication), primary productivity historically was dominated by dense stands of macrophytes. Despite high rates of external nutrient inputs, macrophytes continued to dominate until 1947, when hurricanes destroyed large amounts of the bottom vegetation. Opportunistic algal blooms appeared almost immediately, and have persisted unabated to the present.

With the advent of the Surface Water Management Act, funds have recently become available to examine various methods of restoration for Lake Apopka. On the list of strategies of interest to the St. Johns Water Management District is a relatively new technique known as biomanipulation, or ichthyofaunal reconstruction. The goals of this project are to review the available literature on biomanipulation/ ichthyofaunal reconstruction, compile an annotated bibliography, review relevant studies, propose candidate fish species for introduction, and design pilot studies to determine the applicability of the proposed introduction/manipulation to the Lake Apopka environment.

ENVIRONMENTAL STATUS OF LAKE APOPKA

Water Chemistry

Using a trophic state index based on total nutrient concentrations and chlorophyll *a*, Huber et al. (1982) ranked Lake Apopka as the 17th most eutrophic lake in Florida out of a sample population of 573 lakes. Table 2 summarizes the water chemistry of Lake Apopka between 1977 and 1980. These data, which represent the most recent published data on the lake, show that Lake Apopka is relatively alkaline (average pH 8.82) and highly enriched. Total phosphorus (P) and nitrogen (N) concentrations averaged 0.248 mg P and 4.5 mg N L^{-1} respectively; correspondingly, chlorophyll *a* concentrations averaged nearly 70 $\mu g\ L^{-1}$. Secchi disk transparency typically was less than 30 cm because of wind-induced resuspension of sediment particles as well as phytoplankton blooms (Tuschall et al., 1979 and Pollman et al., 1980).

Unlike most of the precipitation-dominated seepage lakes characteristic of Central Florida (Kanciruk et al., 1986), overall ionic chemistry in Lake Apopka is dominated by carbonate chemistry. Ca^{2+} and Mg^{2+} are the dominant cations (1.87 and 1.48 meq L^{-1} respectively); HCO_3^-

Table 1. Summary of the recent history of Lake Apopka (Adapted from: Clugston, 1963; U.S. Environmental Protection Agency, 1978).

Date(s)	Event(s)
1922-1927	Sewage effluent from Winter Garden first discharged into lake.
1924	Waste water from preparation of fresh fruit first discharged into lake.
1942	Discharge from muck farms begins.
1947	September hurricane(s) destroyed large amounts of bottom vegetation. First algal bloom reported in October.
1948	Citrus concentrate waste first discharged into lake. Chemical control of water hyacinths attempted. Apopka-Beauclair Canal opened.
1948-1950	Rooted aquatic vegetation disappears. Frequent algal blooms.
1950-1955	Game fishing peaks.
1952	Lake water level stabilized by control structure placed in Apopka-Beauclair Canal.
1957	Rough fish estimated as 82% of fish population (by number).
1957-1959	Three separate selective poisonings killed a total of 9 million kg (20 million lbs) of shad.
1963	In May, gas embolism killed 4.5-9 million kg of rough fish and 0.2 million kg of game fish.
1970	Rough fish estimated as 82% of fish population (by number).
1971	Experimental gravity drawdown. Death of alligators, turtles and fish attributed to Aeromonas (bacteria).
1976-Present	Abatement of muck farm discharges.
1977	Discharge of citrus concentrate wastes ends. Winter Garden begins construction of tertiary sewage treatment plants.

Table 2. Water chemistry in Lake Apopka, 1977-1980 (Adapted from: Brezonik et al., 1978 and 1981; Tuschall et al., 1979;3 and Pollman et al., 1980).

Parameter	Year				Mean
	1977	1978	1979	1980	
Secchi disk (cm)	30	28	25	23	26
pH	9.01	8.44	8.86	8.99	8.82
Specific conductance ($\mu S\ cm^{-1}$)	405	451	406	368	406
Ca^{2+} ($mg\ L^{-1}$)	48.9	32.9	36.3	37.5	38.9
Alkalinity ($mg\ L^{-1}$ as $CaCO_3$)	119	120	116	123	119
Cl^{-1} ($mg\ L^{-1}$)		36.8	37.8	40.4	38.3
SO_4^{2-} ($mg\ L^{-1}$)		21.0	25.3	28.9	25.1
TP ($mg\ L^{-1}$)	0.214	0.157	0.309	0.311	0.248
SRP ($mg\ L^{-1}$)	0.042	0.042	0.082	0.036	0.050
TON ($mg\ L^{-1}$)	3.3	4.6	4.8	4.9	4.4
NH_4^+-N ($mg\ L^{-1}$)	0.048	0.062	0.147	0.056	0.078
SiO_2 ($mg\ L^{-1}$)	2.49	2.46	2.37	0.97	2.06
TOC ($mg\ L^{-1}$)	45.9	77.4	76.4	79.7	69.6
DOC ($mg\ L^{-1}$)	28.5	53.8	29.6	42.6	39.7
IC ($mg\ L^{-1}$)	21.0	12.2	32.7	18.4	21.3
Chlorophyll *a* ($ug\ L^{-1}$)	39.1	60.7	84.1	85.3	67.3
TN/TP	18.5	35.7	16.2	17.5	22.0
TIN/SRP	4.1	3.7	3.3	4.1	3.8

and CO_3^{2-} together are the dominant anions (C_T approximately 2.38 meq L^{-1}). Shifts in pH occur, apparently related to changes in primary productivity (e.g., Kelts and Hsu, 1978); highest pH values tend to occur in the summer and lowest values in the winter (Pollman et al., 1980; Brezonik et al., 1981). Maximum pH levels observed in Lake Apopka between 1977 and 1980 typically approach 9.5, and biogenically induced calcite precipitation during periods of intense primary production may remove inorganic phosphorus from the water column through the formation of hydroxyapatite (Pollman, 1983).

During the period that Brezonik and co-workers monitored Lake Apopka, irrigation backpumping directly to the lake had been reduced and phosphorus concentrations in the lake were considered to have stabilized between 0.2 and 0.3 mg L^{-1}. Despite apparent reductions in external loading rates, no discernible reductions in total phosphorus (TP) and total nitrogen (TN) concentrations occurred between 1968-69 and 1977-80. Instead, nutrient concentrations fluctuated tremendously as a function of antecedent conditions, and sediment resupply of nutrients (i.e., internal loading) along with external supply, now appears to control nutrient dynamics in the lake (Pollman, 1983). Unpublished data collected by Reddy et al. since July 1988 and limited data collected by Crisman and Beaver (1988) show that the overall trophic state has not improved; for example, TP and TN concentrations during late summer 1987 averaged 0.50 mg P and 7.50 mg N L^{-1} respectively, and chlorophyll *a* concentrations averaged 168 μg L^{-1}.

Reflecting the virtually constant rain of algal-based detritus, the sediments in Lake Apopka are extremely flocculent and unstable (>96% water content; Pollman, 1983 and Reddy et al., 1988), with a net accretion rate of 20 cm between 1968 and 1987. The sediments represent a large pool of nutrients potentially available to the overlying water column; Pollman et al. (1988) estimate that the total labile pool in the unconsolidated sediments is 1.39×10^6 kg, or 11.2 g m^{-2} lake surface area. At an average depth of only 1.7 m, this pool represents 6.6 mg available phosphorus per liter of water column. Because Lake Apopka is so shallow and has such a broad fetch, sediment resuspension occurs frequently (Tuschall et al., 1979; Pollman et al., 1980), and inorganic phosphorus concentrations in the lake can more than double during a single, moderate wind event (cf. Pollman and Brezonik, 1979; Pollman, 1983).

The Redfield ratio of N:P concentrations in algal biomass has often been used to examine which major nutrient limits primary production. Brezonik et al. (1981) suggest that N:P >15 is indicative of P limitation, whereas N:P <5 indicates N limitation. Table 2 summarizes N:P ratios between 1977 and 1980 for both total and inorganic forms. Application of the Redfield ratio *sensu stricto* pertains only to available forms (cf. Stumm and Morgan, 1981), and average inorganic ratios in Lake Apopka range from 3.3 to 4.1. These ratios suggest nitrogen limitation but are not conclusive; the relationship between soluble reactive phosphorus (SRP) and true ortho-phosphorus is unclear, and there is some evidence that current analytical methods for SRP may over predict ortho-phosphorus by one to two orders of magnitude (Rigler, 1975).

Biological Conditions

Phytoplankton and Zooplankton. The most extensive data base on plankton community structure, densities, and seasonal dynamics was developed by Brezonik and co-workers between 1977 and 1980 (Brezonik et al., 1978, 1981; Tuschall et al., 1979; Pollman et al., 1980). More recently, Crisman and Beaver (1988) examined primary production and plankton dynamics in Lake Apopka during late summer 1987 as part of a series of *in situ* enclosure studies on the effects of biomanipulation on lake trophic state. This summary of current biological conditions is based on the results of these two major studies.

Primary productivity in Lake Apopka is high, with net primary production averaging 140 mg C m^{-2} h^{-1} in 1977. Crisman and Beaver (1988) measured net production rates averaging 74.1 mg C m^{-3} h.

Algal assemblages in Lake Apopka are dominated by Cyanophyta (blue-green algae), which contribute at least 60% of total algal abundance. Statistical analysis of monthly characterization data for 1977 through 1980 shows that cyanophytes were correlated with total phytoplankton ($r = 0.91$; $p < 0.001$), not only for Lake Apopka, but for the other downstream Oklawaha lakes as well (Brezonik et al., 1981). Chlorophyta (green algae) and Chrysophyta (principally diatoms) are the most important subdominants.

Brezonik et al. (1981) observed the following overall seasonal pattern of phytoplankton succession: during fall, winter, and early spring, the colonial blue-green *Microcystis incerta* is dominant; during spring and summer, filamentous blue-greens, notably *Lyngbya limnetica* and *Spirulina laxissima*, dominate. Brezonik et al. (1981) suggested this pattern was the result of changes in species-specific nutrient uptake rates as a function of temperature, and changes in zooplankton species composition and selective grazing pressures. In the downstream Oklawaha lakes, Brezonik et al. (1981) noted a correlation between total zooplankton density with chlorophyte abundance, apparently reflecting resource availability.

Total zooplankton densities for Lake Apopka between 1977 and 1980 are summarized in Table 3. Zooplankton abundance in Lake Apopka tends to peak in the winter and spring months when cladocerans become dominant (Brezonik et al., 1981). During the summer, calanoid copepods are dominant. The shifts in zooplankton dominance are not clearly understood, but appear to be interrelated with shifts in algal community structure. Mallin (1978) demonstrated that macrozooplankton, such as cladocerans, graze more efficiently on filamentous rather than colonial blue-green algae, and crashes in cladoceran and cyclopoid copepod populations in late spring account in part for concomitant shifts in phytoplankton dominance from *Microcystis* to *Lyngbya*.

Fishes. Lake Apopka hosts at least 27 species of fishes (Table 4), including two introductions. Recent surveys by Holcomb et al. (1977) and Johnson et al. (1982) indicate that the species represented in

Table 3. Plankton in Lake Apopka, 1977-1980. Data compiled from Brezonik et al. (1978 and 1981), Tuschall et al. (1979), and Pollman et al. (1980).

Parameter	Year				Mean
	1977	1978	1979	1980	
Phytoplankton density (no. cells $mL^{-1} \times 10^{-3}$)	313.2	497.9	299.8	280.5	347.8
Phytoplankton richness	21	23	24	26	24
Zooplankton density (no. individuals mL^{-1})	176	1416	1943	1697	1308

Table 4. Fishes collected from Lake Apopka during three surveys.

	Dequine and Hall (1951)	Holcomb et al. (1977)	Johnson et al. (1982)
Lepisosteus osseus	X	X	
Lepisosteus platyrinchus	X	X	
Amia calva	X	X	
Anquilla rostrata	X	X	
Dorosoma cepedianum	X	X	X
Dorosoma petense		X	X
Notemigonus crysoleucas		X	X
Notropis maculatus		X	
Erimyzon sucetta	X		
Ictalurus catus	X	X	X
Ictalurus natalis	X	X	
Ictalurus nebulosus	X	X	X
Noturus gyrinus		X	
Strongylura marina		X	X
Fundulus seminolis		X	X
Lucania goodei		X	
Gambusia holbrooki		X	X
Heterandria formosa		X	X
Poecilia latipinna			X
Menidia berylinna		X	X
Morone chrysops X saxatilis			X
Lepomis gulosus		X	
Lepomis macrochirus		X	X
Lepomis microlophus	X	X	X
Micropterus salmoides	X	X	X
Pomoxis nigromaculatus	X	X	
Tilapia aurea		X	X

the lake probably are similar to the pre-bloom ichthyofauna, but the relative abundances of the component species have changed dramatically.

Dequine (1950) documented the initial shift of the ichthyofauna during the period when the first phytoplankton blooms occurred. In 1947, gamefishes represented 35% of the lake's fish biomass; by 1950, as blooms persisted, gamefishes were 69% of the biomass. The latter resulted from a rise in the population level of the gizzard shad, specifically young individuals that served as perfect forage for larger gamefishes. As gizzard shad grew to adult size (and therefore too large for gamefish predation), and aquatic vegetation and gamefish spawning areas disappeared due to eutrophication and development effects, gamefish biomass levels crashed, reaching 18% in 1956 to 1957 (unpublished GFWFC brochure cited in Clugston, 1963). Data from 1973 to 1976 surveys placed gamefish biomass as 23% (Holcomb et al., 1977) and, even more importantly, noted that the major native gamefish, the largemouth bass, had essentially ceased reproducing.

Florida Game and Fresh Water Fish Commission efforts in Lake Apopka in recent years have concentrated on the reintroduction of largemouth bass and the introduction of an exotic gamefish, the hybrid sunshine bass (Johnson et al., 1982). Work concurrently continues in these areas and on sport and commercial fisheries (Marty Hale, John Barton, and Sam McKinney, personal communication).

LITERATURE SEARCHES

Literature searches were conducted using the Lockheed DIALOG Information Retrieval Service. The data bases searched were BIOSIS and Aquatic Science and Fisheries Abstracts. Several key word combinations were used--e.g., ichthyofaunal reconstruction, silver carp, bighead carp, pond studies. Most of the references identified through these searches are published journal articles. A considerable volume of literature on candidate species (i.e., silver carp, bighead carp) was found, and consequently these entries dominate the bibliography. Many additional references were added from personal libraries and on-site visits to regional libraries. In several cases, the actual document was not seen and only the citation and possibly an abstract were included in the bibliography. Entries without abstracts were included if they were considered important. The resulting annotated bibliography was compiled on WordPerfect version 4.2 using identifiers for each field (author, date, title, source, abstract) to make the file adaptable to data base programs. A printout of the annotated bibliography is included as Appendix A.

EVALUATION OF BIOMANIPULATION STUDIES

For the purposes of this review, we regard trophic structure manipulation (biomanipulation) and ichthyofaunal reconstruction as different terms for the same process of interest--biologically controlling unwanted algae and improving water quality in culturally eutrophic lakes by the addition or removal of consumers (fish). Policy makers and managers view this biological control concept as an attractive alternative to more expensive or logistically constraining, but effective, methods of eutrophication control such as diversion or abatement of nutrient inputs.

Biomanipulation theory is based on the concept that biomass and abundance of organisms in pelagic food webs are controlled by consumers (McQueen et al., 1986). Therefore, we begin with a brief review of the impact of planktivorous fishes on plankton communities in freshwater systems. Direct and indirect effects of particulate and filter-feeding fishes are discussed and related to the theory of biomanipulation as a lake management strategy. This discussion is accompanied by a review of descriptive and experimental studies concerning the impact of fish predation on planktonic communities.

IMPACT OF PLANKTIVOROUS FISHES ON PLANKTON COMMUNITIES

Planktivorous fishes, through selective feeding activities, are known to exert various influences on plankton numbers, biomass, size distribution, and species composition in lentic systems (see Lazzaro, 1987 for review). This knowledge has led many to cite predation along with competition and nutrient input to be an important factor in the structuring of freshwater communities (Zaret, 1980).

Plankton-feeding fish may be classified as particulate feeders, which visually select their prey, or as filter feeders, which selectively strain plankton from the water column (Lazzaro, 1987). Particulate feeders can cause shifts in the size distribution of zooplankters within a community by reducing populations of large-bodied herbivorous forms, such as Daphnia spp. In addition, eutrophic lakes are often characterized by an absence of large-bodied zooplankters and an abundance of planktivorous fishes (Nilssen, 1984). There have been many documented cases of this relationship in both experimental (e.g. Lynch, 1979; Hurlburt and Mulla, 1981; Post and McQueen, 1987) and descriptive (Stenson et al., 1978; Timms and Moss, 1984; Spencer and King, 1984; Shapiro and Wright, 1984) studies. These observations prompted Shapiro (1979) to propose that manipulations of planktivore populations could be used to indirectly control unwanted algal populations in eutrophic lakes. To date, most studies have employed conducted manipulations of visual feeders (e.g., Hrbacek et al., 1961; Andersson et al., 1978; Stenson et al., 1978; Benndorf et al., 1984; Goad, 1984; Shapiro and Wright, 1984; Post and McQueen, 1987).

The addition of filter-feeding fishes to graze directly on unwanted algae and improve water quality in culturally eutrophic lakes and reservoirs has been proposed (Vovk, 1974; Aliyev, 1976; Barthelmes, 1982; Crisman, 1986; Drenner et al., 1987). However, little information

is available concerning the impacts of direct grazing on plankton in eutrophic waters (but see Drenner et al., 1986, 1987; Leventer, 1981, 1987).

It is evident that biomanipulation approaches could include removal of particulate-feeding fish to indirectly enhance algal grazing by zooplankters, or the introduction of filter-feeding fish to directly ingest algae.

REVIEW OF SELECTED STUDIES

For comparative purposes, we have divided relevant studies into experimental and descriptive (quasi-experimental) studies, following Hurlburt and Mulla (1981). Experimental studies were defined as those that included adequate controls and replication, and descriptive (quasi-experimental) studies were defined as those that lacked controls and/or replication. In addition, in studies where only one replicate per treatment was used, inferential statistics could not be applied (Hurlburt, 1984). Summary tables adapted from Hurlburt and Mulla (1981) were used to compare salient features of pertinent studies in terms of the effects of fish manipulation on water quality and plankton community dynamics (Tables 5 and 6).

Experimental Studies

Hall et al. (1970) conducted experiments using bluegill (Lepomis macrochirus), and documented considerable effects on diversity and size distribution of zooplankton. Bluegill, known visual feeders, had much greater influence on prey populations than did invertebrate predators.

Hurlburt and Mulla (1981) found that high densities of visually feeding mosquitofish (Gambusia affinis) greatly reduced zooplankton numbers in comparison with control (no fish) pools. Cladocerans (Daphnia pulex and Ceriodaphnia sp.) were almost completely eliminated, whereas cyclopoid copepods were slightly affected. Phytoplankton increased in the presence of fish, with corresponding changes in pH and dissolved oxygen.

Lynch and Shapiro (1981) examined the indirect effect of fish predation on phytoplankton communities. They found that in enclosures containing bluegill (Lepomis machrochirus), algal biomass increased an order of magnitude over the control (no fish) densities due to the increase of Oocystis lacustris, Anabaena civernalis, and Aphanizomenon sp. These algal species were not found in the controls, indicating that fish predation had caused a change in taxonomic structure as well as biomass.

Vanni (1987a) found that phytoplankton density increased in response to nutrient enrichment in enclosures with or without fish. He also found that nutrient enrichment increased phytoplankton density to a much greater extent than did the reduction in zooplankton size due to fish predation.

Table 5. Summary of effects of fish introduction as demonstrated by experimental studies. Letters indicate changes in ponds or enclosures with fish relative to fishless controls.

	Study						
	Lynch (1979)	Goad (1984)	Post and McQueen (1987)	McQueen and Post (1988)	Crisman and Beaver (1988)		Vanni (1987a)
	Fish Species						
	Lepomis macrochirus	*Perca flavescens* *Salmo gairdneri*	*Perca flavescens*	*Perca flavescens*	*Tilapia aurea*	*Dorosoma cepedianum*	*Lepomis macrochirus*
Experimental conditions							
Pond surface area (m^2)	1.0	4.0	50.3	50.0	10.0	10.0	12.5
Maximum depth	1.8	3.0	15.0	15.0	2.0	2.0	1.3
Macrophytes present	no	no	no	no	no	no	no
Fish length (mm)	75-114	25-50	?	?	340	170	
Stocking rate (no./m^2)	1.3-6.3	5-50	200-600	30-50	0.8	0.8	
Replicates/treatment	1-2	1	1	1	3	3	3
Phytoplankton							
Standing Crop	I	V	V		I		V
Zooplankton numbers							
Total rotifers	I	a	V	?	V	NC	I
Total cladoceran	I	a	I	D	I	D	I
Total copepods	NC?	a	D	?	V	D	V
Total zooplankton	I	I	V	D	V	D	D
Zooplankton numbers: ratios							?
Rotifers/crustaceans	I	a	a	?	D	I	I
Cladocera/copepods	I	D	D	?	I	D	?
Large cladocera/small caldocera	D	V	D	D	I	a	I
Calanoida/cyclopoida	D	V	NC	?	NC?	NC	
Predaceous insects							
Transparency	?	a	D	D	NC	NC	a
Total phosphorus	?	a	NC	?	NC	I	V
Total nitrogen	?	a	NC	?	V	I	V

NC = No Change
I = Increase
D = Decrease
V = Variable
a = Absent, not recorded
? = Uncertain or not determined

Table 6. Summary of effects of fish removal or introduction as suggested by descriptive studies.

	Study				
	Hrbacek et al. (1961)	Brooks and Dodson (1965)	Wells (1970)	Hutchinson (1971)	Stenson et al. (1978)
	Fish Species				
	Various	Alosa Psuedharenqus	Alosa Psuedharenqus	Alosa Psuedharenqus	Various
Lake or Reservoir Characteristics					
Surface area (ha)	0.18	80.0	57×10^5	10.0	1.0
Maximum depth (m)	5.56	14.0	281.0	18.0	8.0
Macrophytes present?	?	yes	yes	yes	?
Other fish present?	?	yes	yes	yes	?
Removal/Introduction	Removal	Removal	Removal	Removal	Removal
Phytoplankton					
Standing crop	D	I	?	?	I
Bluegreen					
Green					
Other					
Zooplankton					
Total rotifer	D	I	?	?	?
Total cladoceran	I	D	D	D	D
Total copepodids	D	NC	D	D	I
Total zooplankton	D	D	D	D	I
Zooplankton ratios					
Lg. cladoceran/sm. cladoceran	I	D	D	D	I
Calanoidea/cylopoidea	?	D	D	D	?
Cladocera/copepodids	?	I	D	NC	?
Transparency	I	?	?	?	I
Total phosporus	V	?	?	?	D
Total nitrogen	V	?	?	?	a

NC = No Change
I = Increase
D = Decrease
V = Variable
a = Absent, not recorded
? = Incertain or not determined

Table 6. (Continued.)

	Study			
	Andersson et al. (1978)	Henrickson et al. (1980)	Shapiro and Wright (1984)	Benndorf et al. (1984)
	Fish Species			
	Carassius carpio *Abramis brama* *Rutilus rutilus*	*Leuciscus rutilis* *Perca fluviatilis*	*Stizostediun vitreum* *Micropterus salmoides* *Lepomis macrochirus*	*Salmo gairdneri*
Lake or Reservoir Characteristics				
Surface area (ha)	.0007	1.0	12.6	0.044
Maximum depth (m)	2.2	8.0	10.5	7.0
Macrophytes present?	no	?	yes	no
Other fish present?	no	?	no	yes
Removal/Introduction	Removal	Removal	Introduction	Introduction
Phytoplankton				
Standing crop	I	I	V	NC
Zooplankton				
Total rotifers	I	?	a	I
Total cladocerans	D	D	D	I
Total copepods	V	I		I
Total zooplankton	?	I	D	I
Zooplankton ratios				
Lg. cladoceran/sm. cladoceran	D	I	I	I
Calanoidea/cylopoidea	V	?		?
Cladocera/copepodids	D	D		?
Transparency	?	I		I
Total phosporus	I	D	D	?
Total nitrogen	?	D	D	?
Primary production	a	D	a	?

NC = No Change
I = Increase
D = Decrease
V = Variable
a = Absent, not recorded
? = Uncertain or not determined

In a series of experiments Vanni (1987b) tested the hypothesis that zooplankton communities were not affected by food availability or fish predation. By manipulating both food availability and fish numbers, he showed that overall population densities of zooplankton were influenced more by food availability than by fish predation. He also found that small-bodied zooplankton communities were better able to withstand predation pressure by altering life history characteristics (age at first reproduction, fecundity etc.).

Post and McQueen (1987) manipulated the densities of yellow perch in enclosures located in a eutrophic lake, Lake St. George, Canada. They controlled phosphorus loading in an attempt to alleviate the confounding factor in Shapiro and Wright's (1984) study. The expected negative relationship between zooplankton and fish was found. A geometric mean regression indicated an inverse relationship ($r^2 = -0.77$, $n = 54$) between fish biomass and zooplankton biomass in the enclosures. Their fish free enclosure had consistently greater clarity (Secchi depths of 3.0 to 5.0 m) than fish enclosures (Secchi depths ranging 1.0 to 3.0 m). Phytoplankton was only weakly correlated with zooplankton biomass. Initially, phytoplankton biomass was lower in fish free enclosures, presumably due to zooplankton grazing, but during blooms, phytoplankton biomasses were high in all enclosures despite the presence of herbivorous zooplankters. The authors suggested that zooplankton grazing rates were insufficient to control these blooms, and on the average, zooplankton size structure has only a weak effect on phytoplankton biomass.

In a similar study, these same authors (McQueen and Post, 1988) found that high Daphnia biomass was correlated with increased water clarity and a spring "clear-water" phase. During the summer, water quality degraded due to an abundance of the alga Gloeococcus that was a poor food source for Daphnia. However, data from all enclosures showed no correlation between Daphnia biomass and percentage of poor food source algae. This led the authors to suggest that grazer effects were not necessary for the onset of the summer blooms.

The only study actually performed in a subtropical lake (Lake Apopka), was that of Crisman and Beaver (1988) who used enclosures stocked with blue tilapia (Tilapia aurea) and gizzard shad (Dorosoma cepedianum) to evaluate their impacts on water quality. Although this study was short term, some interesting results were obtained. Enclosures containing only blue tilapia had elevated numbers of larger cladocerans, but no change in chlorophyll, nutrient concentration, or water clarity relative to controls. In gizzard shad enclosures, zooplankton numbers were significantly lower, but the relationship between zooplankton and phytoplankton was similar to that seen in the tilapia treatment. Gizzard shad were thought to be responsible for nutrient enrichment within their treatments.

Descriptive Studies

The first demonstrations of the relationship between fish predation and zooplankton communities were by Hrbacek et al. (1961),

Brooks and Dodson (1965), and Straskraba (1967). Brooks and Dodson (1965) showed that size-selective predation by fishes can greatly reduce the average size and species composition of zooplankton communities. The introduction of a filter-feeding planktivore (the alewife Alosa pseudoharengus) into a small New England Lake caused changes, including altered taxonomic composition and average size of the herbivorous forms when compared with a similar lake not stocked with alewives. Other authors have provided additional comparative evidence on the impacts of planktivorous fish removal or introduction on zooplankton communities following fish-kills or from observations on various water bodies (e.g., Wells, 1970; Hutchinson, 1971; Spencer and King, 1984; Timms and Moss, 1984).

In Sweden, Stenson et al. (1978) used rotenone to keep one small lake free of fish for several years and compared the consequent effects on plankton communities and water quality to a nearby "reference lake." Both lakes were oligotrophic. In the rotenone treated lake the authors found that primary productivity was reduced by approximately 90%; biomass of net phytoplankton increased (dominance of Pyrrophyta); zooplankton changed from a dominance of small cladocerans (Bosmina longirostris) to a dominance of large copepods (e.g., Eudiaptomus gracilis); transparency increased; pH was lowered, probably reflecting the lowered primary production; total phosphorus concentration was lowered; and invertebrate plankton predators increased in abundance.

In Round Lake, Minnesota, Shapiro and Wright (1984) conducted a biomanipulation study involving complete removal of all fishes followed by restocking with a different assemblage. Prior to manipulation, Round Lake was characterized by high transparency and supported abundant piscivore populations. Over a period of years, the lake became eutrophic with low transparency and dominated by planktivorous (black crappie Pomoxis nigromaculatus, and bluegill Lepomis macrochirus) and benthivorous (black bullhead Ictalurus melas) fishes. These species were removed from the lake using rotenone; the lake was then restocked with piscivorous walleye (Stizostedion vitreum) and largemouth bass (Micropterus salmoides) at a ratio of 2.2 bluegills to one piscivore. Channel catfish (Ictalurus punctatus) were added to prevent the reestablishment of black bullhead. For two years following the restocking, zooplankton and phytoplankton community composition, transparency, and total nitrogen and phosphorous were monitored. Secchi transparency averaged 2.1 m for the pre-biomanipulation year and increased to a mean of 4.8 m during the post-biomanipulation year; however, readings for individual months decreased to pre-biomanipulation levels. The zooplankton communities shifted to dominance of large bodied species, especially Daphnia. Phytoplankton biomass decreased presumably due to increased grazing pressure by zooplankters, however an observed decrease in nutrient loadings complicated this assertion.

Benndorf et al. (1984) added piscivorous fish to a small eutrophic lake and followed the subsequent changes in ecosystem parameters. The biomass of planktivorous fishes declined rapidly; herbivorous zooplankton biomass increased by 400%, due mostly to increases in Daphnia hyalina and D. cucullata. The authors felt that predation by invertebrates was an important factor producing these

results. There was an increase in body size of crustacean zooplankton in late summer and fall. Despite the increased grazing pressure by zooplankton, phytoplankton biomass did not change. Transparency in the lake increased considerably over the two-year observation period.

As noted above, the impacts of filter-feeding fishes on plankton communities have received relatively little attention in terms of biomanipulation. Filter feeders can reduce phytoplankton by direct grazing or enhance them by suppressing herbivorous zooplankton and by increasing nutrient availability. If the direct effects are not countered by these enhancement effects, filter feeders can suppress total phytoplankton biomass.

Empirical and experimental studies examining the effects of filter-feeding silver carp on water quality and plankton communities have been conducted in Europe (Kajak et al., 1975) and Israel (Leventer, 1987). The Israeli project is by far the most closely monitored and probably the only working example of biological control in water quality management. Aspects of this program have been detailed by Leventer (1981, 1987). Several fish species were used to control various components of the food webs in a series of reservoirs known as the Israeli National Water Carrier (INWC), with silver and bighead carp used to control phytoplankton and zooplankton, respectively. In Lake Kinneret, the ultimate water supply for the INWC, silver carp were introduced over the past 15 years (Spataru and Gophen, 1985; Leventer, 1987). The authors noted that the number of phytoplankton Peridinium, the most abundant species in the lake, was not related to the presence of silver carp. Leventer (1987) monitored various water quality parameters as well as plankton between the first reservoir and the source, Lake Kinneret, and compared plankton numbers between the intake and the lake; he attributed changes in phytoplankton and zooplankton numbers to the presence of silver and/or bighead carp. According to this analysis, phytoplankton levels decreased each year since 1976. Within one year (1985), the suspended matter reduction was significantly greater with higher densities of fish. From Leventers' (1987) report it is difficult to evaluate the success of the project, as his methods are comparative and reflect a "wait and see" approach typical of many exotic introductions (Courtenay and Robins, 1988).

Drenner et al. (1987) studied the effects of Tilapia galilea which grazed on phytoplankton and zooplankton as a function of particle size. They also found crustaceans, rotifers, and Peridinium spp. declined as functions of fish density. The suppression of Peridinium spp. by fish, resulted in a reduction of total chlorophyll and gross primary production. Drenner et al. (1984) found that algae consumed by fish may include net phytoplankton that are too large to be ingested by herbivorous zooplankton.

Critique of Biomanipulation Studies

There are several problems with the biomanipulation studies that have been conducted to date. The available studies have been short-term, and for the most part correlative; adequate experimental confirmation of many parameters is sorely lacking. Most of the purported

experimental studies reviewed were actually quasi-experimental (Hurlburt, 1984). In addition, McQueen and Post (1988) contend that biomanipulation theory often fails to explain the observed outcomes. They point out that decreases in water quality following the predicted spring clear-water phase seen in several studies was not attributable to reduced zooplankton grazing. Crisman and Beaver (1988) also found high chlorophyll concentrations in the presence of fish-enhanced populations of herbivorous zooplankters.

Another factor not adequately addressed in the fish removal studies is the impact of rotenone on plankton communities (Lazzaro, 1987). Concentrations used to kill fish are strong enough to kill zooplankton and phytoplankton. The consequences of this in relation to interpretation of study results is not known (Henrickson et al., 1980; Cooke, 1986).

These problems aside, the biomanipulation studies have generally shown that the negative relationship between planktivores and zooplankton is predictable. However, effects on the zooplankton-phytoplankton relationship are less predictable (McQueen and Post, 1988), apparently because many complex interactions taking place at this level are not known. Further, most of the case studies have been conducted in temperate lakes, where larger bodied zooplankters (e.g., Daphnia spp.) are more common (Lazzaro, 1987). The ability of large bodied cladocerans to adequately graze and assimilate phytoplankton is central to the success of this type of biomanipulation. In tropical and subtropical lakes, zooplankton communities are characterized by smaller mean body size (Bays and Crisman, 1983; Nilssen, 1984). This information suggests that removal of visual selective predators would not trigger a negative response on the phytoplankton assemblage through zooplankton grazing. However, the removal of filter-feeding gizzard shad may improve water quality in Lake Apopka by reducing the planktivorous and nutrient enchancing effects of the shad.

Despite the apparent success of some experiments discussed in this report, biomanipulation as a lake management strategy, is still in its infancy and should be regarded as experimental rather than operational in the sense of mechanical and chemical methods (Cooke, 1986).

PILOT STUDY DESIGN

APPLICABILITY OF BIOMANIPULATION TO LAKE APOPKA

The literature does not provide enough information to make definitive statements regarding the potential effectiveness of biomanipulation in a subtropical lake such as Apopka, and all alternatives should be carefully evaluated prior to consideration of this approach as a management strategy. However, biomanipulation may provide some proximate improvements to water quality. If for some reason, political, economic or otherwise, a biomanipulation approach to managment is desired, we have provided in the following sections the basic pilot study design that should accompany any such attempt. The program begins with candidate species selection and is followed by pilot study design.

SELECTION OF CANDIDATE FISH SPECIES

As mentioned previously, impacts of direct grazing by phytophagous species have received considerably less attention than grazing by sight feeding planktivores despite the suggestions of several authors (Crisman 1986; Drenner et al., 1986; Lazzaro, 1987) that direct grazing filter-feeding fishes would be worthy of investigation as algal control agents, particularly in subtropical lakes. We agree with these authors that a filter-feeding fish would be the best candidate for the Lake Apopka situation.

Water quality management often includes the introduction of filter-feeding fishes such as the exotic Tilapia spp. or silver and bighead carps. The intentional use of exotic species as means of biological control raises concern over potential ecological impacts. Any introduction of an exotic species into a native environment results in physical and biological alterations of that environment (Simberloff, 1981; Taylor et al., 1984). In fact, the effect we are seeking, phytoplankton control, is by definition a biological alteration. Environmental consequences of the accidental or intentional release of exotic fishes into native aquatic ecosystems have been extensively reviewed (Courtenay and Robins, 1973; Li and Moyle, 1981; Taylor et al., 1984; Courtenay and Robins, 1988). A classification of the ecological effects of introduced exotic fishes on native aquatic communities is presented in Table 7 based on Taylor et al. (1984). All these effects could potentially occur in Lake Apopka if exotic fishes are released for water quality management. Predicting which effects might be important is difficult. A major concern would be the potential spread of exotic fish throughout the Oklawaha chain of lakes and ultimately into the St. Johns River. The ecological ramifications of such an undesirable scenario are unknown, but, many or all of the effects listed in Table 7 are possible.

Despite the possibility for ecological calamity, purposeful introductions may actually work if proper steps are taken prior to any introduction (Courtenay and Robins, 1973). Most intentional stockings of exotic fishes have been undertaken on a trial and error basis, and many have been costly failures (Courtenay and Robins, 1973, 1988). This again underlines the significance of the pilot studies presented herein.

Table 7. Classification of ecological effects of introduced, exotic fishes on native aquatic communities (From: Taylor et al., 1984).

I. Habitat alterations

- A. Removal of vegetation
  1. by consumption
  2. by uprooting
  3. by increasing turbidity
- B. Degradation of water quality
  1. by siltation
  2. by substrate erosion
  3. by eutrophication

II. Introduction of parasites and diseases

III. Trophic alterations

- A. Forage supplementation
- B. Competition for food
- C. Predation

IV. Hybridization

V. Spatial alterations

- A. Aggressive effects
- B. Overcrowding

An initial question when considering an exotic introduction is: "Will a native species achieve the desired results?" Therefore we first considered manipulation of a native filter feeder--the gizzard shad.

Feeding studies on gizzard shad indicate that they are omnivorous pump-filter feeders that strain a variety of benthic and suspended particles (Bodola, 1965; Baker and Schmitz, 1971; Jester and Jensen, 1972; Jude, 1973; Pierce et al., 1981). These studies also mentioned that detritus was important; one study reported direct observations of shad actually feeding on the substrate (Baker and Schmitz, 1971). These factors suggest that gizzard shad may not have significant impacts on plankton numbers and/or species composition over time. Further, the numerical dominance of gizzard shad in Lake Apopka at present demonstrates its ineffectiveness as a direct phytoplankton grazer. Gizzard shad may actually enhance phytoplankton populations through increases in internal nutrient loading and differential ability to digest algae. Assuming that gizzard shad do enhance phytoplankton biomass in Lake Apopka, large scale removal has been proposed and is currently being tested at the small lake level. This study is significant in the light of using a native species for biomanipulation. If this approach is unsuccessful, the introduction of another filter-feeding species may be appropriate.

We have directed our search for candidate filter-feeding species to two Asian carps, the silver carp (Hypophthalmichthys moltrix) and the bighead carp (Hypophthalmichthys nobilis). These species have been used extensively in the aquaculture field and there is a considerable body of literature available on their feeding habits, mostly from pond studies (Bialokoz and Krywosz, 1981; Burke et al., 1986; Cremer and Smitherman, 1980; Jennings, 1988; Kajak, 1977a,b; Kajak et al., 1977; Kajak et al., 1975; Kajak and Zawisza, 1973; Milstein and Hepher, 1985; Milstein et al., 1985; Milstein et al., 1988a,b; Moav et al., 1977; Omarov and Lazareva, 1974; Opuszynski, 1968; Opuszynski, 1981; Sapiro, 1985; Shan et al., 1985; also see Appendix A). Again we would only advocate the use of one or both of these fishes as biological control agents after the alternatives have been exhausted. Should the proposed introduction meet all of the necessary requirements (Courtenay and Robins, 1973), then, and only then, we believe that the silver and/or bighead carp will be the best candidates on which to perform experiments.

Silver and bighead carp were first used for biological control of phytoplankton in polyculture systems (e.g., Moav et al., 1977; Lin, 1978; Costa-Pierce et al., 1985). Both species are filter feeders, but due to differences in the branchial feeding mechanism, each filters different sizes of particles (Spataru, 1977; Burke et al., 1986). In general, the silver carp tends to consume mostly phytoplankton, whereas the bighead carp feeds on large quantities of zooplankton and detritus, as well as phytoplankton.

Food Habits

Silver carp feed on a variety of suspended matter (algae, zooplankton, and detritus) but are considered phytoplanktivorous. Particles are strained through a specialized gill raker mechanism with

openings of about 20 mμ (Burke et al., 1986; Spataru, 1977). The presence of a suprabranchial organ which secretes mucous could contribute trapping very small particles such as bacteria. Several authors have examined the feeding habits of silver carp in culture ponds (Spataru, 1977; Cremer and Smitherman, 1980; Burke et al., 1986; Opuszynski, 1979; Januszko, 1974; see Appendix A.), eutrophic lakes (Kajak et al., 1977), wastewater treatment lagoons (Henderson, 1983), or reservoirs (Leventer, 1980, 1987; Spataru and Gophen, 1985; Sapiro, 1985; Moskul et al., 1974). From these reports it is apparent that silver carp feed upon phytoplankton, zooplankton, bacteria, and detritus. Kajak et al. (1977) reported that silver carp were capable of considerable selectivity in food habits. Leventer (1981) found that silver carp consumed algae present and almost all suspended matter in relation to their proportion in the Israeli reservoirs. In Tsalmon reservoir, the fish subsist on Peridinium cinctum from January to May; in the summer they feed upon blue green algae Chroococcus and Microcycstis. In an adjacent reservoir, silver carp feed upon Dinobryon in the spring and in autumn and winter it consumes diatoms Phacus and Euglena. Leventer (1987) reviewed the literature on silver carp feeding studies and concluded that they feed on bacteria, algae, zooplankton, and detritus. For our interests, it does appear that silver carp will consume algae, including blue greens (Kajak et al., 1975). Leventer (1987) indicated that detritus was quantitatively, very important, however, Lin et al. (1983) confirmed that detritus was of limited nutritional value to the fish. The same result was found by Moskul (1974). There also appears to be size related changes in dietary composition; larger fish consumed more phytoplankton (Sapiro, 1985; Leventer, 1987). Significant amounts of zooplankton were found in the guts of silver carp from Lake Kinneret by Spataru and Gophen (1985). Furthermore, Bitterlich and Gnaiger (1984) found that zooplankters were rapidly digested in the gut fluid of silver carp and suggested this as a reason for the scarcity of zooplankton in silver carp gut contents analyses.

Bighead carp are also filter feeders, but due to morphological differences they consume larger sized particles than silver carp. Big head carp have been used in polyculture systems to control water quality though not as frequently as the silver carp. A recent review of biological data on bighead carp was compiled by Jennings (1988). The primary food items are zooplankton, algae, detritus, and possibly bacteria. Moskul (1977) found bighead carp to feed upon algae, zooplankton, and suspended organic material. In the Israeli reservoirs, Leventer (1981) reported that the bighead carp consumes mostly zooplankton (cladocerans and copepods) until the numbers are reduced; they then feed near the bottom of the reservoirs where they consume filamentous algae.

Effects on Water Quality in Ponds

In some pond studies (Januszko, 1979; Opuszinsky, 1979; Leventer, 1987) the amount of phytoplankton in ponds containing silver carp increased while zooplankton decreased. Opuszinsky (1979) stocked silver carp at high density (4000 to 12000 ha^{-1}) when these results were obtained. This prompted Opuszinsky (1979) to advance the theory of "ichthyoeutrophication", which contends that fish digestive activities

contribute to the nutrient loading of the pond. Burke et al. (1986) investigated using silver and bighead carp in polyculture with channel catfish. They found a reduction of zooplankton density between treatment and control ponds; however, phytoplankton biomass was significantly higher in ponds containing silver and bighead carp than in control ponds. The species composition of the phytoplankton community may be altered by the silver carp feeding. This causes a shift to smaller sized zooplankters accompanied by an overall increase in nannoplankton. They also concluded that their stocking densities were too high. Smith (1985) found silver carp to be effective in controlling unwanted algae in plastic pools when a refuge was used to keep zooplankton away from the carp. In this system, the silver carp grazed on small zooplankters and algae and the larger zooplankters (protected by the refuge) fed upon the smaller algae.

As discussed earlier, both silver and bighead carp species were included as the plankton consumers in a multi-species biological control project in a series of Israeli reservoirs (Leventer, 1981, 1987). Results of these studies have been contradictory and difficult to compare because of differences in design and geographic setting. Evaluation of the effectiveness of either species as biological control agents will indeed require field studies in the Lake Apopka environment. Others have pointed out the disparities among studies and Spataru and Gophen (1985) stressed the need to conduct independent pilot studies relevant to the body of water receiving the introduction.

PHASE I ENCLOSURE STUDIES

In Situ Rationale

If fish introduction is considered the best alternative for short-term modification of the existing ecology of Lake Apopka, then properly designed pilot studies are required before wholesale introductions are initiated. Pilot studies should provide, on a small scale, replication of existing ecological conditions and allow the accurate monitoring of the system as biomanipulation (exotic fish introduction) runs its ecological course.

Traditionally, experimental pond studies have been used to estimate responses of aquatic systems to stress (see extensive bibliography in Brazner et al., 1987). Although natural ponds are sometimes used, man-made ponds have been the more frequently chosen pathway for field studies. Ponds are dug out and lined with plastic sheeting or cement (the safest route since "trickle" effects are negated) or soil. This approach has numerous limitations, the most obvious being the inability to accurately reproduce the existing ecological conditions of the larger body of water. Artificial ponds, in part because of their small size, are also subject to more abrupt and far-reaching biological and physical environmental fluctuations than the larger target lake. When these limitations are coupled with the costs associated with construction of lined man-made ponds, it becomes clear that an alternative enclosure test system is desired.

The use of littoral enclosures is considered the best strategy. As demonstrated by Brazner et al. (1987), this system

1) is suited for use in lakes;
2) is relatively simple and economical;
3) is conductive to accurate environmental chemistry studies;
4) allows for true experimental replications;
5) includes the natural, undisturbed sediment and shoreline;
6) is representative of the aquatic ecosystem being portioned; and
7) includes habitats impacted directly or indirectly by actual use.

It is our opinion that use of littoral enclosures will best provide the information needed to determine if full-scale exotic fish introductions are justified in Lake Apopka.

The major potential problems involved with enclosure studies are patchiness of distribution of plankton in the lake's water (i.e., will all enclosures receive the same inoculation of plankton?) and maintenance of the integrity of the enclosures against waves and wind. The latter should be soluble from an engineering standpoint.

Study Site Selection

Placement of the littoral enclosures is recommended at a site on the eastern shore of Lake Apopka because of the prevailing easterly winds in the area. Exact placement will depend on accessibility and land ownership restrictions, but the area adjacent to Crown Point might be desirable since the point potentially could offer additional protection from westerly and southwesterly winds.

Experimental Design

We propose the construction of littoral enclosures to test the effects of bighead carp and silver carp on existing Lake Apopka ecology. The quantified inclusion of gizzard shad, the abundant native filter feeder in Lake Apopka, an important player in its ecology, is also included in our experimental design. Eight experimental combinations are thus required: bighead carp, silver carp, and gizzard shad alone; bighead-silver, bighead-gizzard, silver-gizzard, and all three in combination; plus a control (none of the three species). For an optimal design, a preliminary study using several enclosures will be needed to determine within combination variability. Using the variance estimates from these preliminary studies, power analyses (Cohen, 1977) can be used to determine number of replicates needed to detect the desired degree of change in the measured variables (chlorophyll _a_, zooplankton biomass, phytoplankton biomass, nutrient levels, etc.). A preliminary study will also be needed to determine appropriate stocking densities of the candidate fishes. Following their review of manipulative fish pond studies, Hurlbert and Mulla (1981) recommended at least four replicates of each treatment if inferential statistical tests are to be performed. The concept of preliminary studies, prior to the actual experiment is to assure a sound design allowing the application of inferential statistics

(Hurlburt, 1984). From a statistical analysis standpoint, univariate or multivariate analysis of variance could be applied to this repeated measures design.

Brazner et al. (1987) utilized 5 m x 10 m enclosures in a 2 ha pond. We also believe this size enclosure is appropriate for the proposed design. Although it might be nice to have larger enclosures from a fish perspective, this proposed smaller sized enclosure is more manageable, less expensive to construct and maintain, and will provide meaningful plankton and water chemistry results.

Depending upon shoreline topography, the enclosures should be constructed consecutively or in as few closely located blocks as possible. Site selection should be made with the presupposed section that the littoral areas are relatively uniform in diversity of aquatic plants (if any) and bottom topography. Each enclosure will include 5 m of shoreline and will extend 10 m towards the center of the lake. As such, each enclosure should represent a mesocosm of the lake with natural sediments, water, and shoreline.

The consistency of the native lake ichthyofauna as related to this type of study presents a troublesome philosophical problem. Since one of the major inherent advantages of littoral enclosure studies is the purported replication of lake ecosystem in each enclosure, it would seem logical that the ichthyofauna ought to be included within each mesocosm. However, fish populations are often severely clumped within a lake, which could lead to serious differences in composition and/or abundance between individual enclosures. In addition, since a native fish (the gizzard shad) is part of the experimental design, precise quantification is required for this species. Therefore, it is recommended that after enclosure construction, the native fishes be removed by use of electrofishing (ichthyocides may affect plankton populations). The rationale here is that, with the exception of gizzard shad, all fish species removed are non-planktivores that should not greatly influence the overall progression of the intended plankton manipulation studies. Alternatively, if it is thought that this type of action violates one of the basic tenets of the design (i.e., ecological replication), then selected reintroduction of native fishes into the enclosures after ichthyofaunal removal would be desirable. Reintroduction should reflect the average composition and abundance of all the enclosures, thereby insuring evenness within this segment of the biota.

Replicate combinations of fishes should be assigned in a random fashion within the blocks of enclosures. Again we suggest using the optimum stocking densities, as determined from the preliminary studies. The density used for each fish species will be constant in all treatments. For example, if it was determined that 10 bighead carp should be used, then 10 fish will be used in all treatments requiring bighead carp.

Environmental monitoring should start one month prior to introduction of exotic fishes to the enclosures and continue on a weekly basis throughout a one-year study period. Pre-initiation monitoring is necessary to quantify base-line ecological conditions during a

stabilization period when the microcosms are equilibrating after the ecological trauma involved in enclosure construction. Weekly sampling of plankton and water chemistry parameters is required to accurately monitor short- and long-term trends associated with exotic introduction; the year-long duration of the study allows for documentation of how natural seasonal shifts in the above parameters influence the manipulative progress of the study.

Physical Design

Brazner et al. (1987) provided a detailed protocol for construction of littoral enclosures (Appendix B) which should be followed. Since enclosures in Lake Apopka are likely to be subject to more intense wave action than those encountered in a 2 ha pond, we suggest the addition of increased protective baffling around the outer perimeter of the enclosures.

Fish Methodology

Since capture of fishes from within enclosures is ecologically disruptive, resulting in extensive resuspension of bottom sediments and thereby adversely influencing water chemistry and plankton dynamics, and since the focus of the study involves the latter parameters rather than the cultured growth rates of fishes, we urge restraint in quantification of the introduced fishes. Fishes should be counted, measured, and weighed prior to inoculation in the ponds and at the end of the study. This will provide adequate growth/conversion data without altering the natural progress of the experimental design. All fish used during the pilot studies should be sterile (triploid).

Water Chemistry Methodology

The overall objective of the Phase I enclosure studies is to demonstrate that biomanipulation does indeed offer potential as a restorative measure. As a result, the water chemistry monitoring program should focus on parameters that facilitate understanding the trophic state dynamics that occur during the study. Chemical parameters to be monitored are summarized in Table 8 and are listed by one of three major sp. categories: nutrients, major ions, and physical parameters. Major ions are included to delineate changes in water chemistry that may affect phosphorus availability (e.g., precipitation of hydroxyapatite) or ammonia toxicity. Because of the analytical uncertainty in what SRP truly measures, we recommend that ion chromatography be used to compare direct ortho-phosphorus measurements with SRP values obtained by the ascorbic acid-molybdenum blue method.

Sampling should be conducted weekly because of the extreme variation in major constituents observed month to month in Lake Apopka (e.g., Brezonik et al., 1981). In situ parameters include vertical profiles (0.3 m) of temperature, specific conductance, and dissolved oxygen. Stable stratification is not likely (but should be verified because the enclosures by design are effectively isolated from wave-induced current mixing within the lake), and water samples should be collected at 0.5 m depth and well above the sediment-water interface.

Table 8. Summary of chemical parameters to be measured in Phase I Pilot Study.

Nutrient Forms	Major Ions	Physical
Total phosphorus	pH	Secchi transparency
Soluble reactive phosphorus	Alkalinity	Turbidity
Total Kjeldahl nitrogen	Calcium	Temperature
Ammonia	Magnesium	Dissolved oxygen
Nitrate + nitrite	Potassium	Color
SiO_2	Sodium*	
	Sulfate	
	Chloride*	
	Conductivity*	

*QA/QC check parameters (ion balance and ion ratios).

Individual enclosures will encompass 50 m^2; as a result, a single station within each enclosure should be representative of the entire enclosure. Enclosure effects on major ion chemistry as well as other parameters should be quantified by including controls in the open water of the lake as well as within the mesocosms.

Plankton

The success of biomanipulation relates fundamentally to direct changes in zooplankton community structure and indirect and/or direct changes in the phytoplankton community structure due to changes in selective grazing pressures within the food web. The emphasis of the plankton sampling program is thus on changes in species composition and standing crop. Recommended parameters are summarized in Table 9. Included in the monitored parameters are gross and net primary productivity, measured using the free water diurnal method of Odum and Hoskin (1958). Single enclosures within each treatment level should be selected at random and implemented with recording dissolved oxygen meters to measure gross productivity and community metabolism directly. Consistent with the chemistry monitoring program, weekly sampling for all other plankton-related parameters is recommended.

Supplemental Studies

Lacustrine rates of primary production may be more a function of phosphorus and nitrogen turnover rates within the water column than of phosphorus loading rates. Rigler (1975) notes that nannoplankton take up phosphorus more rapidly than net plankton, and that net plankton are much too large to be consumed by most zooplankton. As a result, the pool of phosphorus stored in the net plankton turns over much more slowly than the nannoplankton pool. Although standing crop ultimately reflects loading rates, differential uptake rates give rise to different dominant species according to in-lake inorganic nutrient concentrations (cf. Odum, 1983). Biomanipulation can affect turnover rates and primary productivity by selecting indirectly for, say, net versus nannoplankton. Isotopic tracer studies similar to Lean (1973) using ^{32}P and ^{15}N are recommended to quantify P and N turnover rates and partitioning into labile and unreactive pools, and into net versus nannoplankton. Simplified model evaluations may then be used to interpret shifts in trophic structure and changes in primary productivity.

PHASE II - SMALL LAKE EXPERIMENT

Lake Selection

Should the Phase I littoral enclosure studies indicate that biomanipulation with a particular fish (or combination of fish) has merit for the restoration of Lake Apopka, a full scale experiment using a lake similar in character to Lake Apopka, biologically and chemically, is recommended. Chemically, the lake most similar to Lake Apopka is Lake Beauclair, located immediately downstream from and connected to Lake Apopka by the Apopka-Beauclair Canal. Comparison of chemical data between 1977 and 1980 shows that the two lakes are nearly identical (Table 10). Unfortunately, the surface area of Lake Beauclair is rather large (452 ha) and the scale of a full-sized project on the lake may be

Table 9. Summary of plankton parameters to be measured in Phase I Pilot Study.

Parameter
Primary productivity
o Gross primary productivity
o Community metabolism
o Net primary productivity
Chlorophyll *a*
o Total chlorophyll *a*
o Net plankton chlorophyll *a*
o Nannoplankton chlorophyll *a*
Phytoplankton species distribution
Phytoplankton (net and nannoplankton) biomass
Zooplankton species distribution
Zooplankton biomass

prohibitively expensive relative to the risk of failure. Moreover, since Beauclair drains into Lake Dora, separating Lake Beauclair hydrologically from the other downstream lakes forming the Oklawaha chain may be problematic.

Lake Carlton, which is connected to Lake Beauclair through a small channel, is recommended as the pilot study lake. Covering 155 ha, Lake Carlton was the site of an experimental lake drawdown study during the late 1970's, and the chemistry of the lake (summarized for 1965-1980 in Table 10) is expected to be functionally equivalent to Lake Beauclair. Drawdown of Carlton failed when the connection between Beauclair and Carlton was breached and Carlton was allowed to refill with degraded water from Beauclair. Biological and chemical characterization data should be collected from Lake Carlton for at least one year prior to initiating the Phase 2 study to 1) verify its comparability with Lake Apopka, and 2) develop a baseline for assessing the results of the biomanipulation program. Recommended sample frequency is every week for the parameters listed in Tables 8 and 9. The major disadvantage to using Lake Carlton is related to depth; based on visual evidence of Carlton's basin during drawdown (C. Pollman, unpublished data), the mean depth of Lake Carlton is probably substantially higher than Lake Apopka (1.7 m). Consequently, lake stratification may exert more control on nutrient dynamics in Lake Carlton than in Lake Apopka, which never stably stratifies. Three to five sampling stations in the lake are recommended to assess within lake variability and patchiness of plankton distributions.

Estimated Stocking Costs

Actual costs for stocking Lake Carlton or eventually, Lake Apopka, with silver or bighead carp are difficult to determine at present. Appropriate stocking rates are to be determined by Phase I studies. Presently there are no commercially available sources of silver or bighead carp in the United States (Mike Endross, Florida Game and Freshwater Fish Commission [FGFFC], Tallahassee, Florida, personal communication). We can provide some rough estimates for stocking costs using current prices for triploid grass carp, which are available from commercial sources. Experience with grass carp indicates that larger individuals (40 cm total length) are needed to lessen predation mortality by fish and birds. Fingerling grass carp (6.35 cm total length) cost approximately $1 per fish; prices for 40 cm grass carp range from $16 to $20 per fish (Mike Endross, FGFFC, personal communication). Leventer (1987) stocked the reservoirs of the INWC with 400 ha^{-1} and 15 ha^{-1} silver and bighead carp, respectively. Using these stocking rates and the average cost of $18 per 40 cm fish, the cost of stocking Lake Apopka would be $4,960,000 for silver carp and $189,000 for bighead carp. These figures are only estimates, nevertheless, Leventer (1987) stocking rates were the lowest reported in the literature for large water bodies.

Table 10. Average water chemistry of Lakes Apopka and Beauclair, 1977-1980, and Carlton, 1965-1980. From Brezonik et al. (1981) and Huber et al. (1982).

Parameter	Apopka	Beauclair	Carlton
Secchi disk (cm)	23	32	48
Turbidity (FTU)	37	26	
Chlorophyll *a* (ug L^{-1})	67.3	118.2	90.7
Color (CPU)	93	98	
Conductance (uS cm^{-1})	368	356	
pH	8.90	8.83	
Dissolved oxygen (mg L^{-1})	9.8	11.3	
Ca^{2+} (mg L^{-1})	37.5	36.8	
Mg^{2+} (mg L^{-1})	18.0	16.7	
Na^{+} (mg L^{-1})	18.1	19.7	
K^{+} (mg L^{-1})	10.6	10.4	
NH_4^{+} (mg L^{-1})	0.056	0.060	
Cl^{-} (mg L^{-1})	40.4	40.8	
NO_3^{-} (mg L^{-1})	0.031	0.042	
SO_4^{2-} (mg L^{-1})	28.9	30.7	
Alkalinity (mg $CaCO_3$ L^{-1})	123	119	
Total phosphorus (mg L^{-1})	0.311	0.339	0.123
SRP (mg L^{-1})	0.036	0.065	
TKN (mg L^{-1})	4.92	4.93	3.65[1]
SiO_2 (mg L^{-1})	1.0	0.8	
Total carbon (mg L^{-1})	98	81	
Inorganic carbon (mg L^{-1})	18	17	
Total organic carbon (mg L^{-1})	80	63	
Dissolved organic carbon (mg L^{-1})	42	40	

CONCLUSIONS AND RECOMMENDATIONS

Utilization of biomanipulation as a means of lake restoration is still in an experimental stage. At best, biomanipulation appears to be only a temporary solution to the eutrophication problem. Due to the general lack of information on biomanipulation attempts in subtropical lakes, careful preliminary studies should be conducted before attempting biomanipulation in Lake Apopka. For purposes of experimentation it appears that filter feeding silver and bighead carp would be the best candidates due to their ability to strain suspended matter from the water column. These species are exotic, therefore adequate justification will be required prior to their use. The pilot studies may provide some justification. Nevertheless, all alternative restoration methods should be examined prior their introduction. Biomanipulation (removal) of native gizzard shad and exotic blue tilapia should be evaluated before introduction of exotic carps is effected. If biomanipulation does emerge as the only alternative, and the pilot studies outlined in this report prove positive, supporting the release of carp into Lake Apopka, every attempt should be made to prevent the dispersal of silver and/or bighead carp into the Oklawaha chain of lakes and especially the St. Johns River.

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APPENDIX A

ANNOTATED BIBLIOGRAPHY

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ABSTRACT: Based on the analysis of the spawning run, passive drift of eggs and downstream migration of juveniles the time of the spawning migrations was determined and spawning grounds were detected. Data are presented on fecundity, size-age composition of spawners and reproduction efficiency. It has been established that larvae and underyearlings occur in the coastal areas of the Caspian Sea at the salinity of 6-12 ppt till sexual maturity is reached. Spawning takes place in the Terek R. 125-260 km upstream from the delta. The peak of spawning falls on late May-early June.

Aksenova, E.I.; Idrisova, N.K. 1978. Use of the chlorophyll method for studying fish nutrition. Gidrobiol. Zh. 14(5):109-112.

ABSTRACT: The chlorophyll method was used together with the usual volume-calculation method for analysis of the nutrition of silver carp and bigheads in fish hatchery ponds. Two suspensions were taken simultaneously from the contents of the digestive tracts of the fish; 1 was fixed with formalin and processed with the usual method, while the other was fixed with adhydrous acetone and processed with spectrophotometry. While the biomass of phytoplankton registered by the volume calculation method was only 0.1-25.0% of the plant components contained in the digestive tract, the total phytogenic substances determined by the chlorophyll method varied from 3-100%. The chlorophyll method is an essential addition to the usual volume calculation method for objective quantitative analysis of the use by fish or organisms of the 1st trophic level.

Aliyev, D.S. 1976. The role of phytophagous fishes in the reconstruction of commercial fish fauna and the biological improvement of water. J. Ichthyol. 16(2):216-229.

ABSTRACT: None.

Amangaliyev, D.A.; Yereshchenko, V.I.; Markova, Y.L. 1972. The development of ichthyological and fish industry research in the Kazakh-SSR. J. Ichthyol. 12(6):922-930

ABSTRACT: None.

Andersson, G.; Berggren, H.; Cronberg, G.; Gelin, C. 1978. Effects of planktivorous and benthivorous fish on organisms and water chemistry in eutrophic lakes. Hydrobiologia 59(1):9-15.

ABSTRACT: The effects of planktivorous and benthivorous fish on benthic fauna, zooplankton, phytoplankton and water chemistry were studied experimentally in two eutrophic Swedish lake using cylindrical enclosures. In enclosures in both lakes, dense fish populations resulted in low numbers of benthic fauna and planktonic cladocerans, high concentration of chlorophyll, blooms of blue-green algae, high pH and low transparency. In the soft-water Lake Trummen, total phosphorus increased in the enclosure with fish, but in the hard-water Lake Bysjon total phosphorus decreased simultaneously with precipitation of calcium carbonate. Enclosures without fish had a higher abundance of benthic fauna and large planktonic cladocerans, lower phytoplankton biomass, lower pH, and higher transparency.

The changes in enclosures with fish can be described as eutrophication, and those in enclosures without fish as oligotrophication. The possibility of regulation of fish populations as a lake restoration method is discussed.

Barash, H.; Plavnik, I.; Moav, R. 1982. Integration of duck and fish farming experimental results. Aquaculture 27(2):129-140.

ABSTRACT: In 1977 and 1978, 2 fish ponds at the Dor Aquaculture Experiment Station were integrated with duck production. Each pond's area was 400 m2 and they were stocked with a polyculture of common carp [Cyprinus carpio] [nilotica], silver carp [Hypophthalmichthys molitrix] and grass carp [Ctenophayrngodon idella] (White Amur). The ducks were fed with prepared, nutritionally balanced feed, while the fish had to get by with the ducks' droppings plus the feed dropped directly from the ducks' beaks into the ponds. The ducks' performance on the ponds was superior to their land control in growth rate, feed efficiency, viability and cleanness of feathers and skin. The average daily gain of the fish was 38.5 kg ha-1, not significantly different from ponds receiving similar mixtures of dry poultry manure plus supplementary feeds. The system is very efficient and its use should be expanded in warm water aquaculture.

Barash, H.; Schroeder, G.L. 1984. Substrate for fish poly culture in stagnant water ponds. Aquaculture. 36(1-2):127-140.

ABSTRACT: The possibility was tested of replacing part or all of fish feed pellets (15% fish meal, 16% soybean meal, 69% sorghum and/or wheat) with cow manure recently fermented for methane production. Nine stagnant, freshwater ponds were stocked with fingerlings of common carp, tilapia and sliver carp which were grown to market size. Substitution of 46% of the pellets by fermented cow manure at a replacement rate of 1:4.6 (weight of dry matter), respectively, did not reduce the total fish yield. Complete substitution of the pellets by fermented cow manure caused a 47% decrease in the total fish yield, mainly the result of decreased growth rate of common carp. were much less affected. The data for silver carp showed no clear trend. The variability of fish yield among ponds receiving the same feed/manure ration increased as the pellet portion was decreased and the fermented cow manure was increased. Addition of sorghum grains to ponds receiving fermented cow manure improved only the growth of common carp. The possible effect of pond dimensions on fish yield is discussed.

Barnes, A. 1983. Production of the fresh water prawn Macrobrachium rosenbergii in Israel 1. Integration into fish poly culture systems cohen d; ra'anan z;. Aquaculture 31(1):67-76.

ABSTRACT: Two major problems observed in prawn monoculture can be solved using polyculture with fish. The introduction of low stocking densities of common carp, silver carp and grass carp prevents undesired unicellular or multicellular algal blooms and improves the O2 regime. No effect on prawn yield characters is observed, while the marginal fish yield improves the profitability of the pond. The low average weight and the wide size distribution of prawns stocked at high densities are avoided in a strategy of marginal prawn production with high stocking densities of common carp, sp. and mullet in commercial ponds. Stocking of prawns at a low density of .apprx. 5000 ha-1 results in 90% of the prawns growing to the large market size (> 45 g) within 130 days, a survival rate of 43-96% and yields of 96-312 kg .cntdot. ha-1. Since prawns grow on natural productivity alone, and the production costs are shared, prawn yields at such levels are highly profitable.

Barthelmes, D. 1982. Basis for the management of lakes with seston-eating fish. Fortschr. Fischereiwiss. 1:109-115.

ABSTRACT: Stocking seston-eating fish is one of the most promising possibilities of increasing fish yields from eutrophic lakes in the range of a few hundreds of kg per hectare. Out of the two species concerned, silver carp seems to fit best in a strategy called cyclic management, characterized by radical seining every 4 years and restocking afterwards. While seining is not advisable during the growth period, intensive eel stocking and catching seems to be possible throughout the period(s). In addition, removal of predatory fish prior to stocking renders usual management of these fish impossible. Probably the bighead carp will fit in an alternative strategy, matching nearly all requirements of an usual lake fishery. It may be called normal management therefore. The main point to open this way is higher growth intensity of this species at lower stocking rates, allowing for additional yields of the same magnitude (200 kg/ha) with a much smaller input of stocking material (only 40 fish/ha.).

Barthelmes, D.; Boettcher, S. 1984. On the recapture of carps (Cyprinus carpio), silver carps (Hypophthalmichthys molitrix) and bighead (Aristichthys nobilis) in lakes and the problem of super-annuated fish. Z. Binnenfisch. Ddr. 31(11):326-330.

ABSTRACT: In lakes stocked with Cyprinus carpio, Hypophthalmichthys molitrix and Aristhichthys nobilis, the recapture rate is an important economical factor. Fish grown up have to be caught as completely as possible to prevent the development of superannuated stocks. Recapture rate for H. molitrix and had been estimated to be at least 80%. Improved catching methods (set nets of large mesh size) are necessary.

Barthelmes, D.; Kleibs, K. 1978. Influence of silver carp Hypophthalmichthys molitrix on plankton of shallow waters according to investigations in carp ponds. Int. Rev. Gesamten. Hydrobiol. 63(3):411-420.

ABSTRACT: No severe changes take place in the plankton of highly eutrophic non-stratified water bodies up to a stocking rate of 1,000 Si3/ha. This rate gives an additional yield of 200-300 kg/ha. Stocking rates of 10,000 Si3/ha allow selective overexploitation of microphytoplankton including bluegreen algae and of nearly all zooplankton. Yields reach, in this case, 1 ton/ha in 1 m deep waters.

Bays, J.S.; Crisman, T.L. 1983. Zooplankton and trophic state relationships in Florida lakes. Can. J. Fish. Aquat. Sci. 40(1):813-1,819.

ABSTRACT: Zooplankton, including ciliated protozoans, were collected from 39 Florida lakes of widely ranging trophic state. Annual mean biomass values for different zooplankton groups were regressed against Carlson's Trophic State Index based on annual mean chlorophyll a concentration. Whereas total zooplankton biomass yielded a significant regression with increasing trophic state, microzooplankton (ciliates, rotifers, and nauplii) accounted for more of the relationship than macrozooplankton (cladocera, calanoids, and cyclopoids). Within the microzooplankton, the regression improved with decreasing body size. Macrozooplankton biomass exhibited a weak statistical relationship with lake trophic state, but the different component groups were variable in their response. The dominance within the zooplankton community shifts from macrozooplankton to microzooplankton with increasing trophic state, and the microzooplankton can constitute between 50 and 90% of the total zooplankton biomass in eutrophic lakes. Changes in zooplanktivore community structure with increasing trophic state show that whereas total fish biomass increases, dominance shifts from visually oriented predators, such as bass and bluegill, to pump filter-feeding planktivores, such as gizzard shad (Dorosoma cepedianum). While Florida zooplankton communities are similar in size structure to tropical communities, no statistically significant differences were found between empirical equations of crustacean zooplankton biomass and trophic state determined from temperate and Florida data bases.

Bednarz, T.; Szmyt, E.; Wrona, J. 1978. Plankton development and an evaluation of carp production in poly culture with silver carp. Rocz Nauk Roln Ser H Rybactwo 99(2):153-176.

ABSTRACT: The best fishery production occurred in the polyculture ponds and totals 138% for carp and 452% of silver carp in comparison with the monocultural stock of these fish. Polyculture stock influenced the increase in phytoplankton development. The most development of zooplankton appeared in the pond stocked with carp alone.

Behrends, L.L.; Kingsley, J.B.; Price, A.H., III 1986. Polyculture of freshwater prawns, tilapia, channel catfish and Chinese carps. 16. Annu. Meet. of the World Mariculture Society Orlando, FL (USA) 13 Jan 1985. J. World Maricult. Soc., 16:437-450.

ABSTRACT: Juvenile Macrobrachium rosenbergii, fingerling Ictalurus punctatus, young-of-year Tilapia spp., F-1 hybrid female Aristichthys nobilis x male Hypopthalmichtys molitrix, and Ctenopharyngodon idella were costocked into 4 replicate 0.05-ha earthen ponds in 1983 and 1984 and cultured for 124-150 days, respectively. Stocking densities of prawns (20,000/ha), tilapia (2,500/ha), and grass carp (120/ha) were held constant during both years. However, in 1984 stocking densities of channel catfish and hybrid carp were reduced to 7,500/ha and 160/ha, respectively. Throughout each study, a commercial floating catfish feed containing 32% protein was broadcast into the ponds daily at 1600 hours. Average net production figures were very similar in both years -- 3,180 kg/ha in 1983 and 3,150 kg/ha in 1984. Mean feed conversion values for all species combined were 1.4:1.0 and 1.0:1.0 in 1983 and 1984, respectively. Net production and mean individual weights of component species during 1983 were: prawns (445 kg/ha, x = 30 g), channel catfish (1,411 kg/ha, x = 180 g), tilapia 653 kg/ha, x = 284 g, hybrid carp (546 kg/ha, x = 1,186 g), and grass carp (127 kg/ha, x = 1,337 g), and in 1984 were: prawns (287 kg/ha, x = 19 g), channel catfish (1,698 kg/ha, x = 263 g), tilapia (522 kg/ha, x =291 g), hybrid carp (389 kg/ha, x = 4,430 g), and grass carp (253 kg/ha, x = 2,924 g).

Behrends, L.L.; Maddox, J.J.; Madewell, C.E.; Pile, R.S. 1980. Comparison of two methods of using liquid swine manure as an organic fertilizer in the production of filter feeding fish. Aquaculture 20(2):147-153.

ABSTRACT: Yield trial experiments were conducted in 10.5 m2 plastic-lined pools to test liquid swine manure as an organic fertilizer for fish production. Silver carp (Hypophthalmichthys molitrix), bighead carp (Aristichthys nobilis) and tilapia (Tilapia nilotica) were cultured together for 52 days during August and September 1977 to determine growth and yield responses to various manure fertilization treatments. Net fish yields were 1.8 times greater in pools receiving direct manure fertilization than in pools receiving phytoplankton slurries produced with comparable amounts of manure. Early morning dissolved O2 concentrations became critical (< 1 ppm) when direct manure fertilization exceeded 4 l/pool per day.

Ben-Tuvia, A. 1981. Man-Induced Changes in the Freshwater Fish Fauna of Israel. Fish Manage. 12(4):139-148.

ABSTRACT: Changes in Israel's freshwater fish fauna during the past 50 years were caused by: (1) introduction or transfer of foreign and native species for culturing, development of fishery resources in Lake Tiberias and Reservoirs, and ecological control (2) land reclamations and (3) utilization of water reserves for domestic, agricultural and industrial purposes. The exotic fishes that reproduce naturally in inland waters are Gambusia affinis, Cyprinus carpio, Sarotherodon niloticus and Basilichthys bonariensis. A population of Salmo gairdneri in habits the upper reaches of the Jordan River, but it is doubtful if it reproduces. Non-naturally reproducing exotic species include: Hypopthalmichthys molitrix, Ctenopharyngodon idella, and Aristichthys nobilis. This species are, however, artificially reared and propagated.

Benndorf, H.K.; Kossatz, K.; Penz, E. 1984. Manipulation of the pelagic food web by stocking with predacious fishes. Int. Revue ges. Hydrobiol. 69(3):407-428.

ABSTRACT: Two water bodies, which are quite different with respect to nutrient load and hydrophysical conditions, are used to perform long-term experiments in the whole water on the manipulation of the pelagic food web. Experimental water 1: Bautzen Reservoir (Dresden County, GDR); hypereutrophic, mean depth = 7.4 m; extremely exposed to wind. Experimental water 2: small pond in a former quarry (Dresden County); mesotrophic; mean depth = 7.0 m; extremely protected against wind. Only the results of Experiment 2 are given in detail. Experiment 1 is not yet finished. Experimental water 2 was investigated in 1979 and 1980 when no predatory fish species were present, and in 1981 after introduction of predators (mainly Salmo gairdneri). The response of the ecosystem can be summarized as follows: (1) The biomass of the zooplankton-eating fish (mainly Leucaspius delineatus) decreased rapidly; (2) The biomass of herbivoric zooplankton increases to nearly 400%; (3) This funding reveals that the dense population of an invertebrate predator (Chaoborus flavicans) is not able to compensate for the feeding pressure of the small fish. But the intensive feeding activity of the young larvae of Chaoborus leads to a strong increase (200 to 300%) in the mean individual body size of the crustaceans during late summer and autumn, which supports the "balanced predation hypothesis"; and (4) The remarkable enhanced grazing pressure of the herbivorous zooplankton on the phytoplankton does not exert any effect on the total phytoplankton biomass. This result is interpreted as a consequence of growth limitation of the algae due to low nutrient (Fe, P) supply in that mesotrophic water body. But the phytoplankton composition does reveal a strong response to the enhanced grazing pressure. The Secchi depth increases as a consequence of this change in the phytoplankton composition. The conclusion is drawn that, when using ibomanipulation as a means of water quality management, it is obviously necessary to take into account the complex interrelationships between fish stocks, predacious invertebrates, herbivorous zooplankton, phytoplankton as well as nutrient load and hydrophysical processes in the particular water.

Bialokoz, W.; Krywosz, T. 1981. Feeding intensity of silver carp Hypophthalmichthys molitrix from the Paproteckie Lake, Poland in the annual cycle. Ekol. Pol. 29(1):53-62.

ABSTRACT: Between April 10, 1976 and March 25, 1977 the amounts of food consumed by silver carp introduced to Paprotockie Lake were estimated. The passage period depended on temperature and was from 10 h at 22.6.degree. C to 108 h at 4.0.degree. C. On the average, the food weight in fish caught in particular seasons of the year ranged from 0.02 g (0.02.permill. of fish body weight) at the end of Sept. to 28.47 g (32.54.permill. of fish body weight) in June. The diurnal food ration calculated according to the modified equation of Bajkov (1935) was between 0.03.permill. (in Sept.) and 117.13.permill. (in June) of fish body weight. The feeding intensity of silver carp generally increases with the temperature rise and decreases with its drop. During the year the fish consumed .apprx. 8800 g of food each, of which > 90% was consumed during the 3 warmest months of year. Feeding coefficients calculated on the basis of the estimated food rations and body weight of fish increase fluctuated between 7.89 and 24.65. The coefficients obtained for the period between the fish stocking and mid-Aug. (19.19) and between the fish stocking and the end of Sept. (18.39) were considered the most reliable.

Bitterlich, G. 1985. The nutrition of stomachless phytoplanktivorous fish in comparison with Oreochromis mossambicus. Hydrobiologia 121(2):173-180.

ABSTRACT: The contents of alimentary tracts of stomachless phytoplanktivorous fish, including silvercarp (Hypophthalmichthys molitrix), Esomus danrica thermoicos, and Amblypharyngodon meletinus were investigated microscopically and compared with those of tilapia (Oreochromis mossambicus, a fish with a stomach). The predominance of detritus in the food and the low efficiency with which phytoplankton is utilized prove that stomachless fish are not primarily herbivorous. The possibility of omnivorous feeding as an alternative is discussed. These results may contribute to our understanding of the role of filterfeeders in aquaculture and ecosystems.

Bitterlich, G.; Gnaiger, E. 1984. Phytoplanktivorous or omnivorous fish? Digestibility of zooplankton by silver carp, Hypophthalmichthys molitrix (val.). Aquaculture, 40:261-263.

ABSTRACT: Small zooplankton, rotatoria and nauplii decomposed rapidly during in-vitro incubation in the gut fluid of silver carp. Algae remained unchanged. Gut content analysis, therefore, erroneously suggests a phytoplanktivorous strategy, whereas omnivorous feeding may actually be required to maintaining a positive energy balance in these stomachless fish.

Bitterlich, G.; Schaber, E. 1986. Bacteria-food or food competitors of silver carp Hypophthalmichthys molitrix. J. Fish Biol. 29(5):605-612.

ABSTRACT: The role of bacteria in the nutrition of silver carp was studied by in-vitro tests, which confirmed earlier results that the potentially important source of nitrogen in bacteria is not utilized by the fish. Cultures of aerobic and anaerobic bacteria, recovered from a fish pond, were incubated with digestive fluids from the gut contents and from tissues surrounding the alimentary tract (Organ of Leydig) respectively. Growth of aerobic isolates was not affected by the digestive fluids whereas growth of all anaerobes was inhibited. A susceptibility test revealed a bacteriostatic rather than bactericidal effect of the digestive fluid on the bacteria. During 42 h incubation at approximately 20.degree. C of gut fluid, trypsin activity decreased between 14% (in fore-gut fluid) and 62% (in mid-gut fluid). The addition of aerobic bacteria (to the mid-gut fluid) or anaerobic bacteria (to the fore-gut fluid) did not accelerate the degradation of trypsin.

Boyadjiev, A.; Petrov, P. 1981. Fishbreeding and economic aspects of average yield over 500 kg/decare. Izv. Inst. Sladkovodn. Rybovyd. Plovdiv Izv. Inst. Presnovodn. Rybovod. Plovdiv Proc. Freshwat. Fish. Res. Inst. Plovdiv. 14:77-89.

ABSTRACT: The experiment was carried out in two ponds: No.5 (2,5 decares) in 1977 and No. 2 (25 decares) in 1978 at the research facilities of the Freshwater Fishery Research Station in Plovdiv. In pond No. 5 with a stock of 600 pcs/decare carp, 100 pcs/decare bighead Aristichthys nobilis, and 10 pcs/decare grass carpe Ctenopharyngodon idella the obtained yield was 534 kg/decare, the food co-efficient being 2,34. In pond No. 2 with a stock of 750 pcs/decare carp, 100 pcs/decare bighead, and 8 pcs/decare grass carp the obtained yield was 623 kg/decare, the food co-efficient being 2,86. The percentage of herbivorous fish varies from 15,4 to 18,0. The yield of such values does not increase the prime cost of fish production while it increases the profit from unit of area and production due to the high factory-processing price. The profit, calculated for 1 decare and one fishery worker, is two to three times larger than that which has been achieved in the best equipped fishbreeding farms in Bulgaria.

Boyadjiev, At.; Petrov, P. 1977. Experimentation of a method for carp rearing at high density stocking rates. In: Proceedings of the freshwater fishery research station - Plovdiv. 12:139-152.

ABSTRACT: The experiment was carried out in four ponds: two of them at Trivoditsi supplied with Karst water, and the other two at Plovdiv, each covering an area of 2.5 to 75 decares, the stocking rate varied from 240 to 600 larvae/decare. Four types of combinations of stocking were experimented with. The yield obtained from the best fish rearing pond (24 decares) was 480 kg/decare and the growth was 439.5 kg/decare, of which 278 kg/decare were carp (Cyprinus carpio), 115 kg/decare bighead (Aristichthys nobilis), 7.5 kg grass carp, and 39 kg/decare the one-year carp. The average individual weights of the fish obtained were high, and the total nutritive co-efficient was relatively low. The yield obtained from the most economically efficient pond (75 decares) was 424 kg/decare and a growth of 400 kg/decare. The carp growth was 250 kg/decare. Survival and the average individual weight of the fish were relatively high, and the total nutritive co-efficient was low. The share of the herbivorous fish of the total growth was 37.5%.

Boyadjiev, At.; Petrov, P. 1977. A study aimed at establishing the optimum stocking rate of bighead as a polyculture to carp with a view to the maximum fish rearing and economic efficiency. In: Proceedings of the freshwater fishery research station - Plovdiv., 12:115-138.

ABSTRACT: In this paper the authors treat the fish-rearing and economic expediency of growing bighead (Aristichthys nobilis) as a polyculture to carps. Of the four variants of stocking B{SUB-1}, experimented with during the period 1973-1974, the best fish-rearing indices were obtained at 70-90 larvae per decare. From the economic point of view, Variant 4 (30-40/decare) is the most favourable condition, the ponds there having the highest value rates of fish production due to the doubled stocking rate. Optimum stocking rate of B{SUB-1} is achieved when it does not lead to a decrease in the fish production and a surplus over the volume of the production of the monoculture is realized.

Buck, D.H.; Baur, R.J. 1980. Water quality control and management of animal wastes through culture with selected fishes. Univ. Ill. Urbana-champaign Water Resour. Cent. Res. Rep. 0(151):I-XII, 1-118.

ABSTRACT: The contributions of 4 Chinese carps to the biological treatments of 4 oxidation ponds receiving swine wastes are evaluated. The carps used have specialized feeding habits: the silver carp (Hypophthalmichthys molitrix) filters suspended materials (phytoplankton, bacteria); the bighead carp (Aristichthys nobilis) filters zooplankton; the grass carp (Ctenopharyngodon idella) ingests coarse vegetation; the common carp (Cyprinus carpio) consumes benthos and detritus including fish feces. Segment I (1976) utilized different densities of carps in ponds receiving similar amounts of manure; segment II (1977) utilized similar quantities of manure and companion fish but different densities of silver carp; segment III (1978) utilized ponds in series, the 1st containing carps, the 2nd macrophytes; segment IV (1979) evaluated pond aeration in addition to fish. Prawns (Macrobrachium rosenbergii) also were stocked in 1978 and 1979. Studies of autotrophic and heterotrophic communities were intensified in 1979. Through consumption of large quantities of organic matter, living (plankton, bacteria) and dead (detritus, feces), the carps in proper densities and combinations can significantly improve the quality of organically polluted waters and that properly designed systems would have practical applications for small communities, livestock producers and food processers.

Buck, D.H.; Baur, R.J.; Rose, C.R. Experiments in the recycling of swine manure using a poly culture of Asian and North American fishes. Lockeretz, W. (ed.). Agriculture and energy. Proceedings of a conference. St. Louis, MO. June 17-19, 1976. Xiii+750p. Illus. Maps. Academic press: New York, NY, USA; London, England. ISBN
a conference. St.Louis, Missouri, USA. June 17-19, 1976. XIII + 750 p. Agriculture and energy. Proceedings of illus. maps. Academic press: New York, NY, USA; London, England. ISBN.
0-12-454250-6. 1977 385-394

ABSTRACT: None.

Buck, H.; Malecha, S.R.; Baur, R.J. 1981. Polyculture of the freshwater prawn (Macrobrachium rosenbergii) with two combinations of carps in manured ponds. World Conf. on Aquaculture Venice (Italy) 21 Sep 1981. J. World Maricult. Soc. 12(2):203-213.
Includes 11 refs.

ABSTRACT: A study was conducted to evaluate the compatibility of prawns (M. rosenbergii) with carps, especially the effect of the common carp (Cyprinus carpio), and to measure the ability of prawns to utilize the foods available in manured systems. Carps used were the silver (Hypophthalmichthys molitrix), bighead (Aristichthys nobilis), grass (Ctenopharyngodon idella) and common carp (C. carpio). Four ponds were stocked with silver, bighead and grass carps while common carp were stocked in only two ponds. Total fish densities were 8,600/ha where 4 carps were stocked, but only 6,200/ha when common carp were omitted. Post-larval prawns were stocked at densities of 17/m super(2). Swine were housed on pond dikes so that fresh manure continuously entered each pond. Growth, biomass, and survival data are reported.

Buras, N.; Duek, L.; Niv, S.; Hepher, B.; Sandbank, E. 1987. Microbiological aspects of fish grown in treated wastewater. Water Res. 21(1):1-10.

ABSTRACT: Common carp and silver carp were reared in treated domestic wastewater. The most sensitive to this environment was the silver carp, followed by common carp and tilapia. In healthy clean fish, bacteria were not found in the blood or the muscles. They were present in small numbers in various organs and in concentrations of 106-107 g-1 in the digestive tract content. In fish exposed to treated wastewater for the entire growing period, bacteria were found in the muscles. The number of bacteria recovered from various organs ranged between 104-106 g-1 and their concentration in the digestive tract content was 108-109 g-1. The number of bacteria in the pond water determined the presence and concentration of bacteria in the fish. The number of bacteria that caused their appearance in the muscles of fish has been named the "threshold concentration". Considering the public health aspects, fish can be reared in treated wastewater provided the bacteriological quality of the water is compatible with the "threshold concentration" levels of the fish grown in the ponds. The suitability of Escherichia coli (fecal coliform bacteria) as indicators for the bacteriological quality of fish grown in wastewater-fed ponds is examined.

Burke, J.S.; Bayne, D.R.; Rea, H. 1986. Impact of silver carps Hypophthalmichthys molitrix and bighead carps Aristichthys nobilis on plankton communities of channel catfish Ictalurus punctatus ponds. Aquaculture 55(1):59-68.

ABSTRACT: Stocking of ponds with planktivorous carps in polyculture with channel catfish (I. punctatus and a hybrid) reduced the density of zooplankton when compared to controls. Bighead and silver carp similarly reduced zooplankton, though the mechanism of suppression may be different. Phytoplankton biomass was significantly higher in ponds containing bighead and silver carp. Ammonia and nitrite concentrations were similar in bighead and silver carp ponds and were significantly lower than in control ponds.

But, V.P.; Ikryannikova, L.V. 1982. Nursery pond phytoplankton and its use by silver carp. Uzb. Biol. Zh. 0(2):44-45.

ABSTRACT: None.

Carlos, M.H. 1988. Growth and survival of bighead carp Aristichthys-nobilis fry fed at different intake levels and feeding frequencies. Aquaculture 68(3):267-276.

ABSTRACT: This study was conducted to assess the effect of different levels of dietary intake and feeding frequencies on growth and survival of bighead carp, Aristichthys nobilis, fry. The feeding rates consisted of 10%, 20%, and 30% of body weight while feeding frequencies were one, three, and five times daily. Results showed that final weight, final length, and specific growth rate (SGR) differed in relation to feeding rate but not to feeding frequency. Highest values were obtained for fish on the 30% ration and fed once a day. A significant effect of higher feeding rate using lower feeding frequency on growth was manifested in final mean weight and SGR; increasing feeding rate resulted in increased growth. Feeding frequency significantly influenced fry survival with highest values observed when fry were fed once or three times per day. Highest survivals were achieved by fry on the 30% ration fed once daily. At higher feeding rates using lesser feeding frequencies better survival was noted. Survival rate had an inverse relationship to feeding frequency, but no overall relationship existed between feeding rate and survival rate. Both ration and feeding frequency significantly influenced normalized biomass index (NBI). Highest values were again obtained on the 30% ration and feeding once daily. Higher NBI values were observed with higher feeding rates at lower feeding frequencies. Increasing ration resulted in a corresponding increase in NBI.

Chakrabarty, R.D.; Murty, D.S.; Sen, P.R.; Nandy, A.C.; Chakrabarty, D.P. 1976. Short-term rearing of Indian and exotic carps. J. Inl. Fish Soc. India 8:179-183

ABSTRACT: None.

Chen, S.L.; Hu, C.L.; Tian, L.; Sun, X.W. 1985. Study on the digestion and utilization of Daphnia hyalina by fingerlings of silver carp and bighead. Trans. Chin. Ichthyol. Soc. 4:163-170.

ABSTRACT: The digestion and utilization of D. hyalina by fingerling of silver carp (Hypophthalmichthys molitrix) (299 individuals, body-length 9.92 plus or minus 0.44 cm, body-weight 16.39 plus or minus 1.65 g) and bighead (Aristichthys nobilis) (319 individuals, body-length 9.68 plus or minus 0.39 cm, body-weight 17.08 plus or minus 2.27 g) were studied in the years 1980-1982. The nutritive composition of D. hyalina and the nutriments contained in the muscle and feces of the fish were analyzed and the digestibility of food by the fish was determined, and then they were converted into calorific values. Based on the diurnal oxygen consumption of the fish, the daily weight increase of fish, the digestibility of food by fish and relevant heat equivalence, the daily ration of fish and the ratio of energy transformation of D. hyalina were calculated.

Chen, S.L.; Hu, C.L.; Zhang, S.Y. 1986. Feeding intensity of silver carp and bighead under natural condition. 1. Feeding intensity of fingerlings of silver carp and bighead in summer. Acta Hydrobiol. Sin. Shuisheng Shengwu Xuebao. 10(3):277-285.

ABSTRACT: The feeding intensity of fishes varies with time to form a definite diel feeding rhythm. Whether there is such a rhythm also in silver carp (Hypophthalmichthys molitrix) and bighead (Aristichthys nobilis) under natural conditions was investigated. In experiments of subyearling cultivation in covers and bays, a total of 313 silver carp (6.8-12.8 cm in body length and 4.78-33.95 g in weight) and 217 bighead (4.6-11.7 cm in body length and 1.92-27.98 g in weight) were collected for the purpose of studying their diel feeding intensity. The index of fullness of fish intestine in relation to water temperature and dissolved oxygen in the natural environment was determined as well as the evacuation rate of fishes under experimental conditions. According to a modified Bajkov's formula, the estimates of the diel ration of both fishes were obtained. Results showed that-both silver carp and bighead have a-feeding rhythm when living in natural conditions. The daily ration for silver carp was found to be 12.81-23.08% of the body weight for bighead, 8.91-14.63% of the body weight. Dissolved oxygen has a positive influence on feeding intensity of both fishes.

Chervinski, J. 1977. Note on the adaptability of silver carp Hypophthalmichthys molitrix and grass carp Ctenopharyngodon idella to various saline concentrations. Aquaculture 11(2):179-182.

ABSTRACT: A preliminary investigation was carried out to determine the feasibility of rearing 2 species of Chinese carp in brackishwater ponds in areas unsuitable for agriculture. Silver carp (H. molitrix) and grass carp (C. idella) were transferred from fresh water to mixtures of sea water and tap water (20, 25 and 30% sea water) in the laboratory. All the carp survived for 48 h after transfer to the 1st concentration; there was 0% and 100% mortality of silver carp within 48 h in 25 and 30% sea water, respectively, while the grass carp also only died in 30% sea water (20% mortality). After acclimatization for 48 h to 20 or 25% sea water and transfer to 30% sea water, about half the grass carp survived a further 48 h, whereas survival rates for silver carp were 16% (transfer from 20-30% sea water) and 10% (transfer from 25-30%) after 48 h. No silver carp survived in 25% sea water for 30 days. However, only 25% of the grass carp exposed to this salinity for the same period of time died.

Ciepielewski, W. 1986. Experimentally increased fish stock in the pond type Lake Warniak, Poland changes of ichthyofauna between 1970 and 1983. Ekol. Pol. 33(1):37-60.

ABSTRACT: The maximal catches of introduced fish were obtained in years when stocking took place. In the case of bream and bighead-carp the efficiency of catches exceeded 50% of the stocking. It was smaller in the majority of cases for carp, grass carp and silver carp. The additional loading of the lake with introduced benthophagous fish exceeded more than twice the biomass of autochthonous benthophages estimated as about 60 kg .cntdot. ha-1. Vascular vegetation was grazed out entirely in 1976, when the biomass of grass carp was over 120 kg .cntdot. ha-1 during the season.

Cooke, G. D. 1986. Biological controls. In: G. D. Cooke, E. B. Welch, S. A. Peterson, P. R. Newroth (eds.) Lake and Reservoir Restoration. Butterwors. Boston, MA. 392 pp.

ABSTRACT: None.

Costa-pierce, B.A.; Malecha, S.R.; Laws, E.A. 1985. Effects of polyculture and manure fertilization on water quality and heterotrophic productivity in Macrobrachium rosenbergii ponds. Trans. Am. Fish Soc. 114(6):826-836.

ABSTRACT: Water quality effects of high densities of silver carp Hypophthalmichthys molitrix, grass carp Ctenopharyngodon idella, and water hyacinths Eichhornia crassipes in semi-intensive pond culture of prawns Macrobachium rosenbergii were examined. Additional effects of isonitrogenous additions (8 kg N .cntdot. hectare-1 .cntdot. week-1) of dried chicken manure and chicken broiler feeder were evaluated. Excretion, grazing, and sediment resuspension by the carps stimulated phytoplankton productivity and turnover rates of microplankton, led to high early-morning dissolved oxygen (DO) concentrations, and, in theponds fed manure, increased phytoplankton biomass. Removal of phosphorus from the water by water hyacinths led to reduced chlorophyll-a concentrations, primary productivity and microplankton turnover, and to low morning DO concentrations: in hyacinth ponds fed chicken broiler feed, there were large percentage fluctuations in phytoplankton biomass. Additions of manure stimulated autotrophic productivity about 3.0 times, and total microbial productivity about 4.6 times, more than additions of chicken feed. Biological control of phytoplankton dynamics and maintenance of DO concentrations at high phytoplankton standing crops by Chinese carps appears a viable alternative to present methods of water quality control in semi-intensive prawn aquaculture.

Costa-pierce, B.A.; Malecha, S.R.; Laws, E.A. 1987. Yield characteristics of prawns Macrobrachium rosenbergii de man with fish polycultures at low feeding rates. Aquacult. Fish Manage. 18(4):357-364.

ABSTRACT: As currently practised, freshwater prawn, Macrobrachium rosenbergii (de Man), aquaculture in Hawaii [USA] requires large inputs of supplementary feed, water and labour. The high cost of these inputs greatly restricts profit potential. An experiment was conducted to compare an alternative prawn production system which used lower feeding rates and fish polycultures to reduce inputs. Three treatments were run in quadruplicate: (1) control.sbd.prawns stocked at standard densities (11.5 per m2) in monoculture and fed standard prawn pellets at the commercial ration recommendations by New & Singholka (1982); (2) low feed.sbd.prawns at standard densities and fish [silver carp, Hypophthalmichthys molitrix (Valenciennes), grass carp, Ctenopharyngodon idella (Valenciennes), and grey mullet, Mugil cephalus (L.)] fed one-half commercial ration; and (3) maintanance feed.sbd.prawns at standared densities and fish fed one-tenth commercial ration. Although prawn yield characteristics (mean weights, harvestable sizes, survival, net yields) were not significantly different ($P > 0.05$) based on an analysis of variance in the three treatments over the approximately 9.5-month culture period, this lack of significance most likely resulted from interpond variability and the lack of a large number of replicates. The relatively poor survival (60-63%) of grey mullet and an almost twofold difference in prawn yields in the control and maintenance feed treatments suggest that there was in fact competition for resources in the nominally polyculture systems. Nevertheless, the wet weight yield of biomass from all species was twice as high in the low feed ponds as in the control ponds.

Cremer, M.C.; Smitherman, R.O. 1980. Food habits and growth of silver carp Hypophthalmichthys molitrix and bighead carp Aristichthys nobilis in cages and ponds. Aquaculture 20(1):57-64.

ABSTRACT: Analysis of intestinal contents of silver carp (H. molitrix) and bighead carp showed that silver carp consumed primarily phytoplankton while bighead carp consumed large quantities of zooplankton, detritus and phytoplankton. The size of particles filtered by the bighead carp was larger (17-3000 .mu.m) than that filtered by silver carp (8-100 .mu.m). Artificial feed was readily consumed by bighead carp but not by silver carp. No growth difference was indicated for silver carp in fertilized ponds and ponds receiving artificial feed. Growth of bighead carp increased substantially with the addition of artificial feed. Silver carp grew more rapidly in cages than bighead carp.

Crisman, T.L. 1986. Eutrophication control with an emphasis on macrophytes and algae, pp. 200-239. In: Polunin, N. (ed.)., Ecosystem Theory and Application. John Wiley and Sons Ltd.

ABSTRACT: None.

Cryer, M.; Peirson, G.; Townsend, C.R. 1986. Reciprocal interactions between roach, Rutilus rutilus, and zooplankton in a small lake: Prey dynamics and fish growth and recruitment. Limnol. Oceanogr. 31(5):1,022-1,038.

ABSTRACT: Recruitment success of roach varied dramatically between 1979 and 1982 in Alderfen Broad, a small lake in eastern England. When fry were abundant (in 1979 and 1981, but not in 1980 or 1982) the summer zooplankton became sparse and was dominated by copepods and rotifers. In years of good recruitment, as each of the preferred cladoceran prey species entered the diet of underyearling roach, its density dropped dramatically. Mean size of Daphnia hyalina and Ceriodaphnia quadrangula also declined significantly during these seasons. The results of enclosure experiments indicate that the link between roach recruitment and zooplankton dynamics is causal. Older roach also feed to a significant extent on zooplankton, but the 0+ age group exerted the greatest influence. The abundant underyearling roach in years of good recruitment showed poor growth, as a result of depression of their prey populations. Older fish also grew poorly in these years and were then less fecund in the following season. The evidence indicates that there may be a 2-year cycle in roach recruitment, and we describe the unusual circumstances in Alderfen which may be responsible.

Cure, V.; Naziru, M.; Monea, E.; Papandopol, A. 1981. Contributions to knowledge of the hydrobiological conditions and fish production from Lakes Tasaul and Gargalic during 1976-1978. Bul. Cercet. Piscic. (Ser. Noua). 3(1-2):7-38.

ABSTRACT: The results of hydrobiological-piscicultural studies carried out on the littoral lakes Tasaul and Gargalic during 1976-1978 are presented. Taking into consideration the existent ecological conditions, it is considered that the fish production obtained during this period was below the trophic capacity of these two lakes. The fish species that prevailed in this period of time were: in Lake Tasaul, the prussian carp (Carassius auratus), the roach (Hesperoleucus symmetricuw) and the perch-like pike (Lucioperca lucioperca) and in Lake Gargalic, the carp (Cyprinus carpio), the prussian carp and the grass carp (Ctenopharyngodon idella). In order to improve the production, the yearly population of these lakes with carp, silver carp (Aristichthys nobilis) and also perch-pike (in Lake Tasaul) is recommended.

Dabrowski, K. 1984. Influence of initial weight during the change from live to compound feed on the survival and growth of four cyprinids. Aquaculture 40(1):27-40.

ABSTRACT: In a series of trials, larvae of common carp (Cyprinus carpio L.), silver carp (Hypophthalmichthys molitrix Rich.), grass carp (Ctenopharyngodon idella Val.) and bighead carp (Aristichthys nobilis Rich.) were transferred directly from a diet of zooplankton to a dry, compound feed. The dry diet was based on a previously described diet of yeast and freeze-dried animal tissues. Common carp larvae showed the best growth on live zooplankton (46.3 mg individual weight after 14 days) compared to fish fed solely on dry feed (13.8 mg). Transfer of common carp larvae to dry diet when they reached 4.27 mg significantly improved growth, but no dependence was observed on 2 diets tested. Grass carp larvae grew equally well on live food and on the best compound diet (8.7 mg after 15 days), but fish transferred to dry diet at 4.3 mg showed significantly improved growth. The growth rate depended on the diet (12.9-23.5 mg). Silver carp grew better when fed solely on dry diet (23.5 mg), compared to live zooplankton (15.8 mg after 15 days), but this was due to an insufficient supply of suitable live food. Transfer of fish at 6.8 mg to dry diet improved the growth only slightly, and dependence on the kind of dry diet was observed. Bighead carp larvae showed better growth on live zooplankton (42.2 mg after 15 days) than on the best compound diet (18.6 mg). Fish transferred at 5.6 mg to dry diets showed good growth, but high mortality was observed. Common carp larvae are the most difficult to raise solely on dry diet; silver carp larvae are the easiest. The transfer of 4 cyprinids to dry diet improved their growth rate and the transfer is possible at the individual wet weight of 5-6 mg.

Dabrowski, K.; Bardega, R. 1984. Mouth size and predicted food size preferences of larvae of three cyprinid fish species. Aquaculture. 40(1):47-55.

ABSTRACT: Mouth size was examined in larvae and juveniles of three cyprinid fish species: grass carp (Ctenopharyngodon idella Val.), silver carp (Hypophthalmichthys molitrix Rich.) and big head carp (Aristichthys nobilis Rich.). A linear relationship was found between mouth size and the total length of fish, from the initial exogenous feeding stage up to 20-30 mm. Based on the mouth size, the size of the prey which could be consumed was calculated assuming 45 degree of mouth opening for optimum prey width and 90 degree for maximum prey width. Food particle size considered to be suitable for commencement of feeding amounted to 50-90 mu m for silver carp larvae, 90-150 mu m for grass carp larvae and 150-270 mu m for bighead carp larvae. These criteria can be applied to moving rotifers and nauplii as well as to the motionless particles of compound, dry diets.

Das, P.; Kumar, D.; Bhaumik, U.; Roy, B.; Chakraborty, D.P. 1987. Observations on four species culture of major Indian carps and exotic silver carp. J. Inl. Fish Soc. India 14(1):18-22.

ABSTRACT: While feeding of grass carp often poses a problem in pond fish culture the common carp generally show low consumer preference. An experiment was thus conditioned in a 0.25 ha pond for ascertaining the production potential of four species culture with catla (Catla catla), rohu, (Labeo rohita), mrigal (Cirrhina mrigala) and silver carp (Hypophthalmichthys molitrix) at a total stocking density of 7000/ha. With a view to reducing the undesirable initial competition for food between catla & silver carp, the stocking programmes were phased. The fishes were fed on a new commercial item, 'Epic Fish Feed' reducing the expenditure by 37% against conventional feeds. A net fish production of @ 5556 kg/ha/yr from the experiment indicates the efficacies of the species combination, phased stocking and the feed etc.

Das, P.; Kumar, D.; Guha, R.M.K. 1975. National demonstration on composite fish culture in West Bengal, India. J. Inl. Fish Soc. India 7:112-115.

ABSTRACT: Experiments were conducted in a 0.32 ha pond situated within the campus of the Jute Agricultural Research Institute, Nilganj and a 0.1 ha pond at Mirhati [India] during 1973-74. Mahua oilcake (Bassia latifolia) at 250 mg/l was applied in both the ponds initially for clearing the pond of all fishes. At both centers, stocking was done in 2 installments, with fingerlings of catla (Catla catla), rohu (Labeo rohita), mrigal (Cirrhinus mrigala), silver carp (Hypophthalmichthys molitrix), grass carp (Ctenopharyngodon idella) and common carp (Cyprinus carpio var. communis). Fish were fed daily with a mixture of mustard oilcake and rice bran. Grass carp were fed initially with duck weeds, then with napier grass and later on with Hydrilla. Both organic and inorganic manures were applied. The gross production rates were 5,253 and 4,506.5 kg/ha per yr at Nilganj and Mirhati, respectively. The grass carp could not be fed adequately with its preferred aquatic weeds and hence good growth could not be obtained. The growth of common carp was not satisfactory as compared with that of mrigal.

Dickman, M. 1987. Impact of tilapia grazing on plankton composition in artificial ponds in Guanacaste Province, Costa Rica. Journal of Freshwater Ecology, (1):93-100.

ABSTRACT: Twenty-seven shallow tilapia culture ponds, having fish densities of 0.1 to 12 individuals $.m^{-2}$ were studied in Guanacaste Province, Costa Rica. Temporal changes in plankton community structure following the emptying and subsequent filling of each pond were noted. In general, newly filled ponds were initially colonized by microflagellates, which in turn were replaced by green and finally blue-green algae. Microcystis aeruginosa frequently became the dominant phytoplankter. Its density was correlated with both high tilapia densities and low zooplankton concentrations. When tilapia densities were maintained below 0.5 fish $. m^{-2}$, the copepod Mesocyclops leukartii dominated the zooplankton community, and algal biomass was moderate. At higher tilapia densities, rotifers replaced copepods as the dominant zooplankters. When tilapia densities exceeded two adult fish $. m^{-2}$, negligible zooplankton levels were attained, and phytoplankton densities reached their highest levels ($>2 \times 10^6$ cells $. ml^{-1}$). At these high algal densities, nighttime dissolved oxygen concentrations were so low that the tilapia were forced to the water's surface to breathe. As a result, tilapia predation by fish-eating birds was significant.

Dimitrov, M. 1984. Intensive poly culture of common carp Cyprinus carpio and herbivorous fish silver carp Hypophthalmichthys molitrix and grass carp Ctenopharyngodon idella. Aquaculture 38(3):241-254.

ABSTRACT: Intensive polyculture of common carp and herbivorous fish (silver carp and grass carp) at high stocking densities and with intensive feeding with fodder and mineral and organic fertilization was carried out without mechanized aeration and automated feeding. Two stocking patterns were tested. The first, in Pond 1 (2.5 ha), had the following stocking rates: 1-yr carp (C1), 8000 fish/ha; 1-yr silver carp (S1), 1500 fish/ha; and 1-yr grass carp (G1), 200 fish/ha. The yield was 6292 kg/ha of standard consumer fish (C1+ 743 g, S1+ 944 g, and G1+ 1000 g) at a relatively low food conversion ratio (2.24) and high survival of all fish. Within the total yield the 2-yr carp contributed 76%, the silver carp 21% and the grass carp 3%. The 2nd stocking pattern, in Pond 2 (0.25 ha), had the following rates: C1 8500 fish/ha; S1, 2000 fish/ha; and G1, 200 fish/ha, and produced a still higher total yield (6629 kg/ha) at a relatively low food convesion ratio (2.10). The 2-yr carp in Pond 2 contributed 88% of the total yield and the herbivorous fish only 12%, even though they accounted for 20% of the stock. The results (Pond 2) are compared with other record yield experiments under similar conditions but including tilapia. At a total stocking rate of 10,700 fish/ha and without participation of tilapia, over a period of 186 days (as against 126 days in the other experiment), these experiments gave a total yield which was 347 kg/ha higher at a food coefficient 15% lower. The growth period was 60 days longer in these experiments, but it included April and Oct. when water temperature is much below the optimum and only 4% of the total amount of fodder was assimilated.

Dimitrov, M. 1987. Intensive polyculture of common carp Cyprinus-carpio l., silver carp Hypophthalmichthys-molitrix val., and black buffalo Ictiobus niger raf. Aquaculture 65(2):119-126.

ABSTRACT: Intensive polyculture was carried out with common carp, silver carp and black buffalo fed a mixture of 60% pellets (with protein level of 25%) and 40% barley, along with mineral and organic fertilization. Two stocking patterns were tested. From pattern I, in pond 1 (total stocking density 4600 fish/ha), the yield of fish after 180 days was 3538 kg/ha, with standard weight (above 550 g), at a food conversion ratio of 2.36. From pattern II, in pond 2 (total stocking density 9200 fish/ha), the respective figures were 5022 kg/ha and 2.56. An economic comparison of several polyculture trials showed that buffalo fish (bigmouth and black) at a stocking rate of 2000 fish/ha, grown with common carp (2500 fish/ha) and silver carp (1200-1500 fish/ha), gave the best breeding and economic results (a profit of 962 levs/ha or 0.27 lev/kg). The buffalo fish have excellent organoleptic properties and are considered a delicacy favoured on the Bulgarian market.

Dini, M.L.; O'Donnell, J.; Carpenter, S.R.; Elser, M.M.; Elser, J.J.; Bergquist, A.M. 1987. Daphnia size structure, vertical migration, and phosphorus redistribution. Hydrobiologia 150:185-191.

ABSTRACT: The timing and magnitude of diel migration in two daphnid assemblages were determined from a series of vertical profiles of daphnid size distribution. Animals were collected concurrently for gut fullness determination. Only large daphnids (>1.4 mm) migrated, but these animals could account for substantial vertical and diel differences in phosphorus excretion rate. Gut fullness measurements and time courses of diel vertical migration suggested that large Daphnia can cause a net downward flux of phosphorus during summer in thermally stratified lakes.

Drenner, R.G.; DeNoyelles, F.; Kettle; D. % 1982. Selective impact of filter-feeding gizzard shad on zooplankton community structure. Limnol. Oceanogr., 27(5), 965-968.

ABSTRACT: Comparison of ponds containing gizzard shad with control ponds without fish showed that gizzard shad predation suppressed populations of Keratella sp., Diaphanosoma brachyurum, copepod nauplii, Chaoborus sp., and cyclopoid copepodids and adults, but enhanced populations of Diaptomus pallidus copepodids and adults. These results confirm previous laboratory studies which showed that filter-feeding gizzard shad are not size-selective predators, as is typically assumed of planktivorous fish, but instead feed on those animals which have little ability to escape, so that their predation results in a community shift toward the more evasive prey.

Drenner, R.W.; Hambright, K.D.; Vinyard, G.L.; Gophen, M.; Pollingher, U. 1987. Experimental study of size-selective phytoplankton grazing by a filter-feeding cichlid and the cichlid's effects on plankton community structure. Limnol. Oceanogr. 32(5):1,138-144.

ABSTRACT: In laboratory experiments, feeding rates of small (40-61-mm standard length, SL) and large (98-143-mm SL) Galilee Saint Peter's fish (Tilapia galilaea) on phytoplankton and zooplankton increased as a function of particle size, leveling off when particle size exceeded 6-10 μm. Fish had high feeding rates on zooplankton, the large dinoflagellates Peridinium cinctum and Peridinium elpatiewsky, and a few nanoplankton, but most species of nanoplankton were consumed at lower rates.

To examine the community-level effects of the fish, we conducted two 7-d outdoor tank experiments with six fish-density treatments ranging from 0 to 400 g m^{-3}. Crustaceans, rotifers, and Peridinium spp. declined as functions of fish density, but nanoplankton abundance was highest at intermediate fish densities. Suppression of Peridinium spp. by fish resulted in a reduction of total chlorophyll and gross primary production.

Drenner, R.W.; Mummert, J.R.; deNoyelle, F.; Kettle, D. 1984. Selective particle ingestion by a filter-feeding fish and its impact on phytoplankton community structure. Limnol. Oceanogr., 29(5), 941-948.

ABSTRACT: The ingestion rates of filter-feeding gizzard shad for different sizes of suspended particles were measured using mixtures of microspheres and zooplankton. Ingestion rate increases as a function of particle size, leveling off at 60 μm. The particle-size-dependent ingestion rates were consistent with a model of filtering efficiency based on the cumulative frequency of interraker distances of gizzard shad gill rakers.
Comparison of ponds containing gizzard shad with control ponds without fish showed that gizzard shad suppressed Ceratium, the only phytoplankton species large enough to be ingested at a maximum rate. Gizzard shad did not have a significant effect on populations of Synedra, Peridinium, Navicula, Kirchneriella, Cyclotella, and Chlamydomonas. Populations of Ankistrodesmus, Cryptomonas, Cosmarium, Rhodomonas, and algae and bacteria from 2-4μm were enhanced by gizzard shad.

Drenner, R.W.; Threlkeld, S.T.; McCracken, M.D. 1986. Experimental analysis of the direct and indirect effects of an omnivorous filter-feeding clupeid on plankton community structure. Can. J. Fish. Aquat. Sci. 43:1935-1945.

ABSTRACT: In laboratory trials, feeding rates of an omnivorous filter-feeding clupeid, Dorosoma cepedianum, increased as a function of particle size, with maximal rates on microspheres, spherical algae, and zooplankton >40 μm; it did not efficiently feed on filamentous Anabaena flos-aquae. To examine the community level impacts of Dorosoma, we conducted four seasonal outdoor tank experiments of cross-classified design involving two or three densities of Dorosoma and two densities of the zooplanktivorous atherinid fish, Menidia beryllina. We attempted to discriminate between the direct and indirect effects of Dorosoma on phytoplankton by using Menidia to produce indirect effects on phytoplankton by suppressing zooplankton. Experiments began in November, March, June, and September and lasted for 45-53 d. Dorosoma suppressed most zooplankton in at least one experiment and enhanced algal standing crops in all four experiments, as indicated by increased algal chlorophyll fluorescence, turbidity, Coulter counts and microscopic algal counts, and decreased Secchi depths. Because in three out of four experiments Menidia suppressed zooplankton biomass to a greater extent than Dorosoma without enhancing phytoplankton, we reject the hypothesis that the enhancement of phytoplankton by Dorosoma was an indirect effect of zooplankton biomass suppression.

Efimova, T.A.; Nikanorov, Y.I. 1977. Prospects in the introduction of phytophagous fish into the Ivankovskoye Reservoir. Vopr. Ikhtiol. 17(4):715-726.

ABSTRACT: Warm water conditions produced by hydroelectric power plant discharge caused high densities of vegetation growth (220 taxa of aquatic vasculars, 199 taxa of green algae, 193 taxa of diatoms and 64 taxa of blue green algae) in the Ivanovskoye reservoir of the Kalinin Oblast [Russian SFSR, USSR]. These conditions prompted analyses for the prospective introduction of phytophagous fish (carp, Ctenopharyngodon idella and Hypophthalmichthys molitrix) into the reservoir in order to increase water quality and production of commercial fish. Phragmites communis, Glyceria maxima, Equisetum fluviatile, Potamogetom perfoliatus, P. lucens, Polygonum amphibium, Stratiotes aloides and Myriophyllum spicatum comprised the dominant vascular species. Dominant phytoplankton species consisted of Melosira italica, M. granulata, Asterionella formosa, Stephanodiscus hautzschii, Microcystis aeruginosa, M.a.f. flos aquae, Aphanizomenon flos-aquae, Anabaena flos-aquae, Gloeocapsa sp., Scenedesmus, Ankistrodesmus, Coelastrum and Chlamydomonas. The low population of pike in the reservoir was not expected to hinder the success of phytophagous fish.

Elliott, E.T.; Castañares, L.G.; Perlmutter, D.; Porter, K.G. 1983. Trophic-level control of production and nutrient dynamics in an experimental planktonic community. Oikos 41:7-16.

ABSTRACT: The dynamics of ammonium, nitrate, and orthophosphate concentration; algae and zooplankton growth; detrital output; fish production; and gross and net primary productivity (diel oxygen method) were followed through three growth phases (bloom, crash, and stable periods) that occurred over a 52-d period in 220-l experimental systems containing simulated epilimnetic communities (Scenedesmus sp., Daphnia magna, and Pimepheles promelas). Triplicate experimental manipulations were algae alone (A), algae with zooplankton (AZ), algae and zooplankton with fish (AZF), and algae and zooplankton with the fish confined to a cage (AZFC). High algae abundance and turbidity in food chains A and AZF were accompanied by low nutrient levels and high detrital output. Highest rates of primary productivity occurred when resources were abundant and algae were not controlled by herbivory. Controlled fish predation (AZFC) produced stable systems with the highest secondary productivity and high water clarity. Uncontrolled zooplanktivory (AZF) eventually led to classical symptoms of reduced zooplankton abundance and small average body size and concomitant highly increased turbidity. This last treatment had the highest primary productivity but the least stability at the end of the experiment.

Falk, K. 1981. Weight gain results for plankton eating cyprinidae in an experimental fish breeding installation using brackish water. Fisch-forsch 19(1):43-46.

ABSTRACT: The survival rates and population dynamics in glass fiber-reinforced polyester troughs were observed in experiments conducted at the Institute for Deep Sea Fisheries and Fish Processing at Rostock-Marienehe in East Germany. While the production goals for inland fishing for that country have not been met, it has been possible to maintain freshwater norms for the growth rate of marble carp and silver carp during the 1st breeding period in thermostatically controlled brackish water of low salinity. At the present time experiments are being conducted under dynamic temperature-saline conditions in the cool water stream that runs through a brackish water-fed nuclear power plant, used in fish feeding experiments.

Farkas, A. 1978. Experiences of the fish destruction at Kortvelyes the appearance of the herbivorous fishes and the ecological relations of their role. Tiscia (SZEGED) 13:181-182

Ferrara, O.; Mastrantuono, L. 1982. Composition and seasonal variations of the zooplankton in two artificial fishponds (Monterotondo, Latium). Riv. Idrobiol. 21(1-3):113-123.

ABSTRACT: The qualitative and quantitative composition of zooplankton in two artificial fishponds (P sub(1) and P sub(2), Monterotondo, Latium) were studied. A total of 26 species (19 rotifers, 6 cladocerans, 1 copepod) were identified, except for Trichotria pocillum), rarely found only in P sub(2). The specific composition in both ponds were similar but the density values of some species, such Keratella quadrata, Brachionus angularis, Moina micrura, Bosmina longirostris) and Eudiaptomus padanus etruscus, displaied remarkable differences. Such difference in the structure of the zooplanktonic biocoenoses could be ascribed to the different trophy of the two basins. Besides, the selective predation of a planktivorous fish (Aristichthys nobilis), found only in P sub(1), probably affected the composition of zooplankton in both ponds.

Fijan, N. 1976. Freshwater fisheries management in Yugoslavia. Fish Manage. 7(4):85-86.

ABSTRACT: The author described in general terms fisheries in Yugoslavia. There are a total of 246,000 ha of inland water. This is divided into high (salmon) and low (cyprinid) water. Three main river systems are represented. (1) Black Sea system (2) Adriatic (3) Aegean. These three rivers provide a vast number of habitats for fish and approx 160 species are found. The per head consumption of fish in Yugoslavia has risen from 1.3 kg in 1963 to 3.2 kg in 1973. This latter figure represents 7.6 per cent of the protein requirement, a small but not insignificant figure. A fishery is related to exploitation of all creatures in watercourses and therefore to its breeding as well as its cropping. In general terms the trout and salmon waters produce 35 kg/ha/yr and cyprinid waters 80-120 kg/ha/yr. However fluctuations in production are great. Most of the fish farming is cyprinid with the carp being most important. There are 4 genotype of carp reared and selective breeding is well advanced. Large scaled carp are not grown. Common carp are reared. Naked carp (Leather) are poor growers and are not reared. The carp that is grown most is a Nachater strain developed by selective breeding. It has no lateral line scales, a small head and high back. Carp farms are large with the largest single pond being 600 ha (about the size of Chew Valley Lake). The maximum depth of ponds is 4.5 m. Controlled reproduction started 15 years ago. A burst in experimental work 10 years ago produced the first commercial results 4 years ago and this year 35 per cent of carp production was from artificial spawning. Hypophysation is used and eggs are hatched in jars, this ensures a 45 per cent survival as against approx 5 per cent in nature. The first crop of plant eating carp was btained in 1965. 3 species are used. Grass Carp, Silver Carp, and Bighead Carp. The carp are reared separately up to the first winter then polyculture is practised over the winter. Tench are cultivated in polyculture but this is still in its infancy. Wels is cultivated and has a role as a police fish (i.e. it eats all the 'trash' fish that colonize the pond).

Freeze, M.; Henderson, S. 1982. Distribution and status of the bighead carp and silver carp in Arkansas. N. Am. J. Fish. Manage. 2(2):197-200.

ABSTRACT: Bighead carp (Aristichthys nobilis) and/or the silver carp (Hypopthalmichthys molitrix) are being utilized at six hatcheries and have been purposely stocked at four research sites in Arkansas. Reports of silver carp in Arkansas' public waters in January 1980 prompted this investigation. Commercial fishermen reported catching 166 silver carp at seven different sites, but they did not report catching any bighead carp. An intensive sampling effort on the Arkansas River by Arkansas Game and Fish Commission personnel was unsuccessful in procuring additional specimens.

Fuhrmann, B. 1980. Fish-Fry From Herbivorous Fish in Growing Ponds Under Warm Water Conditions in Vetschau, German Dem. Rep., 1979). Z. Binnenfisch. D.D.R. 27(11):342-350.

ABSTRACT: The fry of Hypophthalmichthys molitrix, Aristichthys nobilis and Ctenopharyngodon idella was raised in warm water (24 - 28 degree C) growing ponds (6 ponds 750 m super(2) each, and 5 ponds between 5.000 and 10.000 m super(2), total area 3.5 ha). The population was calculated for the normal stocking density. After about 20 days the survival rate was between 30 and 85,1% for fishes between 0.27 and 0.42g.

Gaigher, I.G.; Krause, J.B. 1983. Growth rates of mozambique Oreochromis mossambicus and silver carp Hypophthalmichthys molitrix without artificial feeding in floating cages in plankton-rich waste water. Aquaculture 31(2-4):361-368.

ABSTRACT: H. molitrix and O. mossambicus were reared without artificial feeding in 0.57 m3 wire cages suspended in human sewage and pig feedlot waste treatment systems. At a cage density of 17 m-3, H. molitrix grew from 15-260 g in 190 days, but then growth ceased due to unknown factors. O. mossambicus grew rapidly at various densities; the maximum being from 10-130 g in 98 days. In both species, the maximum individual daily mass increase of 2.5 (H. molitrix) and 1.4 g (O. mossambicus) occurred during Dec.-Jan. Mortalities were probably mainly due to handling. Those grown in the human sewage treatment system were in a better condition than those from the pig feedlot waste treatment system.

Grabda-kazubska, B.; Baturo-warszawska, B.; Pojmanska, T. 1987. Dynamics of parasite infestation of fish in lakes Dgal, Wielki, and Warniak, Poland in connection with introduction of phytophagous species. Acta. Parasitol. Pol. 32(1):1-28.

ABSTRACT: In 1979-1984, during a survey of fish parasites of lakes Dgal Wielki and Warniak (Mazurian Lakeland) stocked since 1970 with fry of phytophagous fish species (Ctenopharyngodon idella, Hypopthalmichthys molitrix and Aristichthys nobilis), whitefish (Coregonus peled) and carp (Cyprinus carpio), a total of 945 fish specimens of 20 species were examined and 87 parasite species (except protozoans) were found. Dactylogyrus nobilis Long et Yu, 1958, Gyrodactylus sp. and Capillaria sp. (probably C. amurensis Filogenova, 1967) are thought to have been introduced into lakes with phytophagous fish fry. Other species are regarded to be of local origin. More species of parasites and a higher level of infestation were noted in Dgal, only some of the most common species being abundant in Warniak. Seasonal changes in prevalence and density of some parasites were observed, especially of Dactylogyrus spp. Annual changes observed in the level of infestation of fish with particular parasites are regarded as a result of changes in lake biocenosis due to devastation of aquatic plants by phytophagous fish. The high level of infestation of these fishes by local parasites, especially by digenean metacercariae and Ergasilus sieboldi, was noted.

Green, B.W.; Oneal Smitherman, R. 1984. Relative growth, survival and harvestability of bighead carp, silver carp, and their reciprocal hybrids. Aquaculture. 37(1):87-95.

ABSTRACT: Growth and survival in the primary rearing phase (42 days) for bighead carp (Aristichthys nobilis) silver carp, (Hypophthalmichthys molitrix), bighead x silver carp (BHC x SC), and silver x bighead carp (SC x BHC) in ponds and concrete tanks stocked at 370,500 fry/ha were studied. Mean survival for fishes in ponds was 93%, that in tanks was 73%, Yields among all fishes averaged 338 kg/ha. The growth rates of fishes in ponds were similar in tanks, silver carp grew faster than the bighead carp. Growth, survival, and harvestability by seine during the secondary rearing phase (60-day duration) for the same groups of fish were studied. Fingerlings (0.9 g mean weight) were stocked in earthen ponds at 49,400 fish/ha and 98,800 fish/ha. Mean survival of fishes at low stocking rate was 77%, similar to that (71%) for the high stocking rate. Fish yields were similar at the low stocking rate.

Grozev, 1977. Results from the introduction of hybrids between silver carp and bighead in the fish farming practice. In: Proceedings of the freshwater fishery research station - Plovdiv 12:33-58

ABSTRACT: The first experiments of hybridization between silver carp (Hypopthalmichthys molitrix (Val)) and bighead (Aristichthys nobilis (Rieh)) were initiated in 1968-1968. During the period from 1973 to 1975 a total of 29,098,000 larvae of silver carp and bighead were produced, 18,755,000 of which are hybrids (8,906,200 silver carp x bighead, and 12,164,000 bighead x silver carp), or 64.45% of the total production. The average percentage of hatching with the hybrids silver carp x bighead is 6.9-1.9 times higher than that of silver carp, and 3.2-1.5 times higher than that of bighead. The average percentage of hatching with the hybrids bighead x silver carp is 4.9-17.7 times higher than that of bighead and 3.8 times higher than that of silver carp. The hybrids silver carp x bighead have the highest percentage of survival and growth rate per decare.

Grygierek, E. 1987. The effect of silver carp on changes in environmental conditions of carp rearing I. Fishes. Rocz Nauk Roln Ser H Rybactwo 101(2):129-142.

ABSTRACT: The study was aimed at checking the influence exerted by a relatively small amount of silver carp (Hypophthalmichthys molitrix Val.) in ponds with various stocking densities of carp (Cyprinus carpio L.). Addition of small amounts of silver carp (up to 250 kg ha in catchings) to small amounts of carp (400 to 640 kg/ha) results in improved feeding conditions for both species of fish. This is evident in the lowering of the feed coefficient for food in the case of carp and by higher body increments for silver carp as stocking densities are increased, silver carp inclusive. Addition of the same amount of silver carp as above to more numerous stocks of carp.sbd.exceeding 1300 kg/ha.sbd.does not give the same effect. However as the total biomass of fishes increases up to 1500-1800 kg/ha, the rearing conditions for silver carp improves.

Grygierek, E. 1978. The influence of silver carp Hypophthalmichthys molitrix on eutrophication of the environment of carp ponds 4. Zooplankton. Rocz Nauk Roln Ser H Rybactwo 99(2):81-92.

ABSTRACT: Two-year-old silver carp in numbers of 4000-12,000 fish/ha resulted in a distinct decline in the number of zooplankton. The drop in numbers was especially noticeable with respect to crustaceans, multiplying more slowly than rotifers. Proportions between specific species of crustaceans was considerably more favorable for fish than in ponds with carp only. To increase the fishery production of a water body and maintain the mechanisms regulating the amount of phytoplankton, the silver carp should be introduced in such numbers as not to decrease the numbers of zooplankton.

Grygierek, E. 1987. The effect of silver carp on changes in environmental conditions of carp rearing IV. Zooplankton. Rocz Nauk Roln Ser H Rybactwo 101(2):175-188.

ABSTRACT: A small number of silver carp was added to carp ponds with various stocking densities. It was found that the effect of silver carp depends upon the carp biomass. Addition of silver carp (of up to 250 kg in catchings) to ponds with a low carp biomass (of up to 640 kg/ha in catchings) results in improving the food conditions for carp evident as an increase in zooplankton biomass, especially of cladoceran of the Daphnidae family. Addition of a similar amount of silver carp to ponds with a carp biomass of more than 1300 kg/ha in catchings resulted in a growth in numbers of only small zooplankton species of little usefulness for carp, and in only slight changes as concerns total zooplankton biomass.

Guerrero, R.D., III. Species selection for pen culture and sources of stock (SCS/PCC/WP-4). Training Course on Small-Scale Pen and Cage Culture for Finfishes Los Banos (Philippines). Aberdeen (Hong Kong) 26 Oct 1981. Report of the training course on small-scale pen and cage culture for finfish, Los Bbanos, Laguna, Philippines, 26-31 October 1981 and Aberdeen, Hong K.kong, 1-13 November 1981. Guerrero, R.D., III; Soesanto, V., 1982. pp. 53-55.

ABSTRACT: The different species cultured in the fishpens of Laguna de Bay include milkfish (Chanos chanos), tilapias (Tilapia nilotica, T. mossambica), carps (Cyprinus carpio , Carassius carassius, Hypophthalmichthys molitrix and Aristichthys nobilis). The sources of fish seed of each of the species for stocking in the pens are considered.

Gupta, V.K.; Sudan, A.K.; Srivastava, J.B. 1986. Intensive culture of indian and exotic carps in a fresh water pond in Jammu, India. Zool. Orient 2(1-2):49-51.

ABSTRACT: Investigations on the intensive culture of some Indian and exotic carps have been conducted in a newly constructed fresh water pond in Sherpur (Jammu, India). The stocking density used was 11,000 fingerlings per hectare which included the Indian major carps Labeo rohita, Cirrhinus mrigala, the exotic carps Hypophthalmichthys molitrix, Ctenopharyngodon idella and Cyprinus carpio. Cowdung as fertilizer was used at the rate of 5,000 kg/hectare in installments. Rice bran and mustard oil cake (1:1) was given as supplementary feed at the rate of 5-7% body weight. Total production of 7,650 kg/ha/annum was achieved.

Hall, D.J., Cooper, W. S.; E. E. Werner. 1970. An experimental approach to the production dynamics and structure of freshwater animal communities. Limnol. Oceanogr. 15:839-928.

ABSTRACT: The effects of three levels of inorganic nutrients and two predator densities on aquatic animal communities were examined in a series of twenty 0.07-ha freshwater ponds. The treatments were cross-classified in a randomized block design and continued over 3 years. Analyses of the responses include community composition, secondary production, and demographic description of the dominant species of both zooplankton and benthos. The fish populations and their feeding behavior are described in detail. Ancillary data on water chemistry and primary production were available.

Nutrients generally increased production of the zooplankton but had little effect on community composition. Fish predation had profound effects on the diversity and size distribution of the zooplankton but only affected production at lower nutrient levels. The benthos responded markedly to nutrients during the first year, but this was not apparent the second and third years. The response of the benthos to both nutrients and predation was best shown by changes in the distribution of body size. Both zooplankton and benthic communities showed complementary responses between large- and small-bodied organisms. Differences in the physical structure of the environment (i.e., macrophytes) also produced significant changes in production and composition of both systems. The biomass production of the fish populations was clearly related to nutrient level. Both fish and invertebrate predators were size selective, but the fish had a much greater influence on the prey populations.

Hejkai, T.W.; Gerba, C.P.; Henderson, S.; Freeze, M. 1983. Bacteriological, virological and chemical evaluation of a wastewater-aquaculture system. Water Res. 17(12):1,749-1,755.

ABSTRACT: Levels of fecal coliforms (FC) fecal streptococci (FS), Salmonella spp and enteric viruses were monitored in the water, sediment and fish in experimental wastewater-fish ponds near Benton, Arkansas, USA. Concentrations of five heavy metals were also monitored in the fish and wastewater. Concentrations of indicator bacteria were reduced by as much as 99.7% through the series of six ponds which had a calculated total retention time of 72 days. Based on the efficiency of wastewater treatment, an aquaculture system using silver and bighead carp was judged to be a viable treatment system for domestic sewage resulting in a product suitable for animal or human consumption if proper precautions are taken in harvesting and processing the fish.

Henderson, S. Determination of production potential of catfish grow-out ponds supplementally stocked with silver and bighead carp. Arkansas Game and Fish Commission, Little Rock (USA)
Compl. Rep. AR Game Fish Comm.

ABSTRACT: Three experimental ponds were stocked with a polyculture of channel catfish, silver carp, and bighead carp. Three control ponds were stocked with catfish alone. In two of the three sets of ponds, there was little difference in catfish production while total production in the polyculture ponds far exceeded the controls with catfish alone. In the remaining set, catfish production was less in the polyculture pond, but total production remained higher as a result of the additional growth of the silver and bighead carp. Successful artificial spawning methods for the silver and bighead carp, using hormone inducement, were developed. Attempts to cause a natural spawn of the silvers and bigheads in small ponds failed.

Henderson, S. 1979. Production potential of catfish grow-out ponds supplementally stocked with silver and bighead carp. Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 33:584-590.

ABSTRACT: Three experimental ponds were stocked with a polyculture of channel catfish (Ictalurus punctatus), silver carp (Hypopthalmichthyes molitrix), and bighead carp (Aristichthys nobilis). Three control ponds were stocked with catfish alone. In 2 of the 3 sets of ponds, there was little difference in catfish production (less than 1 and 10% by weight) while total production in the polyculture ponds far exceeded the controls with catfish alone. In the remaining set, catfish production was less in the polyculture pond but total production remained higher as a result of the additional growth of the silver and bighead carp.
Lesser objectives were to refine artificial spawning methods and describe the difference in water quality resulting from the presence of the filter feeding Chinese carps. Successful hormone induced spawning techniques were developed and an improvement in pond water quality was noted.

Henrikson, L.; Nyman, H.G.; Oscarson, H.G.; Stenson, J.A.E. 1980. Trophic changes, without changes in the external nutrient loading. Hydrobiologia 68(3):257-263.

ABSTRACT: The impact of the fish population on trophic properties of lake water was experimentally studied in an oligotrophic Swedish forest lake. Biotic changes following fish removal resulted in a development in oligotrophic direction as shown by the drop in limnetic primary production, pH, total phosphorus, total nitrogen, and the increased transparency.

Hepher, B.; Sandbank, S. 1984. The effect of phosphorus supplementation to common carp diets on fish growth. Aquaculture 36(4):323-332.

ABSTRACT: The effect of supplementation of fish diets with P was studied both in tank and pond experiments. In the tank experiments P (6.5% di-calcium or monocalcium phosphates) was added to 3 diets: 2 containing fish meal as the main protein ingredient and the third containing algal meal to replace it. Feeding common carp in tanks with these diets significantly increased fish growth rate ($P < 0.05$) over fish fed the same diets without P supplementation. In the pond experiments P was added to a fish meal diet in 2 different compounds: mono- and di-calcium phosphates (at 1% of the feed). The diets were fed to fish in a polyculture system for 2 consecutive culture cycles. Due to supplementation with phosphate, growth rate of tilapia (Sarotherodon aureus) increased in both culture cycles. The growth rate of common carp fed P-supplemented diets increased over the control only in the 1st cycle, when fish were large and the standing crop of carp exceeded 1.8 ton/ha. At lower standing crops the natural food seems to supply adequate amounts of P. Silver carp [Hypophthalmichthys molitrix] were not affected by P supplementation, probably because they consume very little supplementary feed. Total yield for the entire season (kg/ha) was significantly higher in ponds where fish were fed a P-supplemented diet. Di-calcium phosphate, which is soluble only in weak acids, seems to be more efficient than the water-soluble mono-calcium phosphate in affecting the growth of common carp [Cyprinus carpio] even though this fish lacks a gastric acid secretion.

Hering, G. 1981. Experiments on plankton feeding cyprinids in brackish water using different dry food materials. Fischerei-forschung. 19(2):59-64.

ABSTRACT: The industrial production of plankton feeding Cyprinid fingerlings (Silver carp, Hypophthalmichthys molitrix Big head, Aristichthys nobilis and the hybridform Big head x Silver carp) assumes adaequate feeding materials for the period of first growth as well. Therfore plankton fed hybrids (Ma Si) have been grown by different dry food materials in special arrangements and conventional rearing channels. Equal growth rates have been achieved using "Starterfutter CSF-A" (LIEDER and HELMS 1981) which has been developed in the GDR and "EWOS-Larvstart C10" compared with living plankton: Within a period of 16 days medium mass per specimen was up to 350 mg and survival rate was up to 99.6%. Besides this rearing achievements have been presented for using six different food materials (combinations of food materials).

Hock, G.T.S.; Hong, T.S. 1984. Carp hatchery and nursery techniques in Singapore. Iclarm Conf. Proc. 11.
Summary report of the Asian regional workshop on carp hatchery and nursery technology, Manila, Philippines, 1-3 February 1984.
May, R.C.; Pullin, R.S.V.; Jhingran, V.G. (eds.).

ABSTRACT: Hatchery and nursery techniques for bighead carp (Aristichthys nobilis) and common carp (Cyprinus carpio) are described. The mass production of bighead carp fry is carried out in an indoor hatchery. About 95% of the postlarvae develop into the fry stage. The fry are fed with mass-cultured Moina micrura for ten days. They have a survival rate of 99%. Survival of fingerlings has been estimated at 95%. The mass production of common carp fry is also carried out in an indoor hatchery. Water hyacinth (Eichornia sp.) is used in spawning tanks for attachment of eggs. The fry are fed with M. micrura.

Horwath, L.; Lang, M.; Tamas, G. 1978. The use of copper oxy chloride during larval growth as a preventative measure against the spread of ciliate exo parasites. Bamidgeh 30(3)80-84.

ABSTRACT: During culture of larvae and fry the danger of infection with exoparasitic Ciliates (Trichodina, Chilodonella) increases in correlation to intensification of production. The main damage incurred does not appear as loss.sbd.although this may also occur.sbd.but rather as restricted growth and poor quality. Some copper compounds seemed to be likely candidates for prevention of parasite evoked damage to farmed larvae and fry of cyprinid fish (carp, silver-carp, grass-carp and tench). Instead of the well known and effective but at the same time poisonous copper sulfate, we used the less toxic copperoxychloride. Before treatment of ponds, concentrations effective against parasites were determined under laboratory conditions. The therapeutic dose was 4 mg/l and 20-fold concentrations (i.e., 80 mg/l) were toxic to the fish. In pond treatments parasites were eliminated by the copper compound at a concentration of 4 mg/l. When changes in technology were also instituted, fish developed well and there was no renewal of infection.

Hurlbert, S.H.; Mulla, M.S. 1981. Impacts of mosquitofish (Gambusia affinis) predation on plankton communities. Hydrobiologia 83:125-151.

ABSTRACT: An investigation of the effects of mosquitofish (Gambusia affinis) predation was conducted in 12 experimental ponds in southern California over a period of 10 months. Gambusia essentially eliminated Daphnia pulex and Ceriodaphnia sp. populations, reduced Diaptomus pallidus and Keratella quadrata populations, had little impact on Cyclops vernalis, and caused large increases in K. cochlearis, Polyarthra sp., Synchaeta sp., and Trichocerca spp. populations and in total phytoplankton. Gambusia caused a decrease in the PIE (probability of interspecific encounter) of the planktonic crustaceans and an increase in the PIE of the planktonic rotifers. Hemiptera, such as neustonic Microvelia sp. and nektonic Buenoa sp. and Notonecta sp., and Hyla regilla tadpoles were absent from fish ponds but sometimes abundant in control ponds. Gambusia caused a higher pH and oxygen levels, presumably via its effect on the phytoplankton. The impact of Gambusia on the pond ecosystems was less in winter, when fish numbers and feeding rates were low, than in summer. Results of other fish-plankton studies are summarized in tabular form. A model is proposed to account for variation in the calanoid/cyclopoid ratio; evidence is summarized suggesting that in general calanoids are more susceptible to predation by predaceous zooplankters while cyclopoids are more susceptible to fish predation. Some parallels are drawn between the effects of Gambusia predation and those of insecticide treatments.

Hutchinson, B.P. 1971. The effect of fish predation on the zooplankton of ten Adirondack Lakes, with particular reference to the Alewife, Alosa pseudoharengus. Trans. Am. Fish. Soc. 100:325-335.

ABSTRACT: Stomach contents of alewives collected in Black Pond in 1958 consisted primarily of Diaptomus, Epischura, Mesocyclops, and Daphnia. Food of Black Pond alewives in 1966 consisted mainly of Bosmina, Holopedium, cyclopoid copepods (Cyclops, Macrocyclops, Tropocyclops), and chironomid pupae. Alewife stomach contents were compared with limnetic plankton samples to determine whether the alewives were selective in their choice of food organisms. Both species and size selectivity were observed. The evidence collected suggests that alewife predation was responsible for a change in the zooplankton community of Black Pond. The zooplankton communities of 10 Adirondack lakes were compared. The species and size composition of these communities appeared to be influenced by the presence of planktivorous fish.

Inter, K. 1980. Exotic fishes in Hungarian waters: their importance in fishery utilization of natural water bodies and fish farming. Fish Manage. 11(4):163-167

ABSTRACT: During the last 100 years in Hungary there have been several attempts to acclimatize exotic fish species. Some of these species now play an important role in the fishery utilization of natural water bodies and the farming of species such as Salmo gairdneri, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Aristichthys nobilis, and Ictalurus nebulosus. These introductions caused no problems to either existing fisheries or to the environment. Some species appeared spontaneously in Hungarian waters.

Iwata, K. 1976. Morphological and physiological studies on cyprinid phytoplankton feeders part 1 developmental changes of feeding organs and ingestion rates in kawachibuna Carassius auratus cuvieri silver carp Hypophthalmichthys molitrix and nigorobuna Carassius auratus grandoculis. Jpn. J. Limnol. 37(4):135-147.

ABSTRACT: The course of morphological development of feeding organs of the phytoplankton feeders, Kawachibuna, which is a domesticated race of Gengorobuna (Carassius auratus cuvieri) and silver carp (Hypophthalmichthys molitrix), were compared with those of the omnivorous fishes, Nigorobuna (C. auratus grandoculis) and big head (Aristichthys nobilis). In addition, a comparison of the functions of the feeding organs in Kawachibuna, Nigorobuna and silver carp was attempted by measuring the ingestion rates of 2 different sizes of 14C labeled green algae (Closterium moniliferum, 300 .mu. in length and Selenastrum sp., 10 .mu.) at various growth stages of these fishes. In young silver carp (total length 42-45 mm), relationships between the ingestion rates and the food density of both species of algae were well fit to the following formula; r = 5.54 (1-e-0.160p) for Closterium and r =3.61 (1-e-0.072p) for Selenastrum, where r is the ingestion rate (mgC/W0.81/hr) and p is the food density (mgC/l). The formula for Closterium was also applicable to young Kawachibuna (total length 40-43 mm). However, the ingestion rate of Kawachibuna relating to various food densities of Selenastrum was much lower than that of young silver carp and was rather fit to a linear equation; r = 0.108p-0.225. It is suggested that the difference in the ingestion rates for Selenastrum is mainly caused by the morphological difference in their feeding organs.

Jahnichen, H.; Kubatsch, E.; Schlegel, H. 1985. Additional studies on the wintering of yearling silver carp Hypophthalmichthys molitrix grass carp Ctenopharyngodon idella and bighead carp Aristichthys nobilis in warm water pools. Z. Binnenfisch Ddr 32(8):244-249.

ABSTRACT: 550,743 yearling phytophagous fish species (predominantly silver carp) with an average wt. of 17.7g were kept in warm-water pools in Thierbach and Vetschau {E. Germany} during the winter period of 1983-1984. At the end of May 1984, 450,480 specimens were removed and placed in fish pools. The average wt. was 38.8g and the survival rate was 81.8%. In Thierbach 2.25kg of feed (mixtures of pellet pieces, soybean meal, greenmeal and cereal meal) per kg removed fish were added. The feeding was almost ineffective.
Since 1979/80 total of 1,021,480 yearling phytophagous fish were bred under the conditions of K2 production. With very good survival rate and average final weights of over 25g, these fish represent superior fish even in extremely cold summers (1980 and 1981). This method offers decisive advantages compared to wintering in normal temperature pools and guarantees a sure and systematic formation of batch fish production.

Januszko, M. 1974. The effect of three species of phytophagous fish on algae development. Pol. Arch. Hydrobiol. 21(3/4):431-454.

ABSTRACT: Studies were carried out on the effect of three species of phytophagous fish, namely: bighead carp (Aristichthys nobilis Rich.), silver carp (Hypophthalmichthys molitrix Val.), grass carp (Ctenopharyngodon idella Val.) on the biomass, density, and structure of species composition of algae population. It has been found that at the stock of 1,500-3,000 of silver carp and bighead carp individuals/ha the biomass of algae had increased. The number of algae decreased inasmuch as the small forms gave way to the larger ones. In the presence of bighead carp Cyanophyta were particularly abundant and in the presence of silver carp--Bacillariophyceae. Seasonal changes in the structure of algae composition were favorable for fish development which was evidenced by a considerable increase in their growth. The stock of grass carp numbering 1,500 individuals/ha did not show any effect upon algae.

Januszko, M. 1979. The influence of silver carp Hypophthalmichthys molitrix on eutrophication of the environment of carp ponds 3. Phytoplankton. Rocz Nauk Roln Ser H Rybactwo 99(2):55-80.

ABSTRACT: Development of phytoplankton was observed in ponds with increasing stocking rates with silver carp (Tb2-3) at 4,000, 8,000 and 12,000 fish/ha jointly with carp stocked at an invariable rate of 4,000 fish/ha. The biomass and production of phytoplankton increased with increased stocking density of silver carp. Changes took place in the structure of algae, Chlorophyta receded and Bacillariophyceae were stimulated. As the density of silver carp increased, algae were more numerous and unit weight of the silver carp declined. The multiplying capacity of algae was higher than the possibility of their consumption by the fish.

Januszko, M. 1987. In environmental conditions of carp rearing III. Phytoplankton. Rocz Nauk Roln Ser H Rybactwo 101(2):161-174.

ABSTRACT: Studies were carried out on the effect of small silver carp stocks added to various stocking levels of carp on biomass, production, numbers and species composition of phytoplankton. Indications for fishery production were positive within the range of the stocking densities investigated as concerns phytoplankton abundance in ponds from which catches yielded around 1300 to 2000 kg/ha of carp and 60 to 170 kg/ha of silver carp.

Kajak, Z. 1977. Feeding habits of silver carp Hypophthalmichthys-molitrix and the problem of clean water. Wiad. Ekol. 23(3):258-268.

ABSTRACT: The diet of H. molitrix and its effects on the water system were studied. Phytoplankton, zooplankton and detritus were eaten. Planktonic crustaceans were the preferred food, although proportions of the 3 foods varied with different conditions. Silver carp caused changes in the phytoplankton (blue-green and green algae and diatom) biomass. Explanations for the changes were discussed.

Kajak, Z. 1977. Some patterns of change in lacustrine ecosystems under anthropogenic influence. Hydrobiol. J. (Engl. Transl. Gidrobiol. Zh) 13(2):8-16

Kajak, Z.; Rybak, J.I.; Spodniewska, I.; Godlewska-Lipowa, W.A. 1975. Influence of the planktonivorous fish Hypophthalmichthys molitrix Val. on the plankton and benthos of the eutrophic lake. Pol. Arch. Hydrobiol. 22(2):301-310.

ABSTRACT: The fish at the density 450 and 1,350 kg/ha decreased the biomass of zooplankton on the average of 4.5 and 16 times, as related to control respectively with the smaller and higher density. The biomass of phytoplankton was 4.5 times diminished by fish, being about the same at both fish densities. The share of large blue-green algae decreased, and the share of dinoflagellates and nannoplankton increased in variants with fish. The experiment was carried out in plastic plankton-tight enclosures, 6 m^2 each.

Kajak, Z.; Spodniewska, I.; Wisniewski, R.J. 1977. Studies on food selectivity of silver carp Hypophthalmichthys molitrix. Ekol. Pol. 25(2):227-240.

ABSTRACT: Experimental investigations on the feeding of silver carp were conducted in 4 [eutrophic] Masurian lakes [Poland] with different qualitative composition and biomass of plankton. Distinct food selectivity was observed as regards various food groups (phytoplankton, zooplankton and detritus) and various phytoplankton species. Phytoplankton was the main food component of fish examined, even if concentration was low. Some blue-green algae were not consumed by fish even when the algae dominated in the phytoplankton; in cases where phytoplankton consisted of blue-green algae only the selectivity of zooplankton was higher. The feeding pressure of silver carp on zooplankton seems higher than on phytoplankton. [Cyanophyta, Pyrrophyta, Bacillariophyceae, Rotatoria, Cladocera and Copepoda were examined.]

Kajak, Z.; Zawisza; J. 1973. Experimentally increased fish stock in the pond type Lake Warniak XIV. The relations between the fish and other biocenotic components (summing up the studies). Ekol. Pol. 21(4):681-648.

ABSTRACT: As a result of introducing fish (mainly carp) each year into the pond type, strongly overgrown lake, their biomass doubled in three years time. Parallely to the increasing biomass and pressure of fish the biomass and production of phytoplankton and benthos biomass decreased almost twice, whereas the nannoplankton contribution in phytoplankton biomass and the decomposition of organic matter in water doubled. At an unchanged total zooplankton biomass its big species disappeared, while the abundance, size, fecundity, and production of small species considerably increased. The amount of food eaten by fish decreased and its composition changed but the growth rate of fish decreased only slightly.

Karamchandani, S.J.; Mishra, D.N. 1980. Preliminary observations on the status of silver carp Hypophthalmichthys molitrix in relation to catla in the culture fishery of the Kulgarhi Reservoir, India. J. Bombay Nat. Hist. Soc. 77(2):261-270.

ABSTRACT: The status of silver carp in the culture fishery of the Kulgarhi reservior with particular reference to catla was evaluated. Observations were made on the food habits and growth of silver carp and catla from the Kulgarhi reservoir from 1969 to 1972. Silver carp and catla subsist on almost equal quantities of phytoplankton (18.24% and 15.24%, respectively). Among phytoplankton, the green algae were the most dominant (9.09%) in the diet of silver carp, followed by blue-green algae (4.32%), diatoms (3.76%) and dinoflagellates (1.07%), whereas catla feeds predominantly on blue-green algae (12.96%) but less frequently on diatoms (1.79%), green algae (0.43%) and dinoflagellates (0.06%). In the guts of silver carp, the zooplankton (21.04%) was made up almost entirely of rotifers (20.81%); the only organisms not significantly represented were copepods (0.23%) and cladocerans (0.26%). Catla is mainly a zooplankton feeder. The growth of silver carp was rapid in the early period, i.e., up to 25 mo., when the plankton was abundant and silver carp could feed voraciously on rotifers. The growth of silver carp declined in the later period, i.e., the following 25-50 mo., when rotifers were poorly represented in plankton. Catla belonging to the 1966 brood showed normal growth up to the time silver carp was absent in the reservior, but with the introduction of silver carp in Feb. 1969, catla showed retarded growth thereafter. Catla belonging to the 1968 brood showed extremely poor growth from the beginning. The culture of silver carp in the Kulgarhi reservoir adversely affected the growth of catla.

Karplus, I.; Hulata, G.; Wohlfarth, G.W.; Halevy, A. 1987. The effect of size-grading juvenile macrobrachium-rosenbergii prior to stocking on their population structure and production in polyculture II. Dividing the population into three fractions. Aquaculture 62(2):85-96.

ABSTRACT: Juvenile prawns (ca. 1.1 g) were size-graded into upper (32%), middle (45%) and lower fractions (23%). The graded fractions and the graded and recombined control were stroked into 400-m2 earthen ponds, at a density of 2/m2. The prawns were grown for 97 days in polyculture with tilapia, common carp, silver carp and grass carp. The proportion of females was higher than that of males in all of the groups except the lower fraction in which males predominated. The fractions differed in the proportions of the male and female morphotypes. The upper fraction had a low proportion (8%) of small males (SM) and a high proportion (22%) of blue claw males (BC). The lower fraction showed the reverse trend, with a high proportion (50%) of SM and a low proportion (3%) of BC. The middle fraction was intermediate and similar to the control. The proportions of mature females in the upper and lower fractions were 63 and 6% respectively. The middle fraction was intermediate (21%) but lower than the control group (45%). Survival in the grow-out phase was ca. 88% in all the groups. The three graded groups differed significantly in mean weight, with the largest prawns occurring in the upper fraction. Since the price of prawns is size-dependent, the net income from the upper fraction was almost nine times that of the lower fraction. The weighted mean income from the three fractions did not differ from that of the control. The large differences in yield and net income among the graded fractions, as well as the lack of increase in the net income compared with the control, are explained by early male morphotype determination.

Kasymov, A.G.; Khalilov, A.R.; Akhmedov, I.A. 1987. Hydrobiological characterization of Lake Mekhman Azerbaijan SSR USSR. Izv Akad Nauk Az SSR Ser Biol Nauk 0(1):37-42.

ABSTRACT: Data are presented on the specific and quantitative composition of zooplankton and zoobenthos in Lake Mekhman. Twenty-seven zooplankton species and 84 benthos species were determined. The results showed that Lake Mekhman should be supplied with the water from the Kura River in order to increase the fodder productivity for fish in the Lake. Lake Mekhman should also be stocked with the yearlings of white amur, silver carp, and wild carp, and some other fishes.

Khalil, R.B. 1982. Cage culture in freshwater in Malaysia with emphasis on the program of the freshwater fish culture research station (MARDI), Batu Berendam, Malacca, Malaysia. Training Course on Small-Scale Pen and Cage Culture for Finfishes Los Banos (Philippines). Aberdeen (Hong Kong) 26 October 1981. Report of the training course on small-scale pen and cage culture for finfish, Los Banos, Laguna, Philippines, 26-31 October 1981 and Aberdeen, Hong K.kong, 1-13 November 1981. Guerrero, R.D., III; Soesanto, V., 1982. pp. 177-185.

ABSTRACT: An account of cage culture in Malaysia is given. The objectives, plan of work and design and project area of the Programme of research in cage culture at the freshwater fish culture research station are outlined, and the cage culture of bighead carp (Aristichthys nobilis) is discussed.

Kirilenko, N.S.; Chigrinskaya, Y.N. 1983. Activity of the digestive enzymes of the silver carp Hypophthalmichthys molitrix cyprinidae feeding on blue-green algae. Vopr. Ikhtiol. 23(6):969-973.

ABSTRACT: The activity of the digestive enzymes was studied in the silver carp yerlings feeding on various amounts of Microcystis algae. The distribution of amylolytic, proteolytic and lipolytic enzymes along the digestive tract of the fish was described by clearly pronounced decrease in their activity in the direction at the end part of the intestine. The digestive system adopted to the increased amount of consumed algae by the redistribution of the activities of the enzymes, participating in the cavitary and membrane digestion.

Kirpichnikov, V.S. 1987. Selection and new breeds of pond fishes in the USSR. World Symposium on Selection, Hybridization and Genetic Engineering in Aquaculture of Fish and Shellfish for Consumption and Stocking Bordeaux (France) 27 Jun 1986. Schr. Bundesforschungsanst. Fisch. Hamb. 18-19.
selection, hybridization and genetic engineering in aquaculture. Vol. 2. Tiews, K. (ed.), pp. 449-460 Incl. 43 ref. Vol. I and II DM 395.

ABSTRACT: Selection work has been carried out in the USSR with common carp (Cyprinus carpio), plant-eating fishes (Hypopthalmichtys molitrix, Aristichthys nobilis, Ctenopharyngodon idella), bester (the hybrids between beluga and sterlet, Hucho hucho x Acipenser ruthenus) and peled whitefish (Coregonus peled). Mass individual artificial selection was the main method employed in the research. In some instances, selection for relatives and family selection were used. In all cases, when new pond fish breeds were produced, synthetic crossings were made at the initial stages to increase the genetic variability. New breeds of common carp reared in the USSR are described.

Kozianowski, A.; Schmidt, K. 1984. The development of fisheries management with the silver and bighead carp in GDR). Fortschr. Fischereiwiss. Adv. Fish. Sci. 3:149-156.

ABSTRACT: Since 1971 more than 50 lakes were stocked with silver carp and bighead carp in the GDR on the basis of fry imported from the USSR and rearing the fish in ponds for two to three years. The lakes stocked were mostly 10 to 50 ha in area in highly eutrophic. Stocking density ranged between 30 and 820 fish/ha (mean forsilver carp and bighead carp 180 and 166 ind./ha resp.). Mean stocking size amounted to 350 g. The stocked fish grew rapidly under the climatic conditions of the GDR according to expectation. 7 years after stocking silver carp attained an individual weight of 5.5 kg in the mean, and bighead carp 11 kg. Harvesting began 2 to 3 years after stocking.

Krasznai, Z.; Marian, T.; Buris, L.; Ditroi, F. 1984. Production of sterile hybrid grass carp (Ctenopharyngodon idella Val. x Aristichthys nobilis Rich.) for weed control. Aquacult. Hung. 4:33-38.
Triploid hybrids of female grass carp (C. idella) and male bighead ( ) were produced, using artificial propagation. The triploid character was proved by karyological analyses. Morphological analysis was carried out on second summer hybrids. The scale form, the number of vertebrae and pharyngeal teeth can be used for distinguishing the hybrid from the parental species. The sterility of the hybrid was examined, and the results of the histological analyses of gonads as well as the results of sex hormone analyses are presented. The hybrid can be used for the control of the aquatic vegetation without the risk of overpopulation.

Kruger, D. 1978. Hypophthalmichthys molitrix on eutrophication of the environment of carp ponds 2. Active micro flora changes in nitrogen conversion. Rocz Nauk Roln Ser H Rybactwo 99(2):33-54.

ABSTRACT: The changeability of basic microorganism groups participating in N circulation in a water environment was studied. Ponds with various stocking densities of silver carp (H. molitrix Val.) and carp (Cyprinus carpio) were examined.

Kutubidze, L.E.; Tkeshelashvili, V.G.; Kereselidze, Z.M.; Chikvaidze, N.N.; Kadzh aya, D.D.; Khavtasi, D.D. 1982. Hydrobiological investigation of the Sagaredzho fishery ponds Georgian-SSR USSR. Soobshch Akad Nauk Gruz SSR 107(1):81-84.

ABSTRACT: The hydrologic and hydrochemical regimes of the Sagaredzho fishery ponds are characterized by low transparency, homoiothermy, weak alkalinity, high O2 content summer increase in CO2 and in oxidation and low content of biogenic elements; the water belongs to the sulfate class and Mg group. The phytoplankton of the ponds numbers 154 spp. The low level of primary production can be explained by the low content of biogenic elements. Freshwater and euribiont forms are predominant in the zooplankton (19 spp. in all); zoobenthos is represented by 2 spp. of chironomids. The major food-fish species are Cyprinus carpio L. and Hypophthalmichthys molitrix Vel. The high density of rearing causes a low rate of fish growth.

Kuz'menko, M.I. 1985. Phytophagous fish in the reservoir ecosystem. Kuz'menko, M. I. (ed.), Ryby-fitofagi v ekosisteme vodokhranilishch (phytophagous fish in the reservoir ecosystem). 136 p.

ABSTRACT: This book considers the role of phytophagous fish in controlling water bloom as a factor in water reservoir eutrophication and improvement of the sanitary-biological state of reservoirs. In 1976-1980 an experimental study was made of the hydrological and hydrobiological regimen in Kremenchug reservoir [Ukrainian SSR, USSR], biological and physiological-biochemical indices of silver carp and bighead feeding on blue-green algae, and the toxicological characteristics of these fish. The nutrition and growth of introduced fish, determination of the degree of digestion of seston by phytophagous fish, and the effect of blue-green algae on their biochemical indices and metabolism were discussed. A bibliography is provided.

Kuznetsov, E.A. 1977. Bacteria consumption by the silver carp Hypophthalmichthys molitrix. Vopr. Ikhtiol. 17(3):455-461.

ABSTRACT: A study was made of the role of bacteria in the ecosystem of ponds with intensive polycultures. Analysis of the bacterioplankton of fish-rearing ponds with an intensive polyculture of phytophagous fish indicated that the majority of the bacteria were found in agregates, of which approximately 50% were caught by the filtration apparatus of the silver carp H. molitrix. The silver carp primarily consumed large bacterial aggregates, while single bacteria or smaller aggregates could become concentrated on the mucus secreted by the labyrinth and swallowed with it. The silver carp excessively reduced the bacteria population in the water because of its consumption of bacterial aggregates.

Kuznetsov, E.A. 1979. Effect of pond fishes with varying types of feeding on the development of planktonic bacteria. Vopr. Ikhtiol. 20(1):109-120.

ABSTRACT: A study of bacterioplankton in pisciculture ponds by intense polycultural and laboratory experiments showed that introduction of fish into the aquatic ecosystem increased the number of bacteria in the water. In the presence of Cyprinus carpio L. and Ctenopharyngodon idella (Val.) the bacteria count fluctuated markedly, and processes of bacterial disappearance predominated. In the presence of Hypophthalmichthys molitrix (Val.) the bacteria count increased to 18-25 million cells/ml and stabilized at that level with constant eating of planktonic bacteria by these fish; the rate of propagation remained high, which facilitated acceleration of mineralization of metabolic products of fish and other aquatic organisms. The pond ecosystem with polycultural filter-feeding fish becomes more stable than the pond ecosystem with monocultural carp.

Lai, H.C.; Chua, T.E. 1976. Limnological features of Muda and Pedu Reservoirs with an observation on their suitability for fish culture. Malays Agric J 50(4):480-501.

ABSTRACT: The physical, chemical and biological features of Muda and Pedu reservoir system [Malaysia] were examined along the line of eutrophication. The reservoirs are medium rich. Cultivation of plankton feeders such as bighead carp and silver carp in floating net-cages may require supplemental feed.

Lampert, W.; Fleckner, W.; Rai, H.; Taylor, B.E. 1986. Phytoplankton control by grazing zooplankton: A study on the spring clear-water phase. Limnol. Oceanogr. 31(3)478-490.

ABSTRACT: We tested the hypothesis that a clear-water period, regularly observed in many meso- and eutrophic lakes, is caused by grazing herbivorous zooplankton. Such a clear-water phase occurs during mid-May in the moderately eutrophic Schohsee and involves a rapid increase in Secchi transparency, and a drop in chlorophyll and particulate organic carbon in size fractions <35 μm. Maxima of zooplankton biomass and community grazing rates (170% of volume cleared per day) coincided with the greatest transparency. The algal decline was not related to nutrient depletion or climatic events. Before the clear-water phase small phytoplankton contributed up to 88% of the primary production, but the contribution of large particles was more important after the zooplankton maximum. The effects of herbivory by zooplankton were examined in a series of time-overlapping enclosure experiments. Concentrations of small (<35 μm) particles were always higher in the bags lacking zooplankton than in the controls. A mass development of small algae occurred in the zooplankton-free bags initiated during the clear-water phase, although the presence of zooplankton stimulated the growth of large (>35 μm) algae.

Lazareva, L.P.; Omarov, M.O.; Lezina, A.N. 1977. Feeding and growth of the bighead, Aristichthys nobilis, in the waters of Dagestan. J. Ichthyology, 17(1):65-71.

ABSTRACT: The main component of the food of the larvae of the bighead Aristichthys nobilis, was zooplankton, but its role decreases with the age of the fish, while the role of phytoplankton increases. In view of the paucity of zooplankton in the waters studied, underyearlings and yearlings were in most cases poorly supplied with food and sometimes changed entirely to feeding on phytoplankton and detritus. Detritus constituted 82-98% of the weight of the food.

Lazzaro, X. 1987. A review of plantivorous fishes: Their evolution, feeding behaviors, selectivities, and impacts. Hydrobiologia 146:97-167.

ABSTRACT: The classical approach of limnologists has been to consider the interactions between lake ecosystem components as an unidirectional flow of influence from nutrients to the phytoplankton, to the zooplankton, and finally to the fish, through successive controls by physical, chemical, and biological processes (Straskraba, 1967). The effect of planktivorous fishes on zooplankton and phytoplankton communities was not recognized until the studies of Hrbacek et al. (1961), Hrbacek (1962), Brooks & Dodson (1965), and Straskraba (1965). They showed that (1) in ponds and lakes in the presence of planktivorous fishes, the zooplankton communities were composed of smaller bodied species than in those lacking planktivores; and (2) the resulting small-bodied zooplankton communities affected the phytoplankton communities. Although the variability of the phytoplankton response to fish predation showed the importance of other factors (such as nutrient limitation and interspecific competition of algae), these studies emphasized that zooplankton and phytoplankton communities can be affected by the feeding selectivity of planktivorous fishes. During the last two decades, many limnological studies have focused on this dramatic impact of fish on plankton communities. The direct response of zooplankton communities to visual fish predation (i.e., particulate feeding) has been of major interest, whereas the multilevel effects of filter-feeding fish (predation on zooplankton plus grazing on phytoplankton) have been neglected. The objectives of this review are to document fish-plankton interrelationships in order to (1) provide insights into the impact of fish on plankton communities, and (2) outline mechanistic models of planktivory according to the feeding repertory and the selectivity of the fish, the adaptive responses of the plankton, and the environmental conditions.

The approach adopted here is based on field and laboratory experimental results derived from the literature on tropical and temperature freshwater (occasionally marine) systems. Four types of planktivorous fish are distinguished: the gape-limited larvae and small fish species, the particulate feeders, the pump filter feeders, and the tow-net filter feeders. For each type of planktivore, the mechanisms of prey selection are analyzed from the point of view of both the predator and the prey. To investigate the main determinants of the predator feeding selectivity, and to discuss its potential effects on prey communities, the predation-act is divided into a sequence of successive events (Holling, 1966): detection, pursuit, capture, retention, and digestion for particulate feeders; and capture, retention, and digestion for filter feeders. The strengths and weaknesses of various measures of selectivity (i.e., electivity indices), as well as their appropriate usages are considered. Available prey selection models and optimal foraging theories are analyzed for the different planktivore feeding modes. Mechanistic models based on Holling's (loc. cit.) approach are proposed for each feeding mode to determine differential prey vulnerabilities and optimal diet breadth.

This review has application to several fields, including general ecology, limnology, fisheries management (for example, utilization of planktonic resources, stocking, introduction, or maintenance of natural fish populations), and biological control of the eutrophication processes (biomanipulation approaches). It emphasizes the real need for more knowledge of the feeding selectivity and food utilization of planktivores. It concludes that predator and prey are mutually adapted. Thus, in most cases, study of plankton dynamics and water quality should include the assessment of fish predation and grazing pressures.

Lewkowicz, M. 1984. Effect of intensive carp culture in ponds on zooplankton community. (22.) Congress of the International Association of Limnology (Lyon (France)) 21 Aug 1983. Verh. Int. Ver. Theor. Angew. Limnol. Proc. Int. Assoc. Theor. Appl. Limnol. Trav. Assoc. Int. Limnol. Theor. Appl. 22(3):1,695-1,698.

ABSTRACT: Analysis of species composition, biomass and production of zooplankton in 95 carp ponds in 1965-80 was carried out. There were extensive ponds ca 200 kg carp per ha and intensive ponds up to 8000 kg carp per ha as well as polyculture ponds. The intensive ponds were dominated by: Filinia longiseta, Polyarthra vulgaris, Bosmina longirostris and the quadrangula. Their maximum zooplankton biomass amounted up to 9,97 g dry wt m super(-2) and that of the extensive ones to 2,24 g dry wt m super(-2). The maximum production of Rotifera was 0.086 g dry wt d super(-1) m super(-2), in extensive ponds and 1,18 g dry wt d super(-1) m super(-2) in the intensive ones.

Li, S.; Lu, W.; Peng, C.; Zhao, P. 1987. A genetic study of the growth performance of silver carp from the Changjiang and Zhujiang Rivers, China. Aquaculture 65(2):93-104.

ABSTRACT: From 1982 to 1984, experiments were conducted, using a randomized block design, on the growth rate of wild and hatchery populations of silver carp [Hypophthalmichthys molitrix] from the Changjang and Zhujiang Rivers in typical integrated fish culture ponds at Shanghai and Guangdong. Repeated experiments in both southern and eastern China produced identical results: there were significant differences in the length and weight gain of these populations. Both wild and hatchery populations of silver carp of the Changjiang River gained about 10% more body weight than those of the Zhujiang River. Wild silver carp gained 3-5% more than hatchery stocks from both sources. Therefore, wild silver carp from the Changjiang River grew about 15% more rapidly than hatchery silver carp from the Zhujiang River. Data analysis showed that the significant differences in weight gain among these four populations of silver carp could be attributed to a strong genetic component.

Li, S.F.; Lu, W.M.; Peng, C.D.; Zhao, P.R. 1987. Growth performance of different populations of silver carp and big head. World Symposium on Selection, Hybridization and Genetic Engineering in Aquaculture of Fish and Shellfish for Consumption and Stocking Bordeaux (France) 27 Jun 1986. Schr. Bundesforschungsanst. Fisch. Hamb., Vol. 18-19.
Selection, hybridization and genetic engineering in aquaculture. Vol. 1. Tiews, K. (ed.), pp. 243-256 Incl. 17 ref. Vol. I and II dm 395.

ABSTRACT: None.

Liang, Y.; Melack, J.M.; Wang, J. 1981. Primary production and fish yields in Chinese ponds and lakes. Trans. Am. Fish Soc. 110(3):346-350.

ABSTRACT: A strong correlation between fish yields and gross photosynthesis by phytoplankton occurs for the lakes and ponds along the Yangtze River, near Wuhan, China. Gross photosynthesis is calculated as the difference in oxygen concentration between light and dark bottles and incorporates respiration by heterotrophic and autotrophic plankton. Among the 18 waters included in this analysis, net fish yields (total harvest minus weight of stocked juveniles) ranged from 59-14,586 kg (fresh weight) .cntdot. ha^{-1} .cntdot. yr^{-1}. Two planktivorous fish, siliver carp Hypophthalmichthys molitrix and bighead carp Aristichthys nobilis, constitute the majority of the stocked fish. The regression equation describing the relation between net fish yields (FYn) and gross photosynthesis (PGv, mg O2 .cntdot. 1-1 .cntdot. day-1) measured at 1 subsurface depth is log10FYn = 0.047PGv + 2.44; N = 18; r^2 = 0.76; P < 0.001.

Lin, W.L.; Liu, X.Z.; Liu, J.K. 1983. On the nutritive value of particulate detritus of Microcystis and Daphnia for silver carp and bighead. Trans. Chin. Ichthyol. Soc. 3:13-20.

ABSTRACT: Artificially prepared particulate organic detritus of Microcystis spp. and Daphnia carinata was used to feed the fingerlings of silver carp (Hypophthalmichthys molitrix) and bighead (Aristichthys nobilis). Feeding experiments with the algal detritus were repeated 13 times, those with Daphnia detritus, 6 times. The duration of each experiment varied from two to three weeks. The fingerlings did not die, but they became emaciated and at the and of the experiments, all fishes lost body weight. In three controls in which commercial feed (a mixture of residual flour and pulverized bran) was given instead of detritus, and in two controls in which the fingerlings were fed with living D. carinata the body weight of the experimental fishes increased. It was concluded that particulate detritus of either Microcystis spp. or Daphnia carinata, though of some nutritive value, can not be used as the main energy source for silver carp and bighead. The nutritional significance of such detritus has been grossly over-estimated, at least for plank-tophagous fishes.

Lin, Y.S. 1978. Ecological studies of fish ponds in Chupei. Bull Inst Zool Acad Sin (Taipei) 17(1):43-60.

ABSTRACT: Ten fishponds were chosen from Chupei Fishery Institute [Taiwan] to study the relationships among the amount of chlorophyll, zooplankton, gross production and environmental factors. In July these ponds were stocked with fry of silver carp, common carp, grass carp, bighead and crucian carp. Eight ponds were treated with different fertilizers. From July-October, water samples were taken biweekly for the measurements of various variables. The seasonal variation of chlorophyll, gross production, zooplankton abundance, pH and water transparency were presented. All the variables studied showed no consistent seasonal pattern among the 10 fishponds. The variations existed even between adjacent ponds with similar treatment. The variation of gross production, zooplankton abundance, pH and water transparency were all closely related to the amount of chlorophyll concentration. The mean coefficient of determination suggest that 70% of the variation of transparency in the fishponds could be explained by the chlorophyll concentration. The close relationship of the production of various species of fish on the gross production, chlorophyll concentration and zooplankton abundance were not indicated from this study.

Ludskanova, J.; Paskaleva, E.; Joshev, L. 1985. Current intensive methods for rearing of stocking material in warmwater fisheries. Zhivotnov'd Nauki 22(9):61-67.

ABSTRACT: An experiment for rearing of stocking material of carp, bighead .times. silver carp and Bigmouth buffalo in polyculture was conducted during the year of 1984 in 6 ponds at the experimental base of our institute. As a result of maintained optimal ecological conditions, abiotic and biotic, during the vegetation period and the increased phytoplanktonphagia, zooplanktonphagia and benthophagia on rearing the above species of fish in polyculture of high stocking, the obtained average output from the growing ponds amounted to 2460-3590 kg/ha (maximal 2600-3920 kg/ha) and the feed conversion ratio was lowered to 1.6.

Lynch, M. 1979. Predation, competition, and zooplankton community structure: An experimental study. Limnol. Oceanogr. 24(2), 253-272

ABSTRACT: An experimental investigation of the zooplankton community of a small Minnesota pond was conducted for 2 years to determine the mechanisms maintaining its structure and to show that it is predictably organized. A mechanistic interpretation of the structure of this community cannot be made solely on the basis of predation, but also requires evaluation of the relative competitive abilities of the herbivores. The presence of Chaeoborus and fish place predictable constraints on the abundance of zooplankton species in this pond. The competitive dominant (Ceriodaphnia reticulata) is of intermediate size and is removed when either predator is abundant. In the presence of intense Chaeoborus predation, Ceriodaphnia is replaced by a larger subordinate competitor, Daphnia pulex: when fish predation is intense, smaller species (Bosmina longirostris and rotifers) increase. These small species are also able to maintain large populations in vertebrate-free environments when Chaeoborus is rare. When these small herbivores are abundant, two additional invertebrate predators (Cyclops vernalis and Asplanchna priodonta) arrive, neither of which seems able to reduce its prey to extinction.

Lynch, M.; Shapiro, J. 1981. Predation, enrichment, and phytoplankton community structure. Limnol. Oceanogr. 26(1):86-102.

ABSTRACT: The significance of grazing and enrichment to the Pleasant Pond phytoplankton community was examined through a series of enclosure experiments. The addition of planktivorous fish led to the removal of large herbivores and to an order-of-magnitude increase in total phytoplankton biomass. This was a result of the appearance of several new algal species as well as the increase of most initial resident species. Aphanizomenon flos-aquae was an exception to this pattern. This filamentous blue-green attains its maximum density in the presence of large Daphnia by forming large, ungrazeable colonies; Daphnia may provide a service to Aphanizomenon by removing most potential algal competitors. The addition of phosphorus and nitrogen had no quantitative effect on total phytoplankton biomass either in the presence or absence of fish; changes in species composition did occur, several algae disappearing with enrichment. We summarize the varied responses of lakes to enrichment and suggest that the community-level effects of enrichment can only be understood in the context of a framework that considers initial nutrient status and the structure of planktivorous fish populations.

Lyubeznov, Y.E. 1974. Role of phytoplankton in feed of silver carp fry in ponds of the Tedzhen fish breeding farms Turkmen-SSR USSR. Izv Akad Nauk Turkm SSR Ser Biol Nauk (2):34-40.

ABSTRACT: None.

Lyudskanóva, Z.; Joshev, L.; Paskaleva, E.; Dimitrov, M. 1987. Enhancement of natural productivity of carp growing ponds. Zhivotnov'd Nauki 24(1):72-79.

ABSTRACT: At the Institute of freshwater fisheries in 1984-1985 were conducted experiments to enhance natural productivity of carp growing ponds by improving the method of applying rations of manure, urea, calcium superphosphate, and bringing in a bioproduct (a culture of Scenedesmus obliquus) on rearing a polyculture of carp yearling (C1+), plant consuming fish silver carp yearling (S1+) grass carp yearling (G1+), grass carp two yearling (G2+) and bigmouth buffalo yearling (B1(b)). A natural fish production of 208 kg/dka was obtained without applying feeds. In intensive warmwater fisheries an increase of natural fish production portion (an yield of 170.sbd.200 kg/dka) could result in lowering feed conversion ratio and in economy realization of 25-30%.

Mal'tsman, T.S. 1974. Zooplankton development in intensively exploited fishery ponds. Gidrobiol Zh 10(2):36-41.

ABSTRACT: None.

Malecha, S.R.; Buck, D.H.; Baur, R.J.; Onizuka, D.R. 1981. Polyculture of the fresh water prawn Macrobrachium rosenbergii chinese and common carps in ponds enriched with swine manure 1. Initial trials. Aquaculture 25(2-3):101-116.

ABSTRACT: The feasibility of raising the freshwater prawn, M. rosenbergii, without supplemental feeding was tested in a polyculture system. The experimental design involved 2 flow-through units of 2 ponds each with sizes from 0.09-0.18 ha. One pond in each unit received fresh manure from swine (57-61 ha-1) housed on the pond banks and stocked on 15 May 1978 with silver, bighead and grass carps and later with common carp in a ratio of 65:1:4:12 with a combined density of .apprx. 5500 ha-1. The 2nd pond in the unit received only effluent from the 1st and was stocked with macrophytic plants and a lighter density of fish (i.e., silver carp at 650 ha-1, bighead carp at 79 ha-1, no common carp) and sufficient grass carp (10-15 ha-1) to crop the macrophytes. On 1 June 1978 prawns were stocked at 7.9 m-2 in the manure ponds and 4.6 m-2 in the effluent ponds. The ponds were drained and censused 9-12 October following grow-out periods averaging 175 days for fish and 131.5 days for the prawns. Gains in fish biomass averaged 2516 kg ha-1 (14.38 kg ha-1 day-1) in the manured ponds and 613 kg ha-1 (6.06 kg ha-1 day-1) in the effluent ponds. Gains in prawn biomass averaged 322.3 kg ha-1 (range: 264-414, or 2.46 kg ha-1 day-1). Survival ranged from 17.4% in a pond which suffered a partial kill in Aug. to an average of 48.1% in other ponds. Prawn weights from individual ponds averaged 12.7 g (range: 10.5-17.6). Fastest prawn growth occurred in an effluent pond (no common carp). Swine biomass gain was 179.3 kg and the system-wide food conversion ration dry weight gain (pig feed) to wet weight (fish, prawns and pigs) was .apprx. 1:1.3. Prawn weight gains compared favorably with those achieved under monoculture with supplemental feeding and demonstrated that prawns derived a significant, if not complete, portion of their nutritional requirements from heterotrophic productivity stimulated by a manure/polyculture regimen. Fish and swine gains and the non-existent prawn feed costs demonstrated that polyculture holds a high potential for economic culture of M. rosenbergii.

Man, H.S.H.; Hodgkiss, I.J. 1977. Studies on the ichthyofauna in Plover-cove Reservoir Hong-kong Part 1 sequence of fish population changes. J. Fish Biol. 10(5):493-503.

ABSTRACT: Gill-net surveys were made weekly from May 1971-April 1974 in Plover Cove Reservoir, Hong Kong, and the results were analyzed to determine the fish species composition in the reservoir, the seasonal fluctuation of catches and the length frequency distribution of some major species. Over 20 spp. [Sarotherodon mossambicus, Rasborina sterierii, Coilia sp., Glossogobius giurus, Gambusia affinis, Ophicephalus maculatus, Clarias fuscus, Anguilla japonica, Monopterus albus, Macropodus viridiauratus, Mugil cephalus, Hypophthalmichthys molitrix, Cirrhina molitorella, Aristichthys nobilis, Cyprinus carpio, Carassius auratus, Ctenopharyngodon idellus, Hemiculter bleekeri, Puntius semifasciolatus, Osteochilus salsburyi, Erythroculter ilishaeformis, Zacco platypus] were represented in the fish fauna, including almost all the naturally occurring species as well as the stocked species. Of the 20 spp. some were collected regularly in gill-net samples, while others occurred rarely. Sarotherodon mossambicus (Peters) was the dominant species and contributed the main bulk of the catch. This species showed distinct age groups in the reservoir, and modal changes occurred seasonally. Thus, among the fish species studied only S. mossambicus showed a steady and progressive increase in abundance in the reservoir, and the full development of this fish population with its wide range of feeding habits should be beneficial.

Marking, L.L.; Bills, T.D. 1981. Sensitivity of Four Species of Carp to Selected Fish Toxicants. N. Am. J. Fish. Manage. 1(1):51-54.

ABSTRACT: Methods may be needed for controlling the four species of exotic carps now in the United States - common carp (Cyprinus carpio), grass carp (Ctenopharyngodon idella), bighead carp (Aristichthyes nobilis), and silver carp (Hypophthalmichthyes molitrix). The toxicity of four registered or candidate fish toxicants to the carps under various conditions of temperature, water hardness, and pH was determined. The 96-hour LC sub(50)'s ranged from 0.570 to 1.00 ppb for antimycin, 1.5 to 9.35 ppb for Salicylanilide I, 0.05 to 0.08 ppm for Noxfish, and 0.05 to 0.55 ppm for GD-174. Toxicity of GD-174 to the four species was little affected by variations in water temperature and water hardness, but was increased at higher pH's. All of the test compounds were toxic to the four species GD-174 was more toxic to common carp than to the others.

McQueen, D.J.; Post, J.R. 1988. Cascading trophic interactions: Uncoupling at the zooplankton-phytoplankton link. Hydrobiologia 159:277-296.

ABSTRACT: Four limnocorrals (8 m dia. by 15 m deep) located at Lake St. George, Ontario, Canada; were used to examine the interactions between planktivorous fish, crustacean zooplankton (notably Daphnia galeata mendotae), and phytoplankton. During the spring, in all of the limnocorrals, high Daphnia biomasses were correlated with increased water transparency and a spring 'clear-water' phase. However, as the summer progressed, the relationship between Daphnia biomass and phytoplankton abundance became more complex and less predictable. Investigation of these interactions suggested four conclusions. (1) During late July and throughout August and September, water transparency decreased and algal cell counts increased. In 3 of 4 limnocorrals, deterioration in water quality occurred 3-5 weeks before zooplankton (and Daphnia populations) declined. In all cases decreased transparency was associated with the increased concentrations of algal cells (Gloeococcus) that were poor food sources for Daphnia. These results suggested that decreased water transparency was not 'caused by' decreases in Daphnia biomass. (2) Taken together, data from all of the limnocorrals showed no correlation between the magnitude of July Daphnia biomasses and the percentage of 'poor food source' algae that were observed in August. This suggested that grazer effects were not necessary for the onset of summer 'poor food source' algal blooms. (3) In two limnocorrals, there was a positive correlation between increased Daphnia mortality and the onset of 'poor food source' blooms. In the other two limnocorrals there was no correlation. In all limnocorrals there was no correlation between decreased Daphnia reproductive capacity and 'poor food source' blooms. These data suggested that blooms of 'poor food source' algae were not necessary for the collapse of Daphnia populations. (4) In all 4 limnocorrals there was a strong correlation between the time that 0+ yellow perch planktivores reached biomasses of 30-50 kg ha^{-1} and the collapse of Daphnia populations. Species and size selection was also observed. These results suggested that for this set of limnocorral experiments, fish biomasses in the 30-50 kg ha^{-1} were responsible for the collapse of Daphnia populations in the summer.

McQueen, D.J.; Post, J.R.; Mills, E.L. 1986. Trophic relationships in freshwater pelagic ecosystems. Can. J. Fish. Aquat. Sci. 43:1,571-1,581.

ABSTRACT: Relative impacts of bottom-up (producer controlled) and top-down (consumer controlled) forces on the biomass and size structure of five major components of freshwater pelagic systems (piscivores, planktivores, zooplankton, phytoplankton, and total phosphorus availability) were estimated. Predictions that emerge are (1) maximum biomass at each tropic level is controlled from below (bottom-up) by nutrient availability; (2) this bottom-up regulation is strongest at the bottom of the food web (i.e., phosphorus ---> phytoplankton) and weakens by a factor of 2 with each succeeding step up the food web; (3) as energy moves up a food web, the predictability of bottom-up interactions decreases; (4) near the top of the food web, top-down (predator mediated) interactions are strong and have low coefficients of variation, but weaken with every step down the food web; (5) variability around the bottom-up regressions can always be explained by top-down forces; and (6) interplay between top-down and bottom-up effects changes with the trophic status of lakes. In eutrophic lakes, top-down effects are strong for piscivore ---> zooplankton, weaker for planktivore ---> zooplankton, and have little impact for zooplankton ---> phytoplankton. For oligotrophic lakes, the model predicts that top-down effects are not strongly buffered, so that zooplankton ---> phytoplankton interactions are significant.

Merla, G.; Mueller, W.; Fullner, G. 1985. The presence of heavy zooplankton in ponds with various management variants and multiple cultivation. Z. Binnenfisch DDR 32(8):234-237.

ABSTRACT: None.

Mihai-bardan, A. 1985. Contribution to the knowledge of the diet and growth rhythm of the species Hypophthalmichthys molitrix Aristichthys nobilis and hybrids resulting from their cross-breeding osteichthyes cyprinidae. Trav. Mus. Hist. Nat. 'Grigore Antipa' 27(0):215-226.

ABSTRACT: The food of the species Hypothalmichthys molitrix, Aristichthys nobilis is presented in comparison with that of the hybrids .female. H. molitrix .times. .male. , .female. A. nobilis .times. .male. H. molitrix; the composition of the phyto- and zooplankton from the breeding ponds is also shown from the transition to the exogenous nutrition up to the end of the second summer of growing. The growing rate of the above mentioned species and hybrids is analyzed for the first two years of growing.

Milstein, A.; Hepher, B. 1985. Principle component analysis of interactions between fish species and the ecological conditions in fish ponds I. Phytoplankton. Aquacult. Fish Manage. 16(4):305-318.

ABSTRACT: Interactions between fish species and their effect on the ecological conditions in the fish pond were studied in ten ponds of 0.1 ha each. The ponds were stocked with bottom-feeding fish: common carp, Cyprinus carpio L., and male hybrid tilapia Oreochromis niloticus (L.) .times. O. aureus (Steindachner), and a filter-feeder: silver carp, Hypophthalmichthys molitrix (Valenciennes), in various combinations. This paper deals with the effect of different assemblages of these fishes on the phytoplankton populations in the ponds. A Principal Component Analysis of the data showed that only 20% of the phytoplankton variability is accounted for by the fish combination present in the pond (treatment). The first principal component (PC1) groups the species of phytoplankton which responded to treatment. This component is formed by small size species; Scenedesmus spp., small Chlorophytes (mainly Chlorella), Selnastrum minutum , Ankistrodesmus setigerus, Merismopedia minima and Diatoms of the order Pennales. The presence of silver carp led to an increase in total phytoplankton numbers, concurrently with a decrease in their dominant size. This was due to the predominance in the water of the small size species of the PC1 group, which could not be retained by the gill filtering apparatus of the fish. Reduction in zooplankton abundance by silver carp also contributed to this situation. The presence of bottom-feeding fish resulted in a decrease in total phytoplankton numbers, and in the importance of the small-size species of the PC1 group, and hence in the dominance of larger algae. The interactions between these two trophic types of fish and algae size are discussed.

Milstein, A.; Hepher, B.; Teltsch, B. 1985. Interactions between fish species and the ecological conditions in fish ponds II. Zooplankton. Aquacult. Fish Manage. 16(4):319-330.

ABSTRACT: Interactions between fish species as to their effect on the zooplankton populations in the ponds were studied in ten ponds of 0.1 ha each. The ponds were stocked with bottom-feeding fish: common carp, Cyprinus carpio L., and male hybrid tilapia Oreochromis niloticus L. .times. O. aureus (Steindachner), and a filter feeder; silver carp, Hypophthalmichthys molitrix (Valenciennes), at varying proportions. A Principal Component Analysis of the data showed that the fish combination present in the pond accounted for 30% of the overall variability, through the first two components. The first zooplanktonic component (ZCI) can be considered as expressing community structure, showing high zooplankton diversity on one pole and low diversity on the other. The second component (ZC2) is related to the time of appearance of certain zooplankton groups. The most striking differences occurred between ponds with and without silver carp. The presence of the other bottom-feeding fish caused a reduction of zooplankton diversity, but not so pronounced as that of silver carp. The interactions among silver carp, zooplanktonic trophic groups and algal size are discussed. It is concluded that the effect of silver carp on the zooplanktonic community is a compound one, which includes both direct predation and depletion of their food resources.

Milstein, A.; Hulata, G.; Wohlfarth, G.W. 1988. Canonical correlation analysis of relationships between management inputs and fish growth and yields in polyculture. Aquacult. Fish Manage. 19(1):13-24.

ABSTRACT: Canonical correlation analysis was used to study the influence of management factors on growth and yields in an experimental polyculture system. The major conclusions are: (1) yield of each species was affected mainly by its own stocking density, followed by interactions with other species; (2) the best yields and growth rates of tilapia were obtained with stocking weights of over 13 g and; (3) common carp, Cyprinus carpio L., was affected negatively by silver carp, Hypothalmichthys molitrix (Valenciennes), density and positively by nutrient inputs. Its best performance was obtained at silver carp density below 1000/ha. Analyses of data from commercial production units are required to confirm these conclusions.

Milstein, A; Hepher, B.; Teltch, B. 1988. The effect of fish species combination in fish ponds on plankton composition. Aquacult. Fish. Manage. 19(2):127-138.

ABSTRACT: In continuation of an experiment carried out in 1983, the effect of polyculture of bottom-feeding fish (common carp, Cyprinus carpio L.; tilapia hybrids, Oreochromis niloticus (L.) .times. O. aureus (Steindachner); and grey mullet, Mugil cephalus (L.) and a filter-feeding fish silver carp, Hypopthalmicthys molitrix (Valenciennes) on the nannoplankton and netplankton has been studied. This effect was analysed through principal component analysis. The results confirmed the finding of 1983 that the presence of silver carp in a pond, either alone or with bottom-feeding fish, results in a decrease in netplankton (phyto- and zooplankton) and an increase in nannoplankton which passes through the filter apparatus of the fish. The effect of the silver carp seems to be related more to its numerical density than to its individual weight, since the effect diminished with the decrease in density during 1983-1985. It became least pronounced when the density was 480/ha. Bottom-feeding fish enhance the development of the larger nannoplankton by bringing up nutrients from the bottom, but reduce the number of the netplankton (mainly zooplankton) as compared to the control pond without fish. This effect was more apparent at a higher density of tilapia, but was masked when silver carp was present.

Moav, R.; Wohlfarth, G.; Schroeder, G.L.; Hulata, G.; Barash, H. 1977. Intensive poly culture of fish in fresh water ponds Part 1 substitution of expensive feeds by liquid cow manure. Aquaculture 10(1):25-43.

ABSTRACT: In 1974 and 1975, 9 experimental treatments of fish polyculture in stagnant water ponds without aeration were conducted at Dor. [Israel]. The polyculture was composed of common carp [Cyprinus carpio], silver carp [Hypophthalmicthys malitrix], white amur (grass carp) [Ctenopharyngodon idella] and Aurea. The treatments differed in stocking densities, feeding and manuring levels. The most productive treatment of the experiment, in which the fish were fed with protein-rich pellets, produced 50 kg/ha per day, probably a record for unaerated ponds of stagnant water. Two treatments (low and high stocking densities) fed exclusively with liquid cow manure produced an average yield of around 32 kg/ha per day. The yields of the treatments receiving high-protein pellets exceeded those of the treatments receiving grain pellets by 20 and 9.6 kg/day per ha, at high and low stocking densities, respectively, and in both cases the yield increments justified the extra cost of high-protein feed. The responses of the 4 fish species to the different levels of feeding and stocking densities were widely different. The common carp and white amur showed the greatest responses to increased feeding inputs while the silver carp and , even at high densities, have done equally well at low feeding levels. Total body fat contents of the common carp were 20, 15 and 6.2% when fed with high-protein pellets, grains pellets and liquid cow manure, respectively. Intermittent harvesting did not result in increased yields.

Moskul, G.A. 1977. Feeding of two-year-old silver carp and bighead in foraging lagoons of the Krasnodar Area. Hydrobiol. J., 13:37-41.

ABSTRACT: The food bolus of two-year-old silver carp consists of phyto- and zooplankters, organic substances and mineral particles (the content of the latter was dependent on their quantity in the water: $r = +0.93$, $m_r = \pm 0.07$ and $t_r = 13$). It shows a preference of Euglenaceae, Volvocina, Diatomeae and Protococcaceae. the Daily feeding rate increased towards the evening and reached a peak (454.6 ± 10.32°/‰) at 20.00 hours. The daily ration amounted to 20.9 percent of the weight of the fish. The feeding ratio was 18.8.
The daily feeding rhythm of two-year-old bighead overlapped that of the silver carp. Its daily ration was lower at 14.8 percent of the weight of the fish. The feeding ratio was 12.9.

Mueller, W. 1980. Standard of Development and Use of Techniques for the Intensive Production of Carp in Pond-Culture). Z. Binnenfisch. D.D.R. 27(12):358-363.

ABSTRACT: The total fish production in freshwater of the German Democratic Repubic was 13,000 t in 1980. This yield shall be increased to 22,000 t in 1985 by: 1) intensive pellet nutrition combined with grain nutrition, 2) the introduction of polyculture (plant- and phytoplanktonfeeders, expecially Hypophthalmichthys molitrix and Aristichthys nobilis) in all traditional and modern pond-cultures and suitable lakes, 3) development from an extensive pondculture to a modern and intensive form of aquaculture with technical aeration ect., and 4) a better health control. Better calcuated population density and a better calculated food amount at particular temperatures should decrease the loss of carps in aquaculture. One year old carp production should be increased in warm-water-ponds, wherever warm water occurs.

Mumtazuddin, M.; Khaleque, M.A. 1987. Observations on the relative growth potential of carp hatchlings in relation to fertilization and supplemental feeding. Bangladesh J. Zool. 15(1):71-78.

ABSTRACT: Studies were conduicted in small ponds to find out the relative potentials of silver carp Hypopthalmicthys molitrix, rohu Labeo rohita and mrigal Cirrhinus mrigala hatchlings for a period of 28 days under fertilization and supplementary feeding. Highest growth (40.08 mg/.day) and survival (40.12%) rates were observed in silver carp hatchlings, whereas the lowest in rohu (22.44 mg/day and 32.60%), except the control. Comparing among the species used, the silver carp exhibited 58.42% higher growth and 23.07% higher survival than the rohu hatchlings and the relationships were significant and positively correlated.

Nandeesha, M.C.; Murthy, C.K. 1988. Impact of species composition and artificial feed on the growth of carps. Fish Technol. 25(1):15-17.

ABSTRACT: Two trials conducted to demonstrate the suitability of composite carp culture in a small, seasonal, shallow village pond with varied species composition and stocking density indicated the possibility of obtaining higher production with reduced number of species. During the first trial, the Indian major carps, silver carp, common carp and fringelipped carp were stocked at a density of 5625 fingerlings/ha in the pond in which the maximum water speread area was 1600 m2. The fish grown over a period of seven months yielded a production of only 242 kg. However, during the second trial, an increase in production by 60.33% was achieved over the same period in the same pond by stocking only the Indian major carps and common carp at a density of 4687.5 fingerlings/ha and feeding them daily with silkworm faecal matter based artificial feed at about 5% of their body weight. The results indicated that for seasonal, shallow ponds stocking of only three species of carps, namely, catla, rohu and common carp would suffice to get optimum yield.

Negonovskaya, I.T. 1980. Results and prospects of introduction of herbivorous fishes into natural waters and reservoirs of the USSR. Vopr. Ikhtiol. 20(4):702-712.

ABSTRACT: Data were presented on the introduction of the following species of herbivorous fish of the amur complex into large natural waters and reservoirs of the USSR: Hypophthalmichthys molitrix (Val.), Aristichthys nobilis (Rich.) and Ctenopharyngodon idella (Val.). Positive and negative results of introduction were analyzed as a function of various abiotic and biotic environmental factors. Ways of increasing the effectiveness of acclimatization of these species in temperate waters were stated.

Negonovskaya, I.T. 1980. On the results and prospects of the introduction of phytophagous fishes into waters of the USSR. J. Ichthyol. 20(4):101-111.

ABSTRACT: Data are presented on the introduction of different species of phytophagous fishes from the Amur region into large lakes and reservoirs of the USSR. The positive and negative results of this are analyzed in relation to the different environmental factors (abiotic and biotic). Suggestions are made regarding ways of increasing the efficiency of acclimation work with the species of fish in waters of the temperate climatic zone.

Nilssen, J.P. 1984. Tropical lakes-functional ecology and future development: The need for a process-orientated approach. Hydrobiologia 113:231-242.

ABSTRACT: The major classes of tropical lakes include shallow, lowland lakes; deep, tertiary lakes; high altitudinal lakes; rainforests lakes; and man-made lakes at all latitudes and altitudes. Basic ecological processes are similar in temperature and tropical lakes, including grazing, competition, predation, and abiotic adaption. Small tropical lakes of intermediate age are probably not biotically more complicated than similar-sized temperate lakes. The structure of the areas of adaptative radiation and the dispersal ability of the species are important for the present distribution of taxa. Fish play a key role in the tropics since many species both consume zooplankton and compete with them for algal and pelagic sestonic food. This important co-evolution between fish and algae, leaving a fraction of the algal community with a predation refuge, may have decreased the ability of zooplankton to exploit algae. In addition, heavy predation from juvenile and adult fish may greatly simplify the zooplankton community, and have resulted in the scarcity of Cladocera, notably the efficient filter-feeder Daphnia. Little is known of possible physiological constraints to cladoceran distribution, however. Thus similar co-evolution as hypothesized between fish and algae seems not to have occurred to such a great extent between fish and zooplankton. Diurnal patterns in habitat selection of fish may also influence nutrient re-distribution in the tropics as in many temperate lakes. Serious environmental problems threaten tropical lakes, including eutrophication, clear-cutting of the rain forest, unwise introduction of new species not adapted to prevailing conditions, overfishing, extensive use of biocids, and probably acidic rain in areas with poorly buffered waters. Important processes in tropical lakes could be elucidated by concentrating research upon the fate of phytoplankton successional production, involving competition, grazing, sinking, fungi, and bacterial attack. Co-evolution of fish and algae should be further investigated as it could in part explain the general scarcity and simplicity of the zooplankton community. Limnocorral experiments should also be used for further assessing processes in tropical lakes.

Omarov, M.O.; Lazareva, L.P. 1974. The food of the silver carp in Dagestan ponds and lakes. Hydrobiol. J. (Engl Transl Gidrobiol Zh) 10(4):80-83.

ABSTRACT: None.

Omarov, M.O.; Lazareva, L.P. 1974. Feeding of the silver carp in waters of the Dagestan-ASSR USSR. Gidrobiol. Zh. 10(4):100-104.

ABSTRACT: None.

Opusznski, K. 1978. The influence of the silver carp Hypophthalmichthys molitrix on eutrophication of the environment of carp ponds 7. Recapitulation. Rocz Nauk Roln Ser H Rybactwo 99(2):127-152.

ABSTRACT: The influence of high densities of the silver carp (H. molitrix Val.), a species feeding on phytoplankton, on physico-chemical conditions, bacteria, phytoplankton, zooplankton, benthos, health of fish and fisheries production was studied. Dense stocking with silver carp is ineffective for the control of algae blooms. A theory of ichthyo-eutrophication was formulated in which counteracting eutrophication would consist of tending to maintain the initial structure of the ichthyofauna complex.

Opuszynski, K. 1979. Silver carp Hypophthalmichthys molitrix in carp ponds 1. Fishery production and food relations. Ekol. Pol. 27(1)71-92.

ABSTRACT: The silver carp exerted an influence on increasing pond production under extensive and intensive systems of common carp management. At a super-intensive system of production (above 3,000 kg/ha) the silver carp did not cause a significant increase in production or a saving of fodder. Detritus constituted the basic food of the silver carp. As the density of silver carp increased, individual weight increments declined and quantitative and qualitative changes took place in the food composition, as also in the feeding behavior of fish. The influence of the silver carp on the production of common carp cannot be explained by simple food relations between the 2 spp.

Opuszynski, K. 1981. Comparison of the usefulness of the silver carp Hypophthalmichthys molitrix and the bighead carp Aristichthys nobilis as additional fish in carp ponds. Aquaculture. 25(2-3):223-234.

ABSTRACT: Based on fishery results and food analyses of the silver carp, H. molitrix, and of the bighead carp. The latter is apparently less useful for intensive rearing in ponds jointly with the common carp. Although the bighead carp, due to its rapid growth rate, gave a higher level of production than the silver carp at the same stocking densities, the drop in common carp production with bighead was so considerable that there are doubts as to the usefulness of joint rearing of the 2 spp. in ponds. Comparisons of the amount and composition of food of the silver carp and the bighead carp suggest that food competition of the latter species is greater than common carp. Although neither silver carp nor bighead carp consumed feed given to the common carp (sorghum), and detritus was the main dietary component of the 2 former species of fish, the proportion of invertebrates in the food of bighead carp was greater and the components more similar to the food of the common carp. The silver carp consumed smaller zooplankton species, mainly Bosmina longirostris and rotifers, which were of no significance as food for the common carp. The bighead carp consumed large Cladocera and Copepoda species, and also Tendipedidae larvae, i.e., organisms constituting the basic component of the food of common carp.

Opuszynski, K. 1979. Silver carp Hypophthalmichthys molitrix in carp ponds 2. Rearing of fry. Ekol. Pol. 27(1):93-116.

ABSTRACT: Causes of larval mortality were determined (insufficiency of proper food, low water temperatures and predation) and guiding principles formulated for calculating biotechnies aimed at assuring a high level of effectiveness and stability in the production of stocking material.

Opuszynski, K. 1979. Silver carp, Hypophthalmicthys molitrix (val.) in carp ponds. III. Influence on ecosystem. Ekol. Pol. 27(1):117-133.

ABSTRACT: Dense stocking with silver carp of 4 to 12 thousand individuals per hectare caused a number of environmental and biocenotic changes, among others an increase in phytoplankton biomass and in primary production. A theory of ichthyoeutrophication was formulated according to which fishery counteraction to the process of eutrophication would not consist of intensifying fishery management, but of applying measures aimed at maintaining the primary structure of the ichthyofauna community.

Opuszynski, K. 1981. Comparison of the usefulness of the silver carp and the bighead carp as additional fish in carp ponds. Aquaculture, 25:223-233.

ABSTRACT: On the basis of fishery results and food analyses of the silver carp, Hypophathalmichthys molitrix, and of the bighead carp, Aristichthys nobilis, it was found that the latter species is less useful for intensive rearing in ponds jointly with the common carp. Although the bighead carp, due to its rapid growth rate, gave a higher level of production than the silver carp at the same stocking densities, the drop in common carp production with bighead was so considerable that there are doubts as to the usefulness of joint rearing of the two species in ponds. Comparisons of the amount and composition of food of the silver carp and the bighead carp lead to the conclusion that food competition of the latter species with respect to the common carp is considerably greater. Although neither silver carp nor bighead carp consumed feed given to the common carp (sorghum), and detritus was the main dietary component of the two former species of fish, the proportion of invertebrates in the food of bighead carp was greater and the components more similar to the food of the common carp. The silver carp consumed smaller zooplankton species, mainly Bosminia longirostris and rotifers, which were of no significance as food for the common carp. The bighead carp consumed large Cladocera and Copepoda species, and also Tendipedidae larvae, i.e. organisms constituting the basic components of the food of common carp.

Opuszynski, K. 1968. Carp polyculture with plant feeding fish grass carp Ctenopharyngodon idella and silver carp Hypophthalmichthys molitrix. Bull. Acad. Pol. Sci. Ser. Sci. Biol. 16(11):677-681.

ABSTRACT: None.

Pace, M.L. 1984. Zooplankton community structure, but not biomass, influences the phosphorus-chlorophyll a relationship. Can. J. Fish. Aquat. Sci. 41:1,089-1,096.

ABSTRACT: Simultaneous observations were made of total phosphorus (TP), chlorophyll a (Chl a), and zooplankton biomass and community structure at 12 sites in the Eastern Townships (ET) region of Quebec to determine if zooplankton parameters reduced residual variation in the TP-Chl a relationship. Similar data from three stations in Lake Memphremagog and the literature were also analyzed. Zooplankton biomass was not significant in explaining residual variation in the TP-Chl a relationship of any data set studied. The mean body size of cladocerans was also not a significant additional variable in a TP-Chl a model based on the seasonal mean values in the ET lakes, but cladoceran body size was a significant factor in 13 lakes of the Indian River district of New York. The difference between these results is attributed to the rarity of large daphnids in the ET lakes. An index of zooplankton community structure derived from the slope of log abundance-log weight regressions was significant in explaining residual variation in TP-Chl a relationships for the among- and within-lake data and improved the predictive capability of TP-Chl a models. Lakes with higher concentrations of macrozooplankton relative to microzooplankton have less Chl a per unit TP. These results extend the generality of the hypothesis that large zooplankton differentially reduce Chl a relative to TP. In the ET lakes the effect of zooplankton size structure, however, was weak and this suggests that manipulation of zooplankton community structure to manage algal biomass may be of limited value in many lakes.

Panov, D.A.; Sorokin, Y.I.; Motenkova, L.G. Experimental study of the feeding of young silver carp (Hypopthalmichthys molitrix).

ABSTRACT: The results of C-14 studies of the feeding and food requirements of the white and mottled varieties of H. molitrix at different stages of development are described. The only satisfactory food for the larvae of these fishes in the early stages of their development is small zooplankton, and the optimum concentration of these forms is 1,000/l. In addition to zooplankton, many algae can provide good and suitable food for the young of these fishes at the age of 1.5 mo, the optimum concentration being 20 mg/l, with a minimum of 2-4 mg/l.

Panov, D.A.; Sorokin, Y.I.; Motenkova, L.G. 1969. The assimilation of plant and animal feed by young white amur and the silver carp. Anon. Sbornik Po Prudovomu Rybovodstvu. (symposium on fish culture in ponds.) Moscow, USSR, 1969 from Ref Zh Biol 1969 No. 11 1969 152-158 From Ref Zh Biol 1969 No. 11I152.

ABSTRACT: None.

Panov, D.A.; Sorokin, Y.I.; Motenkova, L.G. 1969. Experimental study of the feeding of bighead and silver carp fry. Vop Ikhtiol 9(1):138-152.

ABSTRACT: None.

Pietrzak, B. 1978. The influence of the silver carp Hypophthalmichthys molitrix on eutrophication of the environment of carp ponds 6. The health of fish. Rocz Nauk Roln Ser H Rybactwo 99(2):109-126.

ABSTRACT: Ichthyopathological examinations conducted on carp and silver carp did not show any significant differences which could be connected with increasing density of stocking with silver carp. Branchionecrosis and Aerocystitis noted in carp occurred in all of the ponds and variants in a similar form, and were diagnosed in a similar number of the fish examined. Infection with Diplostomum volvens (Proalaria) was observed in the silver carp and to a lesser extent in carp, and likewise occurred in all of the ponds irrespective of their variant, resulting in lower weight increments of diseased fish.

Piliev, S.A. 1978. Biological bases of carp raising in a polyculture with herbivorous fishes in the Abkhazian-ASSR. Izv Akad Nauk Gruz SSR Ser Biol 4(2):146-152.

ABSTRACT: Ecological peculiarities of the ponds were studied. The influence of the thermal regime on the development of natural forage reserves and its use by different species of fish was examined. Depending on the intensity of the river water flow, the possibility of silver carp cultivation in polyculture with Hypophthalmichthys molitrix (Valenciennes) was discussed and biochemical analysis of their muscles was made. Carp polyculture was initiated in the thermal carp ponds with the use of cold mountain river waters of the Abkhazian ASSR [USSR].

Piliev, S.A. 1980. Ecological basis for breeding thermophilic fishes in ponds supplied with water from cold mountain rivers of the Abkhazian-ASSR USSR. Izv Akad Nauk Gruz SSR Ser Biol 6(2):147-153.

ABSTRACT: Ecological peculiarities of ponds fed by cold (< 10.degree. C in summer) mountain rivers were studied. The water flow influencing the thermal regime, the nutritional base and the feeding intensity and the growth of the breeding fishes were determined. The influence of the thermal regime on the development of the natural feeding base and on the rate of its use by Cyprinus carpio and Hypophthalmichthys molitrix is apparently dependent on the intensity of the water flow. The feeding conditions of C. carpio in polyculture with H. molitrix were studied. Their combined breeding in ponds fed by cold mountain rivers of Abkhaziya was verified.

Piotrowska, W. 1978. The influence of the silver carp Hypophthalmichthys molitrix on eutrophication of the environment of carp ponds 1. Physicochemical conditions. Rocz Nauk Roln Ser H Rybactwo 99(2):7-32.

ABSTRACT: Amounts of N and organic P, chlorophyll, O^2 and pH values increased in the water with growth of the silver carp density. There were fewer mineral compounds in the water in the presence of the silver carp than in ponds with a carp monoculture. High primary production in ponds with added silver carp was not reflected in the accumulation of organic matter in bottom sediments. The silver carp probably accelerates the matter circulation in carp ponds.

Piotrowska-opuszynska, W. 1987. The effect of silver carp on changes in environmental conditions of carp rearing II. Physico-chemical conditions. Rocz Nauk Roln Ser H Rybactwo 101(2):143-160.

ABSTRACT: Observations conducted over two consecutive years (1978 and 1979) showed a favorable influence of a moderate addition of silver carp on oxygen conditions in carp ponds, as also a high positive correlation between the biomass of fish caught and gross primary production and chlorophyll content in the water.

Piotrowska-opuszynska, W. 1984. Impact of the silver carp Hypophthalmichthys molitrix on the ecosystem of carp ponds. Ekol. Pol. 32():307-340.

ABSTRACT: The presence of the silver carp caused significant changes in the physicochemical and biocoenotical conditions of ponds under study. A growth could be observed in primary production, algal biomass, content of chlorophyll and organic compounds, and a lowering of the level of mineral compounds in the water. The silver carp (except larvae) was found to exert a beneficial influence on the O2 relations in the ponds. The paper discusses the mechanisms leading to the above changes, e.g., the moving of the main organic matter transformation processes from the pond bottom into the water.

Plavnik, I.; Barash, H.; Schroeder, G. 1983. Utilization of duck droppings in fish farming. Nutr. Rep. Int. 28(3):635-642.

ABSTRACT: Two 400 m2, earthen, standing water ponds at the Dor Aquaculture Experiment Station were integrated with duck/fish farming during 2 fish growing seasons. Each pond was stocked (on a per-hectare basis) with 1000 and 2000 Pekin ducks and 10,000-20,000 fish composed of a polyculture of common carp, tilapia, silver carp and grass carp (White Amur). Near the integrated ponds 2 control ponds of equal area were stocked with the same fish population but without ducks. The ducks received a nutritionally balanced feed. Fish growth was sustained by natural foods, the ducks' droppings, and the feed which dropped directly from the ducks' beaks into the ponds. Control ponds received field-dried poultry manure plus supplementary feed at a rate similar to the input of duck manure plus dropped duck feed occurring in the duck/fish ponds. The ducks raised over the pond exhibited a high growth rate, feed efficiency, viability and cleanliness of feathers and skin. Average daily gain of the ducks was 82 kg/ha. The average daily gain of the fish was 36.4 kg/ha in both integrated and control ponds.

Post, J.R.; McQueen, D.J. 1987. The impact of planktivorous fish on the structure of a plankton community. Freshwater Biology 17:79-89.

ABSTRACT: The abundance of planktivorous juvenile yellow perch, Perca flavescens, was manipulated in three 750 m^3 enclosures in a eutrophic lake. There was a significant negative relationship between fish and zooplankton biomasses. At high fish densities the zooplankton community was dominated by small filter-feeding cladocera, primarily bosminids. At low fish densities the zooplankton community was dominated by large filter-feeding cladocera, primarily daphnids. There was no significant relationship between zooplankton and phytoplankton biomasses when considered over the whole experiment but there was a trend towards lower phytoplankton biomass in the enclosure dominated by daphnids during mid-summer. We conclude that although planktivorous fish have a strong negative impact on zooplankton community biomass and size structure, the relationship at the next lower trophic level, zooplankton and phytoplankton, is much weaker. Therefore, the biomanipulation of planktivorous fish populations as a management technique to control phytoplankton abundance is largely ineffective.

Prinsloo, J.F.; Schoonbee, H.J. 1987. Investigations into the feasibility of a duck-fish-vegetable integrated agriculture-aquaculture system for developing areas in South Africa. Water S.A. 13(2):109-118.

ABSTRACT: The production potential of a duck-fish-vegetable integrated aquaculture-agriculture farming system was investigated. Pekin ducks were used which were first grown indoors for a period of 28 days before being released into enclosed fish-ponds with shelters over the pond water. Manure and waste feed was dropped directly into the water containing fish in polyculture which included the European common carp, C. carpio, the bighead carp, silver carp, H. molitrix and the grass carp, C. idella. Only the common cap received predetermined quantities of supplementary feed based on growth, by means of demand feeders, as other species largely utilised the nutrients discharged into the ponds with the faeces of the ducks as well as plankton growths which developed as a result. The nutrient-rich water in the ponds was used to irrigate vegetable crops. Ducks grew to an average of 2,65 kg in a period of 55-56 d. Fish yields obtained exceeded 8 t ha super(-1) over a period of 149 d. Substantial yields of vegetable crops were obtained with vegetables such as tomatoes, spinach and lettuce clearly benefitting from the nutrient-rich water.

Prinsloo, J.F.; Schoonbee, H.J. 1987. The use of sheep manure as nutrient with fish feed in pond fish polyculture in Transkei. Water S.A. 13(2):119-123.

ABSTRACT: Sheep manure was used as a nutrient in addition to formulated feed in a fish-cum-vegetable integrated production experiment conducted during the summer of 1985 to 1986. Results obtained showed that this kind of manure is not very suitable for use in fish-ponds but that the nutrient rich water produced favourable vegetable growth. Fish species used in the polyculture system included the European common carp C. carpio and the Chinese carps H. molitrix, C. idella. A total fish yield of almost 5 t ha super(-1) was obtained over a period of 149 d.

Prinsloo, J.F.; Schoonbee, H.J. 1984. Observations on fish growth in poly culture during late summer and autumn in fish ponds at the Umtata Dam Fish Research Center Transkei, South Africa 1. The use of pig manure with and without pelleted fish feed. Water S A (pretoria) 10(1):15-23.

ABSTRACT: Pig manure, with and without pelleted fish feeds, was employed during the late summer and autumn periods to evaluate its role in a polyculture fish production system in which the growth performance of varieties of the European common carp, the Chinese black, grass and silver carps and the tilapia Oreochromis mossambicus was established. With careful pond management procedures, problems of O2 depletion can be avoided even where large quantities of pig manure are applied daily. Water temperature has an important bearing on the actual fish production capacity of pig manure, especially when it declines below 20.degree. C. Pig manure should not be applied to fish ponds when mean water temperatures decline below 15.degree. C. In the case where pelleted fish feeds supplemented the pig manure, the active growth of most fish was extended and a production of more than 40 kg ha-1day-1 was maintained even at mean water temperatures as low as 15.6.degree. C. During this period, and despite the rapidly declining water temperatures, a total production of almost 4 t[tonne]/ha was obtained within 128 days. With a further decline in water temperature below 15.degree. C a considerable reduction in the actual fish production of the ponds took place. For this reason, pond production probably should be terminated for these fish species when the mean water temperature declines below 15 .degree. C.

Prinsloo, J.F.; Schoonbee, H.J. 1986. Summer yield of fish in polyculture in Transkei, South Africa using pig manure with and without formulated feed. S-afr Tydskr Veekd 16(2):65-71.

ABSTRACT: A high density fish polyculture investigation was conducted during the summer season of 1984-1985 at the Umtata Dam Fish Research Centre, Transkei. Fish species used, included the cross-breed betwen the Israeli Dor 70 and the Aischgrund varieties of the European common carp Cyprinus carpio, bighead carp Aristichthys nobilis, black carp Mylopharyngodon piceus , gass carp Ctenopharyngodon idella , silver carp Hypophthalmichthys molitrix and tilapia, Oreochromis mossambicus. Fresh pig manure was used as nutrient to stimulate pond productivity. In addition, some ponds also received formulated feed. With pig manure alone, a net fish production of 1,66 t ha-1 was achieved over a period of 175 days. Where feed was also provided to the fish, the fish yield over the same period amounted to 8.57 t ha-1. The pond water effluent was used for vegetable production.

Prinsloo, J.F.; Schoonbee, H.J. 1986. Comparison of the early larval growth rates of the chinese grass carp Ctenopharyngodon idella and the chinese silver carp Hypophthalmichthys molitrix using live and artificial feed. Water S A (pretoria) 12(4):229-234.

ABSTRACT: Live and artificial foods were tested for their relative growth potential for larvae of the Chinese silver carp and grass carp during the first ten to fourteen days after commencement of the active feeding stage. The live food was obtained from predominantly rotifer cultures developed in a combination of earthen and concrete ponds fertilized with poultry manure and inorganic fertilizer. Dry food consisted of a commercial larval fish food formula. Results obtained showed that live food yielded the best growth results for both fish species. However, when frozen, live food was inferior to dry food.

Prophet, C.W.; Frey, J.K. 1987. Capture of Diaptomus siciloides and Diaptomus pallidus by suction simulator and Gizzard Shad (Dorosoma cepedianum). Journal of Freshwater Ecology (2):253.

ABSTRACT: The capture of Diaptomus siciloides and Diaptomus pallidus by gizzard shad (Dorosoma cepedianum) was simulated using a suction device. Based on simulations, the capture probability for D. siciloides was significantly greater ($p < 0.025$) than that for D. pallidus. Capture probabilities in the simulations varied from 0.092-0.391 for D. siciloides and from 0.047-0.210 for D. pallidus. These capture probabilities usually underestimated the capture frequencies observed in feeding experiments employing live shad. The shad did not exhibit a tendency to select D. siciloides over D. pallidus but appeared to capture the calanoids in proportion to their densities in the test pools.

Reich, K. 1978. Lake Kinneret, Israel fishing in its development. Bamidgeh 30(2):37-64.

ABSTRACT: During the last 40 yr, the mean yearly catch of Kinneret [Israel] fish increased 6.5-fold from 265 tons during 1935-1940 to 1748 tons during 1969-1973. The yearly catch per fisherman increased from 1.5-2.0 tons during the initial period to a recent value of 9.7 tons. This augmentation is the result of changes in environmental conditions, fishing regulations which protect young fish, technological development of fishing methods, increased marketing possibilities and the stocking of new species. The haul of bleak has grown 10-fold, from an annual mean of 107 tons to 1046 tons. The catch remained at a level of 540 tons for 9 yr. The average yearly crop of barbel plummeted from an annual 90 tons during 1935-1947 to 40 tons in 1949-1954. This drop was due to the cessation of fishing with shore seines and cast nets. Upon the introduction of nylon and monofil fibers, its yield rose and remains constant at 130 tons. An increase in minimum permissible length has not affected the crop. The haul of shot up from a yearly mean of 55 tons to 325 tons. An increase in minimum permissible length raised the catch of Sarotherodon galilaeus and Tristamella simonis. The rise in Tristramella yield was slow and continuous until 1958. After that time it leveled off at an annual mean of 52 tons. The S. galilaeus population rapidly accelerated; in 1946, 120 tons were netted, i.e., 3 times the pre-1942 mean. Since then, the year-to-year fluctuations have been wide. The factors responsible are unknown. The increase in permissible minimum length did not serve to increase the haul of S. aureus. During 18 years, its yearly catch was of a magnitude of several tons. Upon initiation of stocking, there was a definite rise in yield. Based on a multi-yearly average, one million fingerlings produce a harvest of 63 tons. S. zillii is not in demand. Its rapid proliferation might affect other fish. The carp was introduced into this country by fish farmers and penetrated the Kinneret in the early 1940's. Its breeding and growth rates in the lake are low. Therefore its catch has remained low. Mullet stocking has produced quite favorable results: 122 tons of fish for each million fingerlings planted. However, fishing methods are not efficacious enough. The silver carp [Hypophthalmichthys molitrix] grows quite rapidly in the lake. From a biological aspect, it is the fish best suited to the conditions. There still remain technical difficulties in its fishing. During the last 18 yr there has been no increase in the yield of the Kinneret's indigenous fish, other than bleak. Increased hauls during recent years are due mainly to stocking with new species. There is a possibility of greatly increasing the number of fingerlings stocked. There are good chances of increasing the catch by stocking additional species. It would be advisable to stock species which do not spawn in the lake and whose density may be readily adjusted to environmental conditions. One of the possibilities would be the stocking of predatory fish.

Reich, K. 1975. Multi species fish culture polyculture in Israel. Bamidgeh 27(4):85-99.

ABSTRACT: Raising a number of fish of the same species in a pond raises the intraspecific competition and decreases individual growth. Polyculture, even of fish which feed on different natural foods, causes a certain amount of interspecific competition. The fish also influence their surroundings. These changes can improve the growth conditions for other species or worsen them. The yield of each component fish species and the yield of the entire pond is the resultant of the various influences that both diminish and increase the yield. The most successful combination of fish species in a pond is one with the least interspecific competition and the most improving influences. In the polyculture of 3 spp., carp, silver carp and tilapia, a balanced ecological system in which the interspecific competition is small and improvement of the environment large was created.

Rmolin, V.P. 1979. The influence of predators on fish populations in the Saratovskoe Reservoir. Vopr. Ikhtiol. 19(3):476-481.

ABSTRACT: The study of the extent of influence of predatory fishes on populations of plant-eating fishes in relation to prey sizes shows that the size and weight of Hypopthalmichthys molitrix, Aristichthys nobilis, and Mylopharyngodon piceus released to the Reservoir should not be below 20.0-22.5 cm and 200-220 g.

Rothbard, S. 1981. Fishes Cultivated in Fresh Water Ponds in Israeli Fish Culture. Fish. Fishbreed. Isr. 16(3):24-35.

ABSTRACT: The Israeli fish culture was initially based on monoculture of the common carp, introduced to Israel by Jewish immigrants from Central and East Europe, where the carp is cultivated for hundreds of years. Soon, local species of tilapias and mullets were added to the fish population in the fish pond, starting to play an important role among the cultivated species. When Chinese carps were imported from the Far East, the Israeli fish culture was converted into more economic system, significant with high yields and highly sophisticated management. In the present study, biological and morphological characteristics of the fishes like the common carp (Cyprinus carpio), tilapias (Sarotherodon spp.), mullets (Mugil spp.), silver-carp, grass-carp and big-head carp (Hypophthalmichthys molitrix, Ctenopharyngodon idella, Aristichthys nobilis, respectively) are briefly described, all of them comprising the fish populations in Israeli polyculture.

Sarig, S. 1979. Fisheries and fish culture in Israel in 1978. Bamidgeh 31(4):83-95.

ABSTRACT: The total catch of the Israeli fisheries in 1978 was 23,752 tons, an increase of 485 tons (2.1%) as against 1977. The import of salted, frozen and filleted fish decreased by 1532 tons (10%) in 1977 and amounted to 37% of the total consumption compared with 42% in 1977. The pondfish contribution to the total per capita consumption climbed slightly from 3.5 kg in 1977-3.6 kg (35% of the total) in 1978. The marine haul, including that of the Atlantic deep sea fisheries, was 8778 tons, an increase of 855 tons (11%) compared with 1977. The Lake Kinneret harvest was 1692 tons, a drop of 43 tons (2.5%) compared with the previous year. The quantity of pondfish marketed this year decreased by 837 tons (2.5%) and amounted to 13,117 tons, i.e., 56% of the total of the Israeli fisheries. According to governmental statistics, the fishpond area was reduced by 88 ha this year and totalled 4065 ha. The proportion of carp in the total marketed pondfish was 65.5%, an increase of 5% compared with 1977, tilapia increased to 17% of the total, silver carp to 12.7%, mugils to 4.1% and 2 Chinese carp: the grass carp Ctenopharyngodon idella and the big-head Aristichythys nobilis increased together to 0.7%. Pond tilapia comprised 87.4% of the marketed total of this species, and pond mugils, 35% of the total of this species.

Sarig, S. 1982. Fisheries and fish culture in Israel in 1980. Bamidgeh 34(1):3-19.

ABSTRACT: In 1980 the total catch of the Israeli fisheries dropped by 1149 tons (4.7%) as against 1979. There was a reduced yield from all sources ranging between 7-9%, except for that of the pelagic and inshore fisheries which rose by nearly 21%. This year's per capita consumption was 9.7 kg compared to 10.5 in 1979. Imported fish (filleted, processed and frozen) declined by 2142 tons (12.4%) compared to 1979. The pond fish contribution to the total per capita consumption dropped to 3.0 kg (30.2%) compared to 3.3 kg (31.4%) in 1979. There was no difference between the total Israeli marine catch of 1980 and 1979. The Lake Kinneret catch decreased by 163 tons (7.6%) compared to 1979. The total quantity of marketed pond fish was 11,691 tons, a drop of 928 tons compared to 1979. The total pond area was reduced to 3407 ha, 122 ha (3.4%) < in 1979. The national average production of marketed pond fish was 3.37 tons/ha, a drop of 0.12 tons/ha compared to 1979. Seventeen farms on an area of 858 h, 25% of the total pond area, attained an average yield of 4.7 tons/ha. Seven of these farms, on an area of 240 ha, reached an average yield of 5.63 tons/ha. The carp contribution to the total pond production remained almost the same as in the previous year.sbd.62.9%. production was almost 22% and silver carp decreased to 7.8%. Pond tilapia comprised 82%, pond mugils 54% of the total marketed from all sources.

Sarig, S. 1983. Fisheries and fish culture in Israel in 1982. Bamidgeh 35(4):95-108.

ABSTRACT: The total catch of Israeli fisheries in 1982 dropped by 719 tons (3.2%) as against 1981. The main decrease was in Atlantic deep-sea fisheries, a drop of 1079 tons, 21%. Pelagic and inshore fisheries increased by 560 tons.sbd.20%. The pondfish production stabilized itself for the last 3 yr in the range of 11,600 tons/yr. There was a prominent drop in the per capita consumption, from the standard 10 kg of all the previous years, to 9.4 kg this year. A drop of almost 4800 tons, 28%, was recorded in imported fish, compared to 1981. Pondfish contribution to the per capita consumption was 2.9 kg (34%) and was 53% of the total Israeli fisheries. The marine catch (Mediterranean, Red Sea and Atlantic deep-sea) dropped by 562 tons (5% as against 1981). The Lake Kinneret catch increased by 30 tons (1.6% compared to 1981). The total quantity of pondfish marketed in 1982 dropped by 157 tons, compared to 1981. The total pond area went down to 3331 ha, 94 ha less than in 1981. The national average of marketed pondfish was 3400 kg/ha, an increase of 66 kg/ha, 2%, compared to 1981. Twenty three farms on an area of 1285 ha, almost 39% of the total pond area, attained an average of 4.73 ton/ha. The share of carp in the total pondfish production decreased by 424 tons, comprising 63% of the total. reached 20%, silver carp reached 8.2% and mugil reached 6.8% of the total. Pond tilapia comprised 83.6%, and pond mugils 57.7%, of the total marketed from all sources. In addition to the warmwater fish from ponds, 138 tons of rainbow trout and 13 tons of Macrobrachium rosenbergii were produced. Out of the total pondfish production, 960 tons, 8.3%, were processed. The greatest part was sold on the local markets. Most of the fish processed were tilapias.

Sarsembaev, Z.G. 1975. Effect of various ecological conditions of ponds on the reproductive system of the silver carp. Izv Akad Nauk Kaz SSR Ser Biol 13(4):31-38.

ABSTRACT: None.

Schildhauer, B. 1983. Untersuchungen zur Salzgehaltsvertraeglichkeit juveniler Karpfen (Cyprinus carpio L.) und Marmorkarpfenhybriden (Aristichthys nobilis Rich. x Hypophthalmichtys molitrix Val Investigations into the salt tolerance of juvenile carps (Cyprinus carpio L.) and crucian carp hybrids (Aristichthys nobilis Rich. Hypophthalmichthys molitrix Val). Fischerei-forschung. 21(1):24-30.

ABSTRACT: The foreseen production of young limnophilic cyprinids in heated brackish water and the intensive management of selected internal sea waters in the GDR made it necessary to conduct further investigations into the salt tolerance of carp (C. carpio) fry (K sub(6d)), fore-aged carps (K sub(28d)) and crucian carp (H. molitrix) hybrids (MaSi sub(40d)) during 1980. The experiments, which were performed on a total of 9,000 K sub(6d), 4,500 K sub(28d) and 4,500 MaSi sub(40d) consecutively in 45 twenty-litre aquariums at temperatures of 23 plus or minus 1.2 degree C and 26 plus or minus 1.6 degree C, were designed to investigate the salt tolerance of the fry when transferred directly from fresh water into aquariums where the salinity increased gradually 2 to 14 ppt. S and when transferred from fresh water to aquariums with a defined salinity after a 48 h adaptation phase per salinity increment. The salt tolerance was ascertained on the basis of the survival rates, gain in weight and growth in length of the surviving test fishes.

Schoonbee, H.J.; Nakani, V.S.; Prinsloo, J. 1979. The use of cattle manure and supplementary feeding in growth studies of the chinese silver carp in Transkei, South Africa. S. Afr. J. Sci. 75(11):489-495.

ABSTRACT: Cattle manure and inorganic fertilizers were used to grow the Chinese silver carp Hypophthalmichthys molitrix in fish ponds in Transkei. Certain physical and chemical parameters of the pond water were monitored together with fish growth performance to determine adjustments in dosage of manure. Results on the pond water chemistry indicated marked fluctuations in O2 levels but anaerobic conditions did not prevail during the study period of more than 1 yr. An analysis of the macro-invertebrate benthic fauna showed that the benthic feeding common carp Cyprinus carpio should be included in polyculture with the silver carp in manured ponds together with detritus, algal and zooplankton-feeding fish. The inclusion of a predator to eliminate the platanna Xenopus laevis, which prey on young fish, is also recommended.

Schroeder, G.L. 1983. Sources of fish and prawn growth in polyculture ponds as indicated by stable carbon isotope analysis. Aquaculture 35(1):29-42.

ABSTRACT: Concentration ratios of naturally occurring stable C isotopes, 13C:12C (reported as .delta.C), were measured in the natural foods and supplied feeds of fish ponds receiving high rates of chicken manure or high rates of fish meal-enriched feed pellets. These .delta.C values, when compared with the body .delta.C of target animals grown in these ponds, indicated the source of feed used for growth. Half the common carp growth was based on natural foods found on the pond bottom and banks even in the presence of a full ration of enriched feed pellets. hybrids strongly favored natural foods of photosynthetic origin in preference to either manure-related or feed pellet-related foods. Silver carp body .delta.C matched the .delta.C of microalgae centrifuged from pond water which had been passed through a 37 .mu.m screen. Macrobrachium rosenbergii prawn .delta.C was unchanged for the 2 manure-feed strategies, indicating a feeding pattern independent of the presence or absence of a supplied feed pellet. Prawn .delta.C showed a feeding dependence on natural foods found both on the pond bottom and bank. Chironomids found only on secluded rock surfaces had a .delta.C similar ot that of the microalgae.

Schroeder, G.L. 1983. Indigenous tracers in aquaculture food webs. Bamidgeh 35(3):79-90.

ABSTRACT: Based on .delta. C [isotope ratio] analyses of the target animals and of the available foods the following observations were made. In fish-prawn polyculture ponds receiving manure as the only organic input, the fraction of growth originating from the food web based on the manure was common carp 50-65%; tilapia 20-40%; silver carp 0%; prawns 30-50%. The remainder of the growth was attributable to the photosynthetic food web. In raceway culture of penaeid shrimp, oil meal press cake was an inefficient growth substitute for animal meals in pellets already containing in excess of 50% animal meals.

Schroeder, G.L.; Buck, H. 1987. Estimates of the relative contributions of organic and mineral contents of manure to fish growth. J. Aquacult. Trop. 2(2):133-138.

ABSTRACT: Field-dried poultry manure or an artificial manure (herein referred to as stover) composed of leaves and stalks from corn plants (all grains removed) were supplied to earthen, freshwater, 400 m2 ponds six days per week at rates such that all ponds received a daily average of 120 kg organic matter/ha or 5 g organic carbon/m2. Ammonium sulfate and calcium superphosphate were also supplied 6 days/week at a daily rate of 0.4 g N and 0.4 g P per m2. The polyculture was composed of 540 tilapia Oreochromis niloticus .times. O. aureus, 40 siliver carp, 120 common carp and 7 grass carp in each pond. The growout season lasted 95 days. Midday water temperatures averaged 28.degree.C. Net primary productivity (daily gross primary productivity minus 24 hour respiration) was approximately 3 to 6 g C/m2. Daily fish yields averaged 32 kg/ha with poultry manure and 26 kg/ha with stover. Ratios of the naturally occurring stable isotopes of carbon (reported as .delta.C) were used as indigenous tracers in the pond food web. The large difference between the .delta.c of the stover(-12.4) and the algal .delta.C (-24) allowed estimation of the sources of growth of the target fish. These data, in combination with the yields of the individual fish species indicate that, for our polyculture, silver carp (a water column filter feeder) and tilapia hybrid (a bottom omnivore) yields are almost independent of the supplied organic matter provided adequate mineral fertilization is maintained. Common carp and grass carp yields are strongly dependent (40 to 50%) upon the added organic matter. The food web based on algal organic matter, consumed partly directly and partly after microbial processing, sustained a daily fish yield of approximately 25 kg/ha in these ponds. This high yield indicates the effectiveness of intense chemical fertilization as a method for fish culture in ponds.

Shah, K.L.; Tyagi, B.C. 1986. Hypophthalmichthys molitrix held in tropical ponds associated with the bacterium staphylococcus Aureus. Aquaculture 55(1):1-4.

ABSTRACT: The occurrence of an eye disease in silver carp, H. molitrix, associated with a Gram-positive bacterium, S. aureus, is described for the first time from India.

Shakirova, F.M. 1985. Materials on nutrition of Khauzhkan and Saryyaz reservoirs in the Turkmen-SSR USSR. Turkm SSR Ser Biol Nauk 0(4):9-13.

ABSTRACT: Hypophthalmichthys molitrix (Val.) in Khauzkhan and Sariyaz reservoirs feeds on all species of plankton algae, but this fish often consumes the considerable number of zooplankton organisms. The paper discovers the high plasticity of Hypophthalmichthys molitrix (Val.) with respect to transition to calf-lymph nutrition under lack of main feed. The analysis of daily nutrition rhythm of fishes determined 2 pinnacles .sbd. in morning and evening hours.

Shan, J.; Chang, L.; Gua, X.; Fang, Y.; Zhu, Y.; Chou, X.; Zhou, F.; Schroeder, G.L. 1985. Observations on feeding habits of fish in ponds receiving green and animal manures in Wuxi, China. Aquaculture 46(2):111-118.

ABSTRACT: Fish yields and ratios of naturally occurring stable carbon isotopes, 13C"12C (reported as .delta. C) from 1-mu (670 m2) and 5-mu (3330 m2) ponds were measured. The ponds received daily inputs of green and animal manures as the sole organic inputs. Fish yields exceeding 40 kg/ha per day were attained in both the small and large ponds. .delta.C data indicated a strong contribution of the fresh fluid pig manure to growth of the two filter-feeding species, silver and bighead carp. Two grass-eating species, grass carp and Wuchang fish (Megalobrama ambylscephola), had significantly different .delta.C values, indicating partially separate food sources for each of these two species.

Shan, J.; Chang, L.; Gua, X.; Fang, Y.; Zhu, Y.; Chou, X.; Zhou, F; Schroeder, G.L. 1985. Observations on feeding habits of fish in ponds receiving green and animal manures in Wuxi, People's Republic of China. Aquaculture. 46(2):111-117.

ABSTRACT: Fish yields and ratios of naturally occurring stable carbon isotopes, super(13)C: super(12)C (reported as delta C) from 1-mu (670 m super(2)) and 5-mu (3330 m super(2)) ponds were measured. The ponds received daily inputs of green and animal manures as the sole organic inputs. Fish yields exceeding 40 kg/ha per day were attained in both the small and large ponds, delta C data indicated a strong contribution of the fresh fluid pig manure to growth of the two filter-feeding species, silver and bighead carp. Two grass-eating species, grass carp and Wuchang fish (Megalobrama amblycephola), had significantly different delta C values, indicating partially separate food sources for each of these two species.

Sapiro, J. 1985. Food and intestinal contents of the silver carp Hypophthalmichthys molitrix in Lake Kinneret, Israel between 1982-1984. Bamidgeh 37(1):3-18.

ABSTRACT: The food and intestinal contents of silver carp, H. molitrix Val in Lake Kinneret were investigated from Aug. 1982 to February 1984. The gut of large silver carp contained mainly Peridinium cinctum f. westii (up to a maximum of .apprx. 92% of the total volume of the recognizible organisms). The gut contents of small silver carp indicated more omnivorous feeding, besides P. cinctum, they included large quantities of zooplankton, mainly Mesocyclops leuckarti and Bosmina longirostris.

Shapiro, J.; Wright, D.I. 1984. Lake restoration by biomanipulation: Round Lake, Minnesota, the first two years. Freshwater Biology 14,371-383.

ABSTRACT: 1. Rotenone was applied to Round Lake in the autumn of 1980 in order to eliminate predominantly planktivorous and benthivorous fish. The lake was subsequently restocked with a higher population density of piscivores. The effect of this biomanipulation on the phytoplankton and zooplankton communities and on total nutrient concentrations was monitored at fortnightly intervals during the summers, from May 1980 to September 1982.
2. The abundance of phytoplankton was much lower after biomanipulation and was consistent with observed changes in Secchi disc transparency, total attenuation coefficient and chlorophyll a concentration. Zooplankters were also less abundant in 1981 and 1982 but the decrease in numbers was more than offset by the large increase in the mean sizes of the zooplankters present, so that the estimated grazing pressures in 1981 and 1982 were at least double the 1980 value.
3. Daphnia, rare in 1980, became the dominant genus in 1981 and 1982, and a shift to progressively larger-bodied Daphnia species was observed.
4. Although total nitrogen and total phosphorus levels were generally lower after biomanipulation, their decline could not explain the reduction in phytoplankton abundance which was attributed to their increased grazing pressure. Possible causes of the observed declines in nutrient concentrations are discussed.

Shefler, D.; Reich, K. 1977. Growth of silver carp Hypophthalmichthys molitrix in Lake Kinneret, Israel in 1969-1975. Bamidgeh 29(1):3-16.

ABSTRACT: Silver carp grown in Kinneret from 1969-1975 had a growth rate not different from that of other fish ponds. The silver carp grew better during 1969-1971 than during the period of intensive stocking in 1972-1974. This may be an error originating in an inaccurate sampling. Therefore, it might be advisable during the next few years to check whether increased silver carp stocking of Kinneret affects it growth rate. There is a striking difference in weight of fish of identical age. Some of this variance may be explained by a difference in stocking date and fingerling weight. However, there may be genetic variances among the fish which by selection and breeding stock improvement would enable better and uniform growth. It is possible to estimate the growth of silver carp in future years. Silver carp introduced into the Kinneret during July-Aug. would reach a weight of about 400 g during the following spring. During the 1st summer, there would be an increment of about 2 kg, the fish reaching an average weight of 2.5 kg by winter. Due to the varied growth rate of the individual carp, some would weigh only 1.5 kg while others would prematurely attain a weight of 4 kg. During winter when the temperature drops to 15-16.degree. C, the fish would only barely grow, during the 2nd summer the growth rate would accelerate and by winter most of the fish would reach a weight of 5-6 kg. During the 3rd summer, rapid growth would continue so that by winter an additional increase in weight of 3 kg/fish could be expected. Due to non-uniform growth, the individual differences among the fish would also increase so that by the beginning of winter (the fish being 40-41 mo. old) they would weigh between 6.5-10.5 kg. They would undoubtedly continue to grow when at 4 or 5 yr old it could be assumed that the maximum weight would reach about 20 kg. The percentage of viability in the stocking experiments was relatively low. Means of increasing it should be sought, especially nursing of fingerlings in ponds to a weight of 1 or more grams, and by stocking as early as possible. In winter and spring, newly stocked silver carp fingerlings are caught in various gill nets. Concerted efforts must be made to avoid the destruction of these young silver carp.

Sin, A.W.; Chiu, M.T.L. 1987. The Culture of Silver Carp Bighead Grass Carp and Common Carp in Secondary Effluents of a Pilot Sewage Treatment Plant. International symposium on recycling of organic wastes for fertilizer, food, feed and fuel, Hong Kong, Resour. Conserv. 13(2-4):231-246.

Sin, A.W.; Chiu, M.T.L. 1987. The culture of silver carp, bighead grass carp, and common carp in secondary effluents of a pilot sewage treatment plant. International symposium on recycling of organic wastes for fertilizer, food, feed and fuel, Hong Kong, August 28-30, 1985. Resour. Conserv. 13(2-4):231-246.

ABSTRACT: None.

Singit, G.S.; Keshavanath, P.; Varghese, T.J.; Konda reddy, P.; Venkatesh prasad, G.S. 1980. Fish production through composite fish culture in a farmers pond. Mysore. J. Agric. Sci. 14(2):236-240.

ABSTRACT: Composite fish culture in an earthen pond of the size 0.12 ha with an average water depth of 3 m was started: this pond was not put to any use earlier. Seed of Indian major carps, exotic carps and the brackishwater fish, Chanos chanos were released in the pond between July-Nov. 1978, at a stocking density of 8000/ha and harvested in 2 installments in June and July 1979. A production of 6046.25 kg/ha per yr was obtained and the cost of fish production was given. Silver carp, grass carp and catla attained more than 1.0 kg size during the rearing period.

Smith, D.W. 1985. Phytoplankton growth and the enhancement of aquacultural production. Can. J. Fish Aquat. Sci. 42(12):1940-1945.

ABSTRACT: A method is proposed to control phytoplankton biomass in aquacultural ponds, using both zooplankton and filter-feeding silver carp (Hypophthalmichthys molitrix). The technique maintains co-existence of zooplankton and filter-feeding fish by excluding the fish from part of the water column. Zooplankton, which feed on smaller algal species, and silver carp, which feed on large algae and zooplankton, together can consume all sizes of phytoplankton, thus controlling algal biomass. This technique was tested in 1000-L tanks, some containing channel catfish (Ictalurus punctatus) alone, some both catfish and silver carp, and others catfish and silver carp with a zooplankton refuge. The refuge permitted coexistence of high densities of large zooplankters with the filter-feeding fish. This combination of filter-feeders reduced algal biomass by as much as 99%, increased phytoplankton diversity, and showed a trend toward improved silver carp growth compared with treatments without a refuge. The proposed technique could be applied to both intensive and extensive aquacultural systems.

Smith, V.H.; Shapiro, J. 1981. Chlorophyll-phosphorus relations in individual lakes. Their importance to lake restoration strategies. Environ. Sci. Tech.15(4): 444-451.

ABSTRACT: The response of algal biomass to nutrient reduction is critically evaluated in 16 north temperate lakes by using data from the literature. The analysis confirms that reductions in total phosphorus concentration in the lakes are typically accompanied by consistent declines in chlorophyll. The data also suggest that this response can be expected whether a lake is phosphorus or nitrogen limited, although the magnitude of the response may differ. This is in contrast to the conclusion of a recent report which suggests that a threshold response is involved. Furthermore, the responses of some lakes appear unique and may not be accurately predicted by using current global eutrophication models. Modifications of these models to account for additional factors are urged, in order that these prediction errors may be decreased in the future.

Sorokin, Y.I.; Panov, D.A. 1968. Experimental determination of food consumption of larvae and fry of silver carp by means of carbon-14 Hypophthalmichthys molitrix diatom algae rotifer management. Dokl Akad Nauk Sssr 182(1):208-210.

ABSTRACT: None.

Spataru, P. 1977. Gut contents of silver carp Hypophthalmichthys molitrix and some trophic relations to other fish species in a poly culture system. Aquaculture 11(2):137-146.

ABSTRACT: This work is a continuation of the studies conducted in the ponds of the Fish and Aquaculture Research Station, Dor [Israel], in 1975 concerning the components of fish feed under polyculture, with additional food and intensive fertilization. A study was made of the food eaten by the silver carp, H. molitrix (Val.), grown with or without supplementary food in ponds that had previously been used for storage of fish fed on pellets (pond types 1 and 3), or which had been kept dry for various periods of time (pond types 2 and 4). The special pattern of its gills, which are adapted to retain suspended organisms and particles of sizes less than 20 .mu.m, enables the silver carp to filter enormous quantities of phytoplankton and organic particles. A comparative study was made of the trophic relations existing between H. molitrix (Val.), Cyprinus carpio (L.) and aurea Steindachner, which were the principal species in the polyculture system, and of the influence of the type of pond used on the growth of the fish.

Spataru, P.; Gophen, M. 1985. Feeding behavior of silver carp Hypophthalmichthys molitrix and its impact on the food web in Lake Kinneret, Israel. Hydrobiologia 120(1):53-62.

ABSTRACT: Silver carp, H. molitrix Val., have been stocked in Lake Kinneret, Israel, since 1969. From 1972-1981, 11 .times. 106 fingerlings were introduced into the lake. Total silver carp catch was only 642 during this period, resulting in a progressive increase in the silver carp population. Silver carp feed mostly on phytoplankton from Feb.-Aug. From Sept.-Jan. sampled gut contents contained predominantly zooplankton. Indices of electrivity for zooplankton were positive from Sept.-Dec., negative during Jan.-Aug. and vice versa for phytoplankton. Predation pressure of planktivorous fish on zooplankton in Lake Kinneret has been intensified recently. Accumulation of silver carp in the lake probably supported this process. Silver carp compete with commercially valuable native fish species by feeding on the same zooplankton resources during summer and fall. Additionally, the grazing population of microcrustaceans is reduced at the time it is needed to prevent microalge blooms. Market demands for silver carp are low, catchability of this fish is poor and it can be cultured efficiently in ponds. Consequently it is recommended that the stocking of silver carp in Lake Kinneret be stopped.

Spataru, P.; Hepher, B. 1977. Common carp preying on fry in a high density poly culture fish pond system. Bamidgeh 29(1):25-28.

ABSTRACT: Aurea, T. vulcani, and Hypophthalmichthys molitrix were raised in a polyculture fish pond to examine the effects of a large number of fry on the viability and diet of the commercial carp. The amount of fry consumed is dependent upon the size of each species. Intensive spawning inhibits growth of both species. Since carp production in polyculture with is greater than monoculture, an optimal size relationship for maximal removal of fry and their utilization as food by the carp must be developed.

Spataru, P.; Wohlfarth, G.W.; Hulata, G. 1983. Studies on the natural food of different fish species in intensively manured poly culture ponds. Aquaculture 35(4):283-298.

ABSTRACT: Natural food components were analyzed for 6 spp. of fish grown in 9 polyculture ponds. The ponds were stocked with common carp (Cyprinus carpio L.), tilapia hybrids (Sarotherodon (Oreochromis) niloticus L. .times. S. (O.) aureus Steindachner), grass carp (Ctenopharyngodon idella Val), and either silver carp (Hypophthalmichthys molitrix Val.) or bighead carp (Aristichthys nobilis Rich.) or their inter-specific hybrid. The natural food examined and defined was collected both from the guts of fish sampled and from pond water. The proportional amount of phytoplankton found in the guts of silver carp, bighead carp and their hybrid was 88-95%, 0-2% and 28-55%, respectively. The parallel zooplankton values were 4-7%, 75-95% and 32-63%. In ponds stocked with silver carp, bighead carp and their hybrid, the proportional amount of phytoplankton in the pond water was 12-33%, 54-99% and 17-77%, respectively. This demonstrates empirically the inverse relationship between the type of plankton preferentially consumed by a given fish and the predominant plankton type present in ponds stocked with that fish. The mechanism of this preferential feeding is presumably associated with the diameter of the filtering net meshes of the gills of these fishes: 36 .mu.m in silver carp, 84 .mu.m in bighead carp and 56 .mu.m in their hybrid.

Spencer, C.N.; King, D.L. 1984. Role of fish in regulation of plant and animal communities in eutrophic ponds. Can. J. Fish. Aquat. Sci. 41:1,851-1,855.

ABSTRACT: Alteration of fish communities resulted in marked changes in the zooplankton, phytoplankton, and benthic plant communities in nutrient-rich ponds. In ponds containing dense populations of fathead minnows (Pimephales promelas) and brook sticklebacks (Culaea inconstans), intense fish predation resulted in sparse cladoceran zooplankton populations and turbid water dominated by dense blue-green algal blooms. In ponds containing no fish, or dense populations of largemouth bass (Micropterus salmoides), abundant Cladocera reduced phytoplankton densities through heavy grazing, and these ponds were characterized by clear water and dense growths of Elodea canadensis, Potamogeton spp., and Cladophora sp. Manipulation of fish populations to control unwanted algal blooms in shallow eutrophic lakes may yield dense growths of equally undesirable macrophytes and periphyton.

Spittler, P. 1980. Experimental studies on the feeding biology of silver carp Hypophthalmichthys molitrix and bighead Aristichthys nobilis. Wiss Z Wilhelm-pieck-univ Rostock Math Naturwiss Reihe 28(6):537-540.

ABSTRACT: The feeding biologies of H. molitrix and with body weights of 1-2 g are adapted to the preferential ingestion of particles with diameters below 500 .mu.m. Suspended and sedimented substances of no feeding value are ingested at the same time. In contrast to , H. molitrix also filters off particles with diameters less than 40 .mu.m.

Srivastava, J.B.; Chowdhary, S.K. 1979. Culture of catla-catla in a lentic impoundment in Jammu, India. Aquaculture 18(3):283-286.

ABSTRACT: None.

Stenson, J.A.E. 1976. Significance of predator influence on composition of Bosmina spp. populations. Limnol. Oceanogr. 21(6):814-822.

ABSTRACT: Comparisons between Bosmina coregoni and Bosmina longirostris in fish stomachs and net plankton showed a larger mean size in the stomachs and a clear preference for the larger species, B. coregoni. Vertebrate and invertebrate predators may influence distribution and numeric relations between the two species.

Stenson, J.A.E.; Bohlin, T.; L. Henrickson; Nilsson, B. I.; Nyman, H.G.; Oscarson, H.G.; Larsson, P. 1978. Effects of fish removal from a small lake. Verh. Internat. Verein. Limnol. 20: 794-801

ABSTRACT: Fish were removed from a small lake in Sweden using rotenone in November 1973. Subsequent decreases were observed in transparency, primary productivity, and pH. Zooplankton numbers, biomass and species composition changed as a result of fish removal. Similar changes were observed in phytoplankton community structure. None of the above changes were seen in an adjacent lake containing fish.

Stott, B.; Buckley, B.R. 1978. A note on the growth of two exotics in England; the silver carp (Hypophthalmichthys molitrix Val.) and the bighead (Aristichthys nobilis Rich.). J. Fish Biol. 12:89-91.

ABSTRACT: Observations were made on the growth of microphagous silver carp and bigheads in a tank housed under a horticultural polythene tunnel. It is suggested that the species may be of interest for cultivation and might also be useful in removing nutrients from eutrophic waters in the United Kingdom.

Svirezhev, Y.M.; Krysanova, V.P.; Voinov, A.A. 1984. Mathematical modeling of a fish pond ecosystem. Ecol. Model 21(4):315-338.

ABSTRACT: A mathematical model is constructed for a fish breeding pond for carp, silver carp and bighead. The model is a system of ordinary differential equations describing the material transformations in the ecosystem. It allows a choice of optimal regimes of the aeration, feeding and fertilization of a pond for different climatic conditions to maximize the yield.

Tal, S.; Ziv, I. 1978. Culture of exotic species in Israel. Bamidgeh 30(1):3-11.

ABSTRACT: Fish culture in Israel was started in 1939. Currently there are 4000 ha of ponds on 80 farms, 98% of which are in the kibbutzim. The total production for 1976 was 14,000 tonnes. At the beginning of the fish culture industry in Israel, the common carp [Cyprinus carpio] was the only fish raised. Other species were introduced, and today Israeli fish culture is mainly a polyculture system, 6 spp. so far being cultured: common carp; ; silver carp, plus 2 other Chinese carps; and Mugilidae. Exotic species included in the system are aurea, Hypophthalmichthys molitrix, Ctenopharyngodon idella and Aristichthys nobilis. After many years of management of the industry along the conventional lines based on a 3000 kg yield/ha, an intensive or semi-intensive system was initiated based on the following principles: aeration of the pond by various artificial methods as an alternative to water circulation; higher stocking density of the various species; and feeding through controlled automatic feeders. The yields by this system are 8000-10,000 kg/ha. There are some ponds that yield 20,000-25,000 kg/ha. The most recent trend is to integrade this system into the overall irrigation system of the farm and to use the ponds as an empounder of the winter water, usingi it in the summer period for irrigation, especially of cotton. This requires deep reservoirs, which are built on the existing ponds, and adaptation of the stocking rates and management methods to the new situation.

Timms, R.M.; Moss, B. 1984. Prevention of growth of potentially dense phytoplankton populations by zooplankton grazing, in the presence of zooplanktivorous fish, in a shallow wetland ecosystem. Limnol. Oceanogr. 29(3):472-486.

ABSTRACT: In two linked, shallow, freshwater basins, phytoplankton densities in summer were very different. Hudsons Bay supported a large stand of water lilies, and the adjacent open water was clear with chlorophyll a concentrations generally <10 $\mu g \cdot liter^{-1}$. In contrast, Hoveton Great Broad, which received inflow water from the same very fertile source, the River Bure, had chlorophyll a concentrations >10 $\mu g \cdot liter^{-1}$. Hudsons Bay water, in bioassays, could support great phytoplankton growth in summer and did so in spring and fall. The period of clear water coincided with the presence of the lily stand. Zooplankton populations were of rotifers and small-bodied Cladocera in Hoveton Great Broad, but mostly of Cladocera, including large-bodied individuals of plant-associated species, in Hudsons Bay. Zooplanktivorous fish were present and there was evidence of feeding by them in both basins. Coexistence with fish of the large, apparently efficiently grazing Cladocera in Hudsons Bay depended on provision of daytime refuges for the Cladocera among the lilies, and grazing was greatest in the adjacent open water at night. Grazing control was helped by a hydrological regime which favored small and rapidly growing phytoplankters, rather than inedible colonial forms with slow growth. Weed-associated grazers may be important in maintaining the dominance of aquatic plants in shallow lakes which would otherwise more rapidly become dominated by phytoplankton as nutrient loading increased.

Vanni, M.J. 1987. Effects of nutrients and zooplankton size on the structure of a phytoplankton community. Ecology, 68(3), 624-635.

ABSTRACT: In situ enclosure experiments were conducted over two summers (1980-1981) to assess the effects of nutrient (N and P) enrichment and zooplankton size structure on the phytoplankton community of an oligo-mesotrophic lake containing planktivorous fish and small zooplankton species. Exclusion of fish from the community resulted in an increase in mean individual zooplankton size, primarily because the cladocerans Ceriodaphnia and Diaphanosoma attained larger sizes. In 1980, total cladoceran biomass was also greater in the absence of fish. In 1980, total phytoplankton density was significantly lower in the fishless enclosures (where zooplankton were larger and grazing rates presumably higher), at a given nutrient level. The proportion of phytoplankton density comprising species with gelatinous sheaths or other protective coverings was greater in the fishless enclosures, under both enriched and unenriched conditions, presumably because these species are relatively resistant to zooplankton grazing. In 1981, when lower fish densities were used (than in 1980), total phytoplankton density was lower in the fishless enclosures only toward the end of the experimental and only in unenriched enclosures. In enriched enclosures the presence of fish had no effect on total phytoplankton density. However, the proportion of phytoplankton density made up of small, edible (to zooplankton) phytoplankton species was lower in the absence of fish throughout the experiment in both unenriched and enriched treatments. In both years, nutrient enrichment caused phytoplankton density to increase greatly, in the presence and absence of fish. Nutrient enrichment increased phytoplankton density a much greater amount than did reduction in zooplankton size.
The results of these experiments demonstrate that even relatively small changes in zooplankton size (i.e., shift in size within only small species) can result in significant alterations of the phytoplankton community. However, the increase in zooplankton body size resulting from fish exclusion could not buffer all effects of nutrient enrichment on total phytoplankton density.

Varghese, T.J.; Singit, G.S.; Keshavanath, P.; Konda reddy, P.; Vasudevappa, C. 1980. Composite fish culture a case study. Mysore. J. Agric. Sci. 14(2):232-236.

ABSTRACT: Results of composite fish culture using rohu, mrigal, silver carp, grass carp and common carp, conducted at Bhadra Fish Farm [India], B.R. Project are presented. The fish fingerlings were stocked at a density of 5800/ha in a 0.12 ha pond having an average water depth of 1.0 m, on Dec. 5, 1978 and harvested on June 6, 1979, thus allowing a period of 6 mo for the fish to grow. Grass carp registered the best growth among the species stocked. The total production was 6267.5 kg/ha per yr. This production would be higher if catla were also used and the stocking percentage of silver carp were reduced.

Vovk, P.S. 1974. The possibility of using the bighead carp (Hypophthalmichthys molitrix) to increase the fish production of the Dnieper Reservoir and to decrease eutrophication. J. Ichthyol. 14(3):351-358.

ABSTRACT: An account is given on the part played by blue-green algae in the feeding of the bighead carp and their importance in the nutrition of other species of fishes. Consideration is given to the possible effect on the bighead carp of toxic substances given off by blue-green algae. It is concluded that it is desirable to stock the Dnieper reservoirs with bighead carp for fattening with the object of increasing fish output and decreasing the level of eutrophication of these reservoirs by the use of a considerable part of the seston.

Vovk, P.S.; Stetsenko, L.I. 1985. Herbivorous fishes in the water body ecosystem. Naukova Dumka, Kiev (USSR). 135 pp.

ABSTRACT: Based on the results of long-term original studies and on literature material the role of the Far Eastern phytophagans in raising fish productivity and reducing eutrophication of water storage reservoirs is discussed. Consideration is given to feeding and growth of silver carp (Hypophthalmichthys molitrix) and bighead (Aristichthys nobilis), which were introduced into the reservoirs associated with the Dnieper and other southern USSR lowland rivers. Physiologo-biochemical and toxicological characteristics of the species are considered as related to long-term feeding on blue-green algae.

Wasilewska, B.E. 1978. The influence of the silver carp Hypophthalmichthys molitrix on eutrophication of the environment of carp ponds 5. Bottom fauna. Rocz Nauk Roln Ser H Rybactwo 99(2):93-108.

ABSTRACT: Studies were conducted on the influence of increasing densities of the silver camp on bottom fauna of carp yearling ponds. The silver carp exerts a favorable influence on natural feeding conditions of carp. Biomass of the total complex of bottom fauna increased in the presence of silver carp, mainly due to the growth in the proportion of large Chironomidae larvae, and of a drop in the proportion of predacious larvae, potential competitors of the carp for feed. Average weight per predator declined. The higher biomass of bottom fauna remained at this level for a month longer than in ponds stocked with carp only. Development of bottom fauna was more abundant in ponds stocked with 4000 silver carp/ha than in water bodies with an addition of 12,000 silver carp/ha.

Wasilewska, B.E. 1978. Bottom fauna in ponds with intense fish rearing. Ekol Pol 26(4):513-536.

ABSTRACT: The intensive fish rearing practices studied (mineral fertilization, feeding of carps with fodder and polyculture of carp with phytophagous fish; grass carp, silver carp and bighead carp) has a positive effect on the food conditions of the carp. The fish pressure (despite an increase in fish production) on the bottom fauna in these ponds was relatively lower than the ability of this fauna to produce large numbers of larvae. In intensive fish rearing ponds, the time of biomass turnover was generally shorter than in the controls, i.e., the compensation for the benthos eliminated was faster than in the control ponds. The changes in the bottom fauna were accompanied by improved food conditions for the larvae of Chironomidae, representing about 90% of the benthic biomass in the fish ponds under study.

Wasilewska, B.E. 1978. The influence of mineral fertilization feeding of carp and 3 species of herbivorous fish on bottom fauna. Rocz Nauk Roln Ser H Rybactwo 99(2):197-212.

ABSTRACT: Mineral fertilization, nourishment and the presence of 3 spp. of herbivorous fish [the grass carp (Ctenopharyngodon idella Val.), silver carp (Hypophthalmichthys molitrix Val.) and the bighead carp (Aristichthys nobilis Val.)] exerted a favorable influence on the feeding conditions of carp. Despite higher production of fish, bottom fauna biomass increased, and the percental share of predaceous Chironomidae larvae declined. The shorter time period of biomass exchange allowed for a more rapid compensation of the consumed part of the bottom fauna. Changes in the ecosystem of the ponds under discussion indicated possibilities for improving feed conditions for Chironomidae larvae, which might have been the cause of favorable changes in the bottom fauna.

Wells, L. 1970. Effects of alewife predation on zooplankton populations in Lake Michigan. Limnol. Oceanogr. 15:556-565.

ABSTRACT: The zooplankton populations in southeastern Lake Michigan underwent striking, size-related changes between 1954 and 1966. Forms that declined sharply were the largest cladocerans (Leptodora kindtii, Daphnia galeata, and D. retrocurva), the largest calanoid copepods (Limnocalanus macrurus, Epischura lacustris, and Diaptomus sicilis), and the largest cyclopoid copepod (Mesocyclops edax). Two of these, D. galeata and M. edax (both abundant in 1954), became extremely rare. Certain medium-sized or small species increased in numbers: Daphnia longiremis, Holopedium gibberum, Polyphemus pediculus, Bosmina longirostris, Bosmina coregoni, Ceriodaphnia sp., Cyclops bicuspidatus, Cyclops vernalis, and Diaptomus ashlandi.

Evidence is strong that the changes were due to selective predation by alewives. The alewife was uncommon in southeastern Lake Michigan in 1954 but had increased to enormous proportions by 1966; there was a massive dieoff in spring 1967, and abundance remained relatively low in 1968. The composition of zooplankton populations in 1968 generally had shifted back toward that of 1954, although D. galeata and M. edax remained rare.

The average size, and size at onset of maturity, of D. retrocurva decreased noticeably between 1954 and 1966 but increased between 1966 and 1968.

Wiley, M.J.; Wike, L.D. 1986. Energy balances of diploid triploid and hybrid grass carp. Trans. Am. Fish Soc. 115(6):853-863.

ABSTRACT: Grass carp Ctenopharyngodon idella and genetic derivatives are widely used as biological control agents for aquatic macrophytes. The results of bioenergetic comparisons of three types of commercially available grass carp are reported. Empirical relationships were developed for consumption rate, metabolic rate, and assimilation efficiency as functions of temperature and size. Summary energy balances are presented for each type of fish. Diploid and triploid grass carp had similar standardized energy balances: 12-13% of the energy ingested was used in metabolism, 74% was egested, and 13-14% went into growth. Hybrid grass carp (female grass carp.times. male bighead carp Hypophthalmichthys nobilis) metabolized a greater proportion of the energy intake (16%) and egested 81%, leaving only 3% available for growth; they also ingeted food at a significantly lower rate. Thus, intergeneric triploid hybrids appear to be energetically handicapped. Their low consumption rate and reduced assimilation efficiency, coupled with elevated metabolic costs, leaves little energy available for somatic growth. High rates of growth of diploid and triploid grass carp are attributed to their "low efficiency-high volume" energetic strategy, which is quite successful as long as food supplies allow them to feed ad libitum.

Woynarovich, A. 1968. New systems and new fishes for culture in Europe Ctenopharyngodon idella Hypophthalmichthys molitrix Aristichthys nobilis carp. Food Agr Organ UN Fish Rep 44(5):162-181.

ABSTRACT: None.

Yaroshenko, M.F.; Danchenko, E.V. 1973. Feeding of the speckled carp Aristichthys nobilis in a poly culture with the carp. Izv Akad Nauk Mold Ssr Ser Biol Khim Nauk (5):72-77.

ABSTRACT: None.

Yashouv, A. 1969. Mixed fish culture in ponds and the role of in it. Bamidgeh 21(3):75-92.

ABSTRACT: None.

Yashouv, A. 1971. Interaction between the common carp Cyprinus carpio and the silver carp Hypophthalmichthys molitrix in fish ponds. Bamidgeh 23(3):85-92.

ABSTRACT: None.

Yashouv, A.K.; Kajak, Z.; Hillbricht-ilkowska, A. (ed.). 1972. The carrying capacity and ecological niche as management concepts of fish production in ponds productivity problems of freshwaters. Proceedings of the International Biological Programme-unesco Symposium Kazimierz Dolny, Poland, May 6-12, 1970. 918 p. Illus. Maps. Polish Scientific Publishers: Warsaw, Poland. pp. 573-578

ABSTRACT: None.

Zhang, F.L.; Zhu, Y.; Zhou, X.Y. 1987. Studies on the ecological effects of varying the size of fish ponds loaded with manures and feeds. Aquaculture 60(2):107-116.

ABSTRACT: The major species of Chinese carp: grass carp (Ctenopharyngodon idella), bighead carp (Aristichthys nobilis), silver carp (Hypophthalmichthys molitrix), common carp (Cyprinus carpio), crucian carp (Carassius auratus), and Wuchang fish (Megalobrama terminalis) were cultured using the traditional Chinese polyculture system in different-sized ponds loaded with pig manures. The grass carp were given aquatic grass as supplementary feeds. Two experiments were conducted in 1982 and 1983 using nine fish ponds of sizes varying from 1 mu (667 m2) to 11 mu (7333 m2), each for a culture period of 200 days. The average yield attained 6090 kg/ha. The conversion rate of pig manure and aquatic grass to fish biomass was found to average 17:1 and 85:1, respectively. Results indicated higher yield obtained in pond sizes between 3 and 5.7 mu (1999 and 3800 m2) using standard pond management. Bigger ponds with greater surface area were more difficult to manage and often resulted in lower fish yields. The study also indicated that the fish yield in various experimental ponds was affected by the growth and survival rate of the grass carp, the main species cultured. Dissolved oxygen was found to be lower in smaller ponds and increasing frequency of 'fish surfacing' was noted, while other nutrient levels such as that of total nitrogen, ammonia, nitrite, and phosphate did not appear to have a direct effect on the fish yield. There was no direct relationship between primary productivity, organic detritus, and fish yield in different-sized ponds. However, production of filter feeders (silver and bighead carp) was higher than previously recorded indicating the optimal stocking rate in the polyculture system had been adopted.

Zhu, H.; Deng, W.J. 1983. Studies on the digestion of algae by fish. 2. Microcystis aeruginosa and Euglena sp. digested and absorbed by silver carp and bighead. Trans. Chin. Ichthyol. Soc. 3:77-92.

ABSTRACT: Silver carp (Hypophthalmichthys molitrix) and bighead (Aristichthys nobilis) were examined with the tracer-method of super(32)P to confirm whether these species can utilize euglenoid algae as food. Microcystis aeruginosa and Euglena sp. were cultivated in HB No 4 medium containing super(32)P instead of super(31)P. After being cultivated for 3, 6, 12, 24, 48 and 72 hours, the samples were examined. M. aeruginosa and Euglena sp. absorbed large amounts of super(32)P, 99% and 87%, respectively. A series of tracer experiments were conducted and the results showed that M. aeruginosa and Euglena sp. can be ingested, digested and absorbed by both silver carp and bighead. Average absorbency rate was 35-48% in silver carp, 23-38% in bighead for Microcystis aeruginosa, and 17-36% in silver carp, 25-53% in bighead for Euglena sp. Different parts of the fish absorbed different amounts of super(32)P.

Zubareva, E.L.; Vasil'chikova, A.P. 1971. Preliminary results of observations of feeding and growth in silver carp juveniles in warm bodies of water in the Urals. Tr Ural Otd Gos Nauchno-issled Inst Ozern Rechn Rybn Khoz 8:223-229.

ABSTRACT: None.

APPENDIX B

CONSTRUCTION OF LITTORAL ENCLOSURES
(SOURCE: BRAZNER ET AL., 1987)

Construction of Littoral Enclosures

The littoral enclosures are rectangular (5m x 10m), bordered with plastic walls on three sides and a 5 m natural shoreline on the fourth side. They are constructed in three steps. First, untreated wooden walkways are built around the perimeter of the areas to be enclosed in the study pond. Next, walls of plastic and untreated wooden snowfence are assembled at the laboratory, rolled up and transported to the field site. Finally, the walls are unrolled on the walkways surrounding the area to be enclosed, pushed into the sediment at the base of the walkways and stapled to the walkway supports above and below the waterline to complete the enclosure.

Walkway Construction

The first step in walkway construction involves placing a series of supports for the walkway planking along the outer edge of the area where the enclosures will be located. The walkway supports are constructed with pairs of approximately 2.5 m (8 feet) long, 7.5-10 cm diameter (small end) cedar posts driven in the sediment and attached to each other with 1 m long 2" x 4" (5 cm x 10 cm) crosspieces which are nailed to the posts. These supports should be spaced at 2.5 m intervals and be driven into position from a boat or floating platform to minimize sediment disturbance. A flat-bottomed john boat works well for this purpose.

To line up the outer walkway supports properly, drive in a corner post 10 m from shore on one end of the length of shoreline where the enclosures will be located. A distance equal to 6 m multiplied by the number of enclosures to be built should then be measured from this corner post to a point 10 m from shore on the opposite end of the area where the enclosures will be located. A second post can then be driven in and a rope line can be fastened between these two corner posts to help position the outer walkway

in relation to the shoreline. A cloth measuring tape should also be strung between the two corner posts so that the walkway supports can be spaced properly.

Once the orientation line and the measuring tape are in place, the outer walkway supports can be driven into position. Working from one corner post to the other along the orientation line, the cedar posts should be driven solidly into the sediment every 2.5 m along the measuring tape.

Care should be taken to assure that the posts go in as close to vertical as possible, are maintained in a straight line with the other posts already in place along the orientation line and are spaced exactly 2.5 m apart.

Once the inshore posts are positioned properly, they can be paired up with a second post, 1 m further away from shore and on a line perpendicular to the orientation line. The crosspieces which attach these pairs of posts should be nailed high enough above the waterline to allow for fluctuating water levels. For the ERL-D walkways, the crosspieces were nailed approximately 0.30 m above the waterline.

Next, a 5 m x 10 m wooden frame template was constructed from 2" x 4" lumber for spacing the walkway supports that extend from shore out to the outer walkway supports. This frame can be floated over to the inside of the first three walkway supports on one end of the outer line of supports and secured to the inshore post of each of these supports. Marks should be scribed on the frame at 2.5 m intervals from the outer walkway supports towards shore to denote where the inshore to outshore walkway supports should be located. Posts are driven in adjacent to these marks on both sides of the frame and second posts and crosspieces added in the same manner as described for the outer walkway supports. Supports can be put in either by workers wearing chest waders or from a boat. If waders are used, care must be taken to avoid walking in or disturbing the bottom within the area to be enclosed.

After the first set of inshore to outshore walkway supports is completed, planking for the outer walkway can be laid down and nailed into place. Ten meter lengths of 2" x 10" or 2" x 12" rough cut lumber make exellent planking for the walkways. Rough cut lumber milled to 2" x 12" dimensions is better than planed lumber because it provides better footing under wet conditions, has superior strength and is more economical. Two 12" wide planks laid down side by side with a small gap between them make a suitable walkway. Staggering the parallel planks by one set of support posts will improve the sturdiness of the walkway. After the planking for the outer walkway is in place, the planking for the inshore to outshore walkways can be cut to fit and nailed into position.

For 12 enclosures, complete walkway installation, including all necessary finishing work should take about 40 hours with a 5 person crew. Once walkway installation is completed, the walls of the enclosures must be constructed and installed.

Before wall construction can begin, a depth profile and perimeter measurement of each enclosure must be made. The walls for each enclosure should be similar in length, height and width. However, due to irregularities in the uniformity of the shoreline and bottom slope, there will be differences between enclosures. Therefore, water depth on the inside of each walkway support in all the areas to be enclosed and the distance from shore to shore around the entire perimeter of each enclosure should be recorded. Only then can a custom-fitted wall can be properly constructed.

Wall Construction

The enclosure walls can be constructed in cleared areas on site but experience has shown that the job is easier to do indoors. Ideally, the area where the enclosure walls are constructed should have a 35 m long by 4 m wide, flat surface so that the entire length of wall for one enclosure can be unrolled, pieced together and rerolled with adequate room to work.

The enclosure walls are constructed from an 8 mil, woven filament, polyolefin plastic (#888 H UV Clear Scrimweve^{R}, Sto-Cote Products, Inc., Richmond, Illinois) and untreated wooden snowfence. The plastic can be purchased in 30 m (100 feet) long rolls and is available in a variety of widths. The width of the plastic should be a minimum of 1 m wider than the greatest water depth in each area to be enclosed. The snowfence is available only in 1.22 m (4 feet) wide by 15.24 m (50 feet) long rolls. It should be purchased with 3/8" x 1 1/2" slats spaced 2" apart and tied together with 13 1/2 gauge wire.

The length of the wall for each enclosure should be 2-4 meters longer than its perimeter measurement. This will provide extra length on each end of the wall to compensate for fluctuating water levels affecting the shoreline. To construct an enclosure wall, two rolls of snow fence must be fastened together by removing one slat at the end of each piece, overlapping the openings in the wires where the slats were removed and sliding a slat back in through both sets of wires. It is sometimes easier to overlap the openings in the wires where the slats were removed and wrap the two sets of adjacent wires tightly around one another. However, when using this joining method, the wrapped wires must be trimmed short and wrapped with tape to cover the sharp ends that result.

After the adjoined rolls of fence are trimmed to the proper length, the plastic and snowfence can be fastened together to complete the enclosure wall. Before unrolling the wall plastic, the work area should be covered with a clean drop cloth. The wall plastic can then be unrolled on top of the drop cloth and the fitted length of snowfence unrolled on top of that.

Scrimweve is virtually impossible to tear but it will puncture if enough pressure is applied with a sharp object such as the uncovered end of a piece

of snowfence wire. Therefore, care must be taken to avoid puncturing the plastic.

The snowfence should be positioned about 15 cm from one edge along the entire length of the plastic. The 15 cm of extra plastic should be folded over and stapled with a staple gun onto the snowfence with heavy duty, short arm staples. This bottom edge of the enclosure wall will eventually be sunk into the sediment to seal the enclosure. The loose end of the wall plastic should also be folded over onto the other (top) edge of the snowfence and temporarily clipped in place with binder clips. These clips will be removed before final field installation but will make the wall more manageable. Care should be taken not to roll the wall up too tightly as the metal on the snowfence may under extreme pressure, wear through the plastic. A rigid pole inserted through the center hole of the roll makes handling easier.

The walls can also be constructed by substituting approximately 7.5 m of fence that is 0.61 m high (one 1.22 m roll cut in half) to each end of a 15 m long piece of 1.22 m high fence. This will provide a 1.22 m high section for the part of the wall that will be positioned in the deeper/outer section of the enclosure and a 0.61 m high section for the inshore ends of the enclosure wall which will be set in shallower water and extend up to the shore. This modification of fence height will reduce the weight of each wall and will result in less fence protruding above the walkways after installation. Custom fitting not only simplifies transport and installation but also enhances access to the enclosures for sampling. It will take a 3 person crew approximately 20 hours to construct twelve 30 m long enclosure walls.

Wall Installation

Installation of the enclosure walls at the research site is the most labor intensive part of constructing littoral enclosures. For this study, it

took 18 hours with a 10 person crew to install 12 littoral enclosures in a natural pond. First, all rocks, roots, heavy stemmed vegetation and other debris must be cleared around the perimeter of the enclosure where the wall will be sunk into the sediment. Ice chisels and scrapers, mattocks or other long handled, straight-edged cutting tools work well for this purpose. A shallow trough should also be dug up to the high water mark on the shoreline along the base of the walkways on both sides of the enclosure.

To install the enclosure wall, two people using the rigid pole inserted as a lifting handle must lift the rolled-up enclosure wall while 8 to 10 people unroll and carry the wall around the perimeter of the enclosure on the walkway. Once the wall is completely unrolled and properly lined up on both sides of the walkway the wall can be set into the water inside the walkway perimeter. The side of the wall that is completely faced with plastic should be positioned towards the inside of the enclosure. The bottom of the wall should be carefully pushed into the sediment at the base of the walkway support posts, and all points in between the posts, working from the middle, outermost portion of the enclosure toward shore.

After the wall is pushed firmly into the sediment, the binder clips holding the plastic in place at the top of the snowfence should be removed. After the plastic is pushed out of the way towards the middle of the enclosure, the snowfence should be securely stapled to each of the walkway support posts, both above and below the water line, with fencing staples. This may require hammering the staples in 0.5 m or more under the surface of the water. The staples should be positioned so that they straddle the fencing wire and not the wooden slats.

To assure a firm seal between the walkway support posts, a 2.5 m long piece of 1" x 2" planed lumber can be woven between the wooden slats at the

top of the snowfence. After "weaving", the wall is pushed down firmly towards the bottom while the ends of the 1" x 2" lumber are nailed into the nearest support posts. Because of its flexibility, planed lumber is best for this purpose.

The final installation step involves lifting the loose end of plastic out of the water, pulling it taut in line with the snowfence wall it is connected to, rolling it around a series of 1" x 2" pieces of lumber down to just below walkway level and securing the 1" x 2" lumber to support posts.

With the enclosure wall installation complete, the enclosures are ready to be used. The entire walkway and wall building and installation procedure for 12 littoral enclosures will consume approximately 500 person hours but will depend on the accessibility of the study site and the efficiency of the work crew. A diagram of a walkway with an enclosure wall in place appears in Figure 1.

To protect the enclosures, additional snowfence can be attached around the outer perimeter/open pond edge of the walkways as a wave and floating debris barrier and between the inshore ends of each enclosure as a shoreline barrier to wildlife (i.e., turtles, muskrats, etc.).

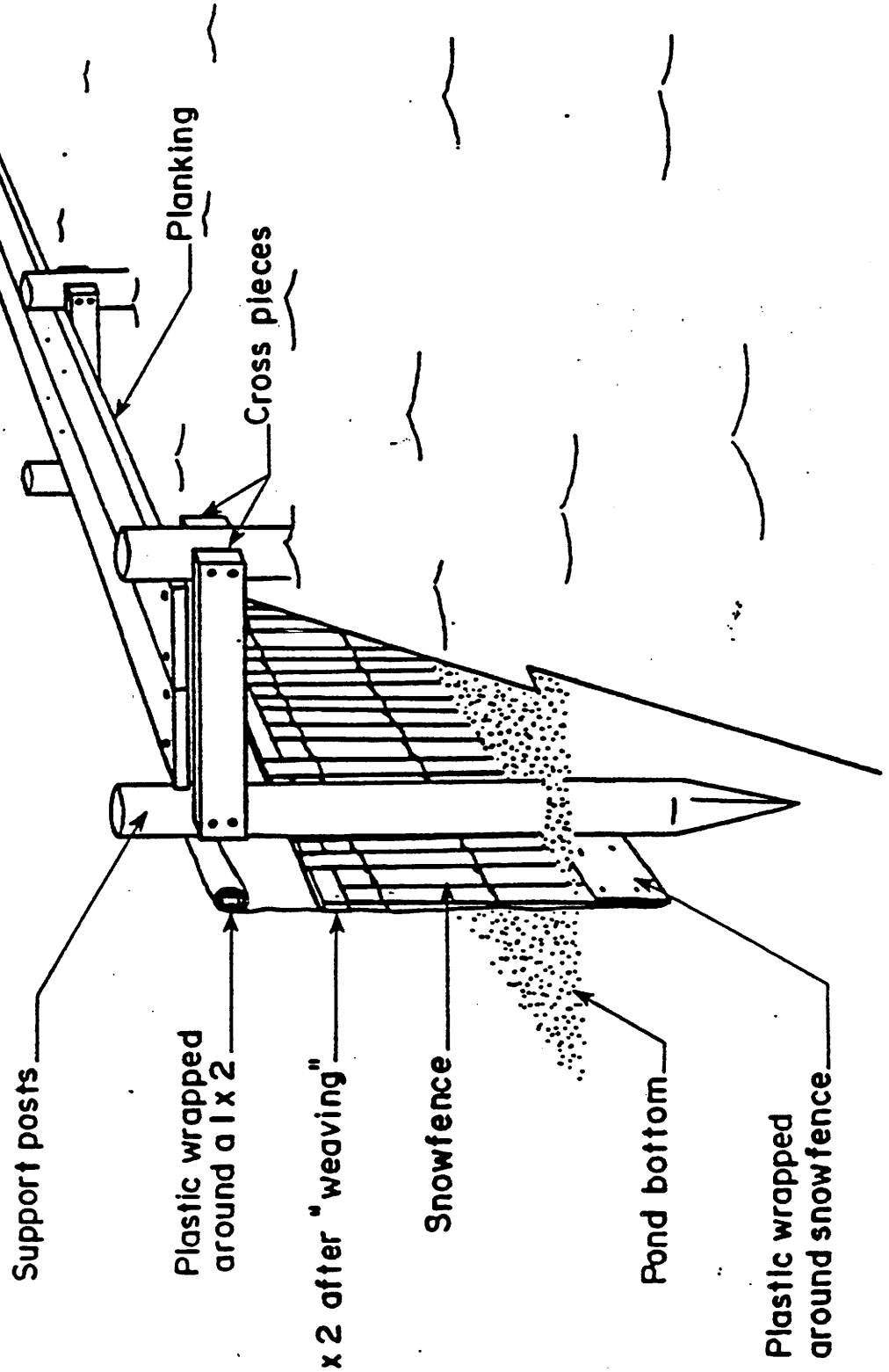

Figure 1. Diagrammatic representation of a littoral enclosure wall and walkway in-situ.