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FISH BIOLOGICAL CONTROL OF THE ISRAELI NATIONAL WATER CARRIER AND DUAL-PURPOSE RESERVOIRS (FISH CULTURE/CROP IRRIGATION): THE ISRAELI CONCEPT

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ABSTRACT. The location of Israel in a semi-arid part of the globe and the seasonal rainfalls that are limited to short periods in wintertime (about 50 days of rain with ~650 mm average precipitation in the north of the country), are the main causes of chronic water shortage and frequent droughts. The Israeli Water Authority planned and constructed the National Water Carrier (NWC) to convey water from the sole Israeli source of fresh water, Lake Kinneret in the north, through the country to the Negev Desert (10 mm average precipitation) in the south. The water is transferred through a system that combines pipes (108 inch diameter), canals, tunnels, and reservoirs. Because the water is intended for human consumption, the reservoirs were stocked with a complex of fish for biological control. To support agricultural irrigation, regional local authorities and private fish farms have also constructed dual-purpose reservoirs in various parts of the country. These reservoirs store water for crop irrigation and also serve for fish culture. Some of them are used solely for irrigation, but in some reservoirs, fish are reared as a by-product. About 250 dual-purpose reservoirs of various capacity and surface areas (10-40 ha) have been constructed in Israel in the last two decades. The first fish species, tilapia, *Oreochromis aureus* (Steindachner), was stocked in reservoirs in the early 1960s, and common carp, *Cyprinus carpio* L., was stocked in reservoirs in the end of 1960s in an attempt to control phyto- and zooplankton. Although the results were positive, it soon became obvious that these species were prolific and had multiplied extensively, which resulted in overcrowded populations of stunted fishes and caused management difficulties. Consequently, a group of Chinese carp was introduced, namely: the phytoplanktophagic silver carp, *Hypophthalmichthys molitrix* (Val.), the macrophytophagic grass carp, *Ctenopharyngodon idella* (Val.), the zooplanktophagic bighead carp, *Aristichthys nobilis* (Richardson), and the malacophagic black carp, *Mylopharyngodon piceus* (Richardson). In addition to these four species, predatory (or “police”) fish have been integrated into the fish complex; these include the marine European seabass, *Dicentrarchus labrax* (L.), or the hybrid striped bass, *Morone saxatilis* (Walbaum) and white bass, *M. chrysops* (Rafinesque), or red drum, *Sciaenops ocellatus* (L.). Red drum is also considered to be a high quality consumer fish. These fish are capable of controlling efficiently the unwanted spawning of carp and tilapia. With these combinations of fishes, various species play specific roles by utilizing specialized feeding niches without competing with other species. Due to the variety of conditions in the reservoirs, the composition of fish species is modified according to individual characteristics of each reservoir (soil, area, depth, source of water, role of the fish, etc.). Adequate stocking of species into reservoirs may positively affect synergism among fish and may have a positive impact on fish growth. Stocking water reservoirs with fish species that cannot reproduce naturally in the water system is advantageous. However, in such cases, the entire process of reproduction, including the incubation of eggs, must be accomplished artificially indoors. Each species is induced to spawn

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with hormones, namely calibrated (carp) pituitary extract (cCPE) or a synthetic substitute of GnRH, s-GnRHa. Both products were developed in Israel and are presently distributed and available worldwide. The fertilized eggs are incubated to hatching and the young are nursed until they are stocked into the various reservoirs. Many countries prohibit the introduction of exotic fishes so as to protect local fish species from competition. An extensive study of chromosome-set manipulation has been carried out in order to develop techniques to produce sterile triploid grass and black carp. Female triploids are preferred because they have amorphous gonads. Such non-reproducing fishes have export potential for biological control purposes (e.g., black carp to control bilharziasis and grass carp to prevent river blockage by aquatic vegetation), without endangering local fish fauna.

Key words: BIOCONTROL, EXOTIC FISH, DUAL-PURPOSE RESERVOIRS, “POLICE” FISH, ISRAELI NATIONAL WATER CARRIER

INTRODUCTION

Israel is located in a semi-arid region, at the meeting point of continental blocks of vast deserts (the Arabian, Syrian, and Sinai deserts) and the eastern part of the Mediterranean Sea. The annual average precipitation in northern Israel is about 650 mm. There is only one natural freshwater lake in the north of the country, Lake Kinneret (also known as the Lake of Galilaea), with a surface area of 165 km^2, a maximal depth of 46 m, and situated at an altitude of -212 m. Lake Kinneret is supplied mainly with waters from the Jordan River and from snows melting on Mount Hermon (Golan Heights). The southern part of Israel, the Negev, although comprising about 50% of the country, is settled only by 10% of its population. Geographically, the Negev is considered as a northern margin of the Sinai Desert and, therefore, its average annual precipitation does not exceed 10 mm.

Due to lack of sufficient rainfall, the rapidly growing population, and small watercourse system, Israel chronically suffers from water shortages and frequent droughts. These led the government, several years after the State of Israel had been established in the 1950s, to nominate a leading water authority, namely the Mekoroth Water Co., to be responsible for planning, constructing, and managing water resources at the national level. The initial plan was to convey water directly from the Jordan River; however, this plan was altered due to political conflict with Syria. The authority generated an alternate and more expensive plan, in which the water is pumped from Lake Kinneret, over distances of hundreds of kilometers, to supply water for the entire Israeli population. Special attention and emphasis was given to ensure delivery of water for the irrigation of the Negev, in order to convert dry desert into settled land. In 1964, the project was realized and named the National Water Carrier (NWC).

The NWC starts directly from Lake Kinneret with a huge pumping station capable of pumping about 450,000,000 m^3 annually. The project meets around 30% of the Israeli demand for fresh water. In order to cross the Ridge of Galilaea Mountains, the water is elevated from an altitude of 210 m below sea level to about 200 m above sea level. The system is comprised of a complex scheme of large-diameter (108 inch) pipelines, syphons, open channels, tunnels, and intermediate reservoirs (Fig. 1). On its route from Lake Kinneret to the Negev, the NWC is also enriched with water from two huge underground aquifers, one located along the Israeli coast and the other on the eastern coastal plain. Both aquifers supply around 700,000,000 m^3 of fresh water for the constantly growing Israeli population. However, in recent years, pumping from the coastal aquifer has been controlled and limited due to the increasing risk of salination caused by the penetration into this aquifer of sea water from the neighboring Mediterranean Sea.

The main reason for the construction of intermediate reservoirs on the NWC course was to regulate and to ensure constant and reliable water-flow through the system.

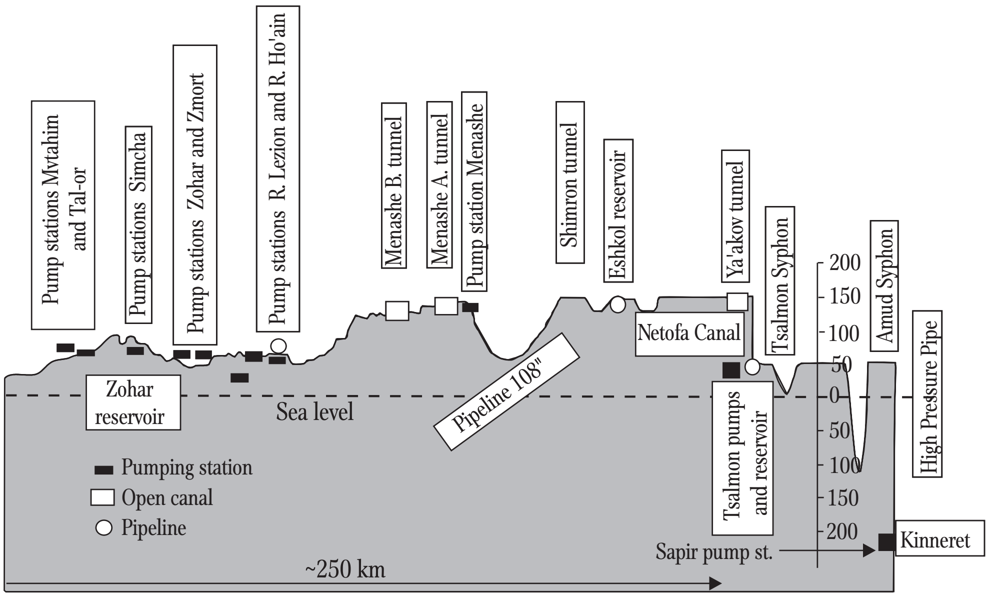

Fig. 1. Side profile of the National Water Carrier (not to scale).

These large water bodies, some of them with a capacity of about 10 million m^3, are exposed to three distinct stages of biological succession: (1) the accumulation of organic sediments on the bottom, (2) the mineralization of the sediments and biological development on the bottom, and (3) the biological succession that accelerates the blooming of phyto- and zooplankton in the entire water column. Since the water of NWC is intended for human consumption, the use of chemicals to control water quality is strictly avoided. This restriction created the necessity of introducing an alternative form of biological control. The biologists at the NWC authority suggested introducing a fish complex comprised of various species, where each fish is able to utilize a different ecological niche (Fig. 2) without interspecific interference (Leventer 1978, 1979, Leventer and Teltsch 1990, Leventer and Gisis 1991).

At the start of the NWC operation (1960s), common carp, *Cyprinus carpio* L., blue tilapia, *Oreochromis aureus* (Steindachner), and gray mullet, *Mugil cephalus* L., were stocked into the reservoirs for the purpose of biological control. About ten years later (1970), four exotic fish, known collectively as the Chinese carp (silver carp, *Hypophthalmichthys molitrix* (Val.), grass carp, *Ctenopharyngodon idella* (Val.), bighead carp, *Aristichthys nobilis* (Richardson) and black carp, *Mylopharyngodon piceus* (Richardson)) were introduced to generate a stable and wider basis for adequate biological control.

Chinese carp require large rivers and specific environmental conditions to reproduce. Without suitable riverine condition, natural reproduction is almost impossible in most riverine ecosystems. Consequently, Chinese carp cannot reproduce naturally in Israel, nor is there any evidence of their natural reproduction on the European continent either. Nevertheless, natural reproduction of Chinese carp has been reported in several locations in North America (Shelton and Rothbard 2006). The ecological impacts of stocking exotic phytophagous Chinese carp into Polish lakes were reviewed extensively and discussed by Opuszyński (1997).

Although the Chinese carp mature in Israel, they cannot reproduce in the wild, which is why they there are propagated artificially in fish hatcheries. Most countries where these fish have been introduced use induced spawning technologies with various types of spawning inducers (CPE, GnRH-a, etc.). While the hatchery operations that include induced ovulation, egg incubation, and larval nursing are not included in this paper, they are reported extensively in the literature (Woynarovich and Horvath 1980, Rothbard 1981, 1982, Jhingran and Pullin 1988).

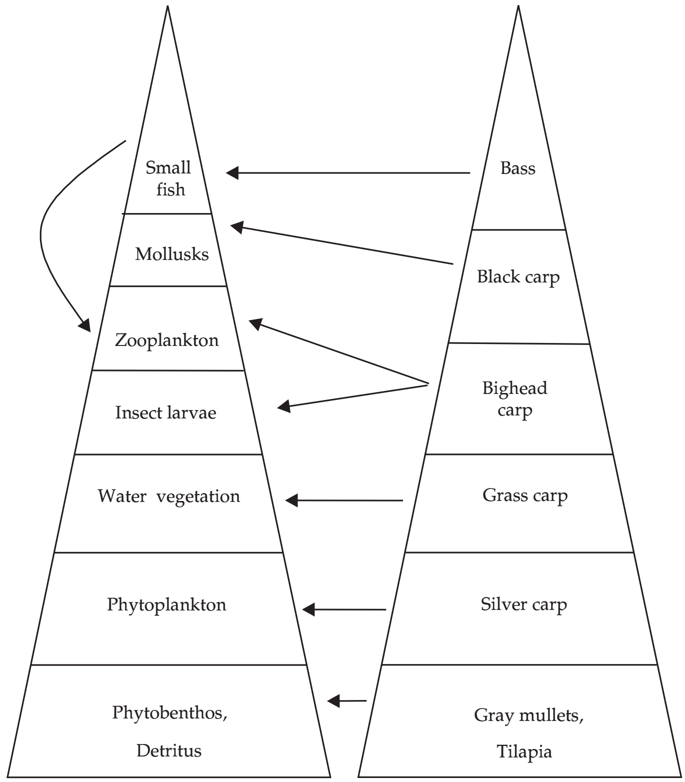

Fig. 2. Inter-relationship between fish-food biota and bio-control fish.

Two North American fish, the hybrid striped bass (Harrell et al. 1990), a cross between striped bass, *Morone saxatilis* (Walbaum), and white bass, *M. chrysops* (Rafinesque), and the diadromous red drum, *Sciaenops ocellatus* L. (Mercer 1984), were introduced as "police" fish, to control the unwanted spawning of common carp and tilapia but also fish penetrating the reservoirs from the wild.

TYPES OF RESERVOIRS

RESERVOIRS OF THE NATIONAL WATER CARRIER AUTHORITY (NWCA)

The major aim in constructing reservoirs as part of the waterway of the NWC was to permit the control and regulation of permanent water flow from the northern to the southern parts of the country. These include a few small-surface area reservoirs (5-22 ha) and four large reservoirs (Table 1), three of them situated in the northern part of Israel, between the Mediterranean Sea and Lake Kinneret (Tsalmon, Sedimentation reservoir and Eshkol) and the largest one (1200 ha) is south of Tel Aviv (Zohar Reservoir).

TABLE 1

The characteristics of four major NWC reservoirs (modified after Leventer, 1974)

The reservoir	Area (ha)	Volume (m^3)	Maximal depth (m)	Construction	
				Bottom	Side walls
Tsalmon	210	600,000	4.5	Quarry debris	Concrete
Sedimentation reservoir	260	1,200,000	5.0	Quarry debris	Concrete
Eshkol	840	4,500,000	7.0	Quarry debris	Concrete
Zohar	1,200	9,000,000	13.0	Soil	Soil and stones

The northern reservoirs receive water from Lake Kinneret and serve as operational reservoirs (sedimentation and purification), while the Zohar Reservoir, together with some smaller reservoirs in south of the country, are fed with water from Kinneret as well as from coastal aquifers, enabling the consistent delivery of water.

DUAL-PURPOSE RESERVOIRS

In the last two decades about 300 reservoirs of various sizes have been constructed all around the country, and some of them serve as dual-purpose reservoirs. The majority of reservoirs are filled with water trapped from winter floods during the very short rainy season. Some of reservoirs were constructed in the vicinities of settlements in order to purify city effluents. Such purified water is used exclusively for irrigation of field crops or orchards and not for direct human consumption.

Dual-purpose reservoirs provide irrigation for crops as well as fish culture. Seasonal fluctuations of water level are significant in all dual-purpose reservoirs. These types of reservoirs have an increasing fish load and corresponding organic input (feeds) during the growing season. Both factors are problematic, because they correspond with the gradual decrease of water volume in the reservoirs due to irrigation (Milstein et al. 1992). Dual-purpose reservoirs attain their maximal water volume after receiving water from winter floods; the water volume is gradually lowered to its minimal level in summer, during the irrigation of fields. Thus, the reservoirs have the maximal fish load when the water volume is lowest. Owners of dual-purpose reservoirs (see below, type b) make efforts to maintain a minimal water level until the fish harvest is completed. Thereafter, the reservoirs can be emptied, dried for several weeks and then refilled with fresh water.

The dual-purpose reservoirs can be divided into two distinct categories, according to their management and function:

(a) these reservoirs serve mainly for irrigation and are stocked with a combination of fishes, according to the stocking policy of private owners, who consider the fish as a by-product. Such reservoirs are usually never dried completely and, therefore, the fish are harvested only by means of various types of gill nets or submerged Chinese nets, similar to those used in Asia. Consequently, only fish that cannot reproduce naturally and can serve as bio-controllers are stocked into such reservoirs. Species that have been selected for this purpose include Chinese carp, gray mullet, and sometimes also a predator to control the accidental and unwanted spawning of common carp and tilapia that are sometimes stocked by fishermen as an oversight or fish that penetrate from the wild.

(b) these reservoirs are constructed mainly for fish culture, and the storage of water for irrigation is a secondary role. These reservoirs are filled with water trapped from winter floods. Usually, such reservoirs have average depths of about 5-6 m. At the end of summer, when irrigation ceases and crops are being harvested, the reservoirs still hold sufficient volumes of water to continue growing fish until their final harvest. Water levels in dual-purpose reservoirs are regulated by means of a drain (monk) similar to fish culture ponds. The drain prevents lowering of the water beyond the level that may put at risk the maintenance of the fish that are still growing. In fall, after the complete harvest of the fish, the reservoirs are drained and refilled after few weeks with fresh water from the winter floods. In such management, which is similar to that carried out in regular fish ponds, the combination of fish that are stocked in each reservoir is planned by the fish farmer. Three types of dual-purpose reservoirs, in relation to their structure, function, and management, are presented in Table 2.

TABLE 2

Three types of dual-purpose reservoirs and the appropriate fish species composition used for their biological control (modified after Leventer, 1979)

Type of reservoir	Reservoir physical characteristics[1]	Bio-control by proposed fish complex
A	Bottom of reservoir covered by excessive amount of organic sediments. Reservoir drained each fall. Extensive development of zoobenthos. Submerged vegetation provides suitable substrate for mollusks	*Cyprinus carpio*[2] *Mylopharyngodon piceus* *Oreochromis aureus* *Mugil cephalus*
B	Fluctuations in water level (due to irrigation). Reservoir drained each fall. Algae and zoobenthos attached to substrate. Submerged vegetation serve as substrate for water gastropods.	*Mugil cephalus* *Hypophthalmichthys molitrix* *Ctenopharyngodon idella* *Mylopharyngodon piceus* *Cyprinus carpio*[2]
C	Water detained for long periods; reservoir not drained each year. Reservoir serves mainly for irrigation; fish are only a by-product. Extensive blooms of phyto- and zooplankton. Accumulation of detritus.	*Sarotherodon galilaeus* (not obligatory) *Hypophthalmichthys molitrix* *Aristichthys nobilis* *Ctenopharyngodon idella* *Cyprinus carpio*[2] (limited number) *Mugil cephalus* (dense stocking)

[1] *Limited numbers of "police" fish (sea-bass, striped bass, red drum) to control unwanted spawning of carp and tilapia are also stocked in all reservoirs*
[2]*Common carp males (male monosex)*

FISH AS BIO-CONTROL OF RESERVOIRS

The only purpose of stocking fish in NWC reservoirs is to improve the aquatic environment and ecology, while in dual-purpose reservoirs, which also serve for fish culture, the proportion of each species and the number of fish to be stocked depends on the polyculture management policy of each individual fish farmer. According to some preliminary observations, there is evidence that fish stocked in reservoirs as biological controls improve water quality; they also have synergistic effects which may beneficially affect the growth of other species present in the same reservoir (Milstein 1992, Milstein and Hepher 1988).

NUISANCE ORGANISMS THAT REQUIRE BIOLOGICAL CONTROL

Since the reservoirs have been operated, either under Israeli NWC authority or under private sector management, as dual-purpose reservoirs, the major problem facing the authority has been to form an appropriate fish stocking combination that will improve the quality of water intended for human consumption and effectively control the nuisances listed below.

1. Taste and odor, predominantly caused by the aggregation and decomposition of unicellular algae, particularly the *Peridinium* and *Oscillatoria*. *Peridinium* blooms in summer in Lake Kinneret are conveyed by water to NWC reservoirs where the alga settles on the bottom, decomposes, and produces a repellent odor in the water. The other alga, *Oscillatoria chalybea*, develops during the hot summer (June-August), on the bottoms of reservoirs enriched with organic sediments and containing hydrogen sulfide. In summer, low levels of oxygen prevail in these reservoirs.
2. Planktonic organisms invade NWC reservoirs with water conveyed from Lake Kinneret. In Israel, natural biological succession is intensified due to optimal temperatures and strong sun illumination, thus enhancing the development of phyto- and zooplankton populations.
3. Emergent aquatic vegetation and several species of submerged plants develop in water reservoirs due to the suitable conditions that exist specifically in shallow waters along dikes. Some of the plants (e.g. *Phragmites australis* (Cav.) Trin. ex Steud. and *Typha* sp.) may reach heights of 1.5-2.5 meters.
4. In some reservoirs, suitable conditions on the bottom may offer the optimal environment for the massive development of insect larvae (e.g. larvae of *Chironomus* sp.).
5. About six species of Mollusks (*Bullinus* sp., *Lymnea* sp., *Corbicula* sp., *Melania* sp. and two species of *Melanopsis* sp.) are present in reservoirs where they colonize submerged vegetation and pipes. Sometimes snails may reach such tremendous densities that they plug and block pipes and pumping systems.
6. The over-abundance of small-sized fish in tremendous numbers can result in masses of stunted fish. Carp and tilapia as bio-controls were stocked into NWC reservoirs at the beginning of their operation. These fish proliferated in reservoirs in enormous numbers. Other fish species that can reproduce naturally (*Clarias gariepinus* (Burchell), *Acanthobrama terraesanctae* Steinitz, *Tilapia zillii* (Gervais), and *Barbus* sp.), penetrate the system with water from Lake Kinneret and cause serious problems, particularly in reservoirs that are not routinely drained.

THE BIOLOGICAL FISH COMPLEX

Common carp, blue tilapia, and gray mullet were stocked into NWC reservoirs for biological control at the beginning of the operation. The purpose of stocking the two detritophagic fish species, the mouth-breeding blue tilapia and the gray mullets, was to eliminate the bad taste and odor of the water. The role of the common carp stocked in reservoirs was to eliminate insect larvae. Tilapia and common carp are very prolific fish that can easily reproduce in ponds and reservoirs. In order to avoid the unwanted reproduction of carp, an attempt was made to stock the reservoirs with only males. However, the presence of even a few female carp among the males can result in tremendous recruitment. A similar phenomenon can be caused by tilapia that spawn in Israel during the summer in several breeding cycles.

Although these fish controlled insects successfully and efficiently reduced the foul taste and odor of the water, they also clogged the basins with wild spawning. In contrast, the detritophagic gray mullet, a marine species that was acclimatized to fresh water prior to stocking for the same purpose as tilapia, does not reproduce naturally in reservoirs. Moreover, since the mullets are valued as high quality table fish by the Israeli consumers, they are also an important and acceptable component in polyculture ponds.

In addition to these three species, a group of four exotic fish, known collectively as the Chinese carp, was introduced by the NWCA in order to improve the water quality of the reservoirs by providing a stable, wider basis for more efficient biological control: silver carp – an exclusive feeder of unicellular algae; grass carp – a species utilized world-wide to control aquatic vegetation in its sterile triploid form (Rothbard et al. 2000); bighead carp – a zooplankton feeder; black carp – a malacophagic fish and efficient predator of water gastropods (Shelton et al. 1995, Rothbard et al. 1996, Rothbard and Rubinshtein 1999, Ben-Ami and Heller 2001).

In general, each fish species used for bio-control is capable of functioning in different ecological niches because it feeds on different part of the food chain (Fig. 2). Silver carp is located on the base of food chain because it feeds only on unicellular algae. Black carp is a carnivorous fish, armed with special set of teeth that enable it to crush the shells of snails and mussels, and to feed on their meat. The effect of stocking NWC reservoirs with black carp was remarkably efficient; the fish eliminated snails in few years, and there was no need to re-stock this species (Leventer 1979). Silver carp is a fast-growing fish and in Israel it can attain 2-3 kg in one year. This species is recognized as a high-jumping fish, which can endanger fishers when fishing. Therefore, they preferred to stock ponds and reservoirs with the silver carp/bighead hybrid, which is calm and jumps less and intermediate feeding habits characteristic of both parents.

To resolve the problem of the unwanted reproduction of carp, tilapia, and fish penetrating from the wild, predatory fish species were introduced into reservoirs. Three predatory fishes, the marine sea bass, *Dicentrarchus labrax* (L.), the hybrid striped bass and recently, the red drum, have been stocked on various occasions. The last two fish have replaced the stocking of sea bass since it is highly sensitive and it is difficult to purchase fry. Striped bass and red drum are exotic fish that were introduced from the USA and at present are reproduced artificially in specialized Israeli hatcheries. The presence of 'police fish' in the reservoirs has been efficient and has drastically reduced populations of unwanted small-sized fish. Table 3 shows the cumulative, positive effects of stocking NWC reservoirs for two consecutive decades (1964-1985) with a complex of fish to perform biological control.

SUMMARY AND CONCLUSIONS

The major aim of biological control is to reduce the rate and the level of eutrophication in an aquatic ecosystem that delivers water for human consumption. In fact, biological control affects the proportion between various aquatic organisms, reducing organisms that prosper in water bodies, and contributes to increase levels of nutrients in water and the fertility of bottom sediments. This activity was also termed by Opuszynski (1997) as "biomanipulation".

There is no problem with stocking prolific carp and tilapia into double-purpose reservoirs since unwanted reproduction is avoided when this type of reservoir is drained and refilled with fresh water at the end of each year and then restocked with new fish. The species composition and fish proportion at stocking is variable, because it depends on the considerations and decisions made by the owners of fish farms.

The composition of the fish species stocked into the NWC reservoirs was significant. Plankton feeding species, silver carp and bighead, have successfully reduced the density of planktonic organism (Table 3). Tilapia and gray mullet were stocked into the NWC system in the eerly of the 1960s, when the NWC was put into operation, while common carp was stocked at the end of the 1960s. The stocking of the latter species had a double effect on the water quality in the reservoirs; bottom grazing by the carp caused increased turbidity throughout the water column, thus interrupting the succession of unicellular algae. On the other hand, carp efficiently control larvae of water insects. Gray mullet and the tilapia improve the quality of water by preventing the succession and decomposition of algae, the main cause of bad taste and odor in water. At present, these two disrupting factors are totally absent from the NWC.

The most significant effect on the ecosystem of reservoirs was achieved by introduction of grass carp and black carp. Grass carp drastically reduced water vegetation that served as a substrate for water snails, while black carp eliminated the snail populations. At present, snails appear in small numbers only in canals and pipes that connect the NWC reservoirs.

Integration of diadromous predator species, the sea bass, the striped bass hybrid, and the red drum was indispensable in the reduction of the number of stunted fishes that resulted from the uncontrolled reproduction of tilapia and common carp, and the penetration of wild fish from the wild. Sea bass was the first species to be introduced as a ‘police’ fish. However, sea bass is a sensitive fish and its reproduction in captivity is difficult; thus, it was soon replaced by a striped bass hybrid and later by red drum. At present, the latter two species are routinely spawned in fish hatcheries and also grown in regular fishponds as table fish.

Since the water from NWC reservoirs serves as drinking water, an intriguing question was raised by the stocking of the reservoirs with fish as aquatic bio-controls: Would coliform bacteria be introduced by the fish into the water?

Fish intestines contain coliforms that are excreted with the feces into the water and accumulate on the bottom. The examination of fish and bottom sediment coliforms were detected, but their concentration in water column did not exceed the acceptable level (Leventer 1979). Moreover, at present, the water pumped and carried via pipes for direct human consumption is routinely chlorinated and filtered, to eliminate the presence of coliforms. Such drinking water is completely clean and safe for human consumption. Just recently, the NWC authority announced to the public that drinking water delivered to consumers is of the same quality as spring water.

Biological control by fish is a long-term process. The positive effects of bio-control can be detected only after a period of months, and sometimes not until after several

TABLE 3

Accumulated effects of biological control of nuisance organisms in NWC reservoirs by fish (1965-1985). Categories indicated by italics express nuisance organisms, which are followed by name of fishes (normal letters) that were stocked in the reservoirs to control the pest (modified after Leventer, 1987)

	Years																					
Pest and Control	1964	1965	1966	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1984	1985
Water snails	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				
Black carp																		V	V	V	V	V
Water vegetation		+	+	+	+	+	+	+	+	+			+				+					
Grass carp									V	V	V		V	V	V		V	V	V	V	V	V
Peridinium and	+	+	+	+	+	+	+	+														
Oscillatoria;																						
Water insect																						
Gray mullet							V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Common carp*																	V	V	V	V	V	V
Blue tilapia							V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
(*O. aureus*)																						
Plankton	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
(Phyto+Zoo)																						
Silver carp																V	V	V	V	V	V	V
Bighead																V	V	V	V	V	V	V
Small wild fish										+	+				+	+				+	+	+
Bass or Red drum															V	V				V		
(police fish)																						

**Common carp males (male monosex); but some females were accidentally stocked* years. However, after the water body is clean of nuisances, the bio-control fish can be used as preventive agents to maintain water clean and acceptable for humans. Nevertheless, it should be emphasized that in each case, the stocking combinations of fish species depends on the characteristics (physical, chemical, ecological, etc.) of each particular reservoir and should be considered individually for each one.

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REFERENCES

Ben-Ami F., Heller J. 2001 – Biological control of aquatic pest snails by the black carp *Mylopharyngodon piceus* – Biol. Control 22:131-138.

Harrell R.M., Kerby J.H., Minton R.V. 1990 – Culture and propagation of striped bass and its hybrids – Striped bass Committee, American Fisheries Society, Bethesda, Maryland, 323 p.

Jhingran V.G., Pullin R.S.V. 1988 – A hatchery manual for the common, Chinese and Indian major carps – ICLARM Stud. Rev. 11, 191 p.

Leventer H. 1974 – The Israeli National Water System; biological succession, nuisances and treatments – Mekoroth, Water Quality Lab., Bnei-Barak, Israel (in Hebrew) 200 p.

Leventer H. 1987 – The contribution of silver carp *Hypophthalmichthys molitrix* to the biological control of reservoirs – Mekoroth Water Co., Jordan District, Central Lab., Nazareth Ilit. Israel. 106 p.

Leventer H. 1979 – Biological control of reservoirs by fish – Mekoroth Water Co., Jordan District, Central Lab., Nazareth Ilit. Israel. 79 p.

Leventer H., Gisis A. 1991 – The improvement of biological treatment in reservoirs and canals with the help of Chinese carp hybrids – Mekoroth Water Co., Jordan District, Central Lab., Nazareth Ilit. Israel.

Leventer H., Teltsch B. 1990 – The contribution of silver carp (*Hypophthalmichthys molitrix*) to the biological control of Netofa reservoirs – Hydrobiologia 191: 47-55.

Mercer L.P. 1984 – A biological and fisheries profile of the red drum, *Sciaenops Ocellatus* – Special Scientific Report No. 41. North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries, Morehead City, NC.

Milstein A. 1992 – Ecological aspects of fish species interaction in polyculture ponds – Hydrobiologia, 231: 177-186.

Milstein A., Hepher B. 1988 – The effect of fish species combination in fishponds on plankton composition – Aquacult. Fish. Manage. 19: 127-137.

Milstein A., Zoran M., Krambeck H.J. 1992 – Fish performance and oxygen dynamics in dual purpose reservoirs (fish farming and field irrigation) in the Israeli Coastal Area – Limnologica 22: 43-50.

Opuszyński K. 1997 – The effect of fisheries, especially the herbivorous fish on water quality in lakes – Monitoring Environment Library, Zielona Góra, 156 p. (in Polish)

Rothbard S. 1981 – Induced reproduction in cultivated cyprinids – the common carp and the group of Chinese carps: I. The technique of induction, spawning and hatching – Bamidgeh 33: 103-121.

Rothbard S. 1982 – Induced reproduction in cultivated cyprinids – the common carp and the group of Chinese carps: II. The rearing of larvae and the primary nursing of fry – Bamidgeh 34: 20-32.

Rothbard S., Rubinshtein I. 1999 – The black carp, a potential biocontrol of mollusks – Isr. J. Aquacult. – Bamidgeh 51: 74-83.

Rothbard S., Rubinshtein I., Shelton W.L. 1996 – The black carp, *Mylopharyngodon piceus*, as a biocontrol of freshwater molluscs – Proc. of 6th Intl. Zebra Mussel and other Aquatic Nuisance Species Conference, Dearborn, Michigan, USA.

Rothbard S., Shelton W.L., Rubinshtein I., Hinits Y., David L. 2000 – Induction of all-female triploids in grass carp (*Ctenopharyngodon idella*), by integration of hormonal sex-inversion and ploidy manipulation – Isr. J. Aquacult. – Bamidgeh 52: 133-50.

Shelton W.L., Rothbard S. 2006 – Exotic species in global aquaculture – a review – Isr. J. Aquacult. – Bamidgeh 58: 3-28.

Shelton W.L., Soliman A., Rothbard S. 1995 – Experimental observations on feeding biology of black carp, *Mylopharyngodon piceus* – Isr. J. Aquacult. – Bamidgeh 47: 59-67.

Woynarovich E., Horvath L. 1980 – The artificial propagation of warm-water finfishes – a manual for extension – FAO Fish. Tech. Pap. (201):183 p.

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STRESZCZENIE

KONTROLA BIOLOGICZNA IZRAELSKIEGO NARODOWEGO SYSTEMU WODNEGO I DWUFUNKCYJNE ZBIORNIKI. KONCEPCJA IZRAELSKA

W pracy scharakteryzowano funkcjonowanie Narodowego Systemu Wodnego (NWC) zapewniającego słodką wodę z jeziora Kinneret dla obszarów położonych na południu Izraela. W NWC przepływ wody odbywa się poprzez system rur, kanałów i tuneli oraz zbiorników retencyjnych, w których magazynowana jest woda pitna (rys. 1). Powierzchnia najważniejszych zbiorników wodnych wynosi od 210 do 1200 ha (tab. 1). Dodatkowo wybudowano zbiorniki o powierzchni od 10 do 40 ha pełniące funkcję rezerwuaru wody dla nawadniania upraw oraz służących do hodowli ryb. W zbiornikach retencyjnych prowadzone są zabiegi biomanipulacyjne oraz utrzymywane są zespoły ryb spełniające rolę organizmów wskaźnikowych (rys. 2).