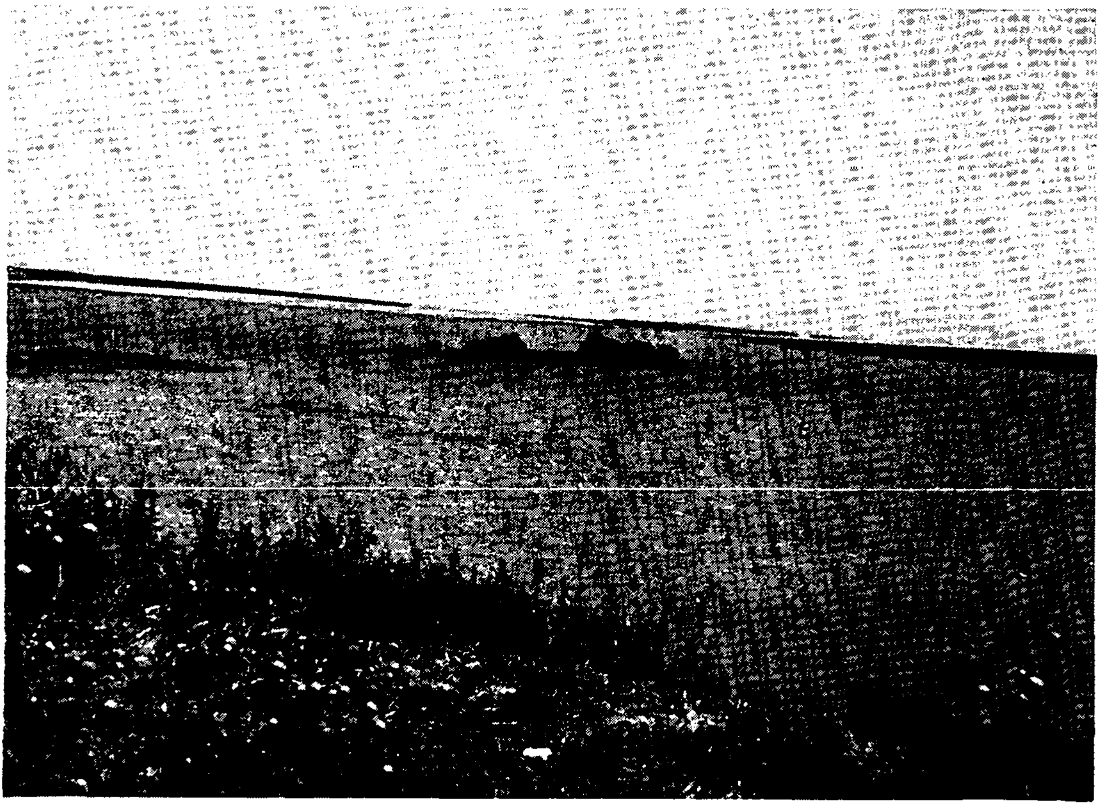
ƆGICAL CONTROL OF RESERVOIRS BY FISH

H. LEVENTER



MEKOROTH WATER CO.
JORDAN DISTRICT
Central Laboratory
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BIOLOGICAL CONTROL OF RESERVOIRS BY FISH

by

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1. INTRODUCTION

The shortage of water in the world's dry zones, and the pollution of the water sources in other regions, have led to the execution of large water supply schemes which carry water over distances of tens and hundreds of kilometers. They are partly based on flow through open channels, pipelines and storage in artificial open reservoirs.

In the sixties the Israel National Water System (INWS) was built and it's main mission was to carry water from the northern part of the country which is rich in rains to the southern desert areas.

In the reservoirs incorporated in the System the biological development was expressed by a rich quantity of phytoplankton, attached algae, submerged plants, snails, shrimps and larvae of insects. Fish have penetrated into the reservoirs, several species multiplied and formed considerable populations. Organic matter has settled in the reservoir bottom and assistance in the growth of algae and animals in the benthos.

Newly formed reservoirs pass in their biological development in three stages. In the first stage, organic matter accumulate on the reservoir bottom, in the second stage mineralization of organic matter takes place and is accompanied by biological development on the reservoir bottom. In the third stage the increase of nutrients in the water causes an increase of phytoplankton and zooplankton.

In some of the System's reservoirs as the Israel National Water System the biological development stoped at the second stage. According to the Saprobic system (Fjerdinghstad 1965) the conditions at the bottom became mesosaprobic, optimal for the appearance of *"Oscillatoria benthonicum community"*. One of the algae, *Oscillatoria chalybea,* became the cause of a considerable nuissance by giving rise to an objectionable taste and odor of the water (Leventer and Eren 1970).

In similar reservoir systems in the world, the water quality is improved by engineering and chemical means – straining and chlorination – at the passage of the water from the reservoirs to the pipe network. Chemical treatment by copper sulfate (Derby 1956) is known as a means of reducing the amount of algae. Chlorine is also used against the spread of sponges (King et al. 1969). In recent years the use of biological control is increasing, Grass carp fish to combate submerged plants and Silver carp to reduce the quantity of algae in the water (Hickling 1971).

In our reservoirs we have tried using copper sulfate but the results were negative. The treatment was effective against algae in the water but encouraged the growth of attached algae and plants. In some reservoirs the planktonic algae were killed, but in 14 to 18 days a new bloom of algae appeared and was greater than prior to the treatment.

From 1970 onwards we have been using biological treatment by different species of fish for the purposes shown below:

SPECIES OF FISH	PURPOSES
Tilapia aurea *Mugil capito* (Grey mullet)	To reduce the quantity of organic matter from the bottom of the reservoir.
Hypophthalmichthys molitrix (Silver carp)	To reduce phytoplankton
Aristichthys nobilis (Big head carp)	To reduce zooplankton
Ctenopharyngodon idella (Grass carp)	To eliminate submerged plants
Myllopharyngodon piceus (Black carp)	To eliminate snails
Cyprinus carpio (Common carp)	
Dicentrarchus punctatus (Sea bass)	A predatory fish

2. THE RESERVOIRS

The reservoirs investigated in this study form part of the Israel National Water System (Fig. 1), which conveys water from Lake Kinneret to the south of the country.

The capacity of the reservoirs range between 200,000 m^3 to 9 million m^3 of water and the deeps between 3 to 13 m. The northern reservoirs receive Lake Kinnereth water and function as operational reservoirs. The southern reservoirs receive Lake Kinneret and aquifers water and are operated as reservoirs which "floats on the system".

The water supplied by the system is used for agriculture, industry and domestic supply. All the water must be of potable water standard. Treatment given to the water includes: partial settling of suspended solids in a settling reservoir situated near the Eshkol reservoir, screening through mechanical screens with 4 mm at the passage from the reservoir to the pipe network and chlorination to insure the presence of 0.2 to 0.3 ppm of residual chlorine.

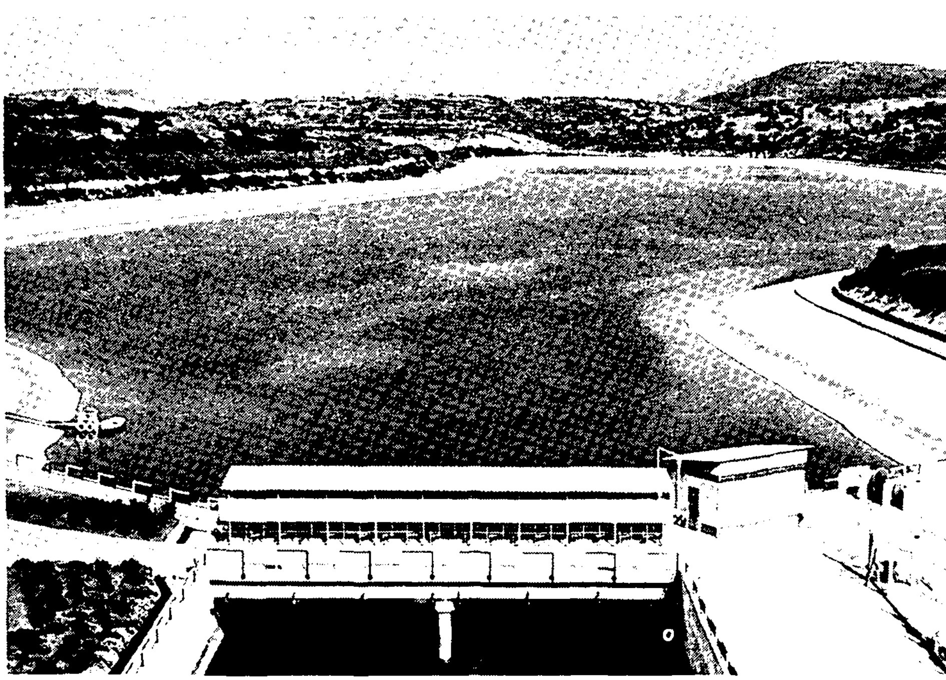
Owing to these treatments, the water is free from coliform bacteria, its turbidity varies between 2 and 3 Jackson units, and it contains 2 to 4 ppm of suspended solids consisting of mineral matter, algae and reproductive elements of aquatic plants and animals. The treatment employed does not prevent the propagation of algae and other organic life along the system.

Prior to the introduction of fish into the reservoirs there was a high development of flora and fauna (Leventer 1969). From the aspect of biological development, the system's reservoirs can be divided into three types:

Type A. Reservoirs in which the water is retained for short periods, continuous supplement of the water takes place and the surface level is constant. The biological development occurs at the bottom and consists of: attached algae, submerged plants, snails, shrimps and larvae of insects. The phytoplankton and the zooplankton which are found in the water, arrive from lake Kinneret and a little development is in the reservoirs itself.

Type B. Reservoirs where frequent replacement of the water takes place and the surface level changes quickly. The bottom are rich in attached algae, snails and larvae of insects.

Type C. Reservoirs where the water is retained for long period without replacement. The upper layers of the water are rich in phytoplankton and zooplankton. The biological development on the bottom is very poor and in the deep parts of the reservoirs anaerobical conditions dominate.



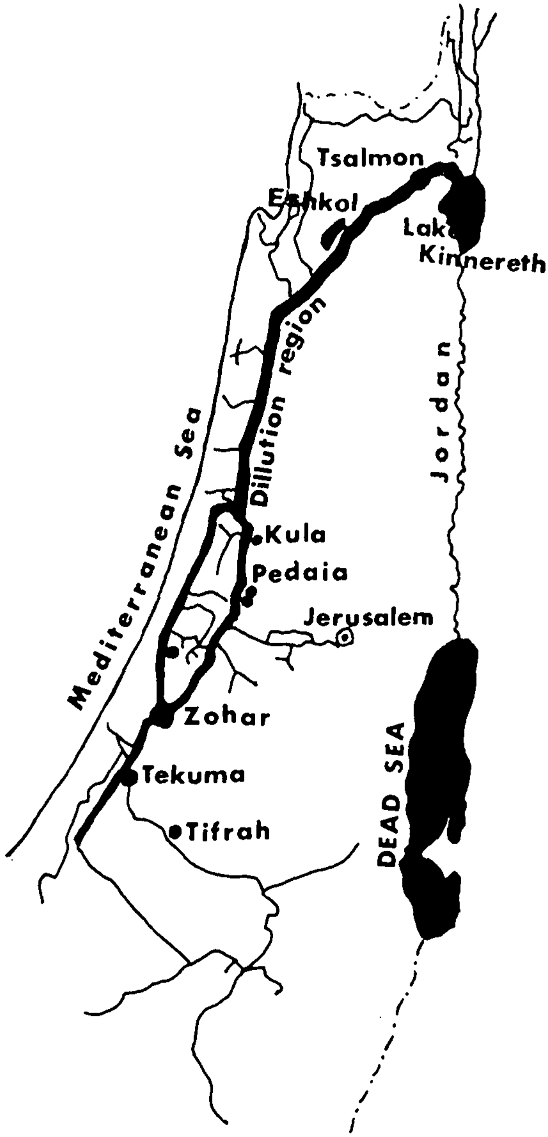


Fig. 1. THE ISRAEL NATIONAL WATER SYSTEM

3. THE PROPERTIES OF THE WATER IN THE RESERVOIRS

3.1 Temperature

In Tsalmon, the temperature of the water ranges between 14–29°C. The minimum is reached in January and maximum in August–September (Fig. 2). The water which flows through the open channels is warmed and in the summer there is a difference of 2–5° C between the water arriving and the reservoir water itself. The difference between day and night is usually 1–2°C.

In Eshkolthe water reaches 10°C in winter, but the maximum is the same as in Tsalmon. The maximum depth of the water is 7m and the difference between the surface water and deep layers does not usually exceed 1°C.

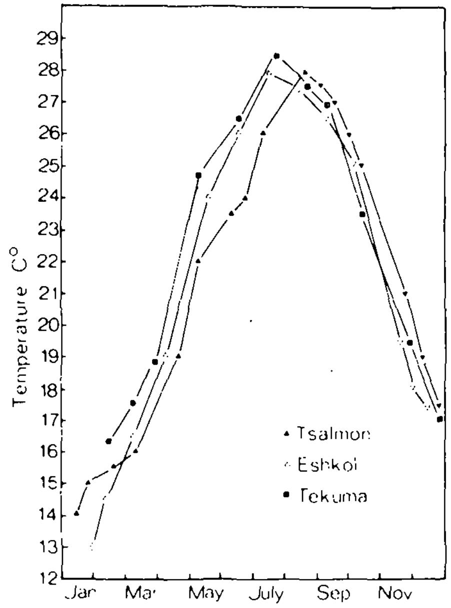
In the Zohar reservoir there is a stratification of temperature from June to August but the fluctuation in water level breaks this stratification. (Fig. 2).

3.2 Secchi disc

The values of transparency measured by Secchi disc were relatively high in the Tsalmon and Eshkol (Fig. 3) reservoirs. The depth of the water in Tsalmon ranges between 2.5–4.5 m and the values for transparency were 2.5–3.5 m. The minimum transparency is in the month of March–April as the alga ***Peridinium cinctum*** and soil particles from run off water enter the system.

In Eshkol reservoir, the depth of the water ranges between 4–7.5m (Fig. 3) and the disc was visible from 3 to 5 m.

In Zohar reservoir the transparency is very low (Fig. 3) and ranges between 1.5–2.5 m. This low transparency is caused by high concentrations of plankton and by bottom-feeding fish constantly disturbing the clay bottom of the reservoir.



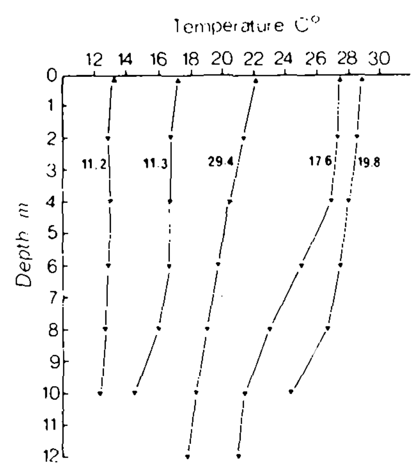


Fig. 2.. The temperature of the water in the reservoirs Tsalmon, Eshkol, Tekuma (above) and Zohar (below) during the year 1967.

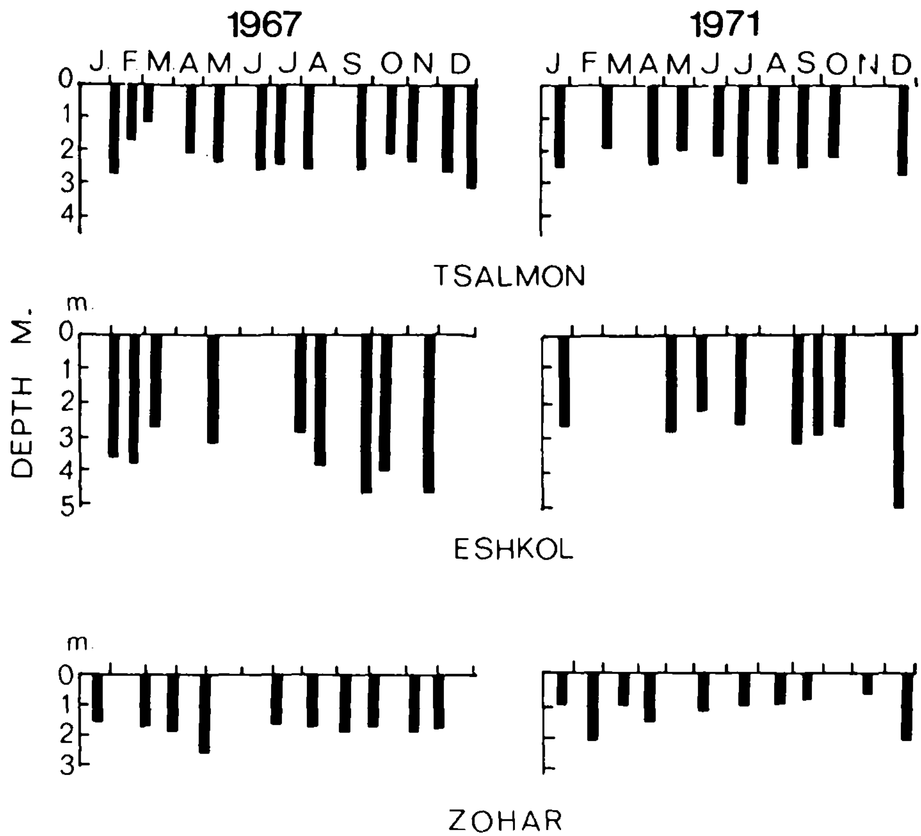


Fig. 3. The Secchi disc transparency in the reservoirs Tsalmon, Eshkol and Zohar in the years 1967 and 1971.

3.3 Dissolved oxygen (D.O.)

The values for D.O. are different for each reservoir and they fluctuate in a different way during the seasons of the year. In the Northern reservoirs the main source of D.O. is the primary production of the attached algae in the channels and the bottom flora of the reservoirs. The water flowing from Kinneret up to the outlow at Eshkol is poor in algae most of the time and thus has little influence on the concentration of dissolved oxygen.

In Tsalmon and Eshkol the concentration of D.O. Fig. 4, 4a is decreased (to 60–70% of saturation) twice during the year: during the months of May–June when the decomposition of the sediments demand oxygen and at the time the submerged plants are detached from the bottom. The submerged plants influence the distribution of D.O. and some time the concentration in the deep layers of water is higher than in the surface water.

The high concentration of D.O. in the deep layers of water lasts longer in Eshkol than in Tsalmon.

A stratification of D.O. has been found in Zohar reservoir (Fig. 5) and in the months of May–August there is a decrease or lack of D.O. in the deep layers of water. The distribution of D.O. is also different at some places in the reservoir. Near the tower where the water flows in and out there is no stability of stratification. The maximum concentration of D.O. is 9.5 mg/l or 120% saturation and the range is between 95–120% in the surface water.

3.4 Chemical composition of the source water

In our system, surface water from Lake Kinnereth and aquifer water meet. The chemical composition of the aquifer water is different in certain places.

Kinnereth water has a high salinity (233–347 mg/l chloride), high hardness (235–294 mg/l as $CaCO_3$), and relatively low concentration of nutrients. After the turnover of the lake, nitrite increases but is oxidized to nitrate.

The other sources of water have a lower salinity (90–150 mg/l chloride), a high hardness and high values for nitrate.

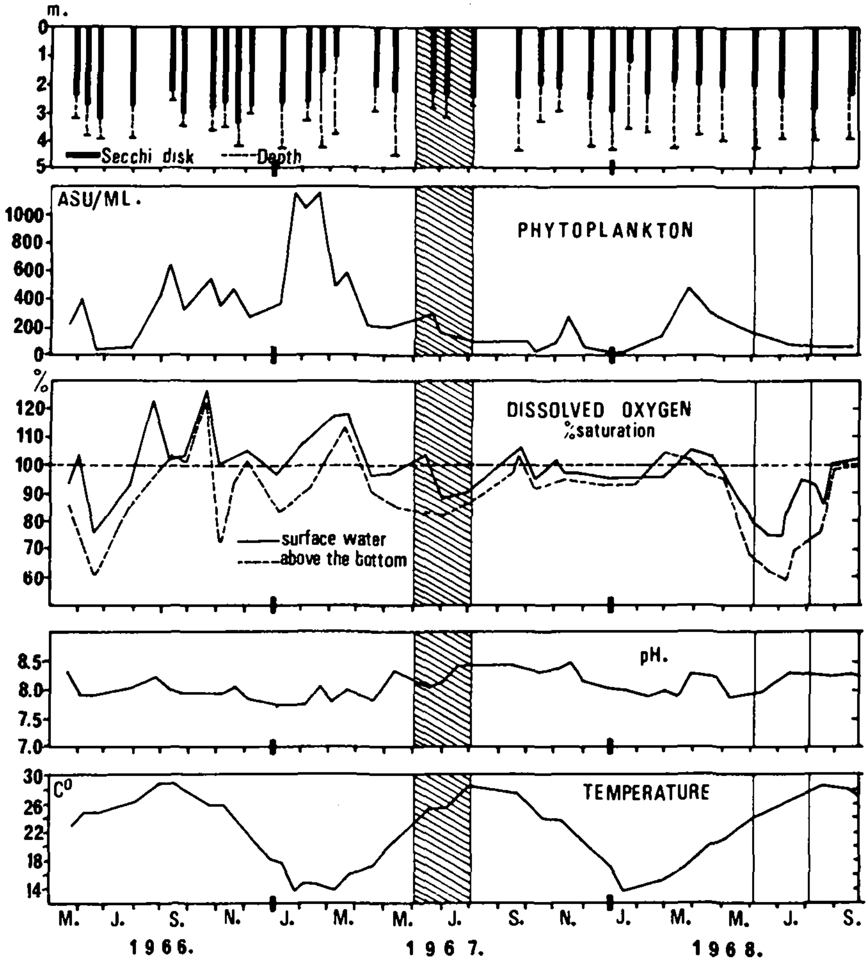


Fig. 4. Tsalmon reservoir. Changes of Temperature, pH., Dissolved oxygen, Phytoplankton and Secchi disc during the years 1966–1968. The hatched area represents the taste and odor period.

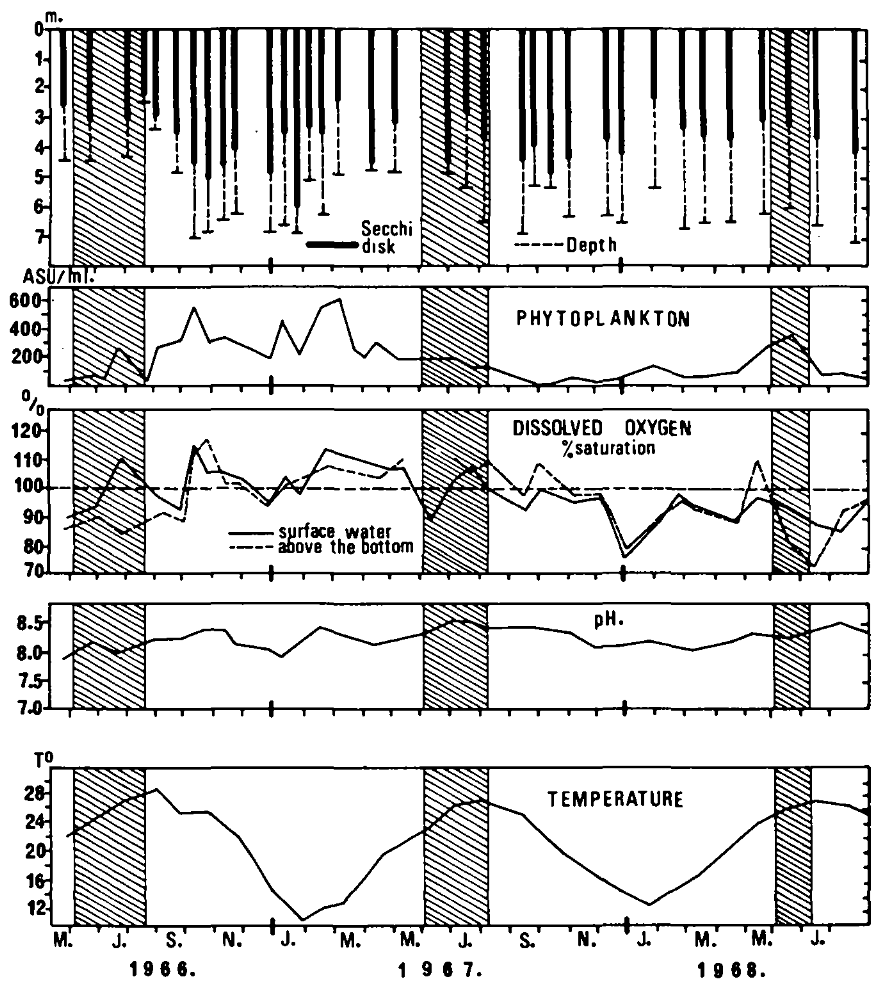


Fig. 4a. Eshkol reservoir. Changes of Temperature, pH., Dissolved oxygen, Phytoplankton and Secchi disc during the years 1966–1968. The hatched area represents the taste and odor period.

The Northern reservoirs, Tsalmon and Eshkol, receive only Kinnereth water while Zohar reservoice receives a mixture of Kinnereth and aquifers water.

Table 1. Chemical composition of source water

	L. Kinneret		Aquifers					
	Eshkol		Karkur 145		Yarkon 3		Gat 23	
/ year	1966	1971	1965	1971	1965	1972	1965	1971
pH.		8.2	7.1	7.3	7.3	7.3	7.3	7.5
Cl^- mg.l.	347	233	90	83	142	159	140	220
NO_3 mg.l.	0.2	0.3	19	15	0	0	28	4
HCO_3^- mg.l.	128	128	363	364	317	293	326	183
H. $CaCO_3$ mg.l.	294	235	337	367	305	307	289	270
Ca mg.l.	51	45	89	82	63	67	56	60
TDS 180^o mg.l.	781	636	493	501	715	635	585	579

P and N compounds

Orthophosphate is found in low concentrations in all reservoirs, but nitrogen exists in all its forms with the most frequent form being the nitrate. In Tsalmon and Eshkol, the nitrite increases after the turnover of Lake Kinnereth and within a short time the concentration in Tsalmon reaches 0.185 mg/l while in Netofa it is 0.070 mg/l.

Table 2. Phosphate and nitrogen concentrations in Tsalmon, Eshkol and Zohar reservoirs.

	Tsalmon	inflowing water		Zohar reservoir
		Eshkol	Zohar	
PO_4 mg/l	.005–.062	.005–.025	.003–.34	.003–.40
NH_4 mg/l	.05–.143	.05–.65	.05–.203	.05
NO_2 mg/l	.003–.185	.003–.070	.014–.062	.003–.025
NO_3 mg/l	.05–3.84	.05–3.3	1.8 – 8.5	1.6 – 4.8

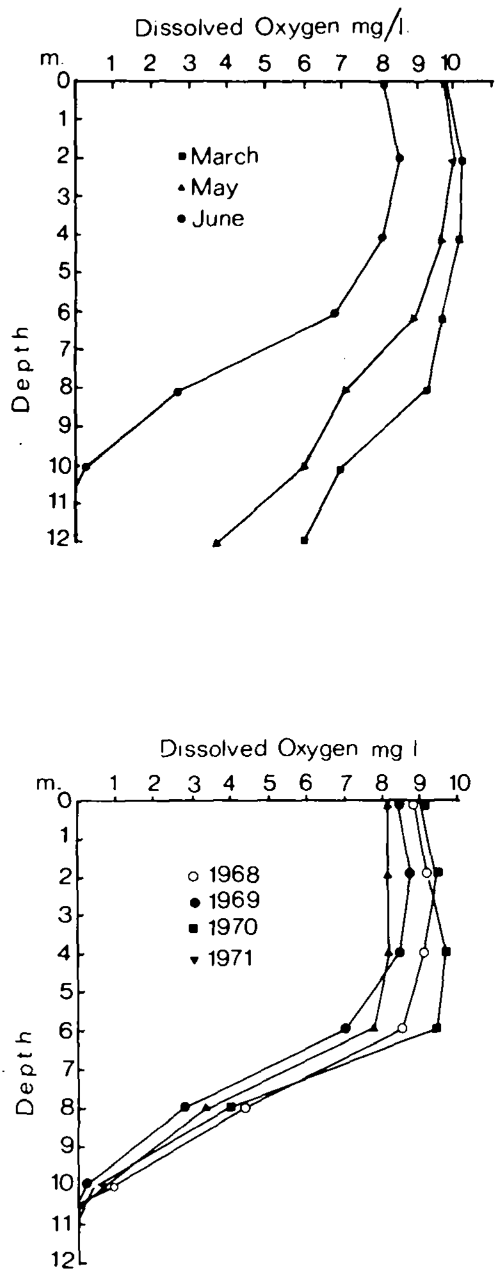


Fig. 5. The concentration of Dissolved oxygen in the water of Zohar reservoir during the month March–May–June (above) and in the month June (below) in the years 1968–1971.

The water in the Zohar reservoir is rich in nitrate as a result of the mixture of Kinnereth water with water from aquifers. The influx contains up to 8.5 mg/l NO_3^- and in the reservoir it ranges between 1.6 and 4.8 mg/l.

Due to the fact that we have not as yet examined the chemical changes occurring in the reservoir itself, we have no information on the quantity of nutrients entering the water from the bottom and vice versa.

4. BIOLOGICAL DEVELOPMENT AND ASSOCIATED ILL EFFECTS

A typical feature of artificial reservoirs is that, beside the biological chain existing in lakes, they exhibit excessive development of some groups of plants and animals that generally give rise to nuissances.

The biological chain in our reservoirs is built of the following groups: Phytoplankton, Rotifera, Crustacea, Molluscs, Larvae of insects, Fish. As a lateral development can be viewed, submerged plants which constitutes a consumer of nutrients and adds organic matter to the reservoir, it both produces and consumes dissolved oxygen. But its principal effect, negative effect, is aiding to some animals as a substrate to lay their eggs, to create good conditions for the development of the embryo and larvae, and save them from predators.

The number of species of algae and animals that are found in the reservoirs are nor numerous but their amount is considerable. The factors effecting biological development in our reservoirs are: quality of Lake Kinneret water, detention time of the water in the reservoirs, surface level fluctuation and temperature (Leventer and Peleg 1977). Despite the fact, that the same water enters in different reservoirs, the biological development in each is different. An ill effect appearing in one reservoir does not pass into another connected with it or it may even fail to appear.

Up to the year 1966 the causes of trouble we had to deal with were: (1) Phytoplankton, (2) Submerged plants, (3) Snails, (4) Fish (5) Taste and Odor in the water.

4.1 PHYTOPLANKTON

The population of phytoplankton consists of some species, but in larger amount are found the following species: the dinnoflagelate alga *Peridinium cictum*, the diatoms *Cyclotella* and *Synedra* and the blue-green alga *Chroococcus.*

The *Peridinium* alga arrives with the Lake Kinneret water, but does not multiply in the reservoirs. Its growth period in Lake Kinneret is from January to June (see Table 3). In the bloom period, March–April, its concentration varies between 1000 and 3000 cells per ml of water. (Serruya and Pollinger 1970). There are variations from year to year with the time of bloom in the lake and the amount of algae which arrive to the reservoirs. In the distribution system, the algae settle, decompose and impart to the water objectionable taste and odor.

Table No. 3 The concentration of the alga *Peridinium cinctum* in Lake Kinneret in the years 1964–1970. Cells/ml.

Year / Month	1964	1965	1966	1967	1968	1970
January	5	230	1035	161	10	100
February	5	161	713	345	80	670
March	120	1227	943	805	1750	3320
April	55	989	828	2208	1700	2960
May	99	1840	1540	391	800	880
June	80	230	207	–	227	210

From : Serruya and Pollinger 1970

The diatom alga **Cyclotella** multiplies in reservoirs in spring (Fig. 6), and **Synedra** in summer and autumn. Concentration of *Synedra* reach up to 7000 cells per ml of water. In some years, instead of the diatom alga **Synedra** appear the blue-green alga **Chroococcus** (Fig. 7).

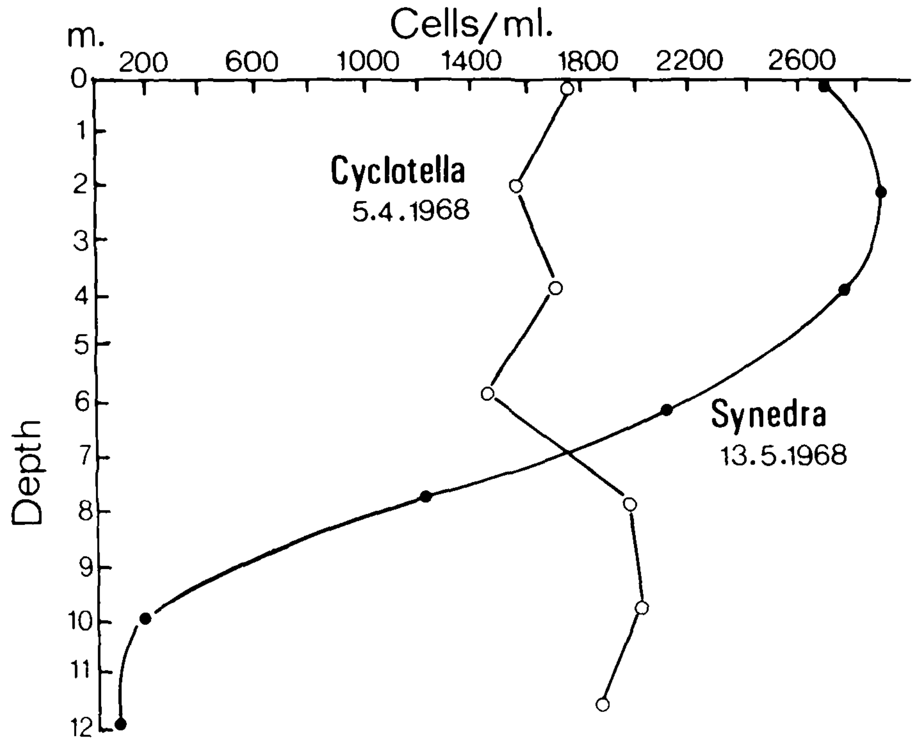


Fig. 6. The concentration of the algae, *Cyclotella* and *Synedra* in Zohar reservoir.

4.2 SUBMERGED PLANTS

On the bottom of the reservoirs, submerged plants include the following species: **Potamogeton pectinatus, P. bertholdi, P. nodosus, P. lucens, Najas marina** and the alga like plant *Chara vulgaris.*

In some of the reservoirs, the **Potamogeton** plants begin growing in the spring months, reach their peak growth at the end of summer and tearing up from the bottom in autumn and early vinter. The detached plants enter into the water, a portion is carried to the banks and the other portion enters into the distribution system.

The plant-like alga *Chara vulgaris* forms colonies in the large reservoirs, but in the small reservoirs it covers the whole bottom reaching a height of 50 – 100 cm. (Fig. 8).

Part of the plants or its reproductive materials are carried by the water to all part of the system. The part of the plant is a vector of propagation of eggs of snails, insects and fish.

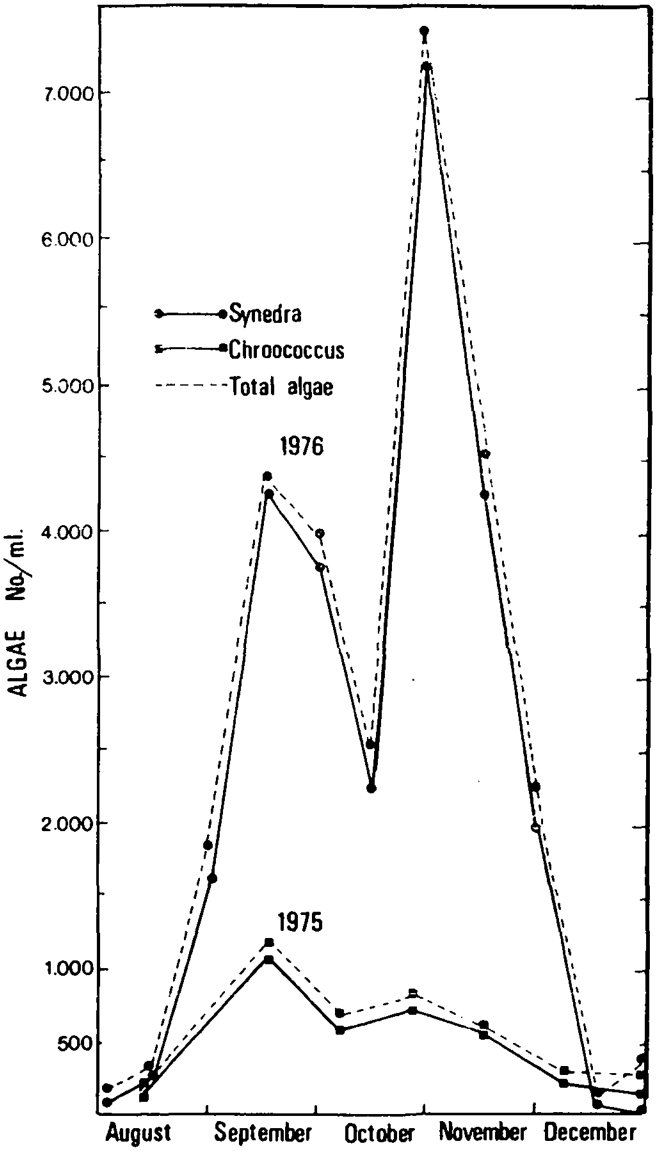
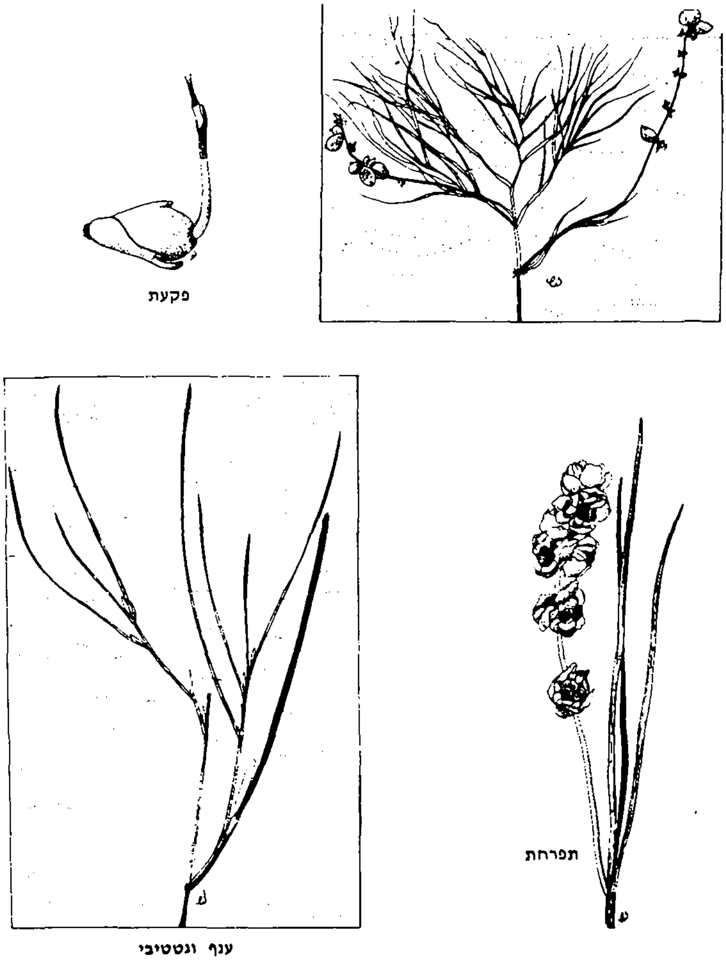
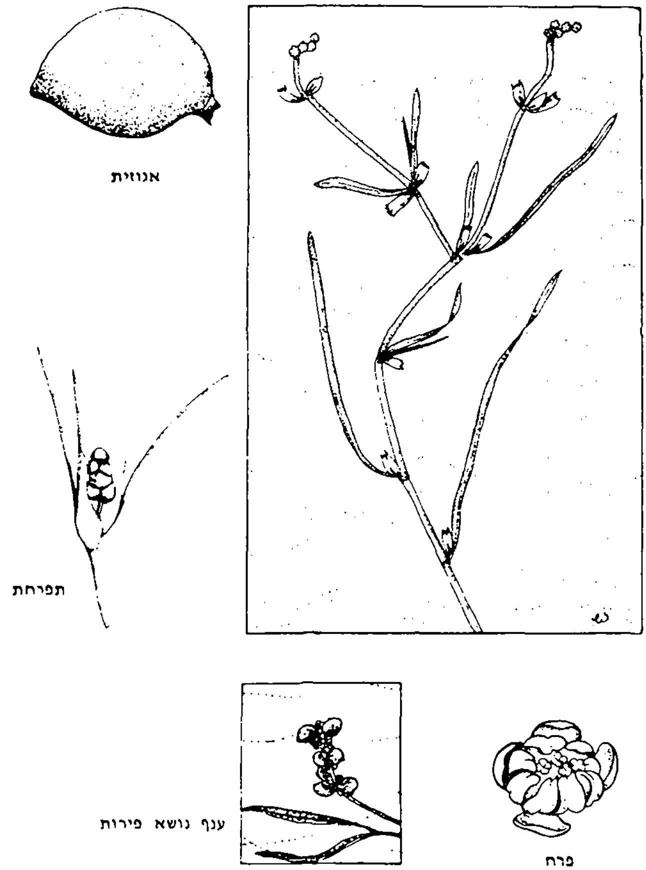


Fig. 7. The concentration of the alga Chroococcus in Eshkol reservoir during the autumn 1975 and the alga Synedra during the autumn 1976.

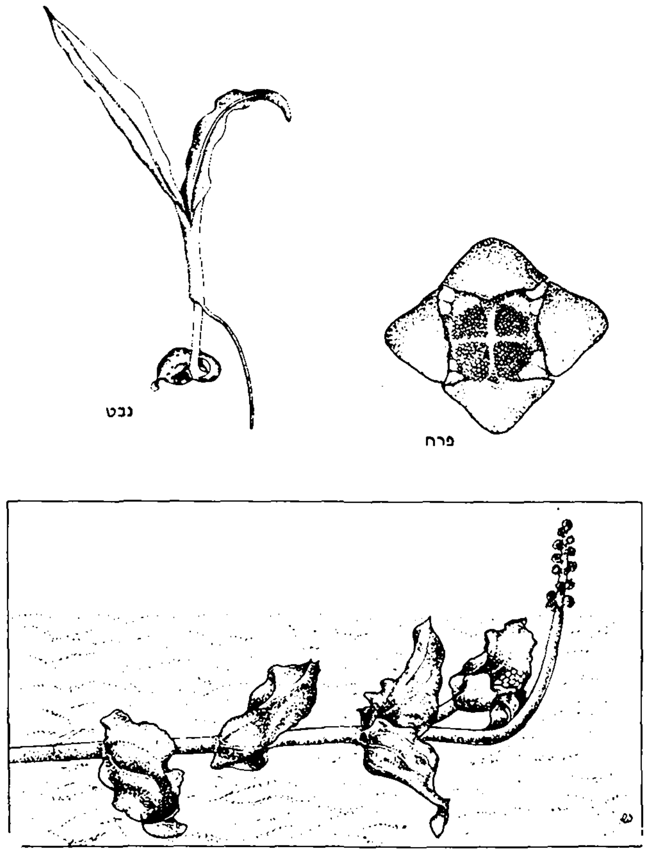


Potamogeton pectinatus L. **נהרונית מסרקנית**

From: Waisel and Liphschitz
Water plants of Israel.



Potamogeton berchtoldii Fieber **נהרונית ברכטולדי**



Potamogeton perfoliatus L. נהרונית לופתת

ט.

פרח עלייני

Najas marina נידת החוף

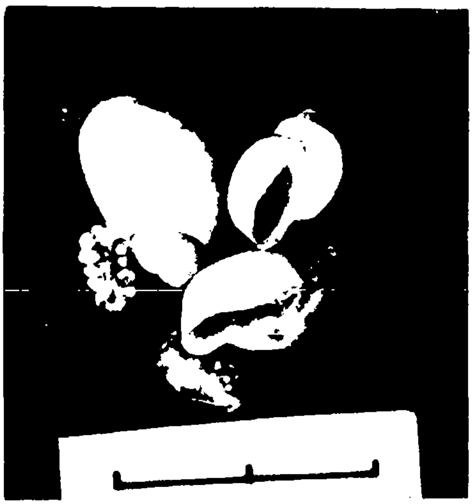
Fig. 8. The alga like plant *Chara vulgaris* in Tekuma reservoir.

4.3 SNAILS

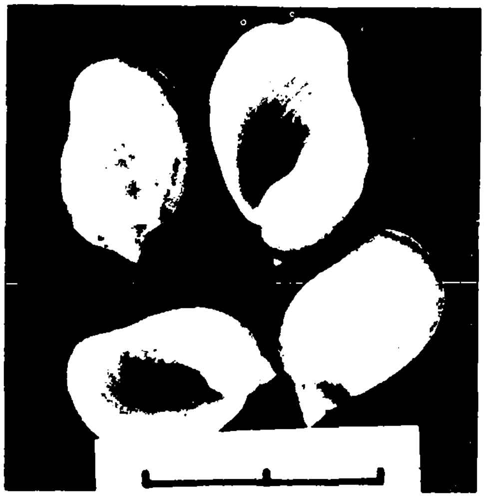
In all reservoirs live and multiply the following snails species: *Lymnea auricularia*, *Bulinus truncatus*, *Melanopsis praemorsa*, *Melanopsis costata*, and *Melania tuberculata*. (Fig. 9). In the lake Kinneret watershed are found other species of snails, which may in the course of time reach the reservoirs. One species of clams, *Corbicula fluminea*, is found in the reservoirs but in very small quantities.

Two snails species, *Lymnea* and *Bulinus* have reached all reservoirs (Fig.10). Their reproduction and propagation is very rapid. In the Ramleh reservoir in July 1971 were found 624 snails of sq.m. of the *Lymnea auricularia* species. In September their concentration reached 1896 per sq.m. and in February 1972 2485 snails per sq. m. (Fig. 11) shows that with increased density more of the smaller snails were dominant (Mantel and Leventer 1973).

Snails and their shells reach the pipe system and cause disturbances in water meters and irrigation equipment.

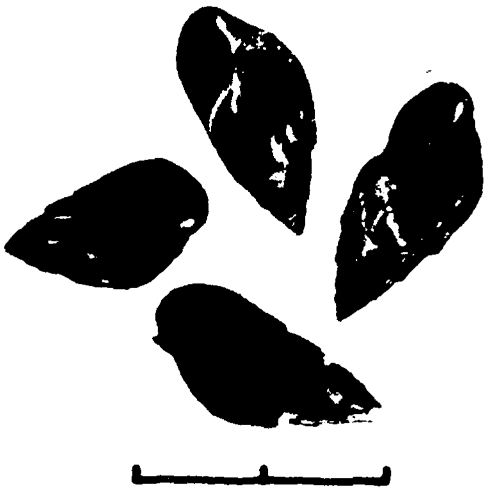


Bulinus truncatus



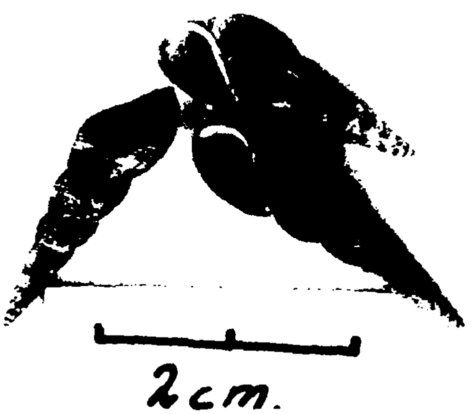
Lymnea Sp.

Fig. 9. The snails and Clam from the reservoirs.



Melanopsis costata

Melanopsis praemorsa



Melania tuberculata

Corbicula

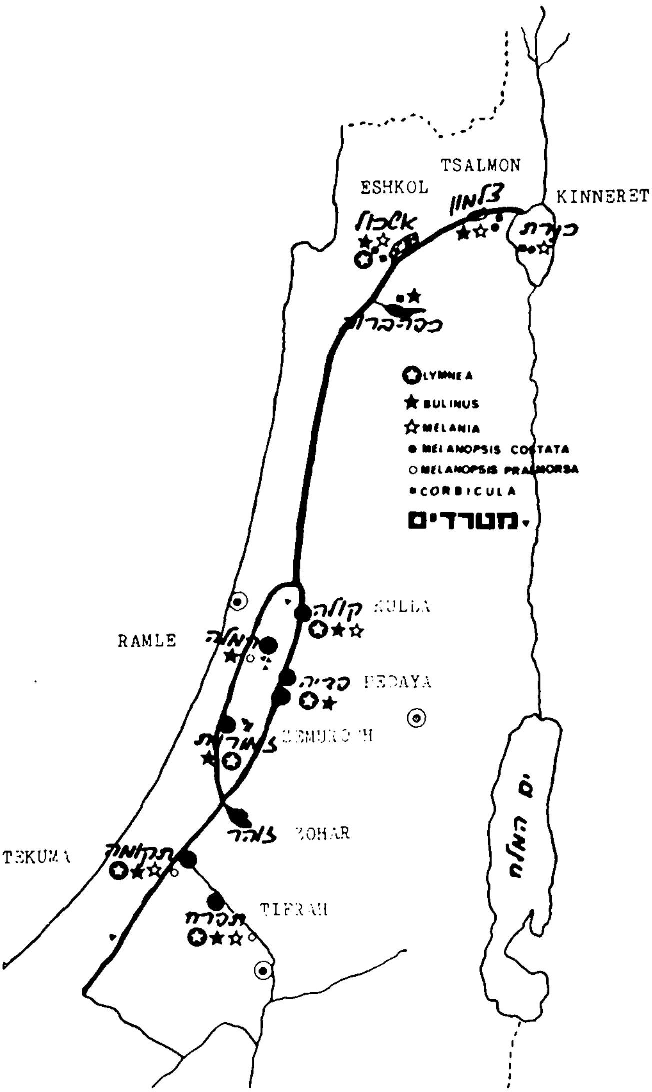


Fig. 10. The distribution of snails and clams in the reservoirs.

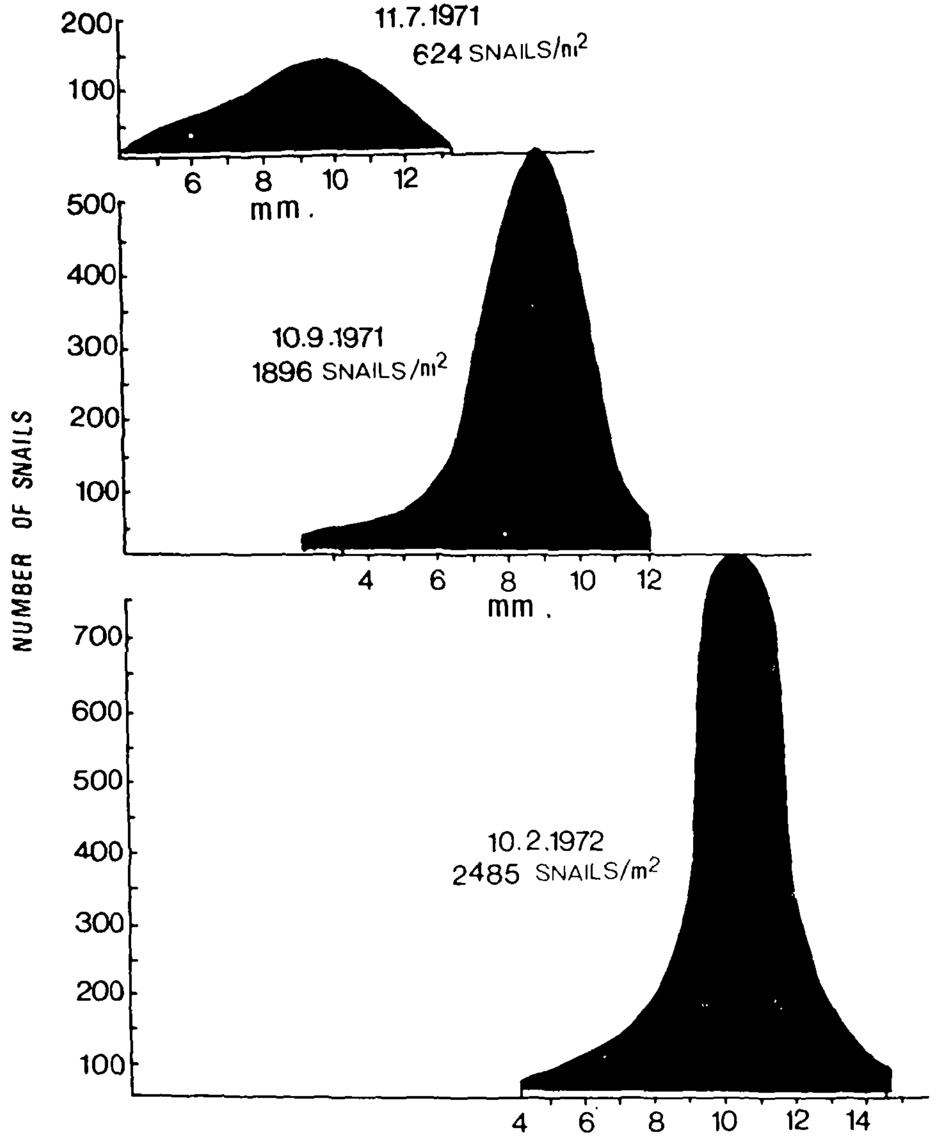


Fig. 11 The increase of the snails population *Lymnea auricularia* in Ramle reservoir during the period January 1971 – February 1972.

4.4 FISH

All the fish species found in Lake Kinneret have found their way to the reservoirs. Three of these species: *Tilapia zillii, Clarias lazera* and *Mirogrex terraesanctae* multiply and have reached very high density. The small fish passed the screen and reached all part of the system (Fig. 12). Despite the presence of these numerous species of fish in the reservoirs and the high density of some species, they had no effect on the biological development in them.

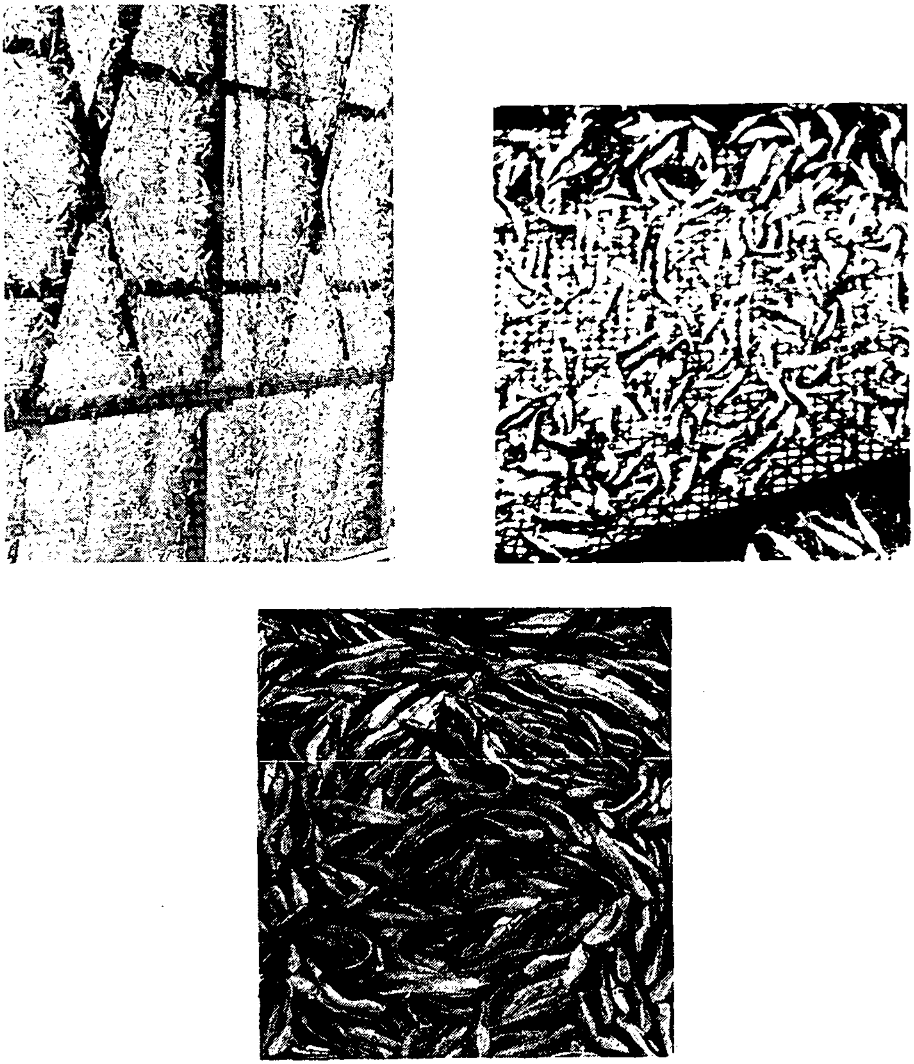


Fig. 12. Fish which are prevented from passing from Eshkol reservoir to the pipe 108" by means of a screen. above: *Mirogrex terraesanctae*, below: *Clarias lazera*

4.5 TASTE AND ODOR OF THE WATER

One of the biggest problems that has afflicted the Israel National Water System was the objectionable taste and odor of the water. From 1966 onwards the water that left the Eshkol reservoir had an earthy-musty after taste. Similar trouble is known in the world and is related to the actinomycetes bacteria (Silvey et al 1950).

In Israel, the nuisances has been caused by the blue-green alga *Oscillatoria chalybea* (Fig. 13) (Leventer and Eren 1970). This alga grows on reservoir bottoms from April to July. In the course of decomposition it imparts to the water the objectionable taste and odor. Its growth is encouraged by conditions obtaining at the reservoir bottom which proves optimum for this alga, but unfavorable to other algae. This alga forms a film over the bottom surface and enjoys the absence of competitors.

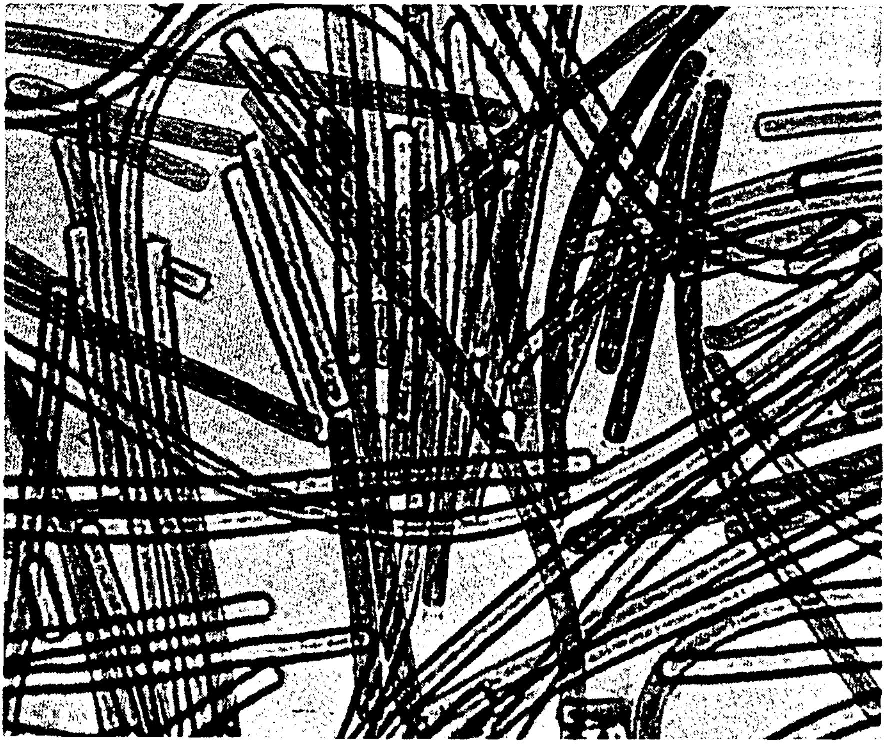


Fig. 13. The blue-green alga *Oscillatoria chalybea*

In the months of winter and spring, large amounts of the ***Dinoflagelate*** alga ***Peridinum*** have been settling and accumulating on reservoir bottom in large quantities. Concentration of organic matter have been reaching 16–18 per cent of the dry material, and even more (Fig. 14). In spring, with the rise of temperature, the decomposition processes increase, the concentration of dissolved oxygen near the bottom decreases (see Fig. 15) and the quantity of hydrogene sulfide in the sediments increase. Conditions which are created in lakes in the termocline zone are created in our reservoirs above the bottom. Under similar conditions blooms of blue-green algae, ***Oscillatoria spp.*** appear in lakes (Findenegg 1965, Tash 1967).

In order to eliminate the trouble of taste and odor in the water and to prevent the growth and bloom of the blue-green alga ***Oscillatoria chalybea,*** we chose the method of reducing the amount of organic matter on the bottom of the reservoirs.

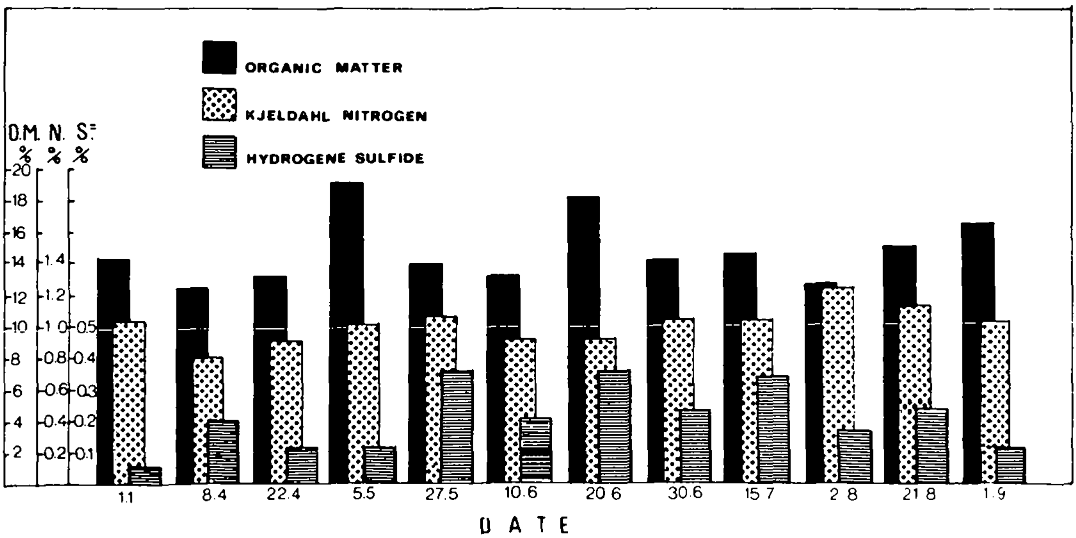


Fig. 14. The concentration of Organic matter, Kjeldahl nitrogen and Hydrogene sulfide in the sediments of Tsalmon reservoir during the year 1968

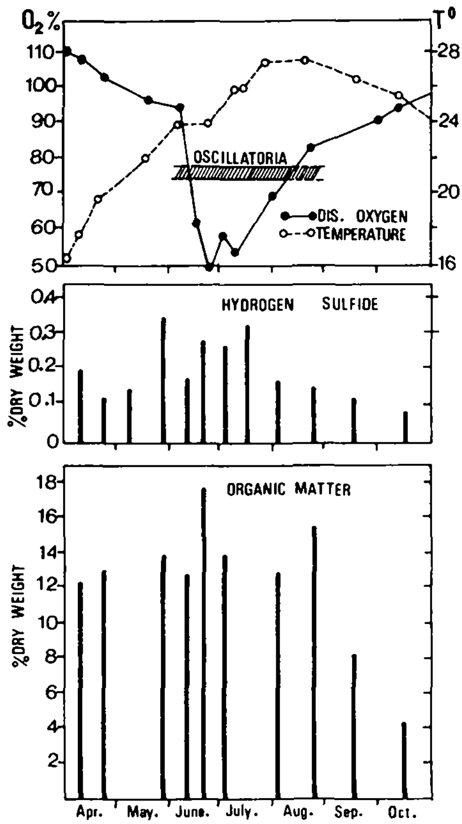


Fig. 15. The concentration of Organic matter, Hydrogene sulfide at the bottom of the Tsalmon reservoir and the Temperature, Dissolved oxygen in the water near the bottom during the time of bloom of Oscillatoria chalybea.

5. BIOLOGICAL CONTROL BY FISH

The purpose of biological control by fish was two folds: firstly to treat all biological components simultaneously and secondly – to reduce as far as possible all biological activity. There was no intention to obtain a radical treatment of one of the link in the biological chain. In two cases, submerged plants and snails the biological treatment reach optimum results.

Dealing with all biological components has called for the use of different fish species, with each depending on a different kind of food. To obtain full effect, it was important to use fish of low initial weight, to provide sufficient density and to remove fish when necessary.

We used nine different species of fish, each subsisting on a different type of food and seeking it out from different places of the reservoir.

	Food habits	Species of fish
1.	Detritophagic	Tilapia aurea, Grey mullet
2.	Macrophytophagic	Grass carp
3.	Benthophagic	Black carp, Common carp
4.	Planktophagic	Silver carp, Tilapia galilea
5.	Zooplanktophagic	Big head carp
6.	Nektophagic	Sea bass

All the above species, with the exception of Tilapia and Common carp, do not breed in reservoirs. Stock of fry fish are obtained by inducing spawning in artificial conditions.

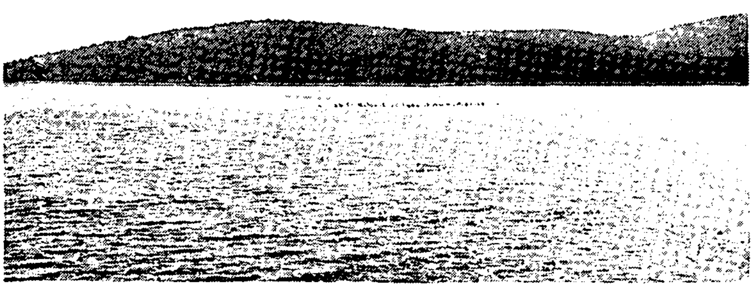
Two of the species, Grey mullet and Sea bass, are sea fish, that are able to live in fresh water.

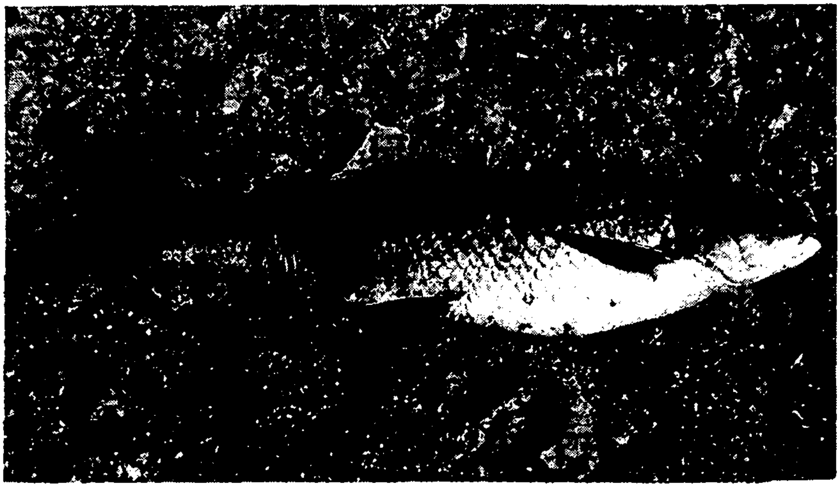
The biological development, from either the qualitative or the quantitative aspects is not the same in all reservoirs. Of the three types of reservoirs described in Section 2, each call for a different composition of fish population and for a different density of fish population.

Type A (Fig. 16) is a reservoir with a great amount of organic matter on its bottom. Biological activity takes place directly above the bottom and is expressed by high development of Zoobenthos, Submerged plants and Snails. Reservoirs of this type have been populated by Tilapia aurea, Grey mullet, Grass carp, Black carp and Common carp.

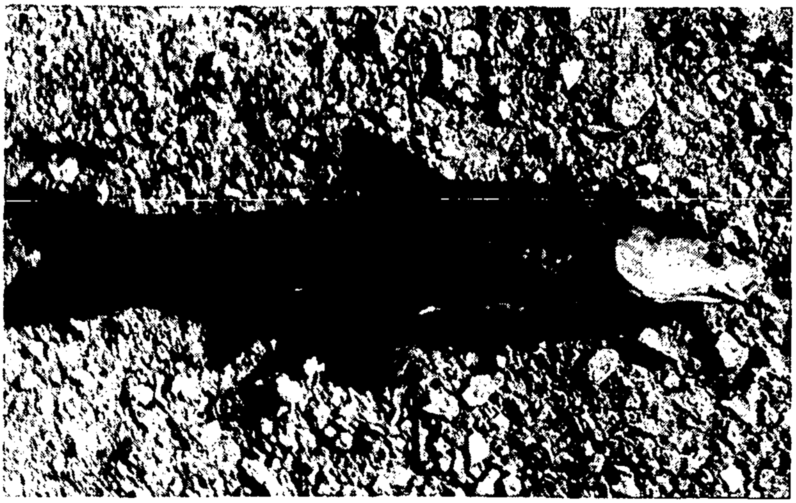
Type B (Fig. 17) represents reservoirs in which water replacement take place and the surface level fluctuations of 0.5 to 7.0 m. occur. On the bottom a widespread growth of attached algae and zoobenthos is found, also snails, occasional submerged plants, mainly the plant-like alga *Chara vulgaris* (Fig. 4). These reservoirs have been populated for biological control by Grey mullet, Black carp, Grass carp, Common carp (male only) and Silver carp.

Type C (Fig. 18) is that of a reservoir in which the water is detained for long periods, and the biological development takes place in the upper water layers and is expressed by the growth of Phytoplankton and Zooplankton. Some of the primary and secondary products settle to the bottom and add organic matter to it. The principal species brought is to populate this type of reservoirs are, Silver carp, Tilapia galilea, Bighead carp, and a few amount of Grey mullet, Common carp and Grass carp.

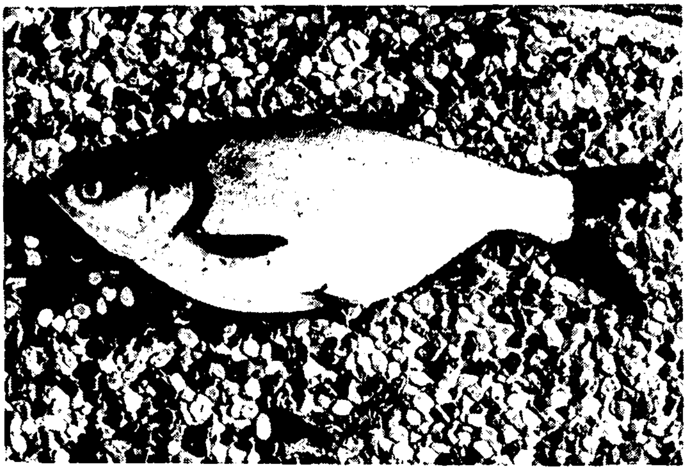




Grass carp – *Ctenopharyngodon idella* – אמור

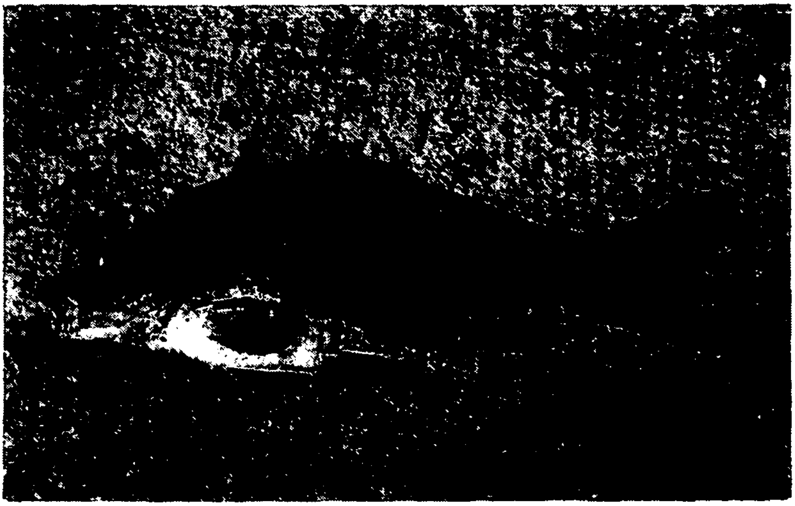


Black carp – *Millopharyngodon piceus* – קרפיון שחור

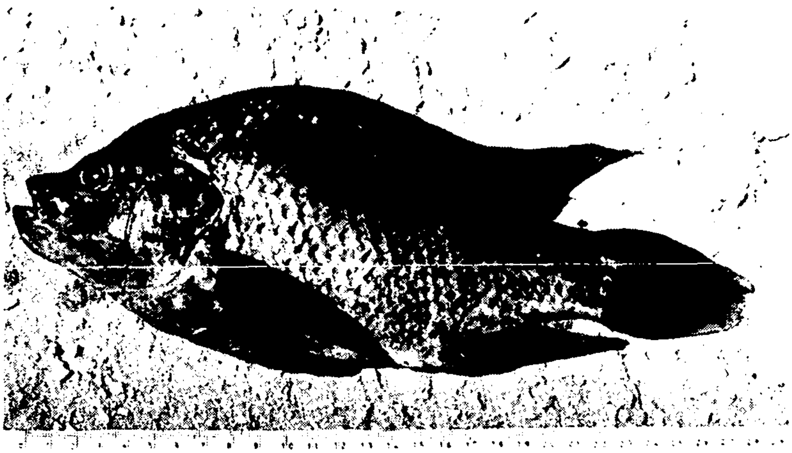


Silver carp – *Hypophtalmichtys molitrix* – כסיף

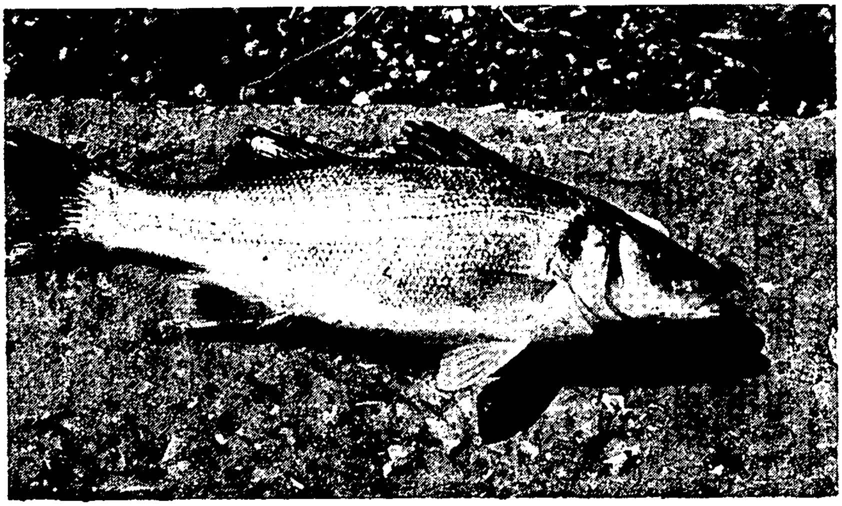
Bighead carp – *Aristichthys nobilis* – קרפיון גדול ראש



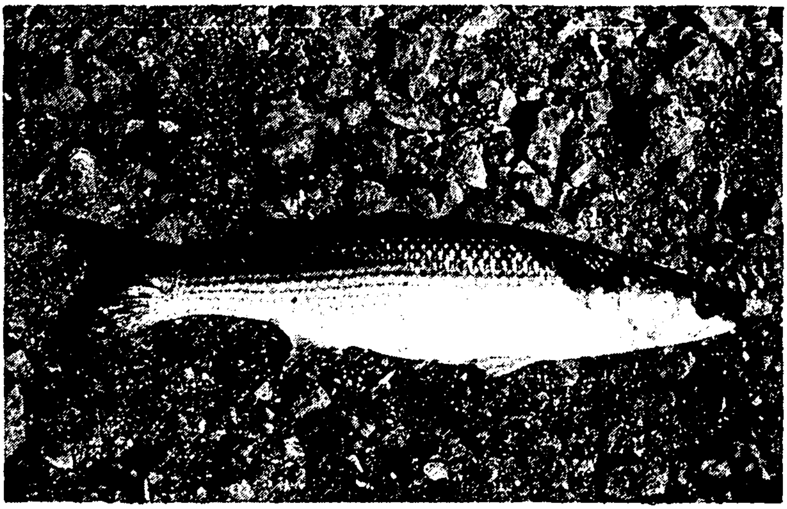
Common carp – *Cyprinus carpio* – קרפיון מצוי



Tilapia aurea – אמנון הירדן



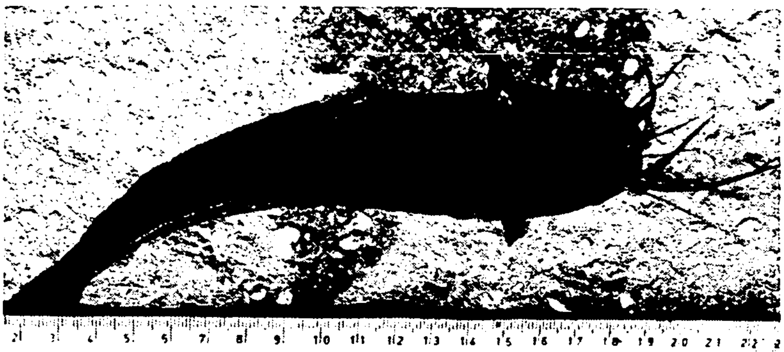
Sea bass – *Dicentrarchus punctatus* – לבראק



Grey mullet – *Mugil capito* – קיפון מצוי

Mirogrex terraesanctae – לבנון

Tilapia zillii – אמנון מצרי



Clarias lazera – שפמנון

Lake Kinneret Fish which arrive at the reservoirs and multiply.

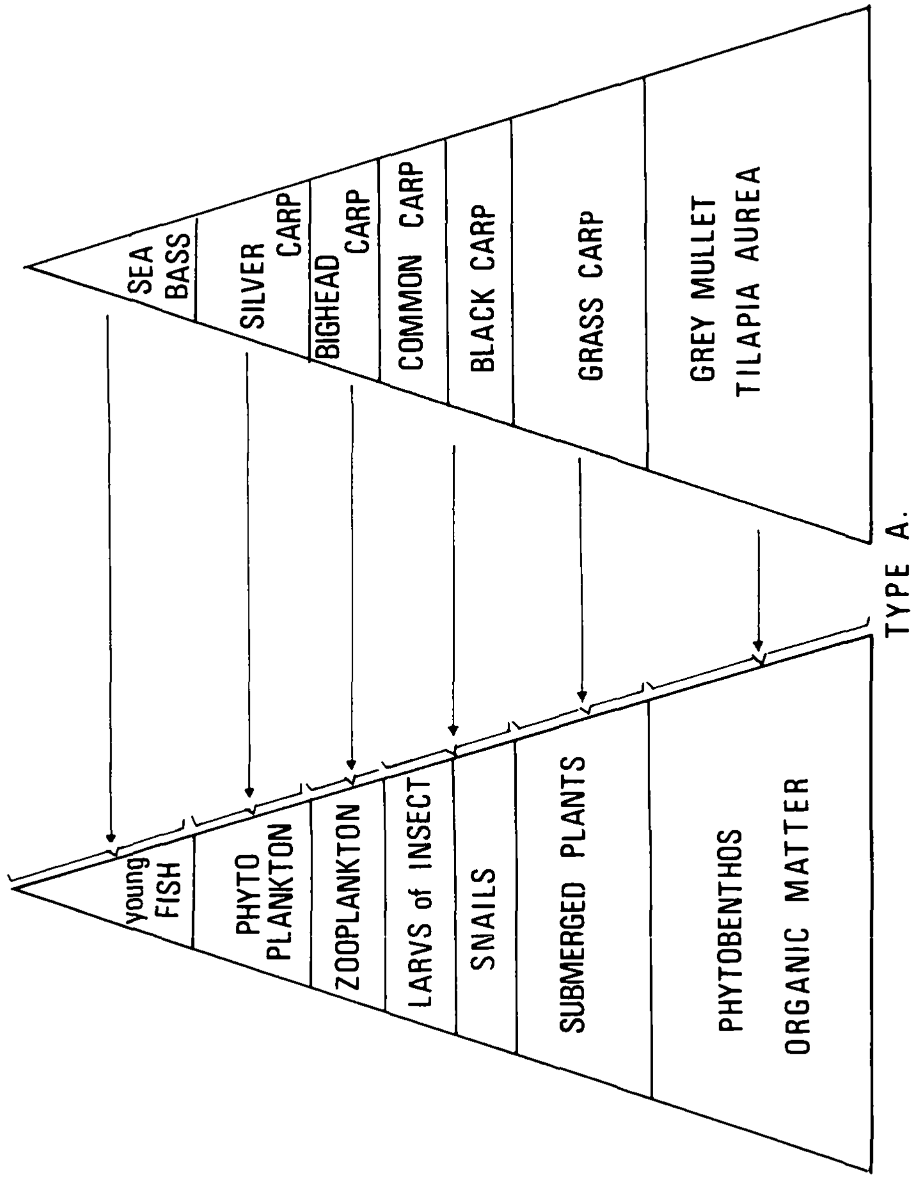


Fig. 16. Interlations between the standing crop of fish-food biota and the stocked fishes of ecologically different species in reservoirs of type A (Tsalmon, Eshkol).

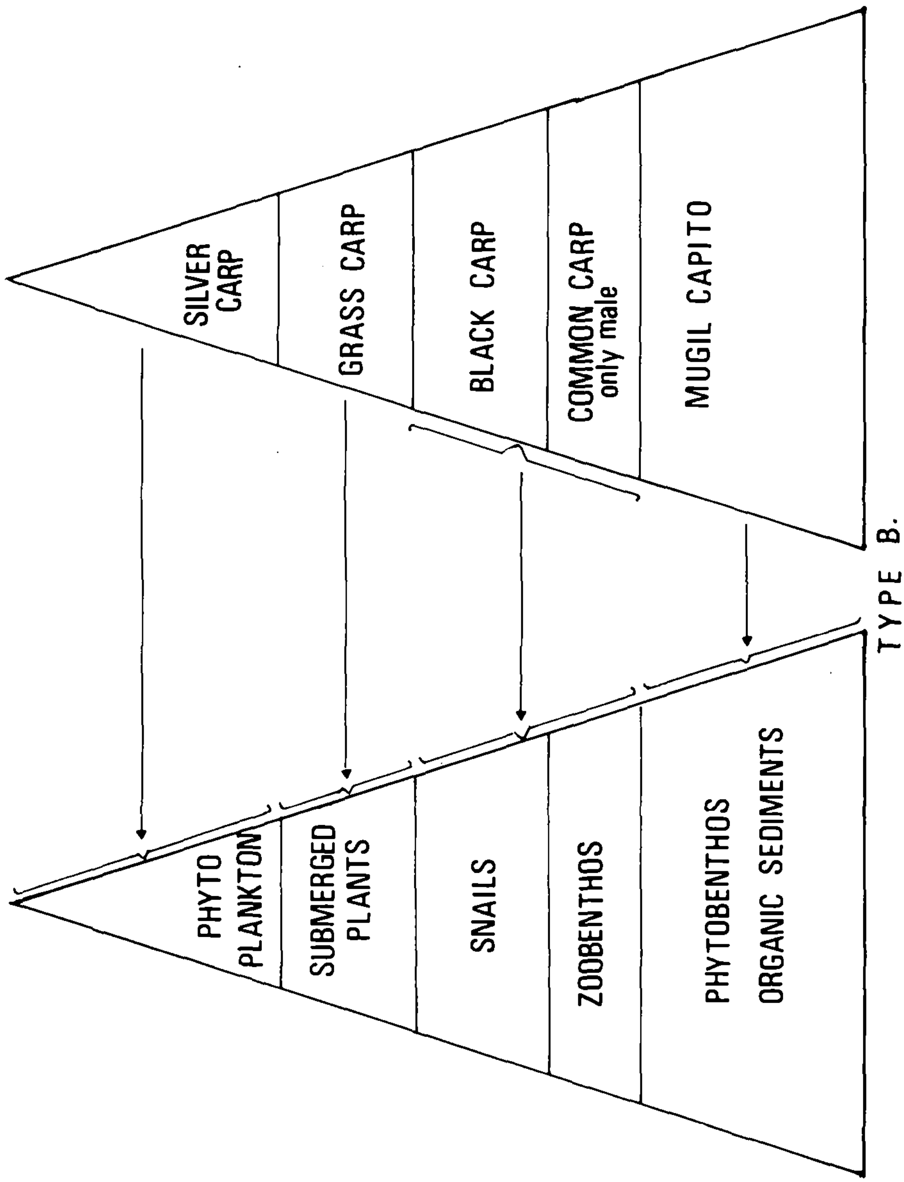


Fig. 17. Interlations between the standing crop of fish-food biota and the stocked fishes of ecologically different species in reservoirs of type B (Kula, Pedaya, Ramle, Zemuroth, Tekuma).

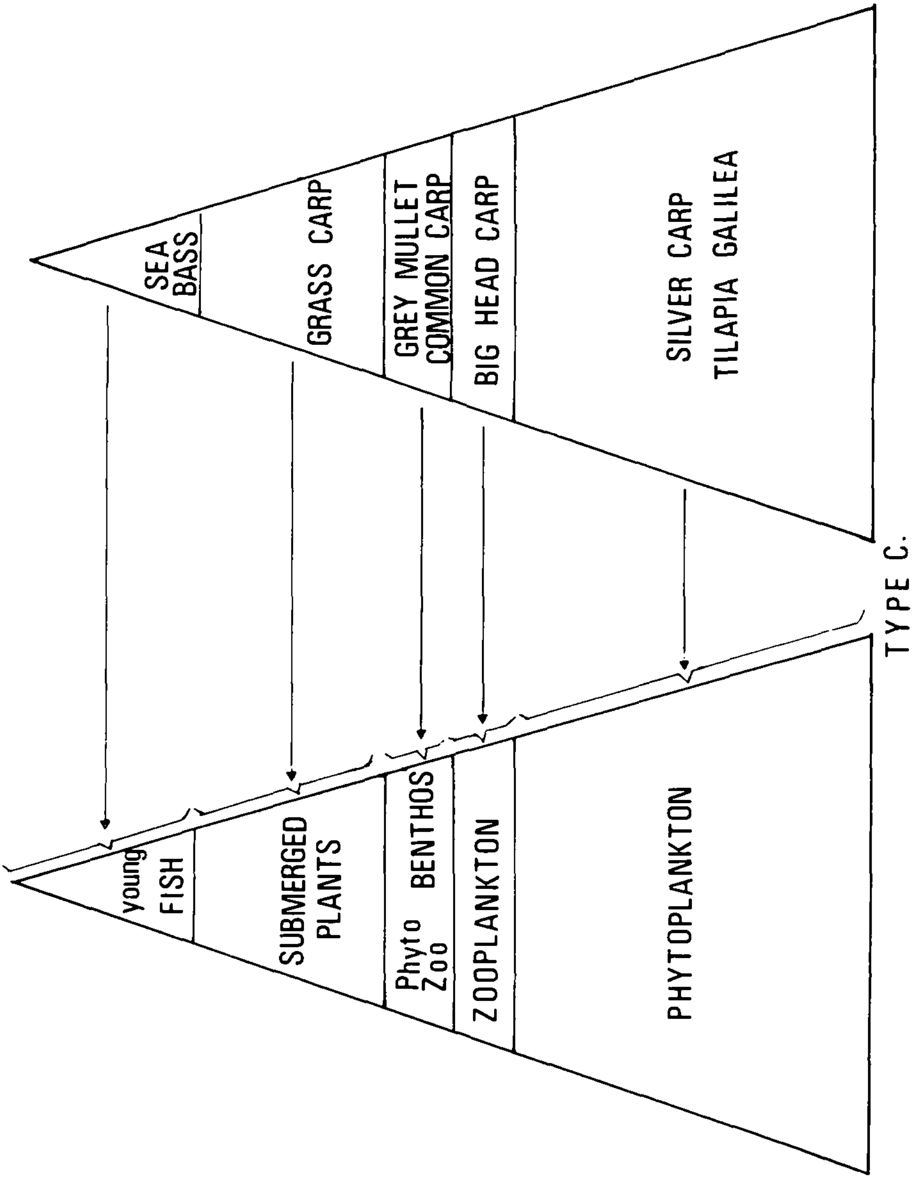


Fig. 18. Interlations between the standing crop of fish-food biota and the stocked fishes of ecologically different species in reservoirs of type C (Zohar, Kfar-Baruch).

5.1 SILVER CARP – *HYPOPHALMICHTHYS MOLITRIX*

The Silver carp comes from China. It subsists on Phytoplankton, Rotifera and occasionally also larvaes of aquatic insects. The algae are strained through a special formation located in the gills which have opening of 20 μ size (Wilamoski 1972). In the examination of Silver carp from Israeli fish ponds (Spataru 1977) the alimentary tract was found to contain green algae, blue-green algae and rotifers.

Januszko (1978) who studied "The influence of Silver carp on eutrophication of the environment of carp ponds" found that the fish in low density not only did not reduce the development of phytoplankton but to the contrary, stimulated it.

In their experience, in fertilized fish ponds (290 kg/ha N and 47 kg/ha P_2O_5 per year) where the density of fish were 4000 carp/ha and 12,000 silver carp/ha, the biomass of algae in the ponds with silver carp was considerably higher than in ponds without silver carp.

Menzel (2974) mentioned that Silver carp did not reduce the quantity of algae but prevent their bloom.

In every reservoir the fish consume algae found in the water. In the Tsalmon reservoir the fish subsisted in the period of January to May on the ***Peridinium cinctum*** alga (Fig. 19) and in the summer on the blue-green alga *Croococcus* and *Microcystis* (Fig. 20). In the Rosh-Haain reservoir they feed in the spring on the ***Dinobryon*** alga and in the autumn and winter on ***Diatoms***, ***Phacus*** and ***Euglena*** (Fig. 21).

Silver Carp feed in our reservoirs throughout all the year. In its alimentary tract food was found at temperature of 10^o to 29^o C. Table No. 4 shows that the food is rich in organic matter and nitrogen.

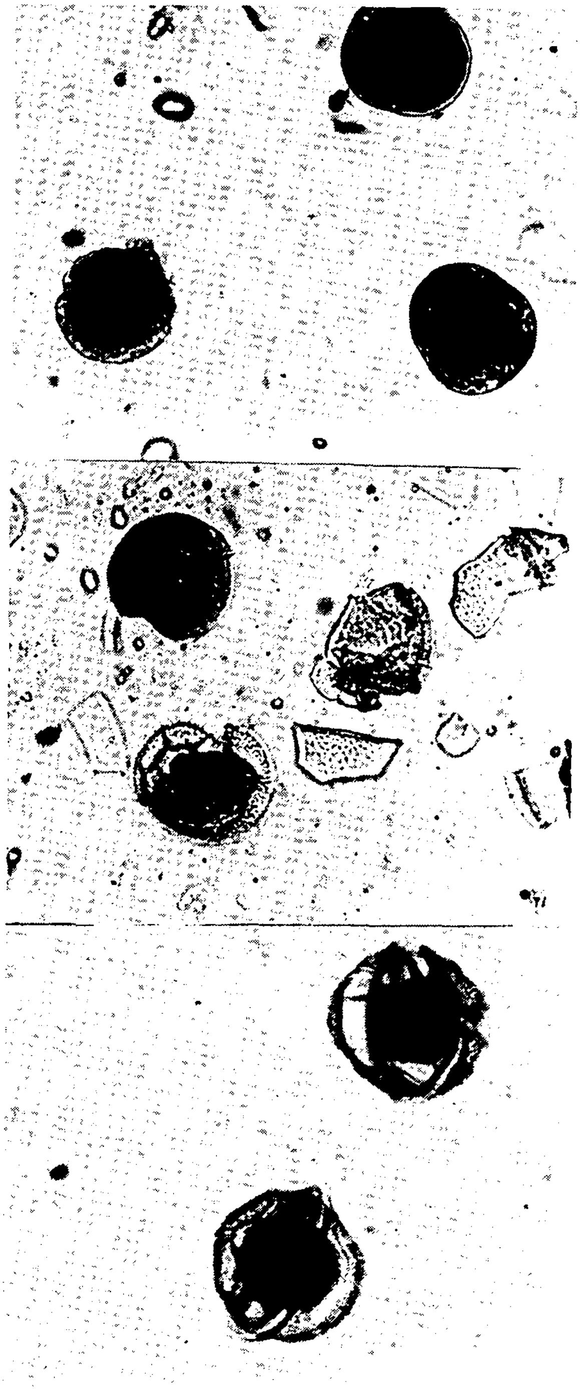
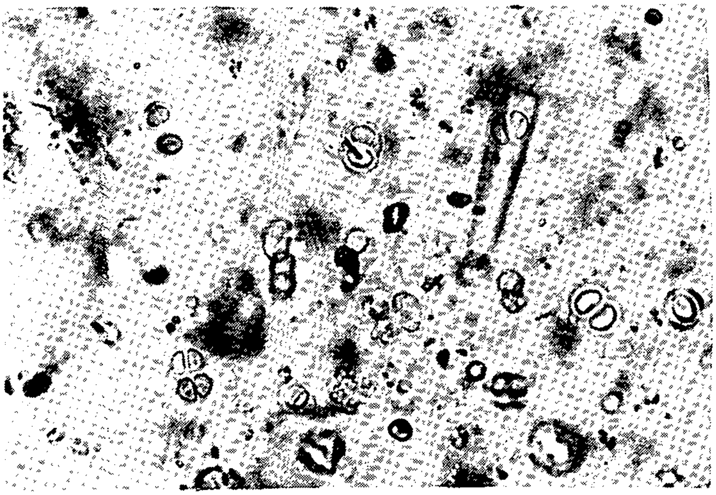


Fig. 19. The alga *Peridinium cinctum* from the intestinal contents of Silver carp fish in spring from Tsalmon reservoir.



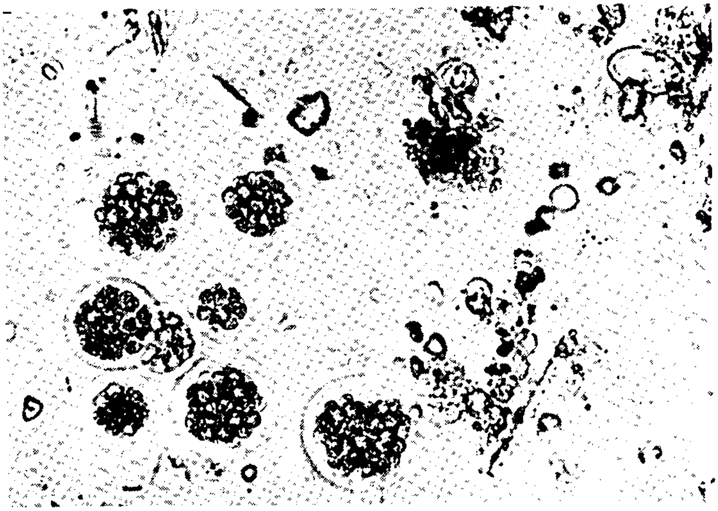


Fig. 20. The algae *Croococcus* and *Microcystis* from the intenstinal contents of Silver carp fish in autumn from Tsalmon reservoir.

Table No. 4 Quality and quantity of the food of the Silver carp from Tsalmon Reservoir.

Date	Weight of fish g.	Intestinal contents		Organic matter %	Kjeldhal nitrogen %
		Wet g.	Dry g.		
12.4.1976	250				
3.5.1976	350	21.8	4.2	61.9	2.94
30.5.1976	425	30.5	5.6	62.3	2.76
14.7.1976	520	31.4	4.9	56.1	2.86
22.9.1976	865	34.2	5.2	57.4	2.44
18.10.1976	940	28.6	4.9	44.7	2.35
5.12.1976	970	26.3	4.4	42.3	2.10
24. 2.1977	1200	64.3	12.4	55.3	2.70

Fig. 21 The algae, *Euglena*, *Peridinium minimum* and *Diatoms* from the intestinal contents of Silver carp fish from Rosh-Haain reservoir.

The growth rate of Silver carp varies from one reservoir to other. In the Tsalmon reservoir it reached in the first year the weight of 1,200 gr., and after four year 5,000 gr. Most of its growth takes place in the summer months (Fig. 22). In Lake Kinneret (Shefler and Reich 1977) and in Kfar-Baruch reservoir, Silver carp grows in its first year to 2 kg, in its second year to 5-6 kg., and in its third year to 6-10 kg.

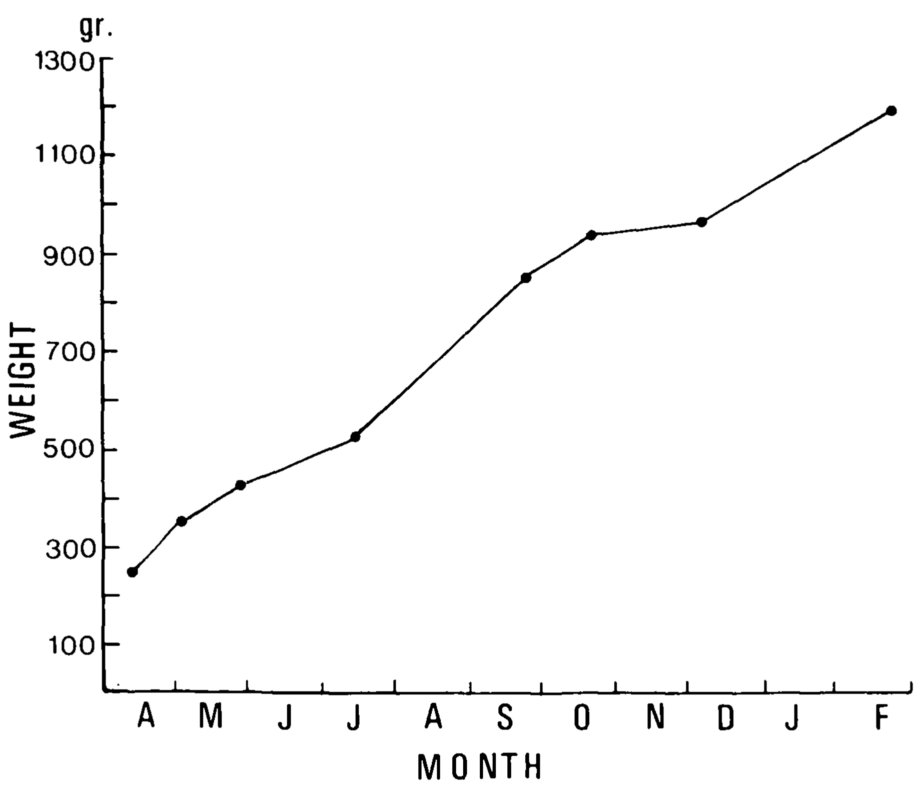


Fig. 22. Increase in weight of Silver carp during the first year in Tsalmon reservoir.

5.2 BIG HEAD CARP – *ARISTICHTHYS NOBILIS*

The big head carp is similar in appearance to the silver carp, but its colour is a darker gray. Its country of origin is China and it is usually considered as a fish feeding on zooplankton. Lazareva et al (1977) found in their study that the Big head carp is able to subsist on algae, shrimps, larvae of water insects and even on detritus.

In our reservoirs (Leventer and Peleg 1977) the zooplankton was composed of the Cladoceran: ***Bosmina, Moina, Daphnia*** and ***Ceriodaphnia***, and the copeod, *Cyclops*. The population of Cladocera is higher in winter and spring than in summer (Fig. 23).

After the introduction of the Bighead fish in the reservoirs the numbers of Cladocera were reduced to minimum.

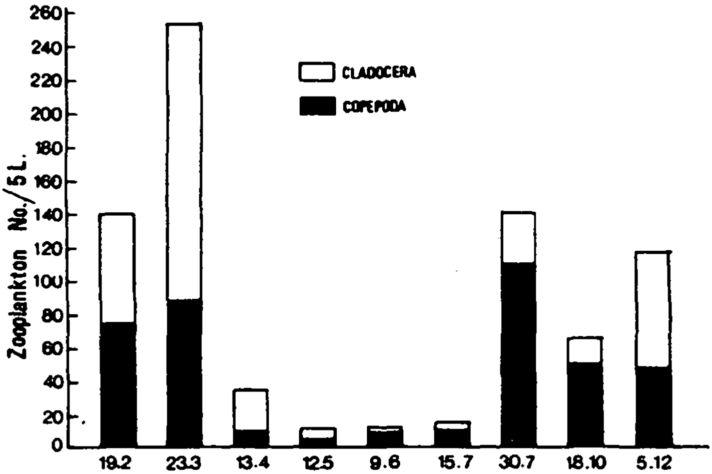


Fig. 23. The concentration of Zooplankton in Eshkol reservoir during the year 1976.

In our reservoirs, we found that the Bighead carp feeds on zooplankton and, having exhausted the supply to a minimum, that they search for food at the reservoir bottom. In its alimentary tract *Cypris* and filamenthous algae were found. The *Cypris* live among the algae, and swallowing of these algae was incidental.

Under the same conditions, the growth of the Bighead carp exceeds by 10 to 20% that of the Silver carp. In the winter months, at temperatures between 10^{o} to $14^{o}C$ the fish feed but do not gain weight. (see Table No. 5).

Table No. 5 The Quality of food in Bighead carp fish from Fish ponds during the summer 1978 and winter 1979.

Date	Weight of fish g.	Intestinal contents		
		Organic matter per cent	N. Kjeldhal per cent	Soil particle per cent
10.08.1978	600	23.20	1.32	75.48
15.10.1978	780	29.30	1.69	69.01
12.02.1979	800	10.20	0.90	88.90
18.03.1979	810	13.80	0.98	85.22
5.04.1979	810	13.00	1.10	85.90

Reduction of the zooplankton in the reservoir is significant. This is due to the fact that the rate of its multiplication falls below that of its consumption by the fish.

5.3 GRASS CARP – *CTENOPHARYNGODON IDELLA*

In some part of the world, Grass carp (Hickling 1971) is used in combating submerged plants. In addition to submerged plants Grass carp can feed on attached algae, larvae of insects and also fry. Young Grass carp weighting between 10 and 100 gr feed on algae and Crustacea.

In some of the reservoirs in our system, their submerged plants were composed of three groups: 1. *Potamogeton spp.*, 2. *Najas marina*, 3. *Chara vulgaris*. Their consumption by the fish was selective: the fish first took to *Potamogeton* and when this plant completely disappeared, the fish feed on *Najas* and finally to the plant-like algae *Chara vulgaris*. At the beginning we assumed that Grass carp did not feed on the two last named species, since one is prickly and the other has an unpleasant odor.

From our experience and other (Prowse 1971, Mintzner 1978, Lembi et al. 1978) we suggest that the behaviour of feeding of Grass carp in a reservoir with a multispecies of plants may be in this order:
Potamogeton – *Ceratophyllum* – *Najas* – *Chara* and at least filamenthous algae.

A great part of the plants which the fish eat there are excreted and settled to the bottom. In some cases there may be negative effects. If the plants contain red pigments they may impart color to the water. They also increase the concentration of orthophosphate and magnesium in the sediments. (Terrell 1975).

In reservoirs which had submerged plants the growth of fish was very good. After 4 years they reach 10 to 12 Kg in weight. Considerable differences were found between the weight of fish put into the reservoir at the same time and of the same initial weight. They varied from 4 to 12 kg in weight.

In reservoirs when the supply of submerged plants was liquidated, the fish feed on bottom fauna and on attached algae. They gained from 600 to 1000 gr. per year.

5.4 BLACK CARP – *MYLLOPHARYNGODON PICEUS*

In his study on "Classical method of fish breeding in China", Liu (1955) stated that Black carp was the principal species bred in fish ponds, They feed on snails and clams. When the food supply in the pond was exhausted additional food was brought from outside. In feeding on 134,650 kg of molluscs, 2,122 kg fishes grew in weight at the rate of 1 to 63. This high ration is due to the great weight of shells that have no nutritional value.

In our work, we were helped by Black carp in combating snails of the species: *Lymnea auricularia*, *Bulinus truncatus*, *Melania tuberculata*. The first trial took place in the two reservoirs of Pedaya (See Fig. 1), where one was used for experimenting and the other for control. The results were highly satisfactory: in the first reservoir the snails were completely eliminated, while in the other, (control) *Lymnea* was found to number 198 units per sq.m., *Bulinus* 31 per sq.m. and *Melania* 8 per sq.m.

The growth of this fish was different in some reservoir. In Ramle reservoir they reached in one year 600-800 gr and in some time in Zemuroth reservoir they reached 4 to 3 kg. Their growth depend on the density of the fish in the reservoir and the quality of food.

Populating the reservoir by Black carp was carried out once only, since after elimination of the snails, nu further additional stock was necessary.

5.5 COMMON CARP – *CYPRINUS CARPIO*

The common carp is one of the first fish which was breed in captivity. It is the main commercial fish in Israel's fish ponds, as well as in the Far East. It feeds on insect larvae, small snails and zooplankton. In searching for food at the reservoir bottom the turbidity increases and interferes indirectly with the development of submerged plants and attached algae.

The common carp (Israeli strain) has been effective in controlling filamenthous algae (Swingle, 1957; Shell, 1962; Grizzell and Neely, 1962; Avault et al, 1966). From our experience we know that the action of the fish has an indirect effect. The fish cut of the algae from the substrate as earth or concrete.

Owing to its ability to breed in reservoirs, use of common carp to populate the reservoirs is not accepted. In some reservoirs we use them in order to reduce the bethos and zooplankton.

The quantity of food in the reservoirs is so abundant that the fish reached in the first year the weight of 2–3 kg., in the second year, 4–6 kg. and after 5 years 10–12 kg.

In reservoirs of type B., Common carp males only were introduced in order to control snails. Every year the fish were removed from the reservoir and replaced by a fresh population. During the year the fish reached 1,300 to 1,800 gr. in weight, at a density of 150 fish per ha.

5.6 SEA BASS – *DICENTRARCHUS PUNCTATUS*

The sea bass is a predatory sea fish capable of living in fresh water, but unable to multiply in it. Its breeding season in the sea is in the autumn. The fry enter in lagoons in winter months.

At the CNEXO laboratories in France it was found possible to obtain fry of Sea bass by inducing spawning in artificial conditions and to grow the fry successfully. Every year we import from France the necessary quantity of fry, the fish weighing 0.4 to 0.8 gr. Further growth and adaptation to fresh water takes place in containers up to the weight of 2–3 gr., the food used being the same as given to trout. The small fish are put directly in the reservoirs.

Sea bass is capable of preying fry when reaching 5 gr. in weight. The growth is different in fish ponds and in reservoirs. In fish ponds they reach in the first year 50–60 gr., and in the second year 150–200 gr. In subsequent years it grows faster. In Eshkol reservoir they reached in the first year 200–250 gr. and in the second year 600–700 gr. Sea bass arrived accidental to Lake Kinneret when fry of Grey mullet where introduced. The fish which were caught weighed between 4.5 to 5.3 kg.

In fish ponds they prey on young fish of Tilapia and in the reservoirs young fish of *Tilapia*, *Mirogrex*, *Clarias* and *Common carp*.

5.7 *TILAPIA AUREA*

Some of the system's reservoirs are reached by three species of *Tilapia* from Lake Kinneret : *T. aurea*, *T. galilea*, and *T. zillii*. They differ one from the other in their feeding habits. *T. aurea* looks for its food on the reservoir bottom; *T. galilea* feeds on algae and *T. zillii* feeds on submerged plants and on attached algae. All three species multiply in the reservoirs, the most prolific being *T. zillii*. The natural increase of *T. aurea* is not great and it is necessary to add fry to the reservoirs.

The origin of *Tilapia* fish is in the tropic and subtropic region. They cannot live at temperatures below 10° C.

Tilapia aurea introduced in the reservoirs, has made an important contribution by reducing the amount of organic matter accumulated on the reservoir bottom. In an investigation of the quantity and quality of food in its alimentary tract (Leventer 1972) food was found throughout the year (Fig. 24 and Table 6) with a concentration of organic matter varying from 32% to 63%. The remaining components of the contents were soil particles. In the sediments the quantity of organic matter varies from 10 to 13%. This fish looks for its food selectively and takes it from the upper film covering the reservoir bottom, especially the algae Peridinium which settle at the bottom (see Table 7).

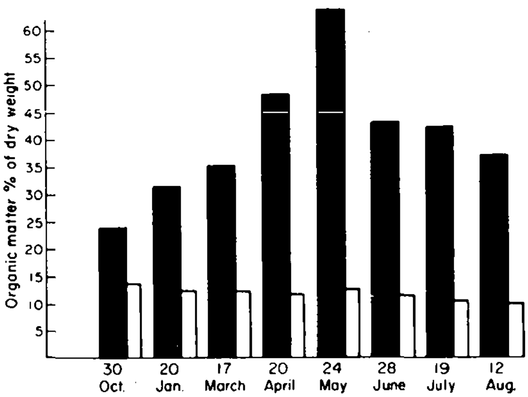


Fig. 24. The concentration of organic matter in the food from the intestinal contents of *Tilapia aurea* fish and from the bottom sediments of Tsalmon reservoir.

Table 6 Quality and quantity of foods in 1 kg. of *Tilapia aurea* and chemical quality of sediments on bottom of Tsalmon reservoir in 1971.

Date	In fish intenstines						On reservoir bottom	
	Wet wt. g.	Dry wt. g.	Organic matter %	Carbon %	Nitrogen %	Carbon to nitrogen ratio	Organic matter %	Nitrogen %
20.1	41.3	9.95	31.79	21.3	2.19	10 : 1	12.4	0.70
17.3	59.6	13.7	34.5	23.1	2.58	9 : 1	12.4	0.96
20.4	44.0	8.6	47.4	31.8	2.97	11 : 1	12.1	0.74
24.5	48.8	8.7	63.4	42.8	2.66	16 : 1	12.9	0.77
28.6	53.4	12.1	42.3	28.3	1.7	17 : 1	12.0	0.80
19.7	30.4	6.4	41.2	27.6	3.03	9 : 1	11.2	0.75
12.8	36.8	10.3	36.8	24.7			10.6	

Table 7: Number of *Peridinium cinctum* cells and chemical composition of food in *Tilapia aurea* fish in the Tsalmon Reservoir on April 20, 1971.

Weight of fish g.	Number of Peridinium cells per g.	Wet material g.	Dry material g.	Organic Material %	Carbon %	Nirogen %	Carbon to Nitrogen ratio
100	68.10^5	9	2.50	43.3	29.1	3.03	9 : 1
300	47.10^5	17	3.70	50.0	33.5	3.16	10 : 1
500	27.10^5	16	3.43	46.9	31.4	3.05	10 : 1
600	48.10^5	31	6.67	50.6	33.9	2.92	11 : 1
700	52.10^5	24	4.49	44.9	30.1	2.99	10 : 1
800	$64.1C^5$	35	5.10	48.7	32.6	2.65	12 : 1

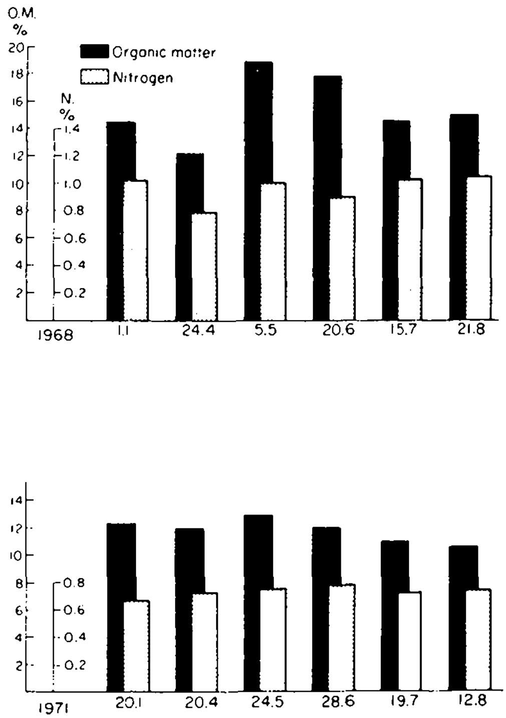


Fig. 25. The concentration of organic matter and nitrogen in the sediments of Tsalmon reservoir in the year 1968 and the year 1971.

In the course of three years, from 1968 to 1971, the fish which were introduced in the Tsalmon reservoir reduced the concentration of organic matter from 14–18 % to 12%, i.e. a reduction of over one fifth (Fig. 25). If we take into account that during that period additional organic matter was brought into the reservoir, the actual decrease is even greater. In 1978, after the passage of 10 years, the organic matter concentration at the reservoir bottom, had gone down to 7%.

The growth of *Tilapia aurea* in its first two years was very good, the fish reached the weight of 700 to 1300 gr. With the decrease in food supply, the growth rate decreased. The initial density was 300 fish per ha. In the course of time, the population grew by the natural increase. The density was sufficient for the biological control.

Despite its great effectiveness in eliminating organic sediments, *Tilapia aurea* is not used in reservoirs with frequent level fluctuation. The fry can penetrate into the pipelines and give rise to trouble.

5.8 GREY MULLET – *MUGIL CAPITO*

The *Mugillidae* live and multiply in the sea. The fry enter in rivers, *M. cephalus* do so in the monhts of November-January and *M. capito* in the months of December-February. After adaptation in fresh water, the fry are introduced directly into the reservoirs. Trials on growing them tilly they reach a 10 gr. weight in fishponds before introducing them to the reservoirs have failed; losses were high and the fry suffered in the transfer.

Grey mullet feeds on detritus. Its advantage compared to *Tilapia aurea* is that it does not breed in reservoirs. On the other hand, it is not always easy to obtain its fry. Two species of *Mugillidae* are used by us: *M. capito* and *M. cephalus*. *M. capito* grows more slowly, and the fish breeders take no interest in it, and we can reach them for populating the reservoirs.

In their alimentary tract numerous earth particles and attached algae were found, mainly diatoms algae. Their growth is slow: in the first year they reached the weight of 300-400 gr. and in the second year 600-800 gr.

6. DISCUSSION

The means employed today in dealing with biological ill effects in the water system can be classed as engineering, chemical and biological. There is general agreement that action is needed to counteract such ill effects, but views differ as to the choise of methods. In their paper on "Algicides – Frends or Foes" Sladeckova and Sladecek (1968) state that biological control of algae is best, since it does not affect the whole biological system. They consider, however, that under present conditions of algae bloom in reservoirs, the biological method is seen as a dream, rather than a practical method. In their view these is no alternative in dealing with algae in drinking water systems other than by chemical means. In Lakes and Reservoirs where it is necessary to preserve the biological system, they note that the use of algaecides calls for great care. Also Palmer (1964) considers that use of algaecides upsets the biological balance and that their continued use permits the growth of one algae species only, which may cause more trouble than the situation prior to such treatment.

Biological control by fish is slow, and its effects can only be ascertained after a long period which, at best, will be several months and, in other cases, a year or several years. Biological control is primarily intended to reduce the quantitative part of the biological activity. It can be viewed as preventive control. Some ecological niches can be modified by reducing the amount of organic matter on reservoir bottom or eliminating some links in the biological chain. Complete elimination is also possible of submerged plants, snails and fry.

The success of biological control will depend on Knowledge of the reservoirs and on a suitable composition of the fish population. In our system, we grouped the reservoirs into three types in accordance with the biological development taking place in them, which is determined by such conditions as: length of water detention, water replacement and level fluctuation.

Every fish species used by us has its own food habits; Grass carp prefers submerged plants, Bighead carp – zooplankton, Black carp – snails. When the preferred food is absent, the fish are able to feed on other food. Their growth rate and physiological condition will be better when the preferred food is available.

In contrast to fish breeders who look for good harversts, we are interested in biological control of the water than in fish breeding.

Through the establishment of a fish population composed of several species, a synergism arises in the reservoirs: Silver carp feeds on Phytoplankton, Bighead carp on Zooplankton. A great part of the strained material is eliminated and sinks to the reservoir bottom, where it is consumed by Tilapia aurea, Grey mullet, Common carp or Zoobenthos. The latter, in its turn serves as food for – Grass carp, Black carp and Sea bass.

In Israel's subtropical climate temperatures vary from 10°C. in the months of February – March to 25–29°C. during most of the remaining months. In the winter, bloom of the Peridinium alga takes place; in the spring growth of filamenthous algae occurs and in the summer growth of submerged plants. Snails multiply throughout the year.

Some of the fish employed by us in biological control, such as Grass carp and Common carp, do not feed in the winter, whereas Silver carp and Bighead carp do feed throughout the year. In the spring of every year there is a short period of one or two months when filamenthous algae and submerged plants reappear, but these are later consumed by the fish.

6.1 MANAGEMENT OF FISH POPULATION

The fish employed in the biological control of drinking water reservoirs are breed commercially in the Far East. The usual density (Tang 1970) in fish ponds and in reservoirs is as follows:

Species of fish	Number of fish Fish pond	Reservoir
Silver carp	3,500/ha	400/ha
Grey mullet	9,000 "	200 "
Bighead carp	500 "	15 "
Grass carp	200 "	80 "
Common carp	10,000 "	200 "
Sea perch	300 "	50 "

In fish ponds breeding is intensive; the fish receive supplementary food and the density is therefore high. In our conditions, we have not yet reached optimum density. A continuous survey is conducted in every reservoir, the biological development is examined and addition or removal of fish from the reservoir if necessary.

From examining the contents of the alimentary tract in the fish, we came to the conclusion that is desirable to have in a reservoir several sizes of the same species. Fish that weigh between 100 and 500 gr are generally more effective for our purposes than big fish.

Reservoirs of Type A are annually populated with Grass carp, Bighead carp, Black carp, Silver carp, Grey mullet and Sea bass, at a density of between 20 and 200 fish per hectare. The natural population increase of Tilapia aurea and Common carp is sufficient to meet requirements.

Suitable nets are used every year to remove big fish. Once in 5 to 8 years according to the development of the fish population, the type A reservoirs are drained, all the fish is removed, and, after refilling a new fish population is introduced.

Reservoirs of Type B are drained every spring and repopulated.

Reservoirs of Type C are never drained, nor is it possible to do so. If it is necessary to remove the fish it is done by use Pro nox fish. These reservoirs are populated annually with Grey mullet, Silver carp, Bighead carp and Grass carp, while fishing takes place to remove the large-sized fish.

6.2 FISH AND WATER QUALITY

In most reservoirs where biological control by fish is carried out the water is used for drinking. When supplied to consumers, it must be free from coliform bacteria and have no color, turbidity taste or odor.

Is it possible to populate drinking water reservoirs with fish? Our work has shown that this is indeed possible, provided the fish population is under control.

In their alimentary tract, the fish contain coliform bacteria, which are eliminated with their excrement and reach the reservoir bottom. In every reservoir we examined the concentration of coliform bacteria in the alimentary tract of the fish, in the sediments and in the water (Table No. 8). Despite the presence of coliform bacteria in the fish and on the reservoir bottom, their concentration in the water did not increase. On passing on from the reservoir to the pipe network the water is chlorinated and is free from the coliform bacteria.

Table 8: Coliforms in water, sediments and fish in Reservoirs.

Reservoir	Date	WATER		SEDIMENTS		FISH			
		Coliforms MPN/ 100ml	Fecal Coliforms MPN/ 100ml	Coliforms MPN/ 100ml	Fecal Coliforms MPN/ 100ml	Species	Weight g	Coliforms MPN/g intestinal contents	Fecal Coliforms MPN/g intestinal contents
Tsalmon	19.7.1971	49	11	168	0	Tilapia aurea	350	$9.3.10^3$	9.10^2
						Tilapia zillii	320	$1.2.10^3$	13
Eshkol	10.2.1972	22	4	11	1	Tilapia aurea	250	$2.6.10^4$	32
						Tilapia zillii	200	$2.1.10^4$	7.10^2
Zohar	13.8.1972	14	5			Tilapia aurea	210	$6\ .10^3$	$2.9.10^3$
						Tilapia galilea	220	$9.5.10^2$	10
						Mugil capito	550	$1.1.10^4$	$4.8.10^2$
						Cyprinus carpio	400	10.10^3	5

The water in the Israel National Water System suffered in the past from a fishy after-taste caused by the *Peridinium alga* and from an earthy-musty odor caused by the blue-green alga *Oscillatoria chalybea* (Leventer and Eren 1970). With the aid of suitable fish we succeeded in combating these two trouble factors.

In addition to these causes of trouble, there is another factor of objectionable taste and odor in the water, appearing regularly in the early spring. This effect is caused by the decomposition processes on the reservoir bottom. During the winter settled and accumulated organic matter at the bottom and with the increase of the temperature the decomposition process is intensified. The decomposition products can be oxidized by chlorination.

All reservoirs show increased turbidity when their level drops. Such turbidity will increase in the presence of fish, mainly Common carp. In reservoirs where level fluctuation regularly occurs in their operation, we avoid introducing Common carp.

The risk of deterioration exists in water when high fish mortality occurs. Of the fish species used by us in biological control, *Tilapia aurea* cannot survive at temperature below 10^{o} C. When in the winter the water temperature drops below 10^{o} C. there is a mortality of this fish. When this happens, the small fish sink to the bottom and decompose, while the large ones float on the surface. Since the temperature is low, decomposition is slow and it is possible to remove the floating dead fish and thus prevent harm to the water quality.

6.3 RESULT OF BIOLOGICAL CONTROL

Biological treatment in the system's reservoirs began in 1968. According to the sequence of appearance of troubles, we had to deal with their causes in the following order: a. Taste and Odor caused by algae, b. Submerged plants, c. Snails, d. Fry, e. Phytoplankton, f. Zooplankton. Experience in combating taste and odor has been accumulated over a period of 10 years, but action on Phytoplankton and Zooplankton began only three years ago.

a. Treatment on objectionable taste and odor in water

Owing to the combined treatment of chlorination as an algistatic measure against the Peridinium alga and the employment of the fish species of *Tilapia aurea*, *Silver carp* and *Grey mullet*, more than 95%

of the algae remain on the reservoir bottom and are consumed by the fish.

With the aid of *Tilapia aurea* and *Grey mullet*,we decreased the organic matter concentration on the reservoir bottom, modified the ecological conditions and eliminated the bloom of the blue-green alga *Oscillatoria chalybea.*

b. Submerged plants

With the aid of *Grass carp,* complete elimination was achieved of submerged plants in the reservoirs. This result came two years after the reservoirs were populated by fish. Grass carp was effective in combating the plant species of *Potamogeton spp., Najas marina* and *Chara vulgaris.* No secondary effects such as colouring of the water or increase of nutrients were observed.

c. Snails

With the aid of *Black carp* and *Common carp,* a decrease of the snail species of *Bulinus Lymnea* and *Melania* was achieved. Their natural propagation reaches the reservoir continuously, but the fish prevent the formation of large snail populations. In the open concrete canals a population exists of *Melanopsis costata* and *Theodoxa jordani* snails. No way has yet been found to eliminate them.

Both the snails fish species look for their food on the reservoir bottom. When the snails population decrease to a minimum, the fish start feeding on insect larvae and shrimps.

d. Fry

In some of the reservoirs lived a large fry population of *Mirogrex, Tilapia zillii* and *Clarias.* In the Eshkol reservoir a large population of Mirogrex appeared after 4 years. Numerous fry weighing 0.5 to 5 gr passed through the mechanical screens and reached all parts of the pipe network. Fig. 12. Owing to the lack of a solution for eliminating the fry, the reservoir was emptied and thus freed of the fry. This solution is good for 2 years only, since after 3 years a new large fry population is found.

In order to combat the fry, the Sea bass were introduced as a pradatory fish. The results of this measure is now in control, and we try to find the good relationship between the fry and the predators.

e. Phytoplankton

Reduction of phytoplankton in the reservoirs is achieved with the help of *Silver carp*, *Tilapia aurea* and partly by *Tilapia galilea* and *Bighead*. Up till now 4 species of algae have been dealt: *Peridinium*, *Cyclotella*, *Synedra* and *Chroococcus*. Positive results have been obtained in control of the alga *Peridinium*, whereas the results on the other species are partial. In reservoirs that have phytoplankton, its amount varies from 2 to 4 ppm. dry material. A Silver carp of 1 Kg weight takes in into its alimentary tract about 10 g. of dry food per day, which is equivalent to straining 3 to 5 m^3 of water. To strain all the water in a reservoir of 4 million cu.m. capacity (Eshkol reservoir), these would be need for 1,000,000 Kg of fish. In one reservoir we have no such density nor do we wish to have it, since it would affect the water quality.

With the aid of Silver carp, we are able to reduce by at least 25% the amount of algae and can in addition, prevent their bloom. A reduction at the rate of 1.0 to 1.5 ppm dry material is very significant for our reservoirs.

f. Zooplankton

With the increase of Phytoplankton in the reservoirs, also Zooplankton began to multiply. The zooplankton is composed of the *Crustacea* species of *Cyclops*, *Bosmina*, *Moina and Daphnia*. The Bighead carp is highly effective in keeping their numbers down. In reservoirs when the zooplankton became scarce, the fish turned to zoobenthos and mainly to *Ostracoda*, (Fig. 26) *Gammarus* and *Athayphyra*. (Fig. 27).

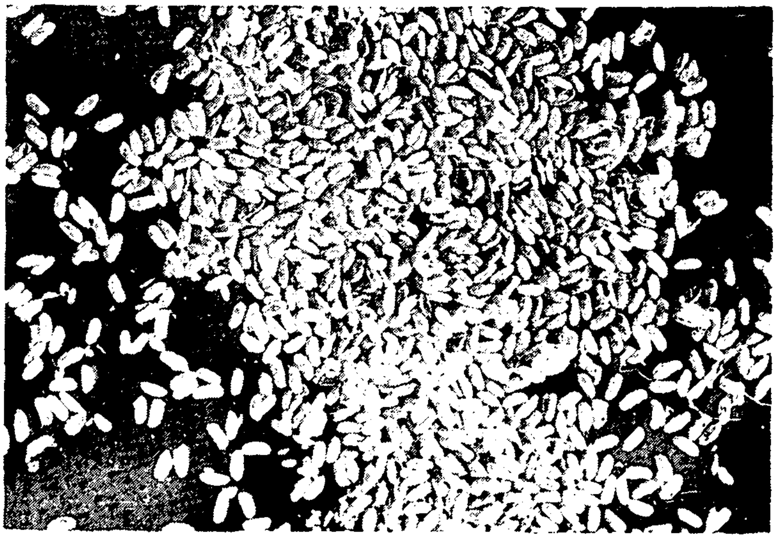


Fig. 26. *Cypris sp.* (Ostracoda)

Fig. 27. The shrimps *Athayphyra desmaresti*

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