Feeding behaviour of silver carp *Hypophthalmichthys molitrix* Val. and its impact on the food web in Lake Kinneret, Israel

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Abstract

Silver carp *Hypophthalmichthys molitrix* Val. have been stocked in Lake Kinneret, Israel, since 1969. From 1972 to 1981, 11×10^6 fingerlings were introduced into the lake. Total silver carp catch however was only 642 during this period, resulting in a progressive increase in the silver carp population.

Silver carp feed mostly on phytoplankton from February through August. From September to January, sampled gut contents contained predominantly zooplankton. Indices of electrivity for zooplankton were positive from September to December, negative during January to August and vice versa for phytoplankton.

Predation pressure of planktivorous fish on zooplankton in Lake Kinneret has been intensified recently. It is likely that accumulation of silver carp in the lake supported this process.

Silver carp compete with commercially valuable native fish species by feeding on the same zooplankton resources during summer and fall. Additionally, the grazing population of microcrustaceans is reduced at the time it is needed to prevent microalgae blooms.

Market demands for silver carp are low, catchability of this fish is poor and it can be cultured efficiently in ponds. Consequently it is recommended to stop the stocking of silver carp in Lake Kinneret.

Introduction

The exotic fish, silver carp (*Hypophthalmichthys molitrix* Val.), was introduced from Japan to Israel in 1966 (Yashouv *et al.*, 1970). Following a restricted series of acclimatization experiments in ponds at the Aquaculture Research Station, Dor, during 1966–1968, the fish was planted in Lake Kinneret in 1969 (Golani, 1980, 1981; Yashouv, 1970). The annual catch of silver carp in Lake Kinneret varied between 10 and 187 tons during 1974–1981 (Table 1), and was composed primarily of large individuals (10–25 kg/fish).

The decision to introduce silver carp into the natural ecosystem of Lake Kinneret was based on the following (Shefler & Reich, 1977):

1. Phytoplankton in Lake Kinneret is consumed by native fish species to a small extent only.
2. The silver carp is thought to be an exclusively phytoplanktivorous species.
3. The high temperatures existing in the lake can initiate a high rate of growth for silver carp.
4. Silver carp cannot reproduce under natural conditions in Lake Kinneret. It should therefore be possible to remove it by intensive fishing if the fish should be found unsuitable for the Kinneret ecosystem.

Thus, disregarding precisely features of this species which might affect the ecological equilibrium (Spataru & Zorn, 1976) and without information on its feeding habits in Lake Kinneret, a massive introduction of fingerlings of silver carp was initiated in 1973 and onwards.

Silver carp has an exceptional filtering mechanism due to its very fine mesh gill rakers (30–40 μm) and sponge-like raker net (Wilamovski, 1972). Cap-

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Table 1. Fish stocking and fishery activities in Lake Kinneret during 1969–1981 (Sarid, 1969–1979; Golani, 1980–1981).

Year	H. mol.			S. gal. + O. aur.			Bleak		
	C	%	Int.	C	%	Int.	C	%	Total
1969	–		40	314	20	2355	886	57	1551
1970	–		40	289	16	3144	1152	63	1830
1971	–		–	312	15	3235	1209	56	2159
1972	–		120	212	12	3140	1016	58	1746
1973	–		634	180	12	1800	969	63	1543
1974	11	0.7	1330	124	9	5050	949	65	1467
1975	23	1.5	665	205	13	5124	1017	65	1571
1976	29	1.4	800	426	20	4750	1248	59	2108
1977	35	2.0	1860	200	16	4856	1027	59	1735
1978	70	4.1	1100	278	16	2250	902	53	1692
1979	108	5.0	1400	371	17	2000	1313	61	2139
1980	187	9.5	1700	392	20	2200	852	43	1977
1981	179	9.5	1500	288	15	2750	965	51	1878

H. mol. = silver carp (Hypophthalmichthys molitrix).
S. gal. = Sarotherodon galilaeus (= Tilapia galilaea).
O. aur. = Oreochromis aureus (= Tilapia aurea).
Bleak = Mirogrex terraesanctae-terraesanctae and Acanthobrama lissneri.
C = annual catch in metric tons and % of the total (%).
Int. = number of introduced fingerlings in thousands.
Total = annual total catch in Lake Kinneret.

ture of this fish is difficult however because it frequently (50%) jumps out of nets (Spataru, unpubl. data) and causes damage to them (Fishermen's Organization, pers. commun.).

Fishery and introduction

Information on fishing and introduction activities of silver carp in relation to other commercial fish in Lake Kinneret is presented in Table 1 (Golani, 1980–1981; Sarid, 1969–1979; Sarig, 1982). Annual catches of silver carp were very low (0–70 tons) between 1970 and 1978, while since 1978 4–10% of the total catch has been silver carp. In comparison, *Tilapia* spp. and bleaks have represented 9–20% and 43–65% of the total catch, respectively (Table 1). The number of introduced silver carp fingerlings varied between 0.63×10^6 and 1.86×10^6 per year during 1973–1981, compared to 1.8×10^6 and 5.1×10^6 fingerlings of *Tilapia* spp. during 1969–1981 (Table 1).

Presented here is an investigation of the food habits of silver carp in Lake Kinneret and the resulting impact on the trophic resources of the lake.

Materials and methods

Silver carp specimens for the analysis of food ingestion were collected from the commercial purse seining catch from various parts and depths of Lake Kinneret. Fish samples were collected monthly from November 1973 to October 1974, and seasonally until 1979. A few specimens were also collected in 1980 and 1981. Total number of sampled fish was 260. The sizes of sampled fish varied between 12.7 and 94 cm SL and 0.12 to 17.00 kg, respectively. Size diversities of sampled fish were similar throughout seasons. Therefore, gut contents, expressed as number of food items per fish, are comparable.

Sampled fish were weighed and measured immediately after being caught. The intestines were removed and placed in 6% formaldehyd solution. Food items were determined qualitatively and quantitatively with a Wild M40, inverted-microscope equipped with an Utermohl's eyepiece (Utermohl, 1958) and 530.66 sq mm plate chamber. Assessment of food components biomass in the gut contents was based on available data of phytoplankton (Berman & Pollingher, 1974), and zooplankton (Gophen, 1973) species biomass.

The degree of digestion of ingested food items was determined by relative comparison of the degradation of food items in various intestinal segments. The degree of digestion of a certain food item traversing the intestines, from the esophagus to the rectum, indicated the role of this food in the nutrition of the fish (Spataru, 1976; Spataru & Zorn, 1978).

Intestine indicies (II) were calculated by using the formula $II = LI\ LS^{-1}$, where LI = length of the intestine and LS = fish standard length. It was found that for several individuals intestines were 10 times longer than body length, typical of phytoplanktophagous fish.

To estimate the degree of satiation (FI = index of fullness), the following formula was used:

$$FI = w \times 100\ W^{-1}$$

where w is the weight of the gut contents and W is the weight of the fish. Utilization degree of the food by the fish is reflected by the condition factor (CF) of the fish. Condition factor values were calculated using the formula of Beckman (1948):

$$CF = W \times 10^5\ L^{-3}$$

where L = standard length, W = weight of the fish.

Index of electivity of the different food components was calculated using Ivlevs formula (1961):

$$E = (r_i - p_i)\,(r_i + p_i)^{-1}$$

where r_i = percentage of food components found in the gut of the fish, P_i = percentage of the same food item found in the entire water.

Results and discussion

Studies on the nutrition of silver carp were presented by Koyama *et al.* (1968), Morissens (1978), Vinogradov (1979), Cremer & Smitherman (1980) and others. It was found that this fish is phytoplanktivorous. Chiang (1971) and Ghosh *et al.* (1973) consider it to be mainly a consumer of Cyanophyta. Kajak *et al.* (1975) observed that in the presence of silver carp the quantity of blue-green algae in the water decreases, while Pyrrophyta and nannoplankton biomass increases. Lin (1969), Januszko (1974) and Spataru (1977) pointed out the importance of Chlorophyta and the tripton in the diet of silver carp. Gryierek (1973) and Opuszynski (1979) concluded that the silver carp has a decisive influence on the biomass of the zooplankton in a given ecosystem. All of these rather contradictory results were collected under different conditions. Parameters of a very high importance were different in these studies, such as size and age of the fish; density and relations of silver carp to other fish species; natural and artificial food availability; geographic location; and the ecological type of the studied ecosystems. It is therefore likely that investigation of the status of silver carp in the Kinneret ecosystem, as well as other exotic species, should be carried out independently. Nevertheless, data collected in other water bodies is possibly relevant to Lake Kinneret.

Average quantities and biomass of phytoplankton and zooplankton food components analyzed in 260 silver carp are shown in Table 2 and in Figs. 1 and 2. It is clear that the zooplankton portion of the ingested food was 50% or more from September to January, while from February to August it was less than 50%. Food (phytoplankton and zooplankton) quantities in the fish guts were above 50 g (w.w.)

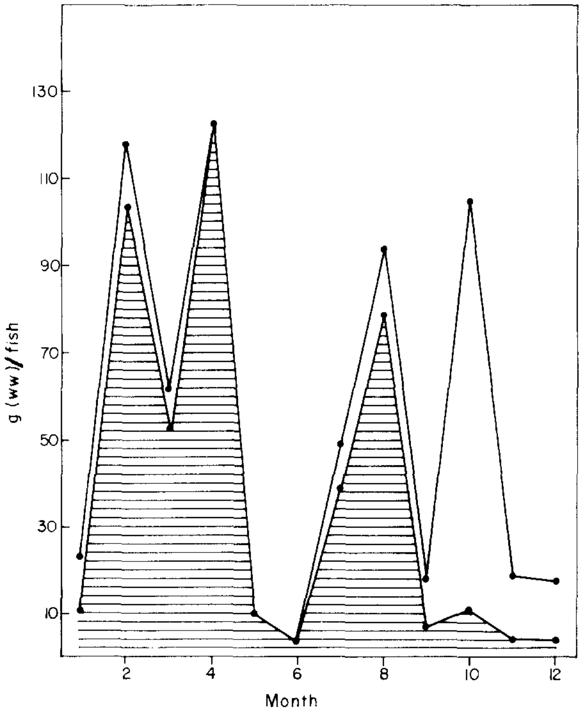

Fig. 1. Food (phytoplankton and zooplankton quantities ($g_{(w.w.)}$ fish^{-1}) (see text) in sampled fish

□ zooplankton

⊟ phytoplankton.

Table 2a. Analysis of gut contents of silver carp from Lake Kinneret.

Month	Zooplankton						
	Rotifer		Cladocera		Copepoda		Total zooplankton
	No.[a]	Biomass[b]	No.[a]	Biomass[b]	No.[a]	Biomass[b]	Biomass[b]
1	0.66	0.07	0.38	7	0.37	4	11.07
2	0.37	0.04	0.71	3	1.05	11	14.04
3	1.42	0.14	0.26	5	0.35	3	8.14
4	0.11	0.01	0.01	0.14	0	0	0.15
5	0	0	0	0	0	0	0
6	0.66	0.07	0	0	0	0	0.07
7	0.02	0.002	0.02	0.37	0.38	9	9.37
8	0.34	0.03	0.25	5	0.06	10	15.03
9	0.08	0.08	0.41	8	0.27	3	11.08
10	0.06	0.006	0.05	0.87	4	93	93.87
11	0.02	0.02	0.07	2	0.53	13	15.02
12	2	0.18	0.44	8	0.26	6	14.18

[a] No. = 10^6 zooplankters: fish.
[b] Biomass = $g_{(w.w.)}$: fish.

Table 2b. Analysis of gut contents of silver carp from Lake Kinneret.

Month	Phytoplankton						
	Cyanophyta		Pyrrophyta		Chlorophyta		Total phytoplankton
	No.[a]	Biomass[b]	No.[a]	Biomass[b]	No.[a]	Biomass[b]	Biomass[b]
1	19	0.95	0.09	9	6	1.26	11.21
2	110	5	0.59	68	35	31	104
3	18	0.90	0.54	52	3	0.50	53.40
4	0.04	0.02	1.18	122	0.53	0.08	122.10
5	39	1.93	0.07	8	0.01	0.001	9.93
6	0.13	0.66×10^{-3}	0.04	4	0.09	0.05	4.05
7	35	4	0.38	35	0.74	0.15	39.15
8	915	46	0.41	33	0.52	0.09	79
9	6	3	0.06	4	0.16	0.03	7.03
10	123	6	0.07	5	0.29	0.14	11.14
11	33	2	0.04	2	0.17	0.02	4.02
12	0.56	0.03	0.04	4	0.43	0.09	4.12

[a] No. = 10^9 cells: fish.
[b] Biomass = $g_{(w.w.)}$: fish.

ind.$^{-1}$ during February–April, August and October. In October zooplankton was most abundant, while during February–April Pyrrophyta *(Peridinium)* and some Chlorophyta were very abundant. In August, Cyanophyta *(Microsystis)* and Pyrrophyta *(Peridinium)* were dominant.

In terms of zooplankton biomass, cladocerans and copepods were dominant in the alimentary canal of the fishes. Cladocera was dominated by *Ceriodaphnia reticulata* and *Bosmina longirostris,* whereas dominant copepods were *Mesocyclops leuckarti* and *Eucyclops serrulatus.*

In September and January silver carp consume phytoplankton and zooplankton in approximately the same quantities. It follows that the decrease of phytoplankton biomass in Lake Kinneret during summer–fall (Pollingher, 1978) is reflected in the silver carp diet by a change from phytoplankton to zooplankton during this period. Due to the large month opening and the fine structure of the filtering apparatus (Fang, 1928; Yokote, 1956; Wilamovski, 1972), silver carp collect, by filtering activity, large

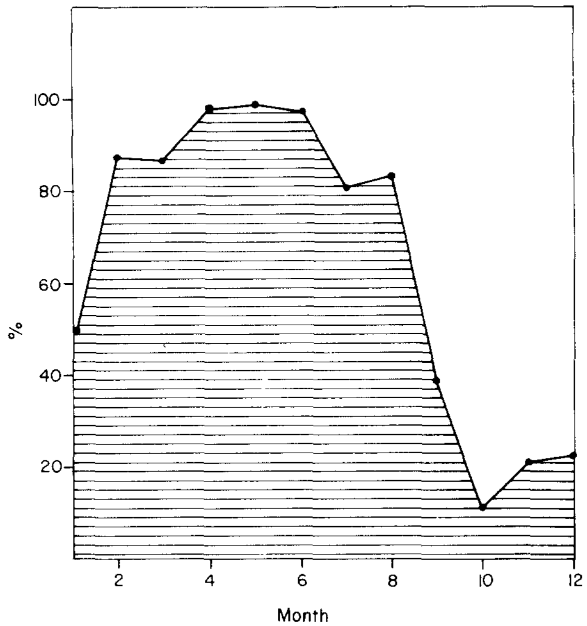

Fig. 2. Food (phytoplankton and zooplankton) composition (%) in sampled fish
□ zooplankton
⊟ phytoplankton.

quantities of suspended food particles, including cyclopoids and Cladocera. Ingesting a high biomass of cyclopoids, which has higher escapability than Cladocera (Drenner *et al.*, 1982), is probably due to the strong sucking power and high filtering rate of the fish.

In Fig. 3 indices of gut fullness, satiation indices and condition factors are presented. It is likely that growth conditions for silver carp are suboptimal during the summer (CF = 1.78) when the satiation index is lowest (3.96). In autumn and winter satiation indices increase from 5.60 and 5.05, respectively. In fall and winter condition factor values are higher than in summer (2.20 and 2.30, respectively), probably due to increasing zooplankton and phytoplankton densities and a decline in temperatures. At the low temperatures in fall and winter fish food requirements are lower than in the summer and food is more available, resulting in a better growth condition. In the spring, during a heavy bloom of *Peridinium*, the satiation index was 4.64 and the condition factor was 2.25. Consequently, summer is the critical period for the silver carp population in

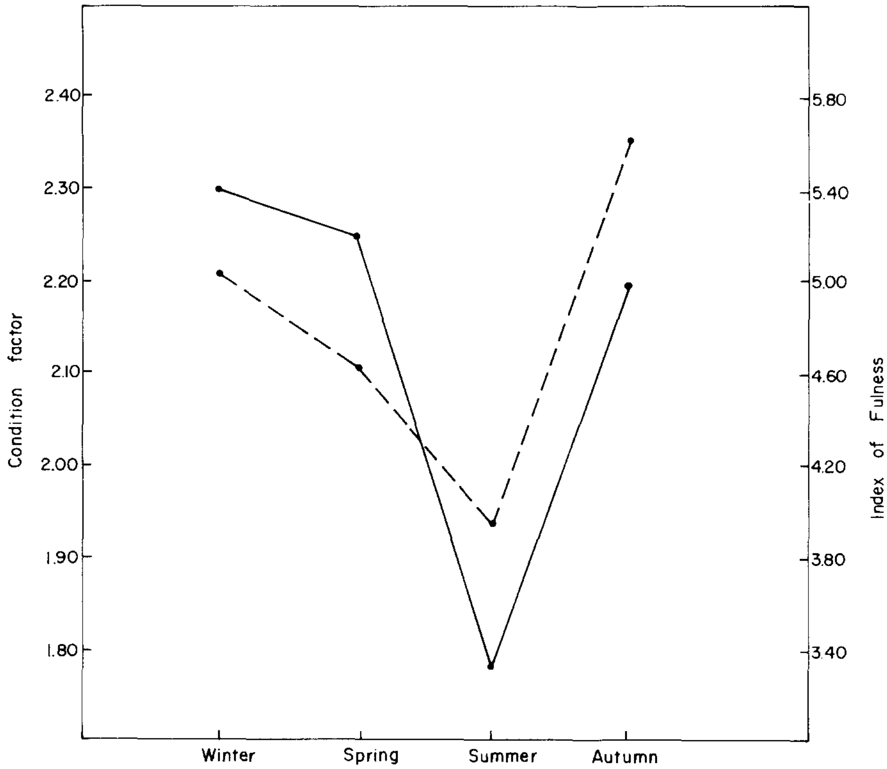

Fig. 3. Seasonal variations of FI (index of intestine fullness) and CF (condition factor) of sampled fish
●- - -● FI
● ● CF.

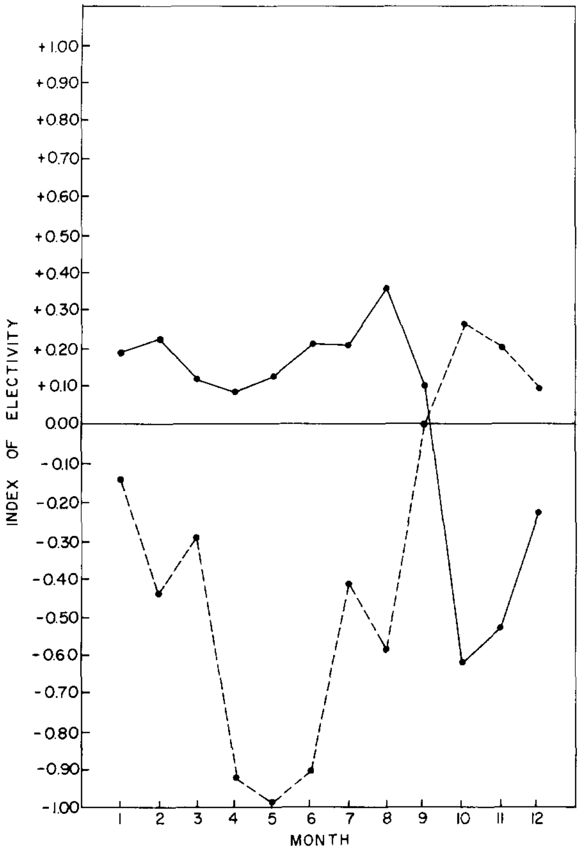

Fig. 4. Indices of electivity (E) for phytoplankton and zooplankton calculated for the sampled fish
●—● phytoplankton
●- - -● zooplankton.

Lake Kinneret. The food requirements of the fish are highest due to the high temperatures, but phytoplankton and zooplankton biomass is reduced. Reduction of zooplankton biomass during summer in Lake Kinneret is caused by fish predation pressure which is higher in summer compared to winter-spring time (Landau, 1979; Serruya *et al.*, 1980).

Preferential feeding behaviour as expressed by indices of electivity (E) is shown in Fig. 4. In Lake Kinneret, indices of electivity of silver carp for phytoplankton are positive during January-September and negative during October-December. Zooplankton indices are reversed. It is likely that silver carp collect suspended food items from the water mechanically rather than selectivity. During October-December, the biomass of phytoplankton is low and the indices of electivity are therefore distinctly negative (between -0.23 and -0.63). On the contrary, in winter-spring, when phytoplankton is very abundant, indices of electivity for algae are positive but low. The high biomass of *Peridinium* in the water raised zooplankton electivity to be very low. When phytoplankton is dominant micro-crustaceans and rotifers are filtered and ingested randomly together with the algae and indices of electivity for zooplankton are negative (from -0.009 to -0.99). Concerning the increase of zooplankton biomass in relation to phytoplankton in the lake during autumn (October-December), indices of electivity for zooplankters are positive but low (from +0.09 to +0.27). Consequently, it is likely that there is no selective feeding of silver carp in Lake Kinneret for phytoplankton or zooplankton. The silver carp consumes whatever is available in the natural plankton assemblage throughout the year. It follows that, contrary to the statement concluded by Reich (1978), the silver carp has no specific and stable niche in Lake Kinneret. Moreover, the commercial value of this fish is low because of fishing and marketing difficulties. We ask a simple question: Why should this fish be stocked in Lake Kinneret? Is there any economical or ecological benefit derived from stocking silver carp in the Kinneret ecosystem?

The silver carp indeed consumes large quantities of phytoplankton, but is also consumes zooplank-

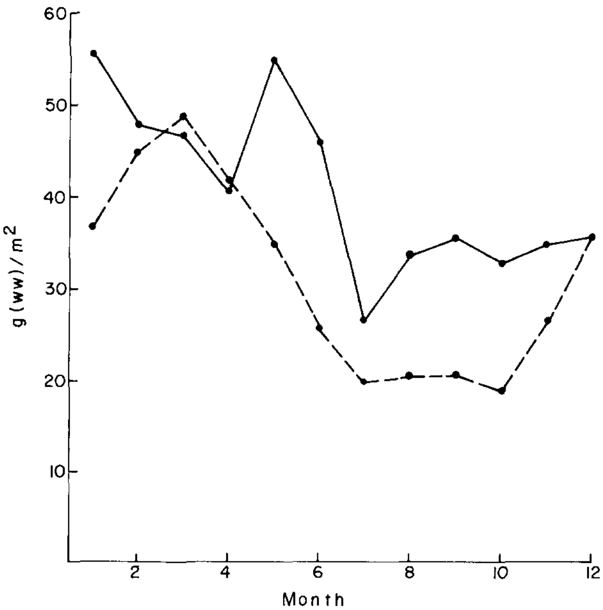

Fig. 5. Zooplankton biomass in Lake Kinneret. Averages of monthly averages for the periods:
1969–1974 (●—●), and 1975–1981 (●- - -●).

ton. Nevertheless, it has not been possible to clearly indicate a direct correlation between silver carp and phytoplankton densities in Lake Kinneret during the years 1969–1981. Probably the status of silver carp in Lake Kinneret is similar to that described by Opuszynski (1980), who determined it as the reason for the 'ichthyoeutrophication' process. We think that silver carp, among other fish, affected the zooplankton communities of Lake Kinneret. Zooplankton biomass in Lake Kinneret was slightly decreased recently (Gophen, 1981, 1982) (Fig. 5). The average of annual averages of zooplankton biomass for the period of 1975–1981 was lower by 22% compared to the average for 1969–1974. We think that the recent slight decrease of zooplankton biomass is mostly due to increasing predation pressure by fish, including silver carp. It was pointed out (Gophen, 1980, 1981) that other environmental conditions, such as temperature and food availability for zooplankton were optimal. The existence of zooplankton communities in Lake Kinneret is of great importance, particularly during summer–fall, for two reasons: 1) to produce a significant grazing pressure on nannoplankton in order to prevent summer–fall blooms that deteriorate water quality; 2) to support optimum fish growth (Landau, 1979, 1974–1981; Serruya *et al.*, 1980). Consequently management recommendations for Lake Kinneret are aimed at lowering zooplankton predation pressure by fish.

Reduction of predation pressure on zooplankton by fish may be achieved by eliminating silver carp and other exotic zooplanktivorous fish like *Oreochromis aureus (Sarotherodon aureus, Tilapia aurea)* (Spataru & Zorn, 1978) from the Kinneret ecosystem. Reduction of stock biomass of the zooplanktivorous endemic species, *Mirogrex terraesanctae-terraesanctae* (Kinneret sardine) (Gophen & Landau, 1977; Gophen & Scharf, 1981) is also recommended.

The summer ecosystem of Lake Kinneret was classified by Serruya *et al.* (1980) as a 'steady-state' type with nannoplankton, zooplankton and zooplanktivorous fish as major components. Increasing zooplanktivorous fish biomass, especially in the summer, will increase their total requirement. Consequently, the most available food, filter feeding zooplankters, will be preyed the heaviest by zooplanktivorous fish. Possibly increasing cladocerans productivity, and/or reduction of their stock biomass is expected. Results presented in Fig. 5 indicate that biomass reduction of zooplankton including Cladocera (Gophen, 1982) is likely. Consequently, organics accumulation as nannoplankton biomass is predicted. Nannoplankton blooms during summer–fall have already been observed in Lake Kinneret (Pollingher, 1978; Pollingher & Berman, 1974) and are probably due to a decrease in grazing pressure. If Cladoceran stock biomass is reduced, food requirements of the grazer assemblage in the lake is also lowered and there is a resulting carbon accumulation as nannoplankton biomass.

We suggest that the reduction in zooplankton biomass (Fig. 5) was partly due to a multiannual increase in silver carp stock biomass in the lake. This assumption is based on the following conjecture: Eleven million silver carp fingerlings were planted in Lake Kinneret during 1972–1981 (Table 1). If only 40% (if less, is it economically worthwhile?) of them survived, and if their life-span is 7–9 years, it is possible that the average body-weight of the survivors is 0.7 kg (Gophen, unpubl. data). So to say, stock biomass of silver carp in Lake Kinneret in 1982 can probably be approximated as 2 400 m.t.: the total stock was assessed as 3 080 m.t. (40% of 11×10^6, times 0.7 kg) of which 642 m.t. were fished (Table 1). Consequently an addition of approximately 0.7 g (w.w.) $m^{-2}d^{-1}$ of zooplankton biomass is needed as food for silver carp during summer months. We think that it can accelerate the increase of nannoplankton biomass. If the present stock biomass of this fish in the lake is 1–2 thousand tons and stocking will be stopped now, it will take a few years to fish all silver carp out of the lake. Therefore the negative impact of the fish on the system will continue even after stocking is stopped. The limited zooplankton biomass that can be channelled to fish in the summer–fall period should be utilized by the most advantageous fish in the system. It was found (Serruya *et al.*, 1980; Spataru, 1976) that *Sarotherodon galilaeus* are most advantageous in the Kinneret system. The reasons for this are: 1) this native fish consumes *Peridinium* very efficiently; and 2) it has a very high commercial value. It is most likely that the stocking of silver carp into Lake Kinneret should be stopped. The commercial value of silver carp is low and this fish can be intensively and efficiently cultured in ponds. If this fish is eliminated from Lake Kinneret, more zooplankton will be available for grazing on nannoplankton as well as for food for advantageous fish such as *Sarotherodon galilaeus.*

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