ISRAEL LAND & NATURE

Front cover:
Painted Tiger butterflies *(Danaus chrysippus*: Heb. *"dana'it tappuah sedom")* are found throughout Israel
(Dror Shaul)

Back cover:
Aerial view of the southern vicinity of the Sea of Galilee
(Dubi Tal)

Inside front cover:
Male kestrel *(Falco tinnunculus*: Heb. *"buzz matzuy")* on the watch
(Eyal Bartov)

Inside back cover:
Maritime squill *(Urginea maritima*: Heb. *"hatzav matzuy")* is a harbinger of fall
(Ofer Si'on)

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Contents

*Many of the articles published in **Israel Land & Nature** are translations and adaptations of material that has appeared in **"Teva va-Aretz"**, the Hebrew magazine of the Society for the Protection of Nature in Israel. All of the articles are based on original research and observations and are selected for their general interest and because of the light they shed on various aspects of Israel's natural and human history. Taken together, they reflect a discipline known in Israel as* "yediat ha-aretz" *(knowledge of the country) or "Israelography" which is a defined and recognized field of study at all levels of the Israel educational system. "Israelography" includes such subjects as geology, botany, zoology, ethnography, Bible, archeology, Jewish as well as general Middle East history, etc. and expresses the close link of the people of this country with the land in which they live. It is this approach that guides the editorial policy of **Israel Land & Nature.***

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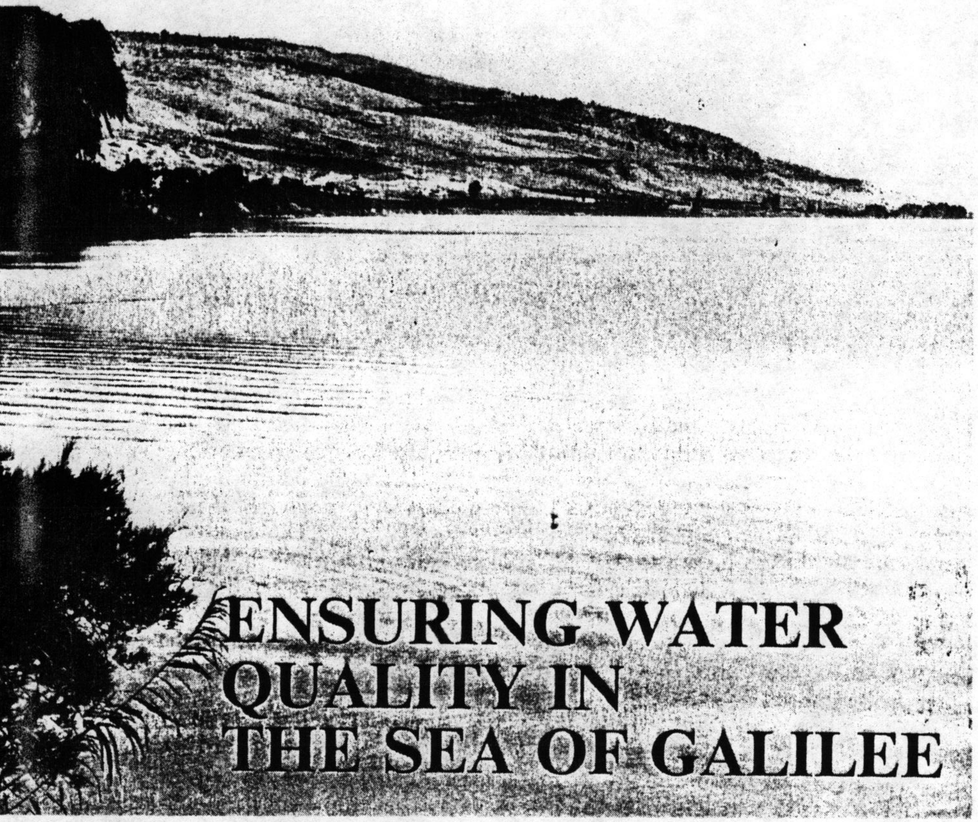


ENSURING WATER QUALITY IN THE SEA OF GALILEE

Part I: THE FOOD WEB STRUCTURE

MOSHE GOPHEN

The Sea of Galilee (Lake Kinneret) [M/O-5/7], Israel's only natural freshwater lake, serves a multitude of functions in this small country. For most people, Israelis and tourists alike, it is one of the loveliest sights in the country's landscape. Its blue expanse mirrors the hills of Lower Galilee in the west and the Golan highlands in the east.

Its Biblical, religious and historical associations for Jews and Christians are many. The lyre of King David is traditionally said to have resembled the shape of the lake, which is called in Hebrew "Kinneret" (literally, small string instrument). Jesus, the founder of Christianity, was very active around the lake's shores. The area abounds in sites sacred to Christians.

In modern times, the Sea of Galilee was a focus of renewed Zionist Jewish settlement in the country. A farmyard overlooking its western shore was the site of one of the 20th century's major social innovations. The concept of the kibbutz (communal settlement) was formulated in the courtyard of the Kinneret farm.

However, the importance of the Sea of Galilee goes far beyond scenic or historical considerations – although they, too, must be taken into account in our crowded corner of the world. With a total area of only 170 square kilometers, the lake contains about 4×10^9 cubic meters of water.

This, in effect, is Israel's only sizeable resource of fresh water. It must suffice for all purposes: drinking and household use, farmland irrigation, industry, and recharging coastal aquifers. It is also the habitat of an intricate network of life, which is vital to ensure the quality of the water for all its other uses.

Carbon sources of the Sea of Galilee

We have attempted to incorporate the different components of the lake's food web into a comprehensive picture which will enable us to understand the course of energy flow through the lake's ecosystem. In order to do this, we compared the data describing the different components of the food chain, in unified units expressing quantity as well as rate of activity.

In the following analysis, we used units of carbon (C) in grams or milligrams per square meter of the lake's surface; the time unit is usually one day, unless otherwise noted.

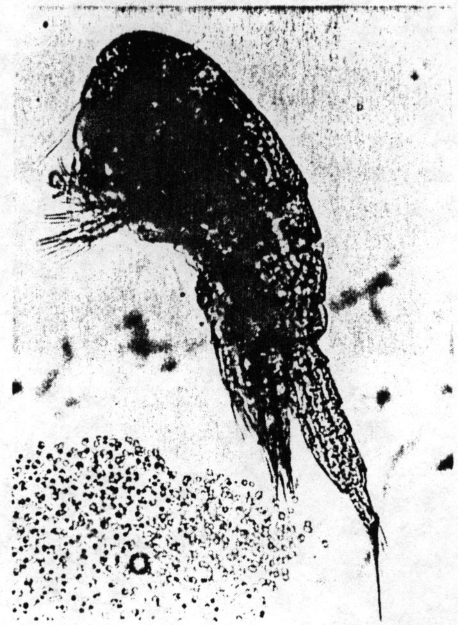
The annual supply of carbon to the lake's water amounts to 730.4 grams per square meter. Eighty-nine percent of this quantity comes from primary production by phytoplankton (microscopic suspended algae). Another 7.9 percent come from drainage of nutrients through the streams flowing into the lake. The Jordan River is the largest and most important of these streams.

The remainder of the carbon is derived from primary production by photosynthetic bacteria, benthic algae and submerged macrophytes (underwater plants). Other external sources of carbon are the excretions of waterfowl, drainage at the lake's shore, dust and rainfall.

Lakes in more northerly regions of the world are usually surrounded by dense forest vegetation. These forests, many of which consist of deciduous trees, are an important source of external carbon, through leaves which drift into the lake water. Streams which flow through swamps rich in grassy vegetation also carry plant debris into the lakes, enriching the water with carbon.

However, all these features are nonexistent in the area of the Sea of Galilee. The region has a subtropical climate. Every year, there is a short period (2-3 months) of vegetation growth at the end of the winter and in the spring. This is immediately followed by the hot, dry summer months.

In the summer, most of the green vegetation is dried by the sun's heat. But during this season there is no water runoff to sweep the dried plants into the lake. Thus, for the Sea of Galilee the internal sources



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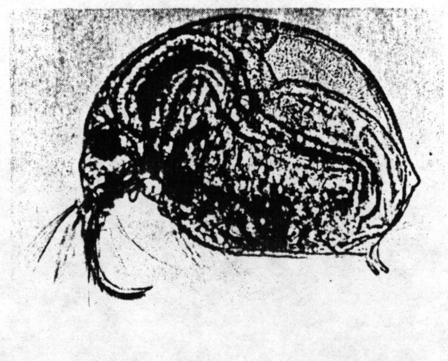

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of carbon – suspended phytoplankton – are far more important than they are in lakes in more northerly parts of the world.

Two food chains

The food web in the Sea of Galilee consists of two superimposed food chains, differing in structure: I – the *Peridinium* alga chain; II – the chain of nanoplankton (phytoplankton smaller than 20 microns). Both chains co-exist throughout the year. In the late winter, spring and early summer, the *Peridinium* chain is dominant. In summer, fall and early winter, the nanoplankton chain predominates. In recent years information has accumulated about yet a third food chain – the "microbial chain" (or "loop").

The *Peridinium* food chain consists of two main components: the *Peridinium* alga (its round cells 40-80 microns in size) and its main consumer, Galilee St. Peter's fish (*Sarotherodon galilaeus)=(Tilapia galilea)*[1]. Other fishes also ingest and digest the alga, but not as efficiently as Galilee St. Peter's fish.

During the period of *Peridinium* bloom (March-May) large quantities of organic material are produced in the lake. About 40,000-50,000 tons of carbon are fixated into algal cells in the lake's water at this time. Only a minor proportion of this quantity (about 15 percent) undergoes elimination from the water by fish consumption as well as through water pumping during the 3 months of the bloom period.

In May, when the bloom is over, dozens of tons of *Peridinium* begin to decompose and settle to the bottom of the lake. The different components of the "microbial loop" take an extremely active role in this process of decomposition.

The process is greatly accelerated by the rapid multiplication and intensive feeding of the various microorganisms which thrive on *Peridinium* degradants. The rapid rate and great quantities involved in this seasonal process make it one of the most dramatic events in the Sea of Galilee's ecosystem.

A tremendous store of detritus particles and dissolved organic matter exists in the lake immediately after the bloom season. Part of the *Peridinium* degradants accumulate in the oxygen-less hypolimnion (the low water layer in the lake, between summer and fall), and become oxygenated in the course of the following winter, when the lake waters become mixed.

Any imbalance in these processes may lead to the accumulation of organic matter which could cause the deterioration of water quality. Living organisms may die in such waters, which then gives off an unpleasant odor.

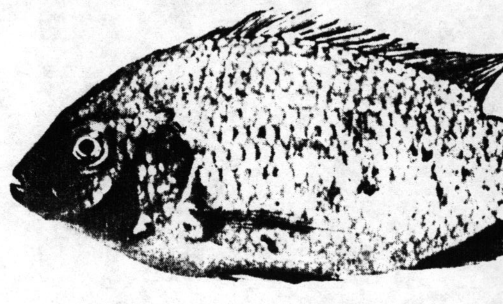
Imbalance can be caused by several different factors. If winter temperatures are high and the water is calm in the absence of wind, the summer stratification partly continues in the winter and the water does not become mixed at all, or is mixed only for a short time.

In such a winter, the hypolimnion remains without oxygen, and the general oxygenation level of the lake is low. This was the case, for example, in the winter of 1984. Organic material remains unoxygenated until the following year, when new matter is produced again.

Under the present circumstances, the population of Galilee St. Peter's fish in the Sea of Galilee declines. In recent years (until 1987) this fish, the main consumer of *Peridinium,* was over-fished, illegally caught by the use of pesticides, or taken from its spawning areas during the breeding season. The decline in the population of Galilee St. Peter's fish can lead to an increase in the quantity of unconsumed *Peridinium* biomass, and to the enhancement of organic material in the lake.

The nanoplankton food chain

This food chain includes three main components: nanoplankton (tiny planktonic algae, 2-20 microns in size), zooplankton (microscopic animals suspended in the water) and zooplanktivorous (zooplankton-eating) fish. Almost all the fishes in the Sea of Galilee feed on fair amounts of zooplankton in summer and fall, since during these seasons it is the main source of food for fish.



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The tiny algae are the basic component of the chain. Their specific activity – photosynthesis, or the production of organic material – is relatively higher than that of *Peridinium.* The planktonic crustaceans strain the small algal cells from the water and feed on them. In turn, the microscopic crustaceans are preyed on by the zooplanktivorous fish.

Any imbalance in this chain leads to deterioration of the water's quality. Thus, for example, an increase in the numbers of bleak or sardines (*Mirogrex terrae-sanctae)*[2] fish, which feed on zooplankton, causes a decline in the densities of their favorite food. As a result, the "grazing pressure" of the nanoplanktonic algae decreases. The algal biomass increases, forming slight blooms in summer and fall.

High densities of these tiny algae in the water also leads to mechanical problems. The algae accumulate on the water filters and block them. This causes difficulties in the water supply to homes and fields, especially in the summer, when demand is greatest. After their death, these algae may serve as a substrate (food base) for the

1) *"amnun ha-galil";*

2) *"lavnun ha-kinneret".*

algae ·
nneret

development of pathogenic bacteria. Obviously, the presence of these algae in the water should be kept to a minimum.

Studies of the relations between the two types of algae – *Peridinium* and nanoplanktonic algae – show that when conditions are normal (with a relatively low level of nutrients in the water, especially of phosphorus) the *Peridinium* food chain predominates. The water then contains a relatively high biomass of *Peridinium* algae, since it can exist when phosphorus levels are low.

When the nutrient concentrations in the water increase, especially of phosphoric materials, on a long-term (multi-annual) basis, the biomass of *Peridinium* shows a relative decline, mainly at the expense of the tiny algae. In the summer, the algal biomass in the lake is too low to supply the higher demands of zooplankton and fish. The fish then feed intensively on zooplankton. As a consequence, the tiny algae then increase, since their major consumer – zooplankton – has declined.

The degree of *Peridinium* predominance over the tiny algae is determined mainly by the regime of nutrient concentrations in the lake's water. More phosphorus leads to relatively less *Peridinium* and more tiny algae. In summer and fall, the biomass of the latter is determined by the "grazing" of crustaceans. The intensity of this "grazing" is, in turn, governed by fish predation.

In other words, unlike other lakes of the world, the waters of the Sea of Galilee may undergo quality deterioration, by a decline in total algae biomass, but an enhancement of nanoplankton. This total decline means less *Peridinium* , but more nanoplankton. The water quality then declines, since the tiny algae are more difficult to remove from the water.

On the other hand, too much *Peridinium* also raises the level of organic matter in the water, which partly stimulates the development of tiny algae in summer. The lake should therefore contain fish to consume the *Peridinium* and make sure the alga does not increase excessively.

Thus, there are seasonal and multi-annual differences in the dominance of each of the food chains. In every case, the "microbial loop" plays an important role in the processes of recycling organic matter originating in *Peridinium* cells.

"*Peridinium* year" compared with "nanoplankton year"

Good examples of the effect of different quantities of nutrient influxes are the years 1972, which was a "*Peridinium* year" and 1975, a "nanoplankton year". The amounts of organic matter and carbon collected in each chain of the food web and the rates of flow from one link to the next were different.

In 1975, the numbers of cells of tiny algae and their biomass were higher. In 1975, the *Peridinium* biomass was lower, although their cells were smaller than in 1972. Changes in the availability of nutrients affect the size of each individual cell as well as the overall number of cells and the total biomass.

In the "nanoplankton year" of 1975, the entire chain was active at a more intensive rate. In the "*Peridinium* year" of 1972, utilization of carbon in the water was higher, with a positive effect on water quality. The quantity of carbon increased by only 259 milligrams a day, compared with 1100 milligrams a day during the "nanoplankton year".

It is now clear that during "*Peridinium* years" water management of the Sea of Galilee should include maximum activity of the "microbial loop", to ensure the utilization of the organic matter which accumulates in the *Peridinium* cells and partially settles on the lake bottom.

Populations of Galilee St. Peter's fish should also be large enough to control the algae. Water pumping during the *Peridinium* season should be massive enough to remove a maximum amount of *Peridinium* cells from the lake. *Peridinium* can be easily and cheaply removed from water supply systems, by slight chlorination of the water.

The organic matter produced by the nanoplankton, on the other hand, is largely consumed by the herbivorous zooplankton which are then caught by zooplanktivorous fish. The trophic (food) situation of the lake during "*Peridinium* years" is more moderate than in "nanoplankton years".

The effect of intensive fish stocking of zooplanktivorous fish in the lake over the past two decades is much more noticeable in a negative way in the moderate conditions of a "*Peridinium* year". The "microbial loop" ensures the desirable rate of degradation of *Peridinium* formed in a "*Peridinium* year".

Proposed changes in the fish population should aim at creating maximum pressure on *Peridinium* during its blooming season, for optimal fish utilization to achieve their growth, as well as minimal pressure on zooplankton in the summer. The fish most suitable for these purposes is Galilee St. Peter's fish. □

Note: This is Part I of a two-part article, which will be completed in a forthcoming issue of ILAN. A selected bibliography will appear at the end of the article.

Glossary

Blooming: a very fast development of algal cells or any other microscopic organism which produces a very dense population of the species.
Hypolimnion: low water layer in a lake, between summer and fall.
Microbial loop: part of the aquatic ecosystem, including bacteria and protozoa.
Nanoplankton: phytoplankton smaller than 20 microns.
Phytoplankton: microscopic suspended algae.
Zooplankton: microscopic suspended animals.