WORLD SALT SYMPOSIUM

June 19-21, 2018 Park City UT, USA

The Role of the Ciliate Protozoan Fabrea Salina in Solar Salt Production

Nikolaos A. Korovessis
Chemical Engineer M.Sc.
Production & Development Director
Hellenic Saltworks S.A.

Authors: Nikolaos Korovessis, George Hotos, George Zalidis

Solar Sea Salt

Production of salt from **seawater** involves the selective recovery of **pure NaCl**, free of other soluble or non-soluble salts and other substances.

Condensation of seawater through **solar evaporation** results in the fractional crystallization of all contained salts.

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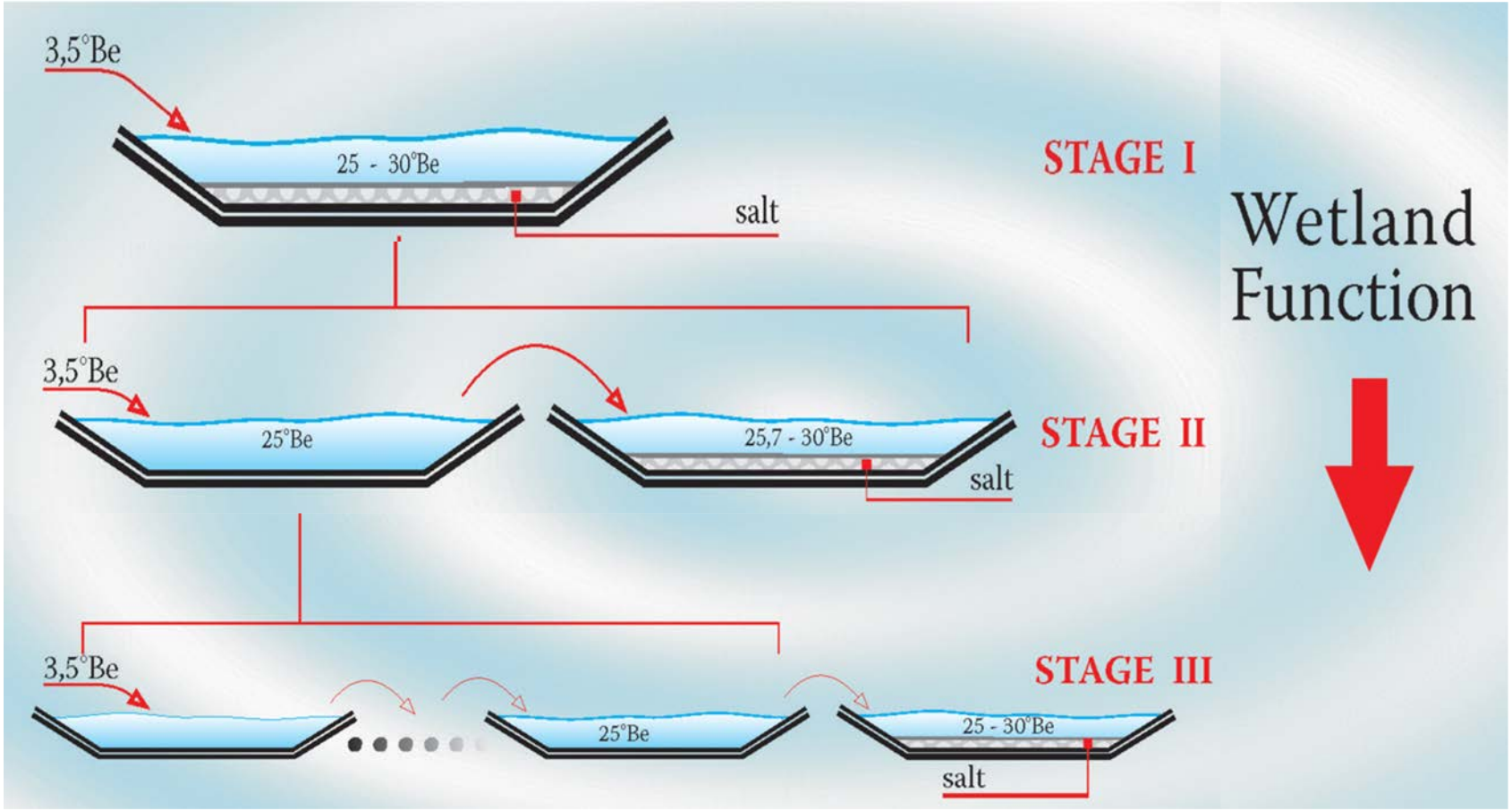
Solar Sea Salt Production Process Evolution



Solar Saltworks – Constructed Ecosystems

Current, industrial Solar Saltworks consist of a series of successive lakes where a **salinity vector** is being developed by solar and wind energy.

Along with the salinity vector, an extremely important **biological process** is also developed throughout the lakes system, consisting of planktonic and benthic communities of microorganisms in large populations.

As each lake functions at steady state, a **unique ecosystem is created where regular and hyper saline environments coexist**.

Solar Saltworks Product Quality

The physical and the biological process of Solar Saltworks **interact strongly** and affect both the quantity and quality of their final product.

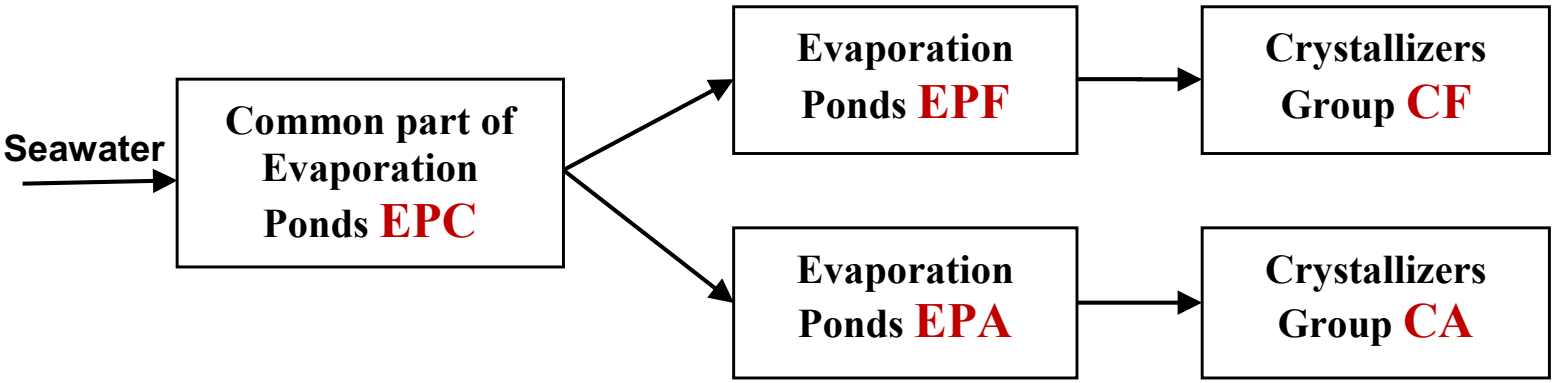
Every microorganism present in the Saltworks pond system has an impact (major or minor) upon the solar sea salt production process.

Prerequisite for the optimal function of Solar Saltworks is the re-establishment and maintenance of a stable and **healthy biological process** (J. Davis 1993).

Unfortunate Conjucture

- An earthmoving machine was trapped in the middle of a dried, brine deposit pond and its surface was disturbed and agitated to a large extent.
- The problem arose when the brine (~13 oBe) used to fill the pond, at the start of the production process, was not thrown away but was led with the entire suspended biological load, to the crystallizers.

The production Scheme of Messologhi Saltworks



Fabrea Salina dominates the Pond system

- As a result, a vast population of Fabrea salina cysts and also nutrients were released from the surface (benthic community) of the pond to the planktonic community of the circulating brine.
- Under these conditions the population of Fabrea salina exploded and dominated in the planktonic communities of both groups of crystallizers (CF & CA) and evaporation ponds EPF & EPA. (Samplings carried out by the Inter Balkan Environmental Center)
- The production process was locked and forced to operate with an extensive disturbance in the developing biological process in almost all high salinity ponds and the crystallizers.

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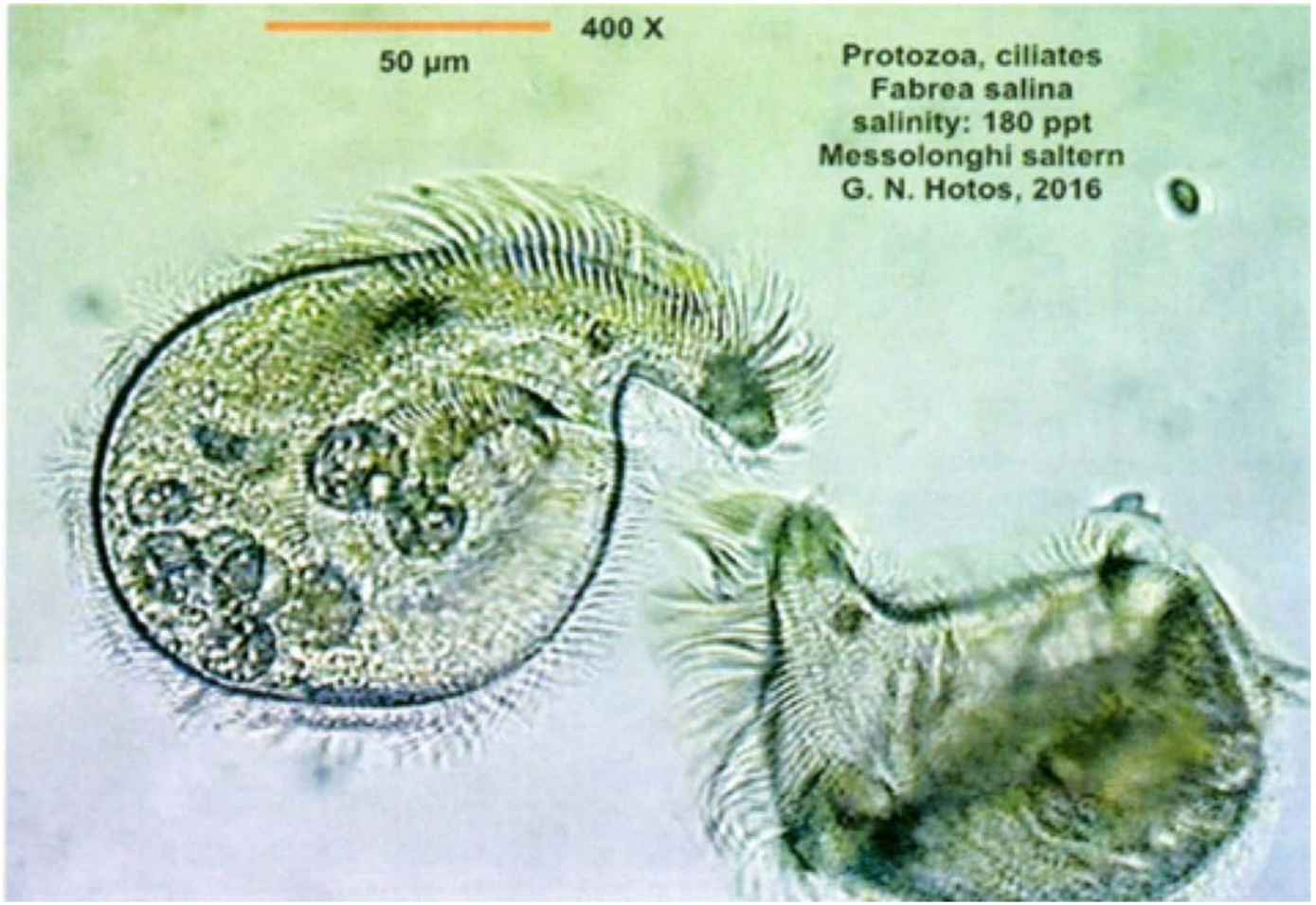
The ciliate protozoan Fabrea salina.



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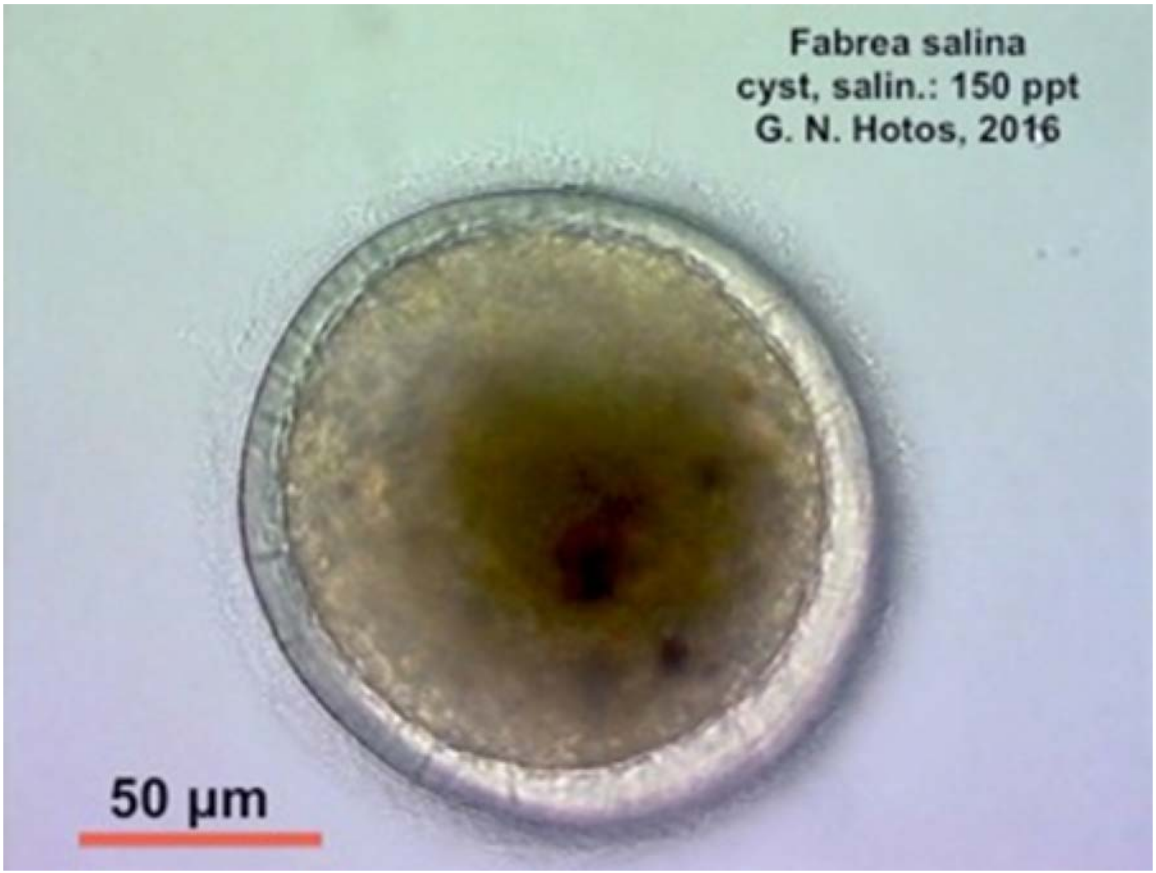
Fabrea Salina Cyst



Impacts on Biological Process

- Disappearance of *Artemia* from all ponds where *Fabrea* was dominating.
- The brine became turbid and cloudy, its color turn to dark brown and it was hard to see the pond bottom.

According to our knowledge and experience it was reasonable to expect a **catastrophic year** with minor production of poor quality.

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Brines dominated by Fabrea Salina

(Dark brown, turbid & cloudy)

In fact things went quite differently!

- As the brine in crystallizers reached concentration density and by the time that salt starts to precipitate the color of the brine gradually changed from brown to red.
- *Fabrea salina* disappeared and the ***Halobacterium salinarum*** developed into large populations and dominated the crystallizers.
- The brine also became crystal clear and transparent.

Brines dominated by Halobacterium

F. salina successfully replaced Artemia!

Its predominance in the brines resulted in the consumption of *Dunaliella*, *Synechococcus and Asteromonas* whereas the *Halobacterium* was kept in a prolonged state of inertia and dormancy.

When the brine density in crystallizers rose above 26 ^{o}Be, the population of *F. salina* collapsed and since almost all other organisms have disappeared, there was the opportunity for *Halobacterium* to proliferate.

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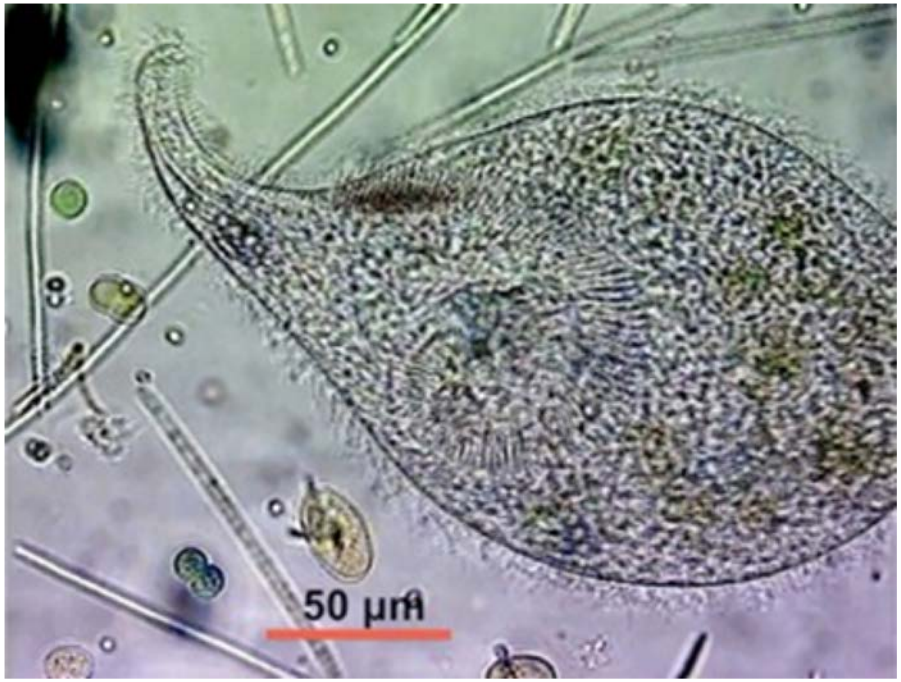
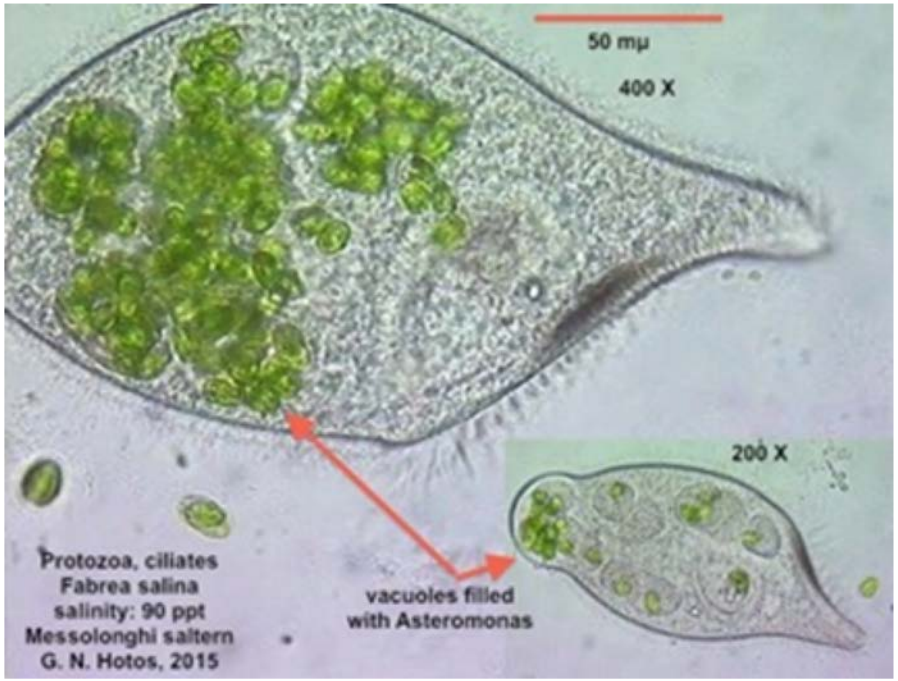
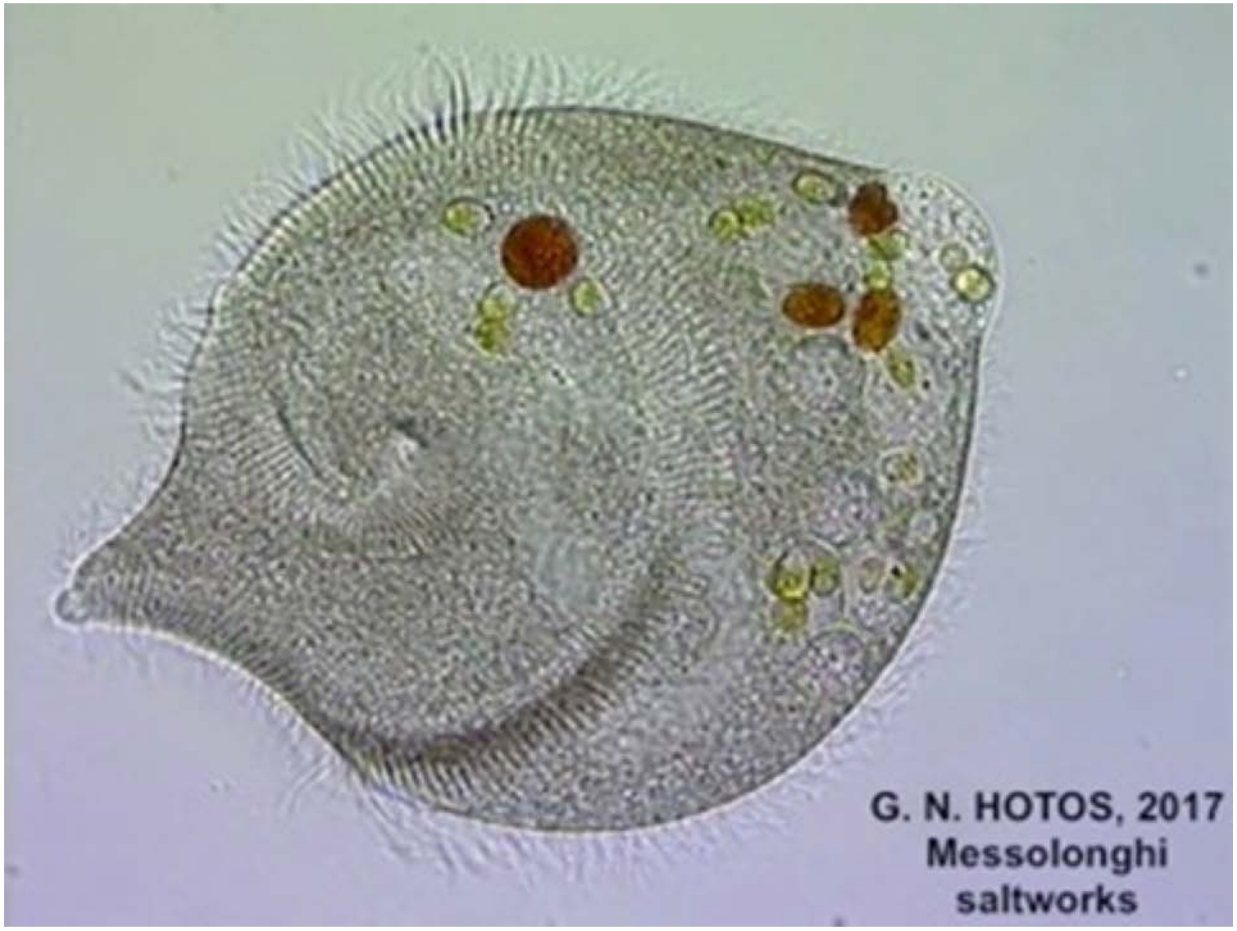
Fabrea Salina digesting Synechococcus cells





Fabrea Salina with ingested Dunalliella cells



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Conclusions I

- Dormant cysts of the ciliate *F. salina* had been previously accumulated in the mud of the dried Brine Deposit Pond.
- It was found that *Fabrea* that emerged from cyst (after its dormancy) is very active in feeding. Actually this ciliate is a voracious consumer of phytoplankton and presumably bacteria.
- It consumes large-celled chlorophytes (***Dunaliella***, ***Asteromonas***) and cocciform cyanobacteria (***Synechococcus***) that can be seen *en masse* into its digestive vacuoles. It is logical to assume that it consumes bacteria as well.

(By *Synechococcus* we mean the mucilage producing cyanobacteria in general as the frequently used in many papers synonyms *Aphanothece* sp. and *Coccochloris* sp. are probably based on their rough morphology rather than to molecular indentification.)

Conclusions II

- *Fabrea* salina, that "awoke" from its cyst dormancy found favorable conditions and its population exploded.
- It rapidly consumed the bulk of microalgae and kept grazing on bacteria. The bacteria including *Halobacterium* was thus prevented from reaching self-limiting numbers and were kept in a prolonged state of "biological youth" with a high rate of assimilation of organic material.
- As the brine density rose above 26 ^{o}Be, the population of *Fabrea* collapsed. *Halobacterium* took over and excellent salt crystallization occurred.
- We finally note that the finding that the Fabrea salina releases mucilaginous substances [3] was not verified by the results of this study.

Conclusions III

It is obvious that the role of *Fabrea salina* should be examined more thoroughly throughout the whole biological process of Solar Saltworks.

In order to exploit the results presented here, we believe that an elaborate study is needed since the case we are examined arose from an unusual disturbance rather than from the normal operation of Solar Saltworks.

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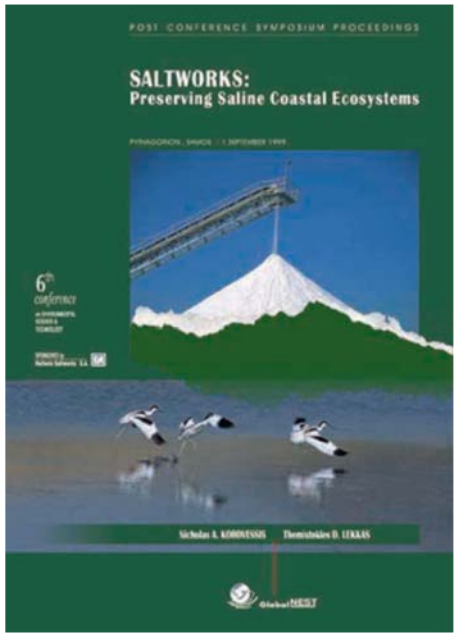
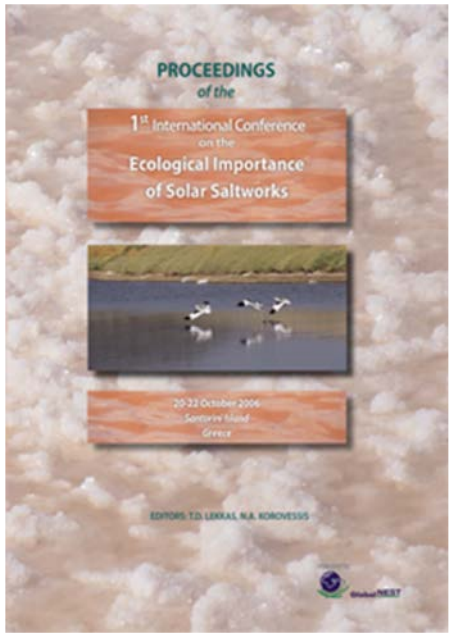
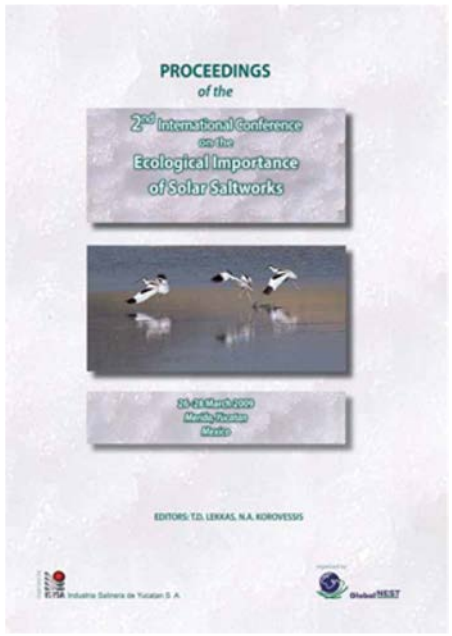
Promoting the Ecological Importance of Solar Saltworks



Samos Symposium
1999



1st CEISSA
2006



2nd CEISSA
2009

Eusalt - CEISSA
2012

Thank you for your attention

www.ceissa.org

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