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ENVIRONMENTAL CHANGES AND THEIR IMPACT ON FISHERIES IN SINOE LAGOON - ROMANIA

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ABSTRACT

NIMRD Constanta performed studies to assess the ecological state of the Sinoe Lagoon and to provide an adequate management plan for this basin. In this aim hydrochemical variables and biological main groups' assessment are important steps, to recover the Sinoe lagoon ecosystem health. Results of this study are pointing out the emergency for applying the ecological recovery measures for this unique aquatic basin. A free water circulation with double sense: Danube River- Sinoe Lagoon- Black Sea may be the only chance to improve the ecological state of this unique ecosystem at the Romanian Black Sea coast.

KEY WORDS: Sinoe Lagoon, ecological state, environmental conditions, fishing structure, fishery, fish production

INTRODUCTION

The Sinoe lagoon is the only lagoon ecosystem along the Romanian seashore. It covers 17,580 ha at the southern end of the Razim-Sinoe complex (Table 1).

Table 1

Sinoe lagoon ecosystem

Genetically type, surface, max.depth, saline regime	**Regime: Major ecosystem function**	**Major human uses**	**Main problems and threats**
Sinoe, lagoon, 17.500 km^2, 3.5 m, freshwater-brackish water	*Protected area and component part of the Reservation "Danube Delta Biosphere Reserve"*: limnetical-brackishwater biodiversity, important habitat for waterfowl	fishing, irrigation, angling, sailing, motor-boats navigation.	Hydrologic-hydrobiologic-sedimentologic instability, hydrotechnical works impact, toxically substances, eutrophycation, negative algal blooming, clogging, swamping associated with poor zoobenthos productivity, overexploitation, fish potential affected, specific habitats destroying, opportunistic and new introduced species

Sinoe lagoon had a permanent double connection:

- with marine waters through natural inlets, which have induced a continuous regime of instability;
- with freshwater permanent inflow from Razim lake, inducing a huge continental pressure;

The geomorphologic features, origin, surface, relief, water level, structure, variety, can be considered a valuable support for a good fishery in Sinoe lagoon.

The evolution of ichtyofauna, connected with the changes of environmental parameters is the results of the natural and anthropogenic impact, occurring in Sinoe Lagoon in some distinct stages:

- between 1971-1974 hydrological works had the aim to use lagoon freshened waters to increase freshwater fish production and subsequently for agricultural irrigation; this transformed it into an oligohaline lake;
- after 1980 the acceleration of freshening and eutrophication process induced catastrophic ecological effect.

The main consequences of all of these were:

- aquatic environment degradation,

- ecosystem balance disturbing,
- traditional biodiversity diminishing,
- natural resources quality decline,
- traditional activities disorganization.

The shift from marine to freshwater condition, also the anthropogenic influences and the fluctuations of lagoon bioproductivity divided the biotic and non-biotic evolution of Sinoe lagoon in four main periods.

- Marine period: 1915-1966
- Brackishwater period: 1966-1977
- Freshening period: 1978-1991
- Freshwater period: 1992-2000

The National Institute for Marine Research and Development "Grigore Antipa" (NIMRD) has systematically studied the evolution and ecological status of Sinoe lagoon during the last 30 years, by a monitoring system. Since 1990 Sinoe lagoon is part of the Danube Delta Biosphere Reserve (DDBR) as a protected area (confirmed by Romanian legislation in 1993).

MATERIALS AND METHODS

The water and sediment samples were drowned from 10 stations placed at the lake border area and at the main links with freshwater and marine waters (Fig. 1). We had in view the main chemical, biochemical and biological parameters for waters and sediment samples have been emphasized. Sampling methods and laboratory analysis are standardized.

The authors used the own control data and the statistics of the Danube Delta Biosphere Reserve. The percent of fish marketing registration is a relative one in the total data area catches. The ichtyofauna structure as a result of euthrophication factors gives significant information about the fish requirement for habitats rehabilitation.

RESULTS AND DISCUSSIONS

Sinoe lagoon constitutes the unique hydrographic complex with a specificity of fauna and flora and some important Ponto-Caspian relict type taxis.

The pressure of the last 25 years freshening and of the last ten years eutrophication changed the Sinoe lagoon into an oligohaline lake, with strong decline of its biodiversity and fish production (Table 2). The changes have been reflected in all components of the biocenosis: phytoplankton, micoplankton, zooplankton, macroflora, macrozoobentos and ichtyofauna. The most severely affected have been benthic invertebrate and fish populations, which can be considered barometers of changing conditions (Fig. 1, 2, 3).

Table 2

Ichtyofauna species list and fish frequency
into the Sinoe lagoon complex, during 1950-2002

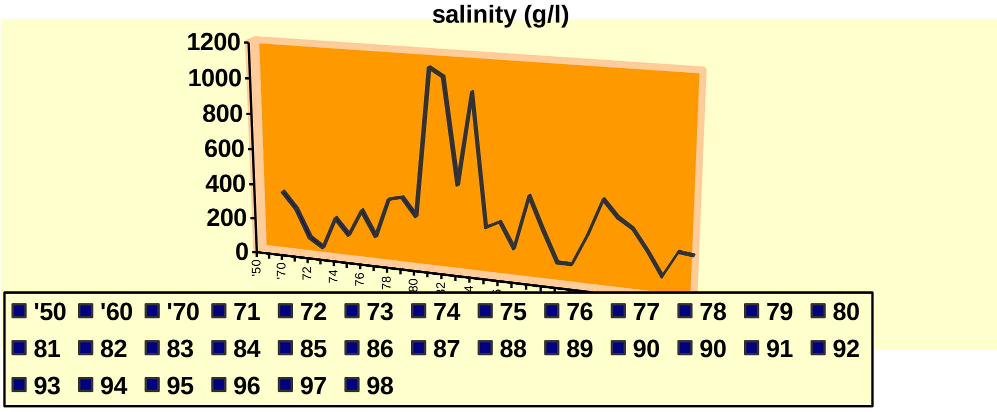
No crt	Systematic Groups / Species	Ecologic Group	Period of references			
			1950-1965	1966-1977	1978-1991	1991-2002
	Acipenseriformes					
1.	*Huso huso* *LINNAEUS,1758	M	+++	+	0	0
2.	*Acipenser güldenstaedti**BRAND,1833	M	+++	+	0	0
3.	*Acipenser stellatus* *PALLAS,1771	M	+++	+	0	0
	Clupeiformes					
4.	*Alosa caspia nordmani* *ANTIPA,1906	ME	++	++	++	+
5.	*Alosa pontica pontica**EICHWALD,1833	ME	++	+	++	0
6.	*Alosa maeotica maeotica**GRIMM,1901	M	++	++	++	0
7.	*Clupeonella cultriventris* NORMAND,1840	M	+++	+++	++	0
8.	*Sprattus sprattus phalericus* RISSO,1826	M	++	+	+	0
	Anguilliformes					
9.	*Anguilla anguilla* LINNAEUS,1758	DE	++	+	++	+
	Esociformes					
10.	*Esox lucius* LINNAEUS,1758	D	++	+++	+++	+
	Cypriniformes					
11.	*Cyprinus carpio carpio* LINNAEUS,1758	D	+++	+++	+++	+++
12.	*Carassius auratus gibelio*BLOCH1783	D	+	++	+++	+++
13.	*Carassius carassius* LINNAEUS,1758	D	+	0	0	0
14.	*Abramis brama danubii* PAVLOV,1956	D	+	+++	+++	+++
15.	*Abramis ballerus* LINNAEUS,1758	D	+	++	+	+
16.	*Alburnus alburnus alburnus* LINNAEUS,1758	D	+	++	+	+
17.	*Blicca bjoerkna bjoerkna* LINNAEUS,1758	D	+	+++	++	+
18.	*Rutilus rutilus carpathorosicus* VLADYKOV,1930	D	+	+++	+++	+++
19.	*Rutilus rutilus heckeli* NORMAND,1840	D	+	+++	+++	+++
20.	*Scardinius erytrophtalmus* LINNAEUS,1758	D	+	+++	+++	+++
21.	*Vimba vimba carinata* PALLAS,1811	D	0	++	+	0
22.	*Tinca tinca* LINNAEUS,1758	D	+	+++	0	0
23.	*Aspius aspius* LINNAEUS,1758	D	0	++	0	0
24.	*Pelecus cultratus* LINNAEUS,1758	D	0	0	+	+
25.	*Ctenopharyngodon idella* VALENCIANNES	D	0	+	++	+
26.	*Hypophtalmichthys molitrix* VALENCIANNES	D	0	+	++	++
27.	*Cobitis taenia taenia* LINNAEUS,1758	D	+	+	+	+
28.	*Silurus glanis* LINNAEUS,1758	D	++	+++	++	++
	Gasterosteiformes					
29.	*Gasterosteus aculeatus* LINNAEUS,1758	ME	++	++	+	+
	Syngnathiformes					
30.	*Sygnatus nigrolinaetus* EICHWALD,1831	ME	++	++	0	0
	Mugiliformes					
31.	*Mugil cephalus* LINNAEUS,1758	ME	+++	+	++	0
32.	*Mugil auratus* RISSO,1810	ME	+++	+	++	0
33.	*Mugil saliens* RISSO,1810	ME	+++	+	++	0
34.	*Atherina mochon pontica* EICHWALD,1831	ME	+++	+++	+++	+++

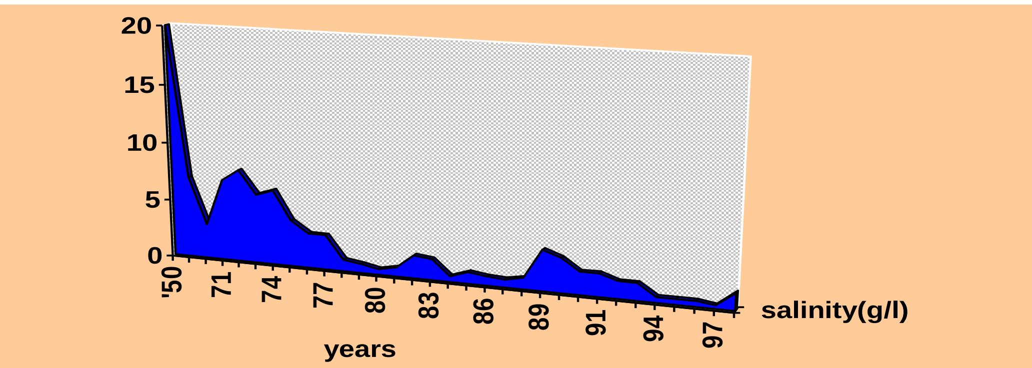
	Perciformes					
35.	*Perca fluviatilis fluviatilis* LINNAEUS,1758	D	+	+++	+++	+++
36.	*Stizostedion lucioperca* LINNAEUS,1758	D	+++	+++	+++	+++
37.	*Gymnocephalus cernua* LINNAEUS,1758	D	+	++	+	+
38.	*Pomatomus saltatrix* LINNAEUS,1758	D	+	0	0	0
39.	*Gobio ophiocephalus* PALLAS,1811	D	++	++	+	+
40.	*Pomatoschistus microps* KRÖYER,1838	ME	++	++	+	+
41.	*Benthophilus stellatus stellatus* SAUVAGE,1874	D	++	++	+	+
	Pleuronectiformes					
42.	*Psetta maeotica* PALLAS,1811	M	+	0	+	0
43.	*Platichthys flesus luscus* PALLAS,1811	ME	++	++	++	0

M - marine species
ME - marine euryhaline species
D - freshwater species
DE - freshwater euryhaline species

* - ponto-caspic relicts
+++ - abundant
++ - frequent
+ - occasionally
0 - absent

Figure nr.1 - Catch (t) evolution in correlation with Sinoe lagoon salinity (g/l)





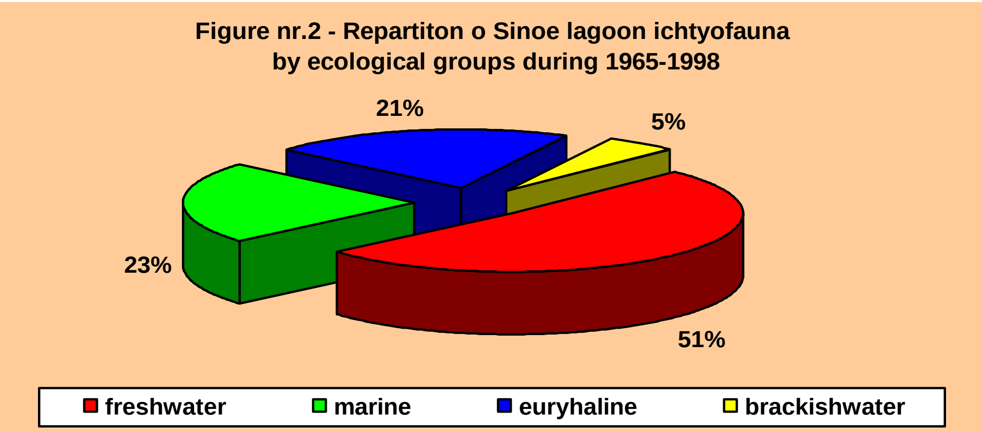


Figure nr.2 - Repartiton o Sinoe lagoon ichtyofauna by ecological groups during 1965-1998

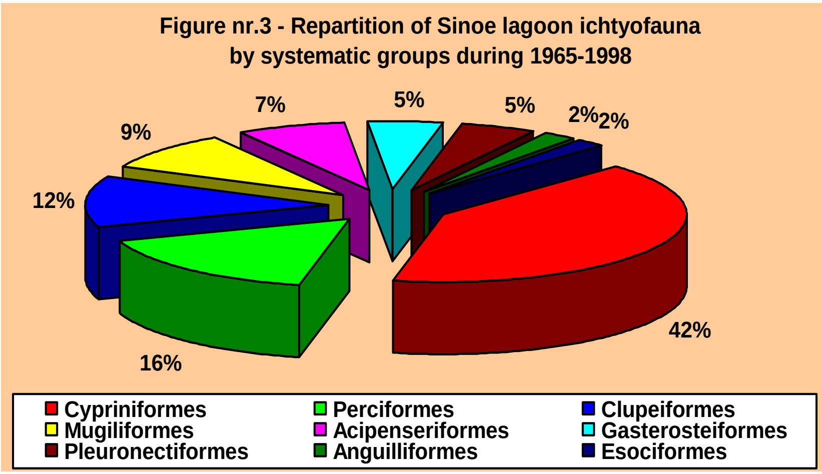


Figure nr.3 - Repartition of Sinoe lagoon ichtyofauna by systematic groups during 1965-1998

In the **marine period** at 15-20 g/l salinity (1950-1952), 22 marine and euryhaline species were registered. The most frequent remained the Mugiliformes. The peak of mullet's production was attained in 1951-630 t (85 % juveniles). They declined dramatically.

The level of salinity - around 20 g/l - explained the presence of typical marine species: *Belone belone euxini*, *Engraulis encrassicholus ponticus* and *Trachurus trachurus trachurus.*

Other marine-euryhaline species with a high ecological or economical value were: *Alosa caspia nordmani*, *A. maeotica maeotica*, *A. pontica pontica*, *Anguilla anguilla*, *Atherina mochon pontica*, *Clupeonella cultriventris cultriventris*, *Gasterosteus aculeatus aculeatus*, *Gobius cephalarges cephalarges*, *G. ophiocephalus*, *Mugil auratus*, *M. cephalus*, *M. saliens* and *Platichthys flesus luscus.*

The flat production starts to decrease since 1961.

In Sinoe lagoon also freshwater species occurred, such as: pike (*Esox lucius*), pike perch (*Stizostedion lucioperca*) and some Cypriniformes. The dominant species was the pikeperch (52%) between 1960-1965. The Cypriniformes ranged between 8% (1961) and 56% (1965) with a representative taxis, the wild native carp.

During the **brackishwater period** (1966-1977) the salinity oscillated between 6.0 and 8.0 g/l. Between 1975-1977 it decreased to 4.23 - 3.17 g/l.

The decreasing of salinity caused by the freshwater inflow (250 cubic m /s) from Razim Lake induced rapid and severe ecological changes (OPREA, 1998; PETRAN, 1997).

– dislocation of the planktonic and benthic populations;
– excessive development of submerged vegetation and common reed;
– dominant development of freshwater ichtyofauna containing species which reduced economic value (giebel carp, plain, bream) and voracious species (perch and pike); all of them were competitors for the space and food needs of the main valuable species: carp and pike-perch (60%);
– installation of an intense freshened zone opposite the Periboina inlet (with a 60 cm risen water level) has closed the marine-euryhaline species entrance for feeding and reproduction, such as: plaice, grey mullet, atherine, pontic shad, and sea gudgeon. For example, shad juveniles (749 kg/year) and mullets (1300.6 kg/year) could be found only at Periboina Point.
– The freshwater species continued to dominant.

During the **freshening period** (1978-1991) period the Sinoe lagoon had a stable hydrological status with salinity range from 0.61 to 1.88 g/l.

The rapid and strong freshening induced important changes:

- rising of water level (with 65 cm);
- almost total replacement of marine biota with typical freshwater species;
- increasing contribution of less valuable fish species, such as giebel carp, plain, bream (from 22% in 1978-1984 to 90.4% in 1985);
- strong diminution of carp (82 t - multi-annual mean) and pike perch (100 t/year) catch;
- decline and disappearance of the most valuable marine species from Sinoe lagoon and from the whole coastal zone: sturgeons, mullets, turbot, flat, clupeids.

Between 1981-1990 average fish production was 554 t/years. The huge recorded catch in 1981 (1141 t) comparing with 61.3 t in 1973 owned to a real potential but also too intense overfishing. The catch contained 11 freshwater species (82.49%).

Since 1985, the catch continued to fall to 145t in1990. The bulk of catch was composed of giebel carp, bream and pike perch. They dominated the production from 67.5% in 1981 to 99.3% in 1988.

The **freshwater period** (1992-2000) is a perfect image of the freshening process, which changed the Sinoe lagoon into an authentic "liman"/double river-marine origin coastal lake (Fig. 4, 5).

Figure nr.4 - Repartitition of Sinoe lagoon ichtyofauna by the feeding regime in 1999

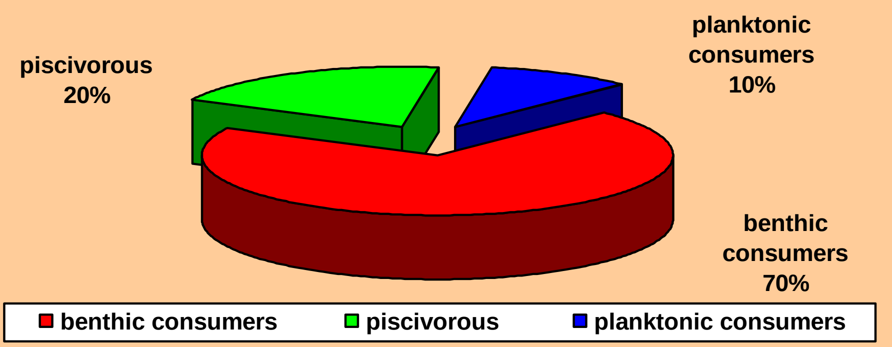
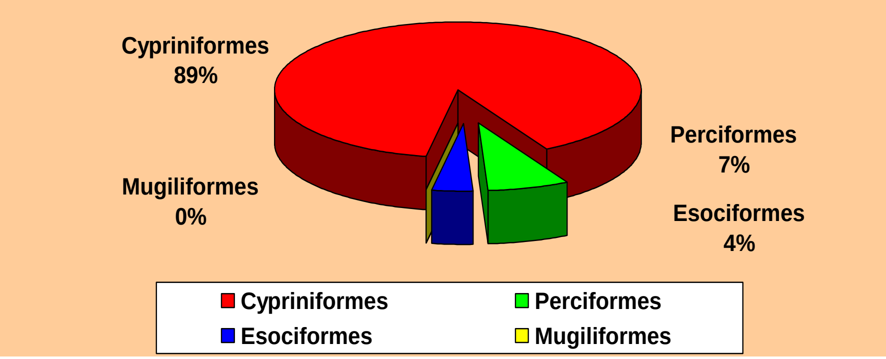


Figure nr. 5 - Repartitition of Sinoe lagoon ichtyofauna by systematic groups during 2001



Other important characteristics have been registered also during this period:

- severe impact of anthropogenic activities;
- water pollution with organoclorurated compounds and detergents, as well as with some bacteria and fungi;
- maintenance of permanent turbidity and huge nutrients stocks;
- dramatically decreasing of biodiversity;

- diminution of fish catch to 341.40 t/year;
- dominance of invaluable freshwater species such as giebel carp, bream, plain and roach;
- loss of important marine and euryhaline species (for ex: shads) in Periboina Point catch (significant for atherine and kilke presence).

The only hopes for a future fish production have been considered, such as:

- high incidence of carp juveniles and of one year old pike-perch, in 1991;
- mullet re-appearance in the main inlets, in 1996-1997 (260 and 402 kg) suggesting a promising recovery of natural population.

Present status of the Sinoe lagoon

The research of 1998-1999 suggested the limits of salinity: 1.32 -1.75 g/l as an encouraging rehabilitation of Sinoe environmental parameters:

- the thermal regime is also depending on excessive continental climate;
- the Periboina and Edighiol inlets and accidental breaches in the littoral belts during heavy storms reflect the present links with marine waters;
- the water level depends of the Danube inflow, drought and storm periods and other variable environmental conditions;
  - the excessive drought periods induce high water level decreasing with important hydrological and ecological consequences;
  - decreasing levels, the lack of traditional water circulation and the huge alluvial sludge material induce a permanent high turbidity;
- high level of eutrophication produced:
  - dislocation of the plankton and benthos populations in the lagoon;
  - intense algae bloom based on less valuable species, like cyanobacteria (Fig. 6);
  - high zooplankton development by some species (Fig. 7) (ALEXANDROV *et al.*, 1993, 1998);
  - the almost total replacement of marine biota with freshwater biota;
  - the excessive development of submerged vegetation and common reed;
  - loss of important benthos species (Fig. 8, 9);
  - the development of freshwater ichtyofauna with low economic value (giebel carp, plain, bream) (CERNISENCU, 2000);
  - the pollution of the water with organochlorurated compounds, detergents, bacteria, fungi and nutrients;
  - the creation of a much freshened zone opposite the Periboina inlet inadequate for marine fish (plaice, grey mullet, atherine, alosa, sea gudgeon) reproduction (NAVODARU, 2001).

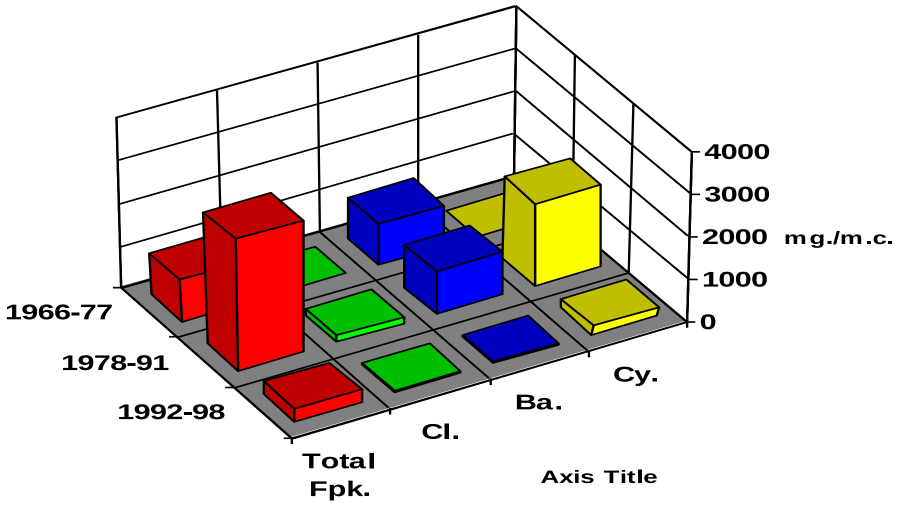


Fig. 6 – Sinoe lagoon phytoplankton biomass evolution, main systematical groups
(Cl = Chlorophycee; Ba = Bacylariophycee; Cy = Cyanophycee) during 1966-1998

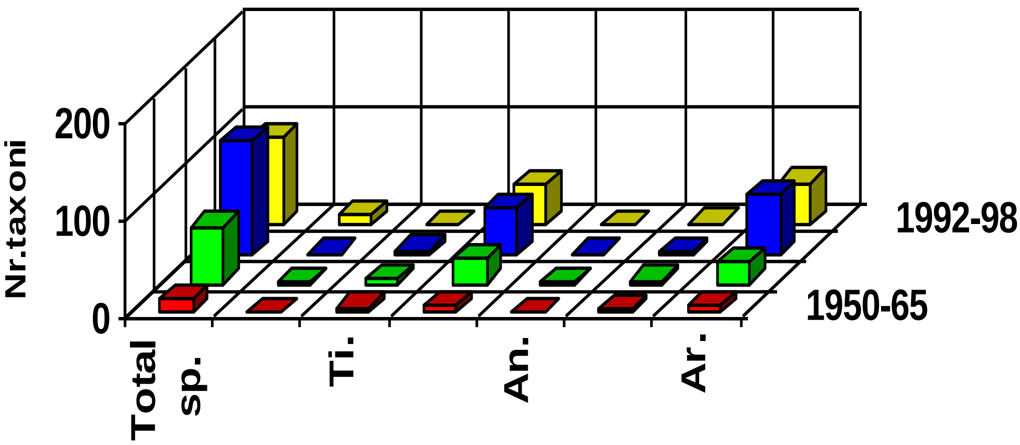


Fig.7 – Sinoe lagoon zooplankton biodiversity, main systematical groups
(Cystoflagelata: Ti = Tintinnoidea; Tr = Trochelminthes; An = Annelida;
Mo = Mollusca; A = Arthropoda), during 1950-1998

In these new conditions fish catch contained:

- 60% freshwater species - roach, silver bream, European perch, giebel carp, carp, bleak, freshwater bream, redfin, silver carp, wells, pike-perch;
- 30% marine species: sand smelt, whiting, kills, Gobi's, anchovy, Caspian shad and Pontic shad.

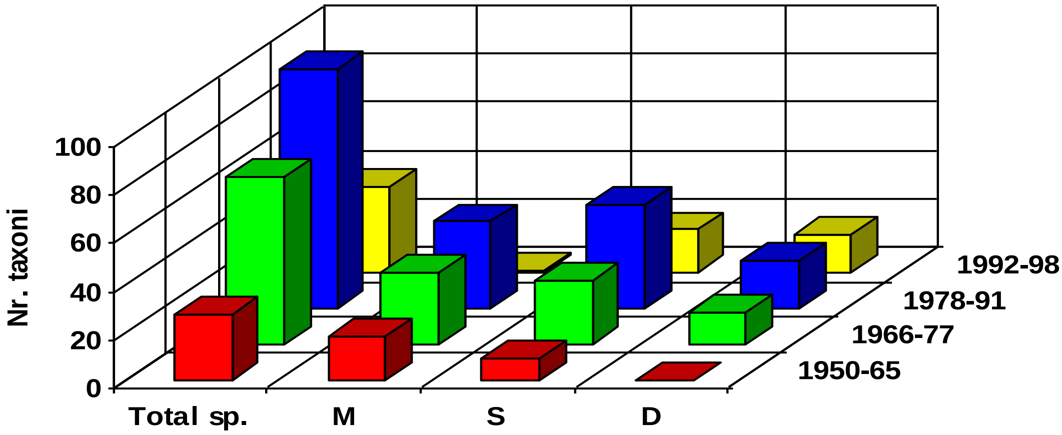


Fig.8 – Sinoe lagoon zoobenthos biodiversity, main ecological groups
(M = marine; S = brackishwater; D = freshwater), during 1950-1998

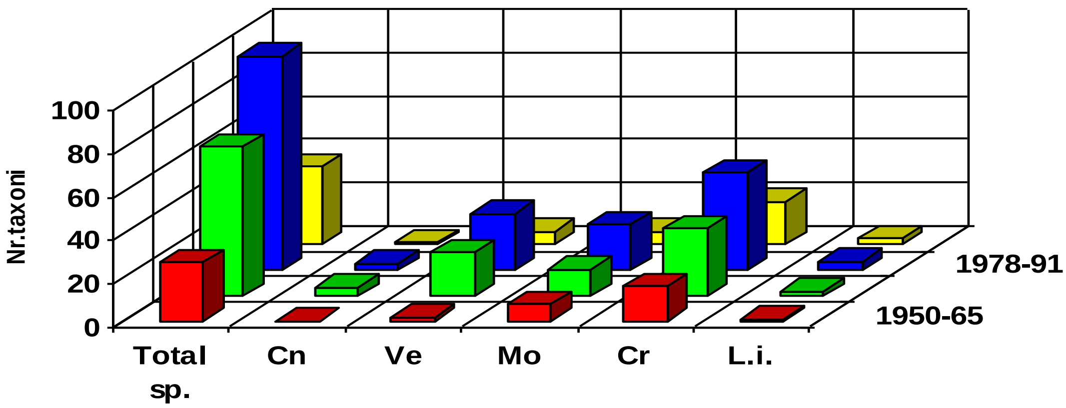
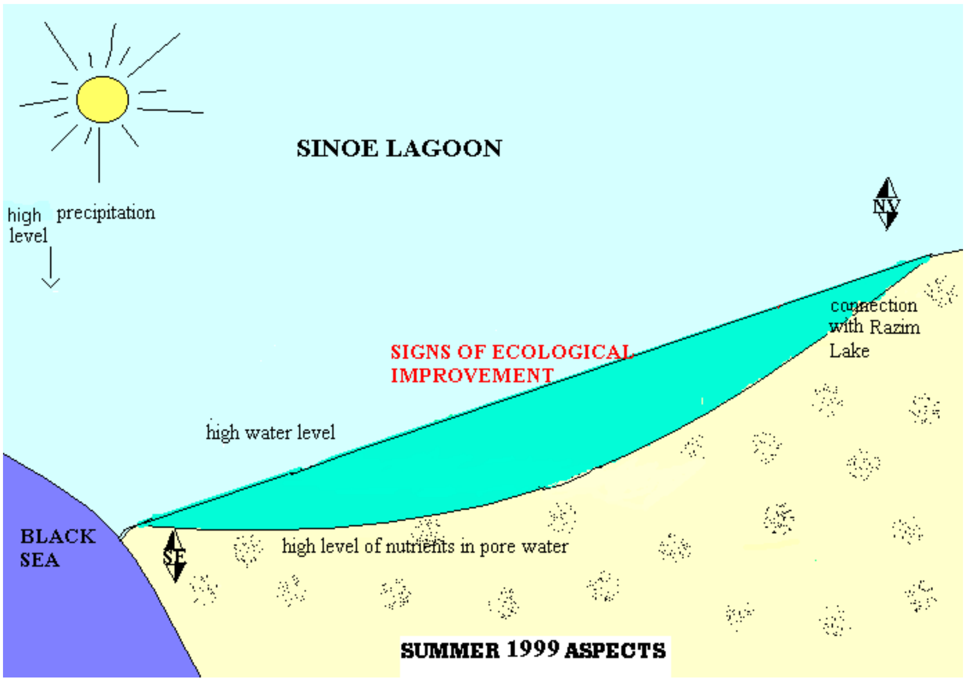


Fig. 9 – Sinoe lagoon zoobenthos biodiversity, main systematical groups
(M = marine; S = brackishwater; D = freshwater), during 1950-1998
Cn – Cnidaria; Ve – Vermes; Mo – Mollusca; Cr – Crustacea; L.i. – Insecta larvae

Fish production was 247 t. per year, 11 taxis have been recorded compared with 31 species in 1991. Three of them (crucial carp, bream and roach) constituted 67% of the catch (Table 2).

A comparative analyze between two consecutive years (Fig. 10), shows again the instability of region concerning both environmental and anthropogenic conditions.



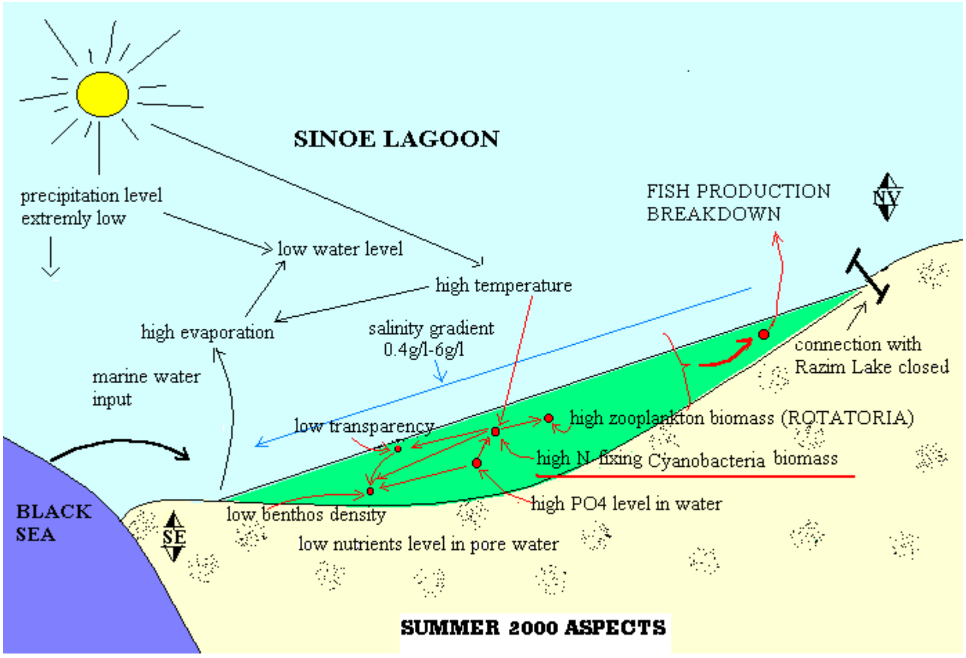
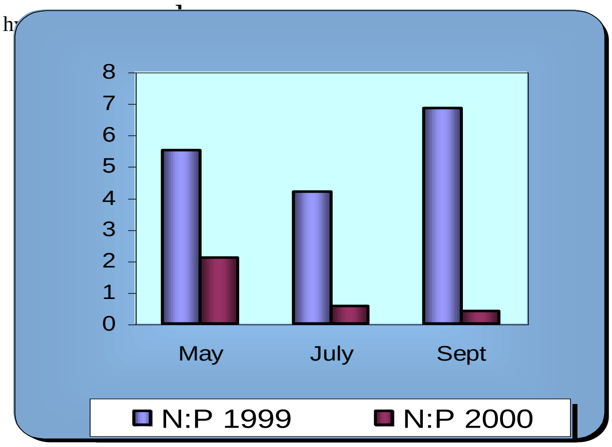
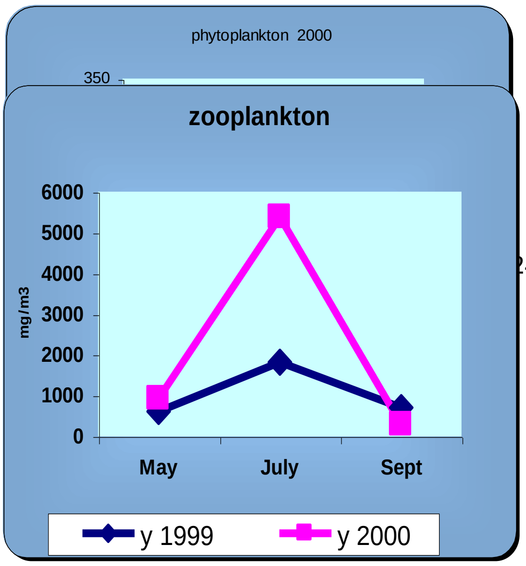
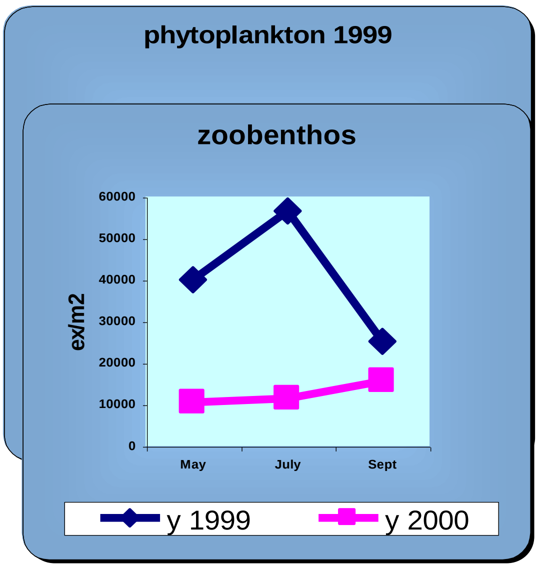


Fig. 10 – Relations between the ecological elements of the Sinoe lagoon ecosystem in two consecutive years – example of environmental instability

Fig.11 – Main h







Under the drought conditions in 2000 the Danube fresh water input decreased in the lagoon. Due to the marine water contribution a NV-SE salinity gradient was installed. The north link with the Razim Lake was closed for economical purposes, followed by the level decreasing and the isolation of the Sinoe lagoon. The specific hydro- and biochemical state was reflected in the qualitative and quantitative structure and distribution of phytoplankton (Fig. 11).

Analyzes results displayed a very high P level, and very low N/P ratios. The N/P stoichiometry was the decisive factor for microalgal species selection. In this way, the N-fixing cyanobacteria dominated the summer and fall phytoplankton production. The very high biomass but the low trophicity of the primary production affected the superior levels in the food web, inducing significant differences at the zooplankton and benthos level and the decrease of fish production.

CONCLUSIONS

1. Since 1974, the massive natural and anthropogenic impact induced important changes in the water quality and living resources of Sinoe lagoon.
2. The most important influences consisted in:
   - ***Freshening,*** with impact on the salinity gradual and distinctive decreasing;
   - ***Pollution,*** by hydrotechnical works, domestic waste products, detergents, agricultural and breeding activities, chemical agents, agricultural fertilizers, pesticides, private vegetable garden works, seasonal sailing and bathing areas, roads and railways access, coast consolidation;
   - ***Others***:
     - Overexploitation, mainly of fish resources,
     - Lack or wrong use of legislation for environmental protection,
     - Lack of reproduction and larval rearing places.
3. The main consequences of all above influences, were:
   - aquatic environment degradation,
   - ecosystem balance disturbing,
   - traditional biodiversity diminishing,
   - natural resources quality decline,
   - traditional activities disorganization.
4. At national level some important actions have been recommended:

- establishment of hydrotechnical measures concerning the discharge of excedentary Razim lake freshwater in order:
- to change the salinity regime of Sinoe lagoon at initial values;
- to ensure the diversification and the rational exploitation of fish population;
- initiation of a special study to update their present inventory of relict species, their communities and biotopes in view of the ecological protection and preservation.

5. The restoration of the initial saline status is disputed problem:
   - maximum fish catch (based on the Cypriniformes contribution, which cannot survive over 2-3 g/l salinity), recorded at 1.5 -2.0 g/l salinity;
   - the most important species (pike-perch) can reach maximum productions at 1.5-2.0 g/l, and could survive till 6-8 g/l;
   - on the contrary, the recovery of marine and euryhaline taxis (sturgeons, alosa, turbot, plaice, mullet, gudgeon) and their productions must be precedent by:
   - the improvement of environmental conditions (as the increasing of salinity - minimum value to 10 g/l - , restoration of bottom integrity, etc.);
   - rehabilitation of the main feeding resources (plankton and benthos communities).
6. The National Institute for Marine Research and Development suggested:
   - to decide the ecological and economical priorities in Sinoe lagoon;
   - to elaborate a sustainable development plan and an integrated coastal zone management for the protection and rational exploitation of the ichtyofauna.
7. It proposed ways for the rehabilitation of Sinoe lagoon biotopes and aquatic resources, by:
   - the use of bio-filter organisms (such as benthic bivalves) in the aim to improve the quality of water and substrate;
   - the improvement and practice of a rational aquaculture with the most accessible and valuable species.
8. In the aim of a rational fishing rehabilitation and development, in Sinoe lagoon, some economical actions have been proposed, too:
   - monitoring of fishing effort and catch,
   - arrangements for (STARAS, 1995):
     - specific scientifically based fishing effort,
     - type and characteristics of fishing equipment,
     - fish circulation to the market;
     - definition and establishment of fishing right.

9. Taking into account all these recommendations, ichtyofauna recovery and its rational use is desirable and could become possible.

Therefore, the radical changes in the species structure and the fish catches was a consequence of the regional climate, hydrological regime, salinity decreasing, intensity of migration of some species from the Black Sea and the last decade increased eutrophication. 30 years long research results could large collaboration project concerning the lagoon area recovery.

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