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Results of the problem based science analysis

3.2.3) The Tyligulskyi Lagoon, Ukraine

Integrated water resources and coastal zone management in European lagoons in the context of climate change

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Contents

1. Introduction

1.1. General description of the Tyligulskyi Liman lagoon

The Tyligulskyi Lagoon (see Fig. 1.1) is located on the Ukrainian coast in the North-Western part of the Black Sea, 60 kilometers away from the city of Odessa at the border of Odessa and Mykolaiv provinces (46°39.3′–47°05.3′N, 30°57.3′–31°12.7′E). The lagoon used to be a valley of the Tyligul River that has been flooded by sea waters; it stretches submeridionally from north-northwest to south-southeast. It is 45 to 52.1 km long and 1 to 4.5 km wide. When the watermark in the lagoon is −0.4 m BS (meters in the Baltic system of heights and depths), the estimated volume and the water-surface area are 693×10^6 m^3 and 129×10^6 m^2, respectively. The southern and central parts of the lagoon are hollows with prevailing depths in the range of 10 to 16 m divided by a shallow bridge (Fig. 1.2). The maximum depth in the southern part of the lagoon reaches 22 m. The northern part of the lagoon, where the Tyligul River flows into, is shallow, with the depths of less than 4 m. The average depth of the lagoon comprises approximately 5 m.

The lagoon is separated from the sea by a natural isthmus which is about 4 km wide and 7 km long. An artificial canal, 25–30 m wide and 0.25–1.5 m deep, has been built through the isthmus to connect the lagoon with the sea (Fig. 1.3). Pursuant to fishery purposes, the canal has to be open in spring to let young fishes into the lagoon for fattening. However, the canal is only occasionally put to use since it is intensively sanded up from the sea side. Lately, the canal is open in late April through early May by means of forced withdrawal of the sand, which is deposited at its marine area, and closed in the natural way in July through August. In addition to the fishery function, the canal is of great importance for stabilization of the lagoon water level. It is through intensive water management in the drainage basin of the Tyligulskyi Liman lagoon and the climate change that the volume of surface runoff of fresh waters into the lagoon (the Tyligul River runoff in the first place) decreased considerably and at presently is already unable to compensate the water the losses through evaporation, being in the summer period 3 times as much as the atmospheric precipitation. Under the lack of salt water inflow into the lagoon through the canal, the lagoon water level may decline almost 1 m in a few years (as it occurred, as an example, in 2006-2008).

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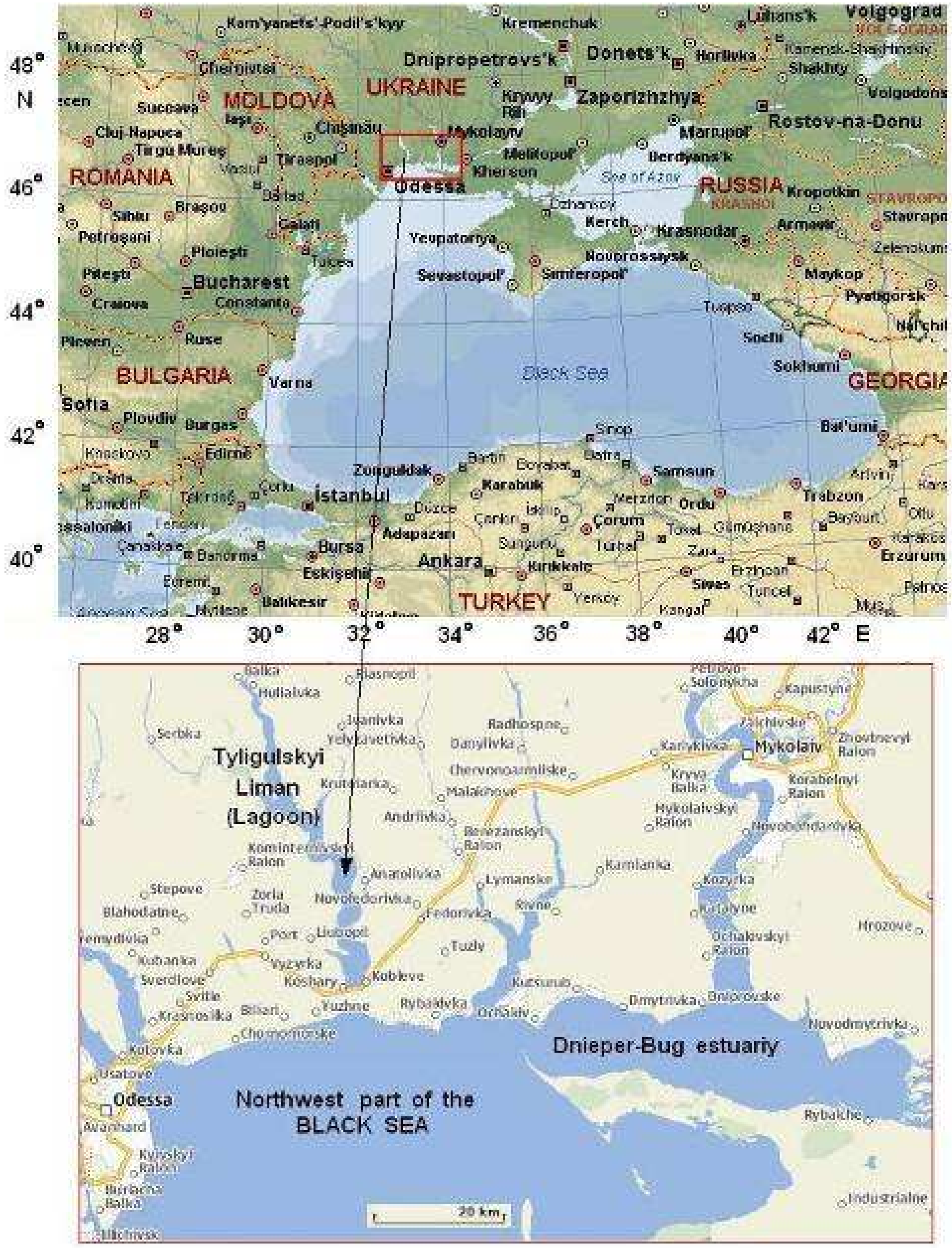

Figure 1.1 Location of Tyligulskyi Liman lagoon

has to be open in spring to let young fishes into the lagoon for fattening. However, the canal is only occasionally put to use since it is intensively sanded up from the sea side. Lately, the canal is open in late April through early May by means of forced withdrawal of the sand, which is deposited at its marine area, and closed in the natural way in July through August. In addition to the fishery function, the canal is of great importance for stabilization of the lagoon water level. It is through intensive water management in the drainage basin of the Tyligulskyi Liman lagoon and the climate change that the volume of surface runoff of fresh waters into

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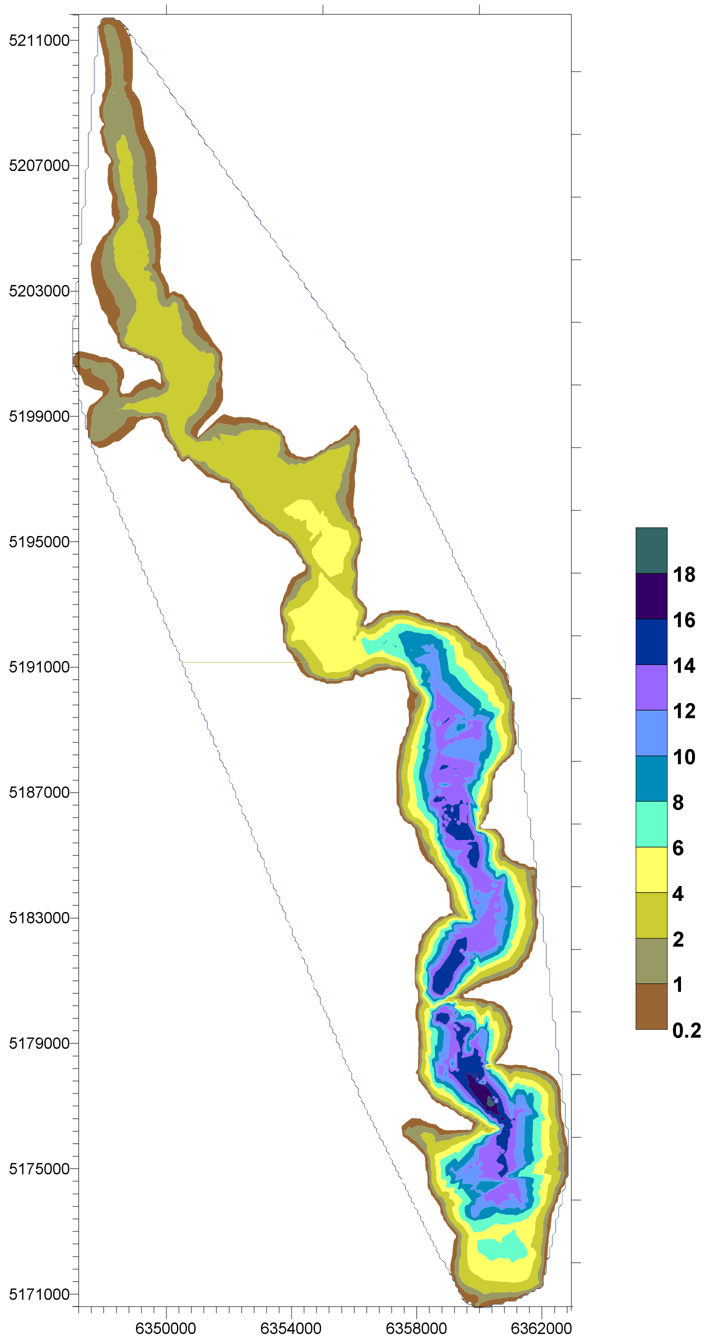

Figure 1.2 Bathymetric map of the Tyligulskyi lagoon in isobaths (in meters) under the watermark of -0.4 m BS. The horizontal coordinate system is WGS-84

However, functioning of the connecting canal has negative consequences for the lagoonal ecosystem in the long run. Unregulated water exchange with the sea through the connecting canal contributes to accumulation of salts in the lagoon and maintains a long-term tendency towards an increase in its water salinity. It may result in the gradual transformation of the lagoon into a hyperhaline water body with considerably less biodiversity of water flora and fauna, as compared to its current state.

Figure 1.3 Location of the artificial canal

1.2. The Tyligulskyi Liman lagoon natural values

The Tyligulskyi Lagoon ecological system has unique conditions for the life of fauna and flora, and the aquatorium of the lagoon is of great value for maintenance of biological equilibrium in the region.

An important role in functioning of the ecosystem in the Tyligulskyi Liman lagoon and its water quality is played by the benthic communities, the macrophytobenthos and the macrozoobenthos in particular. Although macrophytes are widely distributed only in the

coastal shallow zone of the lagoon with the depths of up to 2-4 m, they form considerable part of organic matter in the autotrophic link of the lagoonal ecosystem. Thus, if the maximum phytoplankton biomass is observed during summer months in waters of the Tyligulskyi Liman lagoon and makes up 40-60 $g \cdot m^{-3}$, the macrophyte biomass reaches 2-2.5 $kg \cdot m^{-2}$. Macrophytes play an important role in self-purification of the lagoonal water through extraction of biogenic substances from the water column and the bed silt, inclusion of these substances into their tissues and withdrawal of them from a cycle of matter for a long period of time. The macrophytes thereby regulate trophic levels of the lagoonal water, prevent outbreaks of phytoplankton (algal blooms), and raise the water transparency. Activity of the macrophytes has considerable influence on the pattern for diurnal variability of oxygen content in the coastal zone of the lagoon (Fig. 1.4). Apart from that, macrophyte thickets serve as spawning and feeding grounds for most of the fish species and their young.

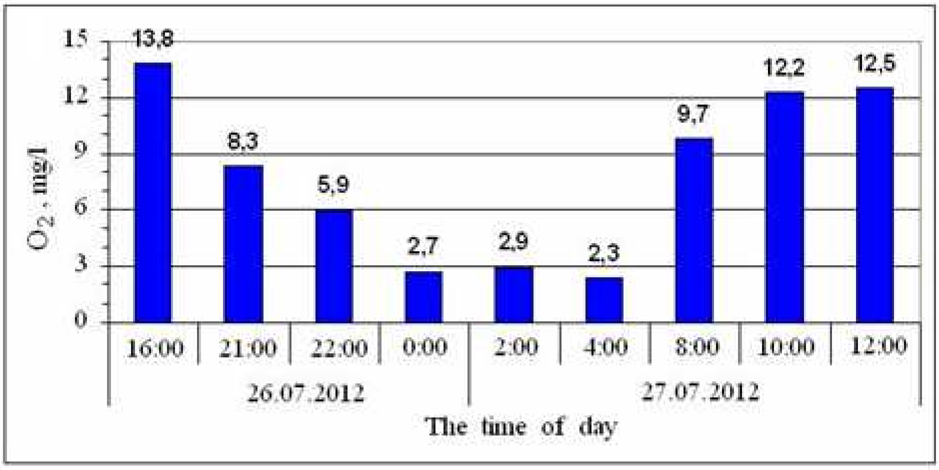

Figure 1.4 Diurnal variation of dissolved oxygen content in the coastal shallow zone in the southern part of the lagoon in August 2012

The macroinvertebrate communities perform an important function of organic substance transformation in the ‘water column – bed silt’ system that determines their significant role in self-purification of the Tyligulskyi Liman lagoon. They play an important role in the biogeochemical turnover of biogenic elements in the lagoon and, specifically, removal of nitrogen and phosphorus from the bed silt as well as return of biogenic elements from the water environment to a surface through imago of amphibiotic insects. The benthic macroinvertebrates regulate gas regime and texture of the lagoonal soils, and are ones of the

main links for information storage and transfer in the water ecosystem. Therefore the macrozoobenthos as well as the macrophytes are good bioindicators for the state of ecosystem in the Tyligulskyi Liman lagoon and its water quality.

Peculiarities in spatial distribution of the macrophytobenthos and the macrozoobenthos of the Tyligulskyi Liman lagoon are conditioned by distribution of depths and types of benthic soils, variability in salinity and oxygen regime of the lagoonal waters.

1.3. Recent environmental changes in the Tyligulskyi Liman lagoon

The main hydrological factor which conditions a long-term tendency in variability of species composition of the bottom flora and fauna, and fishes in the lagoon, is its water salinity. Upon launching of the connecting canal to the sea in 1959 salinity of the lagoonal waters has been rising gradually due to the accumulation of salts inflowing with the sea waters. In the 1960s, when the volume of the Tyligul River runoff constituted a considerable part of the lagoonal water balance and water exchange with the sea was maintained, the average values of water salinity in the northern part of the lagoon made up 8.7‰, in the central part - 11.4‰, and in the southern part - 13–14‰ (Rozengurt, 1974). Under the present-day conditions water salinity in both the southern and the northern parts of the lagoon may increase up to 19-23 ‰ by the late summer – early autumn (Fig. 1.5).. The average annual salinity of the lagoonal waters is above 18‰. In the years with intensive spring flood water salinity in the northern part of the lagoon may decrease to 3-5 ‰.

Within the latest 50 years, under the influence of increased water salinity in the lagoon, the distribution of macrophytobenthos into environmental groups has changed towards an increase in salt water species, from 18.1 to 45.6 %, saltish - salt water species – from 22.3 to 37.7 % and a decrease in saltish water species – from 21.4 to 11.7 %. Currently the freshwater species have almost completely lost their value and persist only in the mouth of the intermittent Tyligul river.

Presently salt water and saltish-salt water species of the macrophytobenthos (100 and 82.8% respectively) prevail in the southern and the central areas of the lagoon, and the role of fresh-saltish water species rises in the northern area. In the years, when the surface runoff of fresh waters into the lagoon increases (for example, under an intensive spring flood), the share of saltish and salt water species, as well as the total species diversity, decreases.

Relative isolation of the lagoon from the sea facilitated persistence of the isolated population of *Cystoseira barbata*, which had become extinct in the North-Western part of the Black Sea in the 1980s, in the Tyligulskyi Liman lagoon. Among the macrophytes inhabiting the lagoon, 1 species (*Chara canescens*) is in the Red Book of Ukraine and 2 species of aquatic flowering plants (*Zostera noltii, Z. marina*) are in the Red Book of the Black Sea. The red alga of *Rhodochorton purpureum* (Lighth.) Rosenv., which was found on *Cystoseira barbata*, is rare in Ukraine. *Vaucheria litorea* Hofm. et Ag. in C. Ag., still being a mass species in the lagoon, is among the ones with decreasing number of specimens in Ukraine.

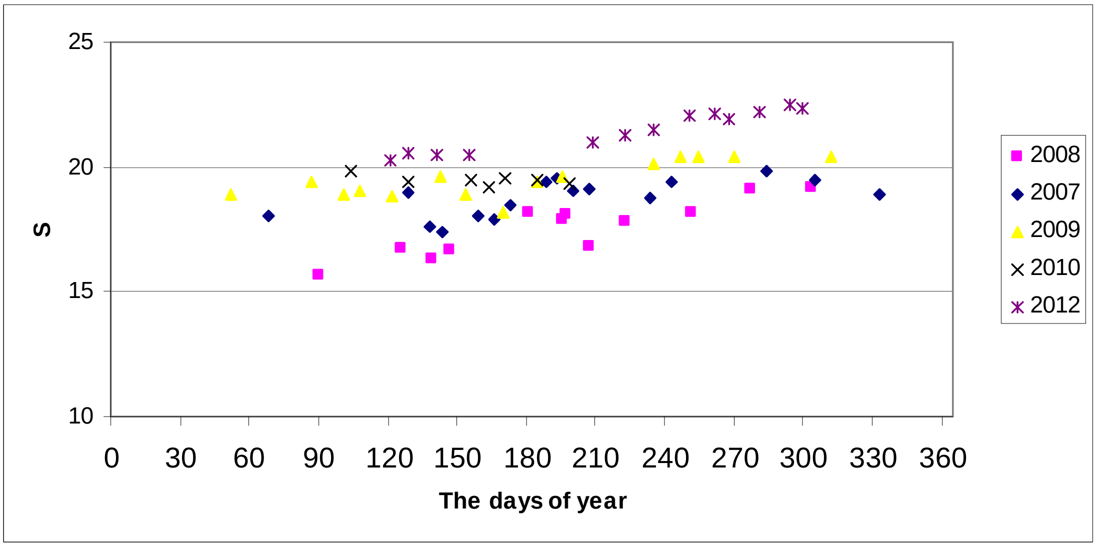

Figure 1.5 Within-year variability of water salinity (‰) in the central part of the lagoon (Pshenianovo village) in the period of 2007-2012

As a result of increased water salinity, the fauna in the Tyligulskyi Liman lagoon has also become more salt water. By the 1980s, as compared to 1947-1952, the number of *Nereididaes, Oligochaetas, Amrhipodes* had increased. The species composition of *Molluscs* had changed. Once having been widespread throughout the lagoon, *Hypanis colorata* had disappeared. The number of *Cerastoderma clodiense*, *Mytilaster lineatus*, *Abra ovata*, *Gastropoda* and *Rhithropanopeus harrisi fridentana* specimens increased. The total biomass of the macrozoobenthos had grown due to increased number of *Molluscs*. A difference in the faunal composition of the macrozoobenthos between the northern and southern parts of the lagoon had become less drastic. *Monodacna colorata* + *Cardium* biocoenosis had become extinct and were replaced primarily by *Cerastoderma* biocaenosis in various versions.

As a result of the increased salinity and trophic level of lagoonal waters, replacement of saltish-water fauna by salt-water one, deteriorated oxygen regime of the lagoonal waters (development of hypoxia and anoxia in the summer period), unstable and uncontrolled operation of the connecting canal, species composition of fish in the lagoon decreased from 48 species in 1964 to 23 in the early XXI century. The volume and value of commercial catches of fish have significantly reduced.

Distribution and variability of quantitative characteristics of the benthic bottom flora and fauna in the water area of the Tyligulskyi Liman lagoon are also determined by the oxygen regime of its waters. In the summer period the dissolved oxygen deficit (hypoxia) occurs in the bottom water layer within the deep water areas of the lagoon as well as in the shallow ones under calm conditions and intense heating of water during nighttime. It is in the waters of deep central part of the lagoon that cases of extreme oxygen deficiency and occurrence of hydrogen sulphide at the depths below the upper quasihomogeneous mixed layer were reported (Fig. 1.6). Under certain wind directions hypoxic waters inflow into the shallow coastal zone which results in the death of benthic hydrobionts and fish. Owing to occurrence of hypoxic and anaerobic conditions in the deeper parts of the lagoon, this zone is not a permanent habitat for the benthic flora and fauna.

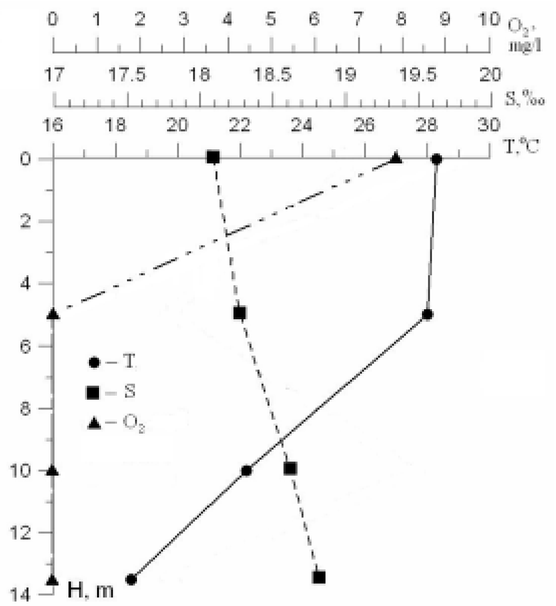

Figure 1.6 Vertical distribution of water temperature (°C), salinity (‰), and dissolved oxygen content (mg·l^{-1}) over the deep hollow in the central part of the Tyligulskyi Liman lagoon in August 2010

2. Main lagoonal habitats and their ecological importance

2.1. The importance of lagoonal benthic habitats

Macrophytobenthos and macrozoobenthos communities are the components of the lagoon biocoenosis and play an important role in conservation of specific diversity in the aquatic ecosystem of the Tyligulskyi Liman lagoon, as well as in the turnover of mineral and organic substances, biological self-purification processes, maintenance of the nutritive base, especially for fish, in the water bodies. Aquatic macrophytes are the first link in the cycle of matter and energy as the primary producers of organic matter. They influence the hydrochemical regime, and serve as a powerful biological filter in the course of natural self-purification of the water bodies. The macrobenthos plays an important role in functioning of the aquatic ecosystems, provision of trophic interconnection of the species; therefore changes in the structure of the benthic communities may affect higher trophic levels. Being sensitive to the changes in environmental conditions, but resistant and well-adapted on occasions of extreme influences, the zoobenthos serves as an excellent indicator for the technogenous or natural factor-driven processes occurring in the water body. Since zoobenthic response to external changes comes not instantly but after a while, the benthic community reflects not the short-term changes in the characteristics of the environment, but their systematic effect over a long period of time.

2.2. The Tyligulskyi Liman lagoon benthic habitats

a) Classification of major bottom types

Unfortunately, there exists no detailed map of bed silt types in the lagoon through its large spatial scales and significant mosaicity of the bed silt. However, as follows from (Kovtun, 2012), it is possible to make a general scheme for distribution of bottom soils in the lagoon, depending on the depths (Fig. 2.1).

b) Presence of benthic macrophytes

The results of research into the macrophytobenthos in the Tyligulskyi Liman lagoon, implemented before 1965, are summarized in the paper (Pogrebniak, 1965). During this

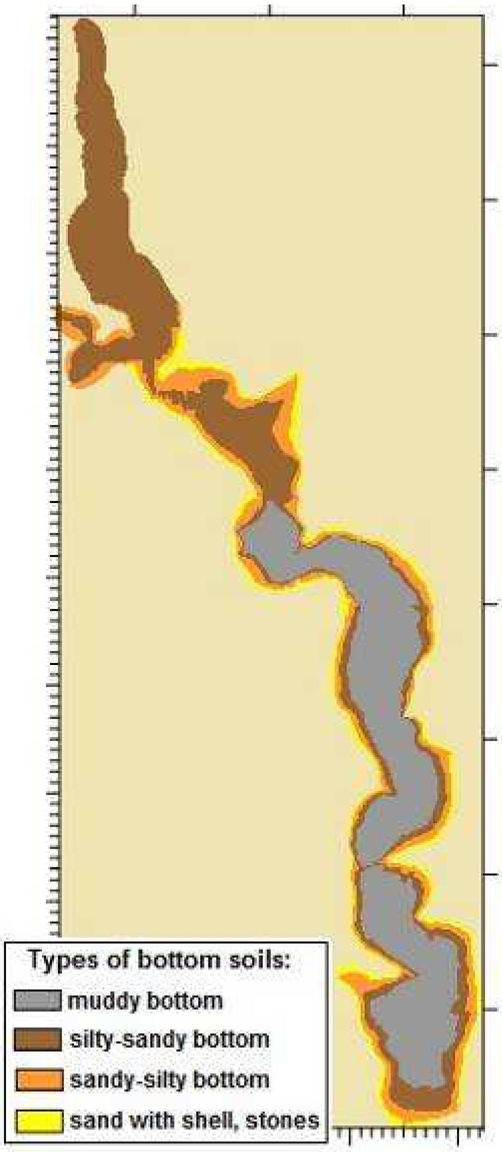

Figure 2.1 The scheme for layout of bottom soils in the Tyligulskyi Liman lagoon

period 213 taxa of algae were found in the lagoon, among which cyanobacteria comprised 42, green algae - 22, diatoms - 128, brown algae - 3, and red algae - 8. There were 5 species of blooming algae registered. 7 algal associations were widespread in the 1850s and 1860s. The coastal area with a stony bottom was occupied by a *Cladophora vagabunda* association. The silted and sandy coastal soils in the southern part of the lagoon were covered by a *Potamogeton pectinatus* association (jointly with *Zanichellia major* and *Ruppia spiralis*). In the southern and the central parts of the lagoon a *Zostera minor* association is prevalent on the sandy soil and *Zostera marina* - near the nehrung. The silted soils, which are located off the coast, have poor macrophyte diversity. They are inhabited by the cyanobacteria of

Oscillatoria genus: *O.brevis, O.amphibia, O. tenuis, O. nigroviridis*, and *Spirulina tenuissima*.

Detailed studies of the phytobenthos in the Tyligulskyi Liman lagoon during 1990-2005 and their comparison with historical data were conducted by O.A. Kovtun (Kovtun, 2012). During the research period he discovered 69 specific and intraspecific taxa of macrophyte algae and 10 species of higher aquatic plants, represented by 5 divisions, 8 classes, 16 orders and 35 genera.

The species diversity of macrophytobenthos in the period of 1990 through 2005 was based on the species of *Chlorophyta* and *Rhodophyta* divisions (30 and 24 species, respectively). The role of brown and yellow-green algae (12 and 2 species, respectively) is less significant. Higher aquatic flowering plants, which dominate in the biomass almost throughout the entire lagoon, are represented by 10 species. Taxonomic composition of macrophytobenthos is presented in Table. 2.1

As compared to the data (Pogrebniak, 1965), 10 new species of green algae are distinguished in the paper (Kovtun, 2012): *Enteromorpha maeotica, Percursaria percursa, Ulothrix limnetica, Cladophora glomerata, C.siwaschensis, C.vadorum, Rhizoclonium tortuosum, Bryopsis plumosa, Spirogyra decimina, S.hassallii*. 4 species, *Entocladia viridis* Reinke, *Gomontia polyrrhiza* (Lagerh.) Born. Et Flah., *Ulothrix tenuissima Kutz.* and *Chaetomorpha chlorotica* (Mont.) Kutz.), specified by I.I. Pogrebniak (1965), were not found among the representatives of *Chlorophyta*.

The species composition of *Rhodophyta* brown algae was supplemented by 9 new species in 1990-2005: *Pylaiella littoralis, Corynophlaea umbellate, Leathesia difformis, Scytosiphon lomentaria, Stictyosiphon adriaticus, Desmotrichum undulatum, Punctaria latifolia, Striaria attenuate, Cystoseira barbata*. However, *Cladosiphon contortus,* which had previously been reported, were not found.

Cyclosporophyceae class is represented by only one species, *Cystoseira barbata*, which was found in the lagoon in the late 1990s. Yellow-green algae were not indicative of the lagoon previously. The specific composition of *Xanthophyta* division is represented by 3 species: *Vaucheria dichotoma f. submarina, V. geminate, V. litorea*.

In the 1940-1950s, when water salinity in the lagoon was more than 2 times lower as compared to the present level, five species of aquatic flowering plants were identified. As a

result of the lagoon salinization, the species composition was supplemented by 5 more salt-tolerant species, and halophobous species were driven off into the upper part of the lagoon.

Table 2.1 Taxonomic composition of the macrophytobenthos in the Tyligulskyi Liman lagoon (Kovtun, 2012)

Taxon	Number of Taxa		
	Genera	Species	Intraspecific taxa
1	***2***	***3***	***4***
CHLOROPHYTA			
ULVOPHYCEAE			
ULOTRICYHALES Bohl.	7/6*	14/14	-/-
CLADOPHORALES Fritsch	3/3	7/10	-/-
SIPHONALES (Endl.)Blackm.et Tansl.	1/1	1/2	-/-
ZYGNEMATOPHYCEAE			
ZIGNEMATALES Krieq	1/1	1/3	-/-
CHAROPHYCEAE			
CHARALES Dumor.	1/1	1/1	-/-
RHODOPHYTA			
BANGIOPHYCEAE			
CONIOTRYCHALES Skuja	2/2	2/2	-/-
BANGIALES Schmitz	-/3	-/3	-/-
FLORIDEOPHYCEAE			
ACROCHAETIALES Garb.	1/3	1/4	-/-
CORALLINALES Silva et Johansen	1/-	1/-	-/-
CERAMIALES Oltm.	3/4	7/16	1/2
PHAEOPHYTA			
PHAEOSPOROPHYCEAE			
ECTOCARPALES Oltm.	1/2	2/3	-/-
CHORDARIALES Setch. et Gardn	1/2	1/2	-/-
SCYTOSIPHONALES Feldm.	-/1	-/1	-/-
PUNCTARIALES Kylin	-/4	-/4	-/-
CYCLOSPOROPHYCEAE			
FUCALES Kylin	-/1	-/1	-/-
XANTHOPHYTA			
XANTHOPHYCEAE			
VAUCHERIALES Bohl.	-/1	-/3	-/1
MAGNOLIOPHYTA			
NYMPHAEALES			
CERATOPHYLLACEAE	1/1	1/1	
HIPPURIDALES			
HALORAGACEAE	-/1	-/1	-/-
NAJADALES			

1	2	3	4
POTAMOGETONACEAE	1/1	1/1	-/-
ZOSTERACEAE	1/1	2/2	-/-
RUPPIACEAE	1/1	1/2	-/-
ZANNICHELLIACEAE	1/1	1/1	-/-
POALES			
POACEAE	1/1	1/1	-/-
TYPHALES			
TYPHACEAE	-/1	-/1	-/-

Note: The numerator is a number of known species, according to the reference data, and the denominator is a number of known species, according to the original data.

Among the macrophytes, which inhabit the lagoon, 1 species (*Chara canescens*) is in the Red Book of Ukraine and 2 species of aquatic flowering plants (*Zostera noltii*, *Z. marina*) are in the Red Book of the Black Sea. *Rhodochorton purpureum* (Lighth.) Rosenv., red alga, which was found on *Cystoseira barbata,* is rare in Ukraine.

A decrease in species diversity, from farther away the sea canal in the southern part towards the upper reaches of the Tyligulskyi Liman Lagoon, is distinctly observed in the distribution of various taxonomic groups of benthic vegetation in the lagoon. At the same time, the total share of green algae rises and the share of red ones declines. The upper (northern) part of the lagoon is presently the most severely affected by changing hydrological conditions. During the spring flood this part was substantially desalinated in certain years. Abrupt but short-term decline in salinity, 18-23‰ to 2-10‰, resulted in a decrease in the number of the brackish and the salt water species and, on the whole, a nearly twofold decrease in the species diversity in the northern part, as compared to the one of the southern part (Table 2.2).

Table 2.2 Area distribution of macrophytes in the phytocenoses of the Tyligulskyi Liman lagoon (Kovtun, 2012)

Division	Area			Total number of species in the lagoon
	Southern (Lyubopol village)	Central (Petrovka village)	Northern (Volkovo village)	
CHLOROPHYTA	32	26	24	34 (39.1 %)
RHODOPHYTA	27	15	6	28 (32.2 %)
PHAEOPHYTA	10	6	3	12 (13.8 %)
XANTHOPHYTA	2	1	2	3 (3.5 %)
MAGNOLIOPHYTA	8	5	4	10 (11.5 %)
Total	79	53	39	87 (100 %)

In the southern and the central areas of the lagoon a predominant position is occupied by the salt water and the brackish – salt water species (100% and 82.8%, respectively), while in the northern area the role of the fresh-brackish water species increases. At present, the freshwater species, in contrast to the 1940-1960s, have almost completely lost their value and persist only in the mouth of the intermittent Tiligul River (Fig. 2.2).

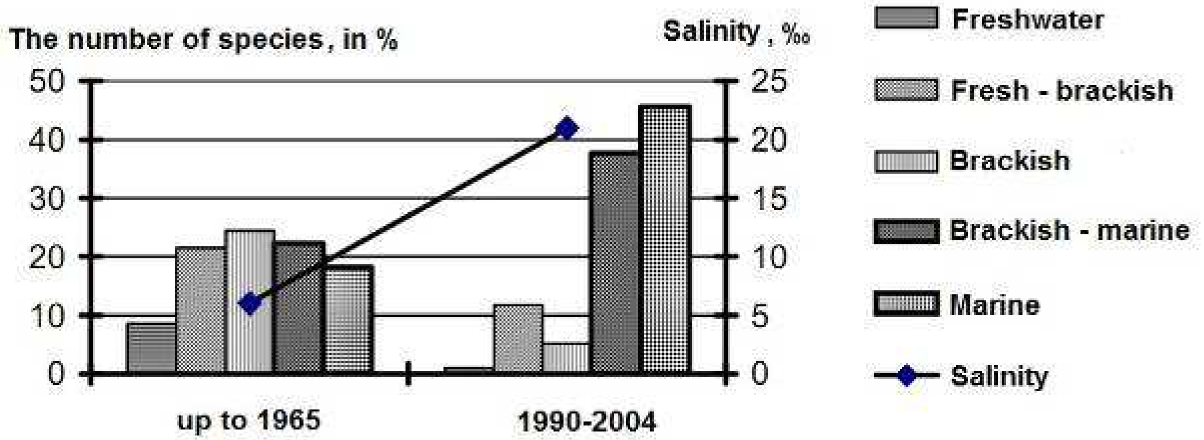

Figure 2.2 The dependence of the number of species (in %) related to macrophyte ecology groups on the salinity under various periods of research: 1 – the data prior to 1965 (Pogrebniak, 1965), 2 – the data for 1990-2004 (Kovtun, 2012).

The distribution of macrophyte ecology groups for the whole of the lagoon prior to 1965 (Pogrebniak, 1965) and within the period of 1990 through 2004 (Kovtun, 2012) is given in Table 2.3.

In the period of 2001 through 2011, the macrophytes in the Tyligulskyi Liman lagoon were studied by the Odessa Branch of the Institute of Biology of the Southern Seas of the National Academy of Sciences of Ukraine. Samples were collected from the shore (at the depths of 0-0.7 m) and with the use of lightweight diving equipment (at the depths of 0.7 - 4.0 m) in the three botany profiles, located in the northern shallow part of the lagoon (Kalinovka Profile), in the central part, on the border of its shallow and deeper zones, (Maryanovka Profile) and in the southern part (Koshary Profile) of the Tyligulskyi Liman lagoon (Fig. 2.3). Standard methods of Water Geobotany were used for sampling the vegetation. The profiles for the outwash to the deep part of the lagoon were developed at the monitoring stations. At the botany horizons, which were singled out by the nature of dominant population

distribution, the quantitative samples of benthic vegetation were taken by means of a periphyton frame (10x10 cm) or (20x20 cm). Projective coverage of the bottom with macrophytes was assessed visually. An identification guide for green, brown and red algae of the Southern Seas (Zinoviev, 1967) was used to identify the specific composition of macroalgae in the Tyligulskyi Liman lagoon. The data bank for the period of 2000 through 2011 includes 21 botanical surveys and 576 quantitative samples of macrophytobenthos.

Table 2.3 Ecology groups of macrophytobenthos in various areas of the Tyligulskyi Liman lagoon (salinity factor)

Ecological Group	Reference data before 1965, %	Area			Total for the lagoon
		Southern (Lyubopol village)	Central (Petrovka village)	Northern (Volkovo village)	
Salt water	18.1	35 (100)	30 (85.7)	15 (42.9)	35 (45.6)
Brackish – salt water	22.3	24 (82.3)	25 (86.2)	18 (62.1)	29 (37.7)
Brackish water	24.5	4 (100)	2 (50.0)	-	4 (5.2)
Fresh – brackish water	21.4	5 (55.6)	3 (33.3)	3 (33.3)	9 (11.7)
Freshwater	8.6	-	-	-	-

Note: parenthesized is the share of the total number of taxa expressed as a percentage

Differences in thermohaline conditions (especially salinity), water transparency, predominant bottom soils, oxygen regime, nutrient concentrations in various parts of the lagoon condition the differences in floristic composition of the macrophytobenthos in the lower (Koshary), the middle (Maryanovka) and the upper (Kalinovka) parts of the lagoon (Table 2.4)

The lower (southern) part of the lagoon (Koshary profile) is distinguished for the widest floristic diversity. The maximum number of macroalga and flowering macrophyte species, as compared to the middle and the upper parts of the lagoon, namely 46, grows there (see Table 2.4). This area is the most exposed to salt water inflow through the connecting canal. As a result of this, there observed the maximum number of representative macrophytobenthos species which are characteristic of the seacoast zone area adjacent to the Tyligulskyi Liman lagoon. Another distinctive peculiarity of the lower part of the Tyligulskyi Liman lagoon is growth of the *Phaeophyta* - *Cystoseira barbata* local population. In the

1980s, this species completely disappeared from the littoral within the Danube-Dnieper coastal area in the North-Western Black Sea region owing to intense eutrophication. The only place in the region where *Cystoseira barbata* continued to develop over the latest 30 years is the southern part of the Tyligulskyi Liman lagoon ecosystem.

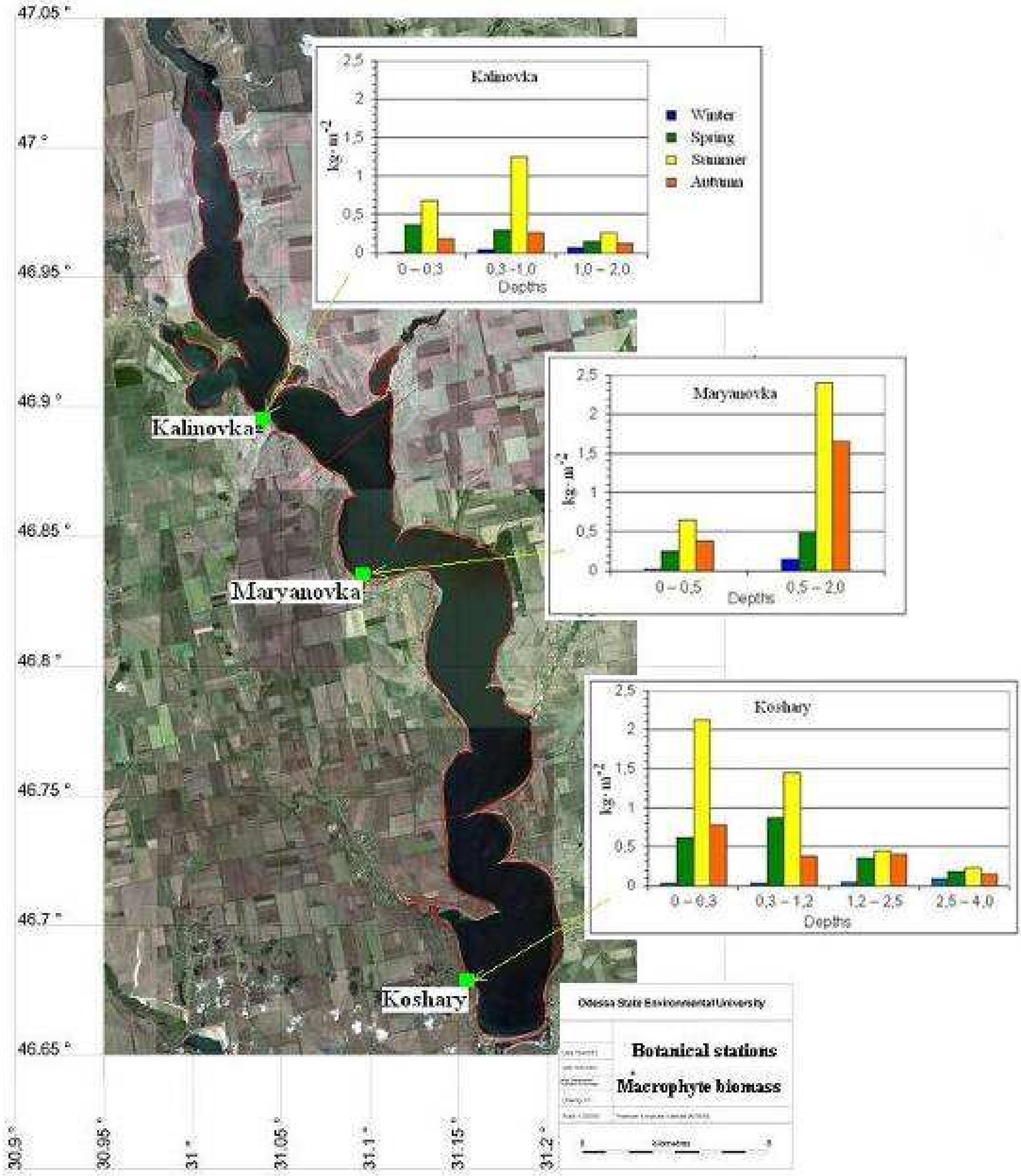

Figure 2.3 Location of the botany stations for sampling macrophytes in the Tyligulskyi Liman lagoon and the registered macrophyte biomass variability, depending on the depth and the season, according to the observational data for the period of 2001 through 2011

Table 2.4 Spatial distribution of the macrophyte species diversity in the Tyligulskyi Liman lagoon

N	Species composition	Spatial distribution		
		Kalinovka	**Mariya-novka**	**Koshary**
	Chlorophyta			
1	***2***	***3***	***4***	***5***
1.	*Bryopsis hypnoides Lamour.*			+
2.	*B. plumosa (Huds.) Ag.*			+
3.	*Chaetomorpha aerea (Dilw) Kutz.*	+		+
4.	*Ch. chlorotica (Mont.) Kutz.*	+	+	+
5.	*Ch. linum (Mont.) Kutz.*	+		+
6.	*Cladophora albida (Huds.) Kutz.*	+		+
7.	*C. laetevirens (Dillw.) Kutz.*	+		+
8.	*C. liniformis Kutz.*	+	+	+
9.	*C. sericea (Huds.) Kutz.*			+
10.	*C. vadorum (Aresch.) Kutz.*			+
11.	*C. vagabunda (L.) Hoek.*	+	+	+
12.	*Enteromorpha ahlneriana (Bliding)*	+		+
13.	*E. clathrata (Roth.) Grev.*	+	+	+
14.	*E. flexuosa (Wulf.) J. Ag.*			+
15.	*E. intestinalis (L.) Link.*	+	+	+
16.	*E. linza (L.) J. Ag.*			+
17.	*E. prolifera (O. Mull) J. Ag.*			+
18.	*Rhizoclonium implexum (Dillw.) Kutz.*			+
19.	*Rh. riparium (Roth) Harv.*			+
20.	*Ulotrix flacca (Dillw.) Thur.*			+
21.	*U. implexa (Kutz.) Kutz.*			+
22.	*U. tenerrima (Kutz.) Kutz.*			+
23.	*U. zonata (Web., Mohr) Kutz.*			+
24.	*Ulva rigida Ag.*			+
25.	*Vaucheria litorea Horm.-Bang. Ag.*	+		
	Phaeophyta			
26.	*Cystoseira barbata (Good., Wood.) Ag.*			+
27.	*Ectocarpus confervoides (Roth.) Le Jolis*			+
28.	*E. siliculosis (Dillwyn) Lyngb.*			+
	Rhodophyta			
29.	*Callithamnion corymbosum (J.E. Smith.) Lyngb.*	+	+	+
30.	*Ceramium arborescens*	+		+
31.	*Ceramium diaphanum*	+	+	+

1	2	3	4	5
32.	*Ceramium elegans*	+	+	+
33.	*Ceramium rubrum*	+		+
34.	*Ceramium strictum*	+		
35.	*Ceramium tenuissimum*	+		+
36.	*Chondria capillaris (Huds.) M.J. Wynne*	+	+	+
37.	*Goniotrichum elegans (Chauv.) Zanard.*	+		+
38.	*Kylinia virgatula (Harv.) Papenf.*		+	+
39.	*Polysiphonia denudata (Dillw.) Kutz.*	+	+	+
40.	*P. elongata (Huds.) Harv.*			+
41.	*P. opaca (C. Ag.) Zanardini*	+		+
42.	*P. sunguinea (Ag.) Zanard.*			+
43.	*P. subulifera (Ag.) Zanard.*	+		+
	Cyanophyta			
44.	*Lyngbia confervoides C. Agardh*			+
45.	*L. lutea (Ag.) Gomont*			+
	Thallassiophyta			
46.	*Potamogeton pectinatus L.*	+		+
47.	*Zostera marina L.*		+	+
48.	*Zostera noltii Hornem.*	+		+
	Total number of species	**25**	**12**	**46**

Proceeding from the peculiarities of distribution of the macrophyte dominant species, 4 depth ranges for bottom vegetation development can be identified in the Koshary profile (Table 2.5). The specified peculiarity of horizontal distribution in the macrophytobenthos is conditioned by the coastal profile characteristics, considerably greater difference of depths within the coastal zone and water transparency in the southern part of the lagoon, as compared to the ones of Kalinovka and Maryanovka.

A horizontal distribution peculiarity of macrophytes in the Koshary profile is the growth of short-cycle, small-scale species of green (*Chlorophyta*) and red (*Rhodophyta*) algae in the upper level (0-0.3 m), near the shore line. *Cystoseira barbata* is widely-distributed up to the depth of 2 meters and reaches its maximum development at the depths of 0.3-1.2 m. The area for development of *Zostera noltii* flowering macrophyte stretches from the depth of 0.3 - 0.5 m on in the soft soil. In the deeper areas it is replaced by larger *Zostera marina* and *Potamogeton pectinatus* flowering macrophytes. It is among the leaves of the flowering macrophytes, *Chaetomorpha chlorotica*, *C. Linum, Rhizoclonium riparium* and *Cladophora liniformis* that green filamentous algae develop in an unattached state. They can form ‘scum’

aggregates with substantial biomass in the depth range of 0.5 through 2.5 m, which are carried by the currents into shallow corner zones of the lagoon.

The area of the Maryanovka botany profile is distinguished by small depths of up to 2 meters. The dominant macrophyte in the area is *Zostera marina*, which forms underwater meadows at the depths of 0.3-0.5 m. It is only near the shore in the shallow water that a *Zostera marina* thicket includes multicellular green and red algae. There is no *Cystoseira barbata* population in the area. In connection with such peculiarities of the bottom vegetation distribution, only two horizons can be distinguished in the area (Table 2.6).

Table 2 .5 Horizontal distribution of the macrophyte dominant species at Koshary botany station

Horizons (levels), m			
0 – 0,3	0,3 – 1,2	1,2 – 2,5	2,5 – 4,0
Enteromorpha intestinalis *E. ahlneriana* *Chaetomorpha chlorotica* *Cladophora albida* *C. liniformis* *Cystoseira barbata* *Ectocarpus confervoides* *Ceramium diaphanum* *C. elegans* *Polysiphonia denudata* *Callithamnion corymbosum* *Zostera noltii*	*Chaetomorpha chlorotica* *Rhizoclonium riparium* *Enteromorpha linza* *Cladophora laetevirens* *Cystoseira barbata* *Ceramium rubrum* *Chondria capillaries* *Polysiphonia subulifera* *Zostera noltii*	*Chaetomorpha linum* *Cladophora liniformis* *Cystoseira barbata* *Ceramium rubrum* *Chondria capillaris* *Polysiphonia subulifera* *Zostera marina* *Potamogeton pectinatus*	*Chaetomorpha linum* *Polysiphonia subulifera* *Zostera marina* *Potamogeton pectinatus*

Due to the extensive development of *Zostera marina* in the middle part of the Tyligulskyi Liman lagoon, the microscopic *Kilinia virgatulla* red alga is a widespread species in the same area. It develops in epiphytic way on the leaves *of Zostera marina* and under its massive growth forms crimson-and-pink ‘velvet’ covers on them.

The depths within the Kalinovka botany profile are also less than 2 meters, however, more botanic belts are observed in horizontal distribution of the macrophytes. For the given area it can be distinguished a level of up to 0.3 m, on the Pontian limestone coastal rocks near the water edge, and two deeper levels (Table 2.7). *Zostera noltii* is the dominant species

among the flowering macrophytes in the area. The growth of *Zostera noltii* is observed from 0.3 m depth on and stretches up to 2-meter depth. At the depths of 1.0-1.5 m a *Zostera noltii* thicket includes *Potamogeton pectinatus* plants. Red and green algae are widely distributed on the rocks near the shore (Table 2.7). Filamentous green algae, which can form ‘scum’ aggregates, grow among the leaves of flowering macrophytes, in the same way they do in the southern part of the Tyligulskyi Liman lagoon. Mass growth of *Zostera marina* in the upper (northern) part of the Tyligulskyi Liman lagoon is not observed.

Table 2.6 Horizontal distribution of the macrophyte dominant species at Maryanovka botany station

Horizons, m	
0 – 0,5	0,5 – 2,0
Enteromorpha intestinalis *E. clathrata* *Chaetomorpha chlorotica* *Cladophora liniformis* *Ceramium elegans* *C. diaphanum* *Polysiphonia opaca* *Chondria capillaries* *Zostera marina*	*Chaetomorpha chlorotica* *Chondria capillaries* *Kilinia virgatulla* *Zostera marina*

Table 2.7 Horizontal distribution of the macrophyte dominant species at Kalinovka botany station

Horizons, m		
0 – 0,3	0,3 – 1,0	1,0 – 2,0
Enteromorpha clathrata *E. ahlneriana* *Cladophora albida* *C. vagabunda* *Ceramium diaphanum* *Polysiphonia denudata* *Callithamnion corymbosum* *Zostera noltii*	*Chaetomorpha aerea* *Rhizoclonium riparium* *Chondria capillaries* *Zostera noltii*	*Chaetomorpha linum* *Polysiphonia subulifera* *Zostera noltii* *Potamogeton pectinatus*

Peculiarities in seasonal dynamics of the macrophyte biomass within the botany profiles are shown in Fig. 2.3 shows that the maximum macrophyte biomasses in the lower (Koshary) part of the Tyligulskyi Liman lagoon in the summer season can exceed 2 $kg \cdot m^{-2}$ near the water edge. The middle part of the lagoon (Maryanovka), as well as the lower one,

are characterized by development of maximum biomass values, higher than 2 $kg \cdot m^{-2}$, in the summer period. However, the maximum biomasses in this part of the lagoon are generated at the deeper levels of 0.5-2.0 m, mainly due to the growth of *Zostera marina* flowering macrophyte instead of the algae. In summer, within the level of 0 - 0.5 m the production is higher on account of more active, as compared to *Zostera marina*, short-cycle multicellular species of green and red algae.

Somewhat smaller absolute values of macrophyte biomass are observed in the Kalinovka botany profile in the northern part of the lagoon during the summer period, as compared to the ones of the middle and the lower parts (Fig. 2.3). As well as in the middle part, the maximum macrophyte biomasses in the Kalinovka botany profile are generated within the second shoreline level off the water edge (0.3-1.0 m). However, it is not *Zostera marina* but *Zostera noltii* that is the dominant species here. This may account for the lower values of the absolute biomass, since *Zostera noltii* plants are of smaller dimensions than *Zostera marina*. In this case, the absolute production of the benthic vegetation in the upper reaches of the lagoon is higher due to wider representation of more environmentally active species. In particular, the productivity of *Zostera noltii* is almost two times higher than that of *Zostera marina*.

In view of the lack of a detailed map for distribution of benthic macrophytes in the water area of the Tyligulskyi Liman lagoon, Fig. 2.4-2.6 shows the schemes for spatial distribution of benthic macrophyte biomass in the Tyligulskyi Liman lagoon during various seasons. The schemes were built by means of spatial extrapolation of the observational data from Koshary, Maryanovka and Kalinovka botany stations performed on the basis of data on depth distribution.

c) Main benthic habitats in the Tyligulskyi Liman lagoon

Qualitative and quantitative analysis of the macrozoobenthos in the Tyligulskyi Liman lagoon in the period of 1980-1983, as well as comparison of the obtained results with the data of research (Grinbart, 1953) in the period of 1947-1952, is presented in the paper (Polischuk, Zambriborsch, Timchenko et al., 1990).

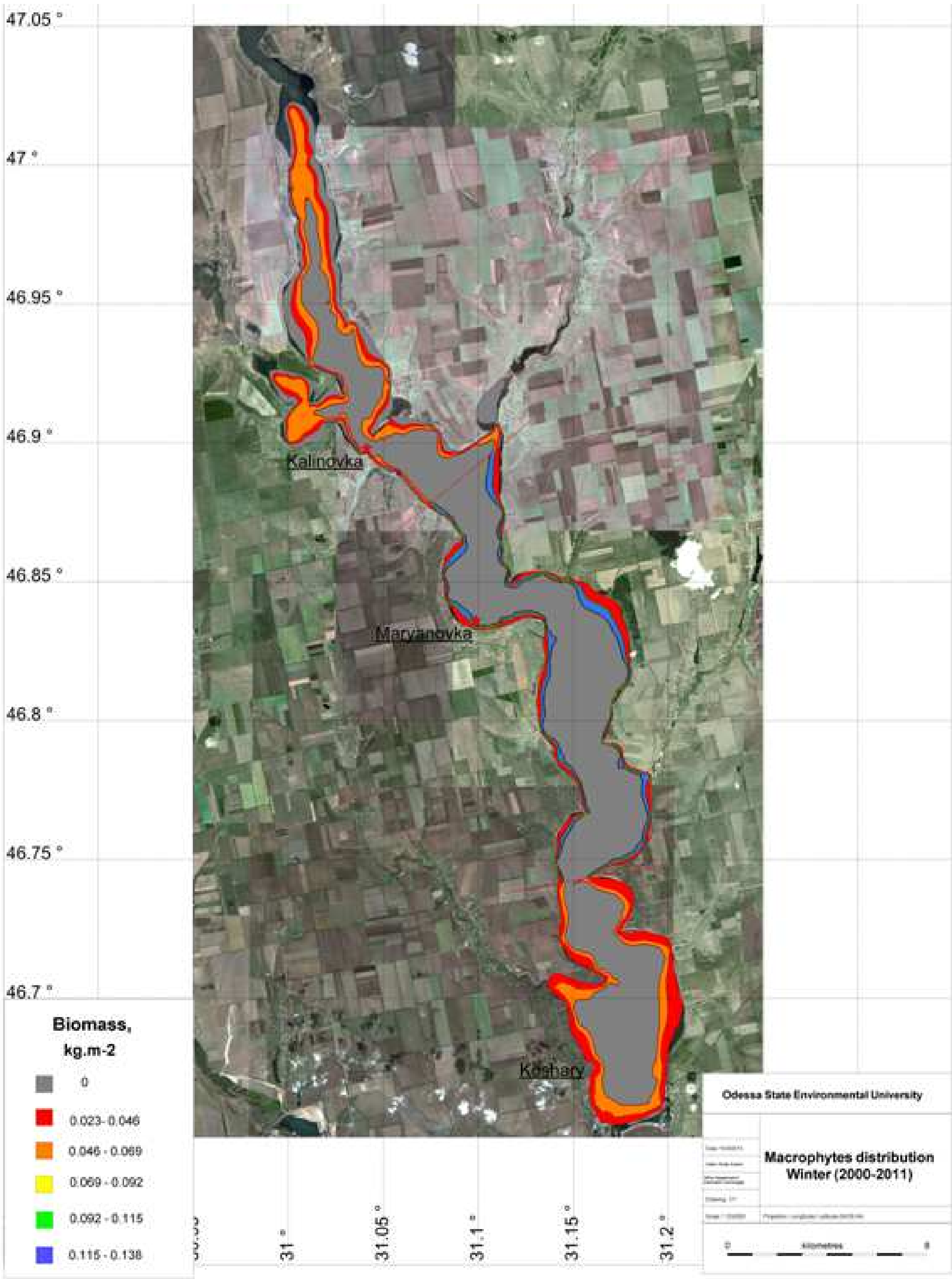

Figure 2.4 Scheme for spatial distribution of the benthic macrophyte biomass ($kg{\cdot}m^{-2}$) during the winter season in the Tyligulskyi Liman lagoon, built by means of spatial extrapolation of the observational data from the botany stations, with regard to the depths

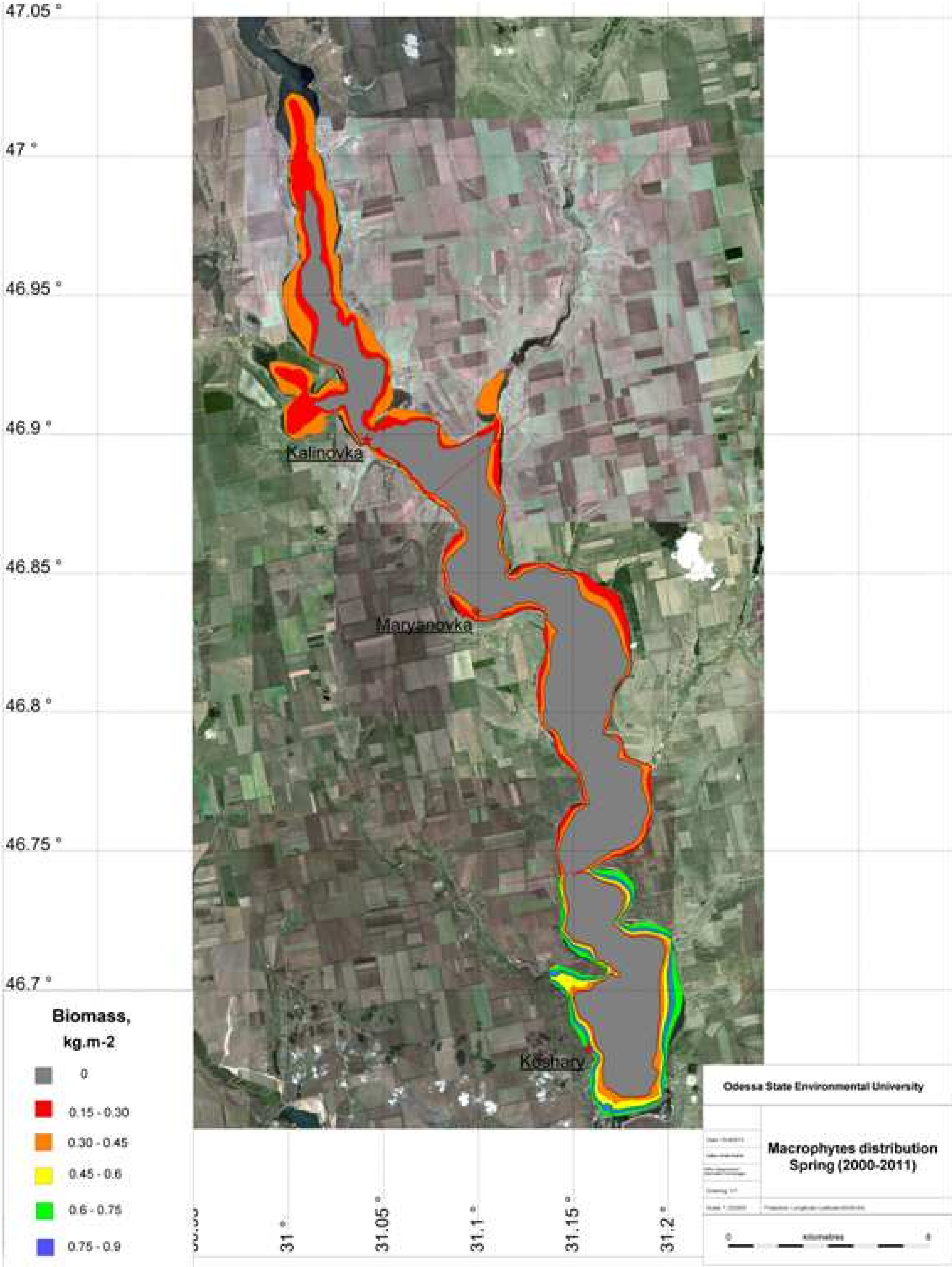

Figure 2.5 Scheme for spatial distribution of the benthic macrophyte biomass (kg·m^{-2}) during the spring season in the Tyligulskyi Liman lagoon, built by means of spatial extrapolation of the observational data from the botany stations, with regard to the depths

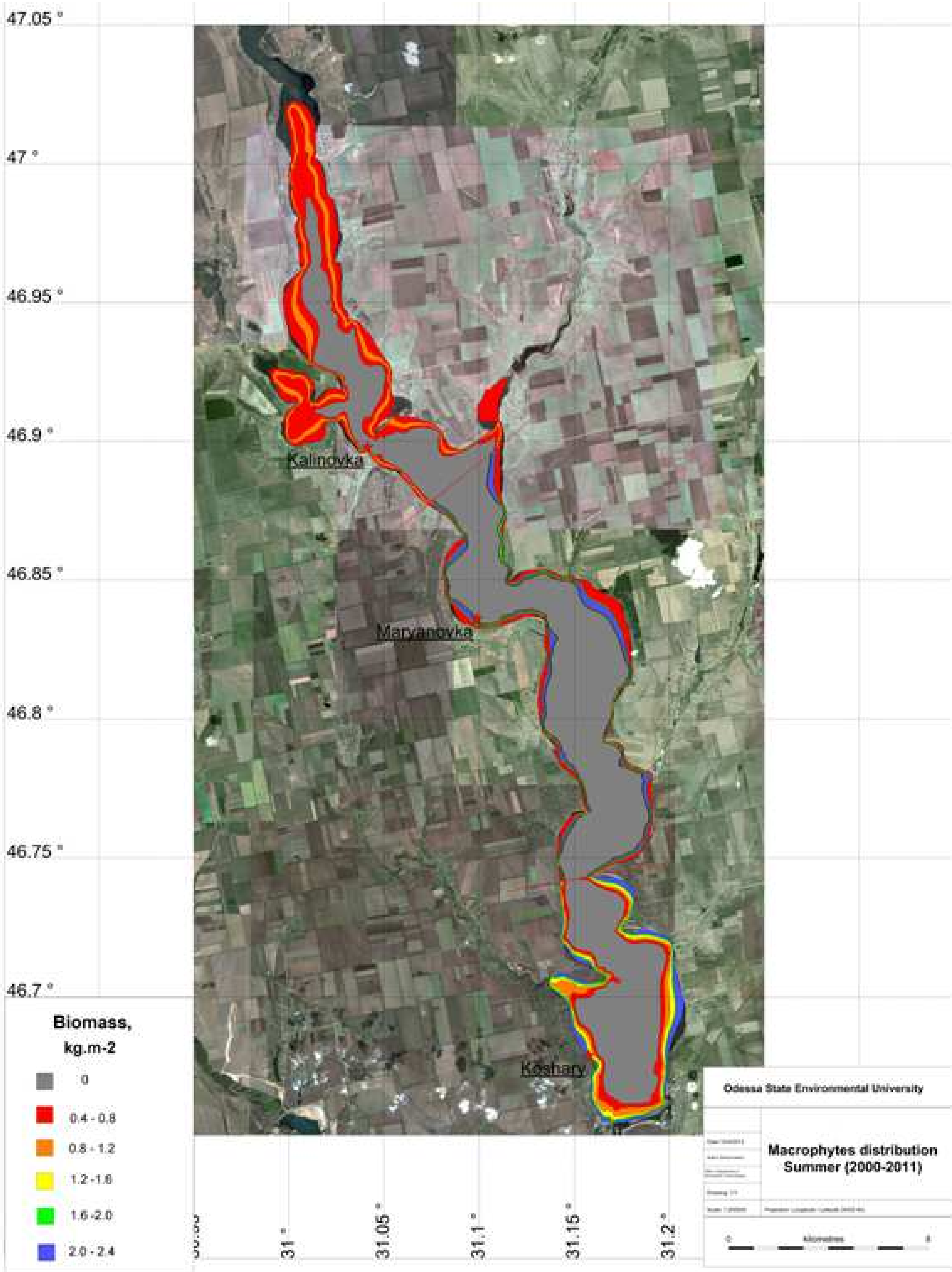

Figure 2.6 Scheme for spatial distribution of the benthic macrophyte biomass (kg·m^{-2}) during the summer season in the Tyligulskyi Liman lagoon, built by means of spatial extrapolation of the observational data from the botany stations, with regard to the depths

In 1980-1983, according to (Polischuk, Zambriborsch, Timchenko et al., 1990), 64 species of bottom-dwelling invertebrates were observed in the Tyligulskyi Liman lagoon, 76.2 % of which were marine species, and 16 % - both brackish water and freshwater ones. Molluscs (especially *Hydrobiidae*) were the richest in respect of the species diversity. By the number of specimens and biomass they were also a dominant group, which in various years comprised 21.9 to 83.2 % of the total number and 93.0-95.6 % of the total biomass. Seasonal dynamics of the benthos number and biomass was characterized by a maximum in the spring-summer period and a minimum - in the autumn-winter one.

It is by the benthos species diversity and quantitative development that authors divide the lagoon into two parts, the northern and the southern. The southern part is larger and deeper. Grey silt and coquina cover more than 2/3 of the bottom area in both parts. The rest of the area is covered by sand and silted coquina.

95.5 % of all of the species observed in the lagoon were registered in the southern part. *Polychaetas, Oligochaetas, Molluscs* and *Amphipodes* are presented in the fullest measure. In the northern part only 60.2 % of species were found. The most diverse fauna was observed on the sand, which is silted to various degrees, and the silted coquina in the southern part, and the least diverse – on the grey coloured silt in the northern part. The quantitative indices for macrozoobenthos distribution in both parts of the lagoon depend on development of *Molluscs,* the number of which is determined by the representatives of *Hydrobiidae,* and the biomass – by *Cerastoderma clodiense, Mytilaster lineatus, Abra ovata* et al. Average indices for the number of specimens and the biomass of bottom invertebrates in various parts of the Tyligulskyi Liman lagoon in 1980-1983 are given in Table 2.8

The paper (Polischuk, Zambriborsch, Timchenko et al., 1990) provides information on the bottom soil preferability for various faunal groups. In the lagoon *Polychaetas* were presented by 8 salt water species. The most diverse *Polychaetas* taxonomic composition was observed on the pure and the silted sands which are adjacent to the nehrung. It is only there that *Fabricia sabella, Capitella capitata, Crubia limbata* were found. There were *Nereis succinea, N.diversicolor, Polydora limicola, Capitomastus minimus* and *Spio filicornis* on the silt and the silt with coquina of the southern part. In the northern part only 3 species of *Polychaetas, N.succinea, N.diversicolor* and *Polydora limicola* were observed on the silts and the silted sands. *N.succinea* and *N.diversicolor* were the most widespread and dominant species among *Polychaetas*. At the same time, *N.succinea* was dominant in the southern,

more brackish part, and *N.diversicolor prevailed* in the northern, less brackish part which can be explained by various degrees of their halotolerance.

Table 2.8 Average indices for the number of specimens (numerator, spec./m^3) and the biomass (denominator, g/m^2) of bottom invertebrates in various parts of the Tyligulskyi Liman lagoon in 1980-1983

Groups	1980		1981		1983	
	North	South	North	South	North	South
Polychaeta	530 4,99	295 9,26	987 8,23	715 5,51	423 2,41	983 3,15
Oligochaeta	420 0,06	410 0,10	520 0,12	324 0,08	1449 0,28	889 0,3
Mollusc	670 142,35	1102 612,79	16242 519,22	11244 538,34	10092 67,1	7363 385,87
Amphipoda	80 0,07	789 0,29	1738 3,32	220 0,21	2619 1,81	1660 1,23
Cumacea	-	25 0,01	108 0,26	5 0,003	568 0,21	489 0,18
Balanus	30 0,05	822 19,03	79 1,35	423 8,82	-	399 9,54
Decapoda	40 1,01	82 15,75	41 7,41	191 11,21	6 0,28	31 7,0
Isopoda	100 0,80	10 0,07	1 0,01	6 0,02	9 0,08	34 0,44
Chironomidae	120 0,07	1624 3,12	44 0,06	260 0,77	81 0,10	556 2,42
Other	580 0,41	61 0,08	4 0,03	5 0,023	3 0,001	9 0,02
Total	2570 149,81	5220 660,5	19764 539,8	13393 565,0	15260 72,28	12413 410,1

In the lagoon *Oligochaetas* were represented by 8 species. *Paranais litoralis, P. Simplex, Tubifex costatus* and *Tubificidae sp. N 1* occured most frequently. The highest values of *Oligochaetas* specimen number and the biomass were observed on the heavily silted sand, the silted coquina and the grey coloured silt. On the pure and slightly silted sand they were reported in smaller quantities.

Amrhipodes in the Tyligulskyi Liman lagoon were represented by 11 species: *C.orientales, C.bonelli, Microdeutopus gryllotalpa, Microprotopus minutus, Dexaminae spinosa, Ampelisca diadema* etc. *Amrhipodes* are the most numerous in the northern part,

where they prefer the silted sand with coquina. *C.orientales* and *C.bonelli* are the dominant species. *Cumaceas* were represented by one widespread species, *Iphinoe maeotica*, which occurred most often on the pure and the silted sand in the southern part of the lagoon.

Among *Isopodes* two widespread species were found: *ldotea baltica basteri*, which was observed in all parts of the lagoon on all of the soils, but preferred the silted sand with coquina, and *Balanus improvises*, which preferred the sand with coquina in the southern part of the lagoon.

3 species of *Decapodes* were observed in the lagoon: *Palaemon elegans, P.adspersus, Rhithropanopeus harrisi fridentana*. The latter was widely distributed in both parts of the lagoon and found on all of the soils.

Chironomidae larvae were represented by 11 species, among which *Chimiiomus f. l. salinarius, Ch. F. L. halophllua* and *l'tocladius* were widespread. They were observed on all of the soils in all parts of the lagoon, though underwent particular development on the grey silt mixed with coquina in the southern part.

Molluscs are found on various soils in the lagoon, but they gave preference to the silted sand with coquina. Among large *Molluscs* the most widespread are *Mytilaster lineatus, Abra ovata* and *Cerastoderma clodiense*. *Mytilaster lineatus* was concentrated mainly in the southern part and was occasionally observed in the northern part. Its maximum biomass and number of specimens were reported on the silted sand with coquina. *Abra ovate* is almost evenly distributed throughout the lagoon, but the largest number of specimens was reported in the northern part. This species was found on all of the soils with a slight prevalence on the silted ones. *Cerastoderma clodiense* is more euryhaline species than *Mytilaster lineatus*. Being observed on all of the soils in both parts of the lagoon, it preferred the silted ones mixed with coquina at the depth of 0.6 - 14 m. *Molluscs Hydrobiidae* reached the highest species diversity. Being widespread on various soils in both parts of the lagoon, they prefer the grey silt and the silted sand.

As a result of comparison of the macrozoobenthos development in the early 1980s with findings (Grinbart, 1953) in the period of 1947-1952 (Polischuk, Zambriborsch, Timchenko et al., 1990) it was established that the difference in faunal composition between the northern and the southern parts of the lagoon had become less pronounced. The number of *Nereididaes, Oligochaetas, Amrhipodes* has increased. The species composition of *Molluscs* had changed. *Hypanis colorata,* widely distributed in the lagoon earlier, had become extinct.

The number of *Cerastoderma clodiense*, *Mytilaster lineatus*, *Abra ovata* and *Gastropoda*, as well as *Rhithropanopeus harrisi fridentana* had increased. The species composition of *Chironomidae* larvae had changed, and the specimen number decreased. These changes indicate that, compared to 1947-1952, the fauna of the Tyligulskyi Liman lagoon in 1980-1983 became more salt-water, Ponto-Caspian species were almost lost and the number of freshwater species decreased. The total of the macrozoobenthos biomass increased owing to a rise in the number of *Molluscs*.

In 1980 *Mytilaster lineatus* biocaenosis dominated in the southern part of the lagoon, and *Cerastoderma clodiense* - in the central and the northern parts. The latter was concentrated mainly on the grey silt with coquina in the central part. As compared to the biocenoses of 1947 – 1957, *Monodacna colorata* + *Cardium* biocenosis had gone extinct and was replaced by *Cerastoderma* biocaenosis, which underwent predominant development in various versions. The biocoenosis of the grey silt remained almost the same, with *Hydrobiidae, Abra ovate* and *Mytilaster lineatus* as the dominant forms.

The present-day characteristics of macrozoobenthos in the Tyliguskyi Liman lagoon are based on the observational data from 59 stations obtained by 12 expeditions which were organized in 2001 – 2011 by the Odessa Branch of the Institute of Biology of Southern Seas of the National Academy of Sciences of Ukraine. Samples were predominantly taken in the eastern part of the lagoon. The bottom macrofauna of the shallow coastal zone with the depths of < 1 m was studied in the most comprehensive way and comprises the data from 45 stations (76.3 % of the total amount), 7 of them - in spring (April-May), and 38 - in summer (June-September). It is only at 14 stations that samples were collected within the depth range of 1.3 – 13.0 m. Only 1 station represents the spring period, with the rest of 13 observation sets related to summer. The layout chart for all of the stations is presented in Fig. 2.7

One of the major factors to form the composition and spatial distribution of quantitative indices of the benthic macrofauna in the water body, is the characteristics of the bottom sediments. In the coastal zone of the lagoon (< 1 m) the bottom sediments are diverse and are distributed quite in a mosaic-like manner, a pictorial view of which is given in Table 2.9. At the depths of 1.3 – 13.0 m only three types of sediments are distinguished. At most of the stations (71.4 %) it is silt with coquina.

The generalized information on the specific composition and quantitative indices of different species of macrozoobenthos in the Tyliguskyi Liman lagoon within the period of

2001 through 2011 is given in Table 2.10. For each of the species the following indices are evaluated: average number - N, spec.·m^{-2}; average biomass - B, g·m^{-2}; occurrence in percentage - P, %. The species which were registered at no less than 50 % of stations are ascribed to the basic ones, the species observed at 25 - 50 % of stations - to the secondary ones, and the species registered at less than 25 % of stations - to the incidental ones.

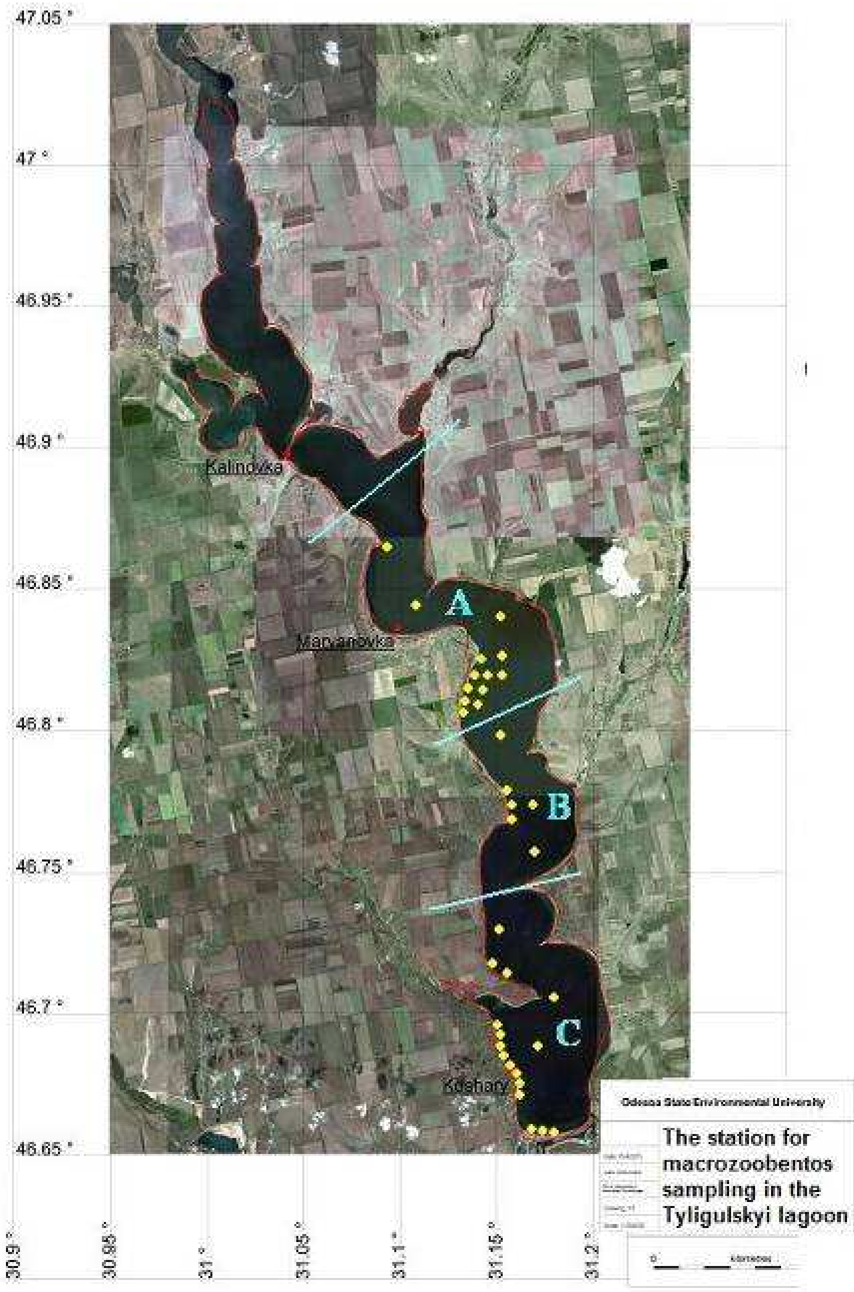

Figure 2 .7 Layout of the stations for macrozoobenthos sampling in the Tyligulskyi Liman lagoon for the period of 2001 through 2011

Table 2.9 Parameters of the bottom sediment at the benthos stations obtained in the Tyligulskyi Liman lagoon at different depths within the period of 2001 through 2011

Parameters of the Bottom Sediment	Number of Stations	
	depth of < 1.0 m	depth of 1.3 – 13.0 m
clay (in some areas with sand and coquina)	5	-
silt	1	2
silt with sand	6	-
silt with coquina	3	10
silt with sand and coquina	9	2
stones with sand and pebble	2	-
washed sand	1	-
muddy sand	6	-
muddy sand with *Zostera*	3	-
sand with coquina	4	-
coquina with sand	3	-
coquina with detritus	2	-
Total	45	14

Tables 2.11- 2.13 represent the information on macrozoobenthos specific composition, average number and average biomass for the three different parts of the lagoon are shown in Fig. 2.7.

A comparative analysis of quantitative parameters for lagoonal macrozoobenthos is presented in Table 2.14. There are 35 taxa in the water body in total: Worms - 10, Mollusca - 6, Crustacea - 14, other (insect larvae) - 5. In the coastal shallow zone with the depths < 1 m there are 34 taxa, and in the deeper zones (1.3 – 13.0 m) - only 16 taxa. The quantitative macrozoobenthos indices at the stations varied within a wide range which is conditioned by a number of influences, the characteristics of bottom sediments and their mosaic distribution among them. In the lagoon as a whole the number of taxa at one station varied from 3 to 20, with the average of 9.4; the number of specimen - from 350 to 77150 spec.$\cdot$m^{-2} (average number – 18561.2 spec.$\cdot$m^{-2}), the biomass - from 4.80 to 3274.32 g$\cdot$m^{-2} (Table 2.14).

In the coastal zone of the lagoon the number of macrozoobenthos taxa was 2.1 times and the average number - 1.8 times greater than the similar indices in the deeper zones, while the average biomass, on the opposite, was 3.6 times less (Table 2.15).

29 taxa (82.9 %) of the euryhaline marine complex form the basis for the bottom macrofauna number (95.5 %) and biomass (99.6 %) in the lagoon. The saltish water fauna was represented by 6 taxa – a Ponto-Caspian relict, amphipod *Pontogammarus maeoticus*, and the insect larvae *Chironomus salinaris*, *Chironomus sp.*, *Clunio marinus*, *Cricitopus vitripennis*, *Eristalis sp.*

The bottom macrofauna number (90.3 %) and biomass (98.3 %) in the coastal zone of the lagoon was based on 10 taxa (Table 2.16), which are aattributed to the basic taxa by their occurrence (P $\geq$ 50.0 %). They included *Hediste diversicolor* and *Polydora cornuta* polychaetes, *Hydrobia acuta*, *Mytilaster lineatus*, *Cerastoderma glaucum* and *Abra ovata* mollusks, *Sphaeroma pulchellum*, *Idotea baltica basteri* and *Gammarus aequicauda* crustaceas, and *Chironomus salinaris* chironomid larvae.

Within the depth range of 1.3 – 13.0 m the basis of macrozoobenthos number (95.4 %) as well as the biomass (98.5 %) was formed by the same basic taxa as in the coastal zone, their quantity, however, decreased from 10 to 6 (Tables 2.16), mainly on the account of crustaceas. The reason for this is the influence of oxygen deficit in the benthic waters which emerges in the summer period when the surveys were performed.

Molluscs prevail among the basic taxonomical groups. The contribution of them in the coastal zone at the depth of < 1.0 m comprised 67.7 % of the total number and 79.7 % of the total biomass, and in the deeper areas – 79.4 % and 98.4 %, respectively (Table 2.17).

It is both in the coastal and the deeper parts of the lagoon that most of the mass are the same species of Mollusca. Thus, in the coastal zone, the total number of two species, *Hydrobia acuta* and *Mytilaster lineatus*, comprised 59.4%, and the total biomass of three species, *Mytilaster lineatus*, *Cerastoderma glaucum*, *Abra ovate*, made up 71.1%. Outside the coastal zone the total number of three species, *Hydrobia acuta*, *Mytilaster lineatus*, *Abra ovate*, comprised 78.6%, and the total biomass of two species, *Mytilaster lineatus* and *Abra ovate*, 96.8%.

By qualitative and measure-and-mass composition, almost all of the macrozoobenthos within the research area, with the exception of *Cerastoderma glaucum* single specimens with

the shell length of < 20 mm, belong to the (fish) fodder benthos. The fodder component biomass comprises 99.1% of the average in the coastal zone, and 100.0% in the deeper areas.

In the coastal shallow zone of the lagoon, among six basic trophic groups, detritophages prevailed in the number of taxa (19) and the number of specimens (59.5%), while sestonophages dominated as regards the biomass (62.9%) (Table 2.18). Outside the shallow zone the number of trophic groups declines from 6 to 4 (with phytophages and polyphages missed out), but by the number of taxa (11) and the number of specimens (56.5%) the detritophages still prevail, as well as the sestonophages, if the biomass (73.5%) is considered. The index of food structure uniformity in the coastal zone was 0.37, with 0.48 at the depth of 1.3 – 13.0 m and 0.45 in the lagoon as a whole.

Three invasion species were registered, which were for the first time discovered in the Black Sea quite recently: *Rhithropanopeus harrisi tridentata* (Maitland) crab - in the Dnipro-Buzkyi Liman lagoon in 1937 (Makarov, 1939), *Polydora cornuta* polychaete - in the Sukhyi Liman lagoon in 1962 (Losovskaya, Nesterova, 1964), *Mya arenaria* bivalved mollusk - in the Odessa bay in 1966 (Table 2.19). These exotic species are considered to have got into the Black Sea in a traditional way - with ballast waters of ships at the stage of pelagian larva, or with biofouling of ship hulls at the stage of egg cell.

All three invasion species were observed in the shallow coastal zone and only *Polydora cornuta* – in the deeper zones. The latter is the most massive among the invasive species which by the frequency of occurrence at the selected depths (P = 50.0 – 55.6 %) and in the whole of the lagoon (P = 54.2%) can be regarded as the basic species. Quantitative indices of invasion species in the lagoon were low. At the depth of < 1 m their total percentage comprised 4.4% of the number of specimens and 0.4 % of the biomass, and in the deeper parts of the lagoon – 6.9 and 0.1%, respectively (see Table 2.19).

Table 2.10 Macrozoobenthos composition and quantitative indices (N is an average number, spec.·m^{-2}; B is an average biomass, g·m^{-2}; P is a frequency of occurrence, %) at various depths in the Tyligulskyi Liman lagoon within the period of 2001 through 2011

Species	The Whole of the Lagoon			Depth < 1.0 m			Depth of 1.3 – 13.0 m		
	N, spec.·m^{-2}	B, g·m^{-2}	P, %	N, spec.·m^{-2}	B, g·m^{-2}	P, %	N, spec.·m^{-2}	B, g·m^{-2}	P, %
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
Turbellaria g. sp.	19.5	0.012	3.4	25.6	0.016	4.4	-	-	-
Harmothoe imbricata (L.)	11.6	0.102	10.2	7.2	0.038	6.7	25.7	0.309	21.4
H*armothoe reticulata* Claparede	0.8	0.006	1.7	1.1	0.008	2.2	-	-	-
Neanthes succinea (Frey et Leuch)	60.2	1.650	20.3	47.8	1.192	24.4	100.0	3.120	7.1
Hediste diversicolor O.F. Muller	582.3	12.179	69.5	681.7	14.006	71.1	262.9	6.305	64.3
Spio filicornis (Muller)	86.0	0.108	32.2	112.8	0.142	42.2	-	-	-
Polydora cornuta Bosc	872.0	0.659	54.2	894.4	0.697	55.6	800.0	0.537	50.0
Capitella capitata (Fabricius)	41.1	0.017	16.9	53.9	0.022	22.2	-	-	-
Capitomastus minimus (Landerhans)	6.8	0.003	3.4	8.9	0.004	4.4	-	-	-
Oligochaeta g. sp.	435.7	0.422	39.0	547.2	0.543	46.7	77.1	0.034	14.3
Hydrobia acuta (Draparnaud)	6863.9	15.289	86.4	8218.9	18.519	84.4	2508.6	4.909	92.9
Setia valvatoides (Milachevitch*)*	566.1	0.326	10.2	742.2	0.427	13.3	-	-	-
Mytilaster lineatus (Gmelin)	4254.2	203.114	66.1	4108.3	89.482	68.9	4722.9	568.360	57.1
Cerastoderma glaucum Poiret	256.4	38.100	54.2	307.8	47.564	60.0	91.4	7.677	35.7
Abra ovata (Philippi)	923.7	59.025	84.7	633.3	18.147	82.2	1857.1	190.417	92.9
Mya arenaria L.	14.7	0.053	1.7	19.3	0.069	2.2	-	-	-
Palaemon elegans Rathke	0.8	0.458	1.7	1.1	0.600	2.2	-	-	-

1	2	3	4	5	6	7	8	9	10
Rhithropanopeus harrisi tridentata (Maitland)	1.7	0.088	3.4	2.2	0.116	4.4	-	-	-
Paramysis kroyeri (Czerniavsky)	1.4	0.003	1.7	-	-	-	5.7	0.011	7.1
Iphinoe maeotica (Sowinskyi)	47.5	0.044	28.8	62.2	0.058	37.8	-	-	-
Sphaeroma pulchellum (Colosi)	685.2	5.285	47.5	898.3	6.929	62.2	-	-	-
Idotea baltica basteri Audouin	572.5	3.281	64.4	737.2	4.262	75.6	42.9	0.129	28.6
Ampelisca diadema A.Costa	16.5	0.042	8.5	21.7	0.056	11.1	-	-	-
Gammarus aequicauda Martynov	1191.3	10.267	61.0	1513.9	13.323	73.3	154.3	0.446	21.4
Marinogammarus olivii M.-Edwards	7.6	0.022	5.1	10.0	0.029	6.7	-	-	-
Dexamine spinosa (Montagu)	20.8	0.026	16.9	27.2	0.034	22.2	-	-	-
Pontogammarus maeoticus (Sowinskyi)	0.8	0.001	1.7	1.1	0.001	2.2	-	-	-
Microdeutopus gryllotalpa A. Costa	76.3	0.104	23.7	95.6	0.131	26.7	14.3	0.017	14.3
Corophium bonelli (M.-Edwards)	38.8	0.030	23.7	45.6	0.031	22.2	17.1	0.026	28.6
Corophium volutator (Pallas)	78.8	0.077	11.9	103.3	0.101	15.6	-	-	-
Chironomus salinaris (Kieffer)	772.2	1.491	61.0	737.8	1.562	51.1	882.9	1.261	92.9
Chironomus sp.	37.3	0.044	10.2	48.9	0.058	13.3	-	-	-
Clunio marinus (Haliday)	0.8	0.002	1.7	1.1	0.002	2.2	-	-	-
Cricitopus vitripennis (Meigen)	15.8	0.009	11.9	18.9	0.010	11.1	5.7	0.006	14.3
Eristalis sp.	0.4	0.007	1.7	0.6	0.009	2.2	-	-	-
Total	18561.2	352.346	-	20736.7	218.189	-	11568.6	783.564	-

Table 2.11 Macrozoobenthos composition and quantitative indices (N is an average number, spec.·m^{-2}; B is an average biomass, g·m^{-2} in part A (fig. 2.7) of the Tyligulskyi Liman lagoon within the period of 2001 through 2011

Taxon	Depth, m			
	< 1.0 (zone A1)		> 1.0 (zone A2)	
	N, spec.·m^{-2}	B, g·m^{-2}	N, spec.·m^{-2}	B, g·m^{-2}
Harmothoe imbricata (L.)	-	-	4.4	0.044
Neanthes succinea (Frey et Leuch)	145.8	5.233	155.6	4.853
Hediste diversicolor O.F. Muller	616.7	4.192	151.1	2.733
Spio filicornis (Muller)	316.7	0.408	-	-
Polydora cornuta Bosc	4212.5	2.417	400.0	0.222
Capitella capitata (Fabricius)	54.2	0.029	-	-
Capitomastus minimus (Landerhans)	58.3	0.025	-	-
Oligochaeta g. sp.	166.7	0.063	120.0	0.053
Hydrobia acuta (Draparnaud)	5162.5	13.946	3151.1	6.342
Mytilaster lineatus (Gmelin)	1708.3	25.942	1448.9	251.884
Cerastoderma glaucum Poiret	266.7	39.892	111.1	10.960
Abra ovata (Philippi)	645.8	7.667	1995.6	224.738
Iphinoe maeotica (Sowinskyi)	125.0	0.100	-	-
Sphaeroma pulchellum (Colosi)	270.8	3.071	-	-
Idotea baltica basteri Audouin	208.3	2.092	48.9	0.182
Gammarus aequicauda Martynov	416.7	4.042	120.0	0.582
Dexamine spinosa (Montagu)	8.3	0.017	-	-
Microdeutopus gryllotalpa A. Costa	216.7	0.525	13.3	0.009
Corophium bonelli (M.-Edwards)	4.2	0.008	26.7	0.040
Corophium volutator (Pallas)	8.3	0.042	0.0	0.000
Chironomus salinaris (Kieffer)	58.3	0.100	324.4	0.400
Chironomus sp.	191.7	0.092	-	-
Cricitopus vitripennis (Meigen)	29.2	0.003	8.9	0.009
Eristalis sp.	4.2	0.067	-	-
Total	14895.8	109.969	8080.0	503.053
Predominant type of bottom sediment	sand, silt, shells		grey silt with shells	

Table 2.12 Macrozoobenthos composition and quantitative indices (N is an average number, spec.$\cdot$m^{-2}; B is an average biomass, g$\cdot$m^{-2} in part B (fig. 2.7) of the Tyligulskyi Liman lagoon within the period of 2001 through 2011

Taxon	Depth, m			
	< 1.0 (zone B1)		> 1.0 (zone B2)	
	N, spec.$\cdot$m^{-2}	B, g$\cdot$m^{-2}	N, spec.$\cdot$m^{-2}	B, g$\cdot$m^{-2}
Harmothoe imbricata (L.)	-	-	40.0	0.760
Harmothoe reticulata Claparede	16.7	0.117	-	-
Neanthes succinea (Frey et Leuch)	16.7	0.133	-	-
Hediste diversicolor O.F. Muller	1150.0	40.667	510.0	13.218
Polydora cornuta Bosc	250.0	0.667	1730.0	1.300
Capitella capitata (Fabricius)	100.0	0.067	-	-
Oligochaeta g. sp.	666.7	0.767	-	-
Hydrobia acuta (Draparnaud)	716.7	1.233	1620.0	2.710
Mytilaster lineatus (Gmelin)	12783.3	79.417	8580.0	677.520
Cerastoderma glaucum Poiret	50.0	1.333	70.0	2.210
Abra ovata (Philippi)	133.3	8.767	1410.0	90.800
Iphinoe maeotica (Sowinskyi)	16.7	0.017	-	-
Sphaeroma pulchellum (Colosi)	400.0	0.833	-	-
Idotea baltica basteri Audouin	1200.0	3.467	40.0	0.040
Ampelisca diadema A.Costa	33.3	0.067	-	-
Gammarus aequicauda Martynov	616.7	4.167	270.0	0.250
Microdeutopus gryllotalpa A. Costa	-	-	20.0	0.040
Chironomus salinaris (Kieffer)	1983.3	3.433	2130.0	3.135
Total	20133.3	145.150	16440.0	792.023
Predominant type of bottom sediment	sand, silt, stones		grey silt with shells	

Table 2.13 Macrozoobenthos composition and quantitative indices (N is an average number, spec.·m^{-2}; B is an average biomass, g·m^{-2} in part C (fig. 2.6) of the Tyligulskyi Liman lagoon within the period of 2001 through 2011

Taxon	Depth, m			
	< 1.0 (zone C1)		> 1.0 (zone C2)	
	N, spec.·m^{-2}	B, g·m^{-2}	N, spec.·m^{-2}	B, g·m^{-2}
1	***2***	***3***	***4***	***5***
Turbellaria g. sp.	31,9	0,019	-	-
Harmothoe imbricata (L.)	9,0	0,047	160,0	0,880
Neanthes succinea (Frey et Leuch)	34,0	0,607	-	-
Hediste diversicolor O.F. Muller	653,5	13,420	280,0	10,800
Spio filicornis (Muller)	88,2	0,110	-	-
Polydora cornuta Bosc	395,1	0,413	680,0	0,320
Capitella capitata (Fabricius)	50,0	0,017	-	-
Capitomastus minimus (Landerhans)	1,4	0,001	-	-
Oligochaeta g. sp.	600,7	0,604	-	-
Hydrobia acuta (Draparnaud)	9353,5	20,722	280,0	0,800
Setia valvatoides (Milachevitch)	927,8	0,534	-	-
Mytilaster lineatus (Gmelin)	3785,4	100,911	18760,0	2980,000
Cerastoderma glaucum Poiret	336,1	52,696	-	-
Abra ovata (Philippi)	672,9	20,676	2400,0	280,000
Mya arenaria L.	23,6	0,087	-	-
Palaemon elegans Rathke	1,4	0,750	-	-
Rhithropanopeus harrisi tridentata (Maitland)	2,8	0,144	-	-
Iphinoe maeotica (Sowinskyi)	55,6	0,054	-	-
Sphaeroma pulchellum (Colosi)	1044,4	8,081	-	-
Idotea baltica basteri Audouin	786,8	4,690	-	-
Ampelisca diadema A.Costa	24,3	0,064	-	-
Gammarus aequicauda Martynov	1771,5	15,633	-	-
Marinogammarus olivii M.-Edwards	12,5	0,036	-	-

1	2	3	4	5
Dexamine spinosa (Montagu)	32,6	0,040	-	-
Pontogammarus maeoticus (Sowinskyi)	1,4	0,001	-	-
Microdeutopus gryllotalpa A. Costa	83,3	0,076	-	-
Corophium bonelli (M.-Edwards)	56,3	0,038	-	-
Corophium volutator (Pallas)	127,8	0,119	-	-
Chironomus salinaris (Kieffer)	747,2	1,650	920,0	1,520
Chironomus sp.	29,2	0,057	-	-
Clunio marinus (Haliday)	1,4	0,003	-	-
Cricitopus vitripennis (Meigen)	18,8	0,013	-	-
Total	21760,4	242,312	23480,0	3274,320
Predominant type of bottom sediment	sand, shells, silt		gray sit with shells	

Table 2.14 Quantitative description of the main indicators for the Macrozoobenthos at various depths in the Tyligulskyi Liman lagoon within the period of 2001 through 2011

Index	The Whole of the Lagoon	Depth, m	
		< 1.0	1.3 – 13.0
Number of Stations	59	45	14
The total number of taxa: *including:*	35	34	16
worms	10	10	5
mollusks	6	6	4
crustaceans	14	14	5
others	5	4	2
The number of taxa at one station	3 – 20	3 – 20	3 – 14
The average number of taxa at one station	9.4	10.3	6.4
The benthos number at one station, spec.·m^{-2}	350 – 77150	350 – 77150	1200 – 33480
The average benthos number, spec.·m^{-2}	18561.2	20736.7	11568.6
worms	11.4	11.5	7.7
mollusks	69.4	67.7	79.8
crustaceans	14.8	20.5	12.5
others	4.4	0.3	-
The benthos biomass at one station, g·m^{-2}	4.80 – 3274.32	4.80 – 1304.10	5.24 – 3274.32
The average benthos biomass, g·m^{-2} *including (%) :*	352.346	218.189	783.564
worms	4.3	10.9	1.3
mollusks	89.7	79.4	98.4
crustaceans	5.6	2.0	0.1
others	0.4	7.7	0.2
The average biomass of pabular benthos, g·m^{-2}	350.854	216.278	783.564
Proportion of pabular benthos, %	99.6	99.1	100.0
<u>Invasive species:</u> the number of taxa	3	3	1
Number, spec.·m^{-2}	888.1	915.6	800.0
Proportion in the total number, %	4.8	4.4	6.9
Biomass, g·m^{-2}	0.800	0.882	0.537
Proportion in the total of the biomass, %	0.2	0.4	0.1

Table 2.15 Comparative characteristics of quantitative indices for macrozoobenthos at various depths in the Tyligulskyi Liman lagoon within the period of 2001 through 2011

Taxa	The number of taxa	Number		Biomass	
		spec.·m^{-2}	%	g·m^{-2}	%
The whole of the lagoon					
major	9	16288.5	87.8	343.405	97.5
minor	4	1254.4	6.8	5.859	1.7
incidental	22	1018.6	5.4	3.082	0.8
Total	35	18561.2	100.0	352.346	100.0
depth < 1.0 m					
major	10	18731.6	90.3	214.491	98.3
minor	4	817.8	3.9	0.874	0.4
incidental	20	1187.7	5.8	2.823	1.3
Total	34	20736.7	100.0	218.189	100.0
1.3 – 13.0 m depth					
major	6	11034.4	95.4	771.789	98.5
minor	3	151.4	1.3	7.832	1.0
incidental	7	382.8	3.3	3.943	0.5
Total	16	11568.6	100.0	783.564	100.0

Table 2.16 Comparative characteristics of the composition and quantitative indices (N is an average number, spec.·m^{-2}; B is an average biomass, g·m^{-2}) for the ***major macrozoobenthos taxa*** (P ≥ 50.0 %) at various depths in the Tyligulskyi Liman lagoon within the period of 2001 through 2011

Major taxa	Depth < 1.0 m			1,3 - 13,0 m Depth		
	N, spec.·m^{-2}	B, g·m^{-2}	P, %	N, spec.·m^{-2}	B, g·m^{-2}	P, %
Hediste diversicolor O.F. Muller	681.7	14.006	71.1	262.9	6.305	64.3
Polydora cornuta Bosc	894.4	0.697	55.6	800.0	0.537	50.0
Hydrobia acuta (Draparnaud)	8218.9	18.519	84.4	2508.6	4.909	92.9
Mytilaster lineatus (Gmelin)	4108.3	89.482	68.9	4722.9	568.360	57.1
Cerastoderma glaucum Poiret	307.8	47.564	60.0	-	-	-
Abra ovata (Philippi)	633.3	18.147	82.2	1857.1	190.417	64.3
Sphaeroma pulchellum (Colosi)	898.3	6.929	62.2	-	-	-
Idotea baltica basteri Audouin	737.2	4.262	75.6	-	-	-
Gammarus aequicauda Martynov	1513.9	13.323	73.3	-	-	-
Chironomus salinaris (Kieffer)	737.8	1.562	51.1	882.9	1.261	92.9
Total	18731.6	214.491	-	11034.4	771.789	-

Table 2.17 Comparative characteristics of the major ***taxonomical groups*** of the macrozoobenthos at various depths in the Tyligulskyi Liman lagoon within the period of 2001 through 2011

Major taxonomical groups	Number of taxa	Number		Biomass	
		spec.·m^{-2}	%	g·m^{-2}	%
The whole lagoon					
worms	10	2116.0	11.4	15.158	4.3
mollusks	6	12879.0	69.4	315.907	89.7
crustaceans	14	2740.0	14.8	19.728	5.6
others	5	826.5	4.4	1.553	0.4
Total	35	18561.2	100.0	352.346	100.0
depth < 1.0 m					
worms	10	2380.6	11.5	16.668	7.7
mollusks	6	14029.8	67.7	174.208	79.8
crustaceans	14	4257.2	20.5	27.233	12.5
others	4	69.5	0.3	0.079	-
Total	34	20736.7	100.0	218.189	100.0
1.3 – 13.0 m depth					
worms	5	1265.7	10.9	10.305	1.3
mollusks	4	9180.0	79.4	771.363	98.4
crustaceans	5	234.3	2.0	0.629	0.1
others	2	888.6	7.7	1.267	0.2
Total	16	11568.6	100.0	783.564	100.0

Table 2.18 Comparative characteristics of ***major trophic groups*** of the macrozoobenthos at various depths in the Tyligulskyi Liman lagoon within the period of 2001 through 2011

Major trophic groups	Number of taxa	Number		Biomass	
		spec.·m^{-2}	%	spec.·m^{-2}	%
The whole lagoon					
Sestonophages	3	4525.3	24.4	241.267	68.5
Detritophages	20	10957.5	59.0	91.205	25.9
Carnivorous	4	33.6	0.2	0.208	0.1
Vegetable - detritophagous	5	2457.4	13.2	18.856	5.3
Phytophagous	2	586.9	3.2	0.352	0.1
Polyphagous	1	0.8	0	0.458	0.1
Total	35	18561.2	100.0	352.346	100.0
depth < 1.0 m					
Sestonophages	3	4435.4	21.4	137.115	62.9
Detritophages	19	12334.6	59.5	55.290	25.3
Carnivorous	4	36.1	0.2	0.178	0.1
Vegetable - detritophagous	5	3160.5	15.2	24.544	11.2
Phytophagous	2	769.4	3.7	0.461	0.2
Polyphagous	1	1.1	-	0.600	0.3
Total	34	20736.7	100.0	218.189	100.0
1.3 – 13.0 m depth					
Sestonophages	2	4814.3	41.6	576.037	73.5
Detritophages	11	6531.4	56.5	206.643	26.4
Carnivorous	1	25.7	0.2	0.309	-
Vegetable - detritophagous	2	197.2	1.7	0.575	0.1
Total	16	11568.6	100.0	783.564	100.0

Table 2.19 Characteristics of ***invasive species of the macrozoobenthos*** in the Tyligulskyi Liman lagoon according to the data of 2001 through 2006

Taxonomical group	Species	Natural habitat	Feeding manner	Life form
Polychaeta	*Polydora cornuta* Bosc = *Polydora limicola* Annenkova	Western Pacific	Detrito-phage	Free-ranging type of the infauna
Bivalvia	*Mya arenaria* L.	North Atlantic	Sestono-phage	Free-ranging type of the infauna
Decapoda	*Rhithropanopeus harrisi tridentata* (Maitland)	North Atlantic	Predator	Free-ranging type of the epifauna

3. *Benthic biological diversity and its distribution*

3.1. Field sampling and processing

To map a spatial distribution of benthic biological diversity indicators, the Tyligulskyi Lagoon was divided onto the three parts: A, B, and C (see Fig. 2.7). Each part contains the shallow water zone (depth ≤ 1 m) marked by the index 1: A1, B1, and C1, as well as the zone with depth > 1 m indexed by A2, B2, and C2. The sites of macrozoobenthos sampling in the Tyligulskyi Lagoon for the period of 2001 to 2011 were groupped by the above zones. The species composition of macrozoobenthos and average number and biomass of species were determined for the zones (see Tables 2.11–2.13).

3.2. Benthic diversity indices

The two main factors taken into account when measuring diversity are richness and evenness. Richness is a measure of the number of different kinds of organisms present in a particular area. For example, species richness is the number of different species present. However, diversity depends not only on richness, but also on evenness. Evenness compares the similarity of the population size of each of the species present.

1) Richness: The number of species per sample is a measure of richness. Species richness as a measure on its own takes no account of the number of individuals of each species present. It gives as much weight to those species which have very few individuals as to those which have many individuals
2) Evenness: Evenness is a measure of the relative abundance of the different species making up the richness of an area.. A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance.

Simpson's Dominance index (D) is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases.

$$D = 1 - \Sigma(n_i(n_i-1)/N(N-1))$$

Where n_i is the total number of organisms of a particular species, and N, the total number of organisms of all species.

The Shannon diversity index (H) is another index that is commonly used to characterize species diversity in a community. Like Simpson's index, Shannon's index accounts for both abundance and evenness of the species present. The proportion of species i relative to the total number of species ($p_i = n_i/N$) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln(p_i)$).

$$H = - \Sigma\, p_i \cdot \log_2(p_i)$$

where, H is Shannon's diversity index, S total number of species in the community (richness), and p_i proportion of S made up of the ith species.

The values of Simpson's Dominance index, Shannon diversity index (H) etc., calculated for the selected parts of the Tyligulskyi Liman lagoon by the observational data on the population of the macrozoobenthos species for the period of 2001-2011 (Tables 2.11 -2.13, Fig. 3.1), are provided in Table 3.1 and in Fig. 3.2.

Table 3.1 The results obtained from the univariate methods applied to the available data on the macrozoobenthos in the Tyligulskyi Liman lagoon (2001 - 2011)

Index		Zones of part A		Zones of part B		Zones of part C	
		A1	A2	B1	B2	C1	C2
Total number of species	S	23	15	16	11	32	7
Total individuals	N	14895,9	8080	20133,4	16420	21760,4	23480
Species richness (Margalef)	d	2,289	1,556	1,514	1,030	3,104	0,596
Pielou´s evenness	J'	0,628	0,630	0,513	0,632	0,584	0,402
Diversity Index of Shannon	H'(log2)	2,841	2,460	2,051	2,188	2,922	1,128
Simpson´s evenness	1-Lambda'	0,780	0,749	0,576	0,681	0,768	0,348
AMBI	AMBI	3,006	2,525	1,04	1,533	2,152	0,636
BI	Biological index	2	2	2	2	2	2

3.3. Benthic diversity distribution in the Tyligulskyi Liman lagoon

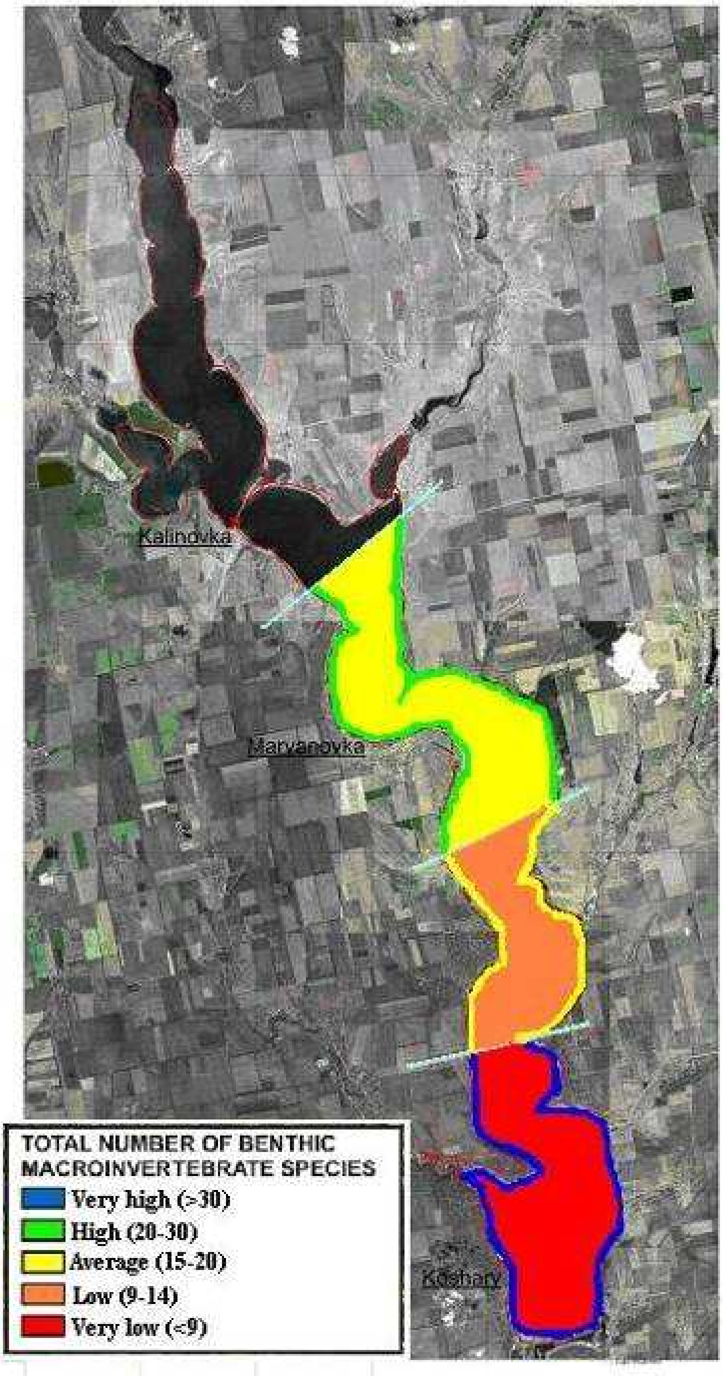

Figure 3.1 Number of benthic macroinvertebrate species for the selected parts of the Tyligulskyi Liman lagoon

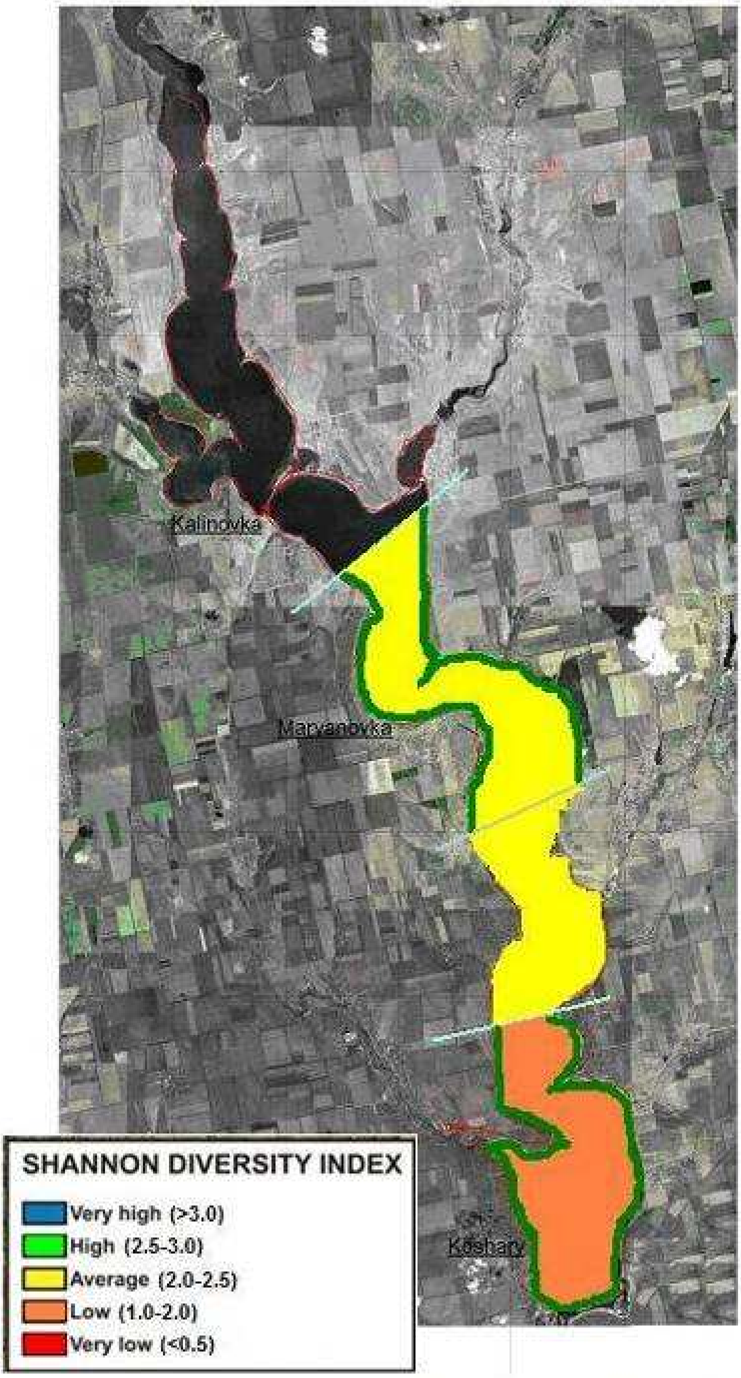

Figure 3.2 Shannon diversity index (H) for the selected parts of the Tyligulskyi Liman lagoon

4. Benthic ecological quality and its distribution

4.1. The AMBI index

Benthic ecology quality for the Tyligulskyi Liman lagoon was assessed by means of AZTI Marine Biotic Index (Muxika et al. 2005). The AMBI is based upon the proportions of five ecology groups (EG) to which the benthic species are allocated:

AMBI = [(0 x %EGI) + (1,5 x %EGII) + (3 x %EGIII) + (4,5 x %EGIV) + (6 x %EGV)] /100

with EG I being the disturbance-sensitive species, EG II the disturbance-indifferent species, EG III the disturbance-tolerant species, EG IV the second-order opportunistic species and EGV the first-order opportunistic species (Borja et al. 2000).

Calculation of the index was made with the use of AMBI_v5.0_2012 (AZTI - Tecnalia, www.azti.es) software. Generalized information on distribution of the macrozoobenthos specific composition in the Tyligulskyi Liman lagoon (2001 - 2011) into environmental groups for calculation of the AMBI index is presented in Table. 4.1. The values of AMBI index, calculated for the selected parts of the Tyligulskyi Liman lagoon, are given in Table. 4.1 and in Fig. 4.1.

Table 4.1 The components and the results of the AMBI index calculation for different parts (Fig. 2.7) of the Tyligulskyi Liman lagoon

Part of the lagoon	Zone	I (%)	II (%)	III (%)	IV (%)	V (%)	AMBI	Mean AMBI	BI from mean AMBI	Standard deviation	Disturbance Clasification	Not assigned (%)
A	A1	15,138	1,401	53,238	28,343	1,878	3,006		2		Slightly disturbed	0,2
	A2	19,438	0,66	73,458	4,955	1,486	2,525	2,766	2	0,339	Slightly disturbed	0,1
B	B1	66,639	6,208	22,102	1,241	3,808	1,04		2		Undisturbed	0
	B2	53,897	0,487	35,079	10,535	0	1,533	1,287	2	0,348	Slightly disturbed	0
C	C1	30,154	4,04	60,988	1,817	2,999	2,152		2		Undisturbed	0
	C2	79,897	0,681	16,524	2,896	0	0,636	1,394	2	1,071	Slightly disturbed	0

4.2. Benthic quality distribution in the Tyligulskyi Liman lagoon

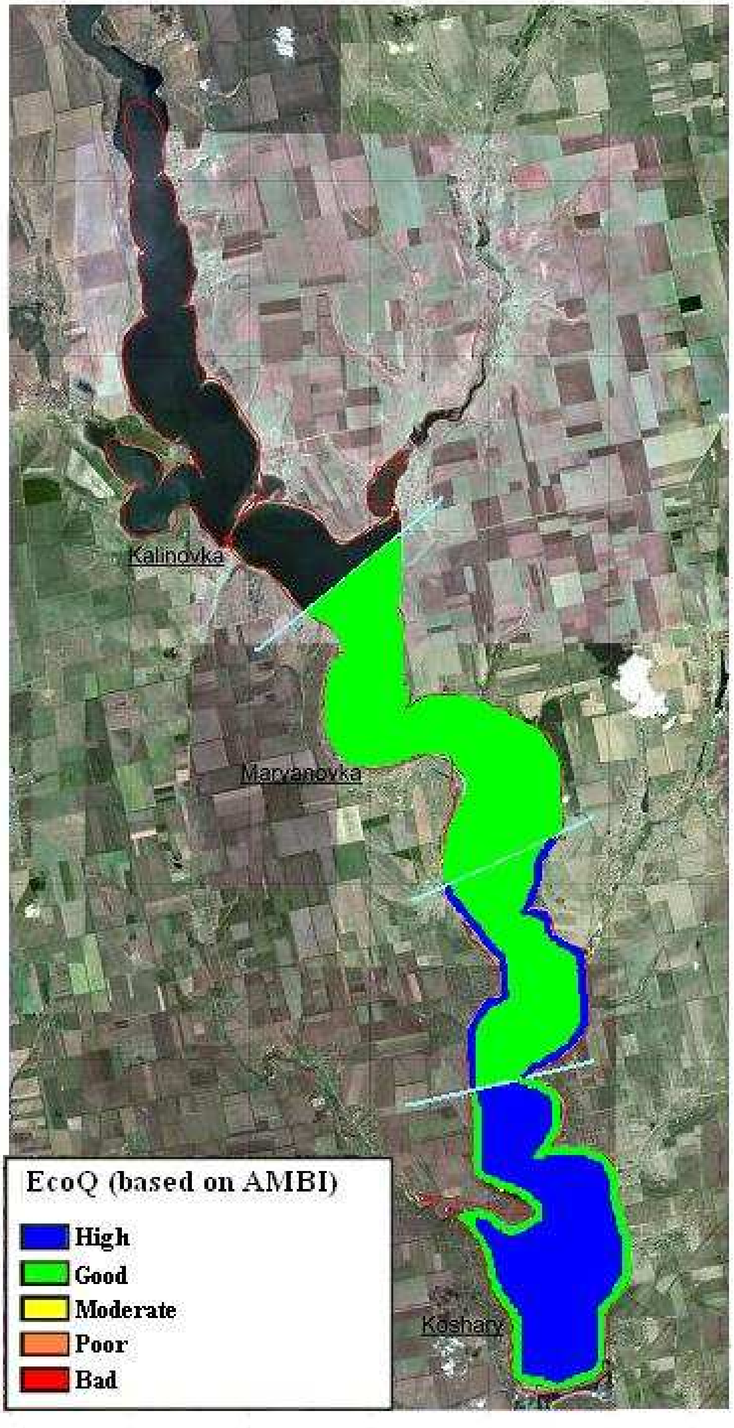

Figure 4.1 EcoQ classification of the Tyligulskyi Liman lagoon bottoms according to AMBI index

5. *Fish community based indices*

Since the Tyliguskyi Liman lagoon is characterized by instability of hydrological parameters and hydrochemical regime, the conditions for fish life (reproduction, feeding and wintering) in its various ecological complexes have constantly been changing and there were changes in the composition of fish fauna and, consequently, in the structure of commercial catches. Provision of artificially regulated water exchange of the lagoon with the sea through the canal which operates periodically contributes to enrichment of the fish fauna. Functioning of the canal makes it possible to use the lower (southern) part of the lagoon as a feeding aquatorium for migratory fishes (*Atherina mochon pontica*, Black Sea *Mugilidae* and *Mugil so-iuy Basilewsky*, in the first instance).

There have been observed a general tendency towards a growth of water salinity in the lagoon and a substantial decline in the number of freshwater fish species in the recent years. Three zones can be distinguished in the Tyliguskyi Liman lagoon in terms of conditions for fish habitation (Fig. 5.1).

1. An oligohaline zone (0.5-5‰) at the top of the lagoon, which is adjacent to the Tyligul River mouth. Its area is small and averages approximately 5 km². The freshwater fish species inhabit only this zone, though many saltwater fishes also enter here from the more saline part of the lagoon. In dry seasons, under decreased water levels in the lagoon, the flooded areas of the Tyligul River become isolated from the lagoon and the oligohaline zone ceases to exist. It is in these periods that the flooded areas turn a refugium for the freshwater fish species.
2. A polyhaline zone in the central part of the lagoon (18-25‰) has the largest area of 140-150 km².
3. A mesohaline zone (12-18‰) in the lower part of the lagoon, which is connected to the sea through the artificial canal, has the area of 15-20 km². It is in this zone that the species which regularly or occasionally penetrate the lagoon from the sea account for the widest diversity of fish species observed and fishery is predominantly (more than 95%) done here. Fixed gill nets are exclusively used for the catch of *Atherina mochon pontica* in this zone.

Literary data of the latest 50 years (Zambriborshch, 1965; Polischuk, Zambriborsch, Timchenko et al., 1990; Shekk, 2004; Sherman, Kutishchev, 2007), as well as the materials from the researches carried out by the Odessa center of the South Research Institute for

Marine Fisheries and Oceanography (PivdenNIRO) in 1995-2012 have been used for conducting analysis of fish fauna composition in the lagoon.

Figure 5.1 - Ichthyological zoning of the Tyliguskyi Liman Lagoon

The data of PivdenNIRO on specific composition of fish fauna were obtained during the analysis of catches and by-catches through the fishing instruments used in the lower and the middle parts of the lagoon (fixed gill nets with the mesh size of 6.5 mm, nets with the mesh size of 20-70 mm, fyke nets with the mesh size of 18 mm, seine nets with the mesh size of 16-18 mm).

The following instruments were used to obtain the data on the density of fish distribution / number of fish:

1) A seine net with 10 m opening and with the mesh size of 6 mm. The standard length of transport is 100 m^2, and the area of fishing - 1000 m^2. 7 catches were conducted in the middle and the lower parts of the lagoon, 1828 spec. of fish were caught, and the average density of distribution made up 26.1 spec./100 m^2, $\ln(\text{number}\cdot 100m^2) = 3.26$;
2) A beam trawl, 1 m wide, 0.7 m high, with the mesh size of 6 mm. The length of transport is 100 m, and the area of fishing is 100 m^2. 16 catches were conducted in the middle and the lower parts of the lagoon, 370 spec. of fish were caught, and the average density of distribution made up 23.1 spec./100 m^2, $\ln(\text{number}\cdot 100m^2) = 3.14$.

Catches by beam trawl and seine net were conducted in the coastal zone without use of a watercraft in the period of May through October.

A change in the composition of fish fauna in the Tyliguskyi Liman lagoon within the latest 50 years is presented in Table 5.1.

Table 5.1 Fish Fauna Dynamics in the Tyligulskyi Liman Lagoon

The family and species of fish	YY				
	1964[1]	1980[2]	2001-2002[3]	2004[4]	1995-2012[5]
1	***2***	***3***	***4***	***5***	***6***
Acipenseridae					
Acipenser stellatus Pall.	+	-	-	-	-
Clupeidae					
Alosa kessleri pontika Eichw.	+	+	-	-	-
Alosa caspia nordmanni Antipa.	+	+	+	-	+
Clupeonella cultriventris Nordm.	+	+	+	+	+
Sprattus sprattus phalericus Risso	+	-	-	+	-
Engraulidae					
Engraulis encrasicolus ponticus Aleks.	+	-	+	+	+
Esocidae					
Esox lucius L.	+	+	-	-	-
1	***2***	***3***	***4***	***5***	***6***

Cyprinidae					
Rutilus rutilus L.	+	+	-	+	+
Rutilus frisii Norton.	+	-	-	-	-
Leuciscus leuciscus (L)	-	-	+	-	-
Skardinius erithrophthalmus L.	+	-	-	-	-
Aspius aspius L.	+	-	-	-	-
Leucaspius delineatus (Heckel)	+	-	-	-	-
Tinca tinca L.	+	-	-	+	-
Gobio gobio L	+	-	-	-	-
Alburnus alburnus L.	+	-	-	-	-
Blicka bjorcna (L).	-	+	+	-	+
Abramis brama L.	+	+	-	-	-
Vimba vimba L.	+	-	-	-	-
Pelecus cultratus L.	+	-	+	-	-
Rodeus sericeus amarus (Bloch)	-	+	-	+	+
Carassius auratus gibelio Bloch.	+	+	+	+	+
Cyprinus caprio L.	+	+	-	-	-
Leuciscus idus	+	-	-	-	-
Coditidae					
Misgurnus fossilis L.	+	-	-	-	-
Siluridae					
Silurus glanis glanis L.	+	-	-	-	-
Belongidae					
Belone belone euxini Gunther.	-	-	+	+	+
Anguillidae					
Anguila anguila L.	+	-	-	-	+
Gasterosteidae					
Pungitius platigaster platigaster.	+	+	+	-	+
Kessler	+	+	+	+	+
Gasterosteus aculeatus L.					
1	***2***	***3***	***4***	***5***	***6***

Syngnathidae					
Nerophis ophidionteres, Risso.	+	+	+	-	+
Singnathu styphle argentatus P.	+	+	+	-	+
Syngnathus abaster Risso	+	+	-	+	+
Mugilidae					
Mugil cephalus L.	+	+	+	+	+
M. so-iuy Basilewsky	-	-	+	+	+
Liza aurata Risso	+	+	+	+	+
L.saliensRisso	+	+	+	+	+
Atherinidae					
Atherina mochon pontica Eichw	+	+	+	+	+
Percidae					
Stizostedion lucioperka L.	+	+	-	+	-
Perka fluviatilis L.	+	+	+	-	+
Percarina demidoffi Nordm	+	+	-	+	-
Gobiidae					
Pomatoschistus microps leopardinus Nordman.	+	+	+	+	+
P. caucasicus Kawrajsky	+	+	+	-	+
Zosterisessor ophiocephalus Pall.	+	+	+	+	+
Mesogobius batrachocephalus Pall.	+	+	+	+	+
Neogobius melanostomusPall.	+	+	+	+	+
N. cephalarges Pall.	+	+	-	-	-
N. fluviatilis Pall.	+	+	+	+	+
Proterorhinus marmoratus (Pallas)	+	+	-	+	+
Benthophilus stellatus	+	+	-	-	-
Knipowitschia longicaudata. Kessler	-	+	-	-	-
Neogobius ratan Nordmann	-	+	-	-	+
Gobius niger L.	-	+	+	-	+
N. syrman (Norman)	+	+	+	-	+
N. gymnotrachelus Kessler	+	+	-	+	+
1	***2***	***3***	***4***	***5***	***6***

Scophthalmidae					
Psetta maeotica Pall.	-	-	+	-	+
Pleuronectidae					
Platichtys flesus luscus Pall	+	+	+	+	+
Solea nasuta Pallas	-	-	+	-	+
Blenniidae					
Blennius sanguinolentis Pall.	-	-	-	-	+
B. sphinxValenc.	-	-	+	-	-
Labridae					
Crenilabrus ocellatus (Forskal)	-	+	-	+	+
Mullidae					
Mullus barbatus ponticusEssipov	-	-	-	-	+
Centracanthidae					
Spicara smaris (Linne)	-	-	-	-	+
Centrarchidae					
Lepomis gibbosus (Linne)	-	-	-	-	+
Carangidae					
Trachurus mediterraneus ponticus Aleev	-	-	-	-	+
Gobiesocidae					
Lepadogaster candollei Risso	-	-	-	-	+
Total	48	38	30	26	41

References: [1] (Zambriborshch, 1965); [2] (Polischuk, Zambriborsch, Timchenko et al., 1990); [3] (Shekk, 2004); [4](Sherman, Kutishchev, 2007); [5] Observational data of the Odessa Center of Southerrn Scientific Research Institute of Marine Fisheries and Oceanography .

Distribution of fish species into environmental and trophic groups is presented in Table 5.2. Notations of types and trophic groups are given in accordance with Practitioners Guide to the Transitional Fish Classification Index (TFCI) Water Framework Directive: Transitional Waters.

Table 5.2 Fish species encountered in the Tyligulskyi Lagoon and their guilds

Species	Type	Trophic guild	Estuarine resident	Estuarine spawners	Nursery species	Habitat preference
1	***2***	***3***	***4***	***5***	***6***	***7***
Clupeidae *Alosa caspia nordmanni Antipa*	CA	Z				P
Clupeonella cultriventris Nordm.	CA	Z				P
Engraulidae *Engraulis encrasicholus ponticus Aleksandrov*	MS	Z				P
Cyprinidae *Rutilus rutilus (L)*	FW	Z				P
Blicka bjorkna (L)	FW	BL				P
Rodeus sericeusamarus (Bloch)	FW	Z				P
Carassius gibelio Bloch.	FW	BL				P
Belonidae *Belone belone euxini Gunther*	MA	P				P
Anguillidae *Anguila anguila L.*	CA	P				P
Gasterosteidae *Pungitius platigaster platigaster Kessler.*	ER	BL	Y	Y		P
Gasterosteus aculeatus L.	CA	BL				P
Syngnathidae *Nerophis ophidionteres Risso.*	ER	BL	Y	Y		D

1	2	3	4	5	6	7
Singnathus typhle argentatus P.	ER	BL	Y	Y		D
Syngnathus nigrolineatus Eichw.	ER	BL	Y	Y		D
Mugilidae *Mugil cephalus L.*	MJ,MS	D			Y	P
M. so-iuy Basilewsky	MJ, ER	D	Y	Y	Y	P
Liza aurata Risso	MJ,MS	D			Y	P
L.saliensRisso	MJ,MS	D			Y	P
Atherinidae *Atherina mochon pontica Eichw. (A. boyeri)*	MS,ER	Z	Y	Y	Y	P
Percidae *Perca fluviatilis L.*	FW	P				P
Gobiidae *Pomatoschistus microps leopardinus Nordmann*	ER	BL	Y	Y		B
P. caucasicus Kawrajsky	MA	BL				B
Zosterisessor ophiocephalus Pall.	ER	BL	Y	Y		B
Neogobius melanostomus Pall.	ER	BL	Y	Y		B
1	2	3	4	5	6	7
N. fluviatilis Pall.	ER	BL	Y	Y		B
Proterorhinus marmoratus (Pallas)	ER	BL	Y	Y		B
Neogobius ratan Nordmann	MA	BL				B
Gobius niger L.	ER	BL	Y	Y		B
N. syrman Nordmann	MA	BL				B
N. gymnotrachelus Kessler	MA	BL				B

1	2	3	4	5	6	7
Mesogobius batrachocephalus Pall.	ER	P	Y	Y		B
Scophthalmidae *Psetta maeotica Pall.*	MA	P				B
Pleuronectidae *Platichtys flesus luscus Pall.*	ER	BL	Y	Y	Y	B
Soleidae *Solea lascaris nasuta Pall.*	MA	BL				B
Blenniidae *Blennius sanguinolentis Pall.*	MA	BL				B
Labridae *Crenilabrus ocellatus (Forskal)*	ER	BL	Y	Y		D
Mullidae *Mullus barbatus ponticus Essipov*	MA	BL				B
Centracanthidae *Spicara smaris (Linne)*	MA	BL				D
Centrarchidae *Lepomis gibbosus (Linne)*	FW	BL/P				P
Carangidae *Trachurus mediterraneus ponticus Aleev*	MA	BL				P
Gobiesocidae *Lepadogaster candollei Risso*	MA	BL				B

Habitat preference: B: benthic fishes; D: demersal fishes; P: pelagic fishes

Numerical correlation of fish species in the catches with a close-meshed seine net and a beam trawl is given in tables 5.3 and 5.4. There were 18 fish species in the seine net catches, with 6 of them being the dominant species, which account for 90 % of the total number of the specimens, and 14 species - in the beam trawl catches, with 7 of them being the dominant ones. The average number of the dominant species is 6.5. Abnormal fishes were not observed.

Table 5.3 Total fish species and relative (%) numerical abundance of fishes captured in the Tyligulskyi Liman lagoon over 7 surveys by seine net.

Scientific Name	% abundance
Nerophis ophidionteres, Risso.	1.7
Singnathus typhle argentatus P.	1.6
Syngnathus abaster Risso	3.1
Pomatoschistus microps leopardinus Nordman.	1.3
Zosterisessor ophiocephalus Pall.	14.7
Mesogobius batrachocephalus Pall.	3.5
Neogobius melanostomus Pall.	20.0
N. fluviatilis Pall.	3.7
N. gymnotrachelus Kessler	0.1
Proterorhinus marmoratus (Pallas)	1.0
Gobius niger L.	0.2
Gobius sp.	0.1
Atherina mochon pontica Eichw	47.8
Crenilabrus ocellatus (Forskal)	1.3
Platichtys flesus luscus Pall	0.2
Blennius sanguinolentis Pall.	0.1
Lepadogaster candollei Risso	0.1
Liza aurata Risso	0.1

Table 5.4 Total fish species and relative (%) numerical abundance of fishes captured in the Tyligulskyi Liman lagoon over 16 surveys by beam trawl

Scientific Name	% abundance
Nerophis ophidionteres, Risso.	0.8
Singnathus typhle argentatus P.	8.4
Syngnathus abaster Risso	9.7
Pomatoschistus microps leopardinus Nordman.	27.6
Zosterisessor ophiocephalus Pall.	8.6
Mesogobius batrachocephalus Pall.	1.1
Neogobius melanostomus Pall.	20.8
N. fluviatilis Pall.	0.8
N. gymnotrachelus Kessler	0.5
Proterorhinus marmoratus (Pallas)	11.4
Gobius niger L.	5.9
Atherina mochon pontica Eichw	0.3
Crenilabrus ocellatus (Forskal)	3.8
Platichtys flesus luscus Pall	0.3

The data for calculation of Estuarine Biotic Integrity Index (EBI) are presented in Table 5.5. According to the two-point scale applied, Medium (EBI ≥ 25), Low (EBI < 25), the environmental quality status of the Tyligulskyi Liman lagoon can be assessed as 'medium'.

The data for calculation of Transitional Fish Classification Index (TFCI) are given in Table 5.6. Currently only 7 of 10 metrics of this index for the Tyligulskyi Liman lagoon can be evaluated. Owing to the fact that the Reference species list has not been elaborated and the indicator species are not defined for the water bodies of the Black Sea basin, the metrics of 1-3 have not been assessed. Nevertheless, the scores for the metrics of 4-10 make it possible to estimate the ecological class of the Tyligulskyi Liman lagoon as ‘good/medium’. It is obvious, that in case of evaluation by all of the 10 metrics the ecological class of the lagoon will be higher.

Table 5.5 Metric values and scores for the Estuarine Biotic Integrity Index (EBI), calculated for the Tyligulskyi Liman lagoon

No.	Metric	Value	Score
1	Number of species (N)	41	5
2	Dominance	6.5	5
3	Fish abundance	3.26	0
4	Nursery species (N)	6	5
5	Estuarine spawners (N)	13	5
6	Resident species (N)	13	5
7	Proportion benthic fishes (%)	0.56	0
8	Proportion abnormal (%)	≤0.01	5
	EBI(sum of metric scores)		**30**

This results in an Ecological Quality Status (EQS) "Medium (EBI ≥25)" (Deegan et al., 1997).

Table 5.6 Metric values and scores for the Transitional Fish Classification Index (TFCI), calculated for the Tyligulskyi Liman Lagoon

No.	Metric	Value	Score
1	Species composition	N/A	-
2	Presence of indicator species	N/A	-
3	Species relative abundance	N/A	-
4	Number of taxa that make up 90% of the abundance	6.5	5
5	Number of estuarine resident taxa	13	5
6	Number of estuarine-dependent marine taxa	6	3
7	Functional guild composition	6	5
8	Number of benthic invertebrate feeding taxa	15	5
9	Number of piscivorous taxa	7	5
10	Feeding guild composition	4	5
	TFCI (sum of metric scores)		**33**

The TFCI value can be converted into an EQR:

EQR = (33 – 10)/(50 – 10) = **0.58**

This results in an ecological class of ‘Good/Moderate’ (Practitioners Guide to the Transitional Fish Classification Index (TFCI) Water Framework Directive: Transitional Waters, Table 10).

6. Fisheries

Fish productivity (as well as fish fauna diversity) of the Tyligulskyi Lagoon has always depended on its hydrological and hydrochemical regime and, first and foremost, on the salinity of its waters. In the 1930s–1950s, when the lagoon was desalinated due to abundant atmospheric precipitation and strong spring floods on the rivers flowing into the lagoon, the catches increased over several years following. In spring, due to a water level rise, breaches of isthmus often occurred and the water exchange with the sea restored. Sea species of fish (*Mugilidae, Gobiidae, Pleuronectidae, Clupeidae, Atherinidae* etc.) were brought into the lagoon through occasional inrushes at the same time as freshwater fish species were taken away with the floods from the Dniprovsko-Buzkyi estuary (*Abramis brama L., Rutilus rutilus L., Cyprinus carpio L., Stizostedion lutioperka L., Carassius auratus gibelio Bloch., Blicka bjorcna (L), Skardinius erithrophthalmus L.* etc.) (Shekk, 2004).

Thirty-four species of saltwater and freshwater fish were registered in the lagoon in 1953. In 1959 a connecting canal to the sea was constructed in the isthmus of the Tyligulskyi Lagoon in order to increase the fishing capacity. Owing to this, 45 species of fish were registered in the lagoon in 1960 and 48 species in 1964 (Table 5.1). Among them 16 (33 %) are brackish water, 14 (27 %) salt water and 19 (40 %) freshwater species. In 1953–1960 an average of 1091.8 tons of fish was caught in the lagoon annually (Fig. 5.2). The largest catch for the lagoon, 2,349.6 tons (146.9 kg/ha), was registered in 1956 (Zambriborshch, 1956, 1965). However, against all expectations, the catches began to decline in the subsequent years. This was due to a decrease in the carrying-out of freshwater fish from the Dniprovsko-Buzkyi estuary to the mouth zone of the Tyligulskyi Lagoon. This was a result of the overregulation of the Dnipro River flow by a cascade of hydroelectric power stations causing a decrease in spring flood intensity, as well as an onset of reservoir salinisation. There

occurred a gradual replacement of freshwater fish by marine species, among which the species of little value prevailed (Shekk, 2004).

In 1968 the canal sanded up and in 1970s–1990s it functioned only intermittently, often with long-term interruptions, which conditioned a gradual growth in water salinity. As a result, in the 1980s 16 fresh water species (e.g., *Acipenser stellatus Pall., Anguila anguila L.* etc., according to the Table 5.1) and previously mass salt water (*Sprattus sprattus phalericus Risso* and *Engraulis encrasicolus ponticus Aeks*) fishes, which had been getting into the lagoon from the sea (Polishchuk et al., 1990), were not found in the lagoon.

In 1961 through 1971, catches decreased from 877.8 to 276.1 tonnes (54.9–17.3 kg/ha), and the fishery was based on *Gobiidae* and *Atherina mochon pontica Eichw,* and since 1974 – on *Atherina mochon pontica Eichw* and *Clupeonella cultriventris Nordm.* In 1976–1979 the average catch in the lagoon went down to 253.5 tonnes (14.6 kg/ha). In the 1980s the predominant catches were *Atherina mochon pontica Eichw* and *Stizostedion lutioperka L.*. The catches ranged from 105.1 to 616.0 tonnes/year, depending on the canal function, (6.5–38.5 kg/ha). *Gobiidae, Mugilidae* and *Platichtys flescus Pall* lost their commercial value, and since 1992 *Atherina mochon pontica Eichw* became the principal commercial object in the Tyligulskyi Lagoon; with catches at the end of the previous century ranging between 107 and 178 tonnes per year (Zaitsev et al., 2006).

At the beginning of the 21st century the connecting canal to the sea was restored and was intermittently opened in spring in a number of years to provide an influx of young saltwater fish from the sea into the lagoon. However, in 2007–2009 the canal ceased to function again and didn’t operate for a long period of up to 2010, when it was open in April through September. The catches of fish, though increased to 309–370 tonnes in 2009–2012, consisted mainly, as before, of low-value species *Atherina mochon pontica Eichw*. The data on commercial catches within the latest decade are presented in Table 5.7 and Figure 5.2. The percentage of *Atherina mochon pontica* in commercial catches comprises 87.2%, and the percentage of *Gobiidae* (mainly *Neogobius melanostomus*) – 9.8%. The rest of the species account for barely 3.0%.

In the summer of 2010, owing to hazardous weather conditions, strong thundershowers in June through July and anomalously high water temperatures in July and August, there occurred mass mortality of fish (*Gobiidae, Mugilidae*). In some coastal areas 20 kg of dead fish per square meter were reported.

In view of the deterioration of water quality indices and the lack of necessary conditions for a sufficient influx of young fish, mainly *Mugilidae*, from the sea to the lagoon for fattening, a mere 20–30 % of the lagoon fishing potential is currently made use of.

Under the present-day conditions a workable way to increase the fishing capacity of the lagoon is through establishment of a population of valuable saltwater fishes: *Mugil so-iuy Basilewsky, Acipenseridae, Platichtys flescus Pall*, and *Gobiidae* could prove prospective species for the introduction. Artificial reproduction and stocking as well as formation of self-reproducing populations are considered the most viable ways to maintain a large population size for these species. In case of aquaculture, the indigenous *Mugilidae (Mugil cephalus L., Liza aurata Risso, L. saliens Riso)* could result in substantial increase of the biomass (Shekk, 2004).

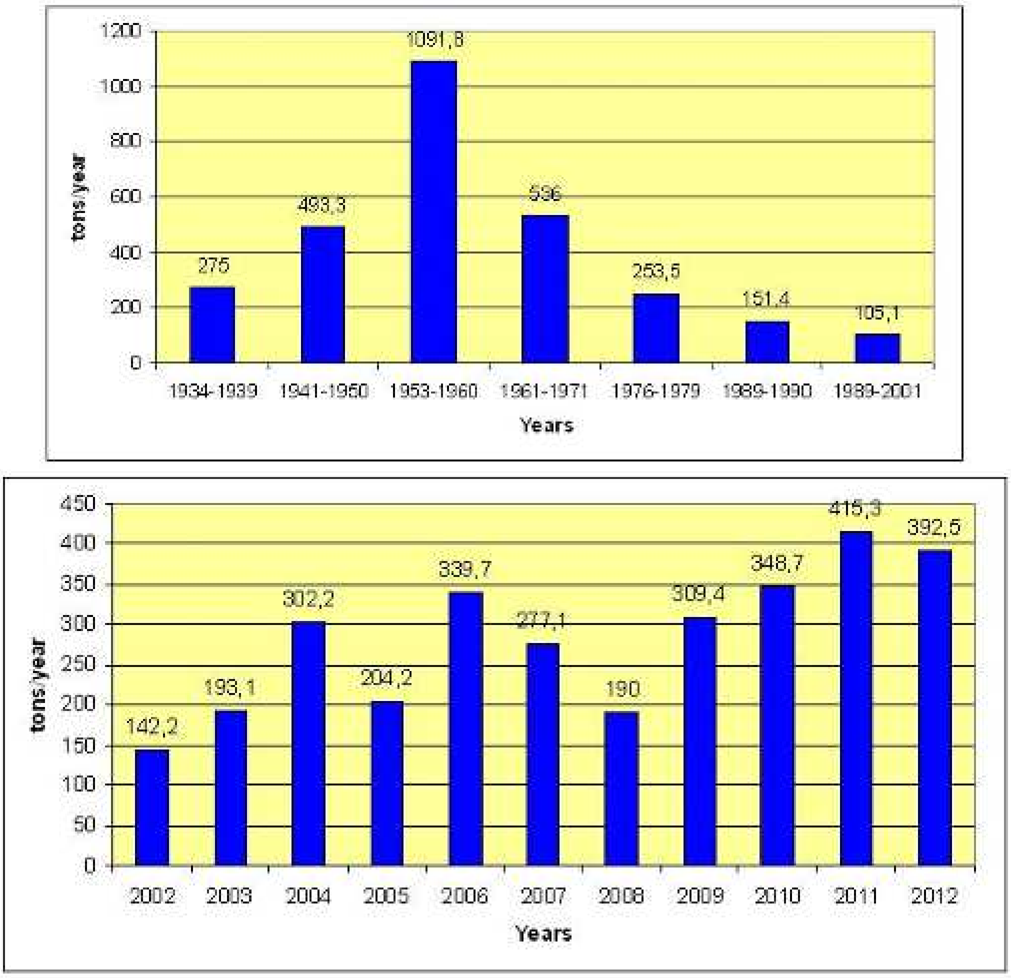

Figure 5.2 Dynamics of the commercial catch of fish in the Tyligulskyi Liman lagoon.

Table 5.7 Dynamics of fish catch (tons/year) in the Tyligulskyi Lagoon

Species	YY										
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Platichtys flesus	-	-	0,138	0,08	0,01	0,02	0,14	0,1	0,2	0,04	-
Atherina mochon pontica	102,8	142,7	256,3	147,15	301,44	252,19	163,2	280,6	315,5	371,3	380,6
Gobiidae	36,5	48,39	37,74	37,05	22,84	24,69	25,4	26,5	25,8	20,0	0,8
Mugilidae	0,01	0,30	7,92	18,53	15,03	0,04	0,4	-	4,1	20,6	0,4
Engraulis encrasicholus	2,0	1,69	-	-	-	-	0	1,0	-	-	10,7
Mugil so-iuy	0,9	-	-	1,34	0,4	0,13	0,8	1,0	2,7	3,34	-
Shrimp	-	-	-	0,02	-	-	0,06	0,2	0,4	-	-
Total	142,2	193,1	302,2	204,2	339,7	277,1	190,0	309,4	348,7	415,3	392,5

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