14-16 September 2012
Tulcea - Romania

Romanian Limnogeographical Association

Danube Delta Biosphere Reserve Authority

Danube Delta National Institute for Research and Development

# Water resources and wetlands

CONFERENCE PROCEEDINGS
14-16 September 2012, Tulcea - Romania

Editors:
Petre Gâştescu
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Editura Transversal

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**Water resources and wetlands**, *Editors: Petre Gâştescu, William Lewis Jr., Petre Breţcan*
Conference Proceedings, 14-16 September 2012, Tulcea - Romania
ISBN: 978-606-605-038-8

# DISTRIBUTION OF VASCULAR PLANTS IN THE COASTAL ECOSYSTEMS OF THE WHITE SEA

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**Abstract**

In the coastal ecosystems of the White Sea, there are the organisms, belonging to different taxonomic groups removed from each other in the scale of their phylogenetic development. Communities of these organisms have developed historically, therefore their organization; structure and functioning have the specific general regularities. They are determined by the key complexes of factors causing their stratification on coastal zone: the basic - a vertical temporary semidiurnal cyclic variable - duration of drainage during low-tide and depth flooding during rising tide, and also gradients of influence of several other ecological factors: salinities, humidity, riches of substratum accessible organic fertilizer. The sublittoral zone is almost deprived the close vegetation and represents the open silt with a rare covering from algae crusts and pioneer species *Eleocharis uniglumis* with an impurity of White sea endemic species - *Salicornia pojarkovae* (in mouth of the southern rivers) and *Bolboschoenus maritimus* in the more northern points. In small ponds removed from tidal zone, there is Hippuris tetraphylla with great abundance. Among *Phaeophyta Fucus serratus* and *Ascophyllum nodosum* start to prevail. With middle abundance *Zostera marina* and *Ruppia brachypus* join to them. On the supralittoral zone vegetative cover is presented by monodominant thickets *Carex subspathacea*, with small abundance *Stellaria humifusa*, *Potentilla egedei* and *Glaux maritima*. The communities with domination *Festuca rubra* and *Sonchus arvensis* are presented in the ecotone zone to the plane vegetation. The basic changes of vegetative cover of salt marsh communities connected with the change of level of the White Sea are the following: the area of plant communities with domination of boreal – European, and boreal – Eurasian species on the marshes wetland of the Pomorsky and Karelian coasts of White Sea is constantly expanding. The area of plant communities *S. pojarkovae* on the drainless depression on the crosspiece from basic coast up to nearby islands has increased, the degradation of the serge-cereal communities (*Carex glareosa* + *Puccinellia coarctata*) takes place on the tidal marshes which do not bear the under flooding, the microcoenosis from hydrophytes (*Phragmites australis*) is appearing in the salt marsh communities.

**Keywords**: saltmarshes, vascular plants, White Sea.

## 1 INTRODUCTION

Investigations of long-term changes of coastal zone ecosystems of Arctic regions is now becoming ever more urgent in connection with quickly developing processes of climate transformation and active development of coasts of the seas and oceans. One of consequences of these processes is the transformation of coastal biota and significant reduction of their area at the coasts of Western Europe (Beeftink, Wolff, 1967, 1975) and Northern America (Jefferies et al., 2002, 2006). Coast of the White Sea, particularly its western coast, gives a rare opportunity to observe both the global climate changes and eustatic rising of the coasts (Kaplin et al., 2005; Kvasov, 1975; Strelkov, 1961).

Lately, the world interest to scientific research materials of 50-100 years of age has considerably increased: the diachronic approach allowing estimation of the changes that have happened for this time in the coastal ecosystems.

The task of using of historical materials as a basis for the biodiversity monitoring has been put forward as a priority by the Second International Conference in Copenhagen in 2005 on planning the Arctic researches (ICARP II, Denmark, 2005) that presents the archival materials especially valuable in a context of studying of coastal biota. Use of the formalized and simplified models of geosystems does not give reliable results, therefore the investigation of flora and vegetation of coastal salt marsh communities allows giving a high-grade picture of dynamics the coastal ecosystems in a long-term trend of its development.

## 2 MATERIALS AND METHODS

The archival materials of the White Sea biological station of Karelian-Finnish branch of Academy of Sciences of the USSR concerning the investigations of the geomorphology of estuary zones of Pomorsky and Karelian coasts of the White Sea, raw material resources of the White Sea, and scientific bases of their

industrial application were analyzed. The theme "Typology of the bays of the White sea" – the project leader Dr. Z. G. Poljanichko – was one of the plan directions of the works of Belomorsky station. During the period from 1949 to 1957, the numerous bays of Karelian and Pomorsky coasts of the White Sea – from the area of Great Salma up to the estuaries of the rivers Kolezhma and Nukcha – were investigated by the researchers of Station. The analyzed materials also included the data concerning the structure of salt marsh communities of the White Sea coasts from the articles of different authors of the Komarov Botanical Institute of the Russian Academy of Sciences and Karelian Research Center of RAS, working on the problem in 1925-1950, 1980-2007 (Breslina, 1981b; Bystrova, Minjaev, 1969; Kravchenko, Kuznetzhov, 2003; Kravchenko, 2007; Pobedimova, 1964; Pobedimova et al. 1989; Chinzerling, 1925). Also, the numerous herbarium materials presented in the funds of Herbarium Department of BIN RAS (LE) were studied. Our own herbarium collections (450 herbarium sheets – PTZ) and 615 geobotanical releveés of coastal vegetation of the White Sea (Pomorsky and Karelian coasts) also were included in the investigation. Descriptions of the plant communities were made within the limits of a natural contour of phytocoenosis (Galanin, 1989; 1991; Kuznetchov, 2006). Non equal distance scale by B. M. Mirkin (Mirkin et al., 1989) has been used for the estimation of the projective cover of the plants. Works were spent in a following points: – island Rjazhkov (1) (2004); estuary of the river Chernaja (2) (2008); bay Kislaja (3) (2008); cape Elovy (4) (2008); bay Nernaja (5) (2008); point in front of island Belaja Luda (6) (2008); southern part of Kyzakotsky bay (7) (2008); settlements - Chypa (8) (2007, 2008); Keret (9) (2007); Belomorsk (10) (2003); Sumsky Posad (11) (2006); Kolezma (12) (2000, 2010); Nyuchscha (13) (2005) (Fig.1). Names of vascular plants are given according to Cherepanov S. K. (1995).


**Figure 1. Map of the points of the investigations. Geographical names of the points see in the text.**

## 3 RESULTS

Based on the ecologic-coenotic optimum of the coastal and salt marsh species the halophytic floristic complex of the coasts of the White Sea has been allocated (Sergienko, 2008). The species, which are a part of this complex, differ on the breadth of their ecological amplitude and are united in such ecological groups, as euhalophytes, strictly dated to primary marches on muddy wetlands and bearing the strong soil salinity; mesohalophytes – the species, growing on the secondary marches and miohalophytes - the species of local flora which are bearing the weak soil salinity.

The coastal vegetation growing in the estuaries zones of all rivers, running into the White Sea has their prominent features (Breslina, 1981b; Babina, 2002; Sergienko, 1983b, 2008).

1. Muddy low wetland from the sea to the central part of marsh – it is characteristic for the estuaries of all rivers, running into the White Sea. Such wetlands stretch out along low accumulative coast up to 700 m in the deep sea. The overgrowing begins with weak vegetative runaways of *Ruppia maritima* (3%) and *Zostera marina* (10%) – in water, more upper on the coast there are the sprouts of *Eleocharis uniglumis* at a

stage of occurrence of 3-d leaf. Up to the 10 cm on the mean low water level, on the muddy sediments can occur the single plants of *Tripolium vulgare* (2%). The higher parts of the marshes are occupied by community with domination *Plantago maritima* s. l. (20%), *Eleocharis uniglumis* (15%), *Agrostis straminea* (10%), *Glaux maritima* (7%), and *Potentilla egedei* (10%). Up to the 15 cm on the mean low water level – on the marsh wetlands the communities with *Agrostis straminea* (25%) and *Potentilla egedei* (25%) are dominated (Fig.2).

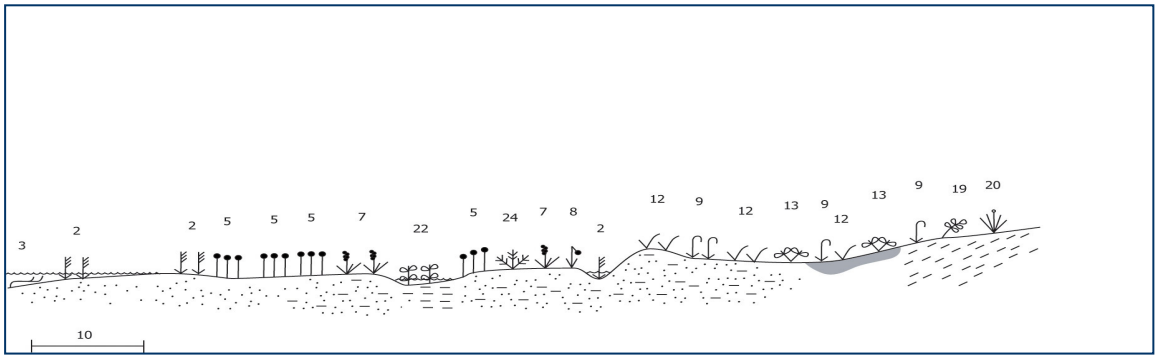


**Figure 2.** Ecological-dynamic series of salt marsh vegetation on Pomorsky and Karelian coasts of White Sea. Symbols - coastal communities with domination: 2 – *Bolboshoenus maritimus*, 3 – *Zostera marina*, 5 – *Eleocharis uniglumis*, 7 – *Triglochin maritima*, 8 – *Tripolium vulgare*, 9 – *Juncus atrofuscus*, 12 – *Carex subspathacea*, 13 – *Potentilla egedei* s.l., 19 – *Lathyrus japonicus* ssp. *pubescens*, 20 – *Phragmites australis*, 22 – *Hippuris tetraphylla*, 24 – *Stellaria humifusa*.

2. Overgrowing the central part of a marsh. Mosaicity of communities, occupying the area up to 150 $m^2$, amplifies. The euhalophytes are gradually replaced by halohydrophytes and mesohydrophytes, but the confinidity the species from genus *Carex* to the microdowndrops and *Salicornia* – to the nonswarding substratum is still kept. The vegetation is presented by communities with domination *Carex glareosa* (5%), *Juncus atrofuscus* (30%), *Glaux maritima* (10%), *Sonchus humilis* (5%), *Festuca rubra* (20%).
On the microdowndrops created due to washout of the ground during the syzygial tide and storms, the *Carex glareosa* (10%), *Juncus atrofuscus* (10%), *Eleocharis uniglumis*( 20%) are dominate, on the microrising places – the *Glaux maritima* (20%), *Potentilla egedei* (15%), *Juncus atrofuscus* (up to 50%) are growing. The final stages are different: on microdowndrops: there are communities with domination of *Bolboschoenus maritimus* (30%) + *Eleocharis uniglumis* (40%); *Bolboschoenus maritimus* (20%) + *Phragmites australis* (15%); on microrising places: *Potentilla egedei* (20%) + *Glaux maritima* (15%) + *Plantago maritima* s. l. (30%) + *Juncus atrofuscus* (40%) + rags (up to 40%).

3. Overgrowing the drainless areas (tombolo or pereyma – the crosspiece from coast to island) at the coasts on all marshes of the White Sea (fig. 3). Most likely, earlier there were channels or drainless salted lakes.

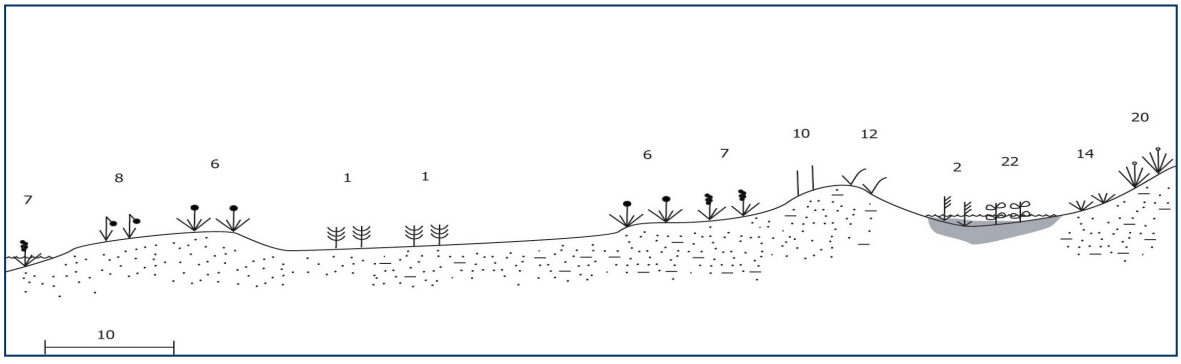


**Figure 3. Ecological-dynamic series of salt marsh vegetation on the inland wetlands** (tombolo or pereyma – the crosspiece from coast to island) at coast of the White sea. Symbols - coastal communities with domination: 1 – *Salicornia europaea*, 2 – *Bolboshoenus maritimus*, 6 – *Plantago maritima* s. l., 7 – *Triglochin maritima*, 8 – *Tripolium vulgare*, 10 – *Puccinellia coarctata*, 12 – *Carex subspathacea*, 14 – *Agrostis straminea,* 20 – *Phragmites australis*, 22 – *Hippuris tetraphylla.*

Now, due to fast rising of coast, their connection with the mail water-currents (the sea or the river) has ended, and overgrowing always begins with the endemic of the White sea area *Salicornia pojarkovae*

(50%) (though, in opinion of Reidar Elven – Project "Pan Arctic Flora", distinctions between *S. europaea* and *S. pojarkovae* are enough problematic), and final stages on these places come to the end with introduction of the euhalophytes from genus *Carex* and from family *Poaceae*: *Triglochin maritima* (35%) + *Salicornia europaea* (40%) + *Carex glareosa* (20%)*, Triglochin maritima* (40%) + *Salicornia europaea* (50%) + *Puccinellia coarctata* (15%) + *P. maritima* (10%).

Community on the higher plots of crosspiece (tombolo) with domination: *Triglochin maritima* (30% )*, Stellaria humifusa* (5% gr)*, Spergularia marina* (15% gr)*, Salicornia europaea* (5%)*, Potentilla egedei* (20%)*, Puccinellia maritima* (5%)*, Carex subspathacea* (15% gr) borders the large drainless depression with *Salicornia europaea* (10%) like as «scallops», specifying a way of former temporary water-currents.

As tombolo or pereyma represents a stripe, connecting island with basic coast (for example near the settlement Kolezhma, Belomorsky district) this crosspiece has coast as from the sea and from a river mouth. The final stages depending from the location the drainless area on the tombolo, are various. More close to the sea side, the overgrowing of the drainless depression comes to the end with community: *Spergularia marina* (20%) + *Salicornia europaea* (30%) + *Triglochin maritima* (30%) + *Agrostis straminea* (40%). More close to the basic coast where there is a flooding by fresh subterranean waters from mire surrounding the marsh, dominates the community – *Triglochin maritima* (20%) + *Bolboschoenus maritimus* (40%) + *Phragmites australis* (30%).

In this community the soil horizons are not expressed, and the ground reminds a dense damp sponge due to the numerous of roots, penetrating this amorphous soil structure.

After the analysis of structure of salt marsh and coastal communities in a long-term trend of their development, the following regularity has come to light.

On the muddy wetlands of the White Sea coasts since last 60-ty years the role of the eurytopic species has increased, that leads to the raise of their productivity, but the presence of the stenotopic species maintains their stability. Dynamic changes in structure of the coastal vegetation on muddy wetlands are presented on fig. 4.

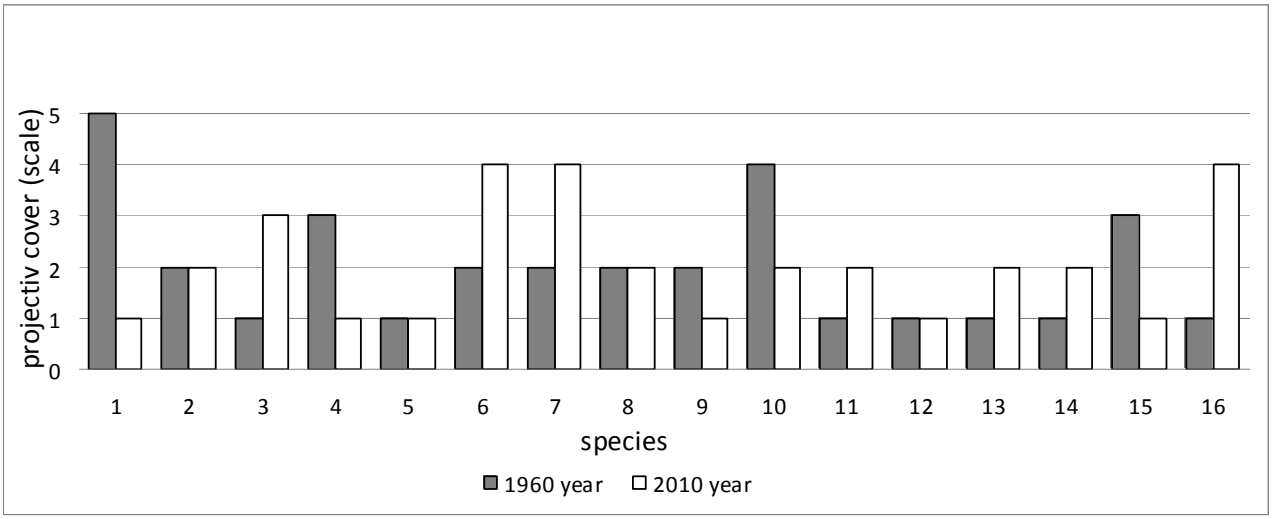


**Figure 4. Dynamics of changes of coastal communities on muddy wetlands of Pomorsky and Karelian coasts of the White sea (1960-2010).** The notes to figures 4,5. 1. The projective cover of plants (an axis of ordinates) on transects is given on B. M. Mirkina's scale in marks: 1– up to 5 %, 2 – 5-15 %, 3 – 15-25 %, 4 – 25-50 %, 5 – 50-100 %. 2. Data on an abscissa axis represent not a dimensional scale, but show the order of an arrangement of species (which can repeat on a full ecological -dynamic line at their distance) from the sea and their removal from the water line (from zero of depths – the lowest sea level). Symbols: 1 -*Zostera marina* (10), 2 - *Bolboschoenus maritimus* (20), 3 - *Eleocharis uniglumis* (28), 4 - *Hippuris tetraphylla* ((35), 5 - *Stellaria humifusa* (42), 6 - *Triglochin maritima* (60), 7 - *Tripolium vulgare* (75), 8 - *Bolboschoenus maritimus* (80), 9 - *Carex subspathacea* (90), 11 - *Juncus atrofuscus* (100), 12 - *Carex subspathacea* (105), 13 - *Potentilla egedei* (110), 14 - *Agrostis straminea* (120), 15 - *Lathyrus japonicus* ssp. *pubescens* (145), 16 - *Phragmites australis* (150-180).

In comparison with 60-years of XX century, the projective cover of euhalophytes *Triglochin maritima* and *Tripolium vulgare* has doubled, and – *Zostera marina* has increased 4 times. At overgrowing of tombolo or pereyma (crosspieces from basic coast to island) the projective cover almost of all dominating species has increased 2-3 times, excepting only the *Carex subspathacea,* which projective cover remains at the same level (fig. 5).

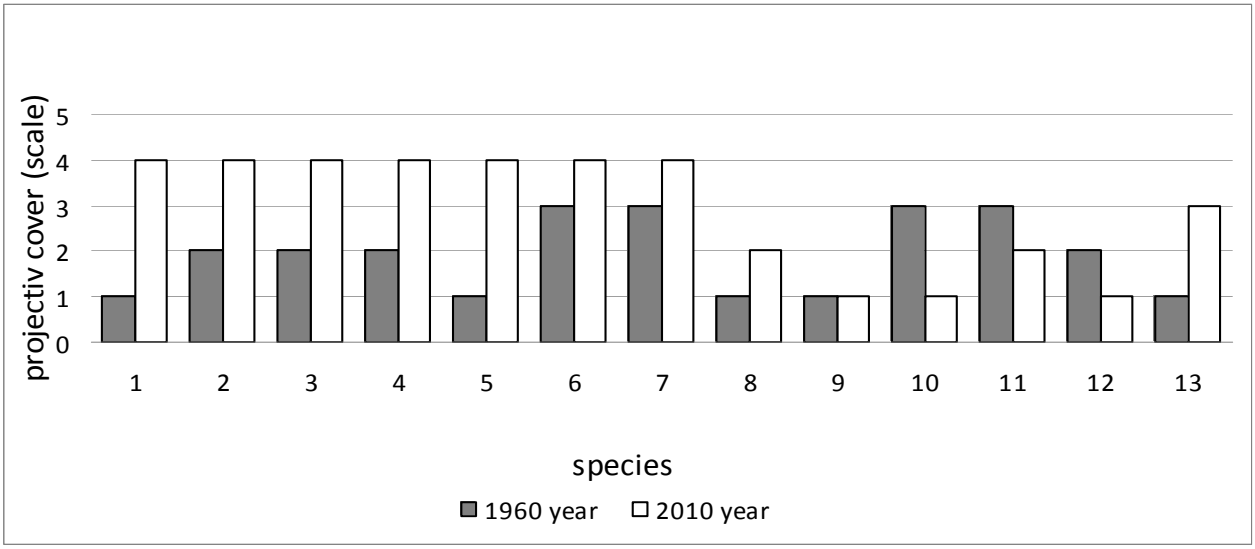


**Figure 5. Dynamics of changes of coastal communities on the tombolo or pereyma (crosspiece from basic coast to island on the Pomorsky and Karelian coasts of the White Sea (1960-2010)**. Symbols: 1 - *Salicornia europaea* (15), 2 - *Triglochin maritima* (25), 3 - *Tripolium vulgare* (35), 4 - *Plantago maritima* s.l. (40), 5 - *Salicornia europaea* (70), 6 - *Plantago maritima* s.l. (75), 7 - *Triglochin maritima* (80), 8 - *Puccinellia coarctata* (85), 9 - *Carex subspathacea* (90), 10 - *Bolboschoenus maritimus* (110), 11 - *Hippuris tetraphylla* (115), 12 - *Agrostis straminea* (120), 13 - *Phragmites australis* (150-180).

## 4 CONCLUSION

Azonality is the main peculiarity of the halophytic floristic complexes of marshes wetland of the Northwest of Russia (Sergienko, 2008). Only not numerous cosmopolitan circumpolar species such as *Carex subspathacea*, *Eleocharis uniglumis*, *Potentilla egedei*, *Stellaria humifusa* are the kernel and initial pathfinger of the communities. The changes in the biodiversity of the partial floras on the marshes wetlands are related to the historical development of the coenosis, geochemistry of landscape, climate, and, in the modern period, anthropogenous pollution. At present postglacial period the coastal marshes of the Northwest of Russia correspond to the place of functioning of ancient water-currents (Kvasov, 1975; Filatov, Terzshevik 2007), but territorially they are young formations in condition of constant change. The coast of the Onega gulf sharply differs from the other coasts of the White Sea in the expressed proficiency of mellow deposit of ice-sea, sea and alluvial genesis (Kaplin et al. 2005; Kvasov, 1975; Strelkov, 1961; Filatov, Terzshevik 2007). The constant decompression raising of the Onega coast is taking place now, which leads to formation of wide (some hundreds meters), gently sloping, flat wetlands, where the modern active transport of tidal sediments occurs on the external parts (from the sea) of wetlands. The basic changes of vegetative cover of salt marsh communities connected with the change of level of the White Sea and with the eustatic raising of coast, are the following: the area of plant communities with domination of boreal – European, and boreal – Eurasian species on the marshes wetland of the Pomorsky and Karelian coasts of White Sea is constantly expanding.

The area of plant communities of *Salicornia europaea* and *S. pojarkovae* on the drainless depression on the tombolo or pereyma (crosspiece from basic coast up to nearby islands) has increased, the degradation of the serge-cereal communities (*Carex glareosa* + *Puccinellia coarctata*) takes place on the tidal marshes which do not bear the under flooding, the microcoenosis from hydrophytes (*Phragmites australis)* is appearing in the salt marsh communities, extensive bush from the hydrophyte - *Phragmites australis* - appear in the ecotone zone.

## 5 ACKNOWLEDGMENTS

The authors is grateful to Maria Shreders, GIS Engineer, for the assistance in the article preparation. The work is executed with the financial support of grants 3832, within the limits of AVCP «Development of scientific potential of the higher school» and GK 14.740.11.0300 within the limits of FCP «The Scientific

and Pedagogical Staff of Innovative Russia for 2009 - 2013», grant from Russian Fund for Basic Research № 12-04-01008-a.

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