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# Interrelations Between the Losses of Sandy Beaches and Biodiversity in Seas: Case of the Bakalskaya Spit (Crimea, Ukraine, Black sea)

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**Abstract**

More than 70% of the beaches in the World are in decreasing stage during the past few decades, and the Black sea beaches are not exclusion. The paper gives a brief conceptual review of published and unpublished results of author's long-term complicated study (1995-2010) in different areas of the Crimean coastline. Interconnections between marine communities and beach erosion are analyzed as well as some anthropogenic impacts on processes in beach area. Self-accelerating mechanism of beach erosion and marine communities degradation was suggested. Two interrelated components in the system "beach-sea" are crucial in regulating the balance of sand on the beach in our case - the coastal vegetation and benthic communities producing clamshells. Two stable state of coastline - fluctuating stable sand beach and no sand beach state - can be. It should be noted that with the rise of sea level, is now observed, the steady state beach is only possible if the existing balance of sand is positive. New perspectives for rational management of sandy beaches require paradigm shifts. Sustainable long-term management of our beaches requires a set of alternative strategies for environmental management and the timely switch from one strategy to the alternative one.

*Keywords*: Beach, mollusks, zostera, alternative states, Black sea

## Introduction

Impact of shoreline zone change is a global threat to human life, livelihoods and natural life-supporting systems. One of the reasons is our inadequate management of our activities in this zone, most populated in the World. Sandy beaches are the most common and dynamic environments comprising 40% of the World's ocean/marine coastline (Bird, 2000). They are highly valued by society: more people use sandy beaches than any other type of shore (Schlacher *et al*., 2007). While the economic and social values of beaches are generally regarded as paramount, sandy shores also have special ecological features and contain a distinctive biodiversity that is generally poor recognized yet (Armonies and Reise, 2000; Schlacher *et al*., 2007). Threats to beaches arise from a range of stressors which span a spectrum of impact scales from localized effects to a truly global reach (e.g. sea-level rise) (Defeo *et al*., 2009). Coastal developments with high economical growth rate during last decades destroyed coastline and coastal marine ecosystems around the World and at first - sandy beaches. More than 70% of the beaches in the World are in decreasing stage during the past few decades (Aybulatov, 1994). More pronounced these negative effects for environment and human society present in enclosed and semi-enclosed seas such as the Baltic and Black seas, the Sea of Japan. There are not only loss of sandy beaches but also loss of sandy/mud-sandy biotopes in coastal waters. As example, in Japan the mean loss of sand beaches is about 1-2 m/yr, maximal cases are more than 10 m per year (Mukai, 2010).

Main reason of beach degradation are decreasing of sand input on beaches through disturbing of natural sediment flows by hydrotechnical constructions (dams on rivers, port and offshore breakwater construction), decreasing of mollusk shell production in coastal marine ecosystems, etc. As example, we can remember a case of Hel peninsula (Poland, Baltic sea) where the concrete breakwaters of port Wladislawowo changed offshore currents and sediment flows and created a huge damage for Hel peninsula and its inhabitants (Korczagin and Jozwiak, 1997). If negative results of beach loss for human society are well known and quantitatively assessed for many cases the results for biota are less studied. And we have little data on role of marine biotope changes for beach degradation, but these interrelations are

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very important (Shadrin and Sosnovskaya, 2001). We must not forget that biogenic materials produced in sea, in the first place - corals, shells of mollusks, may play a significant role in the formation of beaches.

We focus on these aspects; and aim of our paper is to give a brief conceptual review of published and unpublished results of our long-term complicated study (1995-2011) in different areas of the Crimean coastline, at first - on the Bakalskaya spit (Shadrin, 1998; Shadrin *et al*., 2001; Mironov *et al*., 2007; Uryupova and Shadrin, 2009, etc.).

## Material and Methods

To analyze the causes and consequences of degradation of beaches and Bivalvia settlements in the sea, we use primarily own data of long-term study (2000-2011) on Bakalskaya Spit. To analyze the dynamics of beaches in the process of studies we used fixed reference points at certain points of the coastline. In addition we studied number and composition of mollusk shells on some transects through beach. Quantitative benthic samples in sea were taken by manual sampler (0.25 $m^2$). Quantitatively assessment of algae and sea grass (*Zostera*) debris on the shores was made; also we visually observe the impact of this debris on dynamics of the sediments on the beach. Semi-quantitative assessment of the degree of projective coverage of the beach by flowering plants was made. Material and used methods were described in published papers (Shadrin *et al*., 2001; Obryvkov *et al*., 2002; Mironov *et al*., 2007; Uryupova and Shadrin, 2009), and we don't pay attention to it here. Only methods of our experiments on abrasion of mollusk shells by strolling recreants were not described previously. Fresh mussel shells were placed in the dense bags (0.01 $m^2$), then the bags with shells placed on the beach sand and stepping many times on them. After a certain amount of stepping on them, we estimated size range of fragments of shells and their mass (Detailed results of these experiments will be given in separate paper).

## Results and Discussion

### Bakalskaya Sand Spit

Bakalskaya sand spit (45°47'44"N; 33°10'31"E) having formed through merging of two accumulative spits and now stretching along the northwestern coast of the Crimea (Karkinit Gulf) (Zenkovich, 1960; Shadrin *et al*., 2001). The 5-km long western causeway adjoins Kudash shore ledge and extends northward. During the southern and southwestern storms the sea waves roll over the embankment and enter the lake, which lay between spits. Now we observe a loss of sand from both spits, but much more from west one - with rate about 5-10 m per year and more. 12-year long study shows us that this process is conditioned by many reasons both natural/climatic and anthropogenic origin, and to divide the results of action of different reasons, as a rule, is uneasily. But we try. Decreasing or grow of beach is caused by sand balance on beach – input and output. There are three main sources of sediments input into beach: with rivers, from cliff erosion and biogenic produced in marine ecosystems, in our case - only clayey cliff erosion and mollusk shells input. Part of Bivalvia shells was 15-30% of total mass of beach sediments. *Cerastoderma glaucum* prevailed, being 12-41% total mass of shells on the beach. *Chamelea gallina* was subdominant. We identified and calculated shells which thrown out on a beach in the year of research (fresh) or previous years We found a trend of decreasing of a part of fresh shells in total mass of shells, which is one of the reasons why the beaches loss is available in this area. We observed decreasing of shell flows on beaches in other areas of the Crimean coast also, including in Opukskii Nature reservation (Mironov *et al*., 2007). Among reasons of mollusk settlement fluctuations are multiyear rhythms which resulting from climatic variability (Shadrin *et al*., 2004).

Around Bakalskaya spit the marine grass (*Zostera*) and algae occupy huge areas of seabed. Storms pluck off them and throw out to the beach. Total mass of *Zostera* which thrown out to the beach can be very large on Bakalskaya spit – to 1000 kg per 1 m. *Zostera* debris play a very important role in beach forming by two ways: 1. they take part in creation of beach body as biogenic sediments constituting to 10-30% of beach body volume; 2 they decrease sand output flux from beach. Observed *Zostera* population degradation also leads to beach loss.

Decreasing of beach, which acts as natural mechanism of prevention of cliff erosion, leads to increasing of cliff erosion and as result to increasing of water turbidity and decreasing of sand bottom biotopes because clayey particles sediments. Of cause these reasons lead to observed decreasing of mussel settlements as well as marine grass and algae populations on bottom, change their species composition. Mussel shell and marine grass/algae flows on beach decrease more. The mechanism of self-acceleration of loss of beaches and erosion of bank is included.

But these reasons are not all ones causing increasing of beach loss on Bakalshaya spit. There is strong climatic reason – increasing of west winds causes wind tide. There are also anthropogenic reasons: illegal sand mining by local peoples, high level recreation press leading to dune devegetation. Devegetation increases sand leaving from beaches due to high acceleration of wind and water erosion. Smallest sediment particles are moved by wind from devegetated dunes and beaches into sea. It also leads to destruction of bottom sand biotopes with damage to

Bivalvia settlements. A rate of going out of shells from a beach depends also on speed of their mechanical grinding and grinding down by waves and recreational activities. As shown in our experiments people resting and walking along beaches increase a rate of shell grinding. After 100 times of stepping on bags with mussel shells about 5-10% of total mass of shells transformed in dust. It mean that high recreational press can leads to increasing of loss of sediments (shells) from a beach not only through devegetation. Increasing of coastal erosion leads to a growth of sediment flow from beach into the sea and acceleration of sea level rising. A sea level rise stimulates coastal erosion. Again we can see self-accelerating mechanism in work. We think this effect is more pronounced in enclose and semi-enclosed seas. But we haven't quantitative estimation of it.

## Alien Gastropoda *Rapana venosa* Influence on Beach Degradation in the Black sea

Predator *R. venosa* accidentally was introduced in the Black sea from the Sea of Japan in 30$^{th}$ years of 20 century (Gomoiu *et al*., 2002). It preys mostly on Bivalve mollusks. During first years in the Black sea *Rapana* had eaten the large settlements of *Ostrea edulis,* near the Caucasus coast. Before *O. edulis* was main producer of shells for beaches here. When production of new *Ostrea* shells stopped, gradually decreasing of beaches started. After about two decades beaches disappeared or decreased very much, no natural protection against cliff abrasion. And coastal degradation started to accelerate with damages for marine and terrestrial biodiversity, human society. Only very old (subfossil) *O. edulis* shells present on the beaches of Bakalskaya spit. Now *Rapana* eats another Bivalvia mollusks in the Black sea (Shadrin and Afanasova, 2009) decreasing their populations and as a result their shell production. There is no quantified estimation of total role of *R. venosa* invasion on acceleration of coastal degradation in the Black sea.

## Lost of Beaches Leads to a Lost of Biodiversity

Beaches are a harbor for many unique micro- and macroorganisms including mollusks. Degradation of beaches deprives of many species of their habitats. *Donacilla cornea* (Bivalvia) inhabitant of sandy beaches was a common and abundant species in the Black sea. The small wedgeclam *D. cornea* is a species threatened by tourist impact on beaches, water pollution and building of coastal defense constructions that impair the water exchange. During last decades it have disappeared in Russian and Bulgarian coasts. There was opinion that it fully disappeared in the Black sea. But the last findings show that local populations of it are available only on few beaches in Romania, Turkey and Crimea (Ukraine) (Akbulut *et al*., 2002; Boltacheva *et al*., 2002; Micu and Micu, 2006; Shadrin and Afanasova, 2009).

Changes of composition and abundance of Bivalve are among of underestimated reasons of degradation of the Black sea beaches. States of marine and terrestrial beach communities and dynamics of beach are in strong and complicated interconnections; they all react on climate changes and human activities. We need to take it into account to develop of beach management as well as we need to have a realistic ecosystem concept.

## Management of Sandy Beaches and a Need of Paradigm Shift

Currently we have two alternative concepts of ecosystem. Traditionally modern ecology as well as environmental management, mainly, is based on conception, which may be named Concept of quasisteady-state ecosystem (CQSE): Mature ecosystems are stable and in dynamic equilibrium. Ecosystem state fluctuates around alone point of a global equilibrium. All ecosystem changes are within the framework of one norm of reaction. Current paradigm is based on unicity of point of global stability of the ecological systems and prevailing of smooth changes of the system in a neighborhood of point of stability.

But really every ecosystem as well as every complicated integrated system has several alternative stable states. Concept of alternative stable states of ecosystem (CASSE) as a new ecological paradigm is been developing now (Scheffer, 2001; Dent *et al*., 2002; Walker *et al*., 2004, Scheffer *et al*., 2009). In the emerging paradigm dynamics of systems (individual, population, community, ecosystem), and its evolution is characterized by two stages - the coherent evolution/dynamics and incoherent (Krasilov, 1986). Each of these stages in turn includes two divisions (Walker *et al*., 2004). C. Holling (2001) describes patterns and processes over time in many change ecosystems, using four-phase model - the adaptive cycle. During coherent stage a system realizes a smooth adaptation to the changing environment within the existing norms of reaction; during incoherent stage – there are a destabilization of system and its transformation through tipping point in new state. CQSE is applicable for analyzing and understanding of ecosystem dynamics/evolution in coherent stage, but it doesn't work in incoherent stage. We need to use CASSE for system dynamics analyses in incoherent stage.

Looking on our results we can separate two stable state of coastline – fluctuating stable sand beach and no sand beach state. It should be noted that with the rise of sea level, is now observed, the steady state beach is only possible if the existing balance of sand is positive. They are divided by period of incoherent development with tipping points when system chooses the path to one or another stable state. If we abstract from climatic factor then two interrelated components of the system are crucial in regulating the balance of sand on the beach, and in our case - the coastal vegetation and benthic communities, producing clamshells. They have different stable state; we need to know tipping points in their dynamics. Do we know they now? – Alas, no. We also can't quantitatively assess role of different driving factors leading of coastal vegetation and benthic communities to tipping points. Similar problems are observed on most beaches of the world, and we need a new approach to them: "New perspectives for rational management of sandy beaches require paradigm shifts" (Defeo *et al*., 2009).

The above results are further evidence in favor the point of view that look through the prism of CASSE on environment/ecosystem, more adequate to reality than through CQSE. Main goal of traditional environmental management: we should strive to accurately predict the response of the system on our impact and to develop an optimal strategy for ecosystem management and strongly use it. The objectives of management in CASSE case should be: foresight when system to reach a tipping point, estimate of transition probabilities in one of the new alternative stable states, the identify the spectrum of possible alternative states, developing a set of possible socio - economic adaptation strategies in the new environment and their flexible use. These two strategies of environmental management are complementary, because one of them is efficient in terms of coherent dynamics, and another - in terms of incoherent dynamics. Overall goal is to anticipate and, if possible, to prevent unwanted changes, if it is not possible to prevent, then to be prepared for a livelihood in the new definitely not predictable conditions. In this regard, the right choice of management strategy depends on correct estimation of the speed of the system moving to the tipping point and the distance to it. Sustainable long-term management of our beaches requires a set of alternative strategies for environmental management and the timely switch from one strategy to the alternative one.

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