Coupling of Shoreline Erosion and Biodiversity Loss: Examples from the Black Sea

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Abstract The shoreline zone is an area where the sea and land contact and plays a very important role in integrating a sea and its watershed in a whole system. Among the main environmental problems of the coastal zones, two critical ones are - coastal erosion and a biodiversity loss. Problems are most pronounced in semi-enclosed seas as the Black sea. Using results of the long-term studies in different parts of the Black Sea shoreline this paper attempts to make some steps to deepen our understanding of interactions between biodiversity loss and shoreline erosion. An analysis of the results from several case studies was done. Some mechanisms of interrelations between coastal erosion and biodiversity changes are also discussed. The increased concentration of mineral particles, especially hydrophilic ones, as a result of coastal erosion, is a threat not only to benthic organisms, but also to planktonic microalgae and copepods. This negative impact sharply decreases total productivity of coastal waters. De-vegetation of the beaches and cliffs increases movement of sand and soil particles from beaches and cliffs due to high acceleration of wind and water erosion. This also leads to an increased turbidity of marine waters and an associated decrease in their productivity. Other results suggest there is a decrease in mollusk shell production leading to acceleration of a beach degradation which may also increase cliff abrasion. Coastal de-vegetation, marine community degradation and coastline erosion interrelate through a network of chains of cause-and-effect that forms the positive feed-forward and feed-back loops. This creates a self-acceleration mechanism of a development of coastal erosion and biodiversity loss.

Keywords Shoreline erosion; De-vegetation; Mussels; Seaweeds; Sea grasses

1 Background
1.1 General introduction
Shoreline zone is a sea-land contact area playing a very important role in integrating a sea and its watershed in a whole natural system as a crossroad of marine and terrestrial fluxes of matter and energy, connecting marine and terrestrial ecosystems (Zaitsev, 2006; Shadrin, 1998). While marine shoreline environments are some of the most resource-rich and economically important ecosystems in the world, connectivity of structures, functions, and processes that form and maintain stability and transformability of these habitats are complex and poorly understood yet.

Among the main current environmental problems of the coastal zones - are coastline erosion and a biodiversity loss. Threats to them arise from a range of stressors which span a spectrum of impact scales from localized effects to a truly global reach (e.g. climate change, sea-level rise) (Defeo et al., 2009). Such a situation is a global threat to human life, livelihoods and natural life-supporting systems. The coastal zone is a most populated area in the World and one of the reasons for such situation in it is an inadequate management of human activities (Aibulatov and Artiukhin, 1993; UNDP, 1997). These problems are most pronounced in semi-enclosed seas as the Sea of Japan, Mediterranean, Baltic and Black seas, etc (Lotze et al., 2006; Zaitsev, 2006; Muhai, 2010; Shadrin et al., 2012), because the areas surrounding these seas have the highest proportion of lands (altered by human activities) to length of shoreline. The unwanted changes of shoreline and biodiversity loss are caused by the interactions of a lot of the natural and anthropogenic reasons (Aibulatov and Artiukhin, 1993; Zaitsev, 2006; Defeo et al., 2009; Kosyan et al., 2012a; Shadrin et al., 2012). Among the natural ones we can specify the following: global warming, sea
level-rise, a change of wind patterns, geological processes, etc. Among main anthropogenic causes of coastline erosion and biodiversity loss we can separate the direct and indirect impacts. Direct ones occur when a shoreline and a catchment area are physically altered: 1. a shoreline is replaced with a seawall for different purposes including shoreline armoring - “hard” structures such as seawalls, angular rock, jetties, etc, built to protect beaches and shorelines from erosion; 2. a wetland is filled in; 3. a sand extraction from beaches; 4. a reduced river inflow due a dam construction and increasing water use for agriculture and industry; 5. mining; 6. damping; etc. Indirect impacts: 1. de-vegetation of a shoreline and catchment areas, 2. introduction of alien species, 3. bottom trawling, 4. recreation activities, 5. pollution, etc.

It is very difficult to separate the various impacts from the different causes in terms of coastal erosion and biodiversity loss. These interplay in all cases, on every spatial and temporal scale.

To improve a current inadequate management of different human activities in a coastal zone is an immediate task for humans. We can’t reach this task without a clear understanding of interplay of the different factors and processes.

Among the most pressing problems of the Black Sea, as well as other seas, coastline erosion and the changes in system of biodiversity are critical (UNDP, 1997; 2007). The parameter called «Development of the coastline (DCL)» is used for estimation of the biological productivity of natural water bodies (Zaitsev, 2006):

\[ DCL = \frac{L}{2\sqrt{\pi S}} \]

where \( L \) – length of coastline, \( S \) – area of water body, \( \pi = 3.14 \)

DCL reflects high contribution of a shoreline zone into total productivity of a sea. Relatively narrow coastal areas of the sea are the most productive areas; so if their contribution to the productivity of the sea is high, then total productivity of a sea would also be high. However, to use the DCL index it is necessary to take into account the “scale”. The DCL for a whole sea differs from DCLs of different parts of the coastal zone. For lagoons and bays it is usually much higher as for the whole sea (our unpublished data). In the most cases the anthropogenic changes in a coastline area lead to decreasing of DCL on different scales and as a result to a decline of total productivity of marine areas.

The shoreline may be considered as a leverage point – a place within a complex system where a small shift in one thing can produce big changes in everything (Meadows, 1999) – where a small shift in a shoreline area can produce big changes in the whole sea. The shoreline area may also be considered as a “bellwether” of the sea that is it tends to create, influence or set trends for the whole sea. This is why we need to pay special attention to processes and trends in the shoreline zone.

Using results of our long-term observations and studies in different parts of the Crimean (The Crimea is the largest peninsula of the Black Sea) shoreline (published and unpublished) as well as data from the literature, we attempt to deepen our understanding of interactions between biodiversity loss and shoreline erosion.

1.2 The Black Sea and its coastline
The Black Sea is located in south-eastern Europe. It is bounded by Europe, Anatolia and the Caucasus and is ultimately connected to the Atlantic Ocean via the Mediterranean and the Aegean Seas and various straits. According to the degree of isolation from the ocean, the seas may be classified as enclosed or semi-enclosed. The Black Sea forms in an east-west trending elliptical depression which lies between Bulgaria, Georgia, Romania, Russia, Turkey, and Ukraine. The sea waters separate eastern Europe and western Asia. The International Hydrographic Organization (1953) defines the limits of the Black Sea as follows: “On the Southwest. The Northeastern limit of the Sea of Marmara [A line joining Cape Rumili with Cape Anatoli (41°13'N)] in the Kerch Strait. A line joining Cape Takil and Cape Panaghia (45°02'N)”. The Black Sea is the world’s largest meromictic basin where the deep waters have a very limited mixing with the upper layers of oxygenated waters. As a result, over 90% of the volume of the Black Sea is anoxic waters (Zaitsev, 2006). The sea area is 436,400 km². Twenty two countries are entirely or partly located on the catchment area of the Black Sea, and more than 170 million humans live within
the catchment area equals 2.3 mln. km² (UNDP, 2007). The ratio of the catchment basin surface to the surface of a recipient water body is called specific catchment (SC). Higher SC suggests the catchment area that a water body depends more on the surrounding territory and human activity on it. The Black Sea’s SC is > 5 (2,300,000/436,400); it is a high value. For comparison we calculated this value for the Mediterranean and Baltic Seas – 3.39 and 4.1 respectively. This leads to numerous anthropogenic impacts on the Black Sea ecosystem (including its shoreline zone) and results in a lot of environmental problems.

According to modern estimations, the length of the Black Sea’s coastline is approximately 4,340 km (UNDP, 2007). Zaitsev (2006) estimated that the DCL of the Black Sea is 1.063. For comparison, the DCL of the Sea of Azov, which is more productive than the Black Sea, is considerably higher: 2.198. Bearing in mind, coastline length is a fractal value; according the equation it depends on the scale on which we evaluate it (Mandelbrot, 1982):

$$L = cK^d$$

where L – the coastline’s length, K – the used scale, c, d – coefficients.

It was shown that the coefficient “d” for different parts of the Black Sea’s coastline varies from minus 1.4 to minus 2.4 (Shadrin, 2003). The length of coastline between two specifies points was different if we measure it using different scales, and if we use small scales, on which we evaluate many biological, physical and chemical processes, it has a much higher value than on bigger scales. If we do not take this fact into account it is possible to underestimate the total production of microalgae in the shallow part of the sea in several tenfold; underestimation of total primary production in the Black Sea may be at about 20-50% (Shadrin, 2003).

The Black Sea’s coastline is characterized by a variety of types of shores: sand and gravel beaches, spits, rocky and clay cliffs with different heights, mud flats, muddy beaches, lagoons, etc. (Zenkovich, 1958; 1960; Vylakanov et al., 1983; Zaitsev, 2006). Although all of them are changing dramatically as a result of human activities and climate change; the specific causes and mechanisms of these changes are different (Shuisky and Schwartz, 1988; Popescu, 1999; Ocakoglu et al., 2002; Kosyan et al., 2012a; Shadrin et al., 2012). At the same time, their changes do not occur independently of each other, to some extent the entire coastline appears to reacts as a whole system. For example, the degradation of beaches often leads to increases in cliff abrasion, and enhancing of cliff abrasion can lead to the growth of beaches in other place (Zenkovich, 1958; 1960; Kaplin et al., 1991; Ignatov, 2004).

2 Mechanisms of the contribution of coastline erosion to a biodiversity crisis: case studies

2.1 The Vasiljev Ravine case

Vasiljev Ravine (44.30 N; 33.35 E) is situated near Sevastopol city and the Balaklava limestone mine adjoins the Ravine. Waste limestone dumps from the quarry over time accumulated and about 30 years ago there was a huge landslide that buried the ravine and beach (our unpublished data). A unique type of artificial coastline was formed; an intensive erosion and abrasion of the coastline had started here. We observed the impacts of erosion and discharge of slime water for 10 years as well as the experimentally studied effects of increased concentrations of non-toxic mineral particles of microalgae, nutrition, behavior and reproduction of planktonic copepods. Earlier results have been published (Shadrin and Grishicheva, 1999; Shadrin and Litvinchuk, 2005). Erosion and dumping led to increased concentrations of mineral particles in coastal waters. The muddy waters contained a high concentration of hydrophilic limestone particles (2~50 microns in diameter). This resulted in increased turbidity of the sea water with a concurrent reduction in light penetration and therefore primary production. Mineral particles also adhered to microalgae, which caused autolysis of their cells and also drastically decreased phytoplankton primary production. The larger microalgal cells were affected much more than smaller cells. This resulted in a reduction of an average cell size in phytoplankton and a change in the species composition.

An accumulation of these particles on the sea floor led to mortality of all macroorganisms, and resulted in a lifeless area of approximately 0.5 km² on the sea bottom. Hydrophilic particles with the adhered water molecules form a gel-like layer on the bottom of the sea.
On some distance from the site of erosion along the coastline in both directions, where the concentration of particles decreased, there are rocks on the vertical parts of these the young of the year *Mytilus* and *Mytilaster* presented, but not adult animals. The horizontal parts of rocks were covered by a narrow gel-like layer without macroorganisms and microalgae.

On a single rock, we observed one of its sides was influenced by waters with an increased concentration of mineral particles, and the other was not exposed to their influence. On the unexposed side there were more mussels and they were bigger. Species diversity of epibiotic Hydrozoa polyps on mussels and polyp abundance were higher on the unexposed side (Shadrin and Grishicheva, 1999). On the exposed side there were no polyp species with open thecae.

The increased concentration of mineral particles, especially hydrophilic ones, is a threat not only to benthic organisms, but also to planktonic copepods – a ration, somatic and generative production were significantly reduced. Results show that species diversity and total biological production in the studied coastal area were drastically decreased. It is known that fine mineral particles can have a dramatic physical effect on aquatic organisms – they may clog the breathing apparatus (i.e., gills) of fishes and invertebrates, inhibit proper respiratory function in eggs and larvae (suffocation), alter substrates, and bury benthic organisms (Brennan and Culverwell, 2004). Fishes, which caught in the sea near the Vasiljev Ravine, had an abundance of mineral particles in their gills.

### 2.2 Artificial beaches

Similar results when an increased concentration of non-toxic small mineral particles from coastline erosion impacted on marine communities were observed by us in other places of the Crimean coastline. Creation of the artificial beaches from limestone gravel may also lead to same results (case of near Karadag area is an example). An artificial increase of limestone gravel in the beach sediments leads to an increase of turbidity of the water in the sea and degradation of mussel settlements (Klyukin, 2004), because the waves grind down of the limestone gravel of 8% per year (Zhdanov, 1958). As usual an effect of an increase of non-toxic mineral particle in sea water was underestimated making the environmental assessments of a human impact on marine biota. A construction of the artificial beaches with a use of limestone gravel may lead to the negative effects on marine biodiversity, which similar to ones from coastline erosion.

### 2.3 The Bakalskaya Spit case

Bakalskaya sand spit (45°47' N; 33°10' E) having formed through merging of two accumulative spits, now stretches along the northwestern coast of the Crimea (Karkinit Gulf) (Zenkovich, 1960; Goryachkin et al., 2012; Shadrin et al., 2012). The 5-km long western causeway adjoins the shore ledge of Kudash and extends northward. During the southern and southwestern storms the sea waves roll over the embankment and enter into the lagoon-lake (lying between the spits). To analyze the causes and consequences of degradation of beaches and Bivalve settlements in the sea we conducted the long-term study (2000-2013) here. Some results were published previously (Shadrin et al., 2012). A loss of sand from both spits (much more from west one) - with rate of the shoreline retreat about 5-10 m per year and more was observed. Analysis of long-term satellite data of U.S. Geological Survey (http://landsatlook.usgs.gov/) reflected similar results - during the period from 2001 to 2011 the west spit became narrow and moved into the lake 100-200 m. This 12-year long study shows us that the process is due to many reasons both natural/climatic and anthropogenic origin. The interrelationship of climate change and increasing anthropogenic pressure in the degradation of Bakalskaya Spit was analyzed previously (Shadrin et al., 2012). It was shown that human pressure also contributes to the accelerated degradation of the spit, primarily through the spit de-vegetation. De-vegetation increases the loss of sand from beaches due to high acceleration of wind and water erosion. Smallest sediment particles are moved by wind from de-vegetated dunes and beaches. So de-vegetation of the spit and its subsequent erosion has resulted in a significant increase of the sand flow from the spit into the sea and the lake. The decreased beach – sand spit area, which acts as natural mechanism of prevention of cliff erosion, leads to increasing of erosion of clayey cliffs near the spit; a flux of clayey particles into the sea grows; more these particles sediment on sand bottom. Water turbidity also increases.
For similar reasons there were decreased mussel settlements as well as marine grass and algae populations on bottom, change their species composition. We identified and calculated shells which thrown out on a beach in the year of research (fresh) and during previous years (Shadrin et al., 2012). We found a trend of decreasing of a part of fresh shells in total mass of shells. We observed decreasing of shell flows on beaches in other areas of the Crimean coast also, including in Opukskiy Nature Reservation (45°02′N, 36°13′E) (Mironov et al., 2007).

Coastline erosion is one of the causes of mollusk settlement degradation. But it is not alone cause; among reasons of mollusk settlement degradation are multiyear rhythms which resulting from climatic variability (Shadrin et al., 2004).

Decreasing or growth of a beach is caused by sand balance on beach – input and output. There are three main sources of sediments input into beach: from rivers, from cliff erosion and biogenic material produced in marine ecosystems. Here, the inputs are only from the clayey cliff erosion and the mollusk shells inputs. Bivalve shells made up 15-30% of total mass of beach sediments: *Cerastoderma glaucum* dominated, being 12-41% of the total mass of shells on the beach, and *Chamelea gallina* was the second most abundant (Shadrin et al., 2012). This means that a decrease of a mollusk shell production also may contribute to beach erosion here.

Degradation of populations of submerged vegetation was also observed in this area and is one of the reasons for beach losses here (Sadogursky, 1999). Around Bakalskaya spit the marine grass (*Zostera*) and seaweeds occupy huge areas of seabed (Evstigneeva and Tankovskaya, 2011). Total mass of *Zostera* coming ashore onto the beach can be very large on Bakalskaya spit (approx. 1000 kg per 1 m²) with the average more than 100 kg/m². Similar values of *Zostera* debris – (166.5 kg per m of coastline) are known for other parts of the West Crimean coastline (Sadogursky, 1999). *Zostera* debris play a very important role in forming beaches by three ways: 1. They take part in creation of the beach body as biogenic sediments constituting to 10–30% of beach body volume; 2. They decrease the sand output flux from the beach; 3. The promote the development of terrestrial vegetation on the beach (Shadrin et al., 2012).

### 3 Coupling of the changes in biodiversity and shoreline erosion increase: discussion

#### 3.1 Coastal vegetation

Shoreline erosion is a very complicated process, which includes the processes of water and wind erosion, abrasion, landslides, etc. (Kaplin et al., 1991; Easterbrook, 1999; Ignatov, 2004). The terrestrial and marine biota influences this in different ways. Qualitative and quantitative changes in biota lead to pronounced changes in structure and intensity of the erosion process in the shoreline zone. Terrestrial vegetation is one of the main factors, which influence on water and wind erosion as well as on landslides (Greenway, 1987; Easterbrook, 1999; Doody, 2001; Brennan and Culverwell, 2004). De-vegetation of shoreline areas accelerates wind and water erosion, promoting intensification of landslides and rock-falls activities.

We carried out an experiment with two kinds of experimental natural spots on the Crimean coast (44°44′N; 33°33′ E): one with vegetation (85-100% of a cover) and one- without vegetation (0~15 %) (Obryvkov et al., 2002). Monthly loss of soil due to water erosion from de-vegetated spots was 2 – 2.5 times higher than from spots with normal vegetation. As expected, this led to increased water turbidity in the sea near de-vegetated spots.

Our long-term observations along the West Crimean Coast and on Kerch Peninsula showed that de-vegetation of cliffs leads to cracking of soil, growth of cracks and results in new landslides and rock-falls. On the areas with normal developed vegetation, plants consume rain waters; but on areas without vegetation rain waters filtrate into deep layers of ground. De-vegetation of land increases water infiltration during rain events. Water infiltrates before impermeable layer, accumulates here. This leads to sliding of upper layers; it’s one of the mechanisms of a stimulation of landslide activity by de-vegetation. Our observations in different Black Sea countries as well as data from literature (Greenway, 1987; Easterbrook, 1999; Doody, 2001; Brennan and Culverwell, 2004) lead us to conclude that de-vegetation of slopes and upper sides of cliffs...
increases the chances of landslides and rock-falls. This is a very common phenomenon for the Black Sea shoreline. Discussing this issue we need to remember that there is a feed-back loop – an increase of every kind of erosion leads to degradation of vegetation. And again it is a positive feed-back – a mechanism of self-acceleration of de-vegetation and coastal erosion because “A positive feedback loop is self-reinforcing.” (Meadows, 1999).

Areas adjoining to the tops of the cliffs often are plowed in the Crimea for an agricultural use, leaving on the tops of the cliffs only a narrow strip (10-50 m) of unploughed ground. In many cases this leads to a huge concentration of the holes of the small rodents on the unploughed strip. The holes promote to intensify a process of suffusion, which often leads to subsidence, rock-fall, and landslides (our unpublished data).

Coastal soil erosion is also an increase of biogenic elements input into coastal marine waters; this leads to a local eutrophication of marine waters and hypoxia or anoxia in near bottom waters (Arhonditsis et al., 2000; Boesch et al., 2001; our observations). Negative consequences of this for biodiversity are well known.

In addition to landslides in the sea, there is at least long-term increase of marine water turbidity and local eutrophication with all negative consequences from this for marine biodiversity. After the rains and storms there is a sharp increase in turbidity of the marine areas from the eroded clay cliffs and landslides (determined visually or on photos, extend from the coast to the 50-500 m). These areas with sharp increased turbidity temporally occupy most productive zone lead to a decrease of primary production in them. Well developed natural vegetation is one of the best natural mechanisms of a prevention of coastline erosion and degradation of marine communities.

3.2 Marine grasses and seaweeds

6 species of marine grasses (Zostera – at first) and different seaweed species occupy the large areas of seabed along the Black Sea coastline (Kalugina-Gutnik, 1970). Thickets of submerged vegetation (mainly Cystoseira and Zostera) form the "cushions" in some parts of the sea that dampens the pounding waves, protecting the coasts and sea bottom (Zhivago, 1947; 1948; Zenmkovich, 1958; Shadrin, 1998; Sadogursky, 1999). Storms pluck off macroalgae and marine grass and release them up onto the beaches. Their debris in supralittoral areas plays a very important role in regulation of coastline erosion and beach formation (Zhivago, 1947; 1948; Zenmkovich, 1958). Total mass of algae or Zostera on the beach can be very large - to 1000 kg per 1 m² in some parts of the Black Sea shoreline (Zhivago, 1947; 1948; Shadrin, 1998; Sadogursky, 1999). Preliminary calculation showed that 10-15 mln. tons of their biomass are thrown out into the Black Sea supralittoral by waves every year. Destruction of 90-95% of total algae and marine grass biomass produced in the sea occurs in the supralittoral area (Shadrin, 1998). Degradation of populations of seaweeds (Cystoseira – at first) and marine grasses are observed in the Black Sea currently (UNDP, 1997; Sadogursky, 1999; Zaitsev, 2006). On the one hand an increase of coastal erosion is one of the reasons of degradation of submerged vegetation, on other hand – this degradation made input in the increase of coastline erosion rate. We need to make an accent that feed-forward and feed-back loops are both positive.

3.3 Changes in mollusk shell production for beaches

Mollusk shells contribute to the formation of different Black Sea beaches; they may constitute more than 70% of all solid particles forming some beaches (Zenkovich, 1960; Klyukin, 2004; Ivlieva, 2009; Kosyan et al., 2012b; Shadrin et al., 2012). From this it is clear that a change in the intensity of the production of shells and their location on the shore determines dynamics of a beach by many ways.

The large Asian gastropod mollusk Rapana venosa Valenciennes 1846 (Neogastropoda, Muricidae) is native to the Sea of Japan, Yellow Sea, Bohai Sea, and the East China Sea to Taiwan. This predator species has been accidentally introduced to the Black Sea in 30th years of 20 century (Drapkin, 1963; Gomoiu et al., 2002). It preys mostly on Bivalve mollusks. During the first years in the Black sea Rapana had eaten the large settlements of Ostrea edulis, near the Caucasus coast (Drapkin, 1963). Before this, O. edulis was the main producer of shells for beaches here. When production of new Ostrea shells had stopped, a gradual degrading of beaches started. After about two decades the beaches disappeared or decreased with no natural protection against cliff abrasion present. And cliff degradation started to accelerate with damages.
for marine and terrestrial biodiversity, human society (destruction of buildings, death of people). Only very old (subfossil) *O. edulis* shells are present on the beaches of Bakalskaya spit, Opukskiy Nanure Reserve and other parts of the Black Sea shoreline, today.

*Rapana* is also one of the reasons of decreasing of other mollusk populations. Zolotarev (1996) described its’ broad dietary preference for bivalve mollusks. Marinov (1990), Rubinshtein and Hiznjak (1988) have identified that *R. venosa* predation as the prime reason for the decline in *Mytilus galloprovincialis* in Bulgarian waters, the Kerch Strait and the Caucasian shelf. Chukhchin (1984) connected the near extinction of the native big bivalve *O. edulis, Pecten ponticus, and M. galloprovincialis* on the Gudaut bank (Caucasus) to predation by *R. venosa*. Currently *Rapana* eats small Bivalvia mollusks in the Black sea (Zolotarev, 1996; Shadrin and Afanasova, 2009) decreasing their populations and as a result their shell production. *Rapana*, primarily, eats larger individuals in the populations of the *Mytilus* (Govorin and Kurakin, 2011) and *Donacilla* (Shadrin and Afanasova, 2009). It has been shown that large mussels have relatively bigger shells and more contribute to shell production in the mollusk settlements (Shadrin and Lezhnev, 1990). It was also shown that in polluted waters that *Mytilus* has shells of smaller weight than same size mollusks in unpolluted waters (Shadrin and Lezhnev, 1990; Shadrin et al., 1992). Biotic and anthropogenic factors lead to a similar result. There is no quantified estimation of the total role of *R. venosa* invasion in acceleration of coastal degradation in the Black sea.

Changes in species composition of Bivalves (the dominant species) may completely change the functional role of the local mollusk settlements, in particular, in the formation of beaches. As examples there are cases of the replacement of *Mytilus* by invasive species *Mya arenaria* in the waters of Cape Kartkazak (Karkinitsky Bay) (Shadrin and Sosnovskaya, 2001) and others (Ivlieva, 2009). Shells of the dead alien mollusks usually remain in the area of production, and do not brought by waves into the shore due to their ecology and massive shells. We can't quantify this effect yet.

**4 Conclusion**

Erosion of beaches and cliffs lead to decreasing of production of beach forming organisms (mussels, marine grasses, etc.); there is also positive feedback from biota to erosion. Such interactions create a self-acceleration mechanism of an erosion development and biodiversity loss (Shadrin et al., 2012). According to Meadows (1999), "Positive feedback loops are sources of growth, explosion, erosion, and collapse in systems. A system with an unchecked positive loop ultimately will destroy itself. That’s why there are so few of them." Such situation does not give us the optimism to find a simple method to solve the problems of degradation of marine coastal biodiversity and coastline erosion. In an attempt to solve these problems we need to remember that coastline erosion and biodiversity changes are included in the system of connectivity of the whole entity- the sea and its’ watershed. On one hand flux of solid particles into a sea and their sedimentation is one of the reasons of sea-level rise, on another hand – sea-level rise is one of the main factors of an increase of coastal erosion rate (Romine et al., 2013). Increasing of coastal erosion leads to a growth of sediment flow from beach into the sea and acceleration of sea-level rise. Due to coastal erosion about 27 mln. m³ of solid particles enter and sediment in the Black Sea annually (Dimitrov and Dimitrov, 2004). Our calculations showed that it may contribute for about 0.01 mm of sea level-rise per year. This represents less than 1% of the observed sea level-rise in the Black Sea, so we can ignore it in the first approximation.

Damping on rivers leads also to degradations of a lot of the Black Sea beaches and acceleration of a cliff abrasion is other example.

We need to incorporate a watershed perspective in programs dealing with habitat, resource productivity, and conflicts in resource use, but the watershed perspective remains inadequate when considering structures and processes on lower levels and smaller scales; Fractality of Nature (Mandelbrot, 1982; Shadrin, 2003) and Principle of Panarchy (Gunderson and Holling, 2002) are reasons of this. The number and complexity of elements involved in the form and functions of ecosystems on different levels and scales create difficulties to understand and often require us to work at a scale that helps us to understand individual elements or ecosystems that may be embedded within...
“the sea and its watershed” system. Metaphorically we may say that we need to identify the pieces of this complex puzzle and determine how they may be composited into a whole picture. Coastline with all interrelated component is one of a key piece of the complex puzzle "Black sea and its watershed". Recognizing and developing an improved understanding of a connectivity within the puzzle peace “terrestrial coastal vegetation - coastal erosion - marine biodiversity” enhances our ability to properly manage natural resources at multiple scales by incorporating previously neglected elements. We are still far from being able to imagine this puzzle piece as whole; this article, hopefully, will be a small step in this direction. We need to make the next steps, which connect with a quantitative evaluation of processes on different temporal and special scales, including the whole sea scale. To do them we may use geographic information systems (GIS); a comparative study of the changing shorelines may be done for different spatial and temporal scenarios (Thieler et al., 2005). The available aerial and satellite photography can be analyzed in order to reconstruct the coastline changes (Moore, 2000).

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