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THE ROLE OF GLACIERS IN THE EVOLUTION OF PRINCE WILLIAM SOUND LANDSCAPE ECOSYSTEMS, ALASKA

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ABSTRACT. We have demonstrated for the first which is the terrestrial and marine ecosystems of the Prince Wiliam Sound bay, with some examples of biocenosis. Once the glaciers started to melt, a new land mass is discovered for redeveloping the vegetation and wildlife habitat. Under climate change, the land scape evolves and the ecosystems evolved, too. We describe the space cover by glaciers and the evolution of landscape as a result of glaciers retreat. The marine ecosystem has the largest area, about 19801 km², found in study area. In the rainforest, there are living land mammals, a lot of birds' species, amphibians and only one type of reptile. Fresh water ecosystems are fed springs, temporary streams, creeks provided by glaciers, rivers, glacial lakes and water from thawing snow. We show the evolution of Portage Glacier in last century. Prince William Sound was affected by natural disturbance and human activity. An example of natural disturbance in Prince William Sound is provided by the effects of the earthquake. The naval accident and the fishing industry represent the modality of disturbance of Prince William Sound ecosystem, on artificial ways. In fine, the evolution of Prince William Sound landscape may have three directions, each one with the possibility of creating a new ecosystem: a new fiord, a new lake or a new land territory.

Key words: *glaciers, evolution, rainforest, landscape, ecosystem*.

INTRODUCTION

We present the glacial landscape modeling by glaciers (GL) and the variety of biocenoses developed on Prince William Sound (PWS) ecosystems (ES). Both aspects are into relationship with climate changes (Farmer and Cook, 2013), starting from Quaternary. During the Wisconsin Ice Age (from about 50,000 to 10,000 years ago), ice sheets covered the Southern part of Alaska. Also, the environment from PWS, maintaining specific life structures suffered alteration in Holocene as a result of natural impacts – climatic conditions, volcanic activity, and external Earth system – and artificial impacts – human's improvements, naval transports, fishing and hunting.

The observations in the field were made at macro-scale and showing the nature at different levels: in open sea, in proximity of GL, on top of the mountains, lengthways of rivers and near the lakes. The GL occupy a central place in the ES because they can create new spaces for development or can cover the land.

Study area

PWS is situated in South-central Alaska (Fig. 1) and represents a semi-enclosed bay of the Gulf of Alaska. Much of the Sound's coastline is bordered by Chugach Mountains Range stretched in North as well as an arch from East to West. The East sides of Chugach Mountains have several large GL. The geographical dry land of PWS territory is covered by glaciers, which created famous fiords as it follows Blackstone Bay, Passage Canal, Cochrane Bay, College Fiord, Harriman Fiord, Port Fidalgo or Port Valdez. In offshore there are numerous islets and islands as for instance Montague Island, Knight Island or Willard Island.

Fig. 1. *The localization of Prince William Sound on the Alaska map.*

From a climatic point of view, PWS lies in the coastal rain belt and is surrounded by high mountains, Schweiger et al. (2005). The climate is moderated by its proximity to the ocean, thus the temperatures are moderated by the Gulf of Alaska. The climate factor involves the development of a special type of ES in this area.

Background of glaciers from Prince William Sound

In the surroundings of PWS are a lot of GL concentrated around the bigger GL and Ice fields (IF). The IF represent a large mass of ice where many valley GL flow out on all sides.

In the Northern part of the bay spreads the Columbia GL, one of the largest tidewater GL in North America. This GL has 42 miles length and 4 mile wide at terminus and has many branches in all directions. In Eastern part of PWS is another large GL, the Bering GL, which has its origin from Bagley IF. In the opposite part, in west, the large Harding IF and Sargent IF cover most of the higher part of the Kenai Mountains.

In South-east of Kenai Peninsula, there are many valley GL that flow into the ocean. Lawrence GL and Blackstone GL are some examples of GL from Blackstone Bay (Fig. 2) and are called tidewater GL.

Fig. 2. *Blackstone Bay and Blackstone Glacier from Kenai Peninsula, Photo: Petcu*

Other types of existing GL in PWS are the cirque and piedmont GL. Near mountain crests in circular basins or amphitheaters it forms cirque GL, but this type of glaciers are relatively small. For example we recall Muth GL from North-west of PWS between College Fiord and Unakwik Inlet. The creek feed by Muth GL reach in Coghill Lake. Piedmont GL results when a large valley GL flows out from a confined valley into an open area and forms a broad lobe-shaped mass. Sheridan Glacier is a little piedmont GL situated in east of PWS, between Orca Inlet and Copper River Delta.

METHODS

Overview of the approach

The methodology was based on a fieldwork research and on interpretation of the references data about PWS. We created a GIS database with spatial ES. The research in the field had two main objectives: one being about GL and glacial relief, regarding at landforms; the second objective was to investigate the types of ES, and the contained biocenosis. The bibliographic research is based on publications, maps and online references approach about GL and ES from South Alaska, present in the study area. We did not hesitate to ask questions and contact the educators from Alaska Department of Fish and Game, for South-east Region and South-central Region. The approach was implemented using a range of techniques that were specific to geography and derived branches: glaciology, geomorphology, climatology, biology, ecology and geometrics.

Deductive and observation methods

For understand the geographical feature of the territory of the GL and bays in the PWS, we used the deductive method. On the research field we made the research using direct observation, taking record of the type of GL, the melting processes and the slush evolution on Pacific Ocean, near the shore. An important expedition was the navigation on Pacific Ocean, where we had the opportunity to see at a closer look the marine ES and took pictures.

Through intermediate indirect observation, we extracted the information from maps, aerial pictures and satellite images; from research space, we analyzed the realm, IF and GL, valleys and fiords situation.

RESULTS AND DICUSSION

The ES, ecotones and ecoclines presents in PWS

We believe that our results represent actual data for 2012. PWS territory consists of land biomes and water biomes. Both milieu offer living conditions and represents the space for developed ES. Between the land biomes and water biomes is the coastline, but this one does not represent a limit. In case of PWS, there are a lot of islands in open sea and the relationships between the land and water ES are possible.

The boundary of big ES is questionable, because the shore edge can be considered an ecotone of PWS ES. The GL are one motive, they created new fiords or can invade the lands and, of course, the limits vary. Classic examples of ecotones in the study area include land-water, riparian zones in forest, GL-land, GL-water, human-riparian zones, human-water. Ecocline is another type of landscape boundary, but is gradual and continuous change in environmental conditions of an ES. PWS contains forest-berry ecoclines, but do not offer the stability in whole biome.

The components and dynamics of ES

The terrestrial biomes are spread, surrounding the Sound. The most important type of ES in PWS is vegetation of Chugach temperate rainforest. The human establishments are few, but we cannot consider that these settlements form ES. The GL and IF are considered to be barrens zones. On the shore it blends the elements of nature and human activity and there proceeds the connections between ES. Regarding the water biomes, these are repartitions in marine ES and fresh water ES (Fig. 3).

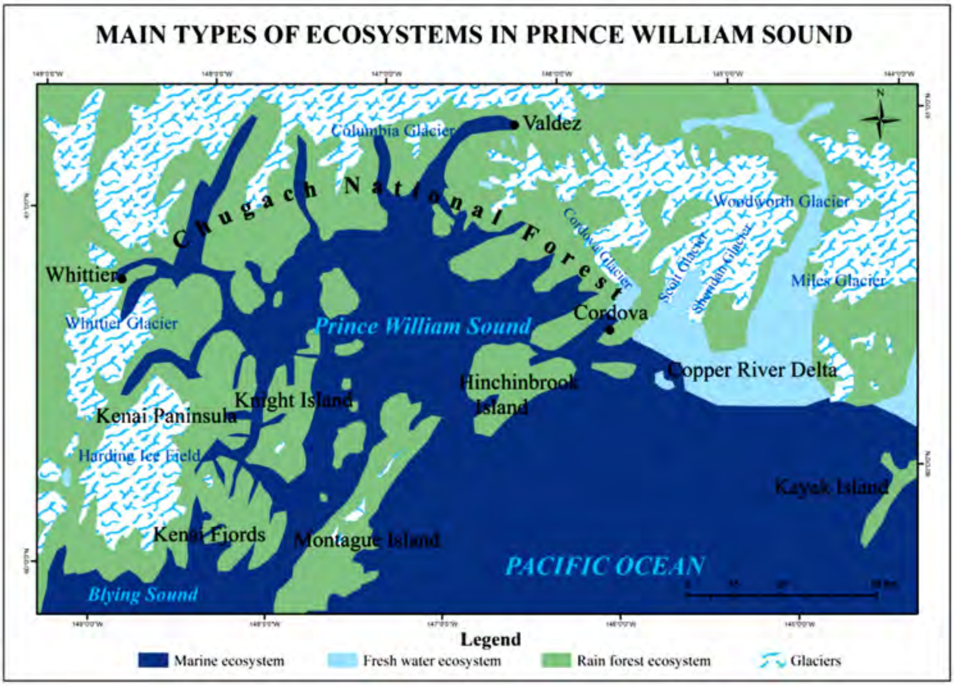

Fig. 3. *Currently the Prince William Sound ecosystems*

The temperate rainforest ES

This type of ES formed by vegetation includes Chugach National Forest (Fig. 4). Chugach National Forest is the second largest forest in Alaska and occupy 18244.60 km² in PWS.

The most common tree species are White spruce (*Piceaglauca*), Black spruce (*Piceamariana*), Western hemlock (*Tsugaheterophylla*), Hemlock spruce (*Tsugacanadensis).* Some trees can grow over 60 meters and up to 3 meters in diameter. After the GL retreat, the forest developed in a succession and the results are many levels of stages starting from grass, until old-grown forest (Fig. 5). The hemlock spruce can live for more than 400 years.

Fig. 4. *Chugach National Forest, Photo: Nistor.*

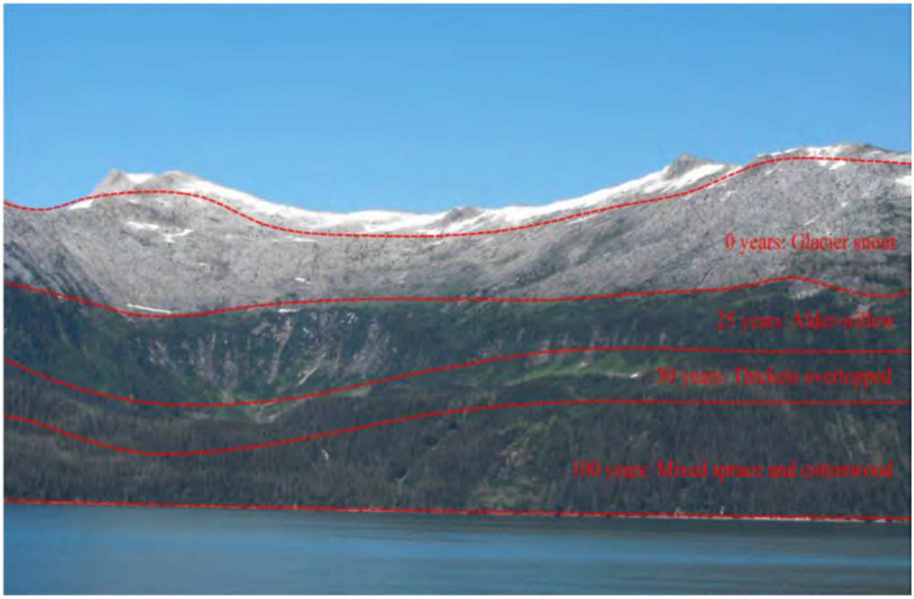

Fig. 5. *Example of vegetation succession in the last 100 years from Prince William Sound, Photo and modify: Nistor.*

Multi-aged trees are important for wildlife, because the different sizes of the trees allows light to penetrate the canopy. During the winter, the upper canopy intercepts falling snow that falls on forest soil in small quantities, giving the animal population easy access to food and shelter against winter storms. The fallen trees are disintegrated by different sorts of insects, small mammals, birds, fungi and lichen. The down trunks of trees are scattered on the forest floor and support living creatures, providing nutrients to the young trees. Thus, the forest ES is complex, with giant trees, while other ones grow up.

The succession of trees and the forest becomes self-renewing and it created the diversified habitat in the PWS rainforest. There are living 40 species of land mammals, more than 200 species of birds, 5 amphibians and only one type of reptile, the garter snake. In the rainforest there is a good density of large predators unrivaled in the world, like the Grizzly bear (*Ursusarctoshorribills*), the Gray Wolf (*Canis lupus*), American marten (*Martesamericana*) and Ermine (*Mustelaerminea*). Some examples of rainforest species of birds are Bald Eagle (*Haliaeetusleucocephalus*), Great Horned Owl (*Bubo virginianus*) and Northern Goshawk (*Accipiter gentilis*) (Fig. 6).

In the western part of PWS, at lap of Chugach Mountains we find spruce trees interspersed with shrubs such as Northern bayberry (*Myricapensylvanica*), Alaskan Blue Willow (*Salix purpurea nana*) and Alaska blackberries (*Rubusalaskensis*). On higher slopes, between rocky places and shrubs, Alaska marmot (*Marmotacaligata*) and Mountain Goat (*Oreamnosamericanus*) are found.

Fig. 6. *Northern Goshawk (Accipiter gentilis), Photo: Balint*

The water biomes

The water biomes are the largest ES from PWS. The marine ES and fresh water ES, occupy about 23205.33 km² and this represent more than 42 % from all PWS (Fig. 7).

Marine ES formed in Pacific Ocean shelter a wealth of aquatic fauna. ”The Sound ES provides vital habitat for more than 300 species of fish, 220 species of birds, at least 12 species of marine mammals, and untold numbers of marine invertebrates” Schweiger et al. (2005). The known fishes which live in this ES are Pacific herring (*Clupeaharenguspallasi*), Halibut (*Hippoglossusstenoleais*) and five species of salmon: Chinook salmon (*Oncorhynchustahawytscha*), Chum salmon (*Oncorhynchusketa*), Coho salmon (*Oncorhynchuskisutch*), Pink salmon (*Oncorhynchusgorbuscha)*, Sockeye salmon (*Oncorhybchusnerka*), Mecklenburg et al. (2002). Looking at these species of fish, the problem in ES are juvenile Pink salmon and Pacific herring, because both species have a big mortality. Large sample of this type of fish are prey for marine mammals, seabirds and another predatory fishes.

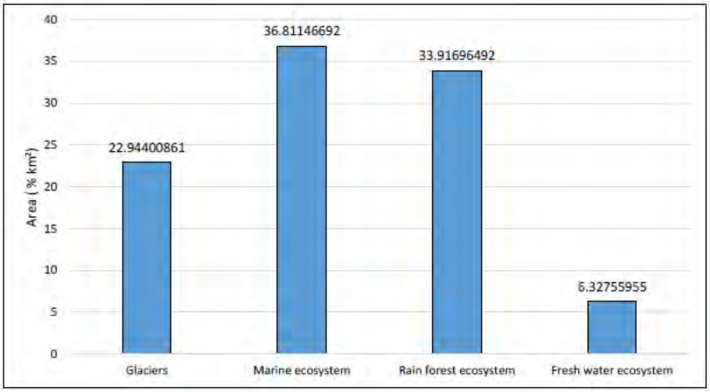

Fig. 7. *The area occupy by each ES and GL.*

Eastern part of PWS represents a natural resource regarding the terrestrial and shore environment. The special ecological sites including Copper River Delta, Wingham Island, Kanak Island, Controller Bay, Okalee Spit, Cordova District, Schweiger et al. (2005).

Passing to marine life from Pacific Ocean, PWS records scientific characteristics. The most important exemplary of marine mammals are fin Whale (Balaenopteramusculus), Steller sea lion (Eumetopiasjubatus), Pacific white-sided dolphin (Lagenorhynchusobliguidens) and Harbor seal (Phocavitulena) (Fig. 8), Mecklenburg et al. (2010). Looking at declining populations, all marine mammals are protected species. The famous invertebrates from PWS are tanner Crab (Chionoecetesbairdi), Octopus (Octopus dofleini) and Razor clam (Siliguapatula). Through other species of fish and birds there are two species of amphibians: Western toad (Bufoboreas) and Wood frog (Ranasylvatica), Mecklenburg et al. (2010).

Fresh water ES are fed springs, temporary streams, creeks provided by GL, rivers, glacial lakes, semi-permanent pools of novation and water from thawing snow. The pools of novation, situated on the high platform, have transparent water and receive an important quantity of light. This provides the energy necessary to born the microorganism. The big glacial lakes, for example Eyak Lake and Bering Lake, formed at terminus of glaciers, are permanent waters and represent lacustrine ES.

As a rule, the lakes contain fishes and the surroundings are populated by seagulls and another species of birds.

Fig. 8. *Harbor seal (Phocavitulena), Photo: Petcu.*

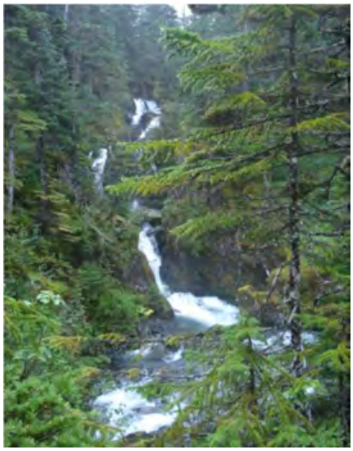

Fig. 9. *The waterfalls in the rainforest, Photo: Nistor.*

The rivers ES is influenced by substrate and slope. The streams and creeks form often successive waterfalls and the speed of the water which flows does not allow for life to thrive. In the vicinity of the shore or at the waterfalls base, the flowing waters erode the shape of the streambed, creating pools (Fig. 9).

The effects of human activity influences the microclimate and ES processes. For the impacts on marine ES, the following factors are responsible: the factory's activities, fishing and naval transports.

Disturbance and Habitat fragmentation is a problem which affects many ES in the world. In the last fifty years, PWS was affected by natural disturbance and human activity. An example of natural disturbance in PWS is provided by the effects of the Earthquake 27 March 1964, which represented an event that altered the pattern of variation in the function of a system. The tragic result of human activity in PWS is owing to a naval accident in 24 March 1989 that affected until now the marine ES. In 2010, it was reported by Schure: "the Exxon Valdez ran aground on Bligh Reef in Alaska's PWS. Eleven million gallons of oil spewed into one of the most bountiful marine ecosystems in the world. It killed birds, marine mammals and fish and devastated the ES in the oil's path. As many as half a million birds died. Over 30,000 carcasses of 90 species of birds were plucked from the beaches, but this was only a fraction of the actual mortality, and harm to birds from chronic effects and decreased reproduction continues today."

Nowadays the fishing industry represents the modality of disturbance of PWS ES. The ES fragmentation in PWS is obvious at the contact of GL or land with Pacific Ocean, where many fiords, deltas or waterfall are formed.

CONCLUSIONS

In future, as a result of melting GL, the evolution of PWS landscape may have three directions, each one with the possibility of creating a new ES. In the case when one GL is sculpting an open valley towards the ocean, after melting, it forms a new fiord; therefore the marine ES becomes bigger. This evolution is very probably at many tidewater GL, for example: Chenega GL, Tiger GL, Brainbridge GL, Harvard GL, Yale GL, Wellesley GL, Meares GL, Columbia GL.

If between the terminuses of one GL and ocean exists a girdle of terminals moraines and marine water does not communicate with water provided by GL, then a glacial lake may appear. This evolution was noticed in the case of Amherst GL, Sheridan GL or Portage GL (Fig. 10). A new fresh water ES appeared. In the north of Kenai Peninsula, one of the quickest movements was recorded at Portage GL, Mayo et al. (1977). This GL has an accumulation zone in Kenai Mountains, it extends on the long valley where it formed a glacial lake. Portage GL was studied from 1880 by Ivan Petroff, but the monitoring starting in 1914 by Tarr and Martin. In the last century this GL retreat was approximately of 5 km, Kennedy et al. (2006). The major average rate of retreat increased to 145 m/year, from 1939 to 1950 (Fig. 11). Almost all the valley is filled with fresh water from thawing ice and the result is Portage Lake.

The last possibility which can describe the evolution of landscape refers to the retreat of GL and IF. In PWS there are many valleys with vegetation, modelled for example by Scott GL, Learnard GL, Ultramarine GL, Princeton GL, Sargent IF.

At once with melting of ice, a new land territory is shown. The creeks settle gravels and step by step it develops the soils. The vegetation grows up in succession: tundra and shrub vegetation developed in an early stage, after that alders and thickets grow, and in the end coniferous trees. Of course, the landscape without GL contains another type of relief forms and represents the space for a new ES: biocenoses and implicit wildlife habitat.

Fig. 10. *The terminus lines of Portage Glacier in last century, Photo and modify: Nistor, Source: Kennedy et al.* (*2006*).

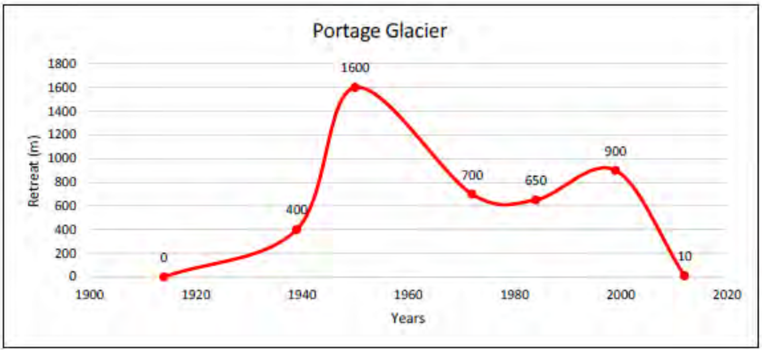

Fig. 11. *The Portage Glacier retreat, Source:* Mayo et al. (1977).

PWS presents a peculiar and complex landscape from different points of view, with endogenous and exogenous processes and glacial modeling activity. Together with ES and GL, the landscape created forms the most famous fiords system in Alaska.

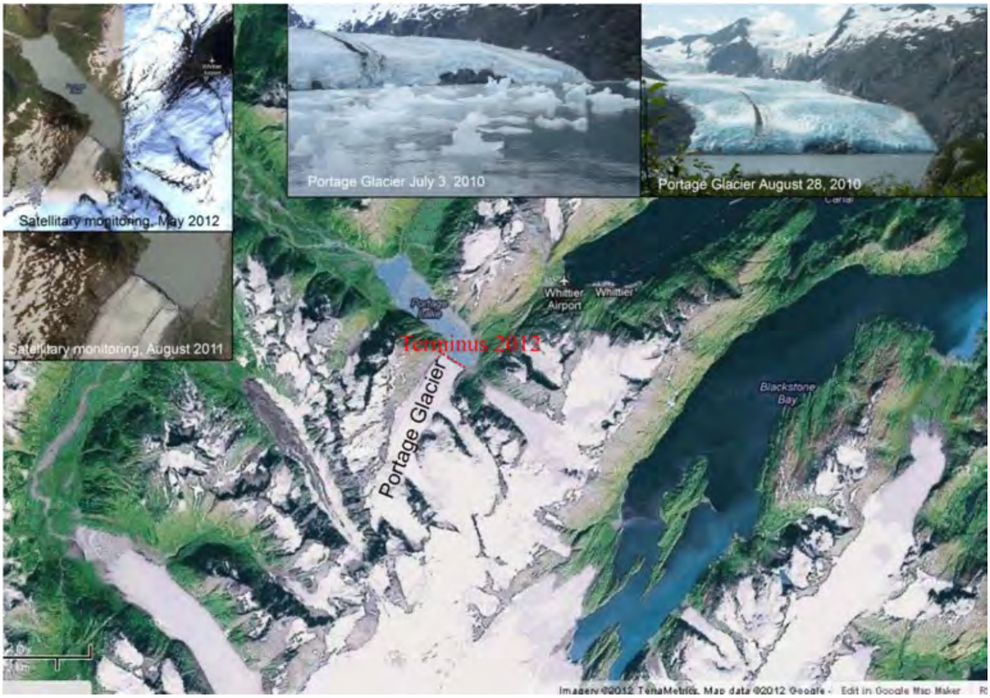

Fig. 12. *Portage Glacier, Mosaic with satellite images and photos, Source: Google maps, Photos: Nistor.*

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