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Water, Terrorist Attacks, Industrial Accidents, and Modeling Possible Impacts of These Incident in Coastal Ecosystems With Computational Model †

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Abstract: Emergent water pollution accidents range primarily based on pollution location, sources of pollution, levels of pollution, and pollution timeframe. Because of climatic conditions, human factors, and technological flaws, inappropriate chemical usage, spills and explosions in the chemical industry, and oil tankers, there have been significant economic losses, environmental devastation, and deaths. In this paper possible changes that would occur in the ecosystem of a coastal in response to a terrorist attack or/and industrial accident will be identified and discussed. A very brief revision will be done on ecosystem organization, succession, effects of pollutants and biomagnification, and coastal water renewal characteristics to draw possible scenario under a terrorist attack or/and industrial accident. Simple computational models will be used to simulate a coastal ecosystem and demonstrate the possible consequences of an incident.

Keywords: water terrorism; water pollution incidents chemical warfare agents; biological warfare agents; risk and assessment emergency response plan; ecological modeling

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1. Introduction

Water without doubt is a necessity for all forms of life. Therefore, Earth with all its biological diversity would have been a completely different planet without water [1]. Emergent water pollution is an activity that creates water contamination, potential health harm, social economy and property loss of income, and social detrimental effect because of economic and social activities and behaviors that violate water resource protection regulations, as well as incidental factors or appealing natural disasters. The specific conversations and mechanisms in place in response to the unexpected water contamination event were rather poor. Coastal ecosystems are of high economic and societal value for providing a multitude of services to humans. The ecosystems provide shelter and nutrients for marine life and are therefore important feeding, spawning, and nursery grounds for fishes and crustaceans [2–4]. Coastal pollution incidents have taken place in many countries frequently resulting in an enormous economic loss. All this ceaseless environmental pollution accidents caused serious effects to local production activities and people's daily lives. Unlike general environmental pollution accidents, pollution incidents and terrorist attacks are unpredictable and sometimes will release considerable polluted substances which will result in a massive damage in environmental, social, and economic respects. Accident impact is determined by examining the sensitivity parameters, which include [5]:

- Special Industrial Areas (sea fishing areas, enclosed fishing areas, fishermen ports and fishing shelters, tourist and recreational facilities, refineries, power plants, submarine power cables, factories, shipyards, cargo, and containers)
- Special Natural Areas (coastal nature gardens, protected areas, cultural areas, important habitat areas, seagrasses, important marine mammal, and bird habitat areas) [6,7].

In this paper possible changes that would occur in the ecosystem of a coastal in response to a terrorist attack or/and industrial accident will be identified and discussed. Simple computational models will be used to simulate a coastal ecosystem and demonstrate the possible consequences of an incident.

2. Theoretical Aspects

Coastal ecosystems are vulnerable from transport accidents of hazardous materials or/and attacks through intentional contamination or physical attacks on critical facilities. After a large perturbation of the environment, there is a regression of the successional stages of a community. Depending on the degree of the perturbation the community can recover, or a new successional process can start. The result can be different from the previous situation before perturbation. The initial, or early successional species, often referred to as pioneer species, are usually characterized by high growth rates, smaller sizes, high degree of dispersal, and high rates of population growth (r-selected species). In contrast, the late successional species generally have lower rates of dispersal and colonization, slower growth rates, and are larger and long-lived (k-selected species) [8].

In early stages of succession, biomass, and biological diversity increase. In middle stages of succession, many species of different sizes may occur. Several processes can occur during succession [9]:

- Facilitation: Early successional species facilitate the ability of later successional species to become established. Knowing the role of facilitation can be useful in restoration of damaged areas. For example, plants that facilitate the presence of others should be planted first.
- Interference: Sometimes certain early successional species prevent the entrance of other species for a period.
- Chronic patchiness: Another possibility is that species do not interact, and that succession does not take place. Earlier entering species neither help nor interfere with other species; instead, as in a desert, the physical environment dominates.

The chemical and biological contaminants in coastal environment could infect individuals via a variety of exposure routes [10]. In order to consider an agent as an effective weapon, it must be weaponized and produced in sufficient quantities to have a significant effect; dissolvable and stable in water, infectious, can cause serious illnesses, is hard to detect, and resistant to chlorination, and is inexpensive for the attackers [10]. Persistent compounds such as pesticides accumulate in the tissues of one species and then are passed up the food web to other species where they become more concentrated. This process is called biomagnification or bioamplification. The pollutants may affect wildlife in different ways. Their birth, death and growth rates may change, also changing their abundance [10]. The sensitive species decrease in abundance and the less sensitive may increase. Pollution, whether chronic or acute, usually tends to favor short-lived opportunistic species [11].

The effect of pollutants and agents may be like the effect of strong physical disturbance. In newly dumped dredge soil, immediately after disturbance (or close to the source of pollution) a few species of abundant, small, and productive polychaetes are found. These are followed by suspension-feeding or surface feeding mollusks either over time or space. The latter are replaced by large, slow-grazing species that live deeper in the sediment, feed on buried deposits, and oxidize the sediment by their activities. There is a close parallel to the gradient over space away from a grossly polluted site [12]. According to the

Pearson-Rosenberg model, with increasing organic input there is an increase of abundance, biomass, and species richness in a first step, and a progressive declining of species richness and biomass when eutrophication increases, while abundance (mainly of opportunistic species) continues rising [13].

3. Results and Discussion

3.1. Consequences in The Coastal Ecosystem from Terrorist Attack or/and accidents of Hazardous Materials

If an incident happens, a degradation of the ecosystem is expected. The worst-case scenario will be the destruction of all living organisms. Expected ecological consequences are described below. At the ecosystem organization the top predators will die or move away and the dominant and the common species decrease in abundance, the more sensitive die. Furthermore, the opportunistic species will find space to develop rapidly (if the environmental is not too degraded), the food web will be shortened and simplified, and the diversity will decrease. Certainly, most of the ecosystem attributes will change from a mature stage to a developmental stage.

At the successional stages the system returns to the first stages of succession and the pioneer/opportunistic species will increase in abundance. With time, if the system was not too degraded, other colonizers, stronger competitors, and long-lived organisms will arrive and occupy the space, replacing the pioneer species. Top predators are expected to establish later and control the lower trophic levels. The successional stages can be shortened by artificially introducing the right pioneer species and/or by engineering works. Eventually, the ecosystem may evolve to an ecosystem different from the previous one.

Especially for Pollution/Bioaccumulation (depending on the agent or substance involved) the Bioaccumulation can be expected, with concentration of the compound in the higher levels of the food chain. The compound can cause diseases and malformations in the next generations, decreasing growth rate and survival. The compound can be selective, affecting only some groups of organisms (possibly top predators), eventually related in a close evolutionary way to the target-species (man). If this last hypothesis is true, trophic food web organization changes are expected, with loss of the higher trophic levels and consequent loss of top– down control. Finally, the pollutant may cause a displacement of a well-organized community to a community dominated by few species of small opportunists, decreasing species richness and biomass.

3.2. Impacts Evaluation Model

A model is always a simplification of nature. Complex models try to re- produce with more precision what happens in nature. But the more complex the model, the more difficult it is to know the proper rates and parameters needed to run it. Furthermore, little is known about trophic organization and food web control. One possible and simple approach is to model the effects of a terrorist attack and accident with hazardous materials on the different groups of species: the predators, the common/dominant species, and the opportunistic species using classical models of growth, competition, and predation.

STELLA software is a graphic, icon-based modeling software package from Isee Systems—The Visual Thinking Company (http://www.hps-inc.com), which can be used in the construction of relatively complex models. The basic structure of the models includes stocks (which represent accumulation), inflow and outflow rates (into and out of a stock), and auxiliary variables (which help define the inflow and outflow rates). Model equations were based on Gamito [14] and Gotelli [15] and references their in.

A model is a simplified representation of what we think that happens in the real world. However, we do not have data. We need experimentation to learn what might really happen after a terrorist attack. But we already know the possible succession of the main groups of species after a severe degradation of the environment.

We have used the classical growth/competition/predator-prey models to represent three groups of species interacting in a coastal system. Some improvements could have been introduced such as including environmental variables that influence growth, such as temperature variation. Also, carrying capacity and growth rates of the different species groups may vary with environmental conditions.

Competition for nutrients or food and competition for space occur in communities. By adding predation and spatial patchiness, more realistic models of community organization can be constructed. The equilibrium model of community organization includes then competition, predation, and spatial patchiness [16]. However, no spatial variation was considered in the model. Again, we have no information. Furthermore, models that include the distribution of organisms are exceptionally difficult to construct. When animals move—either because they are grazing, escaping from a predator, or migrating—it is very difficult to describe those movements correctly [18].

Neither diversity variation nor genetic variability loss were included in our simplified vision of the terrorist effects on our system ecology, nor were possible effects of bioaccumulation on the ecosystem [17].

However, despite the simplifications used in this model, it could show hypothetical changes at ecosystem level due to an incident from terrorist attack or an accident.

3.3. Output Data of the Model

In this section, a use case for the impacts of a terrorist attack or an accident of hazardous materials on the coastal system are illustrated using the STELLA model [18]. Specifically, a terrorist attack or an accident happens. All organisms die. After some time, some opportunistic species start to develop. On the coastal system, some common species may migrate and find good conditions to develop. Later, predators might also stay into coastal. After some time, the system reaches equilibrium again. (Figure 1)

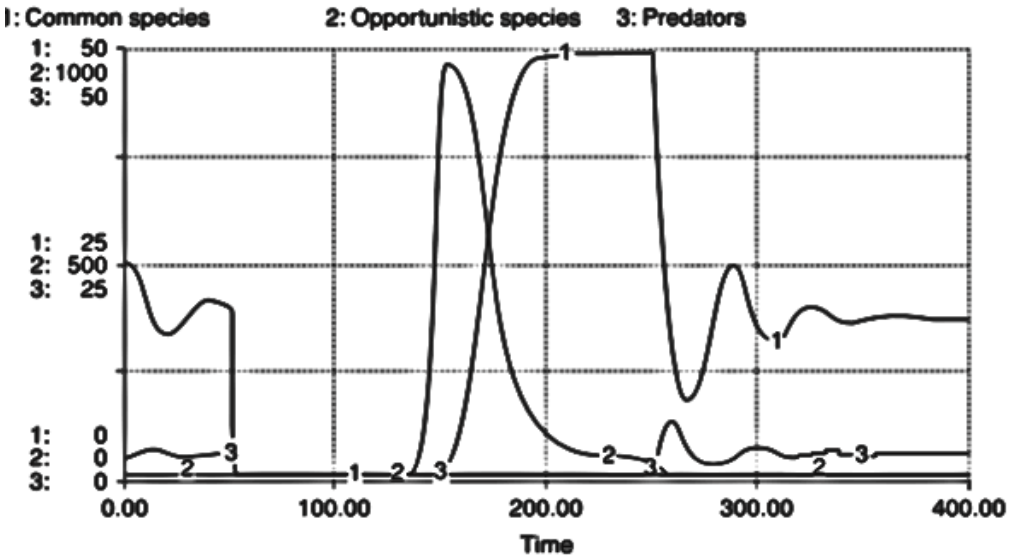

Figure 1. Simulation of the effect in the three groups of species after a terrorist attack.

3. Conclusions

This model system could be applied to any large group of species, such as plankton, benthic invertebrates or fish. When in equilibrium, in each of these groups there are always common species, opportunistic species, and predators. The densities need to be adjusted to each of these groups, as well as the time—faster processes in plankton species, much slower processes in fish.

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