

Chapter 2

The Concept of Disturbance

Disturbances are a set of events that can disrupt any ecological level, environmental component as well as the organizational status of a biological cycle of organisms (Pickett et al. 1989). They are an important aspect in the natural selection and the whole biological evolution, as they modify the environment in which every living being performs its vital functions (Krebs 2001). The effects of disturbance can indirectly pass on other components of the environment, ecosystems, and processes. Even the biological, ecological, and behavioral characteristics of an organism can be a disturbance to other organisms, creating a seemingly endless chain of relationships and perturbations among the different components of an ecosystem.

In ecology, the concept of disturbance is crucial. It is closely related to the concepts of stability, diversity, resistance, resilience, and entropy of the environmental systems and is the basis of theories explaining the mechanisms of species coexistence in the community (van der Maarel 1993). Distinguishing the different types of disturbances is therefore a critical issue of ecology, conservation biology and wildlife management (Soulé and Orians 2001).

Traditionally, disturbances have been considered to be irregular and uncommon events that cause abrupt changes in the structure of populations and biological communities, bringing them away from relatively stable conditions, and close to a potential “equilibrium”. Initially, the disturbance was considered to be *an uncommon and irregular event, which causes structural changes in natural communities that are positioned in chemical, physical or ecological conditions different from those that characterized the community before the event (in a hypothetical equilibrium)* (White 1979).

This definition, however, appeared immediately incomplete for a number of reasons. First of all, its strict determinism has proved inadequate as a reference paradigm for complex environmental systems characterized by a different degree of predictability. In addition, few biological communities persist in equilibrium or in its proximity, and it is extremely difficult to assess the presence of such conditions. Finally, the ‘change’, mentioned in the definition, can be highly variable, ranging from negligible to extreme, and is related to both the intensity of the disturbance

and the intrinsic sensitivity of the impacted environmental components (organisms, populations, communities, ecosystems). Each organism (or group of organisms), in fact, shows specific ecological traits that make it more sensitive to certain disturbances than others (home range amplitude, sociability, niche breadth, body size, sex, age, etc.; Isaac and Cowlishaw 2004).

The changes of the chemical, physical, biological, and ecological conditions of a site or of an environmental component may: (i) be observed within a range of variability, (ii) be periodic or occasional or, (iii) occur by a progressive continuum (gradients of variation) or abrupt leaps (thresholds). The problem of defining what is the degree of change that can be termed as a “disturbance”, along a continuum of events ranging from negligible to extreme, is therefore posed. The definition of an intensity threshold or frequency beyond which the same event can be defined as disturbance is a difficult and often arbitrary operation. In this regard, the convention that a disturbance is an event ‘near to one end’ of the range of variation of natural disturbances can be adopted.

Other definitions have also been proposed. According to some authors (White 1979; Pickett and White 1985; Sousa 1984), *a disturbance is a physical, chemical or biological event, with a different frequency degree, causing an alteration or a damage to one or more individuals and that directly or indirectly creates an opportunity for other individuals. This event is able to move the community towards an unstable state of non-equilibrium*. Here, these authors focus their attention only on the level of individuals.

A broader and widely accepted definition (see also Krebs 2001), is the one given by White and Pickett (1985): *a disturbance is any relative discrete event in time (and space) that disrupts ecosystem, community, or population structures and changes resources, substrate availability, or physical environment*.

According to a different interpretation, Grime (1979) has succinctly defined the disturbance as *an event that removes or damages biomasses*. And, again, according to Petraitis et al. (1989), *a disturbance is any ecological and bio-geographical process that alters the rates of birth, mortality, and survival of a population present in an environmental patch through the direct elimination of individuals or affecting resources, rates of predation and competition. Moreover, a disturbance can be considered as any change of structure in an environmental component (populations, communities, ecosystems) caused by factors external to the hierarchical level of interest*.

In an all-encompassing view, a disturbance may still be defined as *a biotic or abiotic, natural or man-made process that can destabilize the natural systems at any hierarchical level* (see Hobbs and Huenneke 1992).

According to another definition, *a disturbance is an ecological process able to determine the formation of environmental mosaics with different successional stage, structuring patterns of environmental heterogeneity, increasing the β -diversity and species turnover among sites or different patches* (Brawn et al. 2001). Such definition, shows interesting implications at landscape scale and on meta-population dynamics for all those species that are spatially structured.

For Collins and Glenn (1997) the disturbance *is an event that causes extinctions at a local scale (e.g., in an environmental patch)* and its intensity can be indirectly evaluated through the measurement of the number of extinct species in a particular patch.

According to Sommer et al. (1993), a *disturbance consists of (or causes) any fluctuation in the availability of resources*. This definition differs from the others because it implies that not only the discrete changes (through clear-cut thresholds) but also the continuous changes along gradients may be considered disturbance events (see e.g., the seasonal fluctuations or annual cycles of environmental factors and resources).

A universal definition of the concept of disturbance should (Pickett et al. 1989): (1) identify its target, that is, the affected environmental component at a defined ecological level: individual, population, community, ecosystem, etc.; (2) distinguish between changes induced by the disturbance and those due to other limiting factors or processes (for example, internal to the reference level); (3) distinguish between direct and indirect consequences of the disturbance.

The action of a disturbance leads to the definition of a disturbed area (at a given spatiotemporal scale). Its correct detection is required to implement objectives and actions (Myster 2003).

These disturbances can be described using different criteria. They can be divided, for example, in *direct* disturbances, which directly influence an environmental target component (for example, the probability of survival of the individuals of a species, the density of a population, the richness of species in a community), and *indirect* disturbances, that affect specific ecological targets through other environmental components (Pickett and Thompson 1978; Hobbs and Huenneke 1992).

The disturbances can be divided into two groups: those that act in a *selective manner*, for example causing mortality in individuals of a specific target (the population of a species, communities, etc.), and those that, on the contrary, intervene *randomly* manifesting indiscriminately on the entire ecosystem. The first help to maintain high species richness and diversity of a community; the latter tend to simplify environmental systems, continually altering the structure and composition and keeping them far from a state of a hypothetical “equilibrium” (Petraitis et al. 1989).

Even the scale of reference (absolute or relative) can be used as a classification criterion. In particular, if a disturbance occurs as an exceptionality, causing irreversible impacts at a spatial scale greater than the one it was experienced, it can be defined as *catastrophic*; otherwise, it can be defined as a proper *disturbance*.

In addition, the degree of predictability (and thus the *risk of occurrence*) of an event is useful to define and classify a disturbance. There may be cyclic, periodic, and predictable disturbances or irregular and unpredictable ones. Some environmental changes, such as daily cycles (circadian) of light, temperature and humidity but also seasonal climatic cycles, are events able to initiate significant changes in the environment for many organisms. At the same time, a wide range of irregular events may overlap with periodic cycles resulting in an often complex framework.

One of the priorities for the management of an area or of a specific target of conservation is therefore to investigate the scheme of local disturbances. Such evaluation should be conducted for a given site and at a specific spatial and temporal scale of reference and take into account both the natural and anthropogenic disturbances as well as the direct and indirect effects and impacts on the biological diversity, the environmental mosaic, and the other ecosystem components (soil, water, air, etc.).

Impact, Disturbance, Stress: A Population Ecology-Based Terminology

In ecological literature, disturbance, stress, and impact are often considered as related words. They are frequently and mistakenly used as synonyms (disturbance, in particular, is the most misconceived term) and the definitions available in literature are often poorly understood.

Some of the most debated questions of ecological science revolve around the implicitly contradictory definitions of such term. Only the four principal definitions of disturbance, available in general and plant ecology will be discussed in this section. Other definitions, pertaining to applied ecology, have been extensively treated elsewhere in this book.

Grime (1979) distinguished between disturbance and stress. According to his definition, *disturbance* is the total or partial disruption of biomass whereas *stress* is a decrease of biomass growth rate. Grazing and treading by livestock and wild animals cause disturbance, even though such kind of phenomena are predictable and relatively constant. Hurricanes and landslides are also disturbances although highly unpredictable.

Aridity or the presence of toxic substances, inducing a decrease in growth rate are instead considered as stress. Although Grime's definition is very effective when applied to modular organisms such as plants and corals which accumulate biomass, it proves less compelling when dealing with other kinds of nonmodular organisms.

Grime's definition offers a clear distinction between disturbance and stress, which although separate processes, are often confused. As already mentioned it only suffers from the limitation of being inapplicable to organisms other than plants. However, if instead of considering the nature of the different interferences occurring in a community or a population, we focus on the effects exerted by such interferences on species, Grime's definition can be generalized and applied to nonmodular organisms.

As a starting point, let us consider the population growth curve. When resource availability is constant, initially the curve follows an exponential trend but then it slows down until it reaches a steady state.

If the population is decimated by diseases, catastrophic events or other factors after having reached the steady state, it can go back to the initial phase of

exponential growth. Disturbance is therefore a factor by which populations can be maintained in the phase of exponential growth, without reaching the steady state. The departure from steady state conditions does not necessarily occur when disturbance is irregular. Indeed, some populations are adapted to regular disturbance and are constantly kept in a state of exponential growth: for example, the small pleustophytes like those belonging to the genus *Lemna*, whose populations are continuously destroyed by the alterations of water levels in the canals and rivers where they usually thrive, or many species in urban environments. The implications of disturbance for population dynamics have been extensively studied in the case of phytoplankton (Crowley 1975; Sommer 1985), but other common examples are offered by density-dependent species.

To summarize: *disturbance is an interference by which populations and communities depart from a steady state and enter an exponential growth rate. Stress is not a factor which deviates populations and communities from the steady state; rather, it decreases their growth rate. Disturbance can be regular or irregular, natural or anthropogenic. When irregular, it can be defined as a perturbation. Both disturbance and stress are included in the term interference.*

Here follows a presentation of such definitions in the form of a dichotomous key (Ryikiel 1985): *interference* (or *pressure*); a factor which affects populations and communities and can be identified on the basis of their responses:

- it does not deviate populations and communities from the steady state: → *stress*. For example, a pollutant which decreases growth rate (chemical stress).
- it deviates populations and communities from the steady state: → *disturbance*. For example, noise annoyance caused by vehicles passing by on a road located near the nesting site of a stenoeccious species capable of hampering its reproductive success and favoring more generalist species (in this case it is an anthropogenic disturbance).
 - it is predictable → *impact*. For example, grazing exerts an impact on grass biomass.
 - it is unpredictable → *perturbation*. For example, a hurricane.

It should be stressed that the same external factor can be classified in different ways, according to how population and community respond.

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