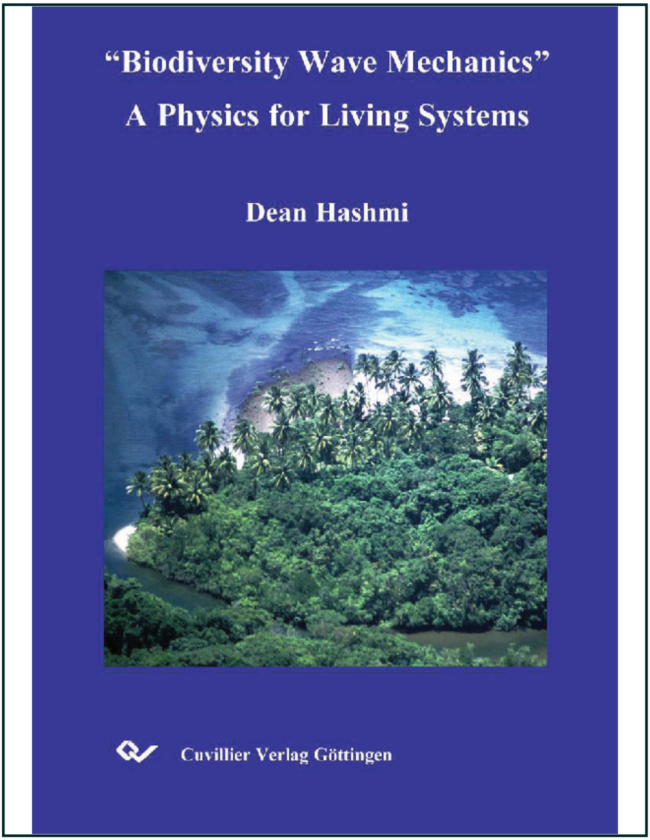
Dean Hashmi (Autor)

Biodiversity Wave Mechanics: a Physics for Living Systems



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Chapter 1: SPECIFICATION OF THE PROBLEM

1.1 Biodiversity studies: scope and relevance

All organisms on earth represent continuous lineages which made it through the past $4x10^9$ years (Eigen et al. 1989; Mojzsis et al. 1996[22]) i.e. survived the five major and countless smaller extinction incidents known from the palaeontological record (Schindewolf 1962; Newell 1967; Raup & Sepkoski 1982). The rapid evolution of human intelligence within the past few million years does at present induce the sixth major mass extinction of species on earth (E.O. Wilson 1992; Aitken 1998). Human cultural evolution is still in an immature stage which has so far not allowed to reach a degree of civilized self-organization that would allow a sustainable use of the biological resources of this planet. The first symptoms of the present mass extinction happened already in prehistorical times, when many large bodied "*megafauna*" species and many species endemic to oceanic islands disappeared in spatial and temporal coincidence with the spread of modern man and presumed direct persecution for food (Wallace 1911; Martin 1967, 1990; Olson & James 1982; Groombridge 1992; Smith et al. 1993; Pimm et al. 1994; Steadman 1995; Holdaway & Jacomb 2000; Diamond 2000). It continued in historical times, when for example additional 60-88 species of mammals (2 % of all recognized modern-era mammals) became extinct during the past 500 years (MacPhee & Flemming 1999; see also Jenkins 1992). The continuing (Smil 1999) increase of the global human population and the associated exploitation of natural resources (Vitousek et al. 1986, 1996; Wright 1987, 1990; Cohen 1995; Kerr & Currie 1995; Maurer 1996) go along with habitat degradation, landscape fragmentation, anthropogenic exchanges of non-indigenous species and various forms of pollution. It has triggered a mass extinction of unknown extent (Gómez-Pompa et al. 1972; Lugo 1988; Skole & Tucker 1993; Bibby 1994; Tilman et al. 1994; Pimm et al. 1995; Brooks et al. 1997; Nepstad et al. 1999; Pimm & Raven 2000; Sala et al. 2000; da Silva & Tabarelli 2000) and equally unknown consequences (Myers 1995; Chapin et al. 2000). It is now often called the "*biodiversity crisis*" (Soulé 1991; Cracraft & Grifo 1999). Unlike the customary economical crises, it is going to reduce the human environment and associated economic potential (Myers 1998) for several million years (Kirchner & Weil 2000), unless it can be brought to halt very soon.

Throughout the past century, awareness and concern about the human impact increased but the scientific efforts to study the biosphere remained negligible. The science of the 20th century, in accordance with the impressive successes of physics and chemistry during its first half, was occupied with the analysis of the structure of matter. High stake issues in biology were the equally successful reductionistic programmes to study the structure and functioning of living matter at suborganismic, cellular and biochemical levels. Highly specialized reductionistic branches of physics and molecular biology nowadays strongly monopolize the research funds of the scientific community. The study of biology at the organismic level also had its benchmark findings and some influential proponents, from population genetics to biogeography, but was not considered by many decision makers in science politics to be intellectually as demanding and sophisticated as physics or molecular biology, to give access to economic wealth, or to play a decisive role in the armed conflict of nations. Consequently, biology at the organismic level could only be the focus of a comparatively small proportion of the scientific community.

At the beginning of the 20th century, the study of organisms was mainly descriptive. Most zoologists and botanists were mere taxonomists, accumulating knowledge on single species or higher taxa, thereby met the cliché that still sticks to organismic biologists in the public and even throughout wide scientific circles. Nevertheless, throughout the 20th century, an increasing number of influential thinkers had developed at least some interest in and participated in the solution of some problems associated with the study of the interactions of organisms, populations and species which went along with the 'neodarwinian synthesis' of evolutionary thinking; combined molecular and organismic aspects of evolution crystallized from contributions of a diverse assembly of skilled minds, like trained mathematicians (Hardy), astrophysicists (Fisher), genetic scientists (Dobzhansky, Wright, Weinberg[23]) and evolutionary biologists (Haldane, Mayr). Many important contributions which anticipated or allowed later findings and concepts had already been published by the middle of the 20th century: e.g. on single species growth (Malthus 1798; Verhulst 1838), on species area relationships qualitatively (Watson 1835; A. de Candolle 1855) and quantitatively (Arrhenius 1921); on competitive exclusion by observation (a number of scientists since A.-P. de Candolle 1820), theoretically (Lotka 1920; Haldane 1924; Volterra 1926, 1931) and experimentally (Gause 1934); on the organization of ecological communities, by Clements (1916) and Gleason (1926)[24]; on first concepts of the niche by Grinnell (1917a, b) and Elton (1927). Only from 1950 onwards, organismic ecologists actually became interested in species diversity: Dobzhansky raised questions about the high number of species in the tropics (Black et al. 1950, Dobzhansky 1950, Murça Pires et al. 1953) and another influential biologist, Hutchinson, defined the modern niche concept (1957) and wondered about the limitations of species richness in biological communities (1959). In the 1960s and early 1970s, MacArthur as an experienced field biologist and talented mathematician formulated simple models to understand the structure of ecological communities and, by doing so, influenced a whole generation of ecologists (Cody & Diamond 1975).

All these efforts were not so much consequence of the growing awareness about global change but academically rooted interest intrinsic to the curious scientists' minds. Nevertheless, some biologists already became alert to the exploitative Malthusian human population growth at the global scale (Ehrlich 1971; Ehrlich & Holdren 1971) and its possible consequences on the biosphere and, in turn, on the spatially and temporally highly variable quality of human life on earth which is often directly or indirectly[25] a consequence of a regional shortage of natural resources. Even for nations which do not suffer a shortage of natural resources at present, in the short or in the long run, there are many values of biodiversity (Ehrlich & Ehrlich 1992, Constanza et al. 1997) which should catch the interest of the political strategists of the global economy due to purely economical reasoning.

The term "*biodiversity*" was coined on the occasion of a meeting of the National Academy of Sciences of the United States of America and the Smithsonian Institution in 1986 (Wilson 1988). The formation of a new, interdisciplinary branch of science complied the increasing awareness of our own impact on the biosphere, the associated extinction of species and the potential consequences of the reduction of species as well as the strongly neglected academic study of the biosphere, its complexity and sustainable use. The word biodiversity has subsequently been used in many different ways (Takacs 1996; Ghilarov 1996) and has become quite popular among fund raisers and science politicians. Therefore, not only because this thesis carries the term biodiversity in its title, it is important to bear in mind E.O. Wilson's (1992) definition of the terms "*biodiversity*" and "*biodiversity studies*":

Biodiversity is the "*variety of organisms considered at all levels, from genetic variants belonging to the same species through arrays of species to arrays of genera, families, and still higher taxonomic levels; includes the variety of ecosystems, which comprises both the communities of organisms within particular habitats and the physical conditions under which they live.*"

Biodiversity studies are the "*systematic examination of the full array of different kinds of organisms, together with a consideration of the*