BIODIVERSITY OF INSECT AND CONSERVATION

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ABSTRACT

Biological diversity of insect has undergone changes over a period of time. A variety of factors influence the diversity and species dynamics of insects. Insects occur in a wide range of habitats and have acquired specific adaptations for feeding habits, behaviour patterns and other biological features that contribute to their diversity. Insects comprise of 73% of total animal species constituting the single and most dominant group of organisms on earth. The most conservative estimates suggest that five to eight million insect species have not been discovered. Coleoptera are the most diverse species of animals, containing about 38% of all insects and 10% of all animals. Insects are ideal models in evolutionary biology for examining speciation, biogeography of species, and organismic interactions such as mimicry, mutualism and parasitism. Genetic diversity among insects is increasingly becoming necessary keeping in view of the alarming growth of pest population and the quickness with which the insects are able to adapt themselves to the changing pest control and crop breeding strategies. Techniques like RFLP and PCR come handy in the mapping of genes. The majority of animals on the planet are insects and, if the factors that endanger other animals also affect insects, the number of endangered insects must be very large.

INTRODUCTION

Biodiversity refers to the variety of life forms: the different plants, animals, microorganisms, the genes they contain, and the ecosystems they form. This living wealth is the product of hundreds of millions of years of evolutionary history. The process of evolution means that the pool of living diversity is dynamic; it increases when new genetic variations are produced, a new species is created or a novel ecosystem formed; it decreases when the genetic variations within a species decreases; a species becomes extinct or an ecosystem complex is lost. Biodiversity also has important social and cultural values. Growing population needs more food and increasing availability of land to live. This has focussed all our attention on the objectives-growing more food, in the less and lesser available space. This necessitated us to change and even sometimes overrule laws of nature and natural selection leading to a greater impoverishment of variety in life forms of plants, animals, insects and even ecosystems (Pimental *et al.*, 1990).

Many biologists now believe that ecosystems rich in diversity gain greater resilience and are therefore able to recover more readily from stresses such as drought or human induced habitat degradation. When ecosystems are diverse, there is a range of pathways for primary production and ecological processes such as nutrient cycling, so that if one is damaged or destroyed, an alternative pathway may be used and the ecosystem can continue functioning at its normal level. If biological diversity is greatly diminished, the functioning of ecosystems is put at risk. The only certain way to save the biological diversity is to use them sustainably (Janzen, 1992).

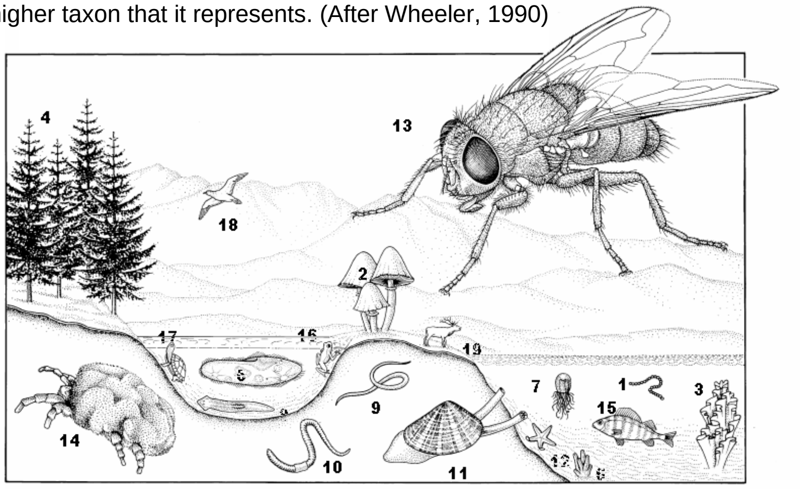
Although there are millions of kinds of insects, we do not know exactly (or even approximately) how many. This ignorance of how many organisms we share our planet with is remarkable considering that astronomers have listed, mapped, and uniquely identified a comparable diversity of galactic objects. Although dominant on land and in freshwater, few insects are found beyond the tidal limit of oceans. Even from our present limited knowledge it is clear that insects occur in a wide range of habitats and have acquired specific adaptations, feeding habits, behavioural patterns and other biological features that contribute to their diversity. This paper deals with the biodiversity of insects, the ways in which diversity can be measured and conservation of insects effected.

OVERVIEW OF THE INSECT

Insects represent the single most diverse group of organisms on earth. At the latest count, there are approximately 1.75 million living species known to science, but their precise classification and standing are yet to be worked out. For clarity, the more agreed-upon figure of 14,13,000 life forms (animals, plants, fungi, protozoans, bacteria and viruses) so far identified and known to science is considered. Of these, about 7,51,000 or 54% are insects. This becomes more acute when insects are taken as a percentage of the 10,32,000 known animal species, in which they would now comprise about 73% of this total (Wilson, 1993) (Figure 1). Even more remarkable are the estimates of how many insects we have not cataloged. Most insect species that have been classified and named to date are from temperate zones, but tropical habitats harbour far more. The sheer number and mass of insects reflect their enormous ecological impact. Apart from being the most species of all organisms, they also play a critical role in the functioning of all terrestrial ecosystems, for instance as pollinators, herbivores and predators (mostly of other insects). As the Harvard biologist E. O. Wilson wrote, "*So important are insects and other land dwelling arthropods, that if all were to disappear, humanity probably could not last more than a few months."*

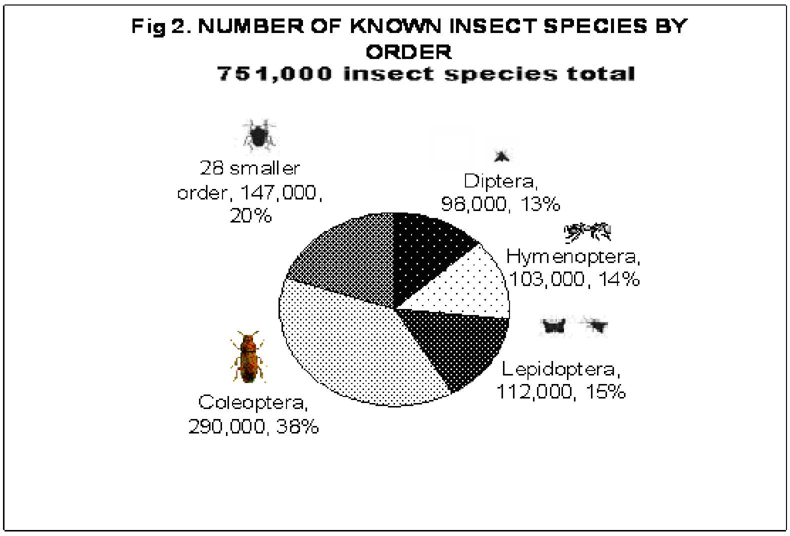
The insects are divided into 32 orders according to morphological and genetic relationships. The four dominant orders, which include the majority of all species on Earth, are the Coleoptera (beetles), Hymenoptera (bees, wasps, and ants), Lepidoptera (butterflies, skippers, and moths), and Diptera (mosquitos and flies). All total, these four orders make up nearly 80% of all known insects, the other 28 orders only about 20% (Wilson, 1993) (Figure 2). By far, the Coleoptera comprise the most diverse species of insects, containing about 2,90,000 species, or 38% of all insects and 10% of all animals. With more than 1,12,000 species, Lepidoptera are the second most diverse group. Like the beetles, the Hymenoptera vary greatly in body morphology and habitat types. There are about 1,03,000 known species. There are about 98,000 species of Diptera.

Fig. 1 : Species cape, in which the size of individual organisms is approximately proportional to the number of described species in the higher taxon that it represents. (After Wheeler, 1990)



(Sources : P.J. Gullan and P.S. Cranston, 2004)

1. Prokaryotes	2. Fungi	3. Algae	4.Plants
5. Protozoa	6. Porifera	7. Cnidaria	8.Platyhelminthes
9. Nematoda	10. Annelida	11. Mollusca	12. Echinodermata
13. Insecta	14. Non-insect Arthropoda		15. Pisces
16. Amphibia	17. Reptilia	18. Aves	19. Mammalia



Evolution & Biodiversity of Insects

Biodiversity is not static: it is a system in constant evolution, from a species, as well as from an individual organism point of view. The average half-life of a species is estimated at between one and four million years, and 99% of the species that have ever lived on earth are today extinct. Biodiversity is not distributed evenly on earth. It is evident from fossilized specimens that insects were living 400 million years ago. The myriapods (millipedes and centipedes) are most likely descended from a segmented worm-like ancestor (Gullan and Cranston, 2004). The head, thorax, and abdomen of insects are formed from groups of fused segments. Insects are the first animals with the capability of flight and some scientists think that wings probably originated from insect gills. Shortly after the development of wings, about 330 million years ago, an explosion of insect species is seen in the fossil record, documenting the spread of insects into new habitat types. Today, there are insects inhabiting almost every major ecosystem in the world except the oceans. There are insects inhabiting Antarctica and in the Great Salt Lake.

Insects are ideal models in evolutionary biology for examining important events such as speciation, biogeography of species, and organismic interactions such as mimicry, mutualism and parasitism. According to the classical theory of origin and evolution of species, when a species is divided into separate populations based on their physical, chemical or biological identities, each would accumulate different genes as a result of natural selection. This particular variation leads to polymorphism, and over a period of time leads to the evolution of a new species (Berry, 1974).

HOW TO EXPLORE INSECT DIVERSITY

Measurement of insect diversity

To study the insect biodiversity, it must be able to measure and quantify it

A. Step 1. Determine which elements of biodiversity are present in the area of interest (e.g., genes, species, and ecosystems)

Step 2. To study the inventory species in the area

Which consist of two alternatives

(a) Rapid assessment of a few groups by experts

(b) Comprehensive collecting and shipment to experts

B. First component of diversity is species richness

1. This measures species richness

    a) Species richness is the number of species present at a site.

C. A second component of diversity is evenness

1. Measure of equitability

    a) Based on the relative abundance of different species

    b) If an ecosystem has similar relative abundance of each species, evenness is considered high (close to 1); if an ecosystem has dissimilar relative abundance of each species, evenness is considered low (close to 0).

Genetic diversity as a critical component

Few would disagree that genetic diversity is a critical component of biodiversity. This can be measured both directly (identifying and cataloguing variation in nucleotides, genes and chromosomes) or indirectly (quantifying variation in phenotypic features shown – or often just assumed – to have a genetic basis). Genes are constructed from strings of nucleotides (DNA). The total number, position and identity (there are four different types) of the nucleotides that are all critical in the coding of biological information. Generally, multicellular organisms tend to have more DNA than single celled organisms but there are exceptions. Similarly, although there appears to be an overall trend of increasing genome size with increasing morphological complexity, this is not invariant. Thus, determining nucleotide sequences is arguably one of the strongest measures of genetic diversity, although there are a large number of other techniques involving DNA analysis. They are Restriction Fragment Length Polymorphisms (RFLPs) and Random Amplified of Polymorphic DNA (RAPD). The former one are being used increasingly in species identification, intra-varietal identification, in fingerprinting, in the construction of genetic maps for locating genes of specific interest and so on (Tanksley *et al.*, 1989; Romans *et al.*, 1991).

Species richness as a common currency

Whilst biodiversity can be measured in a host of ways, in practice it tends most commonly to be measured in terms of species richness, the number of species. There are several reasons why this is so.

1. Practical application. Species richness has proven to be measurable in practice, at least to the point where different workers will provide much of the same estimation of the number of species of a given status (e.g. present, breeding, wintering) in a given taxon in a given area at a given time.

2. Existing information. A substantial amount of information already exists on patterns in species richness, and this has been made available in the scientific literature. Moreover, further information on this can readily be extracted from existing museum collections (which globally comprise many millions of biological specimens) and their associated literature (many millions of volumes), particularly as greater efforts are made to catalogue these collections in computerized databases that are accessible from remote locations.

3. Surrogacy. Species richness acts as a surrogate measure for many other kinds of variation in biodiversity. In general, as long as the numbers involved are at least moderate, greater numbers of species tend to embody more genetic diversity (in the form of a greater diversity of genes through to populations), more organismal diversity (in the form of greater numbers of individuals through to higher taxa), and greater ecological diversity (from representatives of more niches and habitats through to more biomes).

4. Wide application. The species unit is commonly seen as the unit of practical management, of legislation, of political discourse, and of tradition (folk taxonomies have frequently been found to conform closely to modern ones). For a wide range of people, variation in biodiversity is pictured as variation in species richness. The above said, the measurement of biodiversity in terms of species richness does have some significant limitations.

THE VALUE OF INSECT DIVERSITY'S COMPONENTS

Generally, benefits arising from the conservation of components of biological diversity can be considered in three groups: ecosystem services, biological resources and social benefits. Some examples of these benefits follow.

Insects as food for human being

Probably 1,000 or more species of insects in more than 370 genera and 90 families are or have been used for food somewhere in the world, especially in central and southern Africa, Asia, Australia, and Latin America. Food insects generally feed on either living or dead plant matter, and chemically protected species are avoided. Termites, crickets, grasshoppers, locusts, beetles, ants, bee brood, and moth larvae are frequently consumed insects. Although insects are high in protein, energy, various vitamins and minerals, and can form 5–10% of the annual animal protein consumed by certain indigenous peoples, western society essentially overlooks entomological cuisine. Nutritional values obtained from analyses conducted on samples of four species of insects cooked according to traditional methods in central Angola (Africa) are shown in Table 1. The insects concerned are: reproductive individuals of a termite, *Macrotermes subhyalinus* (Isoptera: Termitidae), which are de-winged and fried in palm oil; the large caterpillars of two species of moth, *Imbrasia ertli* and *Usta terpsichore*.

(Lepidoptera: Saturniidae), which are de-gutted and either cooked in water, roasted, or sun-dried; and the larvae of the palm weevil, *Rhynchophorus phoenicis* (Coleoptera: Curculionidae), which are slit open and then fried whole in oil. These fat, legless grubs, often called palmworms, provide one of the richest sources of animal fat, with substantial amounts of riboflavin, thiamine, zinc, and iron. A mature larva of the palm weevil, *Rhynchophorus phoenicis* (Coleoptera: Curculionidae) – a traditional food item in central Angola, Africa (DeFoliart, 1989). The edible caterpillars of species of *Imbrasia* (Saturniidae), an emperor moth, locally called mumpa, provide a valuable market. The caterpillars contain 60–70% protein on a dry-matter basis and offset malnutrition caused by protein deficiency. Mumpa are fried fresh or boiled and sun-dried prior to storage. Further south in Africa, *Imbrasia belina* moth caterpillars, called mopane, mopanie, mophane, or phane, are utilized widely.

Caterpillars usually are de-gutted, boiled, sometimes salted, and dried. After processing, they contain about 50% protein and 15% fat – approximately twice the values for cooked beef.

Table 1 : Proximate, mineral, and vitamin analyses of four edible Angolan insects (percentages of daily human dietary requirements/100 g of insects consumed). (as adapted by DeFoliart, 1989)

Nutrient	**Requirement per capita**	***Macrotermes subhyalinus* (Termitidae)**	***Imbrasia ertli* (Saturniidae)**	***Usta terpsichor* (Saturniidae)**	***Rhynchophorus phoenicus* (Curculionidae)**
Energy	2850 kcal	21.5%	13.2%	13.0%	19.7%
Protein	37 g	38.4	26.3	76.3	18.1
Calcium	1 g	4.0	5.0	35.5	18.6
Phosphorus	1 g	43.8	54.6	69.5	31.4
Magnesium	400 mg	104.2	57.8	13.5	7.5
Iron	18 mg	41.7	10.6	197.2	72.8
Copper	2 mg	680.0	70.0	120.0	70.0
Zinc	15 mg	--	--	153.3	158.0
Thiamine	1.5 mg	8.7	--	244.7	201.3
Riboflavin	1.7 mg	67.4	--	112.2	131.7
Niacin	20 mg	47.7	--	26.0	38.9

Insects as feed for domesticated animals

The nutritive significance of insects as feed for fish, poultry and pigs is recognized in China, where feeding trials have shown that insect-derived diets can be cost-effective alternatives to more conventional fish meal diets. The insects involved are primarily the pupae of silkworms (*Bombyx mori*), the larvae and pupae of house flies (*Musca domestica*), and the larvae of mealworms (*Tenebrio molitor*). The same or related insects are being used or investigated elsewhere, particularly as poultry or fish feedstock. Silkworm pupae, a by-product of the silk industry, can be used as a high-protein supplement for chickens. In India, poultry are fed the meal that remains after the oil has been extracted from the pupae. Fly larvae fed to chickens can recycle animal manure and the development of a range of insect recycling systems for converting organic wastes into feed supplements is inevitable, given that most organic substances are fed on by one or more insect species. Opportunities for insect food enterprises are numerous, given the immense diversity of insects.

Insect as a Pollinator

In higher plants sexual reproduction and perpetuation of species are brought about through cross pollination. These plants may be either self-fertile, capable of setting fruit or seed with their own pollen, or self- infertile requiring pollen from other plants of the same species for cross pollination. In the self-pollinated plants pollen from the anthers automatically fall on to their stigmas. The chief agents of pollination are the wind and the insects. Horticultural crops like fruits, vegetables and ornamental plants and field crops like cotton and tobacco are pollinated by various insects and they have coloured and scented flowers with well developed nectaries to attract the insects. As they visit flowers for nectar, the pollen get dusted all over the body and transferred to the stigma of the flower next visited. The important pollinators are the honey bees, stingless bee, *Trigona spp*, *wasps* and many kinds of flies *Syrphus*, *Bombylius* and *Sarcophaga,* black ants, *thrips, butterflies* and *moths.*

Insects and their commercial value

Insects contain a vast array of chemical compounds, some of which can be collected, extracted, or synthesized for our use. Chitin, a component of insect cuticle, and its derivatives act as anticoagulants, enhance wound and burn healing, reduce serum cholesterol, serve as non-allergenic drug carriers, provide strong biodegradable plastics, and enhance removal of pollutants from waste water, to mention just a few developing applications. Silk from the cocoons of silkworm moths, *Bombyx mori*, and related species has been used for fabric for centuries, and two endemic South African species may be increasing in local value. On the other hand, honey bees play a major role as they provide honey having higher commercial value. The honey can be used as food, as medicine and mythological value. The byproduct from the honey bee, bees wax is also much important. The red dye cochineal is obtained commercially from the scale insect, *Dactylopius coccus* cultured on *Opuntia cacti*. Another scale insect, the lac insect, *Kerria lacca*, is a source of a commercial varnish called shellac. Given this range of insect-produced chemicals, and accepting our ignorance of most insects, there is a high likelihood of finding novel chemicals.

Insects as a model

Insects provide more than economic or environmental benefits; characteristics of certain insects make them useful models for understanding general biological processes. For instance, the short generation time, high fecundity, and ease of laboratory rearing and manipulation of the vinegar fly, *Drosophila melanogaster*, have made it a model research organism. Studies of *D. melanogaster* have provided the foundations for our understanding of genetics and cytology, and these flies continue to provide the experimental materials for advances in molecular biology, embryology, and development.

INSECT ENDANGERMENT

A report by the World Commission on Environment and Development noted, "There is a growing consensus that species are disappearing at rates never before witnessed on the planet" but that "we have no accurate figures on current rates of extinctions, as most of the species vanishing are the least documented, such as insects in tropical forests." Scientists and conservationists agree that insect species are going extinct. But how many have been lost and how many more are at risk remains unclear.

Extinct insects

The International Union for Conservation of Nature and Natural Resources (IUCN) lists 72 species of insects are extinct worldwide. Many scientists believe that these numbers drastically underestimate actual insect extinction and that many hundreds, or perhaps thousands, of species have gone extinct unnoticed in North America and Europe in the last two centuries. If a widespread species can vanish because of human activity, the fate of many endemic tropical species must hang in the balance as their only habitat is destroyed. The Xerces blue butterfly, *Antioch katydid*, Tobias' caddisfly, Colorado burrowing mayfly, Rocky

Mountain grasshopper all were driven extinct by humans. However, human-induced changes to the natural environment threaten vast numbers of these organisms and the vital services they provide to ecosystems.

Endangered insects

Based on available information we can deduce that a very large number of insects are endangered. The majority of animals on the planet are insects and, if the factors that endanger other animals also affect insects, the number of endangered insects must be very large. According to the 2000 IUCN Red List of Threatened Species, 163 species of insects are listed as critically endangered or endangered worldwide (Joy Nicholopoulos, 1999). In 1987, West Germany classified 34% of its 10,290 insect and other invertebrate species as threatened or endangered and, in Austria, this figure was 22% of 9,694 invertebrate species. More recent figures from 2000 for Great Britain show that 10.8% of its 14,634 described insect species are rare, vulnerable, or endangered.

Importance of endangered insects

A rare and endangered species of insect is unlikely to determine the fate of a large ecological system, but as a group they may have a large effect. Ecosystem functions, such as the recycling of nutrients, often are done by specialists like the American burying beetle rather than generalists. There are innumerable specialized insects that feed on particular kinds of wood, dung, or carrion. For instance, the plates that cover the shells of tortoises are made of keratin, a protein, few scavengers can digest. However, in Florida there is a moth, *Ceratophaga vicinella,* whose caterpillar appears to have specialized on a diet of dead gopher tortoise shells. Endangered species also can play a linchpin role in small, specialized systems, such as caves, oceanic islands, or some pollinator-plant relationships. For example, many plant species rely on one or a few pollinators. Decreased abundance or loss of any of these pollinators can have dramatic consequences, especially if a plant depends on a single, obligate pollinator. Some endangered species might provide useful products, such as new defenses against diseases, tools for studying various ecosystem or organismal processes, as well as direct material benefits.

Causes of endangerment

Insects become endangered because of the same destructive forces faced by many other animals. According to the IUCN, the leading causes of animal endangerment are habitat destruction, displacement by introduced species, alteration of habitat by chemical pollutants (such as pesticides), hybridization with other species, and over-harvesting.

Habitat Destruction

Agriculture, commercial development, outdoor recreation (including off road vehicles), pollution, and water development rank as the most frequent causes of habitat degradation affecting federally listed endangered and threatened insect species.

Alien Species

The introduction of various exotic organisms (whether intentional or not) has affected native insects, both directly and indirectly. For example, introduced plants may out-compete native plants and, thus, lead to the loss of insect host plants or habitat. Intentional introduction of insects also may harm native insects. For example, a parasitoid fly, *Compsilura concinnata*, that was released repeatedly in North America from 1906 to 1986 as a biological control against several pests, is implicated in the decline of four species of giant silk moths (Lepidoptera: Saturniidae) in New England.

Over – collecting

Although overcollecting has not been shown to harm healthy populations of insects, it may be an important threat to insect species with very small populations and is included in the list of threats to many of the federally protected insect species. The Endangered Species Act expressly forbids the collection of endangered or threatened species, and most insect conservationists feel that collecting from small populations only should be done for well-designed, hypothesis-driven, scientific studies.

Other potential threats

Pesticides and other pollutants are implicated in the decline of many native bees and some aquatic insects, although the degree of impact is not conclusive. Lights along streets and highways also have been implicated in losses of nocturnal insects, particularly large moths. Finally, even though we cannot specify the exact effects of climate change at this time, it could lead to endangerment of endemic insects with specific, narrow habitat requirements.

CONSERVATION OF INSECT DIVERSITY

The conservation of biological diversity seeks to maintain the life-support system provided by nature in all its variety, and the living resources essential for ecologically sustainable development.

Protecting habitat

To protect any species one must protect its habitat. Some insects need only small areas to thrive, and even backyard gardens may help some pollinator insects. Large swaths of land set aside as reserves, wilderness, national parks, and conservation easements ultimately may benefit insects. Recent evidence, however, shows that some reserves, with management plans tailored to vertebrates, do little to protect insects such as butterflies. One important caveat for setting aside land for insects is that species often have subtle habitat requirements and can be lost even from reserves because of apparently minor habitat changes.

Federal laws and legislative efforts

Federal legislation is vital to the protection of endangered insects. The formal listing of species as threatened or endangered under federal or state endangered species legislation has been an extremely effective habitat protection tool because (1) these species are protected by law and (2) money is allocated for recovery efforts. For most developing countries in the world, protective legislation for insects is either lacking or only sporadically applied. One exception is Papua New Guinea where there is legislation, as well as a management program, that protect the rarest bird wing butterflies, allows only citizens to sell native insects, and protects some insect habitat.

Research

Before we can work to protect insects and other invertebrates, we need to know, at least, what species are present, if populations are stable or declining, and the habitat needs of these populations. In the long run, more emphasis needs to be placed on invertebrate survey, systematics, taxonomy, and population ecology so that these species can be identified, cataloged, and their life histories understood. Research needs to go hand in hand with conservation, for there is little use for a catalog of extinct species.

Education

To conserve insects successfully, the general public, scientists, land managers, and conservationists need to understand the extraordinary value that these organisms provide. An ambitious public education program would enhance recognition of the positive values of invertebrates, and, indeed, all biological diversity.

Conclusion

Considering all the factors presented here, it is imperative for the researchers involved in the studies of biodiversity to develop procedures for measuring biodiversity, carry out surveys and inventories, to develop methodologies for managing and controlling populations sustainably and initiate long term studies on genetic and environmental variations. A multiplicity of genes, species, and ecosystems is a resource that can be tapped as human needs change. It is to be appreciated that the modern technologies can be used in all the components, with care, to study, document, utilize and if needed to enhance the amount of diversity.

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