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ANALYSIS

Biodiversity pressure and the driving forces behind

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ABSTRACT

Since the UNCED Conference in Rio de Janeiro 1992, the need to actively protect biodiversity is universally acknowledged. The UN Convention on Biological Diversity (CBD) defined biodiversity as comprising ecosystem diversity, species diversity and genetic diversity, and decided for the ecosystem level as the basis for describing biodiversity. However, due to conceptual problems as much as to the lack of data, so far no comprehensive measurements of biodiversity have been developed and a single measure quantitatively describing biodiversity seems impossible due to the incommensurability of the three levels. This makes it impossible to directly base policy decision on existing or future estimates of the "total size" of biodiversity. Instead, it is suggested to analyse the pressures threatening biodiversity, which can usually be measured quantitatively, and act as the interface between the socioeconomic driving forces behind them and the biological impacts. The drivers (physical primary drivers, politics and policies causing them as secondary and institutional structures as tertiary ones) do not only affect biodiversity, but a range of sustainability problems. The analysis permits to integrate biodiversity risks with broader environmental and sustainability policies, and thus to mainstream biodiversity preservation.

Such an analysis is presented for Europe, naming pressures and driving forces and illustrating the close links between the causes of biodiversity pressures and other environmental problems. This way, it is possible to develop first ideas how the standard set of environmental policies must be modified and extended to cover the issue of biodiversity.

1. Introduction

At the United Nations Conference on Environment and Development in Rio de Janeiro 1992, the Convention on Biological Diversity (CBD) was signed, providing rules for the protection and use of biodiversity including biosafety concerns. Based on earlier work (OTA, 1988; IUCN et al., 1990), it defines biodiversity as "variability among all living organisms from all sources [...]; this includes diversity within species, between species and of ecosystems" (United Nations, 1993). The Convention aims at protecting biodiversity, enhancing the sustainable use of its components and fair benefit sharing (Ecological Economics, 2005).

Analysing the pressures on biodiversity, their trends and origins has become ever more urgent since the Conference of Parties of the CBD called for halving the loss of biodiversity by 2010, the World Summit for Sustainable Development (WSSD) 2002 in Johannesburg supported that effort and the European Union, even more ambitiously, set the policy objective to halt the loss of biodiversity by the same deadline.

The effectiveness of any policy to this end must be assessed on the different levels of biodiversity, but the policy itself does not necessarily have to follow this structure. To the contrary: on the one hand, at each level of decision-making, the political instruments at hand can only be used deliberately and are most effective within the geographical borders of the

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administration using them (although their impacts may be far reaching or even global), which are not based on biological demarcations. On the other hand, the existing tools–except for the establishment of wildlife reserves like national parks–are not specifically designed for biodiversity protection and usually no vertically integrated biodiversity protection strategies are in place. However, this is not necessarily a tragedy, as the best politics can do to maintain biodiversity is reducing the pressures on it throughout the landscape, either directly or–more durably and thus preferably–by modifying their underlying driving forces, and by offering retreats and regeneration space, i.e., protected areas. Whereas the analysis of biodiversity is a bioscience task, driving forces must be identified by socioeconomic analysis.

So far, biodiversity analysis and indicator development have mainly focussed on the bioscience aspect. Besides vested interests, inertia and ignorance, this one-sided focus is one of the reasons why biodiversity, despite all declarations, plays an insufficient role in day-to-day politics. The calculations of biodiversity costs indicate the need for action, but are not helpful to derive policy priorities in operational terms.

Focussing on in the situation in Europe, this paper describes the state of the art of biodiversity measurement (Section 2) and the key pressures affecting the different levels of biodiversity (Section 3). The pressures identified are then linked to the driving forces behind them, allowing to derive objectives on the policy level which would most probably be effective on the biological level (Section 4). Section 5 discusses the results and Section 6 draws some policy conclusions.

2. Counting biodiversity: no obvious solution

If bioscience analysis could produce one clear-cut, unambiguous, comprehensive and sensitive measure of biodiversity, it has been argued that this could by means of its simplicity be policy relevant. However, the state of the art in bioscience does not support this ambition and the trend of biodiversity measurement goes another way.

2.1. *System diversity*

The CBD has chosen the level of ecosystems as the basis for describing biodiversity, not the more familiar level of species diversity or the rather unexplored one of genetic diversity. However, so far no measurement methodology has been agreed and the indicators finally chosen by the CBD and integrated into its work programme for testing in October 2003 (CBD, 2003a,b) do not include an aggregate indicator for ecosystem diversity, but rather species-based state, plus pressure and response indicators.

One reason is that the definition of borders between ecosystems is far from easy: They are no homogenous units, but are characterised by significantly varying internal conditions, e.g., in the soil and the tree canopies of tropical forests, or in different compartments of a boreal forest on different soils. Whenever the variations inside one supposed ecosystem are significantly higher than those between that ecosystem and a neighbouring one, scientific measures are obscured as criteria for defining borders (Korn, 1999).

This is a general characteristic of system analysis: the definition of the system borders is very much at the disposal of the analyst and each description of a system reflects the observer's purposeful choice how to describe it as much as a characteristic of the system itself (Giampetro et al., 2006). In the case of biodiversity protection, neither the purpose is a simple one (protection, use and benefit sharing may be served best with different system boundaries) nor is a standard definition applicable to all ecosystems on a global scale. Furthermore, the scale of the systems is another matter of dispute, as almost every system can be subdivided into other systems.

Against this background, political concerns play a major role in system definition: if a system is large, it may cross national borders and under the convention establish shared responsibilities, e.g., regarding legislation on protection or who receives the compensation for biodiversity use. In this situation, different players have different interests and press for different definitions of systems and system boundaries.

As a result, it would be surprising if any time soon a broadly agreed system of biodiversity measurement on the ecosystem level would emerge, desirable as it would be, for political and economic reasons as much as for scientific ones.

2.2. *Species diversity*

Both the scientific and the political problems are less pressing with species diversity, although still a lot of taxonomic questions remains unsolved (Grasshoff and Weingarten, 1999; EPBRS, 2004). The privileged knowledge and data situation is not only due to decade long expert work, but results also from the contributions of active lay people like bird watchers, hunters and fishermen. However, their observations are restricted to a limited number of rather large plants and animals, while insects, algae and microorganisms are largely beyond the scope of such observations (Pimm, 2002). As a result, estimates for the total number of species on Earth vary significantly, with 5 to 15 million as a probable range (Stork, 1993; European Union, 2004); up to 100 millions have been suggested (Naeem, 2004). Some researchers consider 7 million species a best guess (May, 1997), of which about 1.7 million are known (European Union, 2004).

Assessing species numbers, abundance, cover values, species frequencies, spatial distribution patterns or the occurrence of flagship taxa are standard procedures in scientific ecosystem analysis. They serve to characterise ecosystems, compare the composition of fauna and flora with the potential natural vegetation or the undisturbed regional state, and thus help analyse the interaction between different internal elements and external impacts. However, neither the persistence of certain indicator species nor the total number of species present provides a suitable indication for biodiversity in all its dimensions.

The number of species is at best a very rough indicator of biodiversity, as it provides limited indications of genetic and ecosystem diversity. As a result, accounting for species alone can be highly misleading as a yardstick of diversity (Wilson, 1988; UNEP, 2002) and the preservation efforts focused on a few species might even be counterproductive with regards to other groups (Lawton et al., 1996). Nonetheless, the high rate of species extinction is alarming regarding biodiversity as a whole (for instance, Pimm, 2002 estimates the current extinction rate to be about 400 times faster than the natural one, and the Millennium Assessment takes it to be 1000 times faster than the background rates typical in Earth's history, MA, 2005).

As a measure of total biodiversity, "flagship taxa" perform hardly better than total species numbers. No single group of species is per se in a position to signal the persistence of all species in an ecosystem, in particular not different groups of organisms. Although the survival of a species high in the trophic chain suggests that the lower levels must be functional, within the levels dramatic changes of composition are possible.

There is another problem with species diversity as a stand-in for biodiversity: it provides insufficient information regarding the one key objective for which biodiversity has been highlighted as an issue of international political importance: biodiversity as an *anchor to ecosystem resilience and stability* (Holling et al., 1998). According to the "insurance hypothesis", even if diversity is not critical for maintaining ecosystem functions as long as the external pressures are too low to significantly disturb benign environmental conditions, it may be essential for system functioning once the conditions change. Another species could "take over" if one "fails" due to the changing conditions. In other words, species which are functionally redundant in a given situation may not be so through time (Loreau et al., 2001).

In systems undergoing processes of evolution and co-evolution, equilibrium and unidirectional causality approaches are inadequate concepts to understand stability properties such as resilience and resistance at the ecosystem level. Instead, a description of the ecosystem state, as the result of a path-dependent choice of one of several possible, temporarily stable dissipative patterns in a far-from-equilibrium situation, may be more adequate. Muradian (2001) concludes that empirical evidence even seemed "to reveal that increasing diversity begets stability at the community level but instability at the population level".

In this dynamic perspective, the feedback mechanisms between biodiversity changes, ecosystem functioning, abiotic factors and anthropogenic influences play a key role. For ecosystem performance, history, geography and local climate are decisive, with *biodiversity an important but secondary factor*. Nonetheless, changes in biodiversity, such as the loss of dominant or the addition of invasive species, can affect how ecosystems work, partly in a predictable and partly in an unpredictable manner. Finally, ecosystem disruptions cannot be ruled out, but their size and frequency may well be reduced by maintaining biodiversity (Naeem, 2004).

Just like for system stability, the relation of species diversity and biological productivity is far from unambiguous: for instance, Vilà and Weiner (2004) report that by adding foreign species to a system its level of productivity fell to that of a monoculture of invaders, well below the productivity of a monoculture of native species. Unlike what biological theory postulated some decades ago, it is now well established that productivity does not respond predictably to species richness or vice versa (Trepl, 1999); species poor ecosystems can have a higher growth rate in early phases of ecosystem succession, but they can also be natural monocultures under unfavourable growth conditions, e.g., in mountain areas.

In some studies, overall species richness declined with the level of disturbance, while some species were insensitive and still others might even benefit from disturbance effects (Lawton et al., 1996).

From a macro-ecological perspective, a consensus seems to emerge, integrating large-scale observational and small-scale experimental insights despite their seemingly contradictory results by taking their different perspectives[1] into account: There is a pattern often observed in nature, "where the most productive ecosystems are typically characterised by low species diversity" (Loreau et al., 2001, p. 806). Closer to a dynamic (and thus temporary) equilibrium state, a minimum level of species diversity seems to be necessary to guarantee stable ecosystem functions and a higher one to maintain them in changing environments. In disturbance-driven systems, the colonisation ability and growth rate of individual species might drive ecosystem processes, generating high growth rates but low functional stability—the character of the system evolves with rapid succession.

2.3. *Genetic diversity*

A link between diversity and stability seems more plausible at the genetic level, since diversity defines the size of the gene pool, and this size in turn defines the range of options available to evolutionary processes and biological adaptation. Undisturbed development tends to permit the broadening of the gene pool as mutations accumulate, as the limited selective pressures allow redundancies to establish and survive. On the other hand, external stresses, in particular multiple simultaneous or rapidly following subsequent ones, act as selection forces on the gene pool.

So under the environmental conditions in Europe, plants have been better off, e.g., if they could stand soil acidification, were tolerant to higher levels of UV-B radiation and higher top speeds of storms (not the average velocity, but the maximum has increased over the last decades, causing severe damage to forests; Deutscher Bundestag, 1994). Each such selection condition narrows the gene pool, and this limits the adaptation capabilities for the next wave of substantially different, anthropogenically caused changes of external conditions.

For example in the 1980s, only a fraction of forest trees in Germany were capable of natural propagation due to air pollution, soil acidification (and in some instances, overgrazing): a biological selection process took place, narrowing the gene pool by excluding the non-resistant genomes (Gehrmann, 1982). Mitigation measures included clean air legislation and seed collections to maintain the broader gene pool at least in vitro; adaptation measures like planting more stress resistant species was considered unhelpful for air pollution problems, but necessary to respond to climate change. In situ, the narrowing of the gene pool may prove an obstacle for adaptation to increasing evapotranspiration,

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[1] Experiments still have a rather narrow basis, as they are limited to relatively few ecosystems, mainly grasslands, few trophic levels and a limited number of species (Vilà and Weiner, 2004).

longer drought and extended rainfall periods, and changing precipitation distributions (IPCC, 1997), while at the same time the value of the gene banks as a resource for restoration measures may be diminishing, since the diversity they contain is isolated from the changing natural environment.[2]

Furthermore, so far all concepts to improve the preservation of genetic diversity suffer from a lack of understanding of the functional role of different genes. Operational concepts and measurement methodologies of genetic variation, even when linked to abundant data to characterise biodiversity based on biological distinctiveness have not resulted in an overall measure of genetic diversity systematically related to system capabilities (UNEP, 2002).

3. Towards a pressure-based assessment

Section 2 has clearly indicated that measures of total biodiversity are unavailable, and proxies are unreliable, time consuming, expensive or insufficient. Consequently, while still important for biodiversity monitoring, bioscience based measures (often focussing on some selected elements of biodiversity) offer on limited potential for deriving political biodiversity protection priorities. In this situation, and given the urgency of providing policy relevant information for the prevention of further losses, another basis must be found for deriving priorities for action.

Pressure reduction must be achieved for all three levels of biodiversity, and thus the relevant pressures have to be identified for each of them. Combining the three pressure lists results in a biodiversity pressure inventory,[3] permitting to identify those pressures, which are mentioned more than once as very important pressures.

The pressure analysis is a first step towards policy definition, but not yet the solution: in Section 4, the drivers behind the pressures will be identified and used to derive priorities for policy action, although directly addressing certain pressures might be necessary as a kind of emergency relief in particularly critical situations.

3.1. *Choosing the scale*

The bulk of biodiversity research has focussed on organisms or species and on ecosystem types, whereas the justification of policy measures rests implicitly or explicitly on the functional attributes of the ecosystem level ("ecosystem services"), be they aesthetic or economic.

Political and administrative decisions, including those on biodiversity pressure management, are taken on the local, regional, national or supranational level, and they apply within political borders, not within ecological boundaries. Pressure analysis, while linked to the biogeographical basis of biodiversity as the object exposed to pressure, points to the anthropogenic causes of biodiversity loss as the agents of pressure generation, i.e., as driving forces, and on their institutional frames and hierarchies. In order to be effective, demands for pressure regulation must fit into the decision-making framework, with measures informed by bioscience analysis. The challenge is then to find strategies on the institutionally adequate scale (in this paper for the EU25 European Union), helping to steer decision-making with a sufficient degree of reliability towards effective biodiversity preservation. In other words, the intention must be to mainstream biodiversity protection within the political processes by transforming biological insights regarding pressure sources into criteria applicable in decision-making. These decisions should be effective in reducing the pressures on biodiversity by modifying the driving forces generating them and to monitor their implementation.

To provide comprehensive results, the analysis should cover the kind and size of the damage factors threatening each of the three levels of biodiversity.

For the EU, key pressures can be identified on the (supra) national level, without necessarily being able or willing to track down their effect to the local scale. Some of the driving forces behind these pressures are open to political influence as for instance the loss of landscape structure through agricultural development, and these are what decision-makers in European politics and administration need to know about. Other information is helpful to contextualise the message, but the essence must refer to what the decision-makers can influence. Such measurement systems can also be used to monitor policy implementation (i.e., the effectiveness of the institutional mechanisms of governance), but not the effectiveness regarding the initial intention, protecting biodiversity. For this behalf, biological data and measurements are still necessary, despite their so far rather patchy results.

3.2. *Monetisation is no solution*

Monetisation of biodiversity has been suggested as a possible solution to the measurement dilemma described, not least as monetary values can be aggregated across levels and scales. A second reason for advocating monetisation is to make the calculus of economics applicable to biodiversity protection, permitting to choose between efficient preservation and adaptation strategies (Perrings, 2005) instead of conducting pressure/driver analyses. A third one is the possibility to address decision-makers in terms familiar to them, talking about value, costs and capital stocks (Reid et al., 2005). However, this "translation" comes at a price and its implications should be taken into account before applying the economic apparatus to biodiversity. In particular the question needs to be answered positively, whether or not monetisation provides suitable instructions for choosing policy priorities and is suitable to monitor policy implementation. Unfortunately, some of these requirements are mutually exclusive. For instance, while without aggregation across scales and systems it is not possible to derive economically efficient macro level policy strategies, aggregation tends to obscure

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[2] Regular exposure to the natural conditions is necessary to keep the process of co-evolution at least rudimentarily intact. Whereas this is part of the usual management practice for many short lived species, it is hardly possible to do so for long-lived ones.

[3] Only if the pressure factors and the susceptibility of the biological systems were identical on all three levels, a one-by-one analysis would be superfluous. This, however, is neither plausible nor empirically proven.

critical pressures and their drivers by adding up all of them into one figure. Without explicitly highlighting the most relevant pressures, however, neither can policy priorities be identified nor the modification of driving forces be monitored.[4] Aggregation is based on the assumption of strong commensurability, i.e., the possibility to measure all objects under concern with the same quantitative scale (the assumptions of strong comparability and commensurability are constitutive for neoclassical economics; see Martinez-Alier et al., 1998; Spangenberg, 2005). In the context of sustainable development, based on the sustained functionality of four capital stocks (man-made, human, natural and social capital), this assumption is at least justified for the economic process. This includes the human-made capital stock and all flows from the other stocks entering the production process at their market price, as far as the question is for their economic value. Regarding individuals and their human capital, value assessments through market prices do usually not exist, but are imposed on the participants by methodologies of subjective value attribution (hedonistic pricing, contingent valuation). However, due to the methodological individualism of modern economics, the discipline has no access to social capital as a collective or common pool good (Polski, 2005). Attempts to express it through individual preferences miss the point as social capital refers exactly to those collective attitudes and values, which cannot be expressed as the sum of individual preferences. Unlike the economic value, where measurement is standard, and the individual value, where it is questionable, the social value is beyond the scope of the established economic methodology (merit goods may represent an exemption from this rule, but have no price determined by the market). So is the environmental value, i.e., the value for the ecosystem, not the value of the ecosystem for the economy, which is an economic value best expressed in monetary terms. The former information, concerning the importance of a certain element of biodiversity for the ecosystem, is what policy decisions need to take into account to be effective. In these cases, monetisation can even be counterproductive as it suggests that one element of the system can be substituted for another, which is true for the economic process, but not necessarily so for the ecosystem processes. The use of the capital stock terminology is often associated with such oversimplifications and the confusion of value dimensions, even if no monetisation is suggested.[5] If the value of the total environment is described as natural capital, the complex interaction of external and internal factors tends to be neglected for the benefit of having a unifying measure of the “capital stock” as a measure of the environment’s value to the economy.

Monetisation of biodiversity is a bit like a call to the arms without identifying an enemy. At best it illustrates one aspect of the multiple values of biodiversity and the urgency of taking action, but this is not enough as a basis for policy steering. So instead of monetising the value of biodiversity, for decision preparation and implementation monitoring, we consider it more adequate to focus on the physical pressures causing biodiversity losses, and their socioeconomic drivers. Otherwise, efficient strategies run the risk of not being effective, as efficiency and effectiveness are assessed for different objectives and using different numeraires.

3.3. *Analysing the anthropogenic pressures*

For Europe, the main anthropogenic disturbance factors (i.e., pressures) have been identified for the three levels of biodiversity (EuroStat, 1999; UNEP, 2002; EEA, 2004, 2005) and pressure indicators derived on this basis (Spangenberg, 1999):

- Human interference by overexploitation (logging, hunting, gathering, farming, grazing), from habitat disturbance and fragmentation all the way down to full habitat destruction,
- Disturbed hydrological regimes from water logging, reduction of forest cover and changed precipitation patterns, and
- Changing geo-chemical and climatic framework conditions through climate change and pollution (acidification, eutrophication, accumulating chemicals and long-range air pollutants). Climate change has already produced numerous shifts in the distribution and abundance of species and will have even more significant impacts in the future. Thomas et al. (2004) predict that 24% (15–37%) of species will be committed to extinction by 2050 in case of a mid-range climate warming. They furthermore show that reducing warming to the minimum feasible today, less losses result (18%), whereas high climate change resulted in an average loss of 35%.

Organism/species level disturbance refers to a decline in the abundance, distribution, or sustained usability of organism populations and the services they provide (e.g., like pollination), and ultimately species extinction. It is mainly caused by

- System fragmentation impeding selectively on the reproductive capacities of species with a larger habitat, thus shifting the balance of species and the state of the system. This implies that not only the total area but as well its specific allocation is important, introducing fragmentation and location as *biodiversity specific policy criteria.*
- Competition with deliberately or unconsciously anthropogenically introduced foreign species (‘biological pollution’). As they are ‘unknown’ to the ecosystems and the domestic species (or at least their characteristics are, as is possible in case of newly bred or engineered organisms), they may thrive without natural enemies, alter the species and product composition of ecological systems, and tend to

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[4] Damage cost calculations can be an exemption from thus rule if combined with a damage cause analysis, as reinsurance companies do; avoidance cost calculations can help finding efficient strategies provided that the policy objective is defined in scientific terms and not derived from optimal cost calculations.

[5] The distinction of different kinds of value is no attempt to develop a new value theory, like the labour or the embodied energy theories of value. To the contrary: while those tried to measure economic value in social or physical terms, the suggestion here is to measure it in economic terms, but to acknowledge important contributions to the functioning of the three non-economic systems discussed in the sustainability discourse (population, society, natural environment) by “system values”, i.e., values to the systems, not of the systems, expressed in the respective “currency” of each “capital stock”.

reduce their productivity (Vilà and Weiner, 2004; Vilà et al., 2004). Through competition, they may suppress native species down to ultimate extinction. Although most invasions cause little change of the overall ecosystem character in the long run, some do, and for instance invasive weeds can have significant economic impacts on agricultural yields (Pimentel et al., 2000).

- The effects of ecotoxics. Accumulating heavy metals are a long-established problem and have been dealt with by European and national policy measures like the introduction of mercury-free batteries and lead free gasoline. Regarding pesticides, even the “dirty dozen” including DDT, Aldrin and Dieldrin has not yet been phased out completely, although their toxic effects are known since decades (Carson, 1963). Other persistent organic chemicals accumulate in the environment and petroleum products are a frequent pollutant of aquatic systems. Knowledge about the detrimental effects of certain pharmaceuticals, their degradation products and other endogenous disruptors, substances that selectively interfere with the regulatory system, is more recent, but no less worrying.

Present and future human-made or anthropogenically accelerated genetic erosion, i.e., the loss of gene-level diversity within populations, is the result of pressure mechanisms including

- Selective pressures on the gene pool from changing environmental conditions. Examples include increasing UV-B radiation, climate change, changing evapotranspiration patterns and physicochemical pollution. For agro-biodiversity, the selection of optimally profitable species, races and varieties plays a similar if stronger role.
- ‘Genetic pollution’ from the increasing number of deliberate releases of genetically modified organisms with traits which might, e.g., penetrate the natural population and reduce its viability, or which could outcompete natural varieties in particular in anthropogenically shaped environments. Like for most invasive species, the impact of the releases will be only detectable with a time lag of several generations, its duration (decades and centuries)-dependent inter alia on the generation length and the reproduction rate of the species affected, and
- Reduction of biotope size and thus of population numbers, threatening genetic diversity through the stochastic processes of genetic drift (Trepl, 1999). The level of risk is dependent on the severity of the human interference (areal transformation), the resilience of the ecosystem and the species affected, their habitat range, minimum criteria to be addressed by reproduction, minimum population, etc.

In total, the dominating pressures in a combined inventory are climate impacts (including hydrological changes), chemicals, fragmentation, biological and genetic pollution and overuse, each mentioned at least twice in the lists above. They define the necessary priorities for biodiversity protection policies.

The generation of such pressures is neither intentional nor incidental, but the result of ongoing socioeconomic processes and policies. In the majority of cases, the negative impact on biodiversity has been detected too late (or not at all) and has been dealt with by suggesting additive measures for biodiversity protection instead of questioning the basic drivers causing these pressures. However, with the current process of biodiversity mainstreaming, such an approach is no longer sufficient to reach the policy objectives set on the global and–even more ambitious–on the EU level. So the next step of analysis aims at identifying the drivers behind the pressures to be able to modify them in order to reliable achieve a permanent reduction of the pressures. This also permits to integrate biodiversity protection into the overall EU sustainability policies.

Combining driver analysis with bottom-up and top-down, forecasting and backcasting scenario techniques, decision support can then be provided to all relevant levels of decision-making and for all relevant sectors.[6]

4. Driving forces: accounting for the causes

Based on an analysis of the national environmental and sustainability strategies published by EU member states, environmental problems commonplace in almost all EU 25 countries were identified (Lorek and Spangenberg, 2001). With climate change, acidification, eutrophication and coastal and inland water pollution, they include the pressures identified as relevant for biodiversity losses (see the left column in Table 1). Other shared concerns like waste problems, health risks and the depletion of natural resources (for an overview, see Grunwald et al., 2001) are not dealt with here, as they have a relatively minor impact on biodiversity as compared to the factors identified above.

Comparative modelling studies come to similar results, e.g., Sala et al. (2000) who have estimated the relative importance of different pressures for a number of scenarios. For Europe as a region without tropic and desert areas, land use change, climate, nitrogen deposition from intensive land use and energy consumption, atmospheric CO_2 and invasive species (called biotic exchange) play a major role for terrestrial ecosystems, while the latter is a key factor for aquatic systems. All these drivers will affect most European ecosystems simultaneously, with synergistic and non-linear interactions of uncertain or at least so far unknown consequences for biodiversity. Although for most of these problems, strategies to moderate their effects have been developed, for some, e.g., for land degradation and greenhouse gas emissions, they have had little effect so far (Jänicke and Volkery, 2001, 2002). At least partly this is due to the failure to develop effective long-term structural solutions instead of only short-term curative treatment.

The right hand column in Table 1 identifies the physical driving forces, causing the problems in the left hand column. Intensive land use, high energy consumption based on fossil fuels and environmental chemicals/massive material flows

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[6] Each level or sector requires a specific contextualisation (the following analysis is dedicated to support public policies at the EU level; in a comparable manner, it could have been done for the national level or for business sectors) and an adequate methodology mix.

Table 1 – The driving forces behind biodiversity loss: pressures in Europe by frequency of being mentioned in national sustainability and environment reports

Pressure	Source	Driving force
Climate change: temperatures, precipitation patterns, evapotranspiration rates, etc.	CO_2 originates when organic materials are oxidised, mainly by burning fossil energy carriers.	Energy consumption
	N_2O (nitrous oxide) originates from few industrial processes, but mainly from agriculture, often due to over-fertilisation.	Land use intensity
	CH_4 (methane) is emitted from rice paddies, cattle breeding and–dominant in EU countries–from waste dumps.	Land use intensity Material flows
Increasing UV-B radiation due to ozone depletion	Ozone depletion is mainly caused by CFC emissions, phased out in most of Europe. Still there are more CFCs stored in products than have been released to the atmosphere so far.	Environmental chemicals (in the EU, CFC emission is a solved problem, but not the release from the stock).
	Methylbromide is mainly used in intensive agriculture.	Land use intensity
Acidification	Acidification is caused by the immission of sulphur dioxide SO_2, ammonium NH_4 and nitrogen oxides NO_x.	Environmental chemicals
	SO_2 originates mainly from the incineration of sulphur containing coal and crude oil but has diminished significantly.	Energy consumption
	NH_4 originates from livestock production and manure management in intensive agriculture.	Land use intensity
	NO_x (NO and NO_2) originate spontaneously with each high-temperature energy release (incineration, industrial processes, fossil fuel motors, etc.).	Energy consumption
Eutrophication	Eutrophication is caused by the immission of bio-accessible phosphorus and nitrogen into terrestrial and limnic ecosystems. Today phosphates mainly originate from agriculture, where they are used as fertiliser.	Land use intensity
	Nitrate is emitted through mineral as well as organic fertilisation in intensive agriculture.	Land use intensity
Chemical pollution	Long-range air pollutants	Energy consumption
	Persistent, bioaccumulative, toxic (PBT) persistent organic pollutants (POPs)	
	• Pesticides like aldrin or dieldrin, linden (ãHCH) and PCP	Land use intensity
	• Industrial compounds like PCBs or brominated flame retardants	Dissipative chemicals use
	• Unintended by-products like dioxins, furans and PAHs	Chemicals production
	Heavy metals and organic compounds (including lead from gasoline or mercury from coal incineration)	Energy consumption, mining material flows
	Other pesticides/biocides other than POPs	Land use intensity
	Petroleum products other than POPs	Energy consumption
	Endocrine disruptors	Consumption and waste generation
Biological GMO pollution and biological invasions	Accidental, deliberate or residual release of GMOs with the subsequent establishment of modified organisms or of modified DNA in natural populations.	GMO production, trade and release
	The mostly unintended introduction of foreign species as a result of global trade, and the establishing of new genes or new combinations of genes in populations as a result of the deliberate release of GMOs.	Global trade
Coastal zone and inland water pollution	The pollution of coastal and inland waters from industrial effluents and municipal waste water has been significantly reduced in Europe. The main source of water pollution today is the run off from intensive agriculture (plus some acidifying inputs from long range air pollution).	Land use intensity
	Coastal eutrophication leads to diatoms' growth, thus reducing silicon concentrations, which combined with high nitrogen and phosphorus levels in turn creates conditions for toxic algae blooms of dinoflagellates and cyanobacteria.	Energy consumption Land use planning Land use intensity
Habitat fragmentation	Reduction of biotope size and fragmentation by infrastructure development (settlement area, transport infrastructure, energy, water and information transport), and large-scale agriculture. Another factor reducing biodiversity is the canalisation of streams and rivers, destroying important breeding grounds.	
Human exploitation	Hunting, grazing, ranching, forest farming, intensive agriculture, infrastructure construction for housing, production and mobility	Land use planning and intensity, mobility
	Logging for construction and heating	Material flows, energy consumption

(continued on next page)

Table 1 *(continued)*

Pressure	Source	Driving force
	Water logging to make land suitable for agriculture or to use the water elsewhere, predominantly for irrigation agriculture, resulting in disturbed hydrological regimes.	Land use intensity
Ecosystem disruption	Overexploitation of biodiversity and/or its biophysical basis by logging, hunting, etc., disturbed hydrological regimes from water abstraction and retention system degradation	Lack of regulation and monitoring
System fragmentation, habitat size reduction	Fragmentation of ecosystems by use patterns and infrastructure development (settlement areas, transport infrastructure, agriculture)	Land use planning

Sources: Lorek and Spangenberg (2001), modified, Maxim, Vighi (2004). Land use intensity distinguishes between protected, cultivated, intensively exploited and anthropogenic land (sealed soil).

and location (fragmentation)/translocation (release, invasions) are behind most of the pressures described in the previous section. The total permissible consumption of resources in the former three categories has been called the 'available environmental space' (Weterings and Opschoor, 1992; Spangenberg, 2002), with an overshot in resource consumption resulting in a level of pressure causing serious environmental damages, including biodiversity loss. Obviously, unless these long-term primary driving forces of environmental degradation, plus the issues related to location/translocation, are directly addressed by altering the underlying socioeconomic development trajectory, i.e., the policies (secondary drivers) and structures (tertiary drivers), only limited progress is to be expected: after a possible reduction due to curative measures, the problems tend to resurface again. The threats these quantitative factors pose for biodiversity processes and components gives another reason to reduce the throughput of industrialised economies and to stabilise it on a sustainable level (Georgescu-Roegen, 1976), with the economy in a physical steady state (Daly, 1991). Fig. 1 illustrates the hierarchical structure of the problem.[7]

Although reductions in resource flows will not in all cases decrease the environmental pressures proportionally, it is a directionally secure environmental objective as once the primary drivers were significantly reduced, so the pressures would be, although to a varying degree. If the input of raw materials (including energy carriers), e.g., by a factor 4 or 10 (Schmidt-Bleek, 1994; von Weizsäcker et al., 1997; Hawken et al., 1999) were achieved, this 'physical slimming' of the economy would ceteris paribus reduce environmental pressures on the output side, thus driving back the resource consumption into the limits of the available environmental space (which by definition implies that the pressures are below the carrying capacity thresholds of the systems affected).

Rather obviously, such a reduction of resource consumption cannot be achieved without effective policies (secondary driver in Fig. 1) aiming at significant changes in production technology and organisation of product use and reuse as tertiary drivers, i.e., a transition to sustainable production and consumption patterns (Lorek and Spangenberg, 2001; Reisch and Røpke, 2004). This requires significant investments into new production, distribution, redistribution and reprocessing infrastructure. The resulting acceleration of technological change provides additional opportunities to pay due respect to the biological effects of production and consumption, by attaching a higher weight to such concerns when designing the new solutions.

The same holds true for the pressures caused by location/translocation: reducing them requires adequate policies (land use planning, chemical and GMO regulations, trade policy), which are essential qualitative aspects of any dematerialisation policy.

5. Discussion

There is growing evidence that ecosystems, and indeed the earth system as a whole have in the past and could again flip into different modes of operation through the influence of intrinsic and extrinsic factors. Stabilisation of ecosystems facing changing environmental conditions by strengthening their responsiveness, resilience and adaptation capacity through preserving biodiversity might provide safeguards against some of the positive feedback loops and help to moderate the system changes, even contribute to avoiding such flips.

For this behalf, biodiversity protection should be integrated into and harmonised with overall environmental policy and monitoring. Obviously, as for any identification of key pressures, the analysis must be adequately scaled to reflect the impacts on the objects under consideration; in this case, it must reflect the three levels of biodiversity. However, when trying to derive policy priorities, the appropriate level is no longer the habitat, but the level of national and European politics. Only on this level–if at all–it is possible to modify past decisions and to change unsustainable socioeconomic trends

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[7] According to the usual classification, socioeconomic drivers include physical or primary ones, which in turn result in pressures causing impacts and provoking responses. This view, however, is double flawed: on the one hand, in complex systems, the assumed causalities are hard to identify, like for environmental chemicals. On the other, the structure described is a narrative, a choice of the observer, for instance an economist's reality. From a bioscience point of view, biodiversity loss may appear to be a driver, resulting in pressures on the socioeconomic system and impacts (economic losses, health problems, etc.) leading to policy responses. Both views combined result in the more realistic, complex model of a cause-effect-cycle as indicated on the right hand side of Fig. 1.

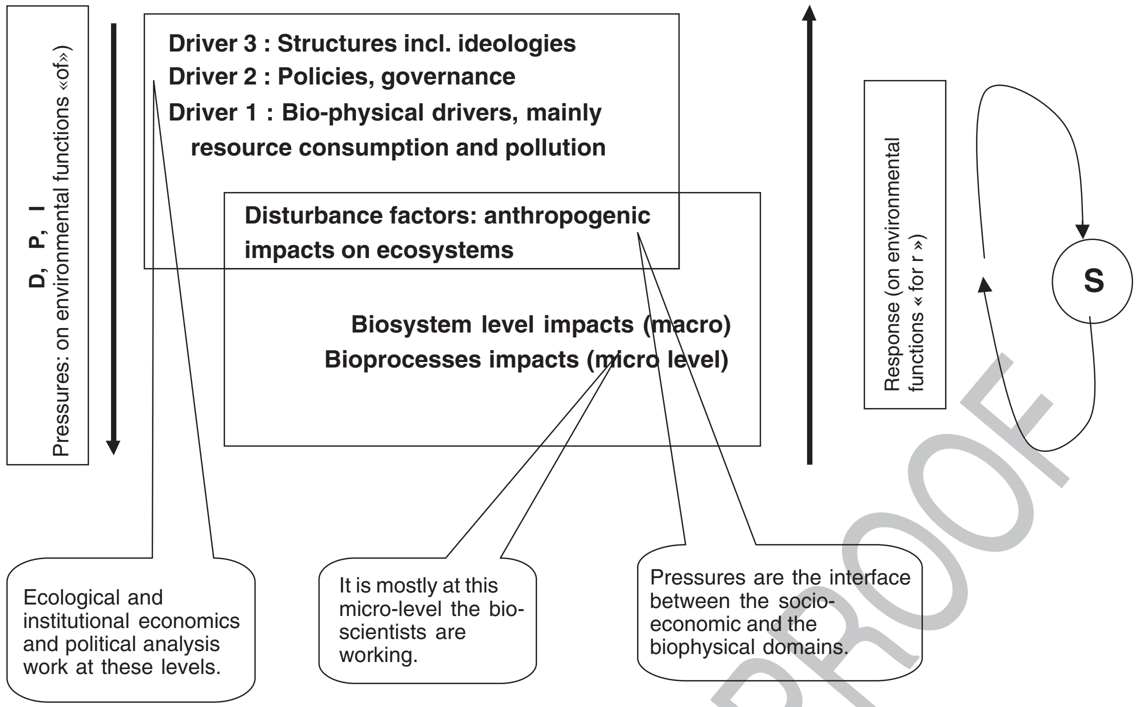

Fig. 1 – Pressures and drivers: structuring the levels of analysis.

affecting not only biodiversity, but a range of other environmental and sustainability objectives, thus mainstreaming biodiversity protection. This calls for an integrated approach to decision-making, combining a reduction of pressure factors originating from resource input quantity and output quality (toxicity or the spatial structures of land use, see Table 2).

From a political perspective, the primary driving forces causing the pressures on biological diversity and the politics shaping them as secondary drivers are

- The transformation of areas from a protected or otherwise unused status to grazing or other low intensity use, and further on to high intensity use like modern agriculture on rather homogenous areas, or large-scale age–class forests managed by clear cutting, and further to infrastructure construction, i.e., sealed soil. The main European policies affecting these trends are the Common Agricultural Policy CAP, and the Structural, Regional and Cohesion Funds; the intensive use of toxic chemicals is part of the resulting impacts.
- Biotope fragmentation and size reduction by new infrastructure, or by changed agricultural land use patterns. Besides the CAP and the Funds, infrastructure construction for the Trans European Networks TEN plays a role here.
- Economic growth, if resulting in high and non-declining material and energy consumption, including combustion processes and the release of chemicals and GMOs. This orientation is at the heart of the EU Lisbon Strategy, which in its revised version ever more calls for sustained growth with social and environmental objectives considered a result, not a precondition of growth. The effects are moderated by other EU legislation like the GMO directives, the new chemicals control system REACH, the new emissions trading scheme or the biocides directive despite the current trend of watering down most of these regulations.
- International trade and tourism as sources of pollutants and gateways for invasive species, often 'imported' by shipments, either intentionally as commercial goods, as pets or for bioregulation purposes, or as biological 'pollutants' of imported goods and their carriers, also alongside roads and canals, and by air transport. Trade policy is a EU domain and again the CAP plays a role here.[8]
- Water pollution, coastal damages and changing hydrological regimes have a wide range of reasons, which are dealt with by the EU. E.g., through the water framework directive now being implemented.

Additional policy responses include high level product and production standards like those foreseen under the EU Integrated Product Policy (IPP) Directive, precaution against disturbances of hydrological regimes under the new Water

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[8] On the global scale, the EU must also be held responsible for its performance in international bodies. Regarding its role as a frontrunner in promoting biodiversity protection standards on the global level, the UN Summit 2002 or the CBD negotiations have been positive examples, but less so the rather limited efforts to redirect institutions like IMF, World Bank and the WTO to implement such regulations into their rules and procedures, and to stop all policies contradicting these objectives. While the readiness of the World Bank to learn some late lessons from past experience and modify their structural adjustment programs, plus the intention to increase the support for renewable energies is reason for some hope in this respect, its inertia in implementing new objectives, the reluctance to phase out fossil fuel investments and even more so the political sclerosis of the IMF illustrate the need for political interventions (on the limits to reform, see, e.g., Ellerman, 2005).

Table 2 – Quantitative and qualitative objectives

Physical, primary drivers	Institutional mechanisms: secondary drivers		Institutional orientations: tertiary drivers	
Driving forces (from Table 1)	Recommended policy initiatives	Relevant EU legislation	Quantitative objectives	Qualitative objectives
Energy consumption	Minimum energy tax agreement, EU energy taxation, kerosene taxation, analysis of trade offs	Eco label, emission trade scheme, subsidies for biofuels	Energy saving	Decarbonisation (within limits due to trade-offs with land use intensity), reducing Hg, NO_x, SO_2, CO_2, etc.
Material flows	Harmonised material flow accounting and taxation, chemicals regulation for small volumes of bioactive substances	Waste directives, REACH; for endocrine disruptors (EDC) and nanoparticles research, but no regulation	Dematerialisation (input), release prevention (output)	Detoxification
Land use planning and intensity, location	Maximum inputs for agriculture, sustainability standards for forestry, standard enforcement in fisheries, integrated assessment of TENs, detailed evaluation of structural funds use	Revised CAP, delinking income and output volumes, support for organic agriculture, sustainability criteria in the structural funds, integrated assessment, Natura 2000 protected areas	De-intensification of agriculture and forestry	Stop habitat fragmentation: no extension of built-up area, bundle-planning, safeguarding species reproduction throughout the landscape, extended nature protection networks increasing the virtual habitat size
Chemicals and GMOs production, trade and release, translocation	Maintaining the moratorium on deliberate releases of GMOs, developing special regulations for pseudo-hormones, etc.	REACH for chemicals, watered down but still progress; deficits regarding small volumes and the degradation products of chemicals	Minimised emissions of chemicals, zero limit for GMOs capable of surviving, enforcing the biosafety protocol	Reversible effects of chemicals, no use of GMOs which can cross-fertilise with endogenous species
Global trade and tourism, organism translocation	Compulsory ship water tank cleaning and air borne monitoring at sea, tourist information, border controls at airports, extended bio-monitoring and appropriate bio-waste treatment	Tourist information, CITES legislation and border controls, cooperation in the World Maritime Organisation WMO for standards	Minimising the import of potentially invasive species	Minimising the establishment of potentially invasive species in European habitats
Overexploitation of biodiversity and/or its biophysical base	Reduce land use intensity	CAP reform	Halting the loss of biodiversity in Europe be the year 2010	Maintaining the reproductive capabilities of the biophysical systems
	Limit fisheries	Quota (insufficient)		
	Reduce fragmentation	Funds reform		

Source: own compilation, with orientations designed to reduce primary drivers and mechanisms from current EU politics; plus plans and recommendations from various stakeholders.

Directive, and extended consumer rights in the framework of the new EU consumer policy.

Two issues specific to biodiversity, habitat fragmentation and biological pollution, deserve a closer look. *Habitat fragmentation* is the major cause of species extinction today and one of the most important human interventions into natural ecosystems (Muradian, 2001). Although there is no linear relationship between habitat size and diversity, given the existing pressures on biodiversity, no additional subdivision of larger habitats into smaller pieces should be accepted. To the contrary: while it may be hard to create large undisturbed areas, setting up networks to link existing protected areas is of foremost importance for biodiversity, combined with de-intensification of land use throughout the landscape (which would emerge as a result of land use deintensification). Such measures not only increase the virtual and real size of habitats, but also create the conditions for species and ecosystem migration biological communities will need to adapt to climate change. The urgency of such supportive measures is illustrated by the fact that changes in flowering periods and regional distribution patterns of insects are already abundant. The resulting demand to the policy process is again obvious: regional planning should establish unfragmented habitats by adequate land use planning, for instance bundling together anthropogenic infrastructure like roads, railways and distribution systems for gas, water, electricity and the like, by preventing urban sprawl through suitable planning and pricing mechanisms, and by agricultural practices respecting habitat structures.

For *biological pollution*, the necessary policy priorities are similarly obvious: global transport is in urgent need of biological quality and safety standards minimising the scope and frequency of biological invasions. Such targeted measures should be implemented with all possible rigour. So far however, safety concerns have rather been perceived as obstacles to free trade and avoided whenever possible. Technical standards can do a lot, contributing to a modernisation of the global shipping fleet, an attempt worthwhile to follow for other concerns like reducing oil spills as well. Genetic pollution is not easy to detect, and so far appropriate legislation is still missing. However, if with improving detection methods full producer responsibility were introduced (the *polluter pays principle*), a higher level of caution could be expected among biocorporations from the very beginning.

6. Conclusion

Biodiversity conservation can and should be integrated with broad environmental and sustainability strategies. For effective damage mitigation and successful transition management, these cannot be restricted to just one policy area, but have to cover a broad range of policy domains in a systematic fashion (Kemp et al., 2005). For the European Union, this could be achieved if the revised EU Sustainable Development Strategy (EUSDS II), which already includes biodiversity preservation, would effectively gain the recognition as a basic policy document to which individual policies, including the revised Lisbon Strategy, must confirm. Unfortunately, elaborating such a systematic approach goes well beyond the scope of this paper.

On the operational level, beyond the existing legal, planning, economic and informational instruments, a number of innovative tools are currently being tested, such as integrated assessment for all European legislation and compulsory risk inventories (e.g., in the REACH program). Rather than hoping for a "silver bullet" like tradable permits, liberalised markets or ecotaxes, systematically combining the instruments offers the best chance for success: a broad transition strategy can hardly give up on any effective instrument.

When using mixed sets of policy tools, as a rule of thumb, measures aimed at specific product qualities should be enforced by legally binding norms best enacted through more or less case specific command-and-control policies (or binding voluntary agreements of the "agree-and-control" kind). This includes bans for particularly risky substances, like for the "dirty dozen" of high risk pesticides, and adequate regulation for the production and use of other substances, like biocides, but also including the production and use, e.g., of sensitising substances and endocrine disruptors, motivated by human and environmental health and safety concerns and based on the precautionary principle.

Volume reductions are rather unspecific and best approached by similarly unspecific means, i.e., by general taxes on energy consumption, material flows and land use intensity (Omann and Schwerd, 2003). In particularly the latter, taxing material flows and land rents is an approach seriously undervalued in political decision-making so far, despite the considerable potential available for taxing excess profits (Bosquet, 2000).

Despite the fact that the main driving forces and the corresponding policy necessary for large-scale biodiversity protection can be clearly named (Table 2), policy responses so far have been ineffective at best. One reason is the predominant focus on qualitative problems like the effects of individual chemicals and the end-of-the-pipe solutions sought to solve them, ignoring the quantitative challenge of total resource consumption exceeding the limits of the available environmental space. Today, it is imperative not only to modify progress towards 'ecological modernisation', but to restructure the 'treadmill of production' (Schnaiberg et al., 2002), i.e., induce structural changes of the economy as a whole according to sustainability criteria.[9]

7. Uncited references

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MNP Netherlands Environmental Assessment Agency, 2004

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[9] A second reason is that the economists' neglect of non-market values has taken over decision making in politics. As a result, the *economic value* of each product as given by the market is well taken into account, whereas the *social and the environmental value* are largely ignored. This holds true in particular for *intangible assets*; the complexity of living systems on all organisational levels is such an intangible asset.

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