Wissel, Silvia; Wätzold, Frank

Working Paper

Applying tradable permits to biodiversity conservation: A conceptual analysis of trading rules

UFZ-Diskussionspapiere, No. 7/2008

Provided in Cooperation with:
Helmholtz Centre for Environmental Research (UFZ)

UFZ-Diskussionspapiere

Department of Economics

7/2008

Applying tradable permits to biodiversity conservation: A conceptual analysis of trading rules

Silvia Wissel, Frank Wätzold

September 2008

Herausgeber:
Helmholtz-Zentrum für Umweltforschung GmbH - UFZ
Permoserstr. 15
04318 Leipzig

ISSN 1436-140X

Applying tradable permits to biodiversity conservation: A conceptual analysis of trading rules

Silvia Wissel and Frank Wätzold**

September 2008

* Helmholtz Centre for Environmental Research - UFZ
Department of Economics
Permoserstraße 15
04318 Leipzig
Germany

Corresponding author: Silvia Wissel
Email: silvia.wissel@ufz.de

Abstract

Tradable permits have already been applied in many areas of environmental policy and may be a possible response to increasing calls for flexible conservation instruments which are able to successfully conserve biodiversity while allowing for economic development. The idea behind applying tradable permits to conservation is that developers wishing to turn land to economic purposes, thereby destroying valuable habitat, may only do so if they submit a permit to the conservation agency showing that habitat of at least the equivalent ecological value is restored elsewhere. The developer himself does not need to carry out the restoration, but may buy a permit from a third party thus allowing a market to emerge. However, applying tradable permits to biodiversity conservation is a complex issue, because destroyed and restored habitats are likely to differ. The purpose of this essay is to discuss on a conceptual level the consequences of these differences along the dimensions of type, space and time for the design of trading rules. We consider the resulting effects on trading activity in the permit market and the cost-effectiveness as well as the ecological effectiveness of the scheme. We find various trade-offs with regard to market activity, cost-effectiveness, ecological effectiveness and transaction costs.

Key words:

Tradable permits, conservation policy, cost-effectiveness, habitat banking, economic development, land use, market based instruments

1. Introduction

Over the past number of decades the continuous destruction of habitats through land use changes caused by economic development has been one of the main reasons for loss of biodiversity (Millennium Ecosystem Assessment 2005). Conservation policies have responded to this threat by permanently designating certain areas for conservation and leaving other areas for economic development. This policy has in many cases helped to conserve biodiversity. However, it has also become obvious that such a static approach has its limits.

Conservation agencies may not have allocated areas cost-effectively (e.g. Ando et al. 1998; Polasky et al. 2008), i.e. designated those areas as habitats for endangered species where conservation aims can be achieved at least costs (costs are understood here as opportunity costs of foregone economic development) (Naidoo et al. 2006). Neglecting the criterion of cost-effectiveness means that scarce financial resources are being wasted that could be used by society for other purposes – including more conservation (Shogren et al. 1999). Conservation policies also risk losing public support if they are considered wasteful (Wätzold & Schwerdtner 2005).

But even if the allocation of land for purposes of conservation and economic development was once cost-effective, the costs of using land for conservation may have changed in a spatially heterogeneous manner over time (Armsworth et al. 2006). As a consequence a previously cost-effective allocation of land may not be cost-effective anymore (Hartig & Drechsler 2008).

A static approach is unable to remedy such violations of the criterion of cost-effectiveness which would require a reallocation of land in the sense that some conservation area is turned back into land for economic development and some part of developed land is again used for conservation. Ecological research indicates that a reallocation of land is feasible under certain conditions as some species are resilient to land use changes and can adapt to small scale disturbances (e.g. Opdam et al. 2006).

However, implementing reallocation of land on the basis of a top-down approach would require an agency to have a high level of information about conservation costs and their changes over time. Furthermore, the agency needs to be in a strong political position. Changing restrictions on the economic development of land implies changes in land prices and is therefore prone to lobbying by interest groups (Drechsler & Wätzold 2009).

Tradable permits, which have been applied in many other areas of environmental policy (OECD 1999; Hansjürgens et al. 2005; Tietenberg 2006), may be a flexible alternative to a top-down approach of changing development restrictions by the conservation agency. The idea of applying tradable permits to conservation is that a developer who wishes to turn land to economic purposes, thereby destroying valuable habitat, may only do so after submitting a permit to the conservation agency. A permit can be gained by restoring habitat of at least the equivalent ecological value elsewhere, but within a certain pre-defined area. Consequently, the overall ecological value in this area remains the same, i.e. the ecological effectiveness of the instrument is ensured. The developer is not required to carry out the restoration, but can buy a permit from a third party. This regulation allows a new market to emerge.

Owners of land on which the costs of conservation are low have an incentive to restore valuable habitats, since they can sell the resulting permits on the market. Owners of land on which conservation is expensive because of foregone benefits of economically developing the land have an incentive to realize these benefits and buy the permits. Hence, in principle, permit markets provide an incentive for landowners to designate their land in such a way that a cost-effective allocation of land use types emerges.

These general reflections on the cost-effectiveness and ecological effectiveness of tradable permits, however, only hold in the unlikely case that the destroyed and restored habitat is identical. Following Salzman and Ruhl (2000) differences in destroyed and restored habitats may arise along the dimensions of type (restored and destroyed habitat provide functional values to different species), space (configuration and connectivity of sites matters) and time (restoration of habitat requires time leading to increased vulnerability).

The purpose of this essay is to discuss on a conceptual level the consequences of differences between destroyed and restored habitats in terms of type, space and time for the design of trading rules. We consider resulting effects on the trading activity and the cost-effectiveness as well as the ecological effectiveness of the scheme and find various trade-offs concerning market activity, cost-effectiveness, ecological effectiveness and transaction costs.

Such conceptual reflections may contribute to a better assessment of existing conservation policies which exhibit some similarities with tradable permit systems (see for Conservation Banking in the USA: Fox & Nino-Murcia 2005; for Eco-accounts in context of the Impact Mitigation Principle in Germany: Köck et al. 2005; and for the Brazil Forest Trade: Chomitz 2004). As there is an increasing trend towards implementing permit schemes for biodiversity conservation (see e.g. the recently implemented Australian BioBanking Scheme (Department of Environment and Climate Change 2008), Biobanking in Malaysia (Malua BioBank 2008), and the EU Green Paper on Market Based Instruments (Commission of the European Communities 2007)) conceptual reflections may also be helpful for the design of new policies.

Without considering any specific existing policy we start by explaining the basic idea of applying tradable permits to biodiversity conservation. It is pointed out that a certain trading activity is required for functioning permit markets, and the factors that impact on trading activity are identified. There follows a discussion of the consequences of differences between destroyed and restored habitats along the dimensions of type, space and time for the design of trading rules. We conclude that trade-offs with regard to market activity, cost-effectiveness, ecological effectiveness and transaction costs exist and outline requirements for further research.

2. Functioning of a permit scheme

The basic idea of applying tradable permits to biodiversity conservation is that particular sites may be destroyed and used for economic development as long as developers can submit a “permit” to a regulatory authority. Landowners can generate permits by restoring habitats within the region. Permits are tradable on the market and trading rules should ensure that the conservation value of the destroyed site and the conservation value of the restored site are equivalent, so that the overall conservation value of the region cannot decline.

To be able to compare the ecological value of a destroyed and restored site an exchange unit is required which measures the ecological value of a site and its contribution to the overall ecological value in the region. For this purpose, the conservation objective needs to be specified: e.g. minimizing extinction risks of selected species or maximizing coverage of species. Depending on how these objectives are chosen, the contribution of individual sites to maintaining the overall ecological value may differ (cf. Nicholson & Possingham 2006).

Depending on the exchange unit used to determine the value of a site, different degrees of complexity are exhibited. A rather simple exchange unit is area. This is easy to measure, but has the disadvantage of being only a rough measure of conservation value because it neglects factors such as connectivity with other sites, which influences the suitability of a habitat for species (cf. Briers 2002). An example of a more accurate exchange unit, but one that is also more difficult to measure, is the contribution of a site to a change in the extinction risk of a species (see also the discussion on surrogates in e.g. Rodrigues & Brooks 2007; Cabeza et al. 2008).

Demand for permits may arise from private firms, e.g. for developing industrial parks and from government agencies, e.g. for infrastructure projects such as new roads. Another source of demand may be private individuals or conservation groups who do not use their permits for development purposes but keep them, thereby enhancing the ecological value in a region.

Supply of permits may come from private landowners such as farmers and forest owners, but also from state authorities and conservation groups in possession of land. If suppliers specialize in the creation of ecological value, cost savings and quality improvements through learning effects and economies of scale are likely.

Permit markets can be designed in such a way that the conservation value of a region is enhanced. Next to the possibility that conservation groups buy permits and do not use them for economic development, trading rules can induce such an effect by requiring that the destruction of habitat of a certain conservation value requires permits that reflect the restoration of habitat of a larger value.

Tradable permit markets are artificially created through the establishment of rights and permits (Montgomery 1972). There are several possibilities for the initial allocation of rights and permits. Similar to the grandfathering approach in emissions trading, one possible initial allocation is based on the existing allocation of land for economic development. The owners are given the right to continue with the existing land use and no permits are needed for the land already used for economic purposes.

In contrast, no landowner is granted the right to use his land for economic development without acquiring a permit. Initially, permits may be allocated through auctions. A landowner who does not obtain a permit is required to stop economic development on his land and use the land for conservation. An auction might only take place during the first round, the subsequent allocations are organized via trading of permits.

A third alternative is to require each landowner to maintain a certain percentage of his land for conservation while allocating him the right to develop the rest of the land. Each unit of land entitles to a certain amount of permits for economic development, but also implies the obligation to submit a certain amount of permits. Depending on the share of the land between conservation and economic development, landowners have either a permit deficit – implying that they have to buy permits or restore habitat – or a permit surplus – implying that they can economically develop parts of their land or sell these permits on the market.

These initial allocations have different distributional consequences. In the case of grandfathering, owners of land used for economic development do not have to pay for permits, whereas auctioning requires payments for past development and consequently generates additional revenue for the government. Obligations according to a certain percentage requirement imply a form of redistribution from owners who have previously caused negative ecological impacts by developing their land, to those who kept their land in a way valuable for conservation.

In the introductory phase of the scheme, auctioning and initial allocations based on the size of land might lead to higher transaction costs than grandfathering, since each landowner has to have sufficient permits for his land. However, these obligations automatically initiate a certain market activity. If preexisting tax distortions are taken into account, auctioning has the advantage that revenues generated from auctioning can be used to reduce distorting taxes in factor markets and, hence, can increase the efficiency of the tax system (Goulder et al. 1997). This is similar to the idea of "double dividends" from environmental taxes where tax revenues are employed to reduce distortionary taxes (Parry et al. 1999).

A regulatory authority is necessary for a functioning permit scheme. One important task of such an authority is to design the rules that determine which habitats are exchangeable and to assess the value of destroyed and created habitats according to these rules. Furthermore, the authority would be responsible for monitoring and enforcement activities which are essential for a functioning market and to ensure that the conservation target is met.

3. Challenges for applying tradable permits to conservation

Permit markets function best if the environmental impacts of the damaging and the compensating activity can be easily quantified and compared. For example, the contribution of burning fossil fuels to the greenhouse effect can be measured in units of CO_2 emissions and the impact of CO_2 is independent of the location and (within limits) the time of its emission, hence comparison is easy. This, however, is different for habitats.

Salzman and Ruhl (2000) identify three important dimensions in which destroyed and created habitat sites may differ: Type (the restored and destroyed site may provide functional values to different species and life stages); space (the destroyed habitat may have been part of a contiguous habitat system for species, whereas the restored habitat may be isolated and thus of less value); and time (species need time to colonize, time lags between destruction and recreation increase vulnerability). Habitats also perform ecosystem functions to different extents, e.g. as places for human recreation and watersheds. However, here we focus on biodiversity conservation only.

Strict requirements in terms of identity of destroyed and restored habitats imply fewer opportunities for restoring habitats and, hence, less active permit markets. However, functioning markets require a certain trading activity. We develop this argument in the next section, and afterwards analyze the implications of habitat differences in terms of type, space and time.

3.1 Market activity

A certain level of market activity is essential for a functioning market. Large markets with a significant number of participants and high trading activities facilitate finding the adequate market partner, implying lower information costs for market participants. Markets with low trading activity increase the uncertainty of permit price developments. False price signals may be the outcome, resulting in wrong decisions about land development (Baron 1999). In extreme cases an expected lack of demand may deter investors who restore habitat from participating in the market, leading to a market collapse (e.g. Panayotou 1994).

Another problem in markets with low trading activity may be market power. Market power exists when a firm can exert an influence on the permit price, which may arise when it holds a large market share (Hahn 1984). On the supply side, market power arises if a firm is able to raise prices above the competitive level. This may lead to a welfare loss if the price increase is high enough to deter economic development that would have taken place given a competitive market price for permits. However, prices can only be raised up to a certain level, namely, the costs an economic developer would incur to restore a habitat on his own (Mead 2008).

On the demand side a dominant firm, e.g. a large-scale investor for a business park being the only developer in a region, might be able to push the price for permits below the competitive level by determining the quantity of demand. Such a situation is unlikely as long as landowners have alternatives for using their land (e.g. for agriculture).

Market activity depends on several factors. Of the factors mentioned below the first two are determined exogenously. Decisions about instrument design may have an influence on the remaining factors:

1. Economic development: In regions with little economic growth the demand for tradable permits will be low, reducing the frequency of transactions.

2. Differences in opportunity costs: If opportunity costs of conservation are equal among sites there is no incentive to trade. The higher the differences, the more gains from trading can be realized.

3. Combination of tradable permits with regulation: Additional regulation may restrict trading opportunities, e.g. regulation may prescribe a minimum density of conservation area on each landowner's site and permits for developing land economically can only be used when this density is secured (see Staehelin-Witt and Spillmann (1994) for a case where implementing an emissions trading scheme on top of regulation failed because the regulation was so strict that no trading developed).

4. Regional size of the market: A larger regional size is likely to lead to higher opportunity-cost differences and, hence, higher trading activities (cf. Newell & Stavins 2003; Chomitz 2004).

5. Exchange requirements: The more specific the requirements for habitat to be exchangeable the less trading activities can be expected.

6. Transaction costs of market exchange: High transaction costs may arise as a result of complicated and time-consuming administrative procedures. Furthermore, if there is no transparency about market prices transactions might be accompanied by costly bargaining. High transaction costs may reduce market activity.

In summary, large markets with high trading activity are preferable. However, when designing tradable permit schemes other aspects need to be considered to which we now turn.

3.2. Type

Here the "habitat type" of a site refers to its suitability for particular species. Habitats are of the same type if they provide the same functional values to a group of species at a certain life stage. If the objective is to maintain the status quo of extinction risks for all species, trade between habitats of the same type is unproblematic, but trade between different types of habitats is bound to violate this target. However, there are arguments for trade between habitat types under certain circumstances.

Habitat types may differ in terms of scarcity so that some species are more endangered than others. If conservation objectives are directed at particularly endangered species, the regulator can create incentives to restore scarce habitat types by determining adequate trading ratios. If, for example, grassland species are more endangered than forest species the regulator may prefer to promote the restoration of grasslands rather than forests. If the trading ratio between a grassland unit and a forest unit is greater than the ratio of costs of restoring a grassland unit and the costs of restoring a forest unit, there will be an incentive to create grasslands rather than forests.

There is a certain risk that the trading ratio does not provide the correct signals with the implication that the scheme ceases to be ecologically effective. For example, the regulator might not be correctly informed of the costs of restoring different habitat types and hence might determine a "wrong" ratio. Costs may also change over time implying the risk that a trading ratio that once provided the correct scarcity signals may not do this anymore.

To avoid the risk that an already scarce habitat becomes even more scarce, trade may only be allowed in one direction. Destroying habitat of the less scarce type may be compensated by restoring all types of habitat, but destroying the scarce habitat type can only be compensated through restoring the same habitat type. In the example given above, the destruction of forests might be compensated by the restoration of grasslands and forests, but the destruction of grassland by the restoration of grassland only.

To ensure that such trading does not lead to a critical loss of habitat for species not currently endangered, a minimum amount of each habitat type might be determined. If this level is reached, trading between habitats would not be allowed or would only be allowed in one direction to secure that the amount of habitat does not go below the critical level.

A more complex way of taking into account the changing levels of scarcity of habitat types is to constantly adjust trading ratios to scarcities. A disadvantage of such a flexible adjustment is the uncertainty for market participants about future values of their land in terms of developing it for conservation. Such a complex regulation also increases transaction costs, here in particular the information a regulator has to acquire about changes in the scarcity of habitat types and the effects of trading ratios on landowners' behaviour.

An advantage of allowing trade between different habitat types is that it leads to larger markets which may generate a higher level of cost-effectiveness and all the positive aspects that arise from increased market activity.

3.3 Space

The survival probability of a species depends not only on the overall habitat size, but also on the configuration of sites, as well as the distance and connectivity between them (Fahrig 2003). Ecological theory shows that for many species connected habitat sites are more valuable than isolated ones, because species can migrate between sites, facilitating recolonization of sites in which a population has become extinct (Hanski 1998). This means that the ecological value of sites is space dependent, i.e. it depends on the location of other habitats. When the spatial dimension is neglected in the design of trading rules, resulting configurations are likely to be less cost-effective than with rules that take into account the spatial dimension (Hartig & Drechsler 2008).

Given that – everything else being equal – neighboring sites tend to have a higher ecological value than isolated ones, there is a straightforward possibility to include spatial interdependencies in trading rules: The restoration of a habitat site in the neighborhood of other habitats leads to a higher valued permit than the restoration of an isolated one, and – analogously – the destruction of a habitat site in the neighborhood of other habitat requires a higher valued permit than the destruction of an isolated site (Drechsler & Wätzold 2009).

This idea is similar to the agglomeration bonus which has been suggested to provide incentives for generating ecologically valuable spatial configurations in the context of conservation payments (Parkhurst et al. 2002; Drechsler et al. 2007). To avoid confusion with the agglomeration bonus idea we call the additional value that is generated through neighboring sites in the context of tradable permits "neighborhood bonus".

The implementation of the neighborhood bonus idea leads to some difficulties. The main reason is that it requires re-evaluation once the land use of neighboring sites changes and decisions have to be made on who receives the created additional permit value and who bears the costs of the destroyed permit value. The problem here is that the re-evaluations may not be a result of the actions of the landowners themselves, but of their neighbors.

The allocation of costs and benefits from land use changes depends on the allocation of property rights (cf. Coase 1960). We can distinguish between two main options: The first option is that landowners have the right to modify land use on their own land, regardless of their neighbors' preferences. The second option is that landowners do not have the right to change their land use without their neighbors' prior agreement. Leaving aside the possibility of negotiations and side payments between landowners, it can be concluded for both options that individual decisions do not take into account the (positive or negative) impact on the ecological value of their neighbors' sites, suggesting that this does not lead to a cost-effective solution.

Assuming profit-maximizing and perfectly informed landowners and taking into account negotiations and side payments, we would for both options expect a neighborhood to find a regionally cost-effective solution, because neighborhood effects are incorporated into the decision (cf. Coase 1960). In the case of the second option, the neighbors will only agree if the intended land use change is beneficial to them, or, if they receive side payments which at least cover their (expected) costs. Expected costs arise if neighbors plan to change their land use in the future and expect higher costs for permit acquisition required for economic development or lower benefits from selling permits generated from habitat restoration. Similarly for the first option voluntary side payments – from the neighbors to the landowner who aims to change his land use – should achieve the same solution. To what extent side payments are likely to happen depends on the related transaction costs.

Which option a society chooses depends strongly on the prevalent perception of the adequate allocation of property rights. Evaluating the neighbourhood bonus one has to consider that trading rules that include a bonus are likely to lead to additional transaction costs. The rule itself might be more complex and hence difficult to understand than exchange rules that are based on a simple unit such as patch size. Moreover, communication and negotiation between landowners increase transaction costs.

Zoning is an alternative to the neighborhood bonus for considering spatial interdependencies of habitat sites on a regional level. Similar to the area of transferable development rights (Thorsnes & Simons 1999) zoning could be applied to conservation in a way that in areas with many isolated habitat sites destruction is allowed whereas in areas with a high habitat density this is not the case (cf. Mills 1980). An alternative rule would be that in areas with a high habitat density destruction is allowed until a certain critical minimum density is reached. Then the destruction of sites is only allowed in other areas.

One disadvantage of zoning is that it puts restrictions on trade which may lead to less market activity and negatively impacts cost-effectiveness by preventing the use of economically valuable areas for economic development. Furthermore, with zoning the connectivity of a site with other sites in the region is only indirectly considered. The likelihood that a site is connected with other sites can be increased when the assigned zones are smaller or the required density is higher. However, this leads to less market activity.

Given that neither zoning nor the neighborhood bonus are perfect solutions, one may also follow Tietenberg's (1995, p.98) proposition that "one way of dealing with the spatial complexity […] is to ignore it". Which of the three options is the best way to deal with spatial interdependencies is an empirical issue. It depends on how important habitat connectivity is for the species to be protected, the size of transaction costs arising from zoning and the neighborhood bonus and the extent trading restrictions influence market activity and cost-effectiveness.

3.4 Time

For species persistence, the continuous existence of habitat is relevant. Frequent change in land use and long time lags between habitat destruction and restoration may negatively impact species survival. Habitats can take a long time to regenerate, e.g. forests require decades of growth before providing adequate habitats for certain species. Also, species need time to recolonize their new habitats (Keymer et al. 2000).

To ensure that an exchange fully compensates an impact, trade should only be allowed after restoration has been successful and the land has been recolonized by species. However, this can lead to difficulties for market participants in finding trading partners which can limit market activity and reduce cost saving potentials. Significant costs may also arise through delayed development (e.g. Eppink & Wätzold 2009) if an economic developer does not find an exchangeable permit at the time he requires it. On the supply side uncertainty about the future permit price exists for landowners when restoring habitat as they will only be able to sell the resulting permit in the somewhat distant future.

One option for facilitating trade when there are temporal discontinuities is banking: After a habitat is restored, permits need not be sold immediately. As a reward for the temporal conservation gain that arises from the temporary provision of additional ecological value, additional permits could be allocated to the land owner similar to interest payments.

If a species is not critically endangered borrowing could be allowed. Development projects would be endorsed without the submission of a permit at the time of destruction, but requiring later submission and additional permits for the time lag again similar to interest payments. Factors that should be reflected in the size of the "interest rate" are the temporal losses in ecological services when the habitat is not provided, and the increase in the risk for species survival as a result of borrowing (for evaluating interim losses of habitat compare Dunford et al. (2004)). Since this risk is species specific interest rates may differ among habitat types. An analysis of banking in emissions trading shows that the trading rules also need to counteract discounting of firms, which results in firms taking environmental action as late as possible (Kling & Rubin 1997).

A knock-on effect of earning interest on the early provision of habitat is that the criterion of ecological effectiveness might be violated as the ecological value of a region might deviate from the targeted conservation level. Suppose a supplier restores habitat and does not sell the permit immediately. Through interest the permit accumulates additional value and can be used to compensate for a destroyed site with a higher ecological value than the previously restored site. Such an exchange results in an reduced overall ecological value. Thus, allowing for banking implies fluctuating ecological values of a region over time. As a consequence, there is a risk that the overall ecological value is reduced to a level which might be considered critical. To avoid that risk a lower limit for the ecological value might be introduced beyond which banking with interest payments and borrowing are not allowed.

One important aspect that needs to be considered if time lags between destruction and restoration are allowed is to ensure that restoration actually takes place. If a permit is given to an individual or an organization based on the promise that the creation of a habitat is being completed at a certain date in the future there is a risk that the individual or organization becomes bankrupt before the habitat is completed. One way of ensuring that the restoration of the habitat is completed in such a case is to keep the payment for the permit or part of it with a trustee until the new habitat is completely restored.

Similarly, appointing a trustee is one option to ensure the availability of financing for habitats that require continuous management. An example of such a habitat type is open grassland which requires management to avoid succession. The regulator could then only issue a permit if the organisation aiming to sell the permit commits itself to managing the habitat over a certain period and offers secured financing. A certain amount of the revenue generated from selling the permit could be given to a trust fund which releases this money (including interest rates generated from it) in installments over the period for which the organisation commits itself to management.

When conservation costs frequently change in a spatially heterogeneous manner, landowners might want to change their land use accordingly. Species, however, might not easily adapt to frequent land use changes. This problem may be addressed by imposing minimum durations on how long a site must be maintained for conservation once it has been restored. This decision again involves a trade-off: While frequent changes in habitat structure endanger the ability of species to adapt, more permanent spatial habitat structures leave less room for trading and hence have a negative impact on cost-effectiveness and market activity.

4. Conclusion and future research

Tradable permits are a promising instrument for biodiversity conservation, since they open up opportunities for cost-effective and ecologically effective dynamic adaptation to spatially heterogeneous economic development. Challenges for applying tradable permits to conservation arise because the destroyed and the restored habitat may differ along the dimensions of type, space and time. We discussed the consequences of these differences as well as the requirement of a certain market activity for the design of trading rules and identified various trade-offs.

Allowing trade between different types of habitats has a positive effect on market activity, but may violate the ecological effectiveness of the scheme. It may still be advantageous from an ecological point of view if trading rules are designed in such a way that they provide incentives for restoring habitat for highly endangered species. As the survival probability of species depends on the connectivity and distance of habitat sites, the criterion of cost-effectiveness calls for the consideration of spatial aspects in the design of trading rules. Two possible options are a neighborhood bonus and zoning, but both options lead to additional transaction costs and may negatively influence market activity. With regard to the temporal dimension, banking and borrowing have a positive effect on trading but may endanger the ecological effectiveness of the scheme. Similarly, allowing frequent changes in land use may endanger the ability of species to adapt. Requiring more permanent spatial habitat structures, on the other hand, leaves less room for trading.

Further research is required to better understand and perhaps quantify the identified trade-offs for specific conservation objectives, so that existing permit schemes can be improved and new schemes can be better designed. Moreover, research is needed to develop innovative trading rules that are able to mitigate the trade-offs. Such research has to take into account both ecological and economic knowledge, thus making close co-operation between ecologists and economists essential (cf. Wätzold et al. 2006; Baumgärtner et al. 2009).

Acknowledgements

The authors are grateful to Florian Hartig and Martin Drechsler from the Helmholtz Centre for Environmental Research – UFZ for valuable comments. Research for this paper has been carried out in the context of the EcoTRADE Project (http://www.ecotrade.ufz.de/) which has been funded by the European Science Foundation and the German Research Foundation (Deutsche Forschungsgemeinschaft).

References

Ando, A., J. Camm, S. Polasky, and A. Solow. 1998. Species Distributions, Land Values, and Efficient Conservation. Science **279:**2126-2128.

Armsworth, P. R., G. C. Daily, P. Kareiva, and J. N. Sanchirico. 2006. From the Cover: Land market feedbacks can undermine biodiversity conservation. Proceedings of the National Academy of Sciences **103:**5403-5408.

Baron, R. 1999. Market Power and Market Access in International GHG Emissions Trading. International Energy Agency Information Paper, Paris. Available from http://www.oecd.org/dataoecd/16/61/2391156.pdf.

Baumgärtner, S., C. Becker, K. Frank, B. Müller, and M. Quaas. 2009. Relating the Philosophy and Practice of Ecological Economics. The Role of Concepts, Models, and Case Studies in Inter- and Transdisciplinary Sustainability Research. Ecological Economics: in press.

Briers, R. A. 2002. Incorporating connectivity into reserve selection procedures. Biological Conservation **103:**77-83.

Cabeza, M., A. Arponen, and A. V. Teeffelen. 2008. Top predators: hot or not? A call for systematic assessment of biodiversity surrogates. Journal of Applied Ecology **45:**976-980.

Chomitz, K. M. 2004. Transferable development rights and forest protection: An exploratory analysis. International Regional Science Review **27:**348-373.

Coase, R. H. 1960. The Problem of Social Cost. Journal of Law and Economics **3:**1-44.

Commission of the European Communities. 2007. Green Paper on market-based instruments for environment and related policy purposes. Available from http://ec.europa.eu/environment/enveco/green_paper.htm (Accessed August 2008).

Department of Environment and Climate Change. New South Wales Government. 2008. BioBanking. Available from http://www.environment.nsw.gov.au/biobanking/index.htm (Accessed

August 2008).

Drechsler, M., K. Johst, F. Wätzold, and J. F. Shogren. 2007. An agglomeration payment for cost-effective biodiversity conservation in spatially structured landscapes. UFZ Discussion Papers 4/2007.

Drechsler, M., and F. Wätzold. 2009 Applying tradable permits to biodiversity conservation: Effects of space-dependent conservation benefits and cost heterogeneity on habitat allocation. Ecological Economics: in press.

Dunford, R. W., T. C. Ginn, and W. H. Desvousges. 2004. The use of habitat equivalency analysis in natural resource damage assessments. Ecological Economics **48:**49-70.

Eppink, F. V., and F. Wätzold. 2009. Comparing visible and less visible costs of the Habitats Directive: The case of hamster conservation in Germany. Biodiversity and Conservation: in press.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology Evolution And Systematics **34:**487-515.

Fox, J., and A. Nino-Murcia. 2005. Status of Species Conservation Banking in the United States. Conservation Biology **19:**996-1007.

Goulder, L. H., I. W. H. Parry, and D. Burtraw. 1997. Revenue-Raising versus Other Approaches to Environmental Protection: The Critical Significance of Preexisting Tax Distortions. RAND Journal of Economics **28:**708-731.

Hahn, R. W. 1984. Market Power and Transferable Property-Rights. Quarterly Journal of Economics **99:**753-765.

Hansjürgens, B., editor. 2005. Emissions Trading for Climate Policy: US and European Perspectives. Cambridge University Press, Cambridge.

Hanski, I. 1998. Metapopulation dynamics. Nature **396:**41-49.

Hartig, F., and M. Drechsler. 2008. Smart spatial incentives in markets for conservation services. arXiv.org, Available from http://arxiv.org/abs/0809.0228v1.

Keymer, J. E., P. A. Marquet, J. X. Velasco-Hernandez, and S. A. Levin. 2000. Extinction thresholds and metapopulation persistence in dynamic landscapes. American Naturalist **156:**478-494.

Kling, C., and J. Rubin. 1997. Bankable permits for the control of environmental pollution. Journal of Public Economics **64:**101-115.

Köck, W., R. Thum, and R. Wolf, editors. 2005. Praxis und Perspektiven der Eingriffsregelung. Probleme der Flächen- und Maßnahmenbevorratung - Verknüpfung mit Umwelt- und Raumplanung. Recht, Ökonomie und Umwelt 15, Nomos, Baden-Baden.

Malua BioBank. 2008. Available from http://www.maluabiobank.com/ (Accessed August 2008).

Mead, D. L. 2008. History and Theory: The Origin and Evoloution of Conservation Banking. Pages 9-32 in N. Carroll, J. Fox, and R. Bayon, editors. Conservation and Biodiversity Banking. A Guide to Setting Up and Running Biodiversity Credit Trading Systems. Earthscan, London.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Biodiversity Sythesis. World Resources Institute, Washington, DC.

Mills, D. E. 1980. Transferable development rights markets. Journal of Urban Economics **7:**63-74.

Montgomery, W. D. 1972. Markets in licenses and efficient pollution control programs. Journal of Economic Theory **5:**395-418.

Naidoo, R., A. Balmford, P. J. Ferraro, S. Polasky, T. H. Ricketts, and M. Rouget. 2006. Integrating economic costs into conservation planning. Trends in Ecology & Evolution **21:**681-687.

Newell, R. G., and R. N. Stavins. 2003. Cost heterogeneity and the potential savings from market-based policies. Journal of Regulatory Economics **23:**43-59.

Nicholson, E., and H. P. Possingham. 2006. Objectives for multiple-species conservation planning. Conservation Biology **20:**871-881.

OECD (Organisation for Economic Co-operation and Development). 1999. Implementing Domestic Tradable Permits for Environmental Protection. OECD Proceedings, Paris:1-243.

Opdam, P., E. Steingrover, and S. v. Rooij. 2006. Ecological networks: A spatial concept for multi-actor planning of sustainable landscapes. Landscape and Urban Planning **75:**322-332.

Panayotou, T. 1994. Conservation of biodiversity and economic development: The concept of transferable development rights. Environmental and Resource Economics **4:**91-110.

Parkhurst, G. M., J. F. Shogren, C. Bastian, P. Kivi, J. Donner, and R. B. W. Smith. 2002. Agglomeration bonus: an incentive mechanism to reunite fragmented habitat for biodiversity conservation. Ecological Economics **41:**305-328.

Parry, I. W. H., R. C. Williams III, and L. H. Goulder. 1999. When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets. Journal of Environmental Economics and Management **37:**52-84.

Polasky, S., et al. 2008. Where to put things? Spatial land management to sustain biodiversity and economic returns. Biological Conservation **141:**1505-1524.

Rodrigues, A. S. L., and T. M. Brooks. 2007. Shortcuts for biodiversity conservation planning: The effectiveness of surrogates. Annual Review of Ecology, Evolution & Systematics **38:**713-737.

Salzman, J., and J. B. Ruhl. 2000. Currencies and the commodification of environmental law. Stanford Law Review **53:**607-694.

Shogren, J. F., et al. 1999. Why Economics Matters for Endangered Species Protection. Conservation Biology **13:**1257-1261.

Staehelin-Witt, E., and A. Spillmann. 1994. Emissionshandel. Erfahrungen in der Region Basel und neue Ansätze. Zeitschrift für Umweltpolitik & Umweltrecht **2:**207-223.

Thorsnes, P., and G. P. W. Simons. 1999. Letting the Market Preserve Land: The Case for a Market-Driven Transfer of Development Rights Program. Contemporary Economic Policy **17(2):**256-266.

Tietenberg, T. 1995. Tradeable permits for pollution control when emission location matters: What have we learned? Environmental & Resource Economics **5:**95-113.

Tietenberg, T. H. 2006. Emissions Trading: Principles and Practice. Resources for the Future, Washington, DC.

Wätzold, F., et al. 2006. Ecological-economic modeling for biodiversity management: Potential, pitfalls, and prospects. Conservation Biology **20:**1034-1041.

Wätzold, F., and K. Schwerdtner. 2005. Why be wasteful when preserving a valuable resource? A review article on the cost-effectiveness of European biodiversity conservation policy. Biological Conservation **123:**327-338.