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Stacking ecosystem services

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Ecosystem service markets are increasingly used as a policy solution to environmental problems ranging from endangered species to climate change. Such markets trade in ecosystem credits created at restoration sites where conservation projects are designed and built to compensate for regulated environmental impacts. "Credit stacking" occurs when multiple, spatially overlapping credits representing different ecosystem services are sold separately to compensate for different impacts. Discussion of stacking has grown rapidly over the past three years, and it will generate increasing interest given the growing multibillion-dollar international market in carbon, habitat, and water-quality credits. Because ecosystem functions at compensation sites are interdependent and integrated, stacking may result in net environmental losses. Unless stacked compensation sites and impact sites are treated symmetrically in the accounting of environmental gains and losses, stacking may also cause environmental gains at compensation sites to be more fully accounted for than losses at impact sites. Stacking should be used with caution until science-based methods, which can account for the ecological relationships between distinct ecosystem credits present at a conservation site, are developed and deployed.

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If you restore a wetland, can you sell the carbon sequestered there to a buyer in Germany while you sell the wetland habitat created to a nearby housing developer and the improved water quality to a municipal treatment plant downstream in the next state? Environmental regulators increasingly confront vexing scenarios such as this at every level of market-based environmental policy, from local water-quality initiatives to global carbon markets.

There are now many markets that trade in environmental credits (increments of environmental improvement created to offset permitted impacts). Local, national, and global jurisdictions have created several market-like arrangements in which, for example, a company that causes environmental damage can mitigate the impacts through the purchase of credits produced by people or firms engaged in resource conservation. Although these credits can be measured in units of area, it is increasingly common to see them defined in units of ecosystem services – the benefits that humans derive from the environment (MA 2005). The move from area-based credits toward function- or service-based credits raises the possibility of *credit stacking* – the sale of multiple credit types from a single site. Credit stacking can incentivize conservation activity by multiplying possible revenue streams from a credit site. However, it also complicates tracking and accounting for the many services involved and challenges ecosystem ecologists and economists to more precisely define and understand what ecosystem service markets are actually designed to conserve.

In a nutshell:

- Ecosystem credit "stacking" is a new practice that involves selling environmental credits like carbon, wetlands, and species
- Credit stacking means that the many ecosystem functions at a single restoration site can be sold as multiple types of credits
- Stacking poses substantial accounting challenges, and while it can highlight the many ecological benefits of conservation sites, it can also draw attention away from unregulated environmental losses
- Stacking presupposes that the relationship between ecosystem functions is clear, quantifiable, and assessable by non-scientists using science-based methods, which is not always the case
- We offer policy solutions to prevent ecological losses (eg to water quality and habitat) in cases where stacking is used as a conservation strategy

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The rise of stacking

In the US, environmental credit markets are driven by diverse state and federal laws that result in a patchwork of overlapping regulatory markets for many kinds of credits (Table 1). Federal regulators have typically allowed only one kind of credit to be sold from a conservation site, but there is no written policy to support this position. The alternative, stacking, allows a single areal unit of property to generate more than one type of credit for sale; for instance, the same acre of restored wetland may create carbon credits, endangered species credits, and water-quality credits for sale separately.

Ecosystem credit stacking has been strongly advocated as a conservation tool and has received both enthusiastic and skeptical responses in policy forums (Bennett *et al.* 2009; Bianco 2009; Morris 2009). However, researchers have only recently begun to explore the issues surrounding stacking (eg Fox 2008; Bennett *et al.* 2009; Cooley

Table 1. Operating and proposed US ecosystem markets

Market and resource (pollutant sold)	*Enabling statute or policy*
Wetlands/stream mitigation (ha or linear m)	CWA[a]; CERCLA[b]
Floodplain trading (ha leveed agricultural land restored to floodplain) (Cheng *et al.* 2001)	TMDL[c]
Variety of species habitat banks (ha habitat)	ESA[d]
CO_2 (tons of CO_2 equivalent)	CARB[e]; voluntary[f]
Copper (kg)	TMDL
Heavy metals (kg)	TMDL
Ammonia (kg)	TMDL
Selenium (kg)	TMDL
Biological/chemical oxygen demand (kg)	TMDL
Phosphorus (kg)	TMDL
Sediment (tons) (Cheng *et al.* 2001)	TMDL[g]
Water temperature (thermal; kCal day^{-1} m^{-1})	TMDL
Nitrogen – including point source, non-point source, and floodplain sources (lbs N; ha of upland buffer in wetlands or m of linear stream buffer)	TMDL
Impervious surface (ha) (Welty *et al.* 2005)	TMDL

Notes: [a]US Clean Water Act (CWA) §404 (13 USC 1344). [b]Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). [c]Total maximum daily load (TMDL) regulated under §303(d), CWA. One example is the Hennepin Levee District in Illinois. Floodplain acreage is used as proxy for nitrogen. [d]§7 and §10, US Endangered Species Act (ESA) or state endangered species regulations. [e]California Air Resources Board (CARB) under AB32. Other potential US regional regulatory programs, such as the Regional Greenhouse Gas Initiative, the Midwestern Greenhouse Gas Reduction Accord, and the Western Climate Initiative, have encountered political and legal obstacles to implementation. [f]Many voluntary carbon credit certification and marketing programs exist. [g]Piasa Creek Watershed, Illinois. Source: US EPA (2009), unless otherwise noted.

and Olander 2012; White *et al.* 2012). Only a small handful of regulatory ecosystem service markets in stacked credits are currently in operation or have been proposed, but related crediting systems in which multiple credit types are defined at a site do exist. Stacking, as a term, has been applied to situations where multiple credit types are sold from a single spatial unit (Willamette Partnership 2010), where multiple credit types are delineated on spatial subunits of a property so that they are not spatially overlapping (NCEEP 2009), or where multiple ecosystem services are defined on a property but are bundled and sold together to compensate for a single impact (NRC 2001).

Because of inconsistencies in terminology, crediting systems called "stacking" (or, erroneously and more colloquially, "double dipping"; see Panel 1) do not all raise the same concerns. In true stacking, spatially overlapping credits compensate for different regulated environmental impacts occurring at different times and places, and the sale of one stacked credit does not prevent the sale of others in the stack.

Stacking has become a much-discussed issue in market-based policy, and its use is poised to expand. Sales of stream and wetland credits for the purposes of compensating for regulated impacts equaled $770 million in 2005; these *regulatory markets* are a large and growing segment of the $2.9 billion market in all (ie both voluntary and regulation-driven) stream and wetland restoration activities (ELI 2007). The global market for biodiversity credits is estimated at $1.8–2.9 billion (Madsen *et al.* 2010).

In this regional and global context, stacking appears to be an efficient way to increase the production of ecosystem services, with clear incentives for both credit providers and policy makers to move toward stacked markets. Regional markets in North Carolina and Oregon have already experimented with limited forms of stacking (Table 2). A third stacked market has been created in Minnesota, but its current status is unclear (CMM 2009). Regulators may find stacking attractive because it can incentivize landowners to increase the ecological value of existing conservation sites, and may also encourage landowners to put additional land into conservation for the production of additional credits. Stacking also appeals to environmental credit producers because it enables them to sell more kinds of products from a single site. This allows them to hedge the risk that demand for one credit type may drop by diversifying their economic production toward providing many kinds of credits. Stacking may also improve site selection or conservation design, as entrepreneurs will see higher profits if they produce or select sites with potential to generate multiple ecosystem services. For these and other reasons, stacking has gained enthusiastic support in the context of US federal regulatory markets (Kenny 2010; Ecosystem Futures 2010). Internationally, policies such as Reducing

Panel 1. Glossary of terms for ecosystem service markets

Ecosystem services: ecosystem functions, or the end products of ecosystem processes, that benefit society (eg nutrient retention, pollination, flood retention). Many overlapping definitions exist.

Ecosystem markets: markets in which ecosystem services are traded as "credits", quantified through ecological assessment techniques. Markets may involve voluntary participants or participants whose purchases are compelled by regulation.

Ecosystem unbundling: representing an ecosystem as composed of discrete and divisible functions and/or services. Ecosystem unbundling is a prerequisite to credit stacking and credit bundling.

Credit stacking: selling credits representing two or more spatially overlapping ecosystem services as separate commodities, each compensating for different permitted impacts.

Credit bundling: selling credits representing a collection of conceptually discrete but spatially overlapping ecosystem services as single commodities.

Double dipping: selling the same ecosystem service credit, however defined, multiple times.

Emissions from Deforestation and Forest Degradation (REDD+, the generation of carbon credits through reduced deforestation), which specifically advocate for the recognition of multiple, spatially co-present ecosystem services (Zwick 2010; Simonit and Perrings 2011), may lay the foundation for stacked markets in the future.

Conceiving of ecosystems as a stack of tradable services has the further advantage of being consistent with the legal treatment of all real property in the US: property in the US legal system is typically treated as a bundle of alienable (tradable) rights (ALI 1993; Penner 1996). Landowners in the US are typically able to sell or lease mineral, timber, development, water, and hunting rights without selling the land itself and can do so simultaneously in separate markets. Why not also sell multiple credits in ecosystem services?

There is a growing literature detailing the problems with conventional (ie unstacked) ecosystem markets, in which compensation sites can generate only one type of credit, which are often sold in coarse units of measure (eg acres or linear feet) that are unrelated to ecosystem functions. The imprecise and inflexible nature of conventional environmental credit markets has in some cases created low-diversity ecosystems designed to meet vague and low performance standards; the poor ecological performance of commercial wetland banking in Mack and Micacchion's (2006) study of Ohio is illustrative. Such sites may meet the requirements of a single-resource regulatory program, providing sufficient water quality but not habitat or biodiversity. Sites developed to offer a single credit type may lack the ecosystem complexity that is usually the target of conservation.

Finally, stacking offers an incentive to provide a fuller and more precise account of a compensation site's ecology, which may yield valuable information to regulators, allowing them to gauge the success of market-based programs, as well as to market participants concerning what exactly they are buying. Although there are clear justifications for the adoption of stacking in ecosystem service markets, given the novelty of the concept and the rapid expansion of ecosystem markets worldwide, it is worth carefully considering the potential implications of such an approach to conservation and where science and policy research must focus to evaluate its effectiveness.

Issues to be resolved

Property rights in ecosystem services

One obstacle to the wider adoption of stacking is that currently it is a policy available only in regulatory markets. Many, but not all, ecosystem service markets derive from government regulations, which create an externally imposed (rather than innate) demand for opportunities for lower-cost compliance with environmental laws. In economic theory, markets work best when the demand is endogenous to the buyer, rather than imposed by the government; this is an important way in which regulatory environmental credit markets are not true markets and should not be expected to behave as such (Robertson and Hayden 2008; Stephenson and Shabman 2011). As a practical matter, this means that stacked markets may only arise where governments act to regulate many kinds of ecosystem properties and functions.

Another complication with stacking is that ecosystem service credits are not considered true property by law, if they are created and defined by the government specifically for the purpose of compensating for regulated environmental losses. Voluntary markets (markets for which no regulations force action; eg some US carbon markets) may therefore be more amenable to stacking. In either case, however, property law on ecosystem services is not a matter that has yet been settled in court, and the status of a property owner's rights to control the ecosystem services produced on their land remains unclear. The emerging research on ecosystem services has revealed difficult issues for US property law (Lant *et al.* 2008); there are currently no clear minimum baselines for the kinds of management activities expected of property owners, for which they are liable and beyond which they could accrue credit (Thompson 2012). For example, if one property owner destroys pollinator habitat on their property, is that owner liable to a nearby farmer whose crops suffer reduced pollination, or should the farmer have been paying for the pollination services in the first place (Ruhl 2008)? The US legal tradition of nuisance

Table 2. Stacked ecosystem markets

	Stacked credit types	*Enabling statute or policy*
North Carolina	Wetlands (acres)	CWA
	Streams (linear ft)	CWA
	Nitrogen (lbs N)	Tar-Pamlico TMDL; Neuse River TMDL
	Riparian buffer (acres)	State Buffer Rules for six basins[a]
Willamette River Basin (Willamette Partnership 2009)	Salmonid habitat (weighted linear m)	Voluntary; ESA; TMDL
	Thermal load trading (kCal day^{-1} m^{-1}) (ODEQ 2007)	ESA; TMDL limits on hot water point sources[b]
	Upland prairie (weighted ha)	Voluntary; ESA
	Wetland: hydrologic function (water storage and delay)	CWA
	Wetland: water-quality support	CWA/TMDL
	Wetland: fish support (fish habitat enhancement)	CWA
	Wetland: aquatic support	CWA
	Wetland: terrestrial support	CWA

Notes: [a]Title 15A of the North Carolina Administrative Code contains regulations defining buffer credits in the Neuse, Tar-Pamlico, Catawba, Randleman Lake, Goose Creek, and Jordan Lake basins. [b]Also used in the Tualatin River Basin, Oregon, and the Vermillion River Watershed, Minnesota.

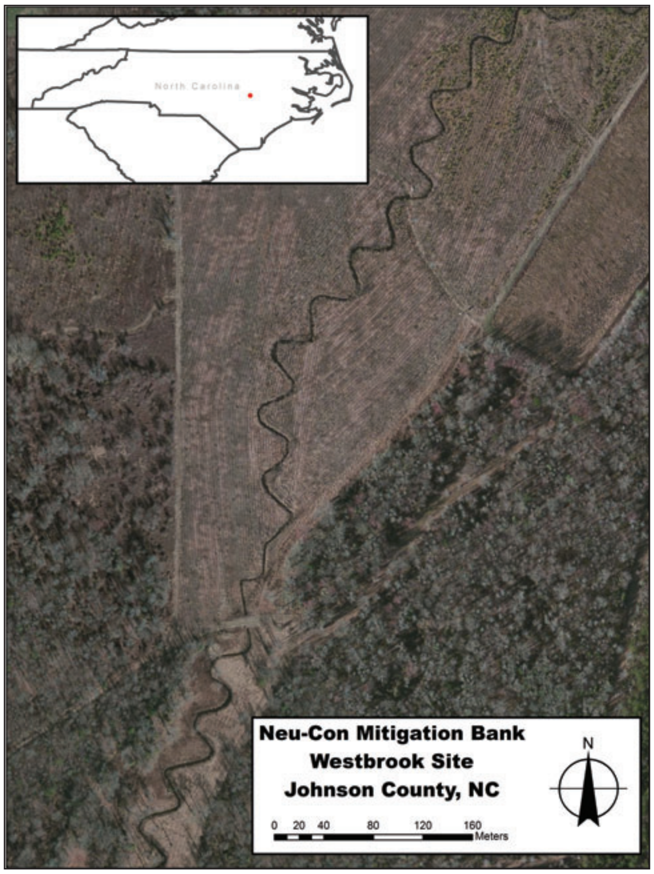


Figure 1. *Aerial photograph of the Westbrook site (red circle in inset map) of the Neu-Con Mitigation Bank in North Carolina. Wetland and nitrogen credits were sold from this site.*

law suggests that individuals cannot use their property in a way that causes harm to the public or other private individuals, but until ecosystem service property rights issues are clarified, it will be difficult for voluntary and regulatory markets in ecosystem services to function properly.

Additionality

A principal concern of stacking is additionality (Bennett 2010; Fox *et al.* 2011; Gillenwater 2011; Woodward 2011) – the principle that credit generators should not receive credit for benefits that would have occurred on a site without their actions – because allowing such credits to be used as compensation for impacts would result in a net decrease in ecosystem services. One extreme, but real-world, example illustrating this issue occurred in North Carolina, when wetland and stream ecosystem services were first defined and sold as wetland credits and then again as water-quality improvement credits (a separate market) a decade later, despite a lack of additional improvements in the meantime (Figure 1; Program Evaluation Division 2009). Since no independent compensation was offered for the second (water-quality) impact, it was argued that a net loss of ecosystem services resulted (Kane 2008).

Additionality has been addressed under the European Union Emissions Trading Scheme, for instance, in which a carbon project cannot claim credits for sequestration (1) performed in the past, (2) likely to occur in future scenarios without the project, or (3) required by law. In the case of stacking, it can be argued (using the example of wetlands) that although many services are created when a wetland credit site is built, none of these services are additional to the wetland credit if they require no additional effort for their production (beyond what was required to produce the wetland credit initially). However, the definition of additionality is not clear; as Gillenwater (2011) points out, there are currently 23 different definitions of additionality to be found in a global survey of current policies, and stacking would fail some tests while passing others. Because of the uncertainty and debate surrounding both stacking and additionality, there is a lack of consensus regarding what kind of additionality issues are presented by stacking.

Additionality is, in part, a legal concern. Certifying that an individual has developed and owns ecosystem service credits to sell in regulatory markets only fulfills the goals of environmental laws when the credit developer is providing services at a level *above* the expected baseline minimum defined by property law. If that baseline is undefined, however, the question of additionality is impossible to resolve, and regulators would be forced to make uninformed assumptions to define when credits truly should be certified. In some regulatory markets, the baseline is defined by guidance or regulation, but for many ecosystem services (eg pollination, groundwater recharge, carbon sequestration) no credible baselines exist.

Symmetry of accounting

Stacking has the potential to solve a problem characteristic of non-stacked (single-credit) markets: the asymmetry that exists between impact site and compensation site. In any impact to a regulated service, there are often also simultaneous impacts to multiple unregulated services for which compensation is not required. For example, a stream affected by development that also decreases the amount of habitat for a rare but unprotected species may require compensation for regulated stream functions but would not require mitigation of the habitat for that rare species – an important service has been *lost*, without notice and with no compensation required. On the other hand, at any compensation site where credits are generated for sale in the regulatory market, concurrent gains of unregulated services usually occur; a stream restoration that improves habitat for a rare species does not receive credit for that habitat if the species is not protected through regulation – an important service has been *gained*, without notice and with no credit given.

A well-designed regulatory market can thus ensure equivalence between compensation site and impact site for the *protected* service. However, it cannot ensure equivalence between many lost and gained *unregulated* services. Therefore, in normal, non-stacked credit markets there will be undetected and unmeasured net losses or net gains.

Stacking has the potential to resolve the accounting asymmetry problem by bringing multiple functional gains and losses at each site into view in the same accounting framework (McElwaine 2005), thereby providing a much more comprehensive view of losses and gains; stacking could therefore potentially increase the precision of ecological assessment of both impact sites and restoration sites.

Unfortunately, moving in this direction presents an enormous challenge for regulators and ecosystem service providers; standardized assessment procedures need to be developed for each type of service and must be ecologically meaningful, yet feasible at the scale of application. Agencies managing even conventional, non-stacked regulatory markets have found that record-keeping and accounting often overburden their staff and capabilities (GAO 2005). Stacking would dramatically increase the complexity and quantity of credits to inventory and trades to oversee.

Perhaps even more problematic is that the number and kind of credits defined at a given stacked site will vary with the markets available, and some of these markets may be regulated by very different resource agencies (eg local, state, federal) and cover a variety of regions, if not different nations. For instance, a stacked stream and wetland restoration site in Clermont County, Ohio, could provide stream and wetland credits in the Little Miami River watershed (a transaction regulated by the US Army Corps of Engineers), nitrogen-based water-quality credits downstream in the parts of the Ohio River watershed in the states of Ohio, Indiana, Kentucky, or Illinois covered by a water-quality trading agreement (a transaction regulated by four different state water-quality agencies), and carbon credits globally (a transaction that could be regulated by the European Union, among several others). An impact to a wetland in the same county, merely three miles away in the East Fork of the Little Miami, will only record losses of wetland acreage; carbon losses go unaccounted for since no regulation requires attention to them, and nutrient impacts go unaccounted for because TMDL load allocations have not been developed for that stretch of river. Thus, in an example that encompasses just one county in the US, gains are evidently accounted more readily than losses. We attempt to express this on the right-hand side of Figure 2.

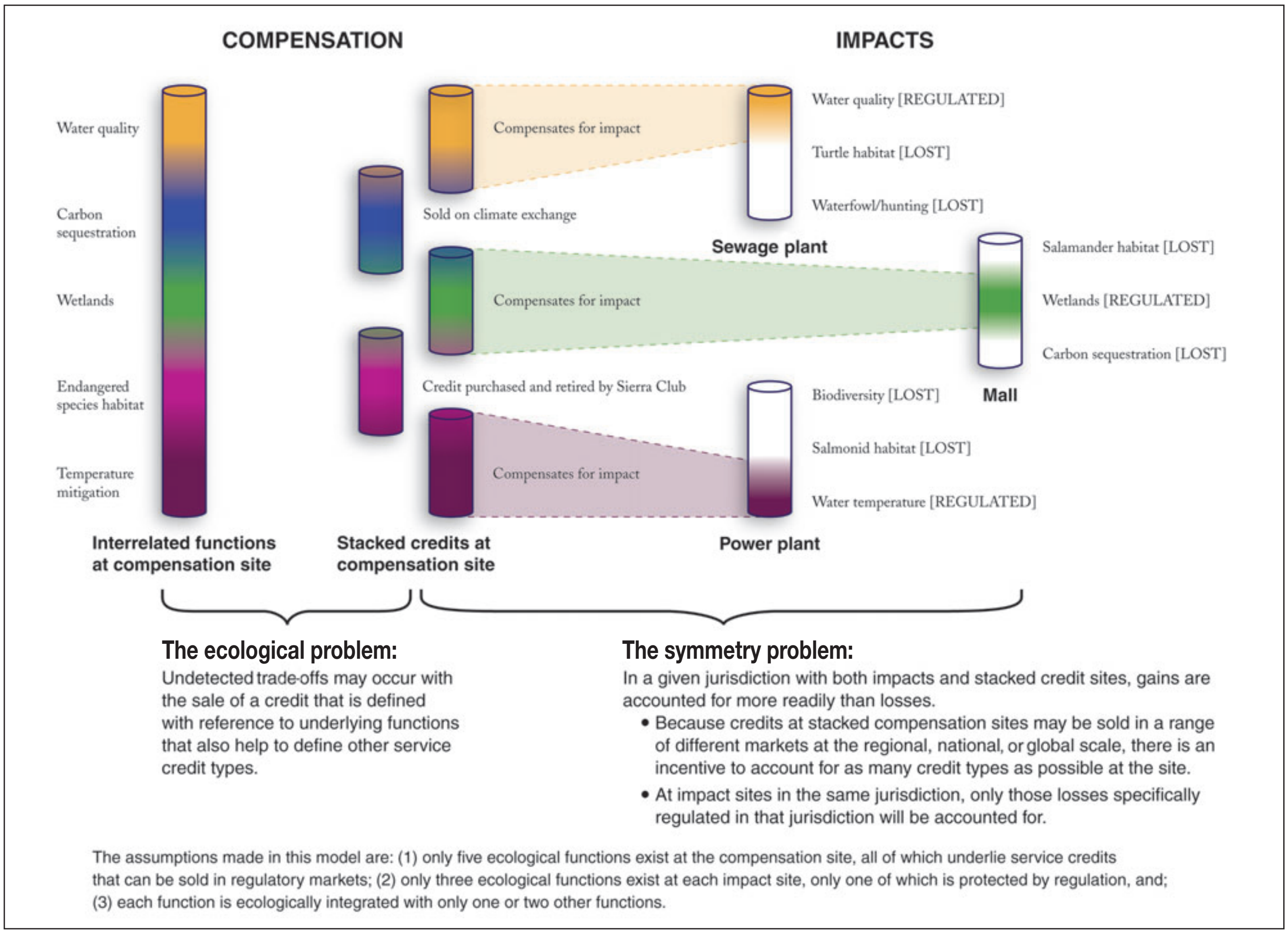
There is also a strong incentive for credit providers to account for stacked credits at restoration sites because revenue can be increased several-fold and financial risks are hedged by market diversification. However, there is a correspondingly strong *disincentive* for developers to account for stacked credits at impact sites as this would require multiple credit purchases. Stacking policies may thus be prone to an asymmetry that (1) makes stacked and non-stacked markets equally unlikely to offer a full accounting of losses and gains at impact sites and (2) makes gains more visible than losses within a given jurisdiction where stacking *is* adopted.

Ecological complexity

A final issue involves very different visions of what ecosystem services are. In one view, ecosystem service credits are thought of as property claims on specific ecosystem functions. These ecosystem functions are the complex and interdependent processes that underlie services, the interrelationships of which are poorly understood and exceptionally difficult to quantify as discrete objects of analysis (Palmer and Filoso 2009) or, consequently, as credits. In another view, a credit is seen as the independent product of ecosystem functions; the functions may be complex and interrelated, but the product itself stands alone as a credit, much like a car produced by a factory. For example, when a stacked credit in water quality is sold, it is seen as a commodity, standing apart from the biogeochemical cycles, hydrology, and biodiversity that created it. Yet it is these functional interrelationships and not the individual components of ecosystems that environmental protection policies have traditionally sought to conserve. The level of precision necessary to accurately quantify and segregate individual functions in isolation, such that their relationship to credits is clear and non-overlapping, may be beyond available technologies, regulatory capacity, or economic feasibility for the foreseeable future (ELI 2005; Kremen 2005). We attempt to express this on the left-hand side of Figure 2.

The first view suggests that if carbon sequestration services and nitrogen load reduction services both depend on interrelated biogeochemical processes (eg ecological stoichiometry, nutrient limitation, etc), then the existence of a carbon credit depends on an underlying suite of functions that also supports the existence of the nitrogen credit. From this perspective, the services transacted in a regulatory market are merely proxies for the functions that produce them; what is actually being credited and sold in stacked markets are claims on those specific functions. Once one of the services is sold, can other services supported by the same functions also be sold without being discounted to some degree? This question may have theoretical answers but has only recently begun to be asked in real-world scenarios.

The second view suggests that ecosystem services should be accounted for as segregated ecological outputs that are distinct from the ecological interrelationships that create them (Boyd and Banzhaf 2007). From this perspective, the services flowing from a site are defined as discrete commodities, and thus trade-offs among them can be accounted for without reference to the complexities of the site's ecology. This is traditionally how economists have approached the production of goods for generic markets, but many have realized that this assumption will be strongly tested in environmental regulatory markets. In one of the only peer-reviewed articles on stacking, the economist Woodward (2011) recognizes the importance of interactions between underlying functions: he distills them into a term, γ, which he warns "may be particularly diffi-



D Warfield

Figure 2. *Two issues in stacking: ecological complexity and symmetry in accounting. The image shows a compensation site represented as an integrated set of functions on the left. The middle column shows the compensation site represented as if broken into component service credits. Three separate impact sites are shown on the right, connected with some of the credits at the compensation site.*

cult to observe or estimate". Fully describing these relationships is a critical piece of both the economic and the ecological puzzles associated with stacking policy.

■ Solutions

There are no regulations addressing stacking or even any guidance documents from US federal resource agencies. However, there is a spectrum of possible solutions to the concerns listed above. At one extreme, policy makers could ensure that ecosystem services be accounted only as a single integrated function: for example "ecosystem condition" (Mack 2006). The ecological rationale for this approach is that because ecosystem service credits represent direct claims on integrated ecosystem processes, they do not resemble segregable property rights in that they cannot be fully separated from one another. The policy rationale is that this represents a practicable accounting and ecological assessment framework for regulatory agencies.

At the other extreme, policy makers could formulate regulations requiring increasingly precise quantification of all, or at least many, ecosystem service impacts, and stacked credits of many kinds could then be matched with the suite of services affected by each impact, without unrecognized losses or gains. Such an approach would represent an ideal of ecological precision, market transparency, and regulatory rigor, but would also require a substantial expansion of regulatory oversight to cover currently unregulated ecosystem functions and services and a corresponding expansion of regulatory power to require compensation for their destruction.

Practical solutions can be found between these two positions, which balance ecological, economic, and regulatory concerns. For instance, one way of addressing asymmetry would be to require that stacked credits at a given site be sold only within a geographic area subject to the same environmental regulatory programs. This would avoid the problem highlighted in the Ohio example discussed previously, of seeing the gains but not the losses of functions that are only marketable in other jurisdictions. Only services protected in the jurisdiction could be stacked in the jurisdiction, thereby ensuring symmetry between stacked credit sites and impact sites. Although this approach would limit stacked markets as long as most jurisdictions protect few services, it might incentivize the expansion of regulatory protections. Similar assessment methods would need to be applied to both impact and compensation sites;

there are movements in this direction in the US (eg Florida Statutes §373.414[18]) and Australia (NSW DECC 2008).

Existing models attempt to address the issue of ecological interrelationships between services, albeit imperfectly. For example, one US firm (Parametrix 2010) has developed algorithms that quantify multiple credit-providing services at stacked sites; when one credit type is sold, the system debits the other credit types to the degree that they are ecologically related to the credit type that has been sold. Thus, the algorithm can reflect the assumption that, for instance, carbon sequestration by riparian vegetation is 40% related to stream temperature regulation at a site by debiting 40% of a water-quality credit when a carbon credit is sold. Model validation and calibration are obviously major concerns, but the debate about whether acceptable levels of ecological precision are reached is a policy decision. In the one stacked market in Oregon that uses this system (Figure 3), the interrelationship between credit types is conservatively rated at 100%, so that the sale of one "salmonid habitat" credit from the stack decreases the number of available credits of other types by one whole credit (Willamette Partnership 2009). Similar systems are in use internationally to quantify the co-presence of ecosystem services, though not usually for the purposes of defining credits for sale.


Willamette Partnership

Figure 3. *Half Mile Lane environmental credit site, Hillsboro, Oregon, in 2010, one year after construction. The area visible in the image supplies salmonid habitat credits, water temperature credits, and wetland credits.*

Clearly there are important roles for ecologists and environmental scientists to play in these emerging policy challenges. Economists have begun developing theoretical approaches to stacking, yet ecologists have expressed concern that these approaches often depend on unrealistically simplistic ecological models (Kremen and Ostfeld 2005; Vira and Adams 2009). Successful stacked markets will require a better understanding of the ecology determining the interrelationships between the functions that may be stacked (Raudsepp-Herne *et al.* 2010). Finally, ecologists will need to play an active role in the legal process, as the property law of ecosystem services evolves.

Policy makers need to recognize that the scientific challenges of stacking are substantial and push the boundaries of basic ecological science; implementing stacking policy also poses new logistical challenges for seemingly routine activities such as project monitoring and measurement. It may be appropriate to begin by adopting policies that recognize some ecosystem services as inseparable from each other (eg nitrogen and phosphorus from the same site, two endangered species in a predator–prey relationship), reducing the set of legally stackable credit types. Moving toward stacked credits will require more thorough regulatory oversight and cooperation among government agencies, and regulators will have to assess and certify each credit type independently while tracking sales across a kaleidoscope of spatially overlapping markets (Table 1).

The US Environmental Protection Agency, Army Corps of Engineers, Fish and Wildlife Service, and Department of Agriculture's Office of Environmental Markets should be charged with coordinating the research and interagency agreements necessary to ensure integrity and transparency in stacked markets, and this should begin with the development of a geospatial data clearinghouse for all regulated ecosystem service markets. Such oversight will be essential to avoid the overleveraging of real ecological values through stacking. If, as a Barclays Capital financial analyst was quoted as saying prior to the 2008 financial collapse, the trade in carbon credits is truly "going to be bigger than the credit derivatives market" (Horwood 2007), then stacked ecosystem service markets will require both solid scientific foundations and transparent accounting to avoid a similar fate.

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