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Submission of a research paper

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Special issue on Metrics and environmental governance coordinated by guest editor Pr
Steven Wolf

Metrics and public accountability

The case of species credits in the USA

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Abstract

This article compares two contrasting cases of a widely used market-based conservation policy, namely private single conservation banks and habitat exchanges as two economic mechanisms for the production and circulation of species credits. The analysis of their economic morphologies reveals how they differ in terms of regulatory pressure, organizational configuration, type of metric and robustness. Despite common objectives, these two policy instruments essentially differ in terms of the type of constitutive agreement they employ: private single conservation banks, as local and confined economic exchanges, are based on an agreement about exchange with little attention to metrics and credit definition. Habitat exchanges on the other hand tend to be wider and inclusive centralized marketplaces within which agreement is settled in terms of metric and credit harmonization. The reliance on distinct metrics establishes varying forms of accountability within these policy instruments and raises questions about the need to regulate metrological processes.

Keywords

Endangered Species Act, conservation banking, habitat exchange, economic morphology, metric, accountability

Introduction

There has been an increasing use of environmental metrics over the last 20-30 years in relation to the rise of sustainability-oriented products and services on one hand (Busch, 2000), and new forms of environmental policies focusing on market-based

instruments on the other (Pirard, Lapeyre, 2014). Conservation policies have reflected this new trend since the late 1980s. Among other market-based mechanisms, the USA has pioneered the use of species credits that are intended to slow down the severe decrease of several species populations that have occurred within its national territory for many years (Cardinale, *et al*, 2012).

Species credits as a part of conservation banking are one instrument stemming from the “no-net loss” policy objective under the US Endangered Species Act (1973) or ESA. In this context, *no-net loss* is defined as the obligation to restore any endangered species habitat being damaged or destroyed by economic development activities. Hence it is theoretically based on the quantification of impacts and of restoration activities in order to ensure equivalence between impacts and gains. Species credits are one of the economic mechanisms available to reach this objective: the restoration of species habitat can be converted into species credits through a certification process carried out by US environmental agencies, the US Fish and Wildlife Service (USFWS) being the leading one. Biodiversity entrepreneurs (or “bankers” in the conservation banking jargon) invest in land and ecological restoration and receive species credits in return. They can then sell these credits to firms whose activities entail the destruction of species habitat and that face the regulatory obligation to offset these impacts. Species credits can thus be considered as “regulatory commodities” as their existence depends on environmental regulations.

The implementation of such policy instruments requires processes of ecosystem measurement and assessment that raises questions about the role of scientific knowledge in the making of an environmental market-based policy. Species credits are

thus regulatory commodities that rely on scientific knowledge as a central input for their production. Scientific knowledge is broadly concerned with conservation biology and species biology. It is thus deployed at several stages in the regulatory protection of endangered species. Species credit production through conservation banking specifically requires conservation biology knowledge as the central operation consists of the conversion of ecological restoration operations into species credits. To do so, environmental agencies rely on what they call a “metric” that aggregates a set of qualitative and/or quantitative bioindicators and an equivalence ratio (Cochran, Maness, 2011). Bioindicators represent a state of the environment at a given time; they are measured regularly throughout the credit certification process to assess recovery of species habitat. The equivalence ratio links units of habitat recovery to a monetary unit, i.e. a number of credits. It is in most cases carried out through a surface equivalency (Pawliczeck, Sullivan, 2011) according to the general equation X acres of species habitat of quality $Y = Z$ credits.

Metrics play a triple role in the implementation of the no-net loss principle: first, they play a scientific role as they allow the assessment of habitat recovery; second, they play an economic role as they are the cornerstone of conservation banking profitability: prior to investing in a conservation bank, bankers build business models within which the number and price of credits helps in assessing potential profit and supports the investment decision; and third, they embody a regulatory dimension as bioindicators have to be in line with regulatory objectives specified by environmental agencies (see Ruhl, 2004a for an illustration of the discrepancies resulting from this). Environmental agencies field-level officers are in charge of bank certification, which implies (among others) the assessment and approval of the metric (validation of bioindicators that are

relevant for the concerned species and bank), the control of habitat measurement (verifying that empirical observations and measurements meet bioindicator criteria) and the release of credits when habitat recovery meets the expected criteria.

While metrics play such a central role in market-based conservation policies, those used in conservation banking can be constructed according to a widely ranging set of possibilities, from very simplistic methods to complex quantification tools (Pindilli, Casey, 2015), suggesting different forms of agreement on how to quantify habitats within conservation banking. Two types of explanations can be found in the literature. The first set of explanations is related to ecosystems as the object of quantification and the second set deals more generally with processes of quantification.

Because of the complexity of ecosystems structures, issues of scale and non-linearity of ecological processes, measurement and assessment of biological diversity is a fluid area of research within environmental science (for a review of methods and debates see Magurran, McGill, 2010). Scholars point to the difficulties faced when attempting to grasp this complexity through the definition of indicators, even when simpler units such as managed ecosystems at a landscape scale are concerned (Chown, Mc Geoch, 2010). Scientific issues of ecosystem measurement are not solely at stake when it comes to conservation policies. Ecological indicators for environmental policies are defined according to conceptual views of ecosystems and to normative aspects of their assessment at the same time (Turnhout et al, 2007). Different measurement goals lead to some indicators being chosen more frequently than others. US conservation banking is based on species recovery but Bruggeman et al. (2005, 2009) explore how function or genetic diversity could also be conservation-banking objectives. In managed ecosystems,

certain indicators may assess and signal changes in the condition of the environment, or highlight the causes of an environmental problem. Sets of indicators often fail to include information about structure, function and composition of ecosystems at the same time, because management programs rely on a small number of proxy indicators that are more easily monitored (Dale, Beyeler, 2001) but are fuzzily correlated with other ecosystem elements (Brown, Byron, 2016). Other scholars have pointed out the incompleteness of ecosystem measurement as a great obstacle to the commoditization process at stake within biodiversity banking (Robertson, 2004). The need for standardized commodities may lead to an “ecological naivety” and thus an oversimplification of ecosystem modeling and measurement for value production (Dempsey, Robertson, 2012, p.967). Careful examination of this simplification process (Robertson, 2006) suggests that market-based conservation policies rely among others on an active selection of conceptions, indicators and knowledge of ecosystems. This may have major implications on policy outcomes as Bull et al. (2014) demonstrate.

Sociology of quantification supplements this view of knowledge selection by stressing the highly political character of such process. Quantification activities are neither neutral nor objective and scientific activities do not keep ahead of such politics of knowledge selection: in disciplines based on quantification of complex systems such as gene-environment, the emphasis may be set (in the name of statistical significance) on easy-to-quantify factors at the expense of hard-to-quantify social factors (Ackerman et al., 2016). Quantification defined as a collective two-step process that entails agreeing on what to measure and how to measure it and subsequently on measurement itself (Desrosières, 2008), ought to be tackled as a scientific as well as an organizational issue

at the same time. Consequently, a sociological analysis of metric selection ought to pay attention to both its social construction and its scientific content.

If one returns to the beginning of this topic, metrics for conservation banking may range from very simple ones to complex quantification tools (Pindilli, Casey, 2015), depending on the varying knowledge selection processes at stake in the method selected for implementing the principle of no-net loss. What are the organizational drivers of metric production leading to more or less complexity? What consequences do they have for policy implementation and outcomes? To what extent does complexity obscure or enhance public accountability? To explore such questions, this paper takes a comparative perspective on two different market mechanisms both aiming at achieving no-net loss of species habitat in the USA, namely single private conservation banks (hereafter “single banks”) and habitat exchanges. It analyzes the economic morphology of both mechanisms and shows how they differ according to regulatory pressures for mitigation, organizational configuration of exchange, type of metric and robustness of the mechanism. Studying contrasting cases helps to reveal a central trade-off between metric complexity and economic mechanism flexibility; this trade-off is then discussed in terms of its consequences for public accountability.

This paper draws on three sources of data. A first set of data was gathered in 2017 during two specific events. The first event was a one-week conservation banking training course organized by and for environmental agency field officers in order to provide and discuss tool kits for conservation bank design and implementation. The second event was the 20th National Mitigation and Ecosystem Banking Conference held in Sacramento, California. These immersion periods gave me the opportunity to engage

in numerous observations and informal interviews with environmental agencies officers, bankers and other stakeholders involved in conservation banking, such as environmental consultants. This first stage led to the gathering of a second set of data through twelve in-depth interviews with bankers, environmental agencies officers (mainly from the USFWS) and environmental consultants. These interviews were transcribed and manually analyzed. The third step of data collection consisted in grey literature analysis of policy documents, policy reports, “bank enabling instruments” (official document for bank certification), habitat exchange guides and habitat quantification tools.

The emphasis on the processes and consequences of quantification on market-based conservation policies is directly related to two areas of recent scholarship. The first is concerned with studies of the difficulties of market construction for environmental policies as well as the discrepancies between the strong policy narratives that sustain them and the practical challenges of their implementation (Bakker, 2005; Boisvert, 2015; Castree, 2008; Robertson, 2012). The second focuses on public accountability within environmental governance in relation with the rise of data-driven and incentive-based policies (Lockie, 2016; Wolf, 2017).

The article is constructed as follows. In the first part, I present the overall federal policy framework of the ESA and its consequences in terms of regulatory pressure for land development-based industries. The second part analyzes the morphologies and metrics of single banks and habitat exchanges as two market mechanisms stemming from the ESA no-net loss principle. The third part highlights the different types of agreement

underlying these mechanisms, which leads on to a discussion on public accountability and the limits of standardization in market-based conservation policies.

1. Degrees of regulatory pressure for no-net loss implementation

Federal regulations, mainly through the ESA, are the main driver for the implementation of species habitat no-net loss. Depending on the protection status of the species, either endangered or threatened, the pressures to cope with this policy vary. Land developers may have to offset impacts for endangered species whereas they are only incentivized to do this for threatened (or “pre-listed”) species. This is mainly the case in states that have their own regulations and environmental institutions, California being the leading one in that regard.

1.1 The Federal level as a driver for species conservation

The Endangered Species Act was adopted in 1973 and placed under the authority of the US Secretary of the Interior who acts through the USFWS and the National Marine Fisheries Service (NMFS). Its first objective was to define what species were endangered. Section 4 of the ESA defines “listing” as the process of defining “endangered” and “threatened” species, differentiating whether the species is in danger of extinction over a significant portion of its range (it then being listed as “endangered”) or is likely to become so in the foreseeable future (it then being listed as “threatened”). Because it was made into law during a decade of intense environmental awareness and related policy-making, the ESA was effective in imposing a ban on the destruction of

endangered species habitat (although not on threatened species habitat), which had potentially severe consequences on economic development.

This severe regulation was soon to be softened: the environmental backlash experienced during the 1980s (Bonneuil, 2015) entailed exceptions to the rule of the ESA: in 1982, “incidental take” (i.e. impacts) on endangered species habitat was allowed under section 7 (for Federal action) and section 10 (for other action) under certain conditions, requiring the issuing of a specific permit (Ruhl, 2004a, p. 421-422). Destroying endangered species habitat then became possible within specific requirements. These included the restoration or conservation of the species habitat in question in the surroundings of impacts so as to neutralize habitat reduction at the landscape scale.

There has been a strong challenge to species listing processes from land development-based industries, as endangered status provides greater protection and incentives for conservation (USFWS, 1983). Since then, there have been a regular series of scientific controversies and court cases involving conservation NGOs, private sector organizations and US Federal agencies for the listing or delisting of a species (for a current case, see DOI, 2019)

1.2 State-level species protection: the Californian case

Exceptions to the rule favored land development but created new obligations for developers. Initially they could either accept responsibility for it and subcontract ecological restoration operations (“permittee-responsible” solution) or finance conservation programs (“in-lieu fee” programs). In 1995, the Sacramento field office of

the USFWS in California proposed a third way, through the use of conservation banks as private commercial enterprises¹ (Froger, 2015). Single banks, as private commercial conservation entities make it possible to comply with the no-net loss policy through a supply-driven economic mechanism: restoration activities are carried out before economic activities impact endangered species habitat. Since the mid-1990s these have been developed in about a dozen states although they continue to be mainly concentrated in California (see chart below).

Insert here chart 1 : Single private banks development in the USA since 1990

Source: (Author, forthcoming)

Such a heterogeneous distribution of single banks within US territory poses questions about the drivers for their circulation across states. Conservation bankers interviewed during this research project tended to outline three main factors as being the drivers for investments: economic preconditions (including a certain level of economic development creating demand), ecologically connected networks of endangered species habitats and a regulatory capacity to enforce the rules (see also van Teefeelen et al., 2014). Rea's research (2017) explored the historical and institutional specificities of California. It shows how California has experienced a good combination of these three drivers as the state combines 1) the presence of a substantial number of endangered species and of important economic developments impacting those species; 2) a high density of environmental regulations and institutional levels; 3) an active environmental movement stemming from groups and individuals within civil society monitoring the implementation of the regulations.

¹ These were modeled on wetland mitigation banks developed since the late 1980s under the Clean Water Act to offset impacts on such areas.

In fact, California also proves to have numerous state-level regulations and institutions (Vogel, 2018). The Californian Endangered Species Act, (voted in 1970, three years before similar Federal legislation was enacted) and whose implementation was enforced by the California Department of Fish and Wildlife (previously known as the California Department of Fish and Game [CDFG]), constitutes the first layer of the overlapping regulatory structure. The Department can also be concerned with incidental protection of endangered species habitat under other regulations (the Magnuson-Stevens Fishery Conservation and Management Act together with the Fish and Wildlife Coordination Act being the main ones). Other Federal agencies (the US Environmental Protection Agency, the US Army Corps of Engineers, the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service) are also often involved in conservation banking as endangered species and wetland conservation regularly intertwine in California. This multi-layered institutional environment has been key to the development of conservation banking: all of the bankers interviewed for this research affirmed that more regulation provides a safer investing environment for conservation bankers as it implies more selling opportunities.

1.3 “Endangered” status as an economic threat for land developers

Impacting endangered species habitat represents an important cost and requires a lengthy process for land developers in states where environmental regulations are implemented. Conversely, the impact on threatened species habitat is not as strongly regulated under the ESA. For that reason, the change of a species status from “threatened” to “endangered” has major economic consequences for land developers.

They consider this an economic risk and may want to engage in risk-management strategies (through species conservation funding) to limit it. Since the early 2010s, new state-led initiatives have occurred in some parts of the USA where threatened species might be on the edge of a status change toward the endangered species category, such as the cases of the Monarch Butterfly² in Missouri, Texas and California, the Utah Prairie Dog in Utah or the Greater Sage Grouse in several northwestern states including Wyoming, Utah, Nevada, and Colorado. These initiatives are labeled “habitat exchanges” and they aim at applying the no-net loss principle to threatened species in order to limit habitat reduction and thus endangered status. Somewhere between five and ten habitat exchange projects are currently under construction or starting their activities (Chiavacci, Pindilli, 2018). The basic rationale is the same as for endangered species: bankers invest in habitat restoration, receive “pre-listed species” (i.e threatened species) credits and sell them to land developers, except that land developers do not have to buy these credits: they are merely incentivized by a potential future change in species protection status. Purchasing credits is for them a voluntary medium-term strategy based on the fact that the “endangered” status brings about serious limitations on economic development activities together with a more complex and therefore lengthier administrative procedure to obtain permits for activities impacting those species habitats. This medium-term strategy has to be a collective one in order to affect species populations meaningfully. The next part of the paper therefore demonstrates how this requirement has consequences for the organizational configuration of habitat exchanges and on the type of metric being used.

² monarchhabitatexchange.org

Beyond acting as a sword of Damocles, environmental regulations do play a role in the making of habitat exchange, as they are the frameworks in regard to which credits are constructed. Just as with credits issued within single banks, “pre-listed species credits” are consistent with regulatory species conservation objectives. In this way, potential bankers and buyers are assured that their initiatives will fulfill future regulatory obligations in case the species becomes listed as endangered. State and federal environmental agencies are involved throughout the habitat exchange development and operating processes.

2. Conservation banks and habitat exchanges: two economic mechanisms to offset impacts from development activities

Federal and state no-net loss regulations entail varying economic constraints for land developers. Regulatory pressure through species status protection either imposes impact mitigation or incentivizes it. Hence endangered and threatened species credits result from different economic mechanisms, respectively single banks and habitat exchanges. This part of the article analyses the morphology of these economic mechanisms as well as the type of metric on which they are based. This provides an understanding of the influence of market structure on knowledge and metric selection.

The Durkheimian notion of “social morphology” has been recently updated to tackle economic concurrence issues through market morphology analysis (Francois, 2008). It consists of characterizing the stakeholders involved in each mechanism (whether people or organizations and their number), the relationships that link them (what kind of relations, according to what networks) and the stability of each mechanism (how robust is it, what is its robustness based on). The description of market structure highlights

power relations at stake, which then supports an interpretation of the robustness or stability of the mechanism.

Such an analysis reveals that conservation banks and habitat exchanges differ on several points: stakeholder configuration, market structure, size of market, type of metrics and robustness. In particular, single banks rely on very simple metrics whereas habitat exchange is based on complex metrics; this difference lies in different levels of restriction or openness in terms of those who may be involved in the metric decision-making process. For single banks, this typically involves only the investment banker and selected representatives of the state environment services whereas habitat exchanges are inclusive mechanisms.

2.1 Single banks for endangered species credits

Single banks consist of areas of land supporting the ecological restoration of an endangered species habitat and that are certified as such by environmental agencies: “a conservation bank is a type of mitigation bank, typically a parcel of land containing natural resource values conserved, restored, created and managed in perpetuity for Federal or state protected species and used to offset unavoidable impacts to comparable resource values occurring elsewhere on non-bank land” (Carroll et al., 2008, cited in West Coast Region Conservation Banking Guidance, 2015). The following graphic represents in simplified form the general process of no-net loss implementation for endangered species: bankers invest in land and species habitat restoration; each conservation bank is individually certified by environmental agencies that deliver credits; credits are sold to land developers seeking to mitigate the impact of their development activities. An important factor to keep in mind is that species credit

markets are local: impacted sites and banks have to be located in the same “service area”.

Insert here Figure 1: No net loss implementation through conservation banking

Source: author

This section of the paper is centered on particular Californian single banks, as most of the banks are located there. Market morphology analysis focuses on the certification process and the role of environmental agencies’ field level officers, as they are directly involved in assessing banks and metrics.

2.1.1 Organizational configuration of certification

Due to the overlap of state and Federal regulations, the certification process entails the participation of several environmental agency field officers who constitute the Inter-Agency Review Team (hereafter referred to as "Review Team"). Due to this specific configuration, certification is both a coordination process between officers of different environmental agencies and a negotiation process between one banker and the Review Team. The coordination process aims at aligning the expectations of each environmental agency in accordance with their own regulatory frameworks. A Recovery Plan states the political choices made by each environmental agency in a context where scientific knowledge about species may be incomplete or controversial; consequently, its content may differ from one agency to another, leading to puzzling situations for field officers who need to stabilize a collective decision-making process. For instance, different agencies may not have the same expectations and definitions of one ecosystem habitat quality. The following excerpt from my field notebook shows how complex and

demanding can be the decision-making process concerning what needs to be conserved and how it should be conserved:

“The people from the state, they have a much more conservative view on conservation, whereas we tend to be more flexible.” This biologist of the Sacramento USFWS office explains how they are involved in up-front mitigation with the Highway Authority, a conservation banker and state environmental agencies. She gives me two examples to illustrate the fact that coordinated action among agencies can be puzzling: firstly, the size of the hole for a fox is 5 inches according to the federal agency guidelines, whereas the State defines it as 3 inches. Secondly, they look at the habitat of a lizard and the potential that it might be threatened in this habitat, whereas the State services do not accept that the lizard may die. She concludes: “it takes hours of negotiations to get to the same point on several issues”. (Transcription of a conversation with a biologist of the USFWS Sacramento Office during the Conservation Banking Training Course, USFWS/USDA, August 2017)

While the overlapping nature of institutional measures and regulations is one precondition for the implementation of the regulations in California (Rea, 2017), it also generates a real coordination problem for environmental agency officers in charge of conservation banking certification. In their empirical study of wetland mitigation banks in Florida, Vaissiere and Levrel (2015) also show how Federal and state regulators may make different assessments of the number of required credits to offset an impact, which leads to difficulties and slowness in the certification process.

Californian state and federal agencies have been working for several years on “a framework for developing and using combined or coordinated approaches to mitigation

and conservation banking (...) to improve consistency of processes, services and products” (MOU Mitigation and Conservation banking and ILF programs in California, 2011) leading to the production of inter-agency program documents and guidance. The progressive harmonization of procedures has facilitated the collective supervision of bank certification.

2.1.2 Simple metrics as a result of coordination issues

The progressive harmonization of procedures has led to a simplification of the metric used for bank assessment. As a former manager of the Sacramento USFWS office states:

« I learnt this early in our banking program; it's the KISS method, Keep It Simple, Stupid. When we came out with the vernal pool crediting program, we had an elaborate quantitative/qualitative formula that would give you a relative sense of what the impact size is, what the bank would be. And it was very confusing to developers and bankers. And you know, a developer would come in and argue strongly that “oh, the size is not good, and I'm not gonna have that big an impact”, bankers would come in and argue the same thing in the beginning but then argue a very high outcome so they would give more credits after you start to manage the site. And, you know, our staff couldn't explain it well. And to me or to the developers or to the bankers. So we shifted to the simple. An acre is an acre. »

This quote reveals how for single banks developed within a multi-layered institutional context, metrics are more likely to be simple; this is the case for 77% of conservation banks in the USA (Carreras, Toombs, 2017). In that situation, the metric consists of

simple easy-to-access bioindicators such as the number of species on site, the height of the vegetation or the presence/absence of water. If these simple requirements are fulfilled, then each acre of restored habitat is granted one credit. As explained during the Conservation Banking Training Course's session on credits, bioindicators are specific not only to the species habitat but also to the bank site where ecological restoration is carried out. They are built on a case-by-case basis (Madsen, 2010). As such, this one acre=one credit metric refers to what Quetier and Lavorel (2011) call "circumstantial reasoning" for biodiversity quantification; they add that its lack of standardization leads to considerable time being devoted to design and assessment. As the number of bank projects increased rapidly in California, some field officers explained to me how they had relied on photographs and GIS views to assess the relevancy of bioindicators, and as a way to reduce the time spent on assessment.

The choice of a simple metric highlights a trade-off between detailed scientific quantification and the likelihood of implementation. The need to streamline the administrative process of bank certification led to a simplification of its scientific content. Metrics prove here to be an important coordination device among environmental agencies. This entails a form of knowledge selection towards simplification of habitat conception and knowledge inputs.

2.1.3 Market structure: in search of monopoly

The choice of this simple metric also has major consequences in terms of the possibility of linking impacts and restoration. It is another illustration of what Robertson (2012: 393) observed for wetland mitigation credits: "asserting and testifying to their equivalence and comparability with other wetland credits is terribly complicated". With

such simple and specific bioindicators, acre-based metrics do not reveal much about the quality of restoration (Quetier, Lavorel, 2011), and as a result credits do not express equal ecological values. This also implies that two bankers could invest different amounts of money for the same species habitat but receive equal numbers of credits. To put it bluntly, no two credits are alike but they are all valid for mitigation of a one-acre impact on the endangered species habitat concerned.

How can this arrangement be viable? How can bankers still be willing to invest in restoration and banking when there is so much uncertainty about the ecological value of credits? In particular, how can bankers still be willing to compete with other bankers given this uncertainty? I argue that this stems from the size and structure of both supply and demand on one side, and from a process of “black boxing” of metrics in the sense of Callon and Latour (1981), (see McKenzie, 2009 for a similar metrical black boxing process).

First, credits can only be sold within the surroundings of the bank, more precisely in the “service area” of the bank, defined by environmental agencies’ field officers according to the ecological range of the species concerned; but in contrast to market size, prices are not regulated. For bankers, it is of great advantage to be the only players in the service area: they can act as price-makers and there is no competition between their credits and those of competitors. As several bankers mentioned during interviews, being first in a service area is a strong driver of investment strategies. Not only does this position them as price-makers but it also neutralizes any potential dumping that may stem from the lack of standardization of credits.

There are also cases where a few banks are located in the same service area; there are thus situations where different credits are competing. However, after credits are released, metrics are black boxed, meaning that information about indicators and measurement remains confined within certification documents and files. Credits are the commodity that circulates and is being exchanged. It embodies and hides ecological indicators at the same time, which underpins trust in credits in a similar process to that which McKenzie (2009) notes about greenhouse gases on a worldwide market: uncertainty remains inside the black box and means it is possible to “make things the same”.

2.2 Habitat exchanges for threatened species credits

Habitat exchanges have been developed since the early 2010s as voluntary multi-stakeholder initiatives in order to provide large-scale mitigation to threatened species with the aim of preventing them from becoming listed as endangered. Given this overall objective, habitat exchanges need to include broad areas of land in order to be inclusive: their key principle is to bring together as many credit buyers and credit producers as possible to ensure sufficient transactions take place and to enhance species conservation. Voluntary stakeholders are involved from the beginning in in-depth discussions and decision-making about market structure and the rules governing exchange. Typical stakeholders are landowners and conservation bankers on the production side, and land developers on the buyers' side.

2.2.1 A centralized marketplace to regulate credit exchanges

Habitat exchanges are organized as centralized marketplaces. The following figure (drawn from the Wyoming Sage Grouse Conservation Exchange's exchange manual (2016) illustrates their organization:

Insert here Figure 2: Organization of habitat exchange crediting system

Source: author

The marketplace is managed by an independent firm but is supervised by state regulators and assisted by a scientific committee in charge of the definition and updating of scientific criteria. Independent third-party verifiers carry out credit assessment and certification as well as debit assessment.

A major difference between single banks and habitat exchanges is the use of a register to centralize information about credit production and transactions for the latter. A registry gives a general view of the market as it lists all certified credits; it also records the tracking of all credits, from their production to their selling and retirement. Akin to single banks, prices are negotiated external to the exchange administrator. This stronger centralization of credits and the greater inclusivity of habitat exchanges are linked with a firm commitment to the use of a single quantification tool for the calculation of credits and debits in order to ensure homogeneity and transparency.

2.2.2 A complex quantification tool for transparency

The centralization of credits and transactions is associated with the use of a single metric that aims at ensuring equity of treatment to all stakeholders (i.e all bankers and

land developers). As stated in the Wyoming Conservation Exchange Manual (2016, p.3), market structure and tools "include the habitat quantification tools (HQTs), a registry, and a trading platform along with the protocols (i.e., processes and rules) to ensure conservation benefits are measurable and repeatable" (Wyoming Conservation Exchange Manual, 2016, p.3). This emphasis on repeatability can be understood as an incentive to enlist more stakeholders in the program.

To ensure comparability and repeatability, metrics are both standardized and complex. The so-called "Habitat Quantification Tools" (or HQT) are developed with the aim of being more specific about the quality of restoration. The core principle is the consideration of both the quantity of land (acreage) and the quality of the habitat restored through the calculation of "functional acres". They are based on a higher number of ecological indicators that aim to characterize the quality of restoration by addressing the evolution of an ecosystem from its initial state to the resulting state. This is measured in terms of a gradient (from 0 to 1) of increasingly effective ecological restoration. These metrics incorporate an assessment of the quality of restoration, which provides a more accurate evaluation of restoration outcomes in credit making. In this case, a unit of surface (i.e. an acre) may not be granted a full credit depending on the quality of restoration and, implicitly, on the amount of investment in restoration: a functional acre ranges between 0 and 1. So does the equivalent credit. For instance, if habitat quality has improved by 75% after restoration, an 80-acre parcel of restored habitat going through certification is granted 60 credits.

Habitat quantification tools are based on standardization and exhaustiveness. For instance, the Wyoming Greater Sage Grouse Habitat Conservation Tool (version 3) is a

substantial 103-page document that proposes a “standardized scoring method” (Quetier, Lavorel, 2011). Measurements are converted into scores attributed to multiple spatial and temporal scales to define habitat quality. They include four levels of spatial scale, three seasonal periods and a set of ten field attributes that are measured at varying times of the year. It also provides a detailed field data collection methodology to ensure equity and comparability in measurement.

2.2.3 The need to protect science

Unlike the simple metrics encountered in a multiple-agency process, an independent scientific team carries out the design process of an HQT prior to any bank certification. It is a long and costly process that can take several months and requires an investment of tens of thousands of dollars. Theoretically, this stage is achieved separately from the participatory stage of rule making. This distinction between the scientific dimension and the economic mechanisms is intended to be a way to keep science and scientists away from conflicts of interests and instrumental pressures.

Interviews with respondents in charge of habitat exchange development reveal that they are much more difficult to bring to a successful stage of routine economic exchanges than single banks. In this case, ecological accuracy is central but its cost and its complexity jeopardize the development of habitat exchanges. The following interview extract shows how stakeholders on the demand side may exert pressure in order to lower credit prices:

“And my job, especially toward the end of the time I spent working on XXX species was to keep the science and the process of developing the exchange separate. We had an intent, I mean our intent was to make the science process a process where the scientists could be free to develop whatever tool they came up with. And I managed that process. (...) And then the process of developing the rules of the exchange itself, so the manual, how the actors interact with each other, was a negotiated stakeholder process. And throughout the project, it became increasingly difficult to keep those two things separate. There were enormous pressures put on myself and others to integrate them. Because the stakeholders did not like the science. Some of the stakeholders did not like what the scientists were doing. Because they could see it was going to cost them money.” (Interview with a former habitat exchange manager, 2017)

This quote shows that unequal power relations within habitat exchange can strongly jeopardize their lifespan (see Wolf, 2019 for an example of habitat exchange that failed). Because they are not based on compulsory economic mechanisms, credit buyers may always have the option of leaving the exchange and accepting the longer-term risk of having to pay more for a potential listing of the species. In the case of powerful stakeholders such as oil and gas companies deciding to leave a project, the whole enterprise is at stake.

For habitat exchanges, metric standardization is a requirement for inclusiveness. Large-scale voluntary participation entails the selection of specific forms of knowledge that can generate a complex metric. Metric complexity allows for transparency and equity of

treatment among stakeholders, but its cost is also a limiting factor that can jeopardize projects.

3. Agreeing on metrics: from low to strong accountability

Single banks as an answer to regulatory obligations and habitat exchanges as voluntary market mechanisms entail two different processes of knowledge selection for credit production: a simplified case-by-case approach and a complex standardized one. In this part of the paper, I show how these processes are linked to different types of agreements and to different relationships with public accountability (Bovens et al, 2014). This leads on to a discussion about the limits of standardization efforts in market-based conservation policies.

3. 1 Metrics for habitat quality assessment: agreement on exchange vs. agreement on metric

I have shown that habitat exchange mechanisms are an ambitious endeavor starting from their inclusivity objective and the complex metric they rely on whereas single banks are based on restricted forms of negotiation between field officers and bankers where simplification helps in streamlining their production. I argue here that single banks and habitat exchanges are based on different key agreements. In the case of single private conservation banks, stakeholders agree on exchanging credits regardless of credit harmonization, whereas habitat exchanges are built on the common will to develop a level-playing field based on the homogenization of metrics. This is a first step in understanding the accountability relationship between field officers and market

players on the one hand and the limits of standardization for market-based conservation policies on the other hand.

The metric used for single private commercial banks leads to a strict equivalence between the number of restored acres and the number of certified credits (one acre = one credit), whatever the initial ecological state of the land may have been, and whatever the quality of ecological restoration as long as it reaches a certain threshold. Regulatory frameworks leave some loose leeway to field-level officers in the attribution of criteria for bank certification. In particular, no quantification methodologies are imposed by the policies and guidance relating to them; mostly they contain advice about what is a good metric. Because there are no official minimal standards to assess habitat restoration quality, acreage becomes the unique equivalence reference between credits and debits of one service area (Pawliczeck, Sullivan, 2011; Carreras Gamarra, Toombs, 2017). This recalls what Desrosières (2008) refers to as “outputs harmonization” in statistical harmonization processes: an agreement is made about the concept of what is being categorized and quantified, leaving open the issue of how to proceed. This methodology has revealed a great sensitivity of measurement outcomes to procedural and practical details. The “homogeneity” of credits is achieved at a last resort after measurements are being “black-boxed” within the administrative procedure and credits become the tradeable unit.

This leads me to argue that in single banks, a reduced number of stakeholders *agree on exchanging*, notwithstanding their fuzzy link to ecological quality and their approximate relation with impact measurement. This agreement is conveyed through the choice of a simple metric that reduces costs of certification and facilitates coordination between

environmental agency officers. As bankers and field officers stated during interviews, time is a valuable factor with regard to ESA no-net loss regulatory compliance. Land developers are willing to obtain their “incidental take” permit rapidly so as not to slow down their activities. Bankers also express interest in obtaining credits as fast as possible as it increases the profitability of their investments. Hence, field officers are aware of stakeholders’ profitability constraints and integrate them in certification processes (author, forthcoming).

Such is not the case for habitat exchanges for which the direct competition between credit producers dictates the use of a more complex and fair metric for resource allocation (standardized scoring method). In this case the principle of homogeneous products is pushed further with the use of a common quantification methodology for all credits and debits. This “input harmonization” (Desrosières, 2008) enforces common observations, reporting and coding operations and ensures a greater equity among market participants. It is linked with a larger amount of ecological references gathered in order to assess the quality of restoration per acre. In that sense, it encompasses more ecological complexity compared to single banking quantification, which makes them more comparable, and provides stable measurement and more costly processes at the same time.

This is why I argue that in habitat exchange cases, stakeholders *agree on metrics*. The inclusivity requirement imposes the construction of a transparent measurement tool. What becomes central is the possibility to compare credits with each other on a common scale as well as credits and debits. This generates a costly procedure of metric definition ahead of the setting-up of economic exchanges. This is the opposite situation to that

where there are single banks: here a tendency toward complexification of metrological processes underlies the making of statewide markets. Yet there is an apparent loophole in this level-playing field design. In this case, agreement is harder to reach due to its important costs. As shown earlier in this paper, the retreat of powerful credit buyers from the participatory process jeopardizes the entire market. Such has recently been the case for some habitat exchanges (Wolf, 2019).

Empirical analysis reveals how single banks and habitat exchanges they differ in terms of market rules (stakeholder configuration) and by the underlying ecological quality assessment methodologies (metrics). Their central agreement – exchange versus metrics – shows how they are opposed by a difference in nature more than a difference of degree. This difference in nature is related to two distinct decision-making methodologies: the single banks’ case-by-case approach to habitat assessment fits into the broader ESA decision-making methodological framework that establishes the “Professional Judgment Method” (Ruhl, 2004b) as prevailing in order to take prescribed action: rather than being a rigorous scientific demonstration of a causal relation between factors (as a scientific methodology would offer), decisions are substantiated by experts in the relevant subject matter. As the default methodology for ESA decisions, this rule of experts entails legitimacy and confidence in the decision-making process, and hence in the field-level officers of the USFWS. Measurements are then black-boxed into credits, which are granted sufficient legitimacy for their circulation. In quite the reverse fashion to this, habitat exchanges and their complex quantification methodologies are similar to what Porter (1995) calls “mechanical objectivity”: where a standardized and detailed scientific methodology brings about a notion of rigor and objectivity, and trust in numbers prevails over trust in experts.

3.2 Consequences for public accountability

The analysis reveals a triple role for metrics. Through the assessment of ecosystem restoration, they are tools for metrological processes. They are also the means of economic value circulation. Lastly, they are tools for stakeholders' coordination.

One last role of metrics needs to be highlighted here. Metrics are a tool that field-level officers and credit certifiers can deploy to hold bankers accountable for the effectiveness of the ecological restoration that is carried out (and not merely the restoration that was foreseen when the banking certification process started); hence they appear as a (more or less) quantitative endeavor to assess the performance of ecological restoration. Metric choice has a direct influence on the ability of regulators to assess, manage and control conservation banks hence on the implementation of the no-net loss principle. Accountability refers here to the mechanism between accountants and accountees, through which accountants assess the adequacy of accountees' behavior (Bovens et al, 2014) and evaluate the extent to which accountees have fulfilled their commitments. Here, credit certification is the mechanism through which the adequacy between a bank project's expectations and completed outcomes is evaluated. Metrics, as central elements of this evaluation, measure and reveal the ability of conservation banks to meet regulatory objectives: they can be considered as "artifacts of public accountability" (Kraft, Wolf, 2016), in line with the growing influence of quantification in law (Espeland, Vannebo, 2007).

Complex metrics for habitat exchanges are based on a standardized scientific approach to ecological restoration that erases the bias that can be encountered in case-by-case approaches based on expert knowledge. Simple metrics highlight in an approximate manner the performance of ecological restoration; but they are less of a transparent filter on the reality they are meant to assess. Because of their structural differences, habitat exchanges and single banks reveal two distinct forms of accountability in reference to the strength of certification and the openness of the mechanism. Complex metrics in habitat exchanges illustrate a form of *strong accountability*: they compel environmental entrepreneurs to engage in a closer and more accurate control of the ecological effects of their action; they are intimately related to the rising notion of “pay-for-performance” in environmental and agricultural policies – the notion of remuneration of outcomes as opposed to funding of means of action (Talberth and al, 2015). They are integrated in inclusive economic mechanisms, and they are themselves open-access tools; due to this, they illustrate the democratic dimension of standardization as it brings about transparency and accountability (Timmermans, Epstein, 2010). Intuitively, one could think that complexity would make public action more complicated; in quite the reverse way the case of habitat exchanges reveals how complexity produces a more precise and accurate view of the unit being assessed. Wolf (2019) argues that the Colorado habitat exchange has failed to introduce accountability, as it has not registered any transactions in a seven-year time period. This leads me to insist on the need to differentiate between two dimensions of metrics: their accuracy in providing an assessment of stakeholders’ commitments - which relates to metrics as artifacts of accountability – , and their implementation costs. Depending on the species concerned and its habitat characteristics, metrics costs may vary while accuracy remains constant. Accountability refers then to the content of the metric, while its

operational implementation ought to be analyzed in relation to the broader organizational and institutional environment in which it is being implemented.

On the contrary, simple metrics in single banks reveal a form of *low accountability*: they only provide a fuzzy view of ecological restoration as they are composed of simple present-or-absent types of indicators; as they are not standardized but designed on a case-by-case basis, one might think that they convey a view of the local habitat specificities – hence a sound basis for assessment – but coordination and time constraints lead to oversimplified metrics and low accountability. The assessment of ecological restoration can also be kept to a minimum when field officers and bankers are routinely involved in certification processes: during the conservation banking training course, one USFWS agent told me: *“The more we know the banker, the more we are likely to trust his measures and not go and verify them”*. Simple metrics not only provide a straightforward view of ecological restoration but also allow for a simplification of control. This micro-level of metric definition builds flexibility into the decision making process as well as a displacement of administrative power into the hands of field-level officers. Whereas habitat exchanges are inclusive and hence built on a democratic approach of quantification, single banks are designed, assessed and controlled in confined arenas and the relationship between bankers and field-level officers plays an important role in their making. The rule of the expert and the circumscribed arenas for decision-making allow for flexibility, simplification and efficiency.

One might think that simple metrics would be seen as having a reduced legitimacy. This would fail to take account of regulatory pressure. Endangered species habitat, on which single banks are built, has to be mitigated. Regulatory pressure highlights the need for

effective mitigation. Two factors explain the use of a single metrics. Firstly, USFWS has authority in relying on the rule of experts (Rulh, 2004b). Secondly, the restrictions imposed on the decision-making process protect it from external contestation. One important point made by Porter (1995) is that quantification is more likely to be *imposed on* rather than *embraced by* actors. For single banks, they are embraced by a small number of stakeholders whose interests converge toward the efficiency of the process.

Conclusion

Habitat exchanges and single conservation banks show the intertwining of regulatory pressure, stakeholder configuration, market rules and metrological processes according to two levels of robustness. Expressed in a nutshell, habitat exchanges rely on a complex and expensive metric that allows for strong public accountability and weak market exchanges. Single banks rely on simple metrics that entail limited accountability; therefore they have spread over US territory and attract land developers seeking to cope with ESA regulatory obligations. The main points of difference between these two regimes of environmental management as discussed in this article are summed up in the following table.

Insert here Table1

Table 1: Points of difference between single banks and habitat exchanges

Given the conclusions of these contrasting cases, I would like to sum-up by touching on the issue of the limits of standardization: is the scaling-up of single banks into wider

markets an impossible quest? Reverseely, could standardized metrics underlie credit exchanges and bring about more equity and accountability? Tsing (2012) defines scalable projects as projects able to expand and remain the same at the same time. They get bigger “without changing the framework of knowledge or action” (p.507). In that sense, habitat exchange may be considered as a scalable endeavor of single banks. So can the spread of single banks over the US territory. Standardized conceptions of biodiversity included in complex metrics are likely to fail to protect threatened species as they miss the efficiency requirements of the economic actors involved. Attention to their failure highlights the need to think over their design through a simpler way to ensure equity. On the contrary, single banks are more successful initiatives but one may want to address the issues raised by the oversimplification of biodiversity they are based on. In the name of conservation and accountability, the balance between ecological standardization and efficiency ought to be taken seriously in future policy frameworks and calls for the regulation of scientific standards.

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References

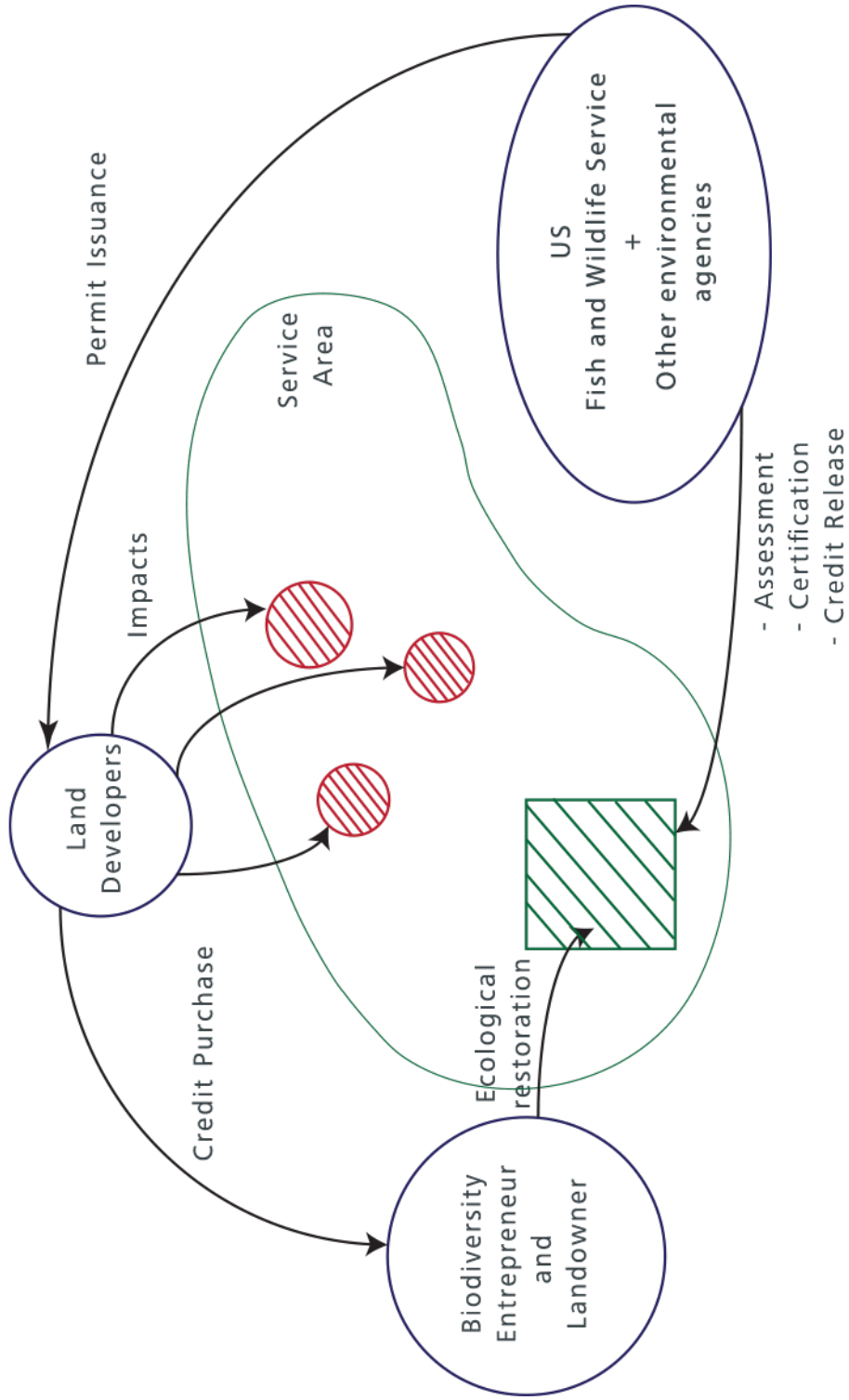
- Ackerman, Sara, Darling, Katherine, Lee, Sandra, Hiatt, Robert, Shim, Janet. « Accounting for complexity : gene-environment interaction research and the moral economy of quantification », *Science, Technology and Human Values*, 41 no. 2 (2016), 194-218.
- Author, « Endangered species credits, a financialized commodity », *Journal of Cultural Economy* (forthcoming).
- Bakker, Karen. “Neoliberalizing Nature? Market Environmentalism in Water Supply in England and Wales.” *Annals of the Association of American Geographers* 95, no. 3 (2005): 542–65.
- Bennett, Genevieve, Melissa Gallant, and Kerry ten Kate. “State of Biodiversity Mitigation 2017. Markets and Compensation for Global Infrastructure Development.” Washington DC: Forest Trend Ecosystem Marketplace, 2017.
- Boisvert, Valérie. “Conservation Banking Mechanisms and the Economization of Nature: An Institutional Analysis.” *Ecosystem Services* 15 (October 1, 2015): 134–42.
<https://doi.org/10.1016/j.ecoser.2015.02.004>.
- Bonneuil, Christophe. “Tell Me Where You Come From, I Will Tell You Who You Are: A Genealogy of Biodiversity Offsetting Mechanisms in Historical Context.” *Biological Conservation* 192 (2015): 485–91.
- Bovens, Mark, Robert E Goodin, and Thomas Schillemans. *The Oxford Handbook Public Accountability*. Oxford University Press, 2014.
- Brown, Eleanor D, and Byron K Williams. “Ecological Integrity Assessment as a Metric of Biodiversity: Are We Measuring What We Say We Are?” *Biodiversity and Conservation* 25, no. 6 (2016): 1011–35.
- Bruggeman, D.J., Jones, M.L., Lupi, F. & Scribner, K.T. Landscape Equivalency Analysis: methodology for estimating spatially explicit biodiversity credits. *Environmental Management*, 36 (2005), 518–534.
- Bruggeman, D.J., Jones, M.L., Scribner, K.T. & Lupi, F. Relating tradable credits for biodiversity to sustainability criteria in a dynamic landscape. *Landscape Ecology*, 24 (2009), 775–790.



- Bull, JW, EJ Milner-Gulland, KB Suttle, and NJ Singh. "Comparing Biodiversity Offset Calculation Methods with a Case Study in Uzbekistan." *Biological Conservation* 178 (2014): 2–10.
- Busch, Lawrence. "The Moral Economy of Grades and Standards." *Journal of Rural Studies* 16, no. 3 (2000): 273–83.
- Callon, M., & Latour, B. Unscrewing the big Leviathan: How actors macro-structure reality and how sociologists help them to do so. In K. K. Cetina & A. V. Cicourel (Eds.), *Advances in social theory and methodology: Toward an integration of micro- and macro-sociologies* (pp. 277–303). Boston: Routledge and Kegan Paul.
- Cardinale, Bradley J, J Emmett Duffy, Andrew Gonzalez, David U Hooper, Charles Perrings, Patrick Venail, Anita Narwani, et al. "Biodiversity Loss and Its Impact on Humanity." *Nature* 486, no. 7401 (2012): 59–67.
- Carroll, N., J. Fox, and R. Bayon. *Conservation and Biodiversity Banking: A Guide to Setting up and Running Biodiversity Credit Trading Systems*. Earthscan, 2009.
- Castree, Noel. "Neoliberalising Nature: Processes, Effects, and Evaluations." *Environment and Planning A* 40, no. 1 (2008): 153–73.
- Chiavacci, Scott J, and Emily J Pindilli. "A Database of Biodiversity and Habitat Quantification Tools Used in Market-Based Conservation." US Geological Survey, 2018.
- Chown, Steven Loudon, and Melodie McGeoch. "Measuring Biodiversity in Managed Landscapes." In *Biological Diversity Frontiers in Measurement and Assessment*, 252–64. Oxford University Press, 2011.
- Cochran, B, and N Robinson Maness. "Measuring Up: Synchronizing Biodiversity Measurement Systems for Markets and Other Incentive Programs." *US Department of Agriculture Office of Environmental Markets*. Hillsboro, OR, 2011.
- Dale, Virginia H., and Suzanne C. Beyeler. "Challenges in the Development and Use of Ecological Indicators." *Ecological Indicators* 1, no. 1 (August 1, 2001): 3–10. [https://doi.org/10.1016/S1470-160X\(01\)00003-6](https://doi.org/10.1016/S1470-160X(01)00003-6).
- Dempsey, Jessica, and Morgan M Robertson. "Ecosystem Services: Tensions, Impurities, and Points of Engagement within Neoliberalism." *Progress in Human Geography* 36, no. 6 (2012): 758–79.
- Desrosières, Alain. *Pour Une Sociologie Historique de La Quantification: L'argument Statistique I*. Presses des Mines, 2008.

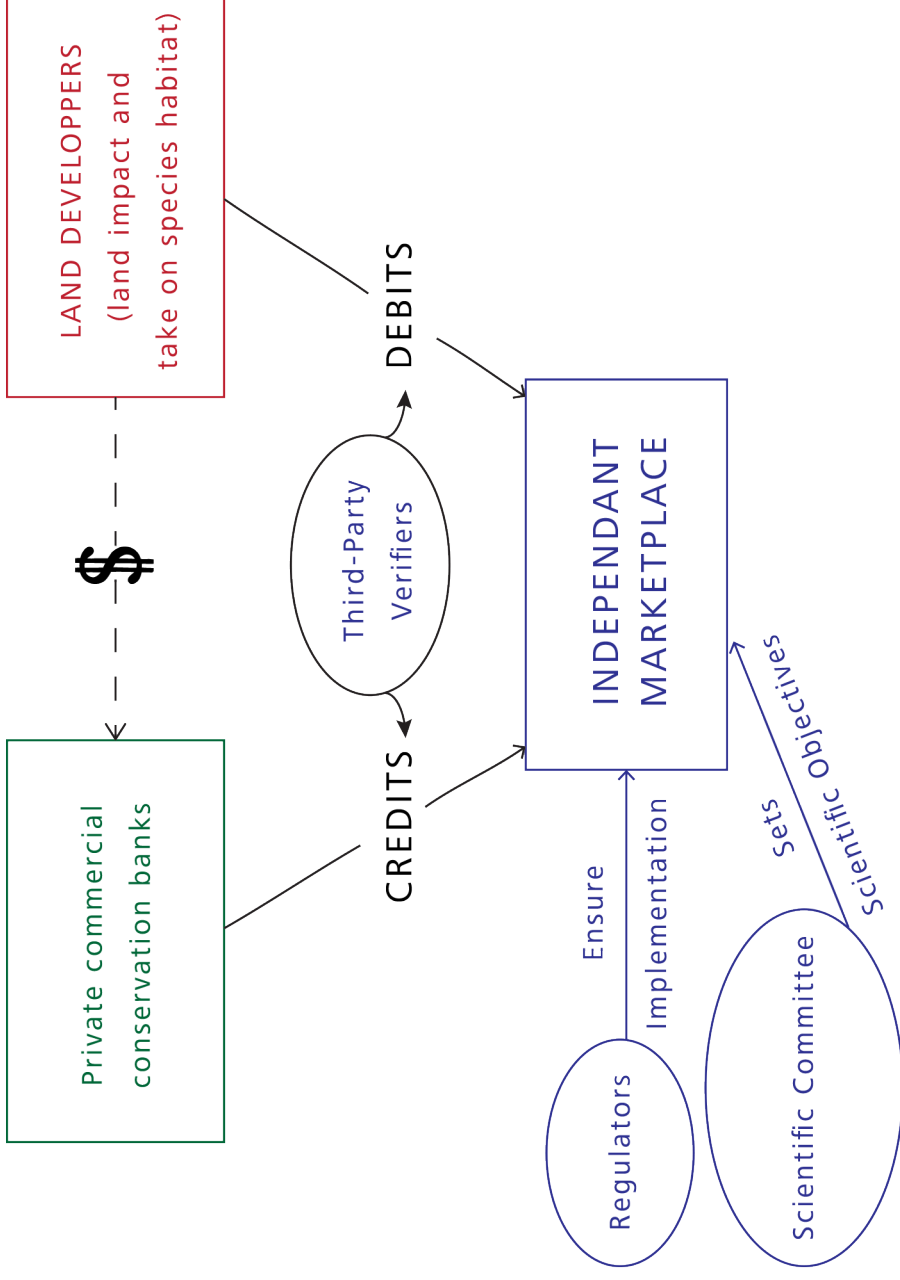
- Department of Interior (2013), « Conservation banking overview and suggested areas for future analysis », DOI Office of Policy Analysis, 16p.
- Department of Interior (2016), Endangered Species Act Compensatory Mitigation Policy
- DOI, 2019, Endangered and Threatened Wildlife and Plants; Reclassifying the American Burying Beetle From Endangered to Threatened on the Federal List of Endangered and Threatened Wildlife With a 4(d) Rule
- Espeland, Wendy Nelson, and Berit Irene Vannebo. “Accountability, Quantification, and Law.” *Annu. Rev. Law Soc. Sci.* 3 (2007): 21–43.
- François, Pierre. *Sociologie Des Marchés*. Armand Colin, 2008.
- Froger, Géraldine, Sophie Ménard, and Philippe Méral. “Towards a Comparative and Critical Analysis of Biodiversity Banks.” *Ecosystem Services* 15 (October 1, 2015): 152–61. <https://doi.org/10.1016/j.ecoser.2014.11.018>.
- Gamarra, Maria Jose Carreras, and Theodore P Toombs. “Thirty Years of Species Conservation Banking in the US: Comparing Policy to Practice.” *Biological Conservation* 214 (2017): 6–12.
- Gonçalves, Bárbara, Alexandra Marques, Amadeu Mortágua Velho Da Maia Soares, and Henrique Miguel Pereira. “Biodiversity Offsets: From Current Challenges to Harmonized Metrics.” *Current Opinion in Environmental Sustainability* 14 (2015): 61–67.
- Kraft, Brandon, and Steven Wolf. “Through the Lens of Accountability: Analyzing Legitimacy in Environmental Governance.” *Organization & Environment* 31, no. 1 (2016): 70–92.
- Lockie, Stewart. “Emergent Themes? A Year in the Life of Environmental Sociology.” *Environmental Sociology* 1, no. 4 (2015): 237–40. <https://doi.org/10.1080/23251042.2015.1125610>.
- MacKenzie, Donald. “Making Things the Same: Gases, Emission Rights and the Politics of Carbon Markets.” *Accounting, Organizations and Society* 34, no. 3 (2009): 440–55.
- Madsen, B, N Carroll, and K Moore Brands. “State of Biodiversity Markets Report: Offset and Compensation Programs Worldwide. Ecosystem Marketplace,” 2010.
- Magurran, Anne E, and Brian J McGill. *Biological Diversity: Frontiers in Measurement and Assessment*. Oxford University Press, 2011.

- Pawliczek, Jamie, and Sian Sullivan. "Conservation and Concealment in SpeciesBanking. Com, USA: An Analysis of Neoliberal Performance in the Species Offsetting Industry." *Environmental Conservation* 38, no. 4 (2011): 435–44.
- Pindilli, Emily, and Frank Casey. "Biodiversity and Habitat Markets—policy, Economic, and Ecological Implications of Market-Based Conservation." US Geological Survey, 2015.
- Pirard, Romain, and Renaud Lapeyre. "Classifying Market-Based Instruments for Ecosystem Services: A Guide to the Literature Jungle." *Ecosystem Services* 9, no. Supplement C (September 1, 2014): 106–14. <https://doi.org/10.1016/j.ecoser.2014.06.005>.
- Porter, Theodore M. *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*. Princeton University Press, 1996.
- Quétier, Fabien, and Sandra Lavorel. "Assessing Ecological Equivalence in Biodiversity Offset Schemes: Key Issues and Solutions." *Biological Conservation* 144, no. 12 (2011): 2991–99.
- Rea, Christopher M. "Theorizing Command-and-Commodify Regulation: The Case of Species Conservation Banking in the United States." *Theory and Society* 46, no. 1 (2017): 21–56.
- Robertson, Morgan M. "The Neoliberalization of Ecosystem Services: Wetland Mitigation Banking and Problems in Environmental Governance." *Geoforum* 35, no. 3 (2004): 361–73.
- Robertson, Morgan M. "The Nature That Capital Can See: Science, State, and Market in the Commodification of Ecosystem Services." *Environment and Planning D: Society and Space* 24, no. 3 (2006): 367–87.
- Robertson, Morgan. "Measurement and Alienation: Making a World of Ecosystem Services." *Transactions of the Institute of British Geographers* 37, no. 3 (2012): 386–401.
- Ruhl, JB. "Endangered Species Act Innovations in the Post-Babbittonian Era-Are There Any." *Duke Envtl. L. & Pol'y F.* 14 (2003): 419.
- . "The Battle over Endangered Species Act Methodology." *Envtl. L.* 34 (2004): 555.
- Timmermans, Stefan, and Steven Epstein. "A World of Standards but Not a Standard World: Toward a Sociology of Standards and Standardization." *Annual Review of Sociology* 36 (2010): 69–89.
- Talberth, John, Mindy Selman, Sara Walker, and Erin Gray. "Pay for Performance: Optimizing Public Investments in Agricultural Best Management Practices in the Chesapeake Bay Watershed." *Ecological Economics* 118 (2015): 252–61.

- Teeffelen, Astrid JA van, Paul Opdam, Frank Wätzold, Florian Hartig, Karin Johst, Martin Drechsler, Claire C Vos, Silvia Wissel, and Fabien Quétier. “Ecological and Economic Conditions and Associated Institutional Challenges for Conservation Banking in Dynamic Landscapes.” *Landscape and Urban Planning* 130 (2014): 64–72.
- Tsing, Anna Lowenhaupt. “On Nonscalability, The Living World Is Not Amenable to Precision-Nested Scales.” *Common Knowledge* 18, no. 3 (2012): 505–24.
- USFWS (1983), Endangered and threatened species listing and recovery priority guidelines, Federal Registration, 48, 43098-43105, RIN 1018-8D46 , Federal Register/Vol. 84, No. 86
- Wolf, Steven. “Accountability, Rationality, and Politics: Critical Analysis of Agri-Environmental Policy Reform in USA.” In *Resistance to the Neoliberal Agri-Food Regime: A Critical Analysis*, Routledge/Earthscan. London: A. Bonanno and S. Wolf, 2017.
- Wyoming Conservation Exchange Exchange Manual, Version 1.0 (2014).
- Wyoming Conservation Exchange Greater Sage-Grouse Habitat Quantification Tool, version 3



-  Restored Endangered Species Habitat
-  Endangered Species Habitat Impacting Activities



	Decision-making methodology	Type of agreement	Robustness of instrument	Accountability
Single banks	Case-by-case rule of expert	On exchange	++	Weak
Habitat exchanges	Inclusive rule of science	On metric	-	Strong