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Towards systematic conservation planning adapted to the local flow of ecosystem services

Jérôme Cimon-Morin[a,b,c,*], Marcel Darveau[b,a,c], Monique Poulin[a,c]

[a] *Laval University, Pavillon Paul-Comtois, Faculté des sciences de l'agriculture et de l'alimentation, Département de phytologie, 2425 rue de l'Agriculture, Québec, Qc, Canada G1V 0A6*

[b] *Ducks Unlimited Canada, 710 Bouvier, bureau 260, Québec, Qc, Canada G2J 1C2*

[c] *Quebec Centre for Biodiversity Science, Montreal, McGill University, Stewart Biology Building, Department of Biology, 1205 Dr. Penfield Avenue, Montreal, Qc, Canada H3A 1B1*

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A B S T R A C T

Ecosystem services (ES) are increasingly included in conservation assessment worldwide to sustain their ability to fulfill human needs. Due to the instrumental value inherent in ES, priority areas for their conservation should be selected based on their capacity to both ensure an available supply and meet beneficiary demands. However, such a methodology has yet to be developed. Aiming to adapt systematic conservation planning procedures to include ES, we conducted a case study in eastern Canada focusing on ten ES for 16 wetland types. We first delimited the ES supply accessible for human use from the total biophysical supply and mapped demand for each ES. Secondly, we assembled conservation networks targeting the accessible supply and demand and compared them with networks targeting either ES biophysical supply or accessible supply. We found that targeting only ES supply resulted in selecting sites that are not in demand and may be up to three times less efficient in fulfilling the demands of beneficiaries for local flow ES. Thus, not considering demand in ES conservation assessment fails to position reserves where ES supply is likely to be most useful. Setting conservation targets for ES supply and demand could therefore help to achieve ES conservation objectives.

1. Introduction

Steady expansion of the world's population and economic growth will continue to increase pressure on natural ecosystems and accelerate the decline of the supply of most ecosystem services (ES) observed around the globe (Chapin et al., 2000; Foley et al., 2005; Millennium Ecosystem Assessment (MA), 2005; Vitousek et al., 1997). ES have been defined as the benefits that humans obtain from ecosystems and have been classified according to four categories: provisioning, regulating, supporting and cultural services (Millennium Ecosystem Assessment (MA), 2005). In the short term, modern land use practices can increase the supply of most provisioning services (i.e. food and material), but in the long term they undermine the capacity of ecosystems to provide other services, such as freshwater supply, climate regulation and recreational opportunities (Foley et al., 2005; Millennium Ecosystem Assessment (MA), 2005). The growing awareness of the importance of ES for human well-being has increased interests in securing their sustainability, notably through land protection and related

* Corresponding author at: Laval University, Pavillon Paul-Comtois, Faculté des sciences de l'agriculture et de l'alimentation, Département de phytologie, 2425 rue de l'Agriculture, Québec, Qc, Canada, G1V 0A6. Tel.: +1 418 623 1650x27.

E-mail address: jerome.cimon-morin.1@ulaval.ca (J. Cimon-Morin).

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conservation actions (Balvanera et al., 2006; Chan et al., 2006; Egoh et al., 2007; Millennium Ecosystem Assessment (MA), 2005; Turner et al., 2007). Human societies' demand for and dependence on ES is expected to grow (Guo et al., 2010), and along with it, the need to sustain ES availability.

ES provide benefits on different spatial flow scales (i.e. ranging from local to global), depending on where a service is produced (source) relative to where its benefits can be perceived (sink) by human beneficiaries (Bagstad et al., 2013; Balmford et al., 2011; Cimon-Morin et al., 2013; Fisher et al., 2009). Protected areas for ES have to be identified based on their capacity to provide a continuous flow of ES to their specific beneficiaries. From a conservation perspective, most ES have a local spatial flow scale; for this reason beneficiaries must approach or enter the protected area where the ES are supplied to obtain its benefits (thereafter referred as ''local flow ES''). For example, recreational angling in a protected area requires the angler to capture (sink) the fish species within the protected area (source), established to conserve nature and its associated ES, even if the benefit (i.e. the meat) can be consumed elsewhere. Moreover, demand for protecting ES, or the sum of the benefits currently obtained in a particular area (Burkhard et al., 2012), is spatially heterogeneous (Burkhard et al., 2012; Nedkov and Burkhard, 2012; van Jaarsveld et al., 2005). Demand for local flow ES generally diminishes with increasing distance from beneficiaries because far fewer people are willing to travel great distances to obtain benefits from nature (Chan et al., 2006; Holland et al., 2011). A spatial mismatch can thus occur between local flow ES supply (i.e. the amount of benefits) and the sites most used by human beneficiaries (i.e. highest demand). For example, demand for recreation services is driven more by the proximity to roads and the size of and the distance to nearby population centers than by the capacity of a site to provide the services per se (Chan et al., 2006; Holland et al., 2011). Accordingly, local flow ES do not necessarily provide actual benefits to human populations everywhere they are supplied, either due to lack of physical access or demand or restrictions by institutional arrangement (e.g. land-use constraints in national parks restrict access to provisioning services; Tallis et al., 2012).

Systematic conservation planning (SCP) is increasingly recommended for safeguarding ES provision (Chan et al., 2006; Cimon-Morin et al., 2013; Egoh et al., 2008). SCP is a multi-component stage-wise approach to identifying conservation areas and devising management policy, with feedback, revision, and reiteration, where needed (Kukkala and Moilanen, 2013; Margules and Sarkar, 2007; Pressey and Bottrill, 2008; Sarkar and Illoldi-Rangel, 2010). SCP notably involves identifying priority areas to effectively achieve conservation goals; traditionally, these goals include representativeness, persistence and cost-efficiency (Margules and Sarkar, 2007). However, due to the anthropocentric focus and instrumental value associated with ES (Reyers et al., 2012), these goals must be expanded to address the spatial relationships between ES supply and their human beneficiaries (Chan et al., 2006; Egoh et al., 2007). Specifically, ES conservation areas should be targeted as a complementary set of sites selected according to their capacity to ensure a sustainable and accessible supply of ES as well as deliver these benefits where they are needed (Cimon-Morin et al., 2013).

Although an increasing number of studies have included ES in conservation assessments (Chan et al., 2006; Egoh et al., 2008, 2007; Larsen et al., 2011; Luck et al., 2009; Naidoo et al., 2008), there is still a knowledge gap on how to effectively prioritize areas based on ES provision, accessibility to beneficiaries and demand (Cimon-Morin et al., 2013; Egoh et al., 2007; Maes et al., 2012; Tallis and Polasky, 2009). The aim of this study is therefore to suggest a modification of SCP procedures that would increase the effectiveness of local flow ES conservation. For this purpose, we conducted a case study in eastern Canada focusing on 16 wetland and aquatic habitats and an associated set of 10 ES (five provisioning, three cultural and two regulating services). We first mapped for each planning unit the biophysical supply of each ES and then used proxies of human occupancy of the territory to define the supply's potential-use spatial range, that is to say, the supply accessible for human use. Concurrently, we mapped ES demand as the probability that a planning unit would be used by beneficiaries in order to obtain the benefits of a specific ES. We compared conservation networks resulting from site-selection algorithms based on the biophysical supply of ES, the potential-use supply or the combination of potential-use supply and demand (i.e. the actual-use supply). The concept of actual-use supply originates from the assumption that the real contribution to human well-being is not only when ES are supplied and the benefits are accessible but also when a minimal amount of demand is fulfilled. Accordingly, the actual-use supply of an ES is defined as when both accessible supply (i.e. potential use supply) and demand occur at the same site. We hypothesized that prioritizing areas based on actual-use supply would foster conservation choices more efficiently towards ES conservation objectives. Finally, we evaluated how to best integrate data on ES demand in SCP to assemble conservation networks that are the most appropriate for satisfying the needs of beneficiaries.

2. Method

2.1. Study area and wetlands mapping

The study was undertaken in the Lower North-Shore Plateau ecoregion and in a southern portion of the Central Labrador ecoregion of boreal eastern Canada (Fig. 1; Li and Ducruc, 1999). The study area covers over 137 565 km^2, most of it part of the black spruce-moss vegetation domain (Saucier et al., 2009). Of the approximately 12 350 inhabitants (0.09 inhabitants/km^2), 9800 are dispersed among fifteen municipalities and 2550 in four First Nations communities (Gouvernement du Québec, 2013). The minimal mapping unit of the Natural-Capital Inventory dataset (Ducruc, 1985), a dataset originally built for the ecological classification of the territory, was used to divide the study area into 16 026 planning units. These units are irregular in shape and size (mean of 8.5 ± 15 km^2) because they are delimited by significant and permanent environmental features, such as landscape topography, surface deposits and water bodies. All mapping was performed using ArcGIS 10.0. (ESRI, 2012). The study area is currently minimally developed but its large freshwater reserves, commercial forests and rivers