One Earth

Gold Standard for the Global Goals
1 ton of CO_2 offset

CellPress
OPEN ACCESS

Perspective

Financial incentives for large-scale wetland restoration: Beyond markets to common asset trusts

Adam D. Canning,[1,*] Diane Jarvis,[1,2] Robert Costanza,[3] Syezlin Hasan,[4] James C.R. Smart,[4,5] John Finisdore,[6] Catherine E. Lovelock,[7] Suzie Greenhalgh,[8] Helen M. Marr,[9] Michael W. Beck,[10] Christopher L. Gillies,[1,11] and Nathan J. Waltham[1]

[1]Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER), James Cook University, 1 James Cook Drive, Townsville, QLD, Australia
[2]College of Business, Law & Governance, James Cook University, Cairns, QLD, Australia
[3]Crawford School of Public Policy, The Australian National University, Canberra, ACT, Australia
[4]Australian Rivers Institute, Griffith University, Brisbane, QLD, Australia
[5]School of Environment and Science, Griffith University, Brisbane, QLD, Australia
[6]Sustainable Flows Ltd, Melbourne, VIC, Australia
[7]School of Biological Sciences, The University of Queensland, Brisbane, QLD, Australia
[8]Manaaki Whenua Landcare Research, Auckland, New Zealand
[9]Kāhu Environmental Ltd, Martinborough, New Zealand
[10]Institute of Marine Sciences, University of California Santa Cruz, Santa Cruz, CA, USA
[11]The Nature Conservancy Australia, Melbourne, VIC, Australia
*Correspondence: adam.canning@jcu.edu.au
https://doi.org/10.1016/j.oneear.2021.06.006

SUMMARY

Wetlands provide ~$47.4 trillion/year worth of ecosystem services globally and support immense biodiversity, yet face widespread drainage and pollution, and large-scale wetlands restoration is urgently needed. Payment for ecosystem service (PES) schemes provide a viable avenue for funding large-scale wetland restoration. However, schemes around the globe differ substantially in their goals, structure, challenges, and effectiveness in supporting large-scale wetland restoration. Here, we suggest wetland-based PES schemes use common asset trusts (CATs) to build investment portfolios of wetlands across landscapes that sustain and enhance overall provision of multiple ecosystem services. CATs can meet the needs of multiple investors, permit bundled payments, and provide flexibility to invest in the restoration of numerous services/values, all using a coordinated, highly collaborative, prioritized, and transparent process. CATs would support financial viability, facilitate efficiency to reduce administrative burdens, and enable credibility and social licence building to restore wetland values and services globally.

INTRODUCTION

Wetland restoration can contribute significantly to meeting many global, national, and local goals and initiatives, including several United Nations (UN) Sustainable Development Goals (SDGs).[1,2] Using the Ramsar definition, wetlands include any inland, coastal, or marine waterbody, still or flowing, fresh or saline, permanent or temporary, to a depth of 6 m at low tide.[3] This includes fens, peat bogs, swamps, marshes, oyster reefs, rivers, lakes and artificial water bodies, mangroves, seagrass meadows, mudflats, and some coral reefs. In many cases, wetlands also include adjacent riparian and coastal zones.[3] Wetland ecosystems provide a range of ecosystem services (i.e., the benefits to humans from ecosystems), including water purification, carbon sequestration, food provision, flood regulation, storm surge protection, and ecotourism, and support biodiversity, and cultural and spiritual values.[1] The global value of wetland ecosystem services is estimated at ~$47.4 trillion/year, with estuarine and palustrine wetlands among the most service-rich ecosystems relative to extent.[4,5] The total value of ecosystem services to human wellbeing comprises both market (market price or exchange values) and non-market values. Estimates of the total value are required to truly recognize the contribution the wetlands make to human wellbeing, and to enable us to appropriately determine the ecosystem services most in need of protecting from degradation or loss.

Despite the well-established provision of ecosystem services, global wetland extent is still declining.[6] Davidson[7] estimates that 54%–57%, and possibly as much as 87%, of global wetlands have been lost as a result of land use change for agricultural, urban, and industrial expansion. Large-scale wetland restoration would directly support the UN SDGs by providing a critical buffer against global climate change, improving water quality, increasing infrastructure resilience to floods and storm surge, protecting or enhancing biodiversity, and addressing food supply crises.[2,8]

The protection and restoration of wetlands is being facilitated by many policy instruments, including outreach and education (e.g., awareness campaigns), international conventions (e.g., the Ramsar Convention and Convention on Biological Diversity), governance instruments (e.g., national policies and programs), regulatory approaches (e.g., environmental standards), covenants and easements, environmental taxes, restoration subsidies, and

market-based approaches (e.g., environmental markets and eco-labeling).[9–11] Among these approaches, public/private funding schemes that include payments for ecosystem services (PES), provide a potential way of raising the financial capital needed to deliver large-scale wetland restoration.[12–14] PES schemes may be regulated (e.g., government-led programs to achieve legislated environmental limits) or voluntary (e.g., non-government organization-led programs to achieving non-binding goals), and seek to provide payment for the additional or sustained existing ecosystem services that restored ecosystems provide, often to offset impacts elsewhere.

PES schemes have primarily arisen from trading carbon for climate change mitigation or trading nutrients for water quality improvement, mitigation banking, or sale of habitat protection/restoration "stamps."[12,15] New scheme mechanisms (e.g., crowd funding), new support technologies (e.g., block-chain mechanisms and remote sensing), and new opportunities (e.g., blue carbon, property protection,[16] and bioenergy) are on the horizon and present options for schemes that endeavor to fund future wetland restoration within the UN "decade of ecosystem restoration (2021–2030)."[17]

While promising, PES schemes do not often deliver the expected benefits from wetland restoration.[15,18,19] These failures can arise where wetland restoration is a secondary objective or a tool supporting a primary objective (e.g., reducing carbon or improving water quality) and where the schemes face their own difficulties.[20] For example, a review of the effectiveness of four North American water quality trading schemes (in which, wetlands are one of many options for improving water quality) identified many challenges, including inadequacy in monitoring, low participant motivation,[21] difficulties in achieving and enforcing compliance, ill-defined property rights, and high administrative and transaction costs.[22] Similar challenges were also identified by a review of PES schemes across China.[20] It is likely that PES-based restoration schemes in other locations will face similar and scheme-specific challenges. If wetland restoration is to deliver a substantial contribution toward local ambitions and ultimately global SDGs,[1,2,23] it is imperative that financial incentive mechanisms, such as PES, are well designed to maximize success in achieving a chief objective of large-scale wetland restoration. This is in contrast to existing schemes that typically primarily focus on ecosystem service provisioning and have wetland restoration as a secondary objective.

Notable types of PES schemes providing incentives for wetland restoration include carbon markets; water quality trading; habitat stamps and wild harvesting; eco-labeling; crowd funding; and water funds. While each scheme has advantages, disadvantages, and room for improvement (Table S1), three cross-cutting challenges exist: (1) demonstrating sustained financial viability; (2) establishing credibility with effective verification and accounting; and (3) balancing trade-offs to achieve general acceptability, and to establish and maintain social license to operate (Table S1).[24–26]

Here, we suggest that PES schemes dedicated to, and specifically designed for, wetland restoration will be more effective than single-service-focused schemes and non-financed instruments in not only increasing the rate and extent of wetland restoration, but also increasing the flow of multiple ecosystem services. Taking on board the challenges faced by many PES schemes (Table S1), we propose using a common asset trust (CAT) approach as the platform for a PES scheme designed to enhance wetland restoration efforts. Below we analyze the three main challenges for PES schemes and how these challenges may be overcome. We then outline how a CAT could solve many of these challenges to enhance wetland restoration, and identify the roles and responsibilities of key stakeholders.

COMMON CHALLENGES ACROSS SCHEMES

The three key challenges across schemes are financial viability, credibility, and maintaining a social license to operate.

Financial viability

Financial viability is critical to the success of any PES scheme. Funding is often insufficient, intermittent, or highly variable, to confidently cover the costs of wetland restoration (including the opportunity cost of land use change), associated assessments, monitoring and administration, and on-going maintenance after construction.[27–29] Financial viability rests on sufficient, stable, and sustained payments for projects and acceptable rates of return for project investors (including public financers seeking societal benefits). Highly variable provision of services may lower investor confidence in returns, deter investors, and erode financial viability. In addition, sometimes measuring/estimating service flows requires complex and expensive assessments to boost confidence.[14,30,31] Often, schemes trade a single-service commodity (e.g., credits for carbon sequestration or nitrogen removal), rather than rewarding the provision of multiple services, where restored wetlands are designed and positioned to optimize cost-effective delivery of that service (Tables S1 and S2).[18,32]

As wetlands can deliver multiple ecosystem services,[1] schemes that focus on a single service (i.e., the primary benefit) do not value and reward the provision of co-benefits (i.e., the secondary benefits).[33] Carbon markets, for example, offer low and highly variable trading prices, with compliance markets having greater demand (driven by legislated limits) and offer better prices than voluntary markets (Figures S1–S3).[34–36] Wetland-based carbon sequestration projects are often only viable and competitive against other offset options in low-cost developing countries, e.g., the Sundarbans Mangrove Restoration in India (Note S1).[28,36,37] Even then, Vietnam's Markets and Mangroves project (Note S2) within the Mekong Delta initially sought funding by selling carbon credits, but were deterred by the administrative cost burden, and instead were funded by an organic eco-label.[38] Trading prices are often insufficient to deliver positive returns from wetland restoration in countries with developed economies.[36,37]

Quantification of ecosystem service provision in market-based schemes can often constitute a substantial cost that affects financial viability.[31,36,39] For example, Günther et al.[40] estimated in 2018 that assessing carbon for a 52 ha re-wetted fen in north-eastern Germany cost between €150,000 and €300,000 over 2–3 years. Several mechanisms, including standard setting, applying trading ratios and using direct fund investment, have been trialed to reduce the compliance costs of participating in wetland restoration projects. Germany's Moor-Futures regional carbon trading scheme has increased the financial viability of peat-wetland restoration by reducing compliance

costs through the setting of local assessment methods and standards (Note S3).[41,42]

North American point-nonpoint source water quality trading markets (e.g., Colorado's Cherry Creek and Ontario's South Nation River schemes; Notes S4 and S5, respectively),[22,43] and wetland biodiversity mitigation markets (e.g., Chicago's wetland mitigation market; Note S6),[44,45] often apply trading ratios, which tend to be conservative, to account for uncertainties in service delivery. Trading ratios are a policy mechanism that require polluters or property developers to offset more than the estimated discharge or loss. For example, Ontario's South Nation River phosphorus trading scheme requires polluters to offset four times the amount of phosphorus discharged (Note S5). Trading ratios could allow for less onerous assessment methods, improving the cost effectiveness of restoring larger wetlands.[22,43] However, very high ratios may render wetland projects uncompetitive against other offset options. Using trading ratios with complementary assessment models or simple estimates of efficacy, can increase certainty, ease monitoring costs, and thereby increase competitiveness compared with other offsets.[46–48] In California's carbon trading scheme (Note S7), wetland restoration has not been driven by credit-generating activities, but from direct investment by the Greenhouse Gas Reduction Fund (funded by the State's revenue from the scheme), which do not require credit generation, bypassing the need for carbon assessment altogether (Note S7).[49]

Fund-based schemes, such as the Latin American water fund (LAWF) schemes, such as those in Mexico, Colombia, Ecuador, Peru, Dominican Republic, and Brazil, and habitat stamp schemes, such as those in the US, Canada, and New Zealand (Note S8; Table S1), have both demonstrated financial viability and efficiency in supporting large-scale wetland restoration.[50–53] For example, the US Federal Duck Stamp, which must be purchased prior to hunting waterfowl, has restored over 2.4 million ha of wetlands.[50] Funds are pooled from multiple sources into a trust, managed by trustees tasked with strategically investing in restoration activities that support trust objectives (e.g., gamebird hunting or improving water quality/quantity). Multiple funding sources support financial resilience but do not guarantee immunity against financial variability.[51,52] Habitat stamp schemes are often funded through hunter licensing and are vulnerable to societal changes in hunting participation.[54,55] While LAWF schemes are funded from a range of public, utility, NGO, multilateral, and private investors, they remain vulnerable to loss of single, large funding sources.[52]

Restoration investment is often financed via a combination of a fund's principal and interest, depending on the size and pace of restoration required balanced against the need to buffer market and political volatility.[52,53] As funding is not dependent on trading revenues from the sale of rival and excludable goods/services (i.e., the goods and services the ecosystem produces; outputs), monetary transfers can be based on activities that generate increases in the provision of ecosystem services (i.e., wetland restoration; inputs). With habitat stamp schemes, restoration activities provide gamebird habitat and broader conservation value (input-based approach); however, hunters are not guaranteed a specific gamebird population size (output-based approach; Note S8). In LAWF schemes, restoration activities may support sediment reduction (input-based approach), but do not guarantee a downstream water quality standard (output-based approach). While outputs in such schemes are not traded, outputs are still measured to evaluate efficacy, support adaptive management, inform future investments, and entice new funding, and are important to ensure that environmental goals are achieved.[51,52] Fund structures that include a centralized agency means the assessment and administrative burden can be low relative to environmental market approaches.[31,39,53] Both habitat stamp and LAWF schemes offer many learnings that could be used to improve the success of PES schemes in restoring wetlands (Table S1).

In contrast to the LAWF schemes that bundle payments for multiple ecosystem services, schemes that stack payments (award discrete payments for multiple services) have rarely been implemented and are often prohibited. Stacking is largely an output-based approach where separate payments are given for each quantifiable service provided, which differs from bundling (largely input-based) where a single payment is given for a package of services.[39,56] Stacking can have high assessment and administrative burdens, as each service requires its own evaluation. This may be particularly burdensome when many services require assessment, reducing the cost effectiveness of the scheme (Table S1). Assessing additionality for stacking can be challenging. For example, if a carbon payment is already received for wetland restoration, an additional environmental improvement may be required to receive further payments for supplying nitrogen removal.[56–58] While stacking can improve financial viability and increase the broader conservation benefit via greater restoration, a potential downside is that increased supply of wetlands could devalue the credit trading prices for provision of individual services.[39,59,60] This, however, could be an advantage if reducing service provision costs is the goal. Simulated credit stacking within the Baltic Sea nutrient trading markets indicates a ~20% reduction in nutrient credit costs as credit supply increases relative to demand.[61] The financial viability of output-based schemes rests heavily on the ability and credibility to provide and assess the additional ecosystem service desired.

Establishing and maintaining scheme credibility

For market-based schemes that incentivize the provision of ecosystem services to be credible, they must demonstrate at least four features[35,39]: (1) *additionality*, where projects need to demonstrate that the offset would not have occurred under a business as usual scenario (e.g., that the generated pollution abatement is additional to that accounted for when pollution discharge licenses and/or catchment load caps were set); (2) *leakage minimization*, where projects need to show a net gain in provision of ecosystem services; i.e., additional provision of ecosystem services has not been outweighed through adverse changes in practice or land use elsewhere; (3) *permanence*, where projects need to minimize the risk that future developments will reduce or remove the benefits delivered, such as a restored wetland being drained again; and (4) *verification*, where benefits need to be measurable and reported in a transparent fashion to ensure environmental gains are realized.[35,39]

The first three requirements can be strengthened (but not necessarily guaranteed) by having a robust accounting framework with baseline data on conditions (at a sufficiently broad

scale), and legally binding covenants and safeguards where needed. The fourth requires cost-efficient and repeatable assessment methodologies (including models based on proxies) being available to projects via sound governance.[35,39] Many market-based schemes struggle to satisfy these four requirements, often lacking robust wetland mapping and accounting of the extent and condition, or requiring onerous assessment of ecosystem service provision (Table S1).

The delivery of ecosystem services by wetlands occurs at multiple scales, underpinned by complex processes that vary spatially and temporally, making quantification of ecosystem services difficult and costly. This can lead to distrust in service provision. Denitrification processes in wetlands, for example, is highly variable (both spatially and temporally) and dependent on inlet nutrient delivery concentrations, wetland size and shape, hydrology, hydraulic residence times, vegetation, temperature, and redox potential.[62] Accurate assessment of variability requires intensive monitoring. The estimation of carbon sequestration for carbon offsets, increased waterfowl population for hunters, sediment removal for drinking water supplies, species occurrences for biodiversity conservation, and other services would be similarly difficult to accurately assess.[31,63,64] Models can be used to estimate service provision; however, they would need to be underpinned by science, validated, reliable, peer-reviewed, robust, and used by appropriately trained operators to be acceptable.[65,66] New Zealand's water quality schemes demonstrate how uncertainties in assessment models can lead to skepticism about the benefits of wetland restoration (Note S9).[67] The use of robust and accepted proxies, models, and standards in Germany's MoorFutures carbon scheme (Note S3); the use of models and conservative estimates of service provision in North American water quality trading schemes (Notes S4 and S5); and the use of input-based assessments (i.e., wetlands meeting a predetermined design standard) rather than output-based assessments (i.e., estimation of service provision) in habitat stamp and water fund schemes,[31] all demonstrate alternative options for avoiding intensive, costly assessment of ecosystem service provision.

In addition to assessment, schemes that need to demonstrate additionality must establish baseline service provision and ensure that leakage is minimal (i.e., that losses are not occurring concurrently).[31,68] For example, an exhaustive survey of US biodiversity mitigation bank schemes in 2006 found that they consistently lacked a maintained database of wetland mitigation bank transactions and sufficient detail to allow third-party verification.[69] Furthermore, reviews of the schemes in Chicago and Florida observed that ~60% of credits have been sold without meeting prescribed ecological performance standards, suggesting that they are either sold immaturely, are poorly developed projects, or have suffered from natural uncertainty.[45,70] The lack of robust and transparent accounting, which is then communicated and used in decision-making, makes it difficult to establish social credibility as the community may be cynical about the validity of offsets and additionality provided.

Social license to operate

All schemes have the potential for both positive and negative impacts, and may create winners and losers, perceived or real. While consensus among stakeholders is highly unlikely, trade-offs need to be managed to ensure schemes are socially acceptable; schemes may be rendered unviable if their social licence is not established or is lost.[71,72] A social licence is the acceptance of an activity or system granted by the community to operate. This is critical for those schemes reliant on legislated environmental limits and legislated trading, as democratic political decisions are highly sensitive to societal appetite. Without a social licence, politicians in a modern democracy are unlikely to support a scheme, which ultimately threatens scheme viability. Trade-offs may arise at multiple points within a scheme as conflict can arise both within and between environmental, social, cultural, and economic goals, including the UN SDGs (Table S1). Contentious areas of trade-off may include differences in ecosystem service provision driven by wetland location and design, and the alteration of individual and/or community use rights.[73–75]

Wetlands differ considerably in the type and amount of ecosystem services generated.[64] Restored wetlands are typically designed to enhance the ecosystem service that attracted the funding for restoration (e.g., nutrient attenuation, carbon abatement, biodiversity payments, waterfowl hunting, or tourism; Table S2). Enhancing the delivery of one ecosystem service can reduce the delivery of other services, potentially creating conflict between goals.[74,75] For example, in Australia an earth wall removed on a floodplain allowed saltwater ingress inland (as an alternative to herbicides) to destroy freshwater aquatic weeds, and also delivered increased carbon sequestration from mangrove expansion, but at the expense of degrading freshwater wetland habitat, used by fish, turtles, and waterbirds.[76]

Likewise, wetlands designed to denitrify nitrogen loads can have low carbon storage and rely on hypoxic conditions that adversely affect wildlife.[77–79] Both examples show potential conflicts between different restoration goals, including the SDGs for carbon action, life below water, life on land, and for clean water and sanitation. Having clear objectives at the outset that are broadly agreed upon by stakeholders, with decision-making well informed of potential consequences, will be necessary for reducing unintended consequences and maintaining a scheme's social licence.[31,80]

Conflicts may arise between environmental and social goals. Poorly implemented restoration schemes—including those supported by PES can result in the loss (or perceived loss) of community use rights sometimes referred to as "green grabbing" and "blue grabbing" in terrestrial and aquatic conservation, respectively.[81,82] Despite good intentions and substantial consultation, agencies and organizations that carry out wetland restoration in areas where communal areas are a common pool resource can disrupt local social norms and displace users reliant on the resource.[83–85] Community displacement can also be exacerbated when developers, and their scientific support partners, make over-zealous promises of outcomes or provision of ecosystem services that are not realized.[86,87] Examples of community displacement have primarily been observed in Africa (e.g., Note S11), Asia, and South America.[88]

The alteration of individual use rights, such as the allocation of pollutant discharge rights/permits to individuals in water quality and carbon trading schemes, can also affect scheme acceptability and viability. By way of example, litigation over the nutrient

Table 1. Eight guiding principles of an effective ecosystem-based CAT, as proposed by Costanza et al.,[97] and the aligning WIF features

Guiding principle	Brief description	WIF features
1. Stewardship responsibility	The trustees have a mandate to sustainably manage the trust to ensure ecosystems are healthy and continually provide services for future generations.	Managed using a deliberative democratic approach with representatives from all stakeholders, including indigenous membership and scientific advisory, that set and work toward wetland restoration objectives that align with local values. Supported by a local scientific/technical support partner, local indigenous/ traditional owners, government, and stakeholders.
2. Systems thinking	The scheme should consider the broad socio-ecological system, with a focus on improving the health and wellbeing of its beneficiaries. Economic, social, cultural, and ecological connectivity across the landscape is understood.	The WIF role includes the early and adaptive identification of values and objectives across the landscape, using spatial planning. This would be informed by working with support partners and stakeholders. Optimal restoration project design and locations would be guided by outputs from the scientific support partner, using tools, such as modeling and multi-criteria analysis.
3. Additionality	Scheme activities to increase ecosystem services should be additional to any in existence or being created by other initiatives and not be lost by destruction elsewhere.	Government would need to ensure legislation supports a no net loss of wetlands policy and operate a broader wetland accounting framework. The scientific support partner would operate a database on the condition, extent, and performance of portfolio wetlands. The WIF would also advocate for the protection of freshwater environments to ensure gains are not lost elsewhere and the integrity of the wetland portfolio is maintained or even improved.
4. Conditionality	Payments should be conditional to the successful provision of the outcomes agreed in contract.	Project developers would be required to demonstrate satisfaction of contracted deliverables by having a trained and approved assessor verify the project deliverables. The scientific support partner would audit assessors and carry out portfolio-wide monitoring with technologies, such as remote sensing would. Deliverables would be based on the provision of inputs, which are more easily verifiable than outputs.
5. Efficiency	The CAT should be efficient in achieving outcomes, with funds invested in high-return projects and maintain low transaction costs.	The WIF operating as a "one-stop shop" for the range of funders and developers to reduce administrative burden, and enabling bundling of funds allowing for large projects that benefit from efficiencies of scale. Spatial planning, supported by guidance on strategic restoration from the scientific support partner, allows for the design and position of wetlands that support optimal provision of desired ecosystem services. Verifying projects using contracted inputs, rather than highly variable outputs, increases assessment efficiency and financial return on investment.

(*Continued on next page*)

Table 1. *Continued*

Guiding principle	Brief description	WIF features
6. Financial sustainability	The trust should secure sufficient funding to remain financially viable and be resilient to social and economic stressors.	The WIF is not limited to provision of a single ecosystem, but flexible to invest in any ecosystem service desired from wetlands. As a result, it can accept and aggregate funds from a wide range of potential sources (Table S2), and invest in a range of wetland restoration projects potentially supporting different services (Figures 1 and 2; Table S2), allowing the fund to hedge bets for both investors and investors. Fund managers can also choose the extent to which funds invested in restoration are sourced from principal or interest earned on principal, which helps to balance growth with resilience to political and market volatility.
7. Intersectoral participation	The trust should operate under a participatory approach, being inclusive of all stakeholders.	The WIF would have strong partnerships with a local scientific/technical support partner and local indigenous/traditional owners. There would also be strong participation by stakeholders, including investors, project developers, and local community.
8. Legally sound	The trust should be established and protected by a set of laws, regulations, policies, and contracts to sustain it over time.	In many jurisdictions, trusts or similar are legally well established. Legal assistance and a partnership with government can help ensure the scheme has adequate legal safeguards.

discharge allocation method in the regulatory limit has stalled the implementation of New Zealand's Rotorua Lakes nitrogen trading scheme (Decision [2019] NZEnvC 136) (Note S11). Contention arose over whether to grant the largest polluters large initial allocations of pollutant discharge rights (to minimize economic disruption) or whether the allocation of discharge permits should be based on land characteristics (to avoid rewarding polluters, incentivize land use positioning, and reduce inequality) (e.g., Decision [2019] NZEnvC 136 and Decision [2017] NZEnvC 037). Similar contentions over the preferred allocation method is also observed in carbon trading schemes, such as the EU ETS (Note S12),[89,90] and China's recent National Carbon Trading Scheme (Note S13).[91,92]

While there appears to be no "one-size-fits-all" approach to achieving general acceptability, the importance of indigenous partnerships and engaged participation of all local stakeholders, particularly when identifying scheme values and objectives, is important for PES schemes.[93] The early identification of catchment community values and scheme objectives, including how values vary temporally, spatially and existing dependencies on ecosystem services can reduce conflicts and trade-offs, increase acceptability and efficiency in achieving objectives, and minimize disruption of local norms.[94–96] Furthermore, moving from site-scale to landscape-scale PES schemes can allow for greater incorporation of diverse stakeholders as different sites can be tailored to meet different needs, which could be facilitated by applying spatial multi-criteria analysis.[31,73]

Forcing all ecosystem services to fit within conventional markets designed for rival and excludable goods is challenging[97] (Table S1). Ecosystem services differ substantially in the extent to which they are rival and excludable, which are conditions necessary for well-functioning markets.[14,72] Many ecosystem services provided by wetlands are not easily excluded (e.g., fish migration to the open ocean and pollutants), are non-rival (e.g., flood protection), and scarcity is often the result of legislatively imposed constraints. Given the variable nature of wetlands, promising a level of service provision to those seeking to purchase offsets *a priori* (e.g., 100 t of carbon will be sequestered over the next 10 years) will be fraught with risk and difficult to guarantee. Any promises of offset made would need to ensure they are meaningful and achievable, reliant on a solid understanding of the local context, ecosystem functioning, baseline conditions, natural feasibility, and social realities. By contrast, adopting a "pay by performance" approach, where fund income is dependent on the selling of credits realized over (say) the previous 5 years would provide variable and uncertain revenue streams, particularly when reliant on trading a single service (while multiple services allows hedge betting).[39,97] This can create an intense focus on assessment, to have confidence in ecosystem service delivery and financial returns. Assessments can be complex, have high uncertainty, and may reduce financial viability. Using models and conservative estimates of service provision can help alleviate the assessment burden but would require larger areas of wetlands to be restored to achieve financial viability.[65] Mechanisms that trade single services are also vulnerable to changes in buyer demand, which can occur if societal values change or legislated limits ("caps") are weakened, removed, or are met.

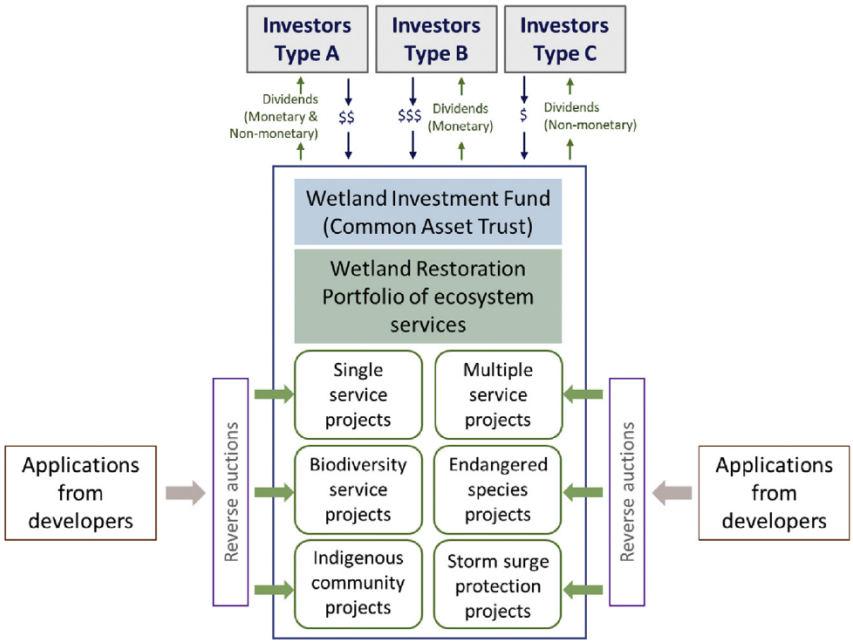


Figure 1. The monetary and service flows between investors, developers, and a proposed wetland restoration investment fund

MOVING FORWARD WITH CATs

An effective PES scheme would ensure the restored ecosystems, and those already in existence, are healthy and safeguarded from detrimental impacts. The scheme would need to support the "wise use" of wetlands, which is a central tenet of international wetland conservation and management policy, such as the Ramsar Convention.[98] Although the concept of wetlands wise use has developed from an ecological worldview, more recent views suggest that this should involve adopting a broader social-ecological worldview that includes social values. A social-ecological view of wise use requires the abiotic (physical components), biotic (biological components and processes), and resource user (individuals and communities that interact with the abiotic and biotic) variables of wetland character to be managed.[98] The scheme would have to be financially viable, requiring reasonably stable income sufficient for covering the costs of restoring and maintaining desired ecosystems. Estimation of service delivery would need to be reliable and credible; and the scheme would need to ensure it is socially and culturally acceptable in the jurisdiction in which it exists.[31,39] Early identification of values and objectives would be necessary to effectively and efficiently deliver outcomes that meet stakeholder expectations. The scheme may require strong indigenous partnership and community engagement to ensure the values, objectives, and projects are well informed and socially viable.[31,39] The objectives, guided by values, would need to recognize that not all wetlands provide the same services and allow for trade-offs in service provision. Restoration activities would need to be high quality and maintained in the long term to ensure continued service provision.

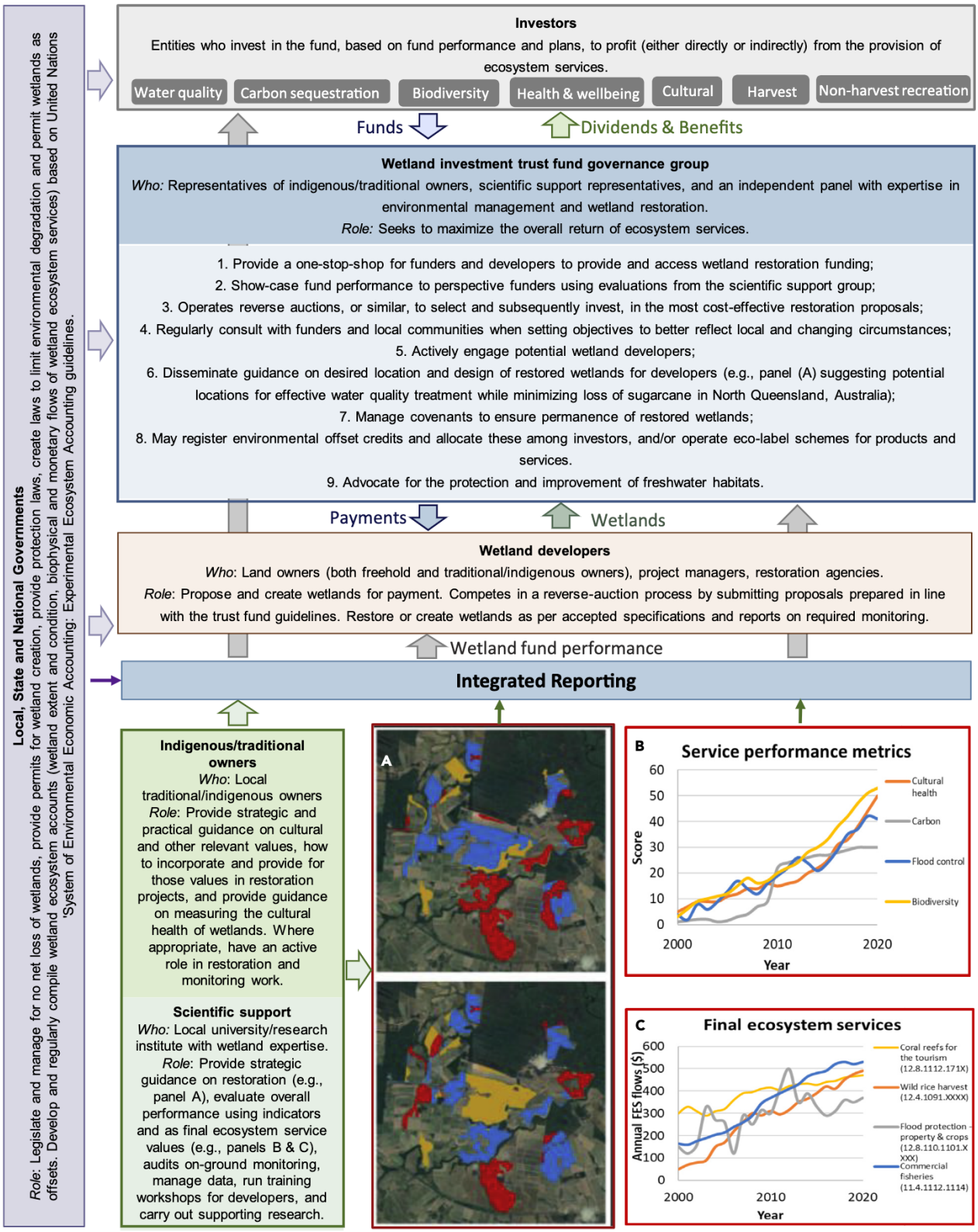
Recently, Costanza et al.[97] proposed thinking of ecosystems (natural capital) as common property, given that many ecosystem services are non-excludable and/or non-rival, and proposed that ecosystems are more effectively managed through CATs. A typical trust involves trustees managing assets on behalf of specific beneficiaries. In the context of ecosystems, a CAT would be a collection of agreements, institutions, and funds that sustainably manages ecosystems (assets) for their benefits (i.e., for delivery of ecosystem services). The implementation of CATs could have multiple benefits, including: having well-established legal mechanisms, with conflict resolution procedures; being objective-focused; permitting flexibility in the investors and investment decisions, enabling investment in multiple ecosystem services; flexibility when dealing with existing property rights by being able to support a mix of property right regimes; allowing a coordinated framework for strategic planning; providing a platform for high levels of collaboration; and supporting administrative and transaction efficiency.[97] In the context of wetlands restoration, a CAT (in contrast to individually managed projects) could manage multiple individual projects under a single unity to efficiently and strategically achieve landscape-scale objectives (Table 1), whereas individually managed projects would likely be ad-hoc and not benefit from the economies of scale.

While CATs present many benefits, the largest downside, as with any new cooperative institution, establishment may be hindered by resistance from vested interests who must be convinced that the new system will be broadly beneficial.[99] Effectively mitigating this risk will inevitably rest heavily on the ability of the CAT to practice deliberative democracy, inclusive policy-making, and identify the communities' values and goals comprehensively early on.

Schemes that focus on wetland restoration could benefit from using a CATs approach, similar to the LAWF and habitat stamp schemes, whereby wetlands are considered as common assets, rather than as providers of independent privitizable services. Here, we outline a Wetland Investment Fund (WIF) scheme structure that aims to: (1) drive large-scale wetlands restoration at multiple locations; (2) operate as an effective CATs, consistent with Costanza et al.'s[97] eight guiding principles (which are based on Ostrom's social-ecological systems approach[100]); and (3) to either avoid, remedy, or mitigate the challenges observed in existing non-wetland focused PES schemes (Figure 1; Table 1).

WIF

A WIF, functioning as a CATs, would aim to maximize the overall return of ecosystem service flows, both monetary and non-monetary, arising from a portfolio of wetland restoration projects (i.e., ecosystem service return on investment from wetland ecosystems; Figure 2).[101] Akin to a conventional managed fund, the



(legend on next page)

WIF could accept investment from multiple *investors* and invest in multiple wetland restoration projects that support multiple scheme objectives,[101] with any benefits arising from the portfolio returned to investors as "dividends" either directly (where excludable and rival) or indirectly (where non-excludable and/or non-rival). For directly apportionable services, investors could choose whether to take their share of any credits generated or the proceeds from the sale of their credit share on a trading market. For example, an airline investor may wish to use their share of carbon credits generated to offset their greenhouse gas emissions, while a finance manager may seek payment from the sale of their share of carbon credits, and a conservation investor may wish the proceeds of their carbon credit share to be invested back into the fund. Under a WIF, fund managers (i.e., the trustees) would have the flexibility to invest in either individual restoration projects that capitalize on the provision of a single service (e.g., improving water purification), or others with multiple complementary objectives, which then collectively increase the overall value of ecosystem services flowing from the portfolio of wetland restoration sites (Figure 3). A local scientific/technical support agency could provide strategic guidance on restoration activities and assess the overall fund performance, based on both intermediate and final ecosystem services.[102]

The WIF could disburse payments to *project developers* (those restoring wetlands) using a reverse-auction format. Reverse auctions have been shown to deliver greater cost effectiveness for the delivery of other conservation and wetland restoration programs than uniform payments.[105,106] Reverse auctions are where individuals/organizations submit a bid for the minimum amount they are willing to accept to undertake a wetland restoration project. Bids are then ranked based on the ecosystem service provision generated by the project and the bid amount.[105,106]

The WIF's funding would come from *investors* who seek dividends from one or multiple ecosystem services generated by the portfolio of restored wetlands. Fund performance, in terms of trends in the ecosystem services return on investment, would attract new investors (Figures 1–3). Investors interested in single ecosystem services, such as airlines seeking carbon abatement, may choose to invest based on historical performance, and anticipated (but not guaranteed) future improvements based on restoration plans for their focal service (e.g., trends in estimated CO_2 equivalent abated). Additional complementary benefits generated (e.g., improvements in water quality, fisheries, tourism, or mental health) could be also be acknowledged in investor marketing, via integrated reporting,[107] to demonstrate the broader societal and environmental benefits generated compared with those initiatives where only one service improves (e.g., technological carbon offset projects).

WIF roles and responsibilities

Elements/components of a successful WIF would include those typical for trust funds.[97,100] A *fund management group (or board of trustees)*, and their supporting staff, would need to be established to manage the investment fund and be responsible for fund performance (i.e., increasing the overall return of ecosystem services on investment over time; Figures 1 and 2; Note S14). The group should include representatives from all stakeholders, including indigenous peoples, community, industry, and technical advisory, each committing to transparency and neutrality, with members focused on setting and achieving the WIF's objectives.[48] Although it can take time, practicing deliberative democracy and inclusive policy-making and programming is necessary for building trust, increasing participation, reducing stakeholder fatigue when consultation processes are bloated or ill-informed, and improving decision-making when stakeholders are divided or polarized.[108–110] Building trust and social capital is critical for building trustworthy institutions such as CAT.[99] Solving environmental issues is not only reliant on technical analysis, but also reliant on knowledge of societal functioning, stakeholder communication, and how activities are carried out and regulated, which all benefit from deliberative democracy.[111]

Roles of the fund management group would broadly include strategic planning, scheme operation, information dissemination, and advocacy. The group would identify values and restoration objectives (including regular consultation with stakeholders and local communities) and provide a one-stop shop for stakeholders, enabling the bundling of funding from multiple sources and reducing administrative burden.[31,72] The group would be responsible for show-casing fund performance to attract funders and then investing funding (via reverse auctions) into restoration projects that are likely to increase ecosystem services flows and support the group's agreed objectives. Where possible, the group would register any credits available (such as carbon credits) and permit and collect royalties from commercial activities (such as tourist operators), and disseminate these as dividends back to investors.

To ensure permanence of the wetland portfolio, the group would instate covenants and other site-specific property right agreements, set and maintain policy on assessment methods and reporting standards, and advocate more broadly in the best interests of protecting the assets (Figures 2 and 3; Note S14). This would include advocating for the protection and improvement of catchment and freshwater management to ensure external activities do not compromise the ability of the wetland portfolio to deliver ecosystem services (Figures 2 and 3; Note S14).

Supporting the WIF would be a *local scientific/technical support partner*, which may include a university, research institution, or consultancy with reputable wetland expertise. The local scientific/technical support partner would need to provide technical, strategic, and practical guidance regarding identification of values, the design and placement of wetlands for maximal delivery of the desired ecosystem services (e.g., using modeling or other analyses, such as multi-criteria analysis; Figure 2; Note

Figure 2. A proposed wetland restoration investment fund with entities, roles, and their relationships

Hypothetical information for demonstration purposes. (A) Mapping exemplifying guidance on strategically locating potential wetlands to maximize provision of a desired service (e.g., DIN removal across the Great Barrier Reef catchment by Waltham et al.[103]). (B and C) Examples of potential performance metrics that could be reported to investors, such as the performance in providing (B) final and (C) intermediate ecosystem services. Numeric codes within (B) are the NESCS-Plus codes for final ecosystem services.[104]

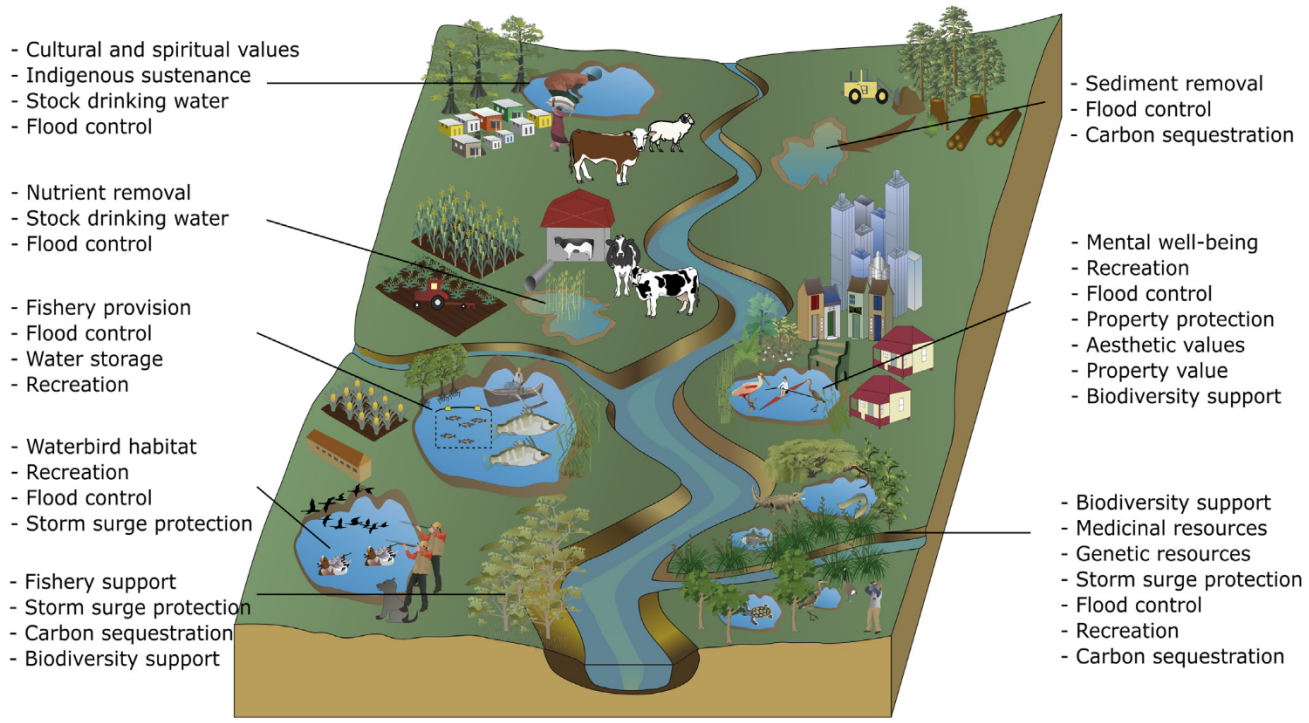


Figure 3. A hypothetical portfolio of wetlands, each wetland supporting a range of different ecosystem services depending on their type, design, and location

S15).[73] They would also be responsible for training wetland assessors, auditing their assessments, maintaining a database of the extent, condition, and function of the wetland portfolio, and providing regular ecological, social/cultural, and economic assessments of the portfolio performance to the fund management group. Portfolio performance should report on delivery of both intermediate and final ecosystem services,[102] as well as any other relevant indicators desired by the fund management group (Figure 2; Note S15). Where appropriate, *local indigenous/traditional owners* would have an active role in incorporating traditional environmental management, values, co-designing and delivering wetland restoration and maintenance, and assessing wetland performance.

Governments would be central and interacting with all groups (Figure 2; Note S16). To minimize leakage and help ensure additionality, government agencies would need to legislate and enforce a "no net loss of wetland extent and condition" policy. To help demonstrate additionality, leakage minimization, and permanence, governments would also need to develop and manage a broader wetland monitoring and accounting system for tracking wetland extent and condition. Governments could also support schemes by providing funding (directly or from Pigouvian taxes), recognizing investment in the fund in offset legislation, ensure legislative mechanisms are adequate for effective CATs functioning, and streamlining environmental approval pathways for wetland restoration projects (Figure 2; Note S16).

Investors enable the continued operation of a WIF. They vary the number of individuals, organizations, and companies, and the diversity of purchasers' changes.[112] Table S2 lists potential groups of investors and the ecosystem services they may desire. Investors become beneficiaries of the trust by purchasing non-refundable, but transferable, units or credits. Investors receive "benefits in the form of annual dividends" arising from the ecosystem services generated by their investment. Where excludable credits are registered, such as carbon or nutrient credits, investors would receive these as dividends (or cash when sold on their behalf), which could be used to offset their organizations' activities.

Royalties collected from commercial use of portfolio wetlands, or from property developers/insurers seeking strategic wetland placement for property protection, could also be returned to investors as dividends or reinvested back into the WIF (if the investor desires). Investors will also benefit more generally, or indirectly, from the provision of non-rival and difficult-to-exclude services. Investors would be able to examine the fund performance and plans, most likely in terms of the ecosystem service(s) they are most interested in, and make investments according to their ability, requirements, and/or desired return on investment. In addition to dividends, the WIF may also create eco-labels or certificates, such as those used/issued by Salmon Safe (Note S17), to attract and recognize large investors that may wish to convey social and environmental responsibility.

The investment providers, or *project developers*, may be landowners (freehold, indigenous/traditional owners, or an aggregation of landholders) or consultants/managers working on their behalf. Project developers propose and create wetlands for payment, competing with one another for funding via a reverse auction. Proposals should not only include wetland creation, but also monitoring and long-term maintenance of the wetland. If accepted, developers are responsible for managing the on-ground

Table 2. Key differences between market-based schemes and common asset trusts for facilitating the management of wetland ecosystem services

Feature	Market-based schemes	Common asset trusts
Community values	Often focused on the value of a single ecosystem service, this may affect community buy-in if it detracts from other non-scheme values.	Facilitates the inclusive identification of community values, necessary to achieve outcomes that build and maintain a social licence.
Objectives	Markets operate efficiently to allocate resources for producing goods and services that are both rival and excludable. When focusing on single ecosystem services that are rarely rival and excludable, artificial markets need to be created and upheld by regulators or governments. Such situations frequently suffer market failure, resulting in non-optimal outcomes, resulting in problems, such as perverse incentives, conflicts between goals, and failure to adequately manage trade-off decisions.	High flexibility allows multiple objectives on the provisioning of any and multiple services as can also accommodate non-rival and non-excludable services across a portfolio of wetlands.
Decision-making and stakeholder participation	Typically participate as traders, with little role in scheme management, may be involved if there is consultation during development. Decisions usually made by Government or a private entity.	Managed by a board of trustees that can include stakeholder representatives, and practice deliberative and inclusive democracy to navigate value trade-offs. Can leverage off well-established legal mechanisms for dispute resolution surrounding trusts.
Transparency	Transparency is often limited as trading a single service reduces the number of stakeholders involved that have direct access to information.	Transparency is embedded as the board of trustees is highly inclusive with multiple stakeholders that have direct access to information.
Financial viability	Rests heavily on performance in supplying (typically) a single ecosystem service. The combination of uncertain wetland performance in service delivery, and being vulnerable to low and volatile trading prices, make investments risky.	The ability to attract funding from multiple public and private sources for providing multiple services across a portfolio of wetlands, and the flexibility to invest either the principal or interest from pooled funds, both provide a buffer against the underperformance of revenue from providing a single service.
Environmental assessment, administration, accounting, and transaction costs	Assessment and administrative burden can be high as payments rely entirely on the delivery of a single service, requiring time-consuming and expensive assessments seeking a high level of estimate certainty from ecosystems that are naturally highly variable and uncertain. Difficult to ensure all assessments are of equivalent quality. Often lack robust environmental accounting and database management.	Has flexibility to use wetland indicators that indicate the performance in delivering multiple services. Assessment, administration, and accounting can all benefit from the economies of scale achieved by having one body overseeing multiple wetlands. Having a dedicated scientific partner allows for continued refining of metrics, consistent training, and quality control, and a central database manager.

construction, including identification of suitable sites, wetland design, organizing staff and machinery, partnering with volunteer organizations, assessment and reporting, and liaising with the fund management group and government. Project developers may design and assess wetlands internally, but *assessors* would require training, approval, and all assessments would be subject to audit against the provisions agreed by the local scientific/technical support partner (mediated by the WIF).

In summary, we have outlined challenges for large-scale wetland restoration using existing PES schemes. We present an alternative PES scheme framework, based on CATs, that could facilitate much-needed large-scale wetland restoration (Table 2). The common challenges identified include achieving financial viability, establishing credibility, and ensuring social acceptability. As a way forward, we propose that future PES schemes fund wetland restoration using an investment trust fund approach that aims to build a portfolio of wetlands across the landscape that maximizes the overall provision of ecosystem services (Figures 1, 2, and 3).[101] The trust fund would act as a single point of contact for all participants, simplifying

administration and compliance monitoring for wetland developers, allowing for strategic planning of wetland restoration, and bundling of multiple funding sources to ensure wetland projects are viable. Fund managers could have the flexibility to invest in wetlands designed and positioned appropriately to support the suite of ecosystem services. Investors could make investment decisions based on the fund's performance in terms of the ecosystem services they desire. As the wetlands would be common assets, the investors would have a sense of ownership (helping with security and community acceptance) and be beneficiaries of all ecosystem services provided. A local scientific/technical support partner, with local network connections and trust among community, businesses, and government, could support the scheme by evaluating performance, providing guidance on restoration design and spatial planning, running workshops, and developing streamlined assessment methods. Governments could provide the enabling conditions for the scheme through broader environmental protection and environmental accounting legislative requirements. We consider that such a scheme will lead to greater wetland protection and restoration, one of the world's most service-rich, yet threatened, ecosystems, by being robust, efficient, easily accessible, credible, effective, and wetland focused.

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2021.06.006.

ACKNOWLEDGMENTS

We thank Dr. Kurt Stephenson and Peter Wilson for their helpful feedback and conversations throughout manuscript development, Dr Jordan Iles and Alicia Castle for constructive feedback on figures, and two anonymous reviewers for their constructive feedback. Funding for this project was provided by the Australian Government's National Environment Science Program Tropical Water Quality Hub.

REFERENCES

1. Mitsch, W.J., Bernal, B., and Hernandez, M.E. (2015). Ecosystem services of wetlands. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. *11*, 1–4.
2. Seifollahi-Aghmiuni, S., Nockrach, M., and Kalantari, Z. (2019). The potential of wetlands in achieving the sustainable development goals of the 2030 agenda. Water *11*, 609.
3. Ramsar Convention Secretariat (2016). An Introduction to the Convention on Wetlands (Previously the Ramsar Convention Manual), 5th (Gland, Switzerland: Ramsar). https://www.ramsar.org/sites/default/files/documents/library/handbook1_5ed_introductiontoconvention_e.pdf.
4. de Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., et al. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services *1*, 50–61. https://doi.org/10.1016/j.ecoser.2012.07.005.
5. Davidson, N.C., van Dam, A.A., Finlayson, C.M., and McInnes, R.J. (2019). Worth of wetlands: revised global monetary values of coastal and inland wetland ecosystem services. Mar. Freshw. Res. *70*, 1189–1194. https://doi.org/10.1071/MF18391.
6. Gardner, R., and Finlayson, C. (2018). Global wetland outlook: state of the world's wetlands and their services to people. In Secretariat of the Ramsar Convention, p. 88.
7. Davidson, N.C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. Mar. Freshw. Res. *65*, 934–941.
8. United Nations General Assembly (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. Div. Sustain. Dev. Goals New York, NY, USA.
9. Zhao, Q., Bai, J., Huang, L., Gu, B., Lu, Q., and Gao, Z. (2016). A review of methodologies and success indicators for coastal wetland restoration. Ecol. Indic. *60*, 442–452.
10. Gardner, R.C. (2002). Rehabilitating nature: a comparative review of legal mechanisms that encourage wetland restoration efforts. Cath. UL Rev. *52*, 573.
11. Greenhalgh, S., Selman, M., Daigneault, A., Kaighin, C., and Sinclair, R. (2014). Policy Instruments for Ecosystem Services. Landcare Research science series*42* (Lincoln, New Zealand: Manaaki Whenua Press). http://www.mwpress.co.nz/__data/assets/pdf_file/0019/74521/Policy_Instruments_for_Ecosystem_Services.pdf.
12. Salzman, J., Bennett, G., Carroll, N., Goldstein, A., and Jenkins, M. (2018). Payments for ecosystem services: past, present and future. Tex. A&M L. Rev. *6*, 199.
13. Benson, C.E., Carberry, B., and Langen, T.A. (2018). Public–private partnership wetland restoration programs benefit Species of Greatest Conservation Need and other wetland-associated wildlife. Wetl. Ecol. Manag. *26*, 195–211.
14. Farley, J., and Costanza, R. (2010). Payments for ecosystem services: from local to global. Ecol. Econ. *69*, 2060–2068.
15. Salzman, J., Bennett, G., Carroll, N., Goldstein, A., and Jenkins, M. (2018). The global status and trends of payments for ecosystem services. Nat. Sustain. *1*, 136–144.
16. Ivčević, A., Statzu, V., Satta, A., and Bertoldo, R. (2021). The future protection from the climate change-related hazards and the willingness to pay for home insurance in the coastal wetlands of West Sardinia, Italy. Int. J. Disaster Risk Reduct. *52*, 101956.
17. Waltham, N.J., Elliott, M., Lee, S.Y., Lovelock, C., Duarte, C.M., Buelow, C., Simenstad, C., Nagelkerken, I., Claassens, L., Wen, C.K.-C., et al. (2020). UN decade on ecosystem restoration 2021–2030—what chance for success in restoring coastal ecosystems? Front. Mar. Sci. *7*, 71.
18. Bullock, J.M., Aronson, J., Newton, A.C., Pywell, R.F., and Rey-Benayas, J.M. (2011). Restoration of ecosystem services and biodiversity: conflicts and opportunities. Trends Ecol. Evol. *26*, 541–549.
19. Hrabanski, M. (2015). The biodiversity offsets as market-based instruments in global governance: origins, success and controversies. Ecosyst. Serv. *15*, 143–151.
20. Pan, X., Xu, L., Yang, Z., and Yu, B. (2017). Payments for ecosystem services in China: policy, practice, and progress. J. Clean. Prod. *158*, 200–208.
21. Stephenson, K., and Shabman, L. (2011). Rhetoric and reality of water quality trading and the potential for market-like reform. JAWRA J. Am. Water Resour. Assoc. *47*, 15–28.
22. Cherry, S., Britney, E.M., Siegel, L.S., Muscari, M.J., Strauch, R.L., and Mcneil, M.S. (2007). Wetlands and Water Quality Trading: Review of Current Science and Economic Practices with Selected Case Studies (U.S. Environmental Protection Agency).
23. Jaramillo, F., Desormeaux, A., Hedlund, J., Jawitz, J., Clerici, N., Piemontese, L., Rodríguez-Rodriguez, J., Anaya, J., Blanco-Libreros, J., Borja, S., et al. (2019). Priorities and interactions of sustainable development goals (SDGs) with focus on wetlands. Water *11*, 619.
24. Bellver-Domingo, A., Hernández-Sancho, F., and Molinos-Senante, M. (2016). A review of Payment for Ecosystem Services for the economic internalization of environmental externalities: a water perspective. Geoforum *70*, 115–118.
25. Schomers, S., and Matzdorf, B. (2013). Payments for ecosystem services: a review and comparison of developing and industrialized countries. Ecosyst. Serv. *6*, 16–30.
26. Bremer, L.L., Brauman, K.A., Nelson, S., Prado, K.M., Wilburn, E., and Fiorini, A.C.O. (2018). Relational values in evaluations of upstream social outcomes of watershed Payment for Ecosystem Services: a review. Curr. Opin. Environ. Sustain. *35*, 116–123.
27. Stephenson, K., and Shabman, L. (2017). Nutrient assimilation services for water quality credit trading programs: a comparative analysis with nonpoint source credits. Coast. Manag. *45*, 24–43.
28. Wylie, L., Sutton-Grier, A.E., and Moore, A. (2016). Keys to successful blue carbon projects: lessons learned from global case studies. Mar. Policy *65*, 76–84.
29. Raffini, E., and Robertson, M. (2005). Water quality trading: what can we learn from 10 years of wetland mitigation banking? U.S. Environmental Protection Agency Papers. 276. http://digitalcommons.unl.edu/usepapapers/276
30. Hou, Y., Burkhard, B., and Müller, F. (2013). Uncertainties in landscape analysis and ecosystem service assessment. J. Environ. Manage. *127*, S117–S131.
31. Friess, D.A., Phelps, J., Garmendia, E., and Gómez-Baggethun, E. (2015). Payments for Ecosystem Services (PES) in the face of external biophysical stressors. Glob. Environ. Chang. *30*, 31–42.

32. Matzek, V., Wilson, K.A., and Kragt, M. (2019). Mainstreaming of ecosystem services as a rationale for ecological restoration in Australia. Ecosyst. Serv. *35*, 79–86.

33. Heberling, M.T., García, J.H., and Thurston, H.W. (2010). Does encouraging the use of wetlands in water quality trading programs make economic sense? Ecol. Econ. *69*, 1988–1994.

34. Bayraktarov, E., Saunders, M.I., Abdullah, S., Mills, M., Beher, J., Possingham, H.P., Mumby, P.J., and Lovelock, C.E. (2016). The cost and feasibility of marine coastal restoration. Ecol. Appl. *26*, 1055–1074.

35. Ullman, R., Bilbao-Bastida, V., and Grimsditch, G. (2013). Including Blue Carbon in climate market mechanisms. Ocean Coast. Manag. *83*, 15–18.

36. Vanderklift, M.A., Marcos-Martinez, R., Butler, J.R.A., Coleman, M., Lawrence, A., Prislan, H., Steven, A.D.L., and Thomas, S. (2019). Constraints and opportunities for market-based finance for the restoration and protection of blue carbon ecosystems. Mar. Policy *107*, 103429.

37. Stewart-Sinclair, P.J., Purandare, J., Bayraktarov, E., Waltham, N.J., Reeves, S., Statton, J., Sinclair, E.A., Brown, B.M., Shribman, Z.I., and Lovelock, C.E. (2020). Blue restoration—building confidence and overcoming barriers. Front. Mar. Sci.

38. McEwin, A., and McNally, R. (2014). Organic Shrimp Certification and Carbon Financing: An Assessment for the Mangroves and Markets Project in Ca Mau Province, Vietnam (REAP Proj. GiZ, SNV), p. 81.

39. Banerjee, S., Secchi, S., Fargione, J., Polasky, S., and Kraft, S. (2013). How to sell ecosystem services: a guide for designing new markets. Front. Ecol. Environ. *11*, 297–304.

40. Günther, A., Böther, S., Couwenberg, J., Hüttel, S., and Jurasinski, G. (2018). Profitability of direct greenhouse gas measurements in carbon credit schemes of peatland rewetting. Ecol. Econ. *146*, 766–771.

41. Joosten, H., Brust, K., Couwenberg, J., Gerner, A., Holsten, B., Permien, T., et al. (2013). MoorFutures®. Integr. von weiteren Ökosystemdienstleistungen einschließlich Biodiversität Kohlenstoffzertifikate–Standard, Methodol. und Übertragbarkeit in andere Regionen (Bonn, Germany: Bundesamt für Naturschutz (BfN)). https://www.bfn.de/fileadmin/BfN/service/Dokumente/skripten/Skript350.pdf.

42. Bonn, A., Reed, M.S., Evans, C.D., Joosten, H., Bain, C., Farmer, J., Emmer, I., Couwenberg, J., Moxey, A., Artz, R., et al. (2014). Investing in nature: developing ecosystem service markets for peatland restoration. Ecosyst. Serv. *9*, 54–65.

43. Tabaichount, B., Wood, S., Kermagoret, C., Kolinjivadi, V., Bissonnette, J.-F., Mendez, A., and Dupras, J. (2019). Water quality trading schemes as a form of state intervention: two case studies of state-market hybridization from Canada and New Zealand. Ecosyst. Serv. *36*. https://doi.org/10.1016/j.ecoser.2019.01.002.

44. Robertson, M. (2006). Emerging ecosystem service markets: trends in a decade of entrepreneurial wetland banking. Front. Ecol. Environ. *4*, 297–302.

45. Robertson, M., and Hayden, N. (2008). Evaluation of a market in wetland credits: entrepreneurial wetland banking in Chicago. Conserv. Biol. *22*, 636–646.

46. McKenney, B.A., and Kiesecker, J.M. (2010). Policy development for biodiversity offsets: a review of offset frameworks. Environ. Manage. *45*, 165–176.

47. King, D.M., and Price, E.W. (2004). Developing Defensible Wetland Mitigation Ratios: A Companion to "The Five-Step Wetland Mitigation Ratio Calculator" (University of Maryland). https://nctc.fws.gov/courses/csp/csp3112/resources/Mitigation/WetlandMitigationRatios.pdf.

48. Needham, K., de Vries, F.P., Armsworth, P.R., and Hanley, N. (2019). Designing markets for biodiversity offsets: lessons from tradable pollution permits. J. Appl. Ecol. *56*, 1429–1435.

49. Sutton-Grier, A.E., and Moore, A. (2016). Leveraging carbon services of coastal ecosystems for habitat protection and restoration. Coast. Manag. *44*, 259–277.

50. Arnett, E.B., and Southwick, R. (2015). Economic and social benefits of hunting in North America. Int. J. Environ. Stud. *72*, 734–745.

51. Goldman-Benner, R.L., Benitez, S., Boucher, T., Calvache, A., Daily, G., Kareiva, P., Kroeger, T., and Ramos, A. (2012). Water funds and payments for ecosystem services: practice learns from theory and theory can learn from practice. Oryx *46*, 55–63.

52. Bremer, L.L., Auerbach, D.A., Goldstein, J.H., Vogl, A.L., Shemie, D., Kroeger, T., Nelson, J.L., Benítez, S.P., Calvache, A., Guimarães, J., et al. (2016). One size does not fit all: natural infrastructure investments within the Latin American Water Funds Partnership. Ecosyst. Serv. *17*, 217–236.

53. Kauffman, C.M. (2014). Financing watershed conservation: lessons from Ecuador's evolving water trust funds. Agric. Water Manag. *145*, 39–49.

54. Vrtiska, M.P., Gammonley, J.H., Naylor, L.W., and Raedeke, A.H. (2013). Economic and conservation ramifications from the decline of waterfowl hunters. Wildl. Soc. Bull. *37*, 380–388.

55. Anderson, M.G., and Padding, P.I. (2015). The North American approach to waterfowl management: synergy of hunting and habitat conservation. Int. J. Environ. Stud. *72*, 810–829.

56. Lau, W.W.Y. (2013). Beyond carbon: conceptualizing payments for ecosystem services in blue forests on carbon and other marine and coastal ecosystem services. Ocean Coast. Manag. *83*, 5–14.

57. Robertson, M., BenDor, T.K., Lave, R., Riggsbee, A., Ruhl, J.B., and Doyle, M. (2014). Stacking ecosystem services. Front. Ecol. Environ. *12* (3), 186–193. https://doi.org/10.1890/110292.

58. Bianco, N. (2009). Stacking Payments for Ecosystem Services (Washington, USA: World Resources Institute). https://pdf.wri.org/factsheets/factsheet_stacking_payments_for_ecosystem_services.pdf.

59. Robert, N., and Stenger, A. (2013). Can payments solve the problem of undersupply of ecosystem services? For. Policy Econ. *35*, 83–91.

60. Cooley, D., and Olander, L. (2012). Stacking ecosystem services payments: risks and solutions. Envtl. L. Rep. News Anal. *42*, 10150.

61. Gren, I.-M., and Elofsson, K. (2017). Credit stacking in nutrient trading markets for the Baltic Sea. Mar. Policy *79*, 1–7.

62. Land, M., Granéli, W., Grimvall, A., Hoffmann, C.C., Mitsch, W.J., Tonderski, K.S., and Verhoeven, J.T.A. (2016). How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? A systematic review. Environ. Evid. *5*, 9.

63. Georgiou, S., and Turner, R.K. (2012). Valuing Ecosystem Services: The Case of Multi-Functional Wetlands (Routledge).

64. Barbier, E.B. (2013). Valuing ecosystem services for coastal wetland protection and restoration: progress and challenges. Resour *2*, 213–230.

65. Schmolke, A., Thorbek, P., DeAngelis, D.L., and Grimm, V. (2010). Ecological models supporting environmental decision making: a strategy for the future. Trends Ecol. Evol. *25*, 479–486.

66. van Voorn, G.A.K., Verburg, R.W., Kunseler, E.-M., Vader, J., and Janssen, P.H.M. (2016). A checklist for model credibility, salience, and legitimacy to improve information transfer in environmental policy assessments. Environ. Model. Softw. *83*, 224–236.

67. Parliamentary Commissioner for the Environment (2018). Overseer and Regulatory Oversight: Models, Uncertainty and Cleaning up Our Waterways (Wellington, New Zealand: New Zealand Parliament). https://www.pce.parliament.nz/media/196493/overseer-and-regulatory-oversight-final-report-web.pdf.

68. Martín-López, B., Gómez-Baggethun, E., García-Llorente, M., and Montes, C. (2014). Trade-offs across value-domains in ecosystem services assessment. Ecol. Indic. *37*, 220–228.

69. Ruhl, J.B., and Salzman, J.E. (2006). The effects of wetland mitigation banking on people. National Wetlands Newsletter*28*, 2nd (Tallahassee, USA: Environmental Law Institute). https://ssrn.com/abstract=878331.

70. Reiss, K.C., Hernandez, E., and Brown, M.T. (2009). Evaluation of permit success in wetland mitigation banking: a Florida case study. Wetlands *29*, 907.

71. Del Corso, J.-P., Nguyen, T.D.P.G., and Kephaliacos, C. (2017). Acceptance of a payment for ecosystem services scheme: the decisive influence of collective action. Environ. Values *26*, 177–202.

72. Kemkes, R.J., Farley, J., and Koliba, C.J. (2010). Determining when payments are an effective policy approach to ecosystem service provision. Ecol. Econ. *69*, 2069–2074.

73. Vogdrup-Schmidt, M., Strange, N., Olsen, S.B., and Thorsen, B.J. (2017). Trade-off analysis of ecosystem service provision in nature networks. Ecosyst. Serv. *23*, 165–173.

74. Howe, C., Suich, H., Vira, B., and Mace, G.M. (2014). Creating win-wins from trade-offs? Ecosystem services for human well-being: a meta-analysis of ecosystem service trade-offs and synergies in the real world. Glob. Environ. Chang. *28*, 263–275.

75. Zheng, H., Wang, L., and Wu, T. (2019). Coordinating ecosystem service trade-offs to achieve win–win outcomes: a review of the approaches. J. Environ. Sci. *82*, 103–112.

76. Abbott, B.N., Wallace, J., Nicholas, D.M., Karim, F., and Waltham, N.J. (2020). Bund removal to re-establish tidal flow, remove aquatic weeds and restore coastal wetland services—north Queensland, Australia. PLoS One *15*, e0217531.

77. Craft, C.B., and Schubauer-Berigan, J. (2006). The role of wetlands in a water quality trading program. In Innovations in Reducing Nonpoint Source Pollution: Methods, Policies, Programs and Measurements, D. Wichelns, ed. (College: Hanova, USA: River's Institute at Hanover), pp. 143–158.

78. Macreadie, P.I., Nielsen, D.A., Kelleway, J.J., Atwood, T.B., Seymour, J.R., Petrou, K., Connolly, R.M., Thomson, A.C.G.G., Trevathan-Tackett, S.M., and Ralph, P.J. (2017). Can we manage coastal ecosystems to sequester more blue carbon? Front. Ecol. Environ. *15*, 206–213.

79. Wurtsbaugh, W.A., Paerl, H.W., and Dodds, W.K. (2019). Nutrients, eutrophication and harmful algal blooms along the freshwater to marine continuum. Wiley Interdiscip. Rev. *6*, 1–27.

80. Standards Reference Group (SERA) (2018). National Standards for the Practice of Ecological Restoration in Australia, 2nd (Society for Ecological Restoration Australasia (SERA)). https://www.seraustralasia.com/standards/National%20Restoration%20Standards%202nd%20Edition.pdf.

81. Fairhead, J., Leach, M., and Scoones, I. (2012). Green grabbing: a new appropriation of nature? J. Peasant Stud. *39*, 237–261.

82. Hill, A. (2017). Blue grabbing: reviewing marine conservation in Redang Island Marine Park, Malaysia. Geoforum *79*, 97–100.

83. Pokorny, B., Scholz, I., and de Jong, W. (2013). REDD+ for the poor or the poor for REDD+? About the limitations of environmental policies in the Amazon and the potential of achieving environmental goals through pro-poor policies. Ecol. Soc. *18*. https://doi.org/10.5751/ES-05458-180203.

84. Chomba, S., Kariuki, J., Lund, J.F., and Sinclair, F. (2016). Roots of inequity: how the implementation of REDD+ reinforces past injustices. Land use policy *50*, 202–213.

85. Hayes, T., and Murtinho, F. (2018). Communal governance, equity and payment for ecosystem services. Land use policy *79*, 123–136.

86. Hackney, C.T. (2000). Restoration of coastal habitats: expectation and reality. Ecol. Eng. *15*, 165–170.

87. Prach, K., Durigan, G., Fennessy, S., Overbeck, G.E., Torezan, J.M., and Murphy, S.D. (2019). A primer on choosing goals and indicators to evaluate ecological restoration success. Restor. Ecol. *27*, 917–923.

88. Von Braun, J., and Suseela, R. (2017). Land Grabbing by Foreign Investors in Developing Countries: Risks and Opportunities (International Food Policy Research Institute).

89. Betz, R., and Sato, M. (2006). Emissions Trading: Lessons Learnt from the 1st Phase of the EU ETS and Prospects for the 2nd Phase. 6 (Climate Policy). https://www.tandfonline.com/doi/abs/10.1080/14693062.2006.9685607.

90. Venmans, F.M.J. (2016). The effect of allocation above emissions and price uncertainty on abatement investments under the EU ETS. J. Clean. Prod. *126*, 595–606.

91. Ye, F., Fang, X., Li, L., Li, Y., and Chang, C.-T. (2019). Allocation of carbon dioxide emission quotas based on the energy-economy-environment perspective: evidence from Guangdong Province. Sci. Total Environ. *669*, 657–667.

92. Wu, J., Fan, Y., and Xia, Y. (2016). The economic effects of initial quota allocations on carbon emissions trading in China. Energy J *37*, 129–151.

93. Chhatre, A., Lakhanpal, S., Larson, A.M., Nelson, F., Ojha, H., and Rao, J. (2012). Social safeguards and co-benefits in REDD+: a review of the adjacent possible. Curr. Opin. Environ. Sustain. *4*, 654–660.

94. Reed, M.S., Allen, K., Attlee, A., Dougill, A.J., Evans, K.L., Kenter, J.O., Hoy, J., McNab, D., Stead, S.M., Twyman, C., et al. (2017). A place-based approach to payments for ecosystem services. Glob. Environ. Chang. *43*, 92–106.

95. Fenemor, A., Phillips, C., Allen, W., Young, R.G., Harmsworth, G., Bowden, B., Basher, L., Gillespie, P.A., Kilvington, M., Davies-Colley, R., et al. (2011). Integrated catchment management—interweaving social process and science knowledge. New Zeal. J. Mar. Freshw. Res. *45*, 313–331.

96. Reis, V., Hermoso, V., Hamilton, S.K., Bunn, S.E., and Linke, S. (2019). Conservation planning for river-wetland mosaics: a flexible spatial approach to integrate floodplain and upstream catchment connectivity. Biol. Conserv. *236*, 356–365.

97. Costanza, R., Atkins, P., Hernandez-Blanco, M., and Kubiszewski, I. (2021). Common asset trusts to effectively steward natural capital and ecosystem services at multiple scales. J. Environ. Manage. *280*, 111801.

98. Kumar, R., McInnes, R., Finlayson, C.M., Davidson, N., Rissik, D., Paul, S., Cui, L., Lei, Y., Capon, S., and Fennessy, S. (2021). Wetland ecological character and wise use: towards a new framing. Mar. Freshw. Res. *72*, 633–637.

99. Rothstein, B. (2005). Social Traps and the Problem of Trust: Theories of Institutional Design (Cambridge University Press).

100. Ostrom, E. (2008). Institutions and the environment. Econ. Aff. *28*, 24–31.

101. Runting, R.K., Beyer, H.L., Dujardin, Y., Lovelock, C.E., Bryan, B.A., and Rhodes, J.R. (2018). Reducing risk in reserve selection using Modern Portfolio Theory: coastal planning under sea-level rise. J. Appl. Ecol. *55*, 2193–2203.

102. Finisdore, J., Rhodes, C., Haines-Young, R., Maynard, S., Wielgus, J., Dvarskas, A., Houdet, J., Quétier, F., Lamothe, K.A., Ding, H., et al. (2020). The 18 benefits of using ecosystem services classification systems. Ecosyst. Serv. *45*. https://doi.org/10.1016/j.ecoser.2020.101160.

103. Waltham, N.J., Wegscheidl, C.J., Smart, J.C.R., Volders, A., Hasan, S., and Waterhouse, J. (2017). Scoping Land Converstion Options for High DIN Risk Low-Lying Sugarcane, to Alternative Use for Water Quality Improvement in Wet Tropics Catchments (Cairns, Australia: Reef and Rainforest Research Centre Limited).

104. United States Environmental Protection Agency. 2015. National Ecosystem Services Classification System (NESCS): Framework Design and Policy Application. EPA-800-R-15-002. United States Environmental Protection Agency, Washington, DC.

105. Hill, M.R.J., McMaster, D.G., Harrison, T., Hershmiller, A., and Plews, T. (2011). A reverse auction for wetland restoration in the Assiniboine river watershed, Saskatchewan. Can. J. Agric. Econ. Can. D'agroeconomie *59*, 245–258.

106. Connor, J.D., Ward, J.R., and Bryan, B. (2008). Exploring the cost effectiveness of land conservation auctions and payment policies. Aust. J. Agric. Resour. Econ. *52*, 303–319.

107. Busco, C., Frigo, M.L., Riccaboni, A., and Quattrone, P. (2013). Integrated Reporting: Concepts and Cases that Redefine Corporate Accountability (Switzerland: Springer International Publishing). https://link-springer-com/content/pdf/10.1007/978-3-319-02168-3.pdf.

108. Curato, N., Dryzek, J.S., Ercan, S.A., Hendriks, C.M., and Niemeyer, S. (2017). Twelve key findings in deliberative democracy research. Daedalus *146*, 28–38.

109. Newton, A., and Elliott, M. (2016). A typology of stakeholders and guidelines for engagement in transdisciplinary, participatory processes. Front. Mar. Sci. *3*, 230.

110. Turner, R.K., Palmieri, M.G., and Luisetti, T. (2016). Lessons from the construction of a climate change adaptation plan: a Broads wetland case study. Integr. Environ. Assess. Manag. *12*, 719–725.

111. Berg, M., and Lidskog, R. (2018). Deliberative democracy meets democratised science: a deliberative systems approach to global environmental governance. Env. Polit. *27*, 1–20.

112. Heberling, M., Thurston, H., and Nietch, C. (2018). Exploring nontraditional participation as an approach to make water quality trading markets more effective. JAWRA J. Am. Water Resour. Assoc. *54*, 586–593. https://doi.org/10.1111/1752-1688.12648.