November 2022

Marine Ecosystem Credits

Advanced credit class design to scale ocean conservation finance

OpenEarth

About OpenEarth

The Open Earth Foundation is a research, innovation and deployment non-profit based in California, using cutting edge digital technologies and multi stakeholder collaborations to advance open-source platforms that help increase planetary resilience. Our approach blends: a complex-systems perspective to Earth-level solutions, emerging technologies, and an ethos of radical collaboration.

Learn more at: openearth.org

Document Authors

- Filippi, Margaux
- Wainstein, Martin
- Shah, Ando
- Constant, Axel
- Fonseca, Maureen
- Durkin, Louisa

Initial Supporters

The Ocean Program and its efforts, including the development of this Marine Ecosystem Credit Class design has been supported by the generous contributions from creative artists participating in the OceanDrop event, the Regen Network, and the OpenEarth Foundation, which includes support from the CarbonDrop.

Draft 1 Request for Comments

This document was first published on July 2022 as a full draft and has an open Request For Comment version (MEC_RFC101). Use the following link to submit your comments > or email the corresponding author.

Creative Commons

Advanced Marine Ecosystem Credits

Filippi, M., Shah, A., Constant, A., Durkin, L., Wainstein, M.* OpenEarth Foundation, 2022

*corresponding author: martin@openearth.org

Abstract

Ocean ecosystems are severely threatened by human activity, yet humanity directly depends on their health. A global goal has been set to protect 30% of ocean ecosystems by the year 2030, but the practice of ocean conservation does not have the funding mechanisms to support the scale of this effort. Marine Protected Areas, for example, are often legally established but governments lack the resources and incentives to provide robust surveillance and enforcement of these pristine environments. We present here the framework for a digitally native class of marine ecosystem credits, designed primarily as financial instruments to support funding at scale the protection and restoration of ocean ecosystems. The credit mechanism is conceived with principles of scientific integrity, social equity, and scalability. They are designed for fully digital implementations, considering advanced monitoring, reporting and verification practices, tokenization, and the use of integrated models for independent claim verifications. The initial types of credits covered by this framework include marine biodiversity, eutrophication, marine plastics, and blue carbon. The ecological crediting system proposed here is also developed with the potential to support nature-backed currencies, sovereign instruments that can further incorporate natural capital into the global economic system.

1. Introduction and Motivations

Humanity faces a planetary emergency due to environmental degradation and the fundamental erosion of Earth system resilience —the ability of natural systems to regenerate themselves after damaging shocks (Rockström et al., 2009). One of the highest imperatives, due to its interconnectivity with global environmental systems, relates to climate change and the need to prevent warming above 1.5C relative to pre-industrial level. The other imperative relates to biosphere integrity; protecting ecosystems that hold the diversity and abundance of life on Earth (Steffen et al. 2015). To this effect, science and geopolitics are aligning on a Global Deal for Nature, one that targets 30% of Earth to be permanently protected by the year 2030 (i.e. 30x30) (Dinerstein et al., 2019). This 30x30 plan is advancing as an analog to the Paris Agreement, which lays out the rules, processes and targets to prevent climate catastrophe, but for nature conservation. The 30x30 initiative encompasses the conservation of both land and ocean ecosystems and the prevention of ecological impacts that affect them (Kubiak, 2020). For oceans, ecological issues range from biodiversity collapse to plastic and chemical pollution. Many of these intermingled issues are caused by the overexploitation of marine resources, by the loss of coastal habitat and by anthropogenic carbon dioxide emissions that affect ocean chemistry and temperature. In turn, marine ecosystems collapse and the ocean's capacity to buffer climate change by absorbing excess atmospheric CO_2 is reduced.

It is therefore paramount to protect the ocean and its ecosystems, especially in the context of warming conditions. To do so, we need to significantly scale up marine conservation. In February 2022, the Open Earth Foundation launched its Ocean Program with a mission to design and build the digital architecture needed to conserve 30% of ocean ecosystems by 2030. This initiative was inspired by the opportunity to support the Cocos Island National Park in Costa Rica, in an expansion plan that significantly increases its protected 'no-catch zone.' One of the primary challenges, however, is the need for a sustainable model to cover the operating costs of ocean conservation efforts. To this end, we set out to develop financial instruments to support financing marine conservation efforts at a 30x30 scale.

In this whitepaper we introduce fundamental designs for Marine Ecosystem Credits (MEC)

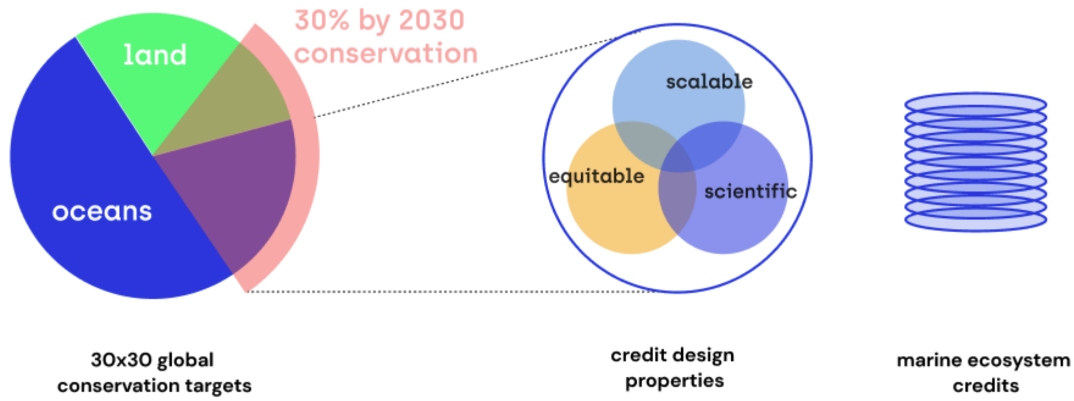


Figure 1 Design goal for marine conservation credits

Classes; families of credits specifically tailored for Marine Protected Areas (MPAs). These outcome-based credits are meant as financial instruments to support the conservation of ocean ecosystems in a manner that is scientifically rigorous, equitable and scalable. As will be further expanded, these credits can be issued to reward marine restoration efforts or to reward marine protection efforts. This paper presents the system architecture for MEC, their overarching methodology and main features.

1.1 Financial mechanisms for marine conservation

The field of conservation lacks financial mechanisms to protect ocean health that adequately scale up to 30% of global oceans. Currently, many marine conservation frameworks, such as MPAs and marine national parks, are constrained to rely on government funding and philanthropy; two processes that are not always scalable. In parallel, more and more coastal restoration efforts are turning towards carbon markets, which were not designed for ocean solutions, and which focus solely on climate rather than more holistic nature conservation goals. Efforts to protect the ocean and its ecosystems are however very important for other aspects of ocean health, such as marine biodiversity or marine pollution.

In the fields of conservation and biodiversity, there already exist several biodiversity offset schemes (BBOP, 2012), but overall, market-based instruments for conservation have had limited success so far (Arlidge et al., 2018; Marshall et al., 2020; Murphy et al., 2021). One of the primary reasons for this failure is the lack of consistency and coherence in establishing performance indicators, including the lack of a clear unit to measure the success of conservation efforts. This is the case for conservation of both land (Arlidge et al., 2018; Marshall et al., 2020) and ocean areas (Eger et al., 2022; Murphy et al., 2021). Additionally, there is a disconnect between the metrics used in the space of offsets and the ecological literature, which often means that the metrics used for offsets are inadequate to capture "the key ecological values they seek to protect" (Marshall et al., 2020). Recent efforts to establish rigorous ecosystem credits include the "PV Nature" biodiversity credits by the Plan Vivo Foundation and the Wallacea Trust, for which the documentation and methodology should be released in the second half of 2022 (Bohannon, 2021; Plan Vivo Foundation, 2022).

To the best of our knowledge, there are no robust financial mechanisms that focus on marine ecosystems and their conservation. This is not only the case for marine restoration efforts, but also for the protection of intact marine ecosystems, which is the initial priority under the *mitigation hierarchy* for conservation (Arlidge et al., 2018; BBOP, 2012; Maron et al., 2015). Given the specificities of ocean systems and their complexities, we need to build adequate financial mechanisms for the protection of marine ecosystems, as well as clear units for metrics to be standardized, measured, and acted upon. To this end, we aim to build the open digital infrastructure for a new class of MEC. Additionally, we partition our MEC into "protection credits" and "restoration credits" to better capture the ecological values that different marine conservation efforts seek to target. This whitepaper focuses on the systems and mechanisms behind these credits.

2. Introducing protection credits

Ocean conservation encompasses the sustainable protection and/or restoration of marine ecosystems. This can take the form of marine parks, of fishing quotas or of specific efforts such as coral reef restoration. Given the 30x30 mandate, the efforts we seek to scale are those supporting Marine Protected Areas (MPAs) and marine national parks, which implies a conservation of their entire habitat and properties, particularly their biodiversity. As described in further detail in the following subsections, most existing biodiversity credits center around rewards that are based on incremental improvements of ecological health (eg. a 10% biodiversity uplift). Given our focus on MPAs and national parks, whose high ecological health are paramount to protect, such payment schemes are less adequate for our objectives. We therefore introduce both the need and design of 'marine protection credits', which are outcome-based credits, particularly well-suited for biodiversity but that aim to reward the preservation of entire marine ecosystems. These protection credits are especially relevant given the established priorities in the framework of mitigation hierarchy (Arlidge et al., 2018; BBOP, 2012).

2.1 Outcome- vs effort-based metrics and payments

While terminology and nomenclatures in conservation are not consolidated and can have loose definitions, conservation and restoration payments can generally be divided in two types: action-based payments and outcome-based payments. Action-based payments are tied to the efforts, or actions, that go towards delivering an environmental service, whereas in the scheme of outcome-based payments, the rewards are tied to the results (Andeltová et al., 2015) of the efforts. Examples of action-based payments include payments for low-intensity land use. Examples of outcome-based schemes include payments for achieving measurable improvements, such as an increase in certain indicator species like rare plants (Wuepper & Huber, 2021).

Examples of outcome-based payments also include carbon markets and plastic markets. In carbon markets, a carbon credit corresponds to a tCO_{2eq} in avoided emissions or in carbon sequestration. Another example of the latter in biodiversity is the aforementioned "PV Nature" biodiversity scheme, in which one credit corresponds to a biodiversity uplift of 10% per hectare (Operation Wallacea, n.d.). This payment scheme rewards incremental improvements in biodiversity and is well suited for rigorous assessments of restoration efforts occurring globally, as well as for efforts to comply to legislation that requires biodiversity uplifts.

- Conservation of pristine habitats with high level of endemism
- Protection of its high but threatned ecological health and natural capital
- Requires patroling and enforcing a large no-catch zone

- Degradation of ecological health via human caused pollution
- Restoration of bull kelp forests to regain ecosystem resilience
- Requires active intervention of kelp farming

Figure 2 Reference Case Studies in Cocos Island, Costa Rica and the Puget Souns, WA, USA

The objective of our MECs is however different because of the focus on supporting MPAs and marine national parks. We thus seek to establish credit metrics and units that are adequate for the protection efforts associated to these areas. In the same manner as a tree farm does not offer the same ecosystem services as an old growth forest, within a conservation payment scheme, the protection of a pristine marine park should be valued more than a restoration effort that builds an artificial coral reef. For marine biodiversity credits specifically, we seek to reward the 'absolute' biodiversity value that results from a given conservation effort: that is, the biodiversity value of the protected area evaluated against global indices and benchmarks. A reward based on incremental improvements would penalize MPAs and marine parks that have been engaged in conservation efforts over multiple decades. We thus introduce the concept of 'protection credits'.

2.2 Protection credits vs Restoration credits

Our proposed 'protection credits' are a type of marine ecosystem credits that contrast with the existing mechanism of 'restoration credits'. In addition to our specific objective to support marine national parks and MPAs, there is a widely-documented need for such protection credits as they align with the priorities of the Mitigation Hierarchy (see Figure 3), a commonly-used framework for determining conservation priorities (Arlidge et al., 2018; BBOP, 2012; Maron et al., 2015, 2016); see work by the Task Force on Nature-related Financial Disclosures and the Science Based Targets Network. Indeed, not all conservation actions have an equal impact on ecosystem health. In this hierarchy of needs, the actions with the highest precedence are those that protect the health of current ecosystems by halting dangerous practices and avoiding damage. In other words, the main priority is avoiding the deterioration of ecosystems. Thus, whenever possible, conservation should precede restoration, and payment schemes should be established accordingly. The current drafts for the United Nations (UN) global agreement for biodiversity, the Convention of Biological Diversity's Global Biodiversity Framework, are underpinned by this set of principles (Milner-Gulland et al., 2021). However, the conservation priorities laid out in the mitigation hierarchy may not always correlated with funding hierarchies (such as in this case study: https://conservationhierarchy.org/casestudies/turtle-conservation-2/).

Distinguishing conservation credits into protection and restoration credits provides a suite of conservation actions that is necessary for maintaining the full health of marine ecosystems. Along with the introduction of protection credits as a category of conservation payment scheme, we

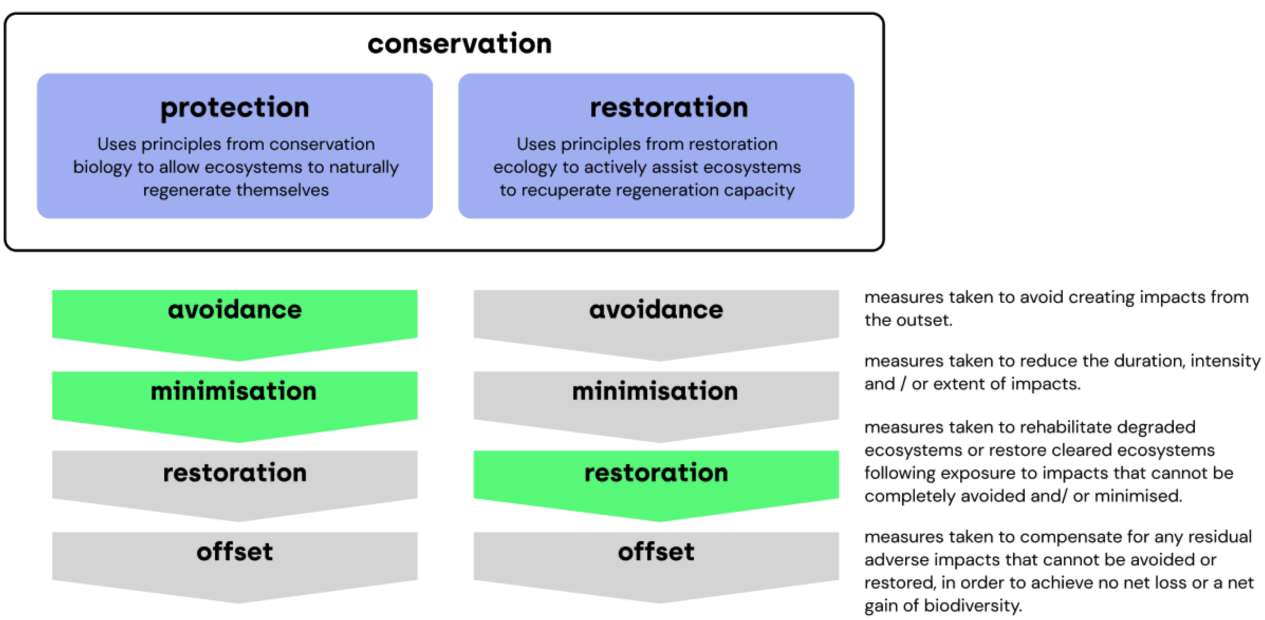
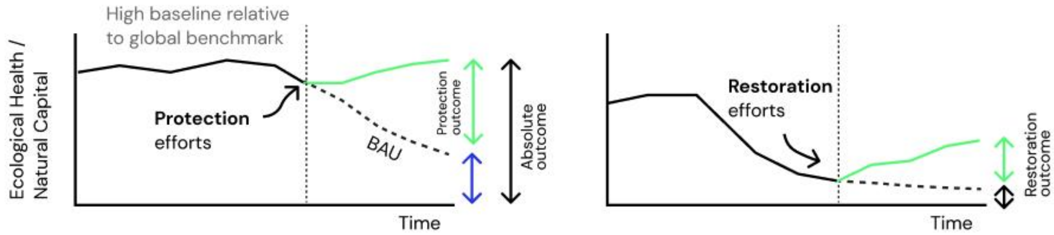


Figure 3 Categorization of Conservation actions in the context of the mitigation hierarchy



		Protection	Restoration
Payment Scheme	Effort-based Scheme	Rewards conservation efforts and costs involved, Eg. payments to surveil and enforce a marine protected area	Rewards the direct restoration efforts and interventions, Eg. payments per unit or area of kelp re-planted
Payment Scheme	Outcome-based Scheme	Rewards the maintenance of ecological health and biodiversity compared to global indices, Eg. credits to a marine park for avoiding degradation from imminent illegal fishing threat and maintaining endemism	Rewards incremental outcomes from restoration efforts, Eg. 10% increase in biodiversity and water quality after kelp reforestation
Credit Type Examples	Biodiversity Credit	Protection of habitats with high biodiversity indices and endemism, Eg. Cocos Island Marine National Park	Re-insertion of species (eg. coral or kelp) that help increase habitat biodiversity, Eg. Bull kelp reforestation in Puget Sound, USA
Credit Type Examples	Eutrophication Credit	Programs that pass and enforce regional or multilateral laws and agreements around nutrient runoff	Bivalve aquaculture projects that reduce nutrient and improves water health
Credit Type Examples	Plastics Credit	Not applicable	Project that remove Tons of plastics from marine circulation
Credit Type Examples	Carbon Credit	Projects that protect areas with high and healthy levels of primary productivity with effective sinks, and are faced with imminent threats	Projects that prove a sustainable increase in CO2 uptake by marine ecosystems through direct interventions, Eg. through seaweed

Figure 4 Comprehensive summary between the Protection and Restoration Categories and payment schemes.

are creating new methodologies for marine biodiversity credits. The overarching goal is to provide tools for existing or future MPAs and national parks to identify new funding opportunities to sustain and scale their marine conservation efforts.

The conservation credit class that we introduce aims to reward the "absolute outcome" that results from conservation efforts: in other words, the goal is to reward the preservation of the natural resources within the conserved area. For instance, the Cocos Island National Park (PNIC) in Costa Rica was established in 1978 and, 44 years later, the waters within PNIC still exhibit very high biological diversity and endemism (Cortés et al., 2017; Enright et al., 2021). Yet, the year-to-year uplift in biodiversity may be marginal and thus the already-existing payment schemes would not reward PNIC much. While current biodiversity credits schemes reward uplifts in biodiversity, they would not reward ongoing efforts like the 44-year-old conservation effort in Costa Rica. Under a payment scheme such as Plan Vivo, for instance, restoration is rewarded more than protection.

Most ecosystem credits currently on the market are in effect restoration credits. As mentioned, a carbon credit corresponds to a tCO_{2eq} in avoided emissions or captured carbon: it is an outcome-based credit that seeks to reward an incremental improvement in atmospheric CO_2 concentrations. In carbon markets, the rewards are given for restoring the climate towards pre-industrial temperature conditions and not towards the "absolute outcome"; if this was the case, credits would be designed and only issued according to the resulting atmospheric CO_2 concentration or average temperature increase —a mechanism that would be complex and slow to implement. While the outcome and incremental restoration efforts of carbon credits make sense in the context of climate change, as could also be the case for rewarding incremental removals of marine plastics, this reward scheme may not be ideal to support the protection of marine biodiversity and its habitats.

A key difference between the traditional restoration-type credits and our introduced protection credits is the metric used to establish the underlying credit unit. Protection credits takes the eco-approach of evaluating a conservation site against global indices and benchmarks that are ecologically relevant for marine conservation. For marine biodiversity, for example, such ecologically relevant metrics can include the richness, the vulnerability, and the distribution range of species (). The goal is to reward meaningful actions for marine conservation. This use of global benchmarks and indices to create a unit is in contrast with the use of counterfactuals, which are reference scenarios that use a "Business as Usual" baseline (Bull et al., 2021). These static or dynamic baselines in counterfactual scenarios are typically used to evaluate development projects and their impact on conservation. Not only are these typically site- and project-specific, but they also remain challenging to establish as they can never be directly measured, only derived (Bull et al., 2021; Grace et al., 2021; Katzner et al., 2022; Maron et al., 2015, 2016; zu Ermgassen et al., 2020). In the case of protection credits, we instead want broadly applicable metrics to reward projects that conserve objectively high-value marine conservation areas. This avoids needing site- or project-specific baselines and can be aligned with global conservation priorities (Arlidge et al., 2018; Simmonds et al., 2020).

Our approach to protection credits, particularly around biodiversity, aligns with the goals of science-based targets such as the KBA system developed by the International Union for Conservation of Nature (IUCN), the Weighted Endemism including Global Endangerment (WEGE) index developed by Farooq et al (2020) and the Species Threat Abatement and Restoration (STAR) metric developed by (Mair et al., 2021). The Key Biodiversity Areas (KBA) system aims to identify biodiversity conservation priorities in terms of international importance and globally standardized criteria. The WEGE index ranks areas in terms of biodiversity priorities on a continuous scale. The STAR metric measures the potential contribution of conservation actions. These metrics are relevant to the methodology for a Marine Biodiversity Credit, a specific protection credit within our MEC family, which will be explained in further details on its own whitepaper and technical methodology.

While we make the specific case for protection credits, restoration efforts and credits are still essential to meet the 30x30 goals and support conservation actions that ensure thriving ecosystem. Our MEC classes are therefore comprised of both protection credits, such as Marine Biodiversity Credits, and "restoration" credits, such as Marine Plastics Credits. This partition matters in terms of metrics and units that are used to issue credits. Figure 4 provides a summary of this partition framework used in our MEC. In terms of the issuance and verification of either credit type, however, there are key overarching features and principles that govern the design of the MEC system and its digital architecture regardless of the type of credits. The following sections explain these key features in further details.

3. Key principles & features of the Marine Ecosystem Credits

MECs are meant as financial instruments to support the conservation of ocean ecosystems, whether through protection or restoration, in a manner that is scientifically rigorous, equitable and scalable. To this end, we have designed the MEC class and system around a few key principles and concepts, including having a rigorous and transparent Measurement, Reporting and Verification (MRV) process that is operated independently from the issuance of the credits.

Key overarching features and principles of our proposed MEC system design and digital architecture are the following:

1. **Modularity—** meaning that the different types of MEC can be stackable and issued independently.
2. **Dynamic—** meaning the scientific uncertainty in the credit estimation modulates the value of the credit and can change over time.
3. **Decentralized—** verification, accounting and tokenization is done using global and

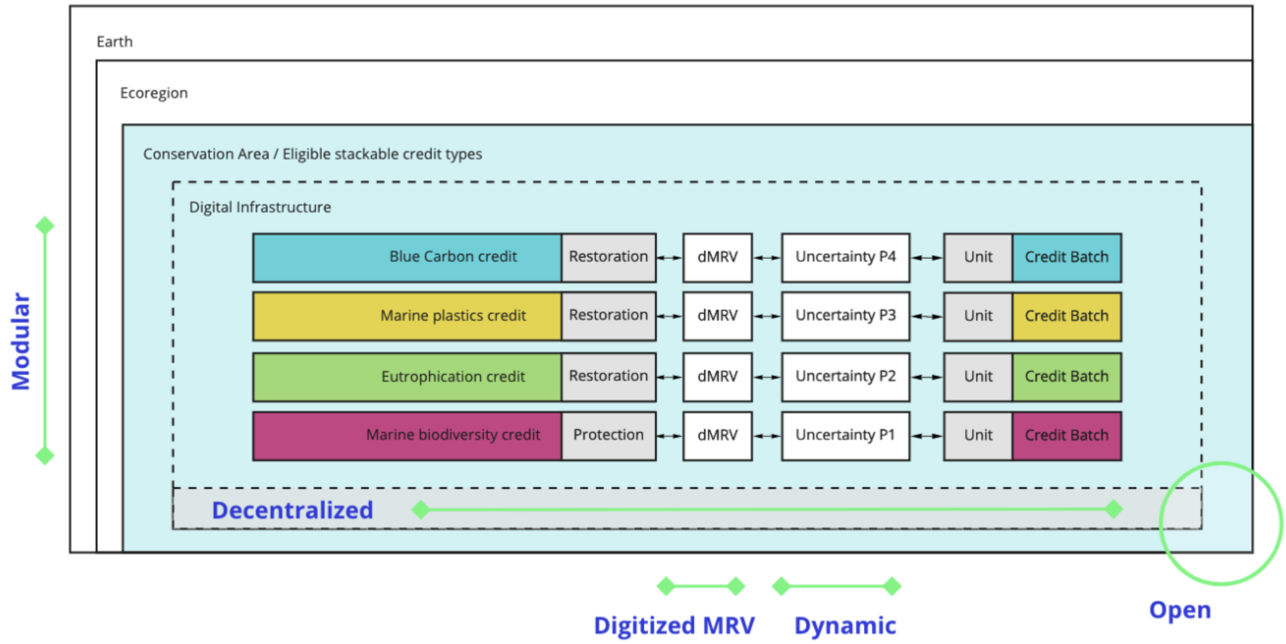


Figure 5 ***Overview of our Marine Ecosystem Credits.*** *Modular credits can be claimed within a defined area (shaded in light blue). For each type and quantity N_i of credits claimed, independent MRV is conducted, taking the additionality of these stackable credits into account. The value of these credits is modulated by the uncertainty of the claim P_i. A third party oversees that the methodologies are respected and that the MRV was done independently by verified certifiers. The credits are then issued on the designated registry, such as the Regen Ledger.*

transparent distributed ledgers to prevent single points of failure.

4. **Digital MRV—** system includes embedded funding for Measurement, Reporting & Verification (MRV), prioritizes methodologies using remote sensing, internet-of-things sensors and federated assessment models, and requires verifications to be carried by independent third-parties with a distinct role for local stewards.
5. **Open—** issuance through an open-source, transparent system that certifies that the credit verification (e.g. MRV) and the credit issuance are done independently.

3.1 Modular and Stackable

The first key feature encompassing the whole MEC class is modularity. This means that within a defined conservation area, different credit types can apply —independent to their protection or restoration categories— which are stackable, or additive, between each other (Robertson et al., 2014). This includes stacking one or more credit types, such as marine plastic credits, marine biodiversity credits, eutrophication credits or blue carbon credits.

If a singular conservation effort produces benefits belonging to two or more types of credits, then it can claim these different types of credits, as illustrated in Figure 5 or 6. For instance, if a group restores bull kelp in Puget Sound and, in the process, cleans up 1 ton of marine plastic waste in the restoration area and effectively sequesters it away from the water cycle, this group could claim both marine biodiversity credits and marine plastic credits.

The purpose of modularity, as opposed to opting for a holistic ocean health credit, is to speed up meaningful action. For instance, the market for each credit type (marine plastic, marine biodiversity, etc.) may be at different maturity stages, or the process of conducting rigorous MRV may be more difficult for some types than others. Therefore, practitioners may elect to seek different credits at different times. Consider our bull kelp restoration example. In addition to biodiversity and plastic

Figure 6 Stackable vs Partitioned Credits

credits, this group could also aim for claiming blue carbon credits. There are still many scientific uncertainties around blue carbon, however, as well as major knowledge gaps in the methodologies needed to calculate the exact amount of carbon that is sequestered away from the atmosphere by seaweed (Boyd et al., 2022; GESAMP, 2019; National Academies of Sciences, Engineering, and Medicine, 2022). It may take several years before MRV can be accurately and decisively conducted for such blue carbon initiatives to have trustable claims. Nevertheless, this bull kelp restoration project may bring many other positive environmental benefits and should be rewarded for the biodiversity and the clean water services it provided, even if we are unable to conduct a holistic assessment of the ecosystem's health. Given the urgency of biodiversity collapse and marine pollution (Steffen et al., 2015), such ecosystem services should be rewarded and scaled up rapidly. As methodologies and science evolves, the project can then claim other type of credits to stack on top of the existing one.

3.2 Dynamic

The second feature of the MEC class is the embedding of scientific uncertainty, which can dynamically vary throughout the lifespan of a project —based on either improved MRV practices or scientific knowledge. In the case of voluntary carbon markets, there are current labels for "high quality carbon credits" (Carbon Offset Guide, n.d.; Environmental Defense Fund, 2021), which are linked to the certainty in measurements as well as the co-benefits produced by the efforts that claim the carbon credit. Beyond a binary qualification of high or low quality, there are few mechanisms that reflect the assurance of a credit and its claims. Due to the complexity of ocean systems, and the major gaps in scientific knowledge around the quantification of marine ecosystem services, embedding scientific uncertainty within the MRV process and credit issuance allows for a dynamic and transparent process in credit valuation.

Consider again the example of a bull kelp restoration project. This effort could potentially claim blue carbon credits for the carbon that is captured by the kelp, but the uncertainty in the quantity of atmospheric carbon sequestered is very high. This does not mean that this effort does not provide any value for climate change mitigation. Assuming that we can quantify the scientific uncertainty, we propose that the value of the Blue Carbon credits claimed by such an effort is modulated by the scientific uncertainty: for instance, if the bull kelp restoration efforts result in 200 Blue Carbon credits that are valued at $100 each, but the quantified uncertainty is 60%, then both credits can be claimed for $8000.

The purpose of including scientific uncertainty in the valuation is to both reward high-quality projects and to offer a financial incentive to conduct rigorous MRV and advance the underlying scientific knowledge and ecosystem modeling. Additionally, it allows some financial capital to flow towards projects that offer ecosystem services even if conducting rigorous MRV is nearly impossible (such as, for example, a comprehensive assessment of marine biodiversity).

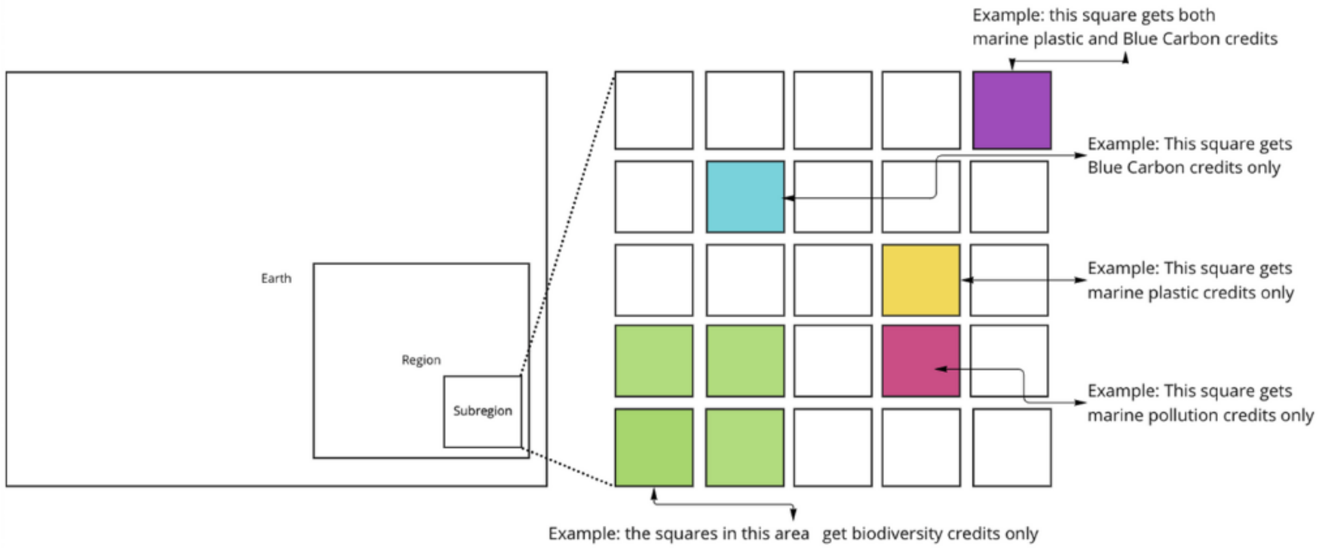


Figure 7 Example of different marine ecosystem credits claimed within an area (the Subregion). Each square represents a project area with defined spatial boundaries. In this example, most projects claim a single type of credit, with the exception of the purple square, within which both marine plastic and a Blue Carbon credits are claimed.

3.2.1 Embedding Scientific Uncertainty into MEC

Our proposed metric to assess scientific uncertainty over the measurement associated to a given MEC is known as the Shannon entropy.

How do we define uncertainty, exactly? Psychologically, Shannon entropy represents the confidence one can have over a given event out of a series of events and reflects the amount of knowledge one would acquire after observing that event being realized, or not. For instance, in a coin flip, there are two possible events: head or tail. Before the coin flip, there is an even probability that the outcome will be head or tail. Accordingly, psychologically, our confidence over the outcome being head or tail should be very low. In this case, Shannon entropy, or uncertainty is at its maximum. After the coin flip, because the outcome is known, there is no uncertainty, and we have perfect knowledge of the possible outcomes.

Mathematically, Shannon entropy is an attribute of a distribution. In the case of the coin flip, the distribution has two outcomes: head; tail. Each of these has a 50% probability of occurrence. After the flip, the distribution becomes 100% for one of the two outcomes, and 0% for the other. The formula to calculate Shannon entropy says that Shannon entropy is the total (negative) sum of the probability of each outcome weighted, or multiplied by the natural logarithmic probability of that outcome:

$$H(X) = -\sum_{i=1}^{n} P(x_i) \log2 P(x_i)$$

Equation 1. Shannon entropy equation used to calculate uncertainty in MEC claims.

By plugging the numbers in the equation above to calculate Shannon entropy for the two distributions, before the flip, and after the flip, one can see that the entropy for the distribution before the flip is 1 (i.e., is maximal), and after the flip is almost 0. This suggests that our psychological understanding of uncertainty maps intuitively on the mathematical notion of Shannon entropy.

This is important since when making a purchasing or investment decision, one is guided precisely by the sort of psychological uncertainty described above. While there may be many strategies to assess the risk of a purchasing decision, assuming that a human will make that decision, ultimately, the decision will always boil down to a decision based on unknown future events that could be realized or not. Scoring our MECs with Shannon entropy, or uncertainty, and adjusting the price of the ecocredits accordingly guarantees that the price of those ecocredits will reflect the kind of information about risk one ought to consider when making an investment decision. The question now is how to move from a distribution about coins to a distribution about nature health and MRV reports, or claims about it?

MECs have several attributes, which also vary depending on the type of credit. Considering for example a Marine Biodiversity Credit, as will be further discussed, these correspond to an area of 1km2 at a given geospatial set of coordinates; area for which the health score is measured (e.g., the WEGE metric that considers endemism and biodiversity endangerment) over a given period – 1 year duration. Shannon entropy, or uncertainty is another attribute of the MEC, and corresponds to the uncertainty over the health metric applied (e.g., WEGE), conditioned upon the data. The entropy over that conditional distribution thus represents our certainty over the correctness of the metric given the data used to compute that metric.

Now one might ask why a measure of health such as WEGE should be viewed as probabilistic, since the WEGE is a formula that connects a set of data. The probabilistic nature of the measure comes from the fact that it will be computed over time for the same area and might change from one computation to the next, depending on how the data underwriting the variables of the WEGE will themselves change over time. This means that both the WEGE metric and the data, when cast over time, become probabilistic constructs for which one can measure the uncertainty. Put another way, ultimately, our measure of scientific uncertainty is a meta-measure: an uncertainty measurement over the scientific process of measuring.

Figure 8 shows a high-level overview of how different credit components would be used to calculate uncertainty given the Shannon entropy equation. However, for proper calculation and implementation, each credit type needs to have a specific methodology and variables that determine uncertainty on their claims. These methodologies will be established for each credit type.

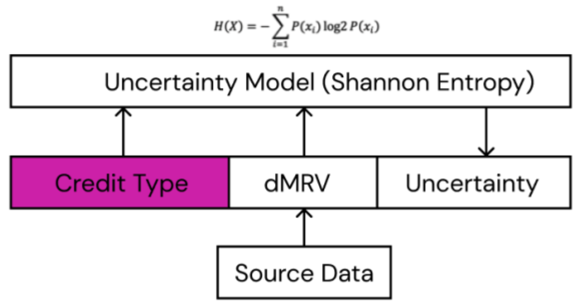


Figure 8 Overview of Uncertainty Calculation

3.3 Decentralized

Decentralization is another key principle in the MEC class. This pertains to both the features and designs of the digital infrastructure underpinning the MEC class and its operation, as well as to the social decentralization and inclusion of entities involved in projects that issue a MEC. In other words, this principle applies to digital decentralization features, and social decentralization features. The main purpose is to prevent control for the crediting system by a single entity or coalition, which can lead to self-serving behaviors and the erosion of both trust and equity in a natural capital mechanism.

3.3.1 Digital decentralization via Distributed Ledger Technology

The MEC class and its operation is conceived as a web3 digitally native system. In recent years, the need to re-build trust on large digital systems, whether a web platform or the whole internet, has led to principles of decentralization and peer-to-peer networks —particularly with the use of Distributed Ledger Technologies (DLT) such as blockchains. These form the backbone of the Web3 movement which seeks to evolve the internet from the established web 2.0 —which has become susceptible to the control of large technology corporations with centralized architectures (i.e. centralized cloud databases, centralized identity and privacy management systems), allowing them to exert power and manipulation over its users (web3 citation here). Given that the MEC class presented here is designed for a global scale in line with the 30x30 goals —implying it should support the flow of billions in financial capital towards conservation projects— the digital architecture and infrastructure underpinning it must meet the highest levels of trust and assurance.

To this end, we include the following features which stem from established tools in the DLT space. While it may be improbable to include all features in early MEC projects, transparency of which features are or aren't incorporated increases trust and allows them to be included over time to build robustness:

- **Self-Sovereign Identities** — Entities interacting on a conservation project eligible to claim MEC (eg. Governments, national park services, field rangers, MRV verifiers, data acquisition sensors, etc.) should be given control of their own digital identities. By using Decentralized Identifiers (DIDs) instead of identities issued by a centralized web platform or registry, agents can trust the data interactions between themselves at scale and in an automated fashion (Tobin & Reed, 2017). This property also allows for signed verifiable claims and attestations, used evidence in the MRV process of a MEC.
- **Multi-agent architecture in MRV** — Decentralization also entails that the MRV process of a project should consider multiple agents (i.e. sensors, satellite, ecological models, mobile phones cameras, people, etc) that can verify (or deny) certain claims. These agents must adopt the DID and SSI principle mentioned above. This increases trust in the verification process and reduces the ability of a single entity to control the quality and result of the MRV. See Figure 10 for illustration of this concept.
- **Tamper-proof data pipelines for key attestations** — Data sources that attest key variables of an MEC (eg. quantitative biodiversity assessment processes, or data derived from satellite imagery) play a very important role in determining how many credits are issued, the quality of those credits and the uncertainty level; all which influence the value and reward of a project. As such, to reduce the ability of an interested stakeholder to manipulate data in a self-serving way, the use of cryptography and DLT to trace data provenance —ensuring it is tamper-proof— increases the level of trust in those data sources and thus the MEC.
- **Tokenized issuance in decentralized registries** — The MECs within our class are designed to contain multiple variables, backed by data and the science in the credit type methodology: from direct measurement readings, integrated assessment models of ocean dynamics, to uncertainty evaluation —all of which are unique for the credit in space and time (eg. 1km^2 over 1 year). To capture this digitized information within the credit and unit and allow its dynamic property, a digital token, particularly a dynamic non-fungible token (NFT) is best suited to encapsule the credit framework. Furthermore, the issuance of these tokens should be done in registries that can prevent double counting or double issuance of credits by using DLT systems.
- **Separation of issuers and verifiers** — A centralized ecocrediting system could have a single entity be: 1) the developer of the credit standard and MRV methodology, 2) the issuer of the credit, 3) the verification body and verifier of the credit, and 4) the retail seller or marketplace for the credit. We believe this to be highly problematic given it produces conflicts of interest and may produce self-serving behavior. A proper segregation of duty should guarantee that the MRV is carried out by third parties that are independent from the credit issuance. This needs to be ensured by the credit contract and underlying digital architecture.

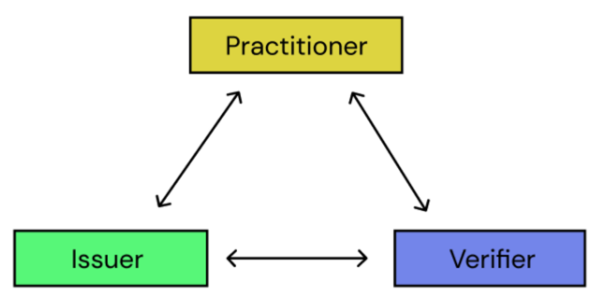


Figure 9 Diagram illustrates the interoperability and independence of the credit verifiers and credit issuers.

3.3.2 Social decentralization with community equity and inclusion

The other important aspect of decentralization is non-digital in nature but equally important to ensure a scalable and equitable mechanism. This entails the incorporation of local communities in the consultation and participation of both the conservation efforts and credit issuance and payment mechanisms. Projects that focus on environmental and economic bottom-lines alone could displace local communities surrounding the ecological habitat, creating a situation where credit buyers and developers are the only centrally benefiting from the activities. Furthermore, these central stakeholders may oversee the fact that local communities not only depend on those healthy habitats, but they can also play an important role as stewards in the ecological protection and commons management of the area (citation here, Ostrom citation).

Projects claiming MEC should consult with local communities —indigenous or not— in the initial project design, participate them in economic incentives for MRV claim attestation and stewardship behavior.

3.4 Digitized & Democratized MRV

The need for rigorous Measurement, Reporting and Verification (MRV) of the MEC claims and issuance process is the fourth principle and key feature of the MEC class. A credit's value and trustworthiness is directly related to the scientific soundness of the MRV methodology and its robust execution. However, MRV can be costly, which can often discourage conservation efforts to properly undertake its process or even take 'shortcuts' when conducting them. Furthermore, even under a robust MRV process, if its data sources and calculations are not properly documented, its results may be hard to replicate and/or directly embed them into the credit token itself. As such, our MEC class holds three features related to MRV: Digitization (of agents and data processes), Prioritization (in remote vs. manual processes), and Democratization (access to a common MRV funding pool and open technology transfers to support small-scale projects and under-served conservation regions).

3.4.1 Digitization

Digitization of MRV pertains first to the fundamental methodology design, second to the agents involved in conducting verification or those attesting to claims and variables in the MRV process, and third to the data process flows and calculations. MRV methodologies are designed for each MEC type (i.e. biodiversity, plastics, eutrophication, carbon etc.) and their corresponding conservation category (i.e. protection or restoration). While each of these can be published in written documents (such as this MEC class whitepaper), their underlying protocols need to be compatible with digitizing their steps with clear inputs (tracking the data sources of those inputs), variables (eg. conversion factors and calculations) and outputs, all managed through

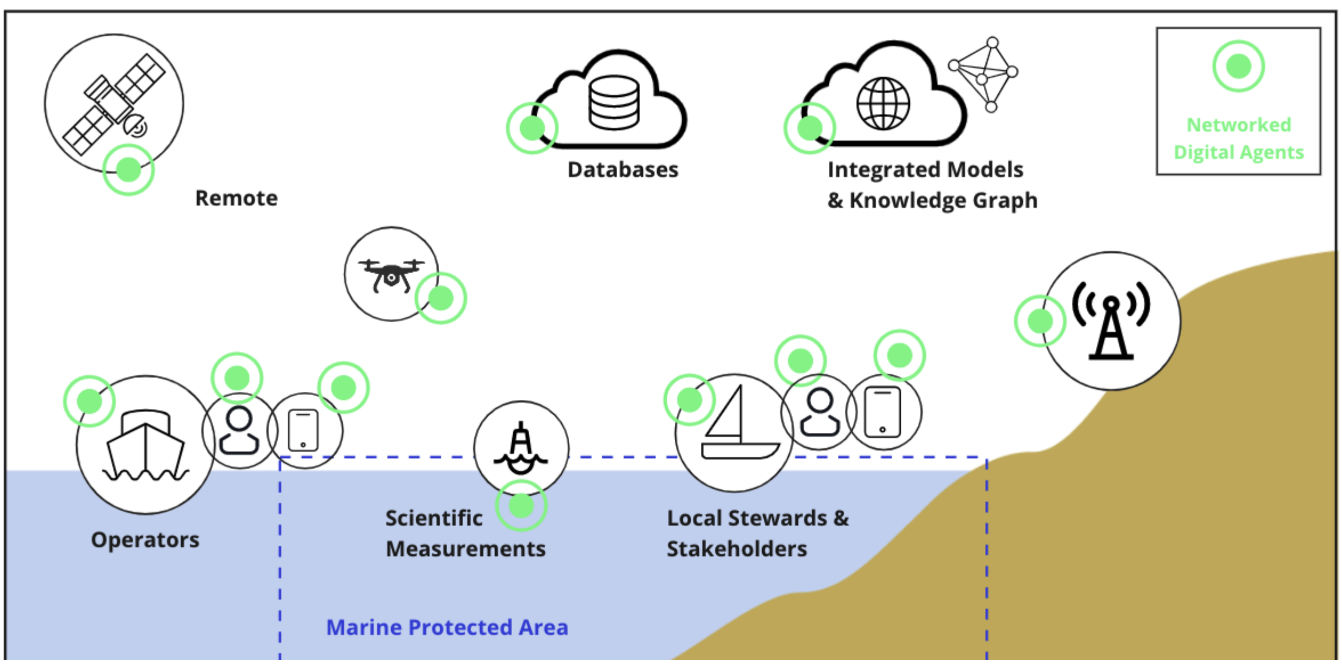


Figure 10 Digital Agent Architecture for robust MRV in ocean conservation

decentralized web platforms. Second, the agents involved in conducting and attesting MRV claims and verifications should be digitally represented in a digital network following the principles of self-sovereign identities and multi-agent architectures. Figure 10 depicts how this MRV agent network applies to ocean conservation MRV. Finally, the feature of 'distributed ledgers for key data handling' applies to the digital MRV, particularly for all attestation that have an incidence on credit quantity and quality calculations.

In combination, the digitization of MRV is designed to increase trust and robustness in the underlying MEC (i.e., allowing reproducible claims and audits by third parties) but also for cost-effectiveness. Historically, some land based MRV processes required third party experts to fly into conservation areas to calculate and verify certain claims. Under a digitized MRV, these claims verifications and calculation can be conducted with remote sensing and machine learning practices that have low marginal costs, equip local actors and stewards to be third-party verifiers themselves, and allow computer algorithms to remove the bulk of manual work in an MRV audit.

3.4.2 Prioritization

For MRV to be a viable business for independent verifiers, they need to process as many requests as possible. However, there is only so much proper, in person verification and follow ups one can do with limited expert availability. One solution, as mentioned in the digitization feature, is to use machine learning (ML) methods to operate verification based on remote sensing data. However, most credible MRV protocol still require people on the ground performing verifications or uploading independent attestation to claims.

A key challenge lies on striking the right balance between using remote and automatic sensing under ML methods and the need for in person verification. For this, we suggest the development of a prioritization engine that assesses the risk of claims on health metrics and thus prioritizes which area to verify first. The goal is to optimize in person MRV scheduling by using remote sensing data. Data is used to build models of the systems and associated health metrics, and the risk on the claims are assessed based on those models. The result would produce a world map identifying where verification is most pressing, as well as reports on what methods need to be applied to perform those verifications. Crucially for this step, the goal is not primarily to use ML methods to get an accurate assessment of current health metrics. Rather, the goal is to use ML assessment to guide decision making on where and when to send in-person MRV teams.

3.4.3 Democratization

As mentioned, MRV processes can be costly, discouraging eligible projects to undertake them, or disincentivizing robust and costly procedures that would bring higher quality to credits. To address this, we propose embedding a % of funding from MEC sales to be automatically earmarked for MRV processes. In fact, we envision that 10% of each credit will be directed towards a common MRV pool: if the MRV verifying entity is paid regardless of the outcome of its assessment, it eliminates the financial incentive for this entity to certify a project positively (i.e. keeping its paying client satisfied). Having access to a common pool is also a means for small-scale practitioners to obtain funding for the certification of their project, removing some of the cost barriers for conservation.

The second feature to reducing cost barriers and democratize a digitized MRV is through digital technology transfer. The prospect of a digitized MRV involving satellite data, machine learning, blockchain, drones and costly sensors may seem prohibitive to third-world economies that are in need to conserve their natural capital through economically beneficial mechanism. To address this, we propose to maximize within the MRV methodology design the use of digital public goods, through open data sets, the development of federated ecological models (where multiple parties contribute to its design but no single one can coopt it), and the ability to create bilateral or multilateral agreements between industrialized nations around digital technology transfers to those less industrialized.

3.5 Open

The fifth key principle in our MEC class is that of openness. This applies to multiple aspects in the credit class design and operationalization:

- **Open Architecture—** This credit class overarching architecture and standard document, as well as the technical solution architecture of the digital infrastructure underpinning MEC shall be published under open access licenses such as creative commons. This allows a level of transparency in the design, improvement by the stakeholder community, and the ability for third parties to develop interoperable solutions that can further augment the crediting ecosystem.
- **Open Access and peer-revision—** This applies to the scientific basis and methodologies in each MEC type and its MRV, also published under open licenses.
- **Open Core API—** The underlying protocol powering the MEC certification and interoperability needs to be published under open licenses and operate under an open application programming interface (API). This ensures interoperability between any agent that interacts with it and the inspection of code that determines critical aspects such as self-sovereign identities and token issuances.
- **Open Data Taxonomies and Spatial protocols—** The underlying data models and schemas of the MEC are published under open licenses and dictionaries, particularly those that are used to define spatial information of projects. Spatial taxonomies, even more than distributed ledgers, are essential for visibility and preventing double counting of projects and credits. Even if projects are hosted in different registries, if they adopt the same spatial protocols, they can still be discoverable through spatial queries.
- **Open Verification of the digital MRV process—** This applies to the open digital code that is fundamentally automating several aspects of MRV, to reduce its cost and remove 'human failure points,' as well as the ability of third-parties or general stakeholders to both openly contribute to attestation of claims as well as access the verification documents and audits
- **Open Governance—** The governance aspects surrounding the MEC class and each credit type are to maintain open principles, whereby rules are public, changes and proposals are made in the public, and any digital tool used in the context of governance needs to be open and auditable. Section 6 further outlines aspects of governance.

The principle of openness does not go against the use of proprietary software in the entire MEC mechanism. In fact, the MEC architecture needs to be able to attract private companies that can develop proprietary services to offer them within the network (eg. new ML models for MRV) or use proprietary software to scale origination or operation of a portfolio of conservation projects. However, because the underlying platform is open, these proprietary developments can be designed to be interoperable and openly disclose their level of transparency. This principle also does not go against a principle of data privacy where applicable.

4. Credit types, units & methodologies

The MEC class encompasses multiple credit types, and their different conservation categories (i.e. restoration and protection). We introduce here some of the credit types that we think are particularly important to scale conservation finance for MPAs but acknowledge that other credit types can be designed with a common standard if they follow the principles and features outlined here. Each credit type requires its own scientifically robust design and MRV methodology. This paper does not cover in depth a specific credit type design and MRV methodology since these are expected to be covered in subsequent publications. However, we describe in this section the role of a Marine Biodiversity Credit since this is a particularly relevant protection credit that supports MPAs such as Cocos Island (PNIC).

Each credit type has its own metric of value, eg. carbon is measured in terms of tCO_{2eq}, while biodiversity is measured in terms of an 'adjusted squared kilometer'. However, in order for credits to be stackable, they all have a common baseline unit of assessment defined in terms of space and time: a squared kilometer of marine area over a 1 year period.

The four main credit types initially cover in the MEC class are:

- **Marine Biodiversity**

- **Marine Plastics**
- **Eutrophication (Marine Health)**
- **Marine Carbon**

4.1 Marine Biodiversity Credits Overview

To develop a scalable system of marine biodiversity credits, we must first define what the credit unit is: for example, on the carbon markets, 1 credit corresponds to 1 ton of carbon dioxide removed from the atmosphere, either in the form of avoided emissions or, more rarely, in the form of carbon capture. What is the equivalent for marine biodiversity credits?

Biodiversity offsets have seen limited success so far (Arlidge et al., 2018) and the primary reasons include a lack of consistency in establishing metrics for success (examples include Marshall et al. (2020), who surveyed biodiversity offsets; and Eger et al. (2022), who surveyed kelp restoration efforts) and the fact that performance indicators for ecosystem health are ambiguous and poorly-defined (Murphy et al., 2021). A commonly-used metric for biodiversity offset is acreage, meaning each credit represents the transaction unit of an area in conservation (see South Pole, n.d.). For instance, this would mean defining 1 marine biodiversity credit by a 1 km^2 (or 1 km^3) of ocean protected.

Our goal in this credit type is to build a "global scale" of marine biodiversity credit that is scientifically sound, equitable and that helps support the financial efforts going into conservation, meaning it must be scalable. Acreage, or any spatial unit, alone would not fit these criteria, and thus other adjustment factors are needed. We strive to build a system of marine biodiversity credits that would capture the ecological values of their ecosystems.

For these reasons, for our first marine biodiversity credit prototype, we are factoring in species diversity and ecosystem resilience in our metrics, with a focus on consistency and standardization.

The simplest metric possible is to issue 1 credit for each 1 km^2 of area conserved, but as mentioned this presents natural limitations. On the other hand, we can seek to estimate the ecological value of the protection area by focusing on weighted endemism or threat level. While this approach may first appear fairer, this incurs a risk of conflicting interests as the number of credits issued would increase with the rarity and threat levels of the species. As such, this could lead to perverse incentives of areas that want to maintain their remaining endemism without collaborating with global conservations, which if effective could reduce the rarity of their endemism.

Our objective with a biodiversity unit is to strike a balance between rewarding biodiversity hot spots and ensuring the resilience of species globally. We thus propose "adjusted square kilometers" as a unit for our marine biodiversity protection credits.

We propose to calculate biodiversity credits as follows: the base unit for the credit is 1 sqkm of area conserved over one year. This base unit of 1 sqkm is then *adjusted* by modulating factors that take into account the ecological value of the conserved area: the richness of the biodiversity, the number of marine habitats included (including deep pelagic layers), the vulnerability and the endemism of the species. These "adjusted km squares" then determine the number of marine biodiversity units. Figure X shows an illustration of how several modulating factors play a role in the calculation and an adjusted sqkm for our biodiversity unit.

4.2 Overview of other MEC Types

While the Marine Biodiversity Unit is the first focused type to be covered under the MEC class, the following are also relevant credits to design and allow project to stack them within conservation efforts.

4.2.1 Eutrophication and Ocean Health

Eutrophication is a process produced by increased runoff from nutrients (primarily Nitrogen and Phosphorus) from land into estuaries and coastal waters, producing chain of effects that include harmful algal blooms (i.e. increased primary productivity), dead zones (water areas without oxygen), fish kills and biodiversity loss. Most nutrient runoffs are produced by agriculture fertilizers, but other anthropogenic factors and industrial activity contribute to eutrophication. Eutrophication represents major thread to MPA and their habitat conservation. As such, establishing a MEC that encourages and rewards protection efforts to prevent eutrophication, as well as

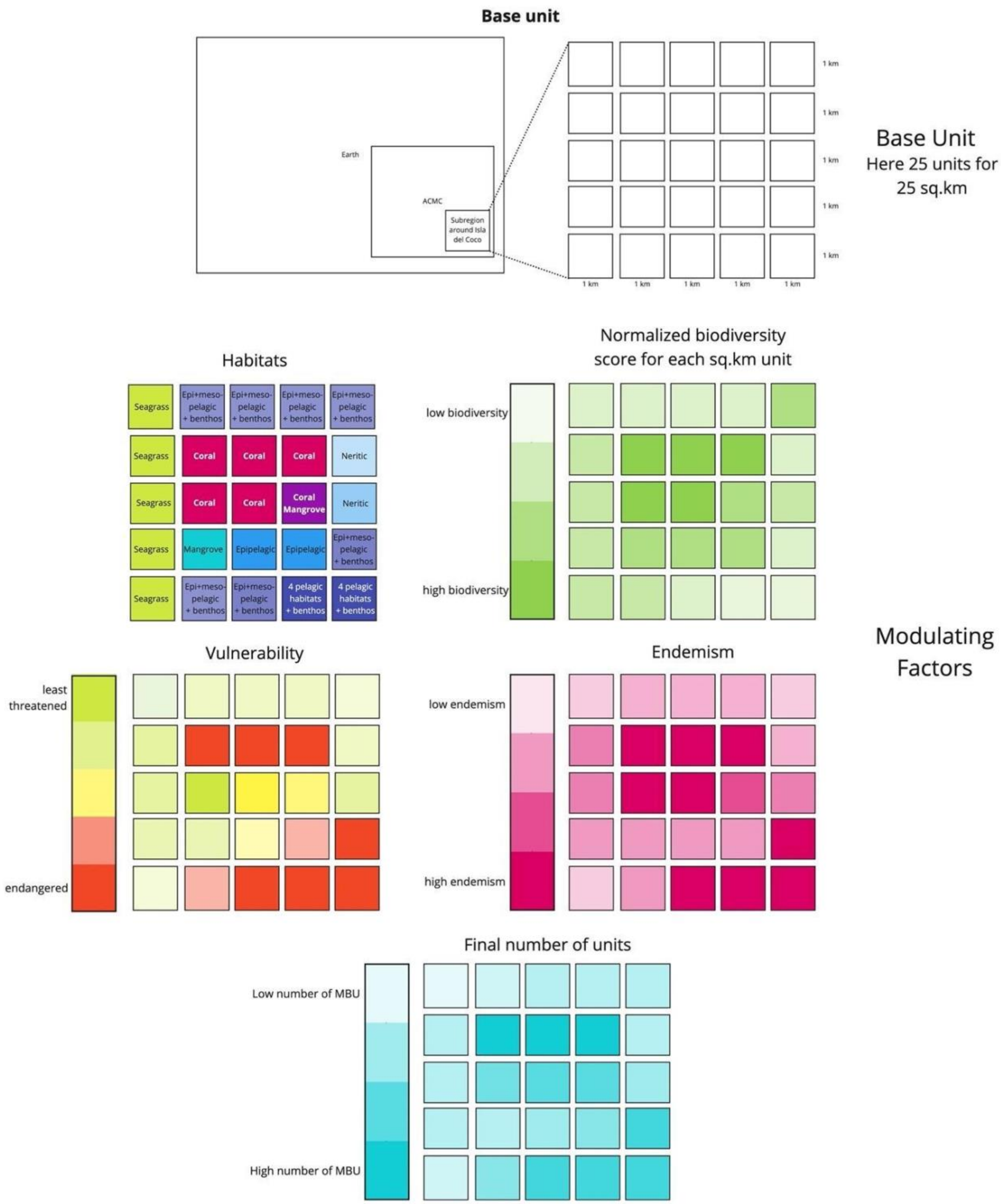


Figure 11 Biodiversity Unit Overview

restoration efforts after eutrophication occurs is an important aspect for ocean conservation.

One way to measure eutrophication is through the Index for Coastal Eutrophication Potential or Coastal Eutrophication Potential (ICEP). ICEP combines nitrogen (N), phosphorus (P) and silica

(Si) values of riverine loadings to estimate levels of ICEP, which can range from 1 to 6 (6 being the maximal ICEP, or maximal level of eutrophication). Positive values of ICEP indicate an excess of N or P over Si, which may lead to blooms of non-diatom, possibly harmful algae species. Thus, established methodologies can be implemented for the creation of a Eutrophication Credit, such as a decrease of increase in ICEP rating of 1 over $1km^2$ and 1 year. Future research and design efforts will be placed for the development of this credit.

Conservation actions that can help protect MPAs against eutrophication include the roll-out of policies to reduce nutrient runoffs near delicate ocean ecosystems, while effective restoration practices in areas affected by eutrophication include the incorporation of aquacultures of bivalve mollusks, which can help remove nutrients from the water as they feed on phytoplankton.

4.2.2 Marine Plastics

Besides nutrient runoffs, another major source of pollution to MPA and ocean ecosystems is plastics —particularly microplastics. As such, an important restoration credit that should be part of the MEC class would be one that rewards efforts that removal 1 ton of plastics from ocean circulation.

4.2.3 Blue Carbon

Blue Carbon pertains to the reduction of greenhouse gas sources or the enhancements of sinks (particularly atmospheric CO_2) by coastal and ocean ecosystems. It is by far the most established practice in ecosystem credits, particularly on coastal projects that use a nature-based sequestration such as kelp or seagrass. However, not only are there still major uncertainties and knowledge gaps to properly assess carbon sequestration from seaweed practices (Boyd et al., 2022; Berger et al., 2022), but many MPA have vast areas that are not coastal in nature, ineligible for these practices, and thus require further methodological developments to properly calculate enhanced carbon sinks from healthy ocean habitats. Nevertheless, Blue Carbon promises to be an important credit type for some MPAs and marine parks, and given the amount of activity in the space we have reprioritized this credit as the first one to focus in the MEC class.

4.2.4 Social Credits

An important ecosystem service produced from marine conservation efforts includes the benefit it brings to human society, particularly through the potential for eco-tourism and sustainable fishing. In fact, many conservation finance efforts have relied on applying a levy on tourism to finance conservation actions, albeit with mixed results (Citation here). Under the MEC class, social credits can be established as a co-benefit from conservation efforts, rather than direct restoration of protection actions. Regardless, these can play an important role in providing much needed credit and rewards to conservation of ocean ecosystems.

Social credits are separate from the other conservation credits for specific equity considerations. Our MEC framework does not consider ecological value only in terms of strict 'ecosystem services' defined by how much financial capital an nature brings to the human economy. If the valuation of credits is done purely from a human finance standpoint, places like Antarctica would be at a disadvantage for conservation credits because its tourism revenues are very low compared to the Scandinavian Arctic; or protecting the waters near Cancún, México would outweigh in hierarchy the conservation of highly protected low-trafficked areas like the Cocos Island National Park in Costa Rica

5. Integrated Process Flow for MEC

Considering the overarching design of the MECs, their principles and features, Figure 12 provides a summary and protocol for the issuance and governance of MEC.

6. Governance of credits & class

As laid out in Figure 12, there are eight steps throughout the MEC process where governance is essential to ensure a trustworthy, equitable and transparent mechanism. The following governance aspects provide further clarity on these steps and where external requirements or further documentation for implementation will be required.

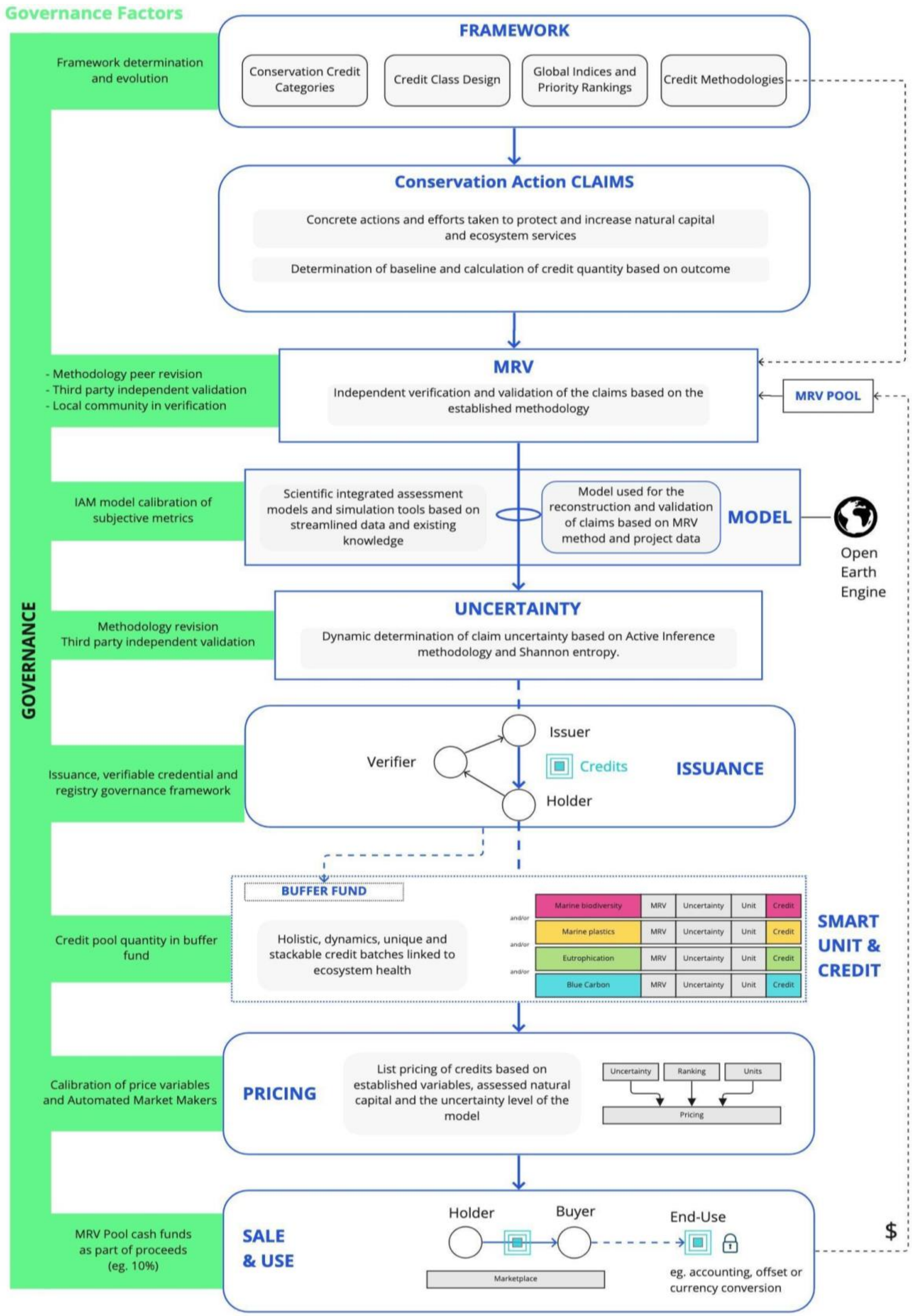


Figure 12 Marine Ecosystem Credit Unit Integrated Process Flow and Governance

6.1 Credit Class Design Framework Determination and Evolution

The OpenEarth Foundation, as credit designer will maintain the most updated documentation around the framework design and maintain an open Request for Comment (RFC) process to ensure public consultation. Furthermore, an Expert Steering Committee will be established to curate adjustments and oversight changes, as well as directly involve the registry and digital infrastructure provider to ensure their governance is also considered in the process. A 'Technical Implementation Document' (see Appendix B) will be established to maintain updates and specific variables that are not covered in this document. This document will be an online document using a 'Wiki' type platform.

6.2 MRV Methodology governance

These are established within each credit type and published under a peer-review process. MRV Methodologies are to be updated in a similar process like this credit class framework document: through open RFC processes with the difference that the expert steering committee also curates who are the appropriate peer reviewers with significant subject matter expertise and reputation to be eligible for publication

An importance governance feature is that third party validators conducting MRV cannot be the same as issuers nor the ultimate holder. In addition, local stakeholders and stewards should be given tools (eg. via mobile apps) to participate in the MRV or ongoing claim attestation (evidence building) process.

The determination of who are local stakeholder and stewards is established on a project basis following general principles: if there are indigenous communities that live on or are socially, economically and/or spiritually dependent on the project's area, then they are considered both stakeholders and stewards (i.e. if they contribute to ecological balance). If, for example, non-indigenous fishing communities are dependent on the area, then a special assessment is needed to determine whether their practice is ecologically sustainable and, if not, alternative solutions need to be developed as part of the project development plan (eg. to avoid leakage and disruptive social relocations).

Figure 13 Marine Ecosystem Credit Process Flow

6.3 Ecosystem IAModels for MRV

Scientific and computational models need to be used whenever possible to assess, calculate and/or verify claims. These models need to be reputable via peer-reviewed science publications, and their scientific basis needs to be auditable (i.e. open access).

If both Issuers and Verifiers are using the same established model, then the data sources for model inputs need to be sourced separately (otherwise they would be re-running the exact models and parameters).

Ideally, models can be established as trusted oracles to input information to the project based on set parameters. Further details on the use of IAM are to be included in the implementation document.

6.4 Uncertainty determination

The uncertainty determination has high level principles, but the exact methodology is specified within each credit type. OpenEarth or other ecosystem actors should maintain an open source (auditable) model running the calculation of Shannon Entropy with clear input-output pipeline

By default, if a project and its credits are deemed to hold an uncertainty level over 60% then these will not be allowed to be issued.

6.5 Roles in Digital Ecosystem — issuers, holders, verifiers, governance

Under the feature of using verifiable credentials and DIDs for the interactions of the agents involved in the credit issuance process, a machine-readable governance document will be maintained per credit and credential type, following the Trust Over Ip Metamodel Specification created by the Governance Stack Working Group (GSWG)

A registry list will be created to add trusted issuers and verifiers that apply across the family of credits and those that are specific to each credit type.

It is expected that the standards laid out in this document will be further adjusted and specified in the technical implementation document to allow for a digital certification of credit classes and issuances for interoperability, transparency and data quality.

Given the initial focus on MPAs, it is expected that host countries of projects are the default holders of credits, as such, they are the main entity determining how and if credits are sold and to whom.

6.6 Credit Buffer Reserve Pool

These are managed by the Credit Class Administrator, are calculated based on a risk-adjusted factor which considers the project's uncertainty value. However, the default value will be set to 20%.

6.7 Pricing governance

Further specifications around governance in credit pricing are to be established in the technical implementation document and will be done in consultation with major registry and marketplace providers, as well as ecological economic experts.

If Automated Market Mechanisms are to be used, then these are established by the marketplace itself.

Uncertainty is to be maintained as a modulating factor applied to adjust pricing, and its calculation and this price adjustments are to be done at least on an annual basis.

6.8 Credit Sales & End-Use

The eligibility for credit commercialization (i.e. whether to sell them and to whom) is to be determined by the holder, which most likely fall under the country hosting the MPA.

10% of sales are earmarked and separated for the MRV pool. The specifics around MRV pool governance will be defined under an open community consultation and defined in the technical implementation document.

7. Markets for the marine ecosystem credits

The MEC design is primarily targeted to finance efforts that can achieve a 30x30 ocean conservation goal, with particular focus on MPAs and marine parks. These are normally within sovereign waters and governed by national or ministerial governments. As such, the countries are ultimately the deciders of where and how the credits are to be marketed. Certainly, in order for a country to commercialize the credits, it needs to assure robust subscription to the principles and quality established in this document, including the principle of additionality —whereby the funding for the conservation efforts supported by the credit revenue would not have been mobilized (i.e. outside government budget) if it were by the existence of the credit market in the first place.

Notwithstanding, the design and digital architecture for the credits need to be compatible with at least the following three categories of funding or market schemes.

7.1 Private and public philanthropic conservation efforts

Philanthropic conservation is a traditional approach to funding MPA and can include public conservation efforts (eg. supported by sovereign funds) such as the Principality of Monaco, who has consistently supported MPAs around the world, as well as private foundations or coalitions such as the Blue Nature Alliance. The differential value of using our credit schemes under this context are twofold. First, the credits represent concrete measurable outcomes that the financier can trust and can lead to direct permanent attributions, and two, given these credits are outcome-based, the philanthropic initiatives can establish payments upon reception of credits only (i.e. as an outcome-based scheme).

7.2 Market based schemes

Markets with diverse eligible buyers and sellers are common with carbon and other environmental assets but non-existent within ocean conservation. These credits, however, could support the development of new markets.

Participation into multilateral compliance markets include regulated biodiversity or conservation markets, particularly as the European Union considers rolling-out biodiversity targets and associated market-based approaches. These credits can also be used in local compliance market policies, such as those that require a corporation to support a conservation initiative to conduct its operations (eg. in the hoteling, fossil fuel or mining industries).

On the other hand, if a country so chooses, these credits can be open to voluntary ecosystem markets, which includes companies or individuals wanting to either offset their impact or simply contribute to making their finances assessed as 'nature-positive.'

7.3 Nature currency mechanisms

We find the previous two credit use-cases extremely important and relevant but ultimately not conducive to ongoing sustainable sources of funding for MPAs considering a 30x30 goal. As such, we particularly focus on the robust design and implementation of these MEC class and standards to support more novel approaches of natural capital schemes. In fact, we believe the improved design and deployment of these credits could support two main formats that consider the ecosystem value as fundamental capital.

The first mechanism these credits could help scale are nature-debt swaps. These would involve a country debtor providing these credits to one or multiple countries in exchange for the cancellation of international debt. Robust and trusted credits can play a role in scaling these schemes, particularly beneficial to countries in the global south, whose natural capital is threatened due to economic pressure, but whose local conservation action can be done with the local currencies, and thus cancel international debt established in more expensive currencies.

The second and certainly most novel approach for the utilization of these credits is in the use of nature-backed currencies. Under these mechanisms, the credits and credit pools are locked into a digital treasury (eg. managed by a central bank) and used to back the minting of a new digital currency. In a simple analogy, we can conceive the creation of a currency that is backed by the health of nature, rather than gold. A sovereign nature-backed currency mechanism is certainly not a simple endeavor, but the digital infrastructure needed to support such a scheme has already been designed and tested successfully by the Klima DAO —an independent carbon-backed currency.

Given the forward-looking opportunity that a mechanism like a Central Bank Digital Currency (CBDC) backed by nature presents, the OpenEarth Foundation will commit resources to further the research and development of this particular credit use-case, in consultation with governments and multiple stakeholders.

8. Integration and conclusion

We present here the overarching design and architecture for a novel family of ecological credits destined to support the financing of ocean conservation towards the international goal of permanently protecting 30% of global oceans by 2030. This work represents a preliminary standard to ensure an ocean ecological asset class is done with utmost principles of scientific integrity and equity as well as leverage the most cutting-edge digital technology to ensure its robustness as it scales.

This document will gain further value as the methodological implementations of each credit types are designed, published, and implemented, particularly that of a protection-based biodiversity credit. We make the case in this document why such a protection credit would support the conservation of pristine marine ecosystems like the Cocos Island National Park in Costa Rica and its broader Eastern Tropical Pacific Marine Corridor (CMAR) that includes the Galapagos Islands.

Finally, we lay out the vision that a robust digital implementation of MEC can lead to the creation of new monetary schemes that can allow countries to gain fiscal sovereignty and humanity to progress on more directly including the value of nature into our economic paradigm.

References

Andeltová, L., Holm-Müller, K., & Braun, J. (2015). *Action-based and outcome-based payments for environmental services: An experimental auction for tree planting* *contracts in Kenya*. https://www.semanticscholar.org/paper/Action-based-and-outcome-based-payments-for-%3A-An-in-Andeltov%C3%A1-Holm-M%C3%BCller/f565fcb56f6ee5679f20c52f9b033ea54e333f22

Arlidge, W. N. S., Bull, J. W., Addison, P. F. E., Burgass, M. J., Gianuca, D., Gorham, T. M., Jacob, C., Shumway, N., Sinclair, S. P., Watson, J. E. M., Wilcox, C., & Milner-Gulland, E. J. (2018). A Global Mitigation Hierarchy for Nature Conservation. *BioScience*, *68*(5), 336–347. https://doi.org/10.1093/biosci/biy029

BBOP. (2012). *Standard on Biodiversity Offsets*. https://www.forest-trends.org/publications/standard-on-biodiversity-offsets/

Bohannon, K. (2021). *Plan Vivo: Delivering Sustainable Impact for Climate, People and Nature over the last 25 years*. Plan Vivo Foundation. https://www.planvivo.org/Blog/plan-vivo-sustainable-impact-for-climate-people-and-nature-over-the-last-25-years

Boyd, P. W., Bach, L. T., Hurd, C. L., Paine, E., Raven, J. A., & Tamsitt, V. (2022). Potential negative effects of ocean afforestation on offshore ecosystems. *Nature Ecology & Evolution*, *6*(6), 675–683. https://doi.org/10.1038/s41559-022-01722-1

Bull, J. W., Strange, N., Smith, R. J., & Gordon, A. (2021). Reconciling multiple counterfactuals when evaluating biodiversity conservation impact in social-ecological systems. *Conservation Biology*, *35*(2), 510–521. https://doi.org/10.1111/cobi.13570

Carbon Offset Guide. (n.d.). High-Quality Offsets. *Carbon Offset Guide*. Retrieved July 15, 2022, from https://www.offsetguide.org/high-quality-offsets/

Cortés, J., Enochs, I. C., Sibaja-Cordero, J., Hernández, L., Alvarado, J. J., Breedy, O., Cruz-Barraza, J. A., Esquivel-Garrote, O., Fernández-García, C., Hermosillo, A., Kaiser, K. L., Medina-Rosas, P., Morales-Ramírez, Á., Pacheco, C., Pérez-Matus, A., Reyes-Bonilla, H., Riosmena-Rodríguez, R., Sánchez-Noguera, C., Wieters, E. A., & Zapata, F. A. (2017). Marine Biodiversity of Eastern Tropical Pacific Coral Reefs. In P. W. Glynn, D. P. Manzello, & I. C. Enochs (Eds.), *Coral Reefs of the Eastern Tropical Pacific: Persistence and Loss in a Dynamic Environment* (pp. 203–250). Springer Netherlands. https://doi.org/10.1007/978-94-017-7499-4_7

Dinerstein, E., Vynne, C., Sala, E., Joshi, A. R., Fernando, S., Lovejoy, T. E., Mayorga, J., Olson, D., Asner, G. P., Baillie, J. E. M., Burgess, N. D., Burkart, K., Noss, R. F., Zhang, Y. P., Baccini, A., Birch, T., Hahn, N., Joppa, L. N., & Wikramanayake, E. (2019). A Global Deal For Nature: Guiding principles, milestones, and targets. *Science Advances*, *5*(4), eaaw2869. https://doi.org/10.1126/sciadv.aaw2869

Eger, A. M., Marzinelli, E. M., Christie, H., Fagerli, C. W., Fujita, D., Gonzalez, A. P., Hong, S. W., Kim, J. H., Lee, L. C., McHugh, T. A., Nishihara, G. N., Tatsumi, M., Steinberg, P. D., & Vergés, A. (2022). Global kelp forest restoration: Past lessons, present status, and future directions. *Biological Reviews*, *97*(4), 1449–1475. https://doi.org/10.1111/brv.12850

Enright, S. R., Meneses-Orellana, R., & Keith, I. (2021). The Eastern Tropical Pacific Marine Corridor (CMAR): The Emergence of a Voluntary Regional Cooperation Mechanism for the Conservation and Sustainable Use of Marine Biodiversity Within a Fragmented Regional Ocean Governance Landscape. *Frontiers in Marine Science*, *8*. https://www.frontiersin.org/articles/10.3389/fmars.2021.674825

Environmental Defense Fund. (2021). *Carbon Credit Quality Initiative*. Environmental Defense Fund. https://www.edf.org/climate/carbon-credit-quality-initiative

GESAMP. (2019). *High level review of a wide range of proposed marine geoengineering techniques* (Boyd, P.W. and Vivian, C.M.G.). GESAMP.

Grace, M. K., Akçakaya, H. R., Bull, J. W., Carrero, C., Davies, K., Hedges, S., Hoffmann, M., Long, B., Lughadha, E. M. N., Martin, G. M., Pilkington, F., Rivers, M. C., Young, R. P., & Milner-Gulland, E. J. (2021). Building robust, practicable counterfactuals and scenarios to evaluate the impact of species conservation interventions using inferential approaches. *Biological Conservation*, *261*, 109259. https://doi.org/10.1016/j.biocon.2021.109259

Katzner, T. E., Allison, T. D., Diffendorfer, J. E., Hale, A. M., Lantz, E. J., & Veers, P. S. (2022). Counterfactuals to Assess Effects to Species and Systems from Renewable Energy Development. *Frontiers in Conservation Science*, *3*, Article NREL/JA-5000-80481. https://doi.org/10.3389/fcosc.2022.844286

Kubiak, L. (2020). 30x30 Is One of the Best Ways to Achieve Biodiversity Goals. *NRDC*. https://www.nrdc.org/experts/lauren-kubiak/30x30-one-best-ways-achieve-biodiversity-goals

Mair, L., Bennun, L. A., Brooks, T. M., Butchart, S. H. M., Bolam, F. C., Burgess, N. D., Ekstrom, J. M. M., Milner-Gulland, E. J., Hoffmann, M., Ma, K., Macfarlane, N. B. W., Raimondo, D. C., Rodrigues, A. S. L., Shen, X., Strassburg, B. B. N., Beatty, C. R., Gómez-Creutzberg, C., Iribarrem, A., Irmadhiany, M., … McGowan, P. J. K. (2021). A metric for spatially explicit contributions to science-based species targets. *Nature Ecology & Evolution*, *5*(6), 836–844. https://doi.org/10.1038/s41559-021-01432-0

Maron, M., Bull, J. W., Evans, M. C., & Gordon, A. (2015). Locking in loss: Baselines of decline in Australian biodiversity offset policies. *Biological Conservation*, *192*, 504–512. https://doi.org/10.1016/j.biocon.2015.05.017

Maron, M., Ives, C. D., Kujala, H., Bull, J. W., Maseyk, F. J. F., BEKESSY, S., GORDON, A., WATSON, J. E. M., LENTINI, P. E., GIBBONS, P., POSSINGHAM, H. P., HOBBS, R. J., KEITH, D. A., WINTLE, B. A., & EVANS, M. C. (2016). Taming a Wicked Problem: Resolving Controversies in Biodiversity Offsetting. *BioScience*, *66*(6), 489–498.

Marshall, E., Wintle, B. A., Southwell, D., & Kujala, H. (2020). What are we measuring? A review of metrics used to describe biodiversity in offsets exchanges. *Biological Conservation*, *241*, 108250. https://doi.org/10.1016/j.biocon.2019.108250

Milner-Gulland, E. J., Addison, P., Arlidge, W. N. S., Baker, J., Booth, H., Brooks, T., Bull, J. W., Burgass, M. J., Ekstrom, J., Ermgassen, S. O. S. E. zu, Fleming, L. V., Grub, H. M. J., Hase, A. von, Hoffmann, M., Hutton, J., Juffe-Bignoli, D., Kate, K. ten, Kiesecker, J., Kümpel, N. F., … Watson, J. E. M. (2021). Four steps for the Earth: Mainstreaming the post-2020 global biodiversity framework. *One Earth*, *4*(1), 75–87. https://doi.org/10.1016/j.oneear.2020.12.011

Murphy, E. L., Bernard, M., Gerber, L. R., & Dooley, K. J. (2021). Evaluating the role of market-based instruments in protecting marine ecosystem services in wild-caught fisheries. *Ecosystem Services*, *51*, 101356. https://doi.org/10.1016/j.ecoser.2021.101356

National Academies of Sciences, Engineering, and Medicine. (2022). *A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration*. The National Academies Press. https://doi.org/10.17226/26278

Operation Wallacea. (n.d.). *Biodiversity Credits*. Operation Wallacea. Retrieved July 13, 2022, from https://www.opwall.com/biodiversity-credits/

Plan Vivo Foundation. (2022). *Statement on Biodiversity*. Plan Vivo. https://www.planvivo.org/news/plan-vivo-foundation-statement-on-biodiversity

Robertson, M., BenDor, T. K., Lave, R., Riggsbee, A., Ruhl, J., & Doyle, M. (2014). Stacking ecosystem services. *Frontiers in Ecology and the Environment*, *12*(3), 186–193. https://doi.org/10.1890/110292

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472–475. https://doi.org/10.1038/461472a

Simmonds, J. S., Sonter, L. J., Watson, J. E. M., Bennun, L., Costa, H. M., Dutson, G., Edwards, S., Grantham, H., Griffiths, V. F., Jones, J. P. G., Kiesecker, J., Possingham, H. P., Puydarrieux, P., Quétier, F., Rainer, H., Rainey, H., Roe, D., Savy, C. E., Souquet, M., … Maron, M. (2020). Moving from biodiversity offsets to a target-based approach for ecological compensation. *Conservation Letters*, *13*(2), e12695. https://doi.org/10.1111/conl.12695

South Pole. (n.d.). *Investments in Biodiversity*. South Pole. Retrieved July 15, 2022, from https://www.southpole.com/sustainability-solutions/investments-in-biodiversity

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Tobin, A., & Reed, D. (2017). *Inevitable Rise of Self-Sovereign Identity*. Sovrin Foundation. https://sovrin.org/library/inevitable-rise-of-self-sovereign-identity/

Wuepper, D., & Huber, R. (2021). Comparing effectiveness and return on investment of action- and results-based agri-environmental payments in Switzerland. *American Journal of Agricultural Economics*, *n/a*(n/a). https://doi.org/10.1111/ajae.12284

zu Ermgassen, S. O. S. E., Maron, M., Corlet Walker, C. M., Gordon, A., Simmonds, J. S., Strange, N., Robertson, M., & Bull, J. W. (2020). The hidden biodiversity risks of increasing flexibility in biodiversity offset trades. *Biological Conservation*, *252*, 108861. https://doi.org/10.1016/j.biocon.2020.108861

Appendix A – Development Roadmap

This whitepaper is under an initial Request for Comment, with evolving versions throughout 2022. Email the corresponding author for inputs.

Parallel output efforts are outlined below:

Marine Ecosystem Credit Class – Technical Implementation Document: Digital publication intended for Q4, 2022.

Marine Biodiversity Credit: This includes the full credit class and type design with MRV methodology for a protection-category of biodiversity, also expected to be published in Q1, 2023.

Nature-Backed Currency whitepaper: The OpenEarth team and collaborators will publish a technical thought piece on how advanced ecocredits can play a role in nature-backed currencies and how these can be designed for scale and a positive ecological economic disruption. Publication is intended for Q4, 2022.

Pilot Implementation of MEC issuance for Cocos Island National Park: By Q2, 2023 we seek to have a working pilot implemented in the Regen Registry that issues Marine Biodiversity Credits in a Testnet. This will inform further technical and design development in consultation with the Costa Rican government and local stakeholders.

Appendix B – Technical Implementation Document

The present document is intended as a high-level credit class family design and conceptual framework. For it to be rolled-out and implemented, a more detailed 'Technical Implementation Document' will be established to maintain updates and specific variables that are not covered in this document. This document will be an online document using a 'Wiki' type platform and most likely based on the technical specifications of the chosen registry and marketplace for the first pilot. This document design and MEC standard is, however, agnostic to registry and marketplace technologies and initiatives.

The link to the technical Implementation document is expected to be published in Q4 2022.