Determination of suitable financial contributions as offsets within the Reef Trust

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Summary

The Australian and Queensland governments have established the Reef Trust to strategically deliver funding to address high priority threats to the Great Barrier Reef (GBR). A component of Reef Trust funds will be derived from the pooling of offsets funds to compensate for residual significant impacts on the Great Barrier Reef. This report investigates a number of technical issues in the delivery of offsets through the Reef Trust. It assumes that the Reef Trust will align with the EPBC Act Environmental Offset Policy and Guidelines (hereafter EPBC Policy), and where necessary offers interpretation of the Policy and Guidelines for the marine environment. The EPBC Policy asserts that "Offsets must directly contribute to the ongoing viability of the protected matter impacted by the proposed action, and deliver an overall conservation outcome that *improves or maintains* the viability of the protected matter as compared to what is likely to have occurred under the status quo, that is if neither the action nor the offset had taken place".

The GBR World Heritage Area (GBRWHA) listing is based on 62 biodiversity and heritage values. Cultural and heritage values are subject to very different considerations of equivalence than biodiversity values, and are not addressed in this report. Similarly, ecosystem services are underpinned by biodiversity, but not addressed under the EPBC Act nor in this report.

The first section of this report examines how to ensure equivalence between the gains resulting from offset interventions and the losses from residual impacts to achieve a net outcome of "improves or maintains the viability of the protected matter". Ecological equivalence must address equivalence of type, space, time and amount. Demonstrating equivalence requires using appropriate metrics and explicit treatment of additionality, baselines, risk and uncertainty. 'Exchange rules' may be required to ensure that the simplification necessary to develop metrics does not lead to undesired outcomes. The key technical issues and options for equivalence are discussed from a theoretical perspective and from worked examples for the scenarios of direct loss of seagrass meadows and increased turbidity from suspended sediment. In general, a tighter definition of equivalence enables offsets to compensate more precisely for impacts, but reduces offset options, with consequent increases in financial cost and administrative complexity.

The second section of this report examines key considerations in determining the financial contributions required to establish offsets, so as to avoid under- or over-pricing. The key technical issues and options for determining financial contributions are discussed from a theoretical perspective and from worked examples for the scenarios of direct loss of seagrass meadows and increased turbidity from suspended sediment. A limited number of practical options is available. One of the most effective approaches is to pay for pre-delivered 'advanced offsets' from a 'bank'. In this case, costs and outcomes are known, and there is no lag in time between impacts and compensation. However, providers of advanced offsets require certainty as to the offsets needed in the future and a functional biobanking framework. An advanced offsets scheme may also face challenges in demonstrating 'additionality' of outcomes beyond the anticipated status quo. Alternative processes consider estimates (models) of the implementation costs for a direct compensatory offset. These

costs are poorly-known in many cases, and have numerous components, including overheads and insuring against ecological uncertainty and risk of under-delivery.

The third section of this report examines the key technical issues for audit and monitoring, and suggests some adaptations that could be made to the current 'Paddock to Reef' Integrated Monitoring Program model to make it more suitable for assessing offset outcomes and informing adaptive management. All monitoring balances the statistical power of sampling against financial cost, but the chosen approach should be robust enough to provide a clear picture of offset effectiveness. Independence and transparency of governance are also key issues for Reef Trust stakeholders.

This report synthesises these technical issues with practical and governance considerations learned from other offsets processes and projects, previous GBR projects, and this project's targeted stakeholder consultation. An overarching recommendation is to develop prescriptive guidance on ensuring ecological equivalence, determining financial contributions and audit/monitoring. This guidance would be consistent with the EPBC Policy but in places more prescriptive. For practical reasons, it might need to be developed iteratively.

As part of this process, it is recommended that the Reef Trust consult more widely regarding the challenges inherent in establishing a biobank, to ensure this key decision is informed by lessons from existing systems. It is also is recommended that the Reef Trust considers developing cost models for what are likely to be the most common offset scenarios. Provision of these models could mitigate some of the political risk around determining offset costs.

The Reef Trust is a new entity that is yet to develop its reputational credentials. It is recommended that the Reef Trust's decisions and process to develop an offsets system are undertaken with close awareness of concerns among some stakeholders about its independence, and about potential conflicts of interest if taking on the roles of both regulator and offsets provider. A number of the technical recommendations highlight the need for stakeholder-endorsed or independently-reviewed processes, and these principles should apply to all of the Reef Trust's actions.

Recommendations

Specific recommendations from this report relating to the Reef Trust are listed below.

Strategic planning

Develop offset-relevant components of a regional conservation strategy, including identification of:

- Spatial limits to offsetability (areas in which impacts cannot be offset, therefore, impacts should not be allowed);
- Spatial priority offset implementation zones; and
- Priority offset implementation actions for key MNES.

Ecological equivalence

Consider developing prescriptive metrics and exchange rules to ensure adequate ecological equivalence. These include:

Exchange rules

- Establish generic exchange rules such as limits to offsetability.

Character and quality equivalence

- Allow offset actions which are indirect, diffuse and geographically remote, as long as a robust link can be demonstrated and measured between the outcomes of those actions and the benefits to the particular MNES affected.
- Base offset exchanges on like-for-like equivalence of biodiversity value or impact type (this recommendation matches EPBC Policy).

Temporal equivalence

- Improve time equivalence by mandating (ecologically mature) advanced offsets and/or time discounting for risk of extinction and/or ensuring positive NPBV through time.
- Consider enhancing societal time equivalence by discounting for societal time preference.
- Enhance time equivalence by requiring that offsets begin before construction starts.

Spatial equivalence

- Consider spatial prioritisation based on stakeholder-endorsed systematic conservation planning.
- Constrain catchment management offsets to catchments contributing to the river discharge 'zone of influence' where the impact is located.

Equivalence of amount

- Establish an explicit baseline, consistent with agreed biodiversity or reef water quality targets, against which the 'improve or maintain' standard is to be achieved.
- Ensure property-level baselines used for calculating offset benefits are consistent with this whole-of-reef baseline.
- Base population viability analyses or landscape equivalency analyses on independent or independently-verified data and models.
- Develop multiple simple metrics and/or compound metrics to reflect each MNES and use alongside appropriate exchange rules.
- Work with local seagrass experts to provide prescriptive guidance for seagrass metrics.
- Prescribe that sediment metrics are tonnes of re-suspendable sediment generated, possibly divided into size classes to match the models and monitoring.
- Measure each impact and offset benefit using the same methods, calculated using the same approaches, and expressed in the same metrics.

Risks and uncertainty

- Consider using insurance and bonds where risks are significant and cannot easily be mitigated.
- Establish an independent expert review process to review precautionary estimates, or to estimate the accuracy of losses and gains, and to incorporate these into the offset calculations.
- Use strong legal structures and independent compliance monitoring to mitigate the risk of non-delivery and, where feasible, long-term persistence and security risks.

Determining financial contributions

- Consider developing the market infrastructure, including regulations and processes, to facilitate the establishment of a biobank of advanced offsets.

Consider developing cost models for the most common offset scenarios. This includes:

- Where possible, ensure that advanced offsets are purchased, at the market price.
- Where advanced offsets are unavailable, ensure that costs are modelled by an independent body or by Reef Trust with an independent review, based on pre-existing cost data.
- Ensure that offset costs include monitoring, reporting and other indirect costs; viz, = costs of direct action x any uncertainty multipliers + costs of preparing models and estimates + costs of auditing delivery + costs of monitoring and evaluation + administration costs of Reef Trust and delivery body [+ any education / outreach + any research]
- Ensure that providers of offset benefits through the Reef Trust seek the full cost of provision.
- Ensure that such 'fully funded' actions do not crowd out applications for other works under the Reef Trust and other existing or planned incentive schemes where an in-kind contribution from the landholder may be expected.

Audit and monitoring

- Develop explicit guidelines for monitoring requirements.

Background

The Great Barrier Reef, the Reef Trust and this report

The Australian and Queensland governments have established the Reef Trust to deliver funding to address key threats to the Great Barrier Reef (GBR) as part of the Reef 2050 Long-Term Sustainability Plan. A proportion of Reef Trust income will be proponents' financial payments to offset unavoidable residual impacts on the GBR. This report investigates a number of technical issues in the delivery of biodiversity offsets through the Reef Trust. It provides a high-level overview with considerations for what might work for the Reef Trust and some worked examples. Developing definitive recommendations will require a wider stakeholder consultation. The report is limited to the technical scientific issues of equivalence, determining financial contributions, monitoring and reporting, and does not include discussion of the administrative nor governance processes.

The area to which this report applies is the Great Barrier Reef region consisting of the Great Barrier Reef World Heritage Area (GBRWHA), in which impacts to biodiversity might need to be offset, and the GBR Catchment (GBRC consisting of the six regional Natural Resource Management (NRM) bodies), in which offsets might be delivered. The GBRWHA lies entirely seaward of the low water mark along the coast but also includes all islands inside its boundaries. The GBRC lies landward of the low water mark to the watershed boundaries, and also includes the island catchments (e.g. the catchments of Magnetic Island) of the islands that are part of the GBRWHA.

The GBR Marine Park (GBRMP) is entirely encompassed by the GBRWHA but is smaller in extent such that some parts of the GBRWHA, mostly islands and some inshore areas, are not within the GBRMP. The Australian and Queensland governments manage the GBRWHA through an intergovernmental agreement (1978) and a system of laws, regulations, and policies. Current governance arrangements are described in detail in the GBR Outlook Report 2014 (GBRMPA 2014)

Among the most noteworthy benthic community features of the GBRWHA are 3000 coral reefs, approximately 5,700 km^2 of seagrass meadows, 3,800 km^2 of mangrove forest as well as salt marsh and large areas of other types of benthic habitats (GBRWHA 2014). Seventy bioregions, of which 30 are reef bioregions, are described for the GBRWHA. As the biological communities of the GBRWHA are highly connected to all Indo-Pacific marine communities, endemism is very low, although species diversity is high. Threatened species are few and generally restricted to larger fauna such as dugongs, cetaceans, turtles, seabirds and migratory birds, which face species-specific threats.

Biodiversity features, including habitats, species, and attributes of these features are together referred to as 'values' in this report. (The word 'value' can potentially be confused with financial and other values, but is used in this context by the EPBC Policy and other standard offset references.) The values addressed by the relevant regulations are summarised below.

The six types of MNES listed under the EPBC Act and applicable to the GBRWHA are:

- world heritage properties;
- wetlands of international importance (listed under the Ramsar Convention);
- listed threatened species and ecological communities;
- migratory species protected under international agreements;
- Commonwealth marine areas; and
- the Great Barrier Reef Marine Park (GBRMP).

Queensland Matters of State Environmental Significance (MSES) are listed in schedule 2 of the Environmental Offset Regulation 2014 as:

- endangered, vulnerable, near threatened and special least concern animals under the Nature Conservation Act 1992;
- areas classified, under the Marine Parks Act 2004, as a conservation park zone, marine national park zone or preservation zone;
- areas declared under the Fisheries Act 1994 to be a fish habitat area; and
- a marine plant within the meaning of the Fisheries Act 1994, unless the plant is in an urban area, or the subject of a prescribed activity administered by the State; and
- legally secured offset areas.

The Queensland Offset Policy also allows for Matters of Local Environmental Significance (MLES) as described in section 5(3) of the Environmental Offset Regulation 2014.

The GBR World Heritage Area listing is based on 62 values. These values include cultural and heritage values, which are subject to very different considerations of equivalence than biodiversity values. Cultural and heritage values are outside the scope of this report but do require future investigation. Similarly, ecosystem services are underpinned by biodiversity, but not addressed under the EPBC Act, and are not addressed further by this report. However, some regulators do include specific ecosystem services in their offset values (e.g. Washington State: Hruby 2010; International Finance Corporation: IFC 2012).

The known threats to the GBRWHA are from climate change, terrestrial pollution discharge, coastal development (urban, industrial, tourism and ports) and fishing. The condition of the GBR is in decline with well-documented losses of coral, seagrass meadows, dugongs, dolphins, turtles, sharks and other large fish. Despite decades of intensive (and internationally well-regarded) management the decline continues (De'ath *et al*. 2012; Brodie and Waterhouse 2012; GBRMPA 2014) and further decline is predicted under the current management regime (GBRMPA 2014). The decline is most severe in the area south of Cooktown (65% of the GBRWHA area). Given these cumulative and ongoing threats and declines, development impacts on the GBR need to be carefully regulated and mitigated. The Reef Trust has been set up to address many of these threats, and "will focus on known critical areas for investment – improving water quality and coastal habitat along the Great Barrier Reef, controlling the current outbreak of crown-of-thorns starfish, and protecting threatened and migratory species, particularly dugong and turtles".

Offset principles

Regulatory biodiversity offsets are activities that are required of proponents by governments to compensate for permitted damage to or loss of biodiversity and ecosystem services. Biodiversity offsets only achieve their aim[1] under strict conditions. Principles encapsulating these conditions are often incorporated into law, policy or guidance. Offset policy and guidance developed for the Reef Trust needs to be aligned with the following policies and principles:

- The Commonwealth government EPBC Act Environmental Offset Policy, which applies by law to all offsetting of significant residual (after all reasonable measures have been taken to avoid and mitigate) impacts to the GBR or constituent Matters of National Environmental Significance (MNES);
- The Queensland Environmental Offsets Policy (https://www.qld.gov.au/environment/pollution/management/offsets/) which applies by law to all offsetting in the GBR;
- The Business and Biodiversity Offsets Programme (BBOP) offset principles, which have no legal basis but are widely regarded as global best-practice;
- The nine principles proposed for Great Barrier Reef offsets by Bos *et al.* (2014), which are adapted from BBOP for the Great Barrier Reef context; and
- The International Finance Corporation's Performance Standard 6, which is followed by >80 financial institutions signed up the Equator Principles, including many investors of proponent projects impacting the GBR.

In addition, individual proponent or project policies may inform Reef Trust offset policy and guidance, including:

- Individual proponents' policies (e.g. Rio Tinto's target of Net Positive Impact www.riotinto.com/npi); and
- Individual development project policies e.g. *Independent Review of the Port of Gladstone* Principle 15: "Environmental offsets should be strategic, measurable and in place prior to impacts occurring, while aiming for a net environmental gain".

Appendix 1 provides additional information for some of these policies, standards and principles.

In these policies and principles relevant to the Reef Trust, the four issues of perhaps greatest concern to stakeholders are:

- The proponents' legal obligation to **avoid and minimise** impacts where possible, and the regulators' obligation to clearly define and regulate avoidance and minimisation (qv Bos *et al.* 2014 for GBR cases; and the Senate inquiry into Environmental Offsets recommendation 5: "the mitigation hierarchy be rigorously implemented, with a greater emphasis on avoidance and mitigation");
- The regulators' obligation to define and observe **limits to offsetability** (because offsets are either ecologically unachievable, practically unfeasible, or socially unacceptable; BBOP 2012; Bos *et al.*

[1] The EPBC Act environmental offsets policy has five key aims and ten over-arching principles to provide environmental benefits to counterbalance the impacts that remain after avoidance and mitigation measures.

2014; Pilgrim *et al.* 2013; the Senate inquiry into Environmental Offsets recommendation 6: "provide greater guidance on developments in which offsets are unacceptable, including a list of 'red flag' areas, such as world heritage and critically endangered ecological communities and species");

- The regulators' obligation to ensure that offsets are genuinely **additional** to what would have happened without the offset (for instance, interventions that would otherwise have been resourced or facilitated by the regulator; the Senate inquiry into Environmental Offsets recommendation 3: "ensure that all offsets adequately reflect the principles of additionality, and are not granted in relation to areas that are already protected under existing Commonwealth, state or territory legislation or policy"); and
- The regulators' and offset providers' obligation to ensure that offset targets are **achieved and maintained**, with measurable long-term benefits to both biodiversity and communities.

There is an implied principle of equivalency in offsets, in that the compensation should be (at least) equivalent to the impact, so as to achieve 'no net loss' and preferably 'net positive impact' or 'net benefit' or, in the words of the EPBC Act, 'improve or maintain the viability' [of the aspect of the environment that is protected by national environment law and affected by the proposed action]. Defining and assessing equivalence (which has aspects of scale, type, place and time) can be challenging, as outlined in this report.

The EPBC Act offsets policy and guidelines

In 2012, the Department of the Environment revised the offset policy and guidelines applied under the *Environment Protection and Biodiversity Conservation Act 1999* after extensive stakeholder consultation. The policy and guidelines are generally accepted to improve certainty for both proponent and biodiversity values (in this case, MNES); however, they do not specifically address marine impacts and offsets. The policy allows for exceptions to the principles for marine offsets due to the perceived uncertainties relating to the marine environment. The 2014 Senate inquiry into Environmental Offsets provided a timely audit of the EPBC Act offsets process, generally endorsing the approach, but recommending some more detailed guidance and better resourcing of assessment, monitoring and compliance.

This report assumes that the Reef Trust will follow the EPBC Policy and associated government guidance documents (hereafter the 'EPBC Policy'), and focuses on issues specific to the marine environment and/or the Reef Trust.

Advanced Offsets

The EPBC Policy encourages the supply of offsets before an impact occurs and describes these 'advanced offsets' as offsets for potential future use, transfer or sale. Advanced offsets are generated when conservation or restoration activities are done with the express purpose of later using or selling offset credits. The Senate Inquiry into Environmental Offsets considered that advanced offsets provide a good opportunity for a more strategic approach to offsets and that their use should be encouraged; this could include, for example, greater use of the biobanking schemes that are available in some States. The Hawke review of the EPBC Act

(Commonwealth of Australia 2009) recommended that the Department of the Environment develop and promote a biobanking system.

Advanced offset systems work best with high demand from proponents, the availability of up-front capital, and strong support and regulation by government (Burgin 2008; Gane 2010). Aspects of advanced offsets are supported by industry– for instance the Minerals Council of Australia submission to the Senate inquiry noted that advanced offsets have "a number of benefits for mining proponents", including "having ready access to offsets" and the NSW Minerals Council submission to the Draft NSW Biodiversity Offsets Policy recommended that "The Government should develop a process for recognising advanced offsets".

The primary advantages of advanced offsets are that they address the issue of temporal equivalence (as discussed later in this report), they minimize the risk that offsets will fail to achieve intended outcomes, and they shift this risk from proponents or governments onto third-party offset providers. Advanced offsets also allow for geographic and strategic consolidation of offsets, which increases the likelihood that offsets will be successful and decreases the costs of assessment, design, implementation, and monitoring. Advanced offsets must meet regulatory offset principles, including demonstration that the action was additional and took place for the purpose of advanced offsetting, and that sufficient baseline information enables a clear assessment of the biodiversity conservation gain.

The primary disadvantage of advanced offsets is that offset providers require a high level of certainty about future offset requirements before they invest in creating advanced offsets. Future offset requirements are dependent on future permitted development activities and their approval conditions. Uncertainty is exacerbated if high levels of ecological equivalence are required. Offset providers also risk substantial upfront costs if there is no ability to raise funds by releasing credits prior to the offset being operational. Another challenge is ensuring the additionality of advanced offsets given the uncertainty around the details of future Government-funded GBR conservation programs.

Existing biobanking schemes have identified other operational considerations such as enabling markets and reducing transaction costs (e.g. OEH 2014). It is out of the scope of this report to consider enabling markets and reducing costs but it is noted that market efficiency depends on feedback between demand, supply and price paid. Overall, the success of biobanks depends on large capital investments, strong regulatory backing and demand from third parties (Burgin 2008; Gane 2010)

Strategic Assessments

Strategic assessments, as defined by the Commonwealth of Australia (2012) develop policy, programs and plans for a large set of actions or 'classes of actions' across a broad landscape. Future development projects which meet the strategic assessment regulations do not need to be referred for further assessment. The GBR Strategic Assessment was endorsed by the Australian Government on 11 August 2014. This assessment provides a big picture analysis of impacts on the reef and certainty about how decisions that may impact the

Reef will be made. Among the commitments made in the assessment and adopted by the Australian and Queensland Governments include:

- A cumulative impact assessment policy and guidelines for a transparent, consistent and systematic approach to identifying, measuring and managing collective impacts on the Great Barrier Reef region and its values; and
- A net benefit policy to guide actions to restore ecosystem health, meaning that any development approved in the Great Barrier Reef region makes a positive contribution to the Reef.

Offsets would be more effective if informed by a regional conservation strategy that identifies three offset-relevant components. First, the strategy should identify spatial priority implementation zones where offsets should be implemented as a default. These priority zones would be complemented by a set of rules identifying the exceptions where offsets are more effective if implemented in close proximity to the impact site. One aspect of the EPBC Policy, the prohibition of using a piece of land already set aside in the conservation estate, would need to be altered for offsets delivered in the GBR which is nearly all gazetted as Marine Protected Area. Second, the strategy should identify spatial limits to offsetability, i.e., areas in which impacts to biodiversity cannot be offset and therefore the impacts should not be permitted. Third, the strategy should identify, prioritise, and cost conservation actions, including restoration actions, for each MNES likely to require offsets. The strategy should explicitly identify which actions are 'additional' to funded biodiversity strategies, programs, and responsibilities of government (see section on Additionality and Baselines). The spatial area for these actions should be defined in parallel with identifying spatial priority implementation zones. These offset-relevant components of a regional conservation strategy would have to fit within the GBR Strategic Assessment and be endorsed by stakeholders.

Recommendation: Develop offset-relevant components of a regional conservation strategy, including identification of:

- *Spatial limits to offsetability (areas in which impacts cannot be offset, therefore, impacts should not be allowed);*
- *Spatial priority offset implementation zones; and*
- *Priority offset implementation actions for key MNES.*

1 Ensuring equivalence of conservation benefits

To achieve 'no net loss' or to 'improve or maintain viability', biodiversity offsets should ensure equivalence between the gains resulting from offset interventions and the losses from residual impacts. Equivalence has dimensions of type, space, time and amount (Salzman and Ruhl 2000). In practice, given the particular characteristics and local uniqueness of biodiversity, equivalence in the strictest sense can never be fully achieved. There is thus is a greater or lesser element of barter (exchanging different kinds of goods) in biodiversity exchanges (Salzman and Ruhl 2000; Walker *et al.* 2009).

1.1 Issues around equivalence for the GBR

The following issues are discussed in this section:

- Marine versus terrestrial offsets;
- Type equivalence:
    - Character and quality equivalence
    - Spatial equivalence;
    - Temporal equivalence;
- Equivalence of amount:
    - Measures and metrics;
    - Additionality and baselines;
- Risk and uncertainty; and
- Exchange rules.

Marine versus terrestrial offsets

Offsets can be more difficult in the marine environment compared to the terrestrial environment for two main reasons: ownership and flows (Bos *et al.* 2014). On land, proponents can purchase sites for offset activities and have a relatively high level of control over what happens on that site. Coastal and marine resources, however, are publically owned and marine sites cannot be purchased. The government can set aside areas for offset implementation, but sustained legal protection of these areas requires continual public support. In addition, impacts and pollutants flow in marine systems, both from the catchments and from other marine areas. This makes it more difficult to control the outcomes within a marine offset 'site'. Many marine species also range over very large areas. Furthermore, much degradation or quality loss has occurred over larger spatial scales than in the terrestrial environment, meaning that offset actions often need to be effected over large scales. However where marine impacts are offset by activities in the GBRC, some offset benefits may be realised in adjacent marine systems.

The differences between terrestrial and marine offsets mean that:

1. different implementation models for marine systems need to be investigated, including offset design;
2. limits to offsetability may be different than in terrestrial systems due to the connectivity of marine systems; and
3. strategic implementation of offsets, through the opportunity to address different impacts to those being offset, might deliver better outcomes for marine systems

Type equivalence

Character and quality equivalence

Character refers to what the biodiversity feature is (e.g. seagrass meadow); quality to important attributes that it possesses (e.g. a particular composition of species). The concept of 'like for like' offsets (BBOP 2012) relates to character and quality equivalence. BBOP (2012) lists relevant features to consider in identifying character and quality equivalence for any given system, including species diversity, functional diversity and composition, ecological integrity or condition and ecosystem services.

The EPBC Policy states:

- Offsets should be tailored specifically to the attribute of the protected matter [MNES] that is impacted in order to deliver a conservation gain;
- In some circumstances it may be possible to demonstrate that a better conservation outcome can be achieved for the protected matter [MNES] by deviating from this rule; and
- In no instances will trading offsets across different protected matters [MNES] be considered as a suitable offset.

'Like-for-like' as set by the EPBC Policy is thus bounded within the same MNES. Importantly, for the marine environment, the Great Barrier Reef Marine Park is considered as one MNES, as well as containing numerous other MNES (e.g. protected species). Under the EPBC Policy, offsets must benefit the equivalent MNES, and usually the impacted attribute of the MNES, but not necessarily relate to the equivalent impact.

As an example, impacts on the GBRMP might be caused by direct removal of seagrass habitat. However, the most effective offset benefits to seagrass habitat might be obtained not by replanting, but by reducing other anthropogenic stresses on seagrass so as to improve its extent and condition commensurate with the loss.

However, this indirect approach may involve a longer chain of causality and be less scientifically robust than for offsets designed to reduce the same impact. For example, offsetting the projected loss of seagrass habitat from increased turbidity and light stress by altering adjacent land uses involves additional theoretical steps to determine equivalence of the impact and the offset benefit. However, if the link between turbidity and seagrass in a particular area is well-established, it may be valid and conceptually relatively simple to offset increased turbidity from, for example, dredging, by reducing turbidity caused by other anthropogenic processes, for example, agriculture. Turbidity for impact and offset should be measured using the same methods and expressed in the same metric (see below).

As yet, there have been no offsets targeting diffuse sources of threats, such as different pollutants from land-based activities. There is no robust ranking of the relative risk of different pollutants (e.g. sediment vs nitrogen vs. phosphorus vs. a specific herbicide vs. a specific toxic metal). Moreover, different pollutants impact different values in different ways. In principle, further research could provide information required for a system whereby different pollutants could be traded, especially through an advanced risk assessment for the GBR, with more sophisticated analysis beyond that recently completed (e.g. Waterhouse *et al.* 2013).

Targeting different types of impacts on water quality, other than turbidity, is theoretically feasible, but robust scientific processes to ensure equivalence are needed. For example, the impact of increased suspended sediment on the GBRMP could be offset by reducing anthropogenic nutrient supply, for example, from sewage treatment plant discharge in the same area. However, in practice, there is no method quantitatively to relate the impact from a measured increase in suspended sediment to a measured decrease in nitrogen or phosphorus.

A form of 'like for not-like' trade within an MNES is feasible within the framework recommended here, i.e. trading one threat to turtles as an impact (e.g. reduced seagrass biomass through poor water quality), for a reduction in another type of threat to turtles as an offset (e.g. removing nets, beach lighting, beach fencing). However, consistent with the EPBC Policy, there can be no trading between different MNES.

Recommendation: Allow offset actions which are indirect, diffuse and geographically remote, as long as a robust link can be demonstrated and measured between the outcomes of those actions and the benefits to the particular MNES affected

Non-equivalent (non-like-for-like) approaches have at times focused on indirect offsets, for example investment in research or education. The outcomes of such interventions are often hard to measure and may not relate in a meaningful way to residual impacts. Using offset monies to fund research and education is increasingly viewed as unacceptable (McKenney and Kiesecker 2009). It is assumed that the Reef Trust will not usually support research or education offsets.

Spatial equivalence

Spatial equivalence has at least two dimensions. The first concerns landscape context and measures of connectivity or fragmentation (including adjacent land uses or condition, patch size, etc.: BBOP 2012). For example, it would not be equivalent to exchange a large site, well linked to other habitat patches, for a scattering of small, dispersed fragments. Strategic offsetting can in principle provide a way for loss of habitat fragments to be exchanged for the retention of parts of larger, contiguous areas.

The second concerns the uniqueness of biodiversity to its location, at all spatial scales. Therefore, the proximity of impact and offset is often a consideration. Distant sites, with the same general habitat but inevitably with different biodiversity, might not be eligible for exchange.

Spatial equivalence applies differently in marine ecosystems than in terrestrial ones[2]. Marine systems are more three-dimensional and generally subject to larger scales of ecological connectivity, both in terms of flows of impacts and attributes, making geographical boundaries less applicable (Game *et al.* 2009). Impacts are often diffuse and arise remotely from the source, unlike the predominance of onsite point-impacts in the terrestrial environment (Orth *et al.* 2006). As long as offset actions benefit the particular MNES impacted, marine offsets might be spatially distant from the MNES. In the GBR, this might mean targeting diffuse (and often indirect) impacts from activities in the catchments (often geographically distant but hydrologically connected) as a way to achieve benefits for marine MNES.

Spatial equivalence may also extend to compensating the same beneficiaries (e.g. people benefiting from local ecosystem services or local biodiversity existence values) who are impacted (Brownlie and Botha 2009; Kiesecker *et al.* 2009; McKenney and Kiesecker 2009). Ecosystem services are not addressed by the EPBC Policy nor this report.

There is frequently a tension between proximity and distance in designing offsets. On one hand, it is not always possible or preferable to replace a value, such as a range-restricted species or recreational fishing access, hundreds of kilometres away from the impact site. On the other hand, impact sites are often in industrial zones with chronic pressures, and the probability of success of an offset close to these sites may be much lower and the cost much higher than in more distant areas. Policies that promote on- or near-site offsets can lead to fragmented restoration sites with high failure rates (NRC 2001). Restoration on development sites can be hundreds of times more expensive than off-site restoration (Rolfe 2000).

McKenney and Kiesecker (2009) argue that offset policies should require regional, landscape planning to select implementation sites. Kiesecker *et al* (2009) applied systematic conservation planning (Margules & Pressey 2000) to identify strategically-located offset sites, finding it advantageous to consolidate multiple offset activities. Implementation of offsets in a few, larger areas rather than small fragmented sites throughout a region is more cost-effective because it consolidates capital expenses, management, and monitoring. It is more likely to achieve ecological outcomes because multiple offset activities can be combined into an ecosystem-based approach (Gane 2010). For example, in one area, three offsets could be implemented simultaneously to address seagrass, turtles and sedimentation, respectively. Exceptions might be necessary for values that have very limited ranges or high spatial variability.

When the key biodiversity elements of interest are migratory species, demanding spatial equivalence may not give the most successful outcomes. Rather, exchanges may be best targeted to places in the migratory pathway where the species show greatest vulnerability (Bull *et al.* 2013, Bennun *et al.* in prep.).

The GBR has both a 'whole-of-GBR' nature, driven by strong connectivity through large-scale larval transport (McCook *et al.* 2009), and a strong regional character and integrity (Fernandes *et al.* 2005) Many threatening processes occur across the GBR, such as coral bleaching related to climate change, reduced calcification

[2] Note that the GBRWHA does include some terrestrial islands

associated with ocean acidification, and agricultural pollution discharges. However, the processes interact at regional scales to produce the declining ecosystem health status of the central GBR compared to the fair-to-good status of the far northern GBR (GBRMPA 2014). To be effective at mitigating the regional impacts of development, offsets will need to be regionally focussed in the same area as the impacts. Appropriate scales of offsets for the GBR are discussed later in the sections on Spatial Equivalence.

Temporal equivalence

When impacts occur before offsets are achieved, there are increased risks (e.g., what if the expected benefits do not materialise) and foregone benefits and lost growth in value (or 'interest' on natural capital). A time gap between impact and offset could have serious consequences for rare or sensitive biodiversity (Bekessy *et al.* 2010), including a heightened risk of extinction (Evans *et al.* 2013). Proponent-implemented offsets typically begin after impacts have occurred, exacerbating the time gap between impacts and benefits.

Advanced offsets, in the form of a biobank or otherwise, can reduce the time gap by ensuring that benefits are achieved before impacts occur. Biobanks are ideal for ensuring temporal equivalence, and can be successful for a variety of conservation values. Because of the long time period needed to achieve some conservation benefits, however, advanced offsets are not always feasible. For example, offsets that reduce the river discharge of suspended sediment through reduced erosion take time to become effective (Appendix 3). Methods such as stream bank tree planting, stream bank fencing (and natural re-establishment of riparian vegetation), pasture management and restoration of high levels of pasture cover, gully stabilization and/or repair take years to decades to achieve effective reduction of erosion and hence suspended sediment loads (Brodie *et al.* 2012; Bartley *et al.* 2014; Wilkins *et al.* 2003). Ideally, advanced offsets should therefore be mature and actually delivering the full benefits, rather than immature and delivering a limited (albeit increasing) proportion of the anticipated benefits. However, an offset that has generated some of the expected ecological benefits is superior to one not yet commenced, as this reduces some uncertainty and some time lag. If offset implementation is not complete, the value of the offset intervention should be discounted accordingly. Net present values for exchanges need to take into account losses and gains in value, payback times and discount rates (Overton *et al.* 2012).

One complex issue is that for many development projects (e.g. port development) some or most impacts may be of relatively short duration - one to a few years. Thus the duration of an offset program for the development becomes relevant: for how long do particular benefits need to be sustained? The answer will depend on the particular impact and its duration, and so requires consideration on a case by case basis. Generally, offsets need to deliver benefits for at least as long as the impacts remain.

Equivalence of amount

To result in no net loss, an offset exchange must ensure that the amounts of loss and gain are equivalent. This requires direct estimation or measurement, in the same metric, of the amount of loss attributable to an impact and the amount of gain attributable to a set of offset actions. These figures must in turn be adjusted for uncertainty and temporal loss.

Measures and metrics

Accounting for losses and gains requires a standard metric, based on biodiversity measures that are applicable to both losses and gains. Such a metric acts in effect as a fungible (mutually interchangeable) currency for biodiversity: however the term 'metric' is preferred to avoid confusion with financial currencies.

Designing metrics is challenging as biodiversity is complex, multi-faceted and locally unique. Any measure of biodiversity will thus inherently be an imperfect representation of, and an imprecise surrogate for, all variation in all components of the biota of a particular area (Salzman and Ruhl 2000; Walker *et al.* 2009; Pawliczek and Sullivan 2011). However, metrics do not have to be technically perfect, but good enough to support policy aims effectively (and to avoid unintended negative consequences).

Metrics may be multiple and complementary, each based on measures for one or a few attributes of the impacted biodiversity value; or a single metric can be aggregated from a suite of measures. Multiple metrics used alongside each other improve ecological equivalence (Quétier and Lavorel 2011; Temple *et al.* 2012; Gardner *et al.* 2013). Individually, they are also easier to interpret – they indicate one thing each. However, they can create difficulties for practical application and exchange. By contrast, aggregated metrics make it simpler to weigh overall losses and gains, but risk over-simplifying necessarily complex assessments. They are likely to require a set of 'exchange rules' (see below) to ensure acceptable ecological equivalence (Salzman and Ruhl 2000; Fennessy *et al.* 2007; Wissel and Watzold 2010; Quétier and Lavorel 2011) and avoid undesirable trading-off among different, non-equivalent elements of the metric (see 'Exchange rules', below).

Some other considerations are important in choosing metrics. Is it clear what they are measuring (Norton 2009), can they be standardised for consistent replication (Quétier and Lavorel 2011) and do they appropriately represent the key variables of concern, both for biodiversity and, importantly, people (Sherren *et al.* 2012)?

Most best-practice systems use species population metrics where available, and/or habitat/vegetation area x condition metrics, where the condition metrics are variably complex and aggregated. Some systems use area without a condition multiplier, and a few use direct economic valuation (BBOP 2012; ICMM and IUCN 2012). The EPBC Policy allows use of the metrics most ecologically appropriate to the circumstances, including number of individuals or demographic factors, number of relevant ecological features, and habitat area x quality.

Metrics used in the GBRWHA Outlook Report 2014 (GBRMPA 2014) and the Reef Plan Report Cards (Queensland Government 2014) include:

- Dugong population numbers from aerial assessment;
- Turtle population numbers from nesting beach counts, capture, tagging and recapture studies and aerial surveys;
- Coral reef fish species counts at a selection of coral reefs;

- Coral 'health' incorporating coral cover, biodiversity, coral recruits, coral disease and crown of thorns starfish numbers at a selection of reefs;
- Seagrass cover (and change in cover), reproduction, and nutrient status (in response to nutrient conditions in surrounding waters);
- Chlorophyll a in marine waters – measured currently in both river discharge and non-river discharge periods as µg/L, via interpretation of MODIS satellite remote sensing, backed up by manual sampling in river discharge periods;
- Suspended sediment in marine waters – measured currently via interpretation of MODIS satellite remote sensing, and reported as suspended sediment (in mg/L), turbidity (in Nephelometric Turbidity Units) and/or clarity (in m^{-1}), which are related measures (e.g. Fabricius *et al.* 2014);
- End of river loads of suspended sediments, nitrogen, phosphorus and selected pesticides in approximately 12 rivers (new sites being added regularly) measured in kg or tonnes;
- Extent of river plume influence in the GBR lagoon;
- Pesticide concentrations in freshwater, estuarine and marine waters – measured from manual samples and passive samplers and reported as concentrations; and
- Number of farmers changing management practices e.g. from C class to B class.

Additionality and baselines

All offset systems need to address 'additionality'. The EPBC Policy reflects and defines additionality in its goal that "Offsets must…improve or maintain the viability of the protected matter as compared to what is likely to have occurred under the status quo, that is if neither the action nor the offset had taken place." The policy further clarifies that offsets must "be additional to what is already required, determined by law or planning regulations or agreed to under other schemes or programs (this does not preclude the recognition of state or territory offsets that may be suitable as offsets under the EPBC Act for the same action)". For example, any land-based offset to reduce sediment flow must demonstrate its additionality to land management schemes already implemented or planned, including activities that are required of proponents under other rules and regulations (e.g. best management practice), and existing and expected future government programs to conserve the GBR. The Reef Trust must define these current and planned requirements in order to provide clarity around additionality.

The EPBC Policy also states that "Where a proponent or offset provider seeks to secure an advanced offset, it must sufficiently document the establishment of that offset, including relevant baseline data, to demonstrate to the department that it is additional". Therefore, any benefits already-banked or in train could only be considered additional if they were clearly commenced explicitly for the purpose of forming part of an offset exchange in the future, and would not have been achieved otherwise.

To measure additionality, offset gains need to be assessed against baselines or counterfactuals – that is, the 'status quo' scenario as defined in the EPBC Policy. Static counterfactuals (e.g., current water quality) are relatively straightforward to generate, as the data are usually available, or can be measured. However, static counterfactuals do not allow for averted losses (e.g., avoiding expected future reduced water quality by avoiding anticipated land-use change that exacerbates sediment runoff), nor are they appropriate in a system that is improving anyway in the absence of the proposed impact (e.g., expected ongoing improvement due to the Reef Rescue program and beneficial management).

Dynamic counterfactuals are more technically complex to model. They may be based on simple extrapolation of recent historical trends, but this approach is likely to prove inaccurate as regulatory and investment scenarios evolve. Alternatively, dynamic counterfactuals can be based on expert-opinion estimates of projected future trends under future regulatory and investment scenarios. The technical uncertainties in determining future trends lead to the governance risk that different stakeholders will attempt to game the model to deliver their preferred outcome.

Projected future scenarios used as baselines must not reflect impacts from activities that themselves would have required offsetting. Averted loss offsets are allowed under the EPBC Policy, but it is important to remember that the approach has the outcome of 'locking-in' outcomes to match the chosen counterfactual if only a no net loss standard is required. Bos *et al.* (2014) conceptualized the measurement of offsets relative to a declining dynamic counterfactual scenario (see Figure 1).

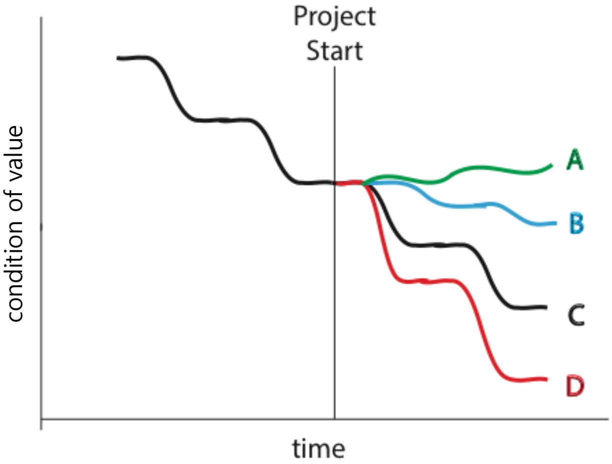

Figure 1. Additionality relative to a declining dynamic counterfactual (from Bos *et al.* 2014).

Line A represents no net loss compared to a static counterfactual of 'before the impact' and is the only approach consistent with system recovery. Line B represents net improvement on the declining counterfactual, but still results in overall system decline due to its reliance on averted loss. Line C is the dynamic counterfactual, and a matching trajectory with the impact and the offset would be considered a no net loss outcome compared to this counterfactual. Line D represents net loss compared to this counterfactual.

Counterfactual scenarios used to estimate the additional offset benefit expected from an intervention at any given site must be consistent with the counterfactual scenario for the entire system – in this case, the GBR or its bioregions. Estimating the additional benefit to GBR water quality that can be attributed to any given action thus requires a three step process:

1. Given the governmental targets set for water quality improvement on the GBR, a trajectory of water quality leading to those targets within the specified time frames would form an appropriate

counterfactual trajectory against which NNL or net gain should be achieved. Any less favourable counterfactual trajectory makes the existing targets moot.

2. Once the intended trajectory of water quality (in the absence of additional impacts and offsets) is described, the set of land use and land cover changes required to achieve this can be modelled. This then reflects the changes that can be anticipated to occur (in the absence of any extra development impacts) to achieve existing water quality targets, through interventions like incentive schemes (e.g. Reef Rescue and its antecedents), regulation and industry changes. Such modelling would need to be spatially explicit to reflect the different practices and effects of a given practice change in different catchments along the coast. These changes might be expressed as the proportion of area currently under a particular management practice that would need to alter that practice in a given way. There are risks to offset funding being used for projects similar to those carried out in Reef Rescue under co-funding arrangements between landholders and government. Landholders' in-kind contributions may be 'crowded out' when they have the option of a fully-funded project under Reef Trust.
3. Only actions that are expected to achieve more than the target-linked counterfactual level of water quality improvement can be considered to generate some additional benefit that can be used to offset an impact. This could be calculated by assuming the probability of a given change in land management occurring without the offset payment was proportional to the area of that change modelled to occur in that catchment in order to achieve the counterfactual.

Recommendation: Establish an explicit baseline, consistent with agreed biodiversity or reef water quality targets, against which the 'improve or maintain' standard is to be achieved.

Recommendation: Ensure that property-level baselines used for calculating offset benefits are consistent with this whole-of-reef baseline.

Risk and uncertainty

Many steps in assessing, designing and implementing offsets involve risks. The EPBC Policy has a principle that offsets must "effectively account for and manage the risks of the offset not succeeding". These may be taken into account in practice via exchange rules and/or via adjustments to equivalence calculations (as currently used in the EPBC Policy) or set multipliers (e.g. as used by DEA&DP 2011). Key risks inherent to the offsetting process include:

- the accuracy of quantified losses (measurement or modelling risk);
- the ecological response of the target values to the delivered offset actions and the accuracy of the counterfactual scenario, both of which affect the accuracy of projected gains (performance risk and measurement or modelling risk);
- the delivery of offsets (transaction risk);
- the long-term persistence of gains after offset actions have ceased (performance risk); and
- the security of the offset site (permanence risk).

Additional risks arise from external impacts (e.g. climate change) and from the offsetting governance system (e.g. the risk of 'regulatory capture', where decisions and/or actions of a regulatory agency are influenced by benefits flowing to the agency from the industry it regulates; Bos *et al.* 2014).

The EPBC Policy addresses the performance, offset measurement, offset modelling and transaction risks with an uncertainty (or confidence) multiplier. The proponent estimates its confidence as a % and this is converted into a multiplier applied to offset requirements. The EPBC guidance document *How to use the offsets assessment guide* states that "the confidence in result is a percentage figure that describes the level of certainty about the success of the proposed offset. Proposed offset actions that are designed to have a lower risk of failure should have a higher confidence in result score… This includes the degree to which the proposed offset actions can be achieved and how likely they are to provide a benefit to the protected matter. Where available, the confidence in result should be based on scientifically sound evidence and knowledge. Where this information is not available, the onus is on the proponent to provide information about the efficacy of proposed techniques or methods. The past record of the proponent should also be taken into account in determining this figure. That is, confidence in result must take into account not only the confidence in being able to achieve the conservation gain but also take into account the risk that the offset may not be delivered." Uncertainties around the translation of indirect, diffuse and/or geographically distant actions to benefits to MNES are likely to be high, and this should be reflected in the multipliers (or 'risk premium') used in calculating the actions that the Reef Trust will need to fund.

Exchange rules

Metrics are constructed to facilitate exchange of equivalent biodiversity, but cannot incorporate all ecological constraints or stakeholder desires without becoming overly complex. Exchange rules, such as minimum thresholds for any component, are needed to constrain substitution between components, otherwise the single final score can mask critical losses sustained by some non- substitutable components (McCarthy *et al.* 2004; Gibbons and Lindenmayer 2007; Bedward *et al.* 2009; Pawliczek and Sullivan 2011; Gardner *et al.* 2013).

Exchange rules can sit above the metrics as high-level principles and can set bounds within and among the metrics themselves, addressing substitutability or limits to loss of particular biodiversity features. They can address issues such as limits to what impacts are offsetable, baselines, additionality, permanence, temporal loss, multipliers, uncertainty and risk.

The Reef Trust should consider establishing generic exchange rules to be followed by all Reef Trust offsets. A number of specific proposals are given in the next section. Already suggested under 'Spatial equivalence' above is that the Reef Trust could define spatial limits to offsetability and any biodiversity values where impacts are never offsetable.

Recommendation: Consider establishing generic exchange rules such as limits to offsetability.

1.2 Assessment of potential options

This section applies the theoretical points discussed above to potential options in the context of the realities of the GBRWHA. Examples of offset conditions and processes from Australia and overseas are given, along with potential examples involving GBR species, ecosystems and environmental issues. Options are assessed against their likely ability to achieve equivalence of each category (type (character and quality), space, time and amount), and to achieve acceptable certainty.

These options can then be assessed against four criteria (see Tables 1 to 5):

1. Alignment with existing **regulation** (EPBC Policy; Queensland Offsets Policy) and international best-practice (BBOP);
2. Certainty and fairness of ecological **outcomes**, which are usually closely linked to their transparency and acceptability to stakeholders;
3. Maximising **opportunities** (and thus reducing costs) for finding suitable offsets; and
4. **Simplicity** and minimising transaction costs (e.g. relating to data collection by proponents, developing models and metrics, proposal assessment by regulators, and monitoring).

Criteria of lesser significance, and hence not used here, include:

- Opportunities for building new conceptual models, processes and offset types; and
- Opportunities to use non-standardised data.

The options are scored against each criterion as:

- ✓✓ for theoretically recommended;
- ✓ for theoretically feasible; or
- X for not theoretically feasible.

Viability is assessed as:

- ✓ for theoretically viable if all criteria are theoretically feasible; or
- X for not theoretically viable if one or more criteria are not theoretically feasible.

Equivalence of type: character

Four practical options for ensuring equivalence in character, here defined to mean the *kind* of listed or target biodiversity value(s), include:

a. Offsetting each impacted biodiversity value with exactly the same biodiversity value (e.g. dugongs with dugongs);
b. Offsetting each impacted biodiversity value with broadly similar biodiversity value(s) (e.g. one seagrass species with a different seagrass species);
c. Offsetting impacts with reductions in exactly the same impact types (e.g. turbidity with turbidity); and

d. Offsetting impacts with reductions in different impact types, which are demonstrated to have equivalent effects on the impacted biodiversity value (e.g. turbidity with herbicide).

The assessment of options for ensuring equivalence in character is shown in Table 1.

Table 1: Assessment of options for ensuring equivalence in character.

Option	Further detail and/or example	Criterion				Viable?
		Regulation	**Outcomes**	**Opportunities**	**Simplicity**	
Offsetting each impacted biodiversity value with exactly the same biodiversity value	Under the EPBC Policy, in no instances will trading offsets across different protected matters be considered as a suitable offset	✓✓	✓✓	✓	✓	✓
Offsetting each impacted biodiversity value with broadly similar biodiversity value(s)	Under the EPBC Policy in no instances will trading offsets across different protected matters be considered as a suitable offset Under the Qld Offsets Policy, a wetland offset site must be within the same broad vegetation group as the impacted regional ecosystem (and within the same bioregion)	X (under EPBC)	✓	✓✓	✓	X
Offsetting impacts with reductions in exactly the same impact type	Qld Urban Utilities invested $1million to offset increasing nitrogen discharges from a sewage treatment plant by repairing riparian corridors to intercept nitrogen otherwise discharging into waterways; nitrogen levels will be monitored and assessed over the next five years (DEHP 2014) Under Qld DEHP's voluntary market-based mechanism for nutrient management, total nitrogen discharges must be offset with total nitrogen, or total phosphorus with total phosphorus	✓✓	✓✓	✓	✓	✓
Offsetting impacts with reductions in different impact types, which are demonstrated to have equivalent effects on the biodiversity value(s)	Hypothetical offsetting of phosphate discharges from a sewage treatment works by reducing the amount of nitrogen discharged from agriculture – but equivalent effects first need to be demonstrated	✓	✓	✓✓	✓	✓

Although theoretically viable, there is currently no robust scientific basis for the final option of offsetting impacts with reductions in different impact types for the particular MNES affected. This needs to be informed by a specific robust scientific process to ensure equivalence of impacts on the MNES.

The only options likely to be acceptable to regulators in terms of ecological outcomes are those focused on like-for-like equivalence of biodiversity value or impact type. Although these are likely to lead to good, transparent outcomes, they constrain offset opportunities.

Recommendation: Base offset exchanges on like-for-like equivalence of biodiversity value or impact type (this recommendation matches EPBC Policy).

Equivalence of type: quality

Equivalence in quality is an important consideration for habitats and ecological communities, but less frequently for species. Options include:

a. Determining offsets based on population viability analyses (PVAs) or landscape equivalency analyses (LEAs) to ensure improved or maintained viability of the MNES;
b. Applying multiple simple (disaggregated) metrics for different quantifiable attributes of a biodiversity value. Each of these simple metrics must be used in the offset exchange. Exchange rules are necessary (Quétier and Lavorel 2011; Gardner *et al.* 2013); and
c. Applying a compound (aggregated) metric, combining metrics of each quantifiable attribute of a biodiversity value into a single metric. Exchange rules are likely to be necessary.

The assessment of options for ensuring equivalence of type (for quality) is shown in Table 2.

Table 2: Assessment of options for ensuring equivalence in type (for quality)

Option	Further detail and/or example	Criterion				Viable?
		Regulation	**Outcomes**	**Opportunities**	**Simplicity**	
Using PVAs or LEAs to ensure improved or maintained viability	Bruggeman and Jones (2008) demonstrate that measures of area and landscape equivalence may not adequately capture metapopulation dynamics; Bruggeman *et al.* (2005, 2009) propose LEAs to use metapopulation genetic theory to estimate viability	✓✓	✓✓	✓	✓	✓
Multiple simple metrics for different quantifiable attributes of a biodiversity value	Under the EPBC Policy, offsets should be tailored to the same attribute of the impacted protected matter, unless a better conservation	✓✓	✓✓	✓	✓	✓

Option	Further detail and/or example	Criterion				Viable?
	outcome can be achieved by addressing another attribute of the same protected matter					
Compound metrics combining different quantifiable attributes of a biodiversity value	Qld Ecological Equivalence Methodology uses an additive sum of 28 ecological equivalence indicators [for terrestrial habitats], with some minimum acceptable thresholds for specific attributes; Under the EPBC Policy, proponents consider site condition (e.g. vegetation condition, structure, diversity, number of relevant habitat features and threats), site context (e.g. connectivity, landscape position, adjacent land uses, condition and patch size, movement patterns of the protected matter, proximity of the site to other areas of suitable habitat, role of the site in relation to the overall population or extent of the protected matter, and neighbouring threats) and species stocking rate (e.g. density of the protected matter and the role of the site in regards to the overall viability or extent of the protected matter)	✓✓	✓	✓✓	✓	✓

Population viability analyses (PVAs) or landscape equivalency analysis (LEAs) require very detailed ecological data. They may be an option in some cases where these data are available, but have not previously been used this way for populations of species in the GBR. PVAs and LEAs might be able to be developed for use for well-studied species e.g. dugongs, or habitats e.g. coral reefs, but need to be based on independent or at least independently-verified data and models.

Recommendation: Base population viability analyses or landscape equivalency analyses on independent or independently-verified data and models.

If PVAs or LEAs are unavailable, then metrics are required as proxies of the biodiversity value's viability or persistence. Multiple simple metrics offer better ecological outcomes than compound metrics because they cannot be substituted for one another and do not need weightings, which are usually poorly substantiated. However, the offset exchange needs to satisfy each of the multiple simple metrics, which often generates fewer offset opportunities than using a compound metric. Both multiple simple metrics and compound metrics need to be developed on a case-specific basis and should be used alongside case-specific exchange rules. These are likely to ensure significantly better ecological outcomes, though they are likely also to raise transaction costs.

Recommendation: Develop multiple simple metrics and/or compound metrics to reflect each MNES and use alongside appropriate exchange rules.

Case studies

These worked examples illustrate practical considerations of the preceding technical discussions. The main recognised anthropogenic impacts on the GBR are associated with climate change, water quality (including agriculturally-derived pollution and coastal development activities associated with coastal urban, industrial and port development), direct impacts of coastal development (marine habitat loss associated with, for example, dredging and breakwaters) and fishing/harvesting (Brodie and Waterhouse 2012; GBRMPA 2014). Impacts which may currently trigger an offset requirement include the direct impacts of ports, harbours and boats/ships, and perhaps the indirect impacts of land management and water-borne discharges. The worked examples of direct impacts on seagrass meadows (dredging that directly removes seagrass meadows) and indirect impacts on seagrass (increased turbidity from suspended sediment leading to light reduction for seagrass growth) are considered to be the scenarios of most relevance to the Reef Trust. A pertinent discussion of the issues arising from offsetting impacts to seagrass in the GBR can be found in Bell et al. (2014) and many of the points from that paper are included (with citation) in these case studies.

Case studies – Metrics for type equivalence

Site condition or quality metrics can be contentious unless co-developed and agreed by stakeholders. The EPBC Policy allows proponents to develop these metrics with guidance from the Department. The previous Queensland offset policy included a series of relatively simple functional, structural, diversity and connectivity parameters to assess equivalence of terrestrial habitat quality. Analogous parameters could be devised for the GBR e.g. coral or seagrass regeneration, species richness and cover.

Seagrass meadows – impact types and offset actions

The impacts on seagrass considered here are (a) direct impacts on seagrass meadows (e.g. dredging that directly removes seagrass meadows) and (b) indirect impacts on seagrass (e.g. increased turbidity from suspended sediment during dredging leading to light reduction affecting seagrass growth).

Offset actions to address these impacts on seagrass fall into two principal categories (Bell et al. 2014):
Active measures at or near the seagrass site including, for example, direct replanting (Appendix 4) or employing measures which help seagrass to re-establish, e.g. benthic sediment stabilisation.
Managing diffuse impacts, for example, reducing turbidity by reducing loads of suspended sediment discharging from nearby rivers (Fabricius et al. 2014) via erosion control management techniques (Thorburn and Wilkinson 2013; Thorburn et al. 2013).

Seagrass meadows: metric

A metric to ensure the character and quality equivalence of impacted and offset seagrass meadows might include the following parameters used in monitoring programs (McKenzie et al. 2012). Note that some of the parameters overlap and may be correlated:

- *Species composition;*
- *Abundance - including assessment of percent cover determined in reference to the Seagrass Abundance Guidelines (McKenzie et al. 2007, 2010);*

- *Biomass or height measures;*
- *Area (of seagrass meadow);*
- *'Health' metrics such as macro-algal cover and epiphyte load;*
- *Seed production or reproductive effort – e.g. the average number of reproductive structures per unit area; and*
- *Nutrient status – based on the ratio of carbon to nitrogen in leaf tissue, reflecting nutrient levels in the surrounding waters.*

The choice of parameters should be based on what is most ecologically relevant to the impact and offset as well as practicality e.g. ability to monitor. For example, a metric might be [biomass x area], with precise definitions for each of these parameters, and with species composition, epiphyte load and number of reproductive structures addressed in exchange rules. The Reef Trust could work with local seagrass experts to provide prescriptive guidance for metrics and exchange rules for seagrass offsets.

Recommendation: Work with local seagrass experts to provide prescriptive guidance for seagrass metrics.

Suspended sediment: metric

For dredging and spoil dumping activities, the closely-related 'sediment' proxies of total suspended solids, turbidity and clarity are used to assess the degree of threat to biodiversity values. River discharge of suspended sediments also can lead to increases in these metrics in the coastal marine waters of the GBR (Fabricius et al. 2014).

The principal metric for suspended sediment load is total tonnes. However, more sophisticated additional metrics might include (but are unlikely to be practical at present):

- *Suspended sediment (tonnes) of a particular size range e.g. <15.7 μm. Fine sediment is more readily re-suspended (Fabricius et al. 2014) and has more ecological relevance to GBR ecosystems (Bainbridge et al. 2012, 2014; Brodie et al. 2014).*
- *Suspended sediment of a particular composition e.g. with respect to nutrient or organic content composition. Sediment with a higher proportion of organic content is more damaging to corals than sediment with less organic matter (Weber et al. 2006, 2012).*

Currently the P2R Source Catchments modelling produces results in terms of loads of a particular size class (loads of <20 μm sediment) whereas the P2R Monitoring program measures size classes i.e. groups their measured loads into <4 μm clay; 4 – 63 μm silt; and >63 μm sand). This allows the different impacts caused by different categories of sediment to be accounted for separately.

While using only fine sediments as the metric might be desirable from a sediment impact priority, there are no clear mechanisms currently in place to target catchment management works that would deliver specific amounts of fine sediment. However research is progressing to identify the best areas within the catchment to reduce fine sediments, and hence this may be possible in the future.

Recommendation: Prescribe that sediment metrics are tonnes of re-suspendable sediment generated, possibly divided into size classes to match the models and monitoring.

Spatial equivalence (and benefits to people)

Options for ensuring equivalence in space include:

a. Constraining offsets to the same ecosystem as the impacts;
b. Constraining offsets to the same administrative area (e.g. the eight GBRMPA planning zones) as the impacts; and
c. Using systematic conservation planning

Options for ensuring equivalence in benefits to people (e.g. people benefiting from local ecosystem services or local biodiversity existence values) are usually delivered by constraining offsets to the same ecosystem or administrative area as the impacts (i.e. options a. and b.).

The assessment of options for ensuring equivalence in space is shown in Table 3.

Table 3: Assessment of options for ensuring equivalence in space.

Option	Further detail and/or example	Criterion				Viable?
		Regulation	**Outcomes**	**Opportunities**	**Simplicity**	
Constraining offsets to the same ecosystem as the impacts	Under the Qld Offsets Policy, offsets should be delivered within a Strategic Offset Investment Corridor closest to the impacted site; or the same sub-region where there is no applicable Corridor; or the same bioregion or adjacent bioregion, where there is no opportunity in the same sub-region. In the GBRWHA offsets could be constrained to the same bioregion (i.e. one of 70).	✓	✓[1]	✓[1]	✓	✓
Constraining offsets to the same administrative area as the impacts	Under the Qld Offsets Policy, offsets should be delivered within the same local government area where there is no applicable Strategic Offset Investment Corridor. Offsets could be constrained within the same zone of the eight GBRMP zoning scheme	✓	✓[1]	✓[1]	✓	✓
Using systematic conservation planning	Gordon *et al.* (2011) demonstrate ecological benefits to being temporally and spatially strategic in choosing offsets locations west of Melbourne.	✓	✓✓[2]	✓	✓	✓

[1]Finer-scale mapping increases ecological equivalence and may improve governance but increases costs and reduces potential for more strategic conservation outcomes

[2]Increases regional conservation outcomes at the expenses of ecological equivalence and, potentially, governance

How the offset options for the GBR should be spatially constrained is a key practical issue. The issue of local spatial uniqueness of biodiversity is generally less substantial for the GBR than for most Australian terrestrial systems. Many impacts and potential interventions are also likely to be diffuse and acting over a large area (e.g. those related to water quality). In marine systems, establishing effective offsets near impact sites may be problematic and costly if those sites are in, for example, industrial zones where impacts are continuing and chronic (Bos *et al.* 2014). However, where local ecosystem services or other benefits are significantly damaged, it may be necessary to ensure that compensation focuses on an appropriate local scale.

Constraining offsets to the same GBRWHA bioregion (70 in GBRMPA 2014) as the impacts would improve equivalence in habitat type and biodiversity. Similarly, constraining offsets to the same administrative area (e.g. GBRMP zone) would improve societal and, to a lesser extent, ecological equivalence. However, these constraints would significantly reduce offset opportunities, and reduce opportunities for strategic offsets.

A form of systematic conservation planning could be applied in the GBR, if spatial priorities for investment could be identified and endorsed by stakeholders. Spatial constraints would need to be considered in the rules. This could be based on, for example, consolidation of fragmented habitats or securing migratory corridors. This has the advantage of ensuring that any investment is located strategically spatially for the benefit of the GBR as a whole. Bos *et al.* (2014) note that combined implementation of offsets in a few, larger areas of the GBR rather than across many small, fragmented sites is likely more effective both for costs and for outcomes. They further recommend integration of these sites into existing regional planning and zoning considerations (both terrestrial and marine).

Recommendation: Consider spatial prioritisation based on stakeholder-endorsed systematic conservation planning.

Offsets should be situated in equivalent habitat (to ensure character and quality equivalence), which might add additional spatial constraints. For seagrass meadows, this includes factors such as depth, light availability and latitude as well as recent recruitment events and seed composition. For coral reefs, this includes factors such as cross-shelf position (inner-shelf, mid-shelf and outer-shelf), wave exposure (e.g. windward reef crests, lagoonal, back reef), land attachment (fringing reefs), sediment environment, depth and latitude.

For catchment management offsets to reduce pollutant loadings, the catchment to be used for offsetting needs to contribute to the 'zone of influence' of the river discharge in the area where the impact from the development lies. River discharge 'zones of influence' have been assessed in current flood plume analysis studies (e.g. Devlin *et al.* 2012; Alvarez-Romero *et al.* 2013) and are readily available from those sources. In addition the recently developed eReefs hydrodynamic model for the GBR (Schiller *et al.* 2014) is able to model the extent of low salinity water dispersion from individual rivers.

Recommendation: Constrain catchment management offsets to catchments contributing to the river discharge 'zone of influence' where the impact is located.

Temporal equivalence

Options for ensuring equivalence in time include:

- Advanced offsets;
- Time discounting for risk of extinction (or local extirpation);
- Time discounting for risk of extinction (or local extirpation) and societal time preferences. The EPBC Policy focusses on MNES, including their extinction risk, and does not address societal time preferences;
- Time discounting for risk of extinction (or local extirpation) and ensuring a positive 'Net Present Biodiversity Value' through time; and
- Fixed multipliers used to address the issues of temporal loss/risk of extinction, and, if required, foregone benefit to people.

The assessment of options for ensuring equivalence in time is shown in Table 4.

Table 4: Assessment of options for ensuring equivalence in time.

Option	Further detail and/or example	Criterion				Viable?
		Regulation	**Outcomes**	**Opportunities**	**Simplicity**	
Advanced offsets	See introductory section and Bekessy *et al.* (2010). Replanting seagrass in an area of recent seagrass loss could form part of an advanced offset in cases where there is the expectation of the development causing some loss of seagrass. However all the issues associated with seagrass restoration in the GBR context (Appendix 2) would need analysis for the specific circumstances of the case.	✓✓	✓✓	✓	✓	✓
Time discounting based on extinction risk	Under the EPBC Policy, an annual time discounting factor is based on extinction risk (= the mean annual probability of extinction based on IUCN Red List criteria plus 0.1% annual probability of catastrophe = 0.2% for matters listed by EPBC as Vulnerable, 1.2% for Endangered and 6.8% for Critically Endangered)	✓	✓	✓	✓	✓
Time discounting based on extinction risk and societal time preferences, reflecting foregone benefits to people	As EPBC Policy plus: Under the UK biodiversity offsetting pilot scheme, a 3.5% discount rate is used to reflect societal time preference but not the impact of temporal loss on the biodiversity value (DEFRA 2012);	✓	✓	✓	✓	✓

Option	Further detail and/or example	Criterion				Viable?
	Denne and Bond-Smith (2012) recommended a 1% discount rate for New Zealand offsets to account for societal time preference but not temporal loss of the biodiversity value (except for the human benefits of ecosystem services).					
Time discounting (as above) plus ensuring a positive 'Net Present Biodiversity Value' through time	As EPBC Policy plus: Overton *et al.* (2013) use 'Net Present Biodiversity Value' and time discounting to provide an explicit mechanism for equity across time	✓	✓✓	✓	✓	✓
Fixed multipliers to address temporal loss / extinction risk	Many systems use multipliers to compensate for a variety of risks, including temporal loss	X	✓/ X	✓✓	✓	X

Advanced offsets offer the best ecological outcomes, and would be the preferred approach in most cases, but these need to provide ecologically-mature offsets, otherwise they also require time discounting. Time discounting for extinction risk and time preference is viable but leads to higher offset costs which are sensitive to the choice of discounting value. Time discounting does not remove the risk of offset failure or extinction before the offset becomes available, but it increases the offset requirement to incentivise timely achievement of offset outcomes and may help compensate society for temporal losses. Discounting for societal time preference is considered to be social best-practice. Prescriptive guidelines are needed to ensure an appropriate choice of discounting value. This is particularly important for the GBR where many components contributing to the GBRWHA as a listed MNES are not listed by the EPBC Act as threatened, and therefore lack a basis in the EPBC Policy for deriving a discount rate.

Recommendation: Improve time equivalence by mandating (ecologically mature) advanced offsets and/or time discounting for risk of extinction and/or ensuring positive NPBV through time.

Recommendation: Consider enhancing societal time equivalence by discounting for societal time preference.

Recommendation: Enhance time equivalence by requiring that offsets begin before construction starts.

Equivalence of amount

The size of the impact/s and of the offset both have to be measured using the same methods, calculated using the same metrics, and expressed in the same metrics. Methods need to be 'standard' methods for metrics already accepted in the GBR by practitioners (e.g. seagrass biomass estimation methods) or newly designed but accepted by the scientific community for this purpose. Unlike the preceding components of ecological equivalence, there are no alternative options to discuss.

Equivalence in amount (e.g. number or extent) is framed by the overall objective. Under the EPBC Policy, this objective is to 'improve or maintain the viability' of the affected biodiversity value. Extent of habitat or number of individuals is often used as a proxy for equivalence in viability. Metrics of viability usually include direct measures (e.g. population parameters) but also indirect measures (e.g. area x condition as a proxy for species viability).

Recommendation: Measure each impact and offset benefit using the same methods, calculated using the same approaches, and expressed in the same metrics.

Addressing uncertainty

As outlined previously, there are uncertainties or risks in implementing offsets around issues of measurement of gains and losses, transaction (delivery), performance (how target values respond, and how well gains persist) and permanence (the security of the offset). Different kinds of uncertainty may need to be addressed in different ways. Complementary options for addressing uncertainty include, in approximate descending order of ecological preference:

a. Advanced offsets (see introductory section and Bekessy *et al.* 2010) can minimise uncertainty in measurement of gains, transaction and performance;
b. Adaptive management to ensure that the final outcomes meet an agreed ecological target. This reduces transaction and performance uncertainties. The costs of this are uncertain and open-ended, so this approach has not generally been favoured by proponents. It would improve regulators ability to monitor outcomes, and could reduce administrative compliance costs for business and encourage innovation;
c. Insurance or bonds also reduce transaction and performance uncertainties, but are more cost-efficient to proponents since they may not be claimed on. However, unless set at an adequate level, this approach still leaves open risks of under-delivery and temporal loss (e.g. Miller 2005; Maron *et al.* 2012);
d. Bet-hedging to reduce performance uncertainty through implementing a portfolio of independent offset actions (Moilanen *et al.* 2009). This may be an effective approach in some cases but may also be inefficient, both through fragmenting efforts and through potential overcompensation;
e. An independent expert review to generate a precautionary (plausible upper bound) estimate or an uncertainty multiplier to minimise uncertainty in measurement of gains and losses, transaction and performance. Any multiplier would be applied to offset requirements and hence costs, as used for accuracy of gains by the EPBC Policy;
f. Fixed multipliers (or 'risk premiums') may be a practical solution to hedge against many types of uncertainty. They are simpler, but provide a 'one size fits all' approach that itself can be risky. Such multipliers are often large (Moilanen *et al.* 2009; Bekessy *et al.* 2010). For example, a 19x area multiplier was required for 95% confidence in no net loss in population size of the EPBC-listed Green and Golden Bell Frog in a real example in Sydney (Pickett *et al.* 2012).

The assessment of options for addressing uncertainty is shown in Table 5.

Table 5: Assessment of options for addressing uncertainty.

Option	Further detail and/or example	Criterion				Viable?
		Regulation	**Outcomes**	**Opportunities**	**Simplicity**	
Advanced offsets	See introductory section and Bekessy *et al.* (2010)	✓✓	✓✓	✓	✓✓	✓
Adaptive management to meet an agreed ecological target	Rio Tinto's Net Positive Impact target www.riotinto.com/npi	X	✓✓	✓	✓	X
Insurance or bonds	Bonds may be required for insurance of success of seagrass offsets in NSW (NSW EPA 2002); The US wetland offset system requires financial assurances to ensure a high level of confidence that the offsets will be successfully completed, and that long-term management obligations for the site can be met (DOD and EPA 2008)	X[3]	✓	✓✓	✓✓	✓
Bet-hedging, through a portfolio of independent offset actions		✓	✓	✓	✓	✓
Precautionary estimate or uncertainty multiplier	Under the EPBC Policy, proponents must estimate the level of certainty of the delivery and ecological success of the proposed offset. This is incorporated into the offset calculations as a multiplier.	✓✓	✓	✓	✓✓	✓
Fixed multipliers	Under the Qld Offsets Policy, multipliers are used for several purposes including risk; Under the UK biodiversity offsetting pilot scheme, fixed multipliers of 1x to 10x are applied to address delivery risk (DEFRA 2012);	X	✓ / X	✓	✓✓	X

Note that although most of these options are complementary, they are assessed in this Table as stand-alone options

Overall, advanced offsets provide the best approach to dealing with most (but not all) uncertainty and risks. Adaptive management to meet an agreed ecological target is not favoured by most proponents as it introduces an unknown cost liability. An alternative or complementary option of adequate insurance / bonds is simple and recommended where offset delivery risks are significant and cannot easily be mitigated.

Recommendation: Consider using insurance and bonds where offset delivery risks are significant and cannot easily be mitigated.

[3] Insurance or bonds are not mentioned in the EPBC policy

An alternative option of precautionary assessment is less attractive if the scenarios are poorly-known (as they often are) and if there is little consensus about how precautionary to be. Precautionary assessment should be informed by an understanding of the causes of uncertainty (e.g. Kujala *et al.* 2012). If there are inadequate data to undertake a precautionary assessment, then uncertainty should be estimated and used as a multiplier following the EPBC Policy. Precautionary assessments and uncertainty estimates should be undertaken by an independent expert review process.

Recommendation: Establish an independent expert review process to review precautionary estimates, or to estimate the accuracy of losses and gains, and to incorporate these into the offset calculations.

In general, strong legal structures and independent compliance monitoring should be used to mitigate the delivery risk and, where feasible, risks to the long-term persistence and security of the offset. Offset permanence is best addressed by ensuring that offsets remain in place in perpetuity, or at least as long as the impact (e.g. under the EPBC Policy, marine offsets should be implemented for the duration of the impact).

Recommendation: Use strong legal structures and independent compliance monitoring to mitigate the risk of non-delivery and, where feasible, long-term persistence and security risks.

Case studies – ecological equivalence

1. Equivalence in offsetting direct impacts on seagrass

More details on the issues and feasibility of re-establishing seagrass meadows can be found in Appendix 3 and Bell et al. (2014).

Character equivalence = like-for-like equivalence of seagrass meadows:

- *Restore all of the impacted species to achieve equivalence of character, or only those species most likely to establish at the offset site to improve probability of success and persistence*
- *Decide between options based on previous examples, expert opinion and, where possible, pilot studies*
- *Capture the equivalence within the exchange rules.*

Quality equivalence = applying multiple simple or compound (aggregated) metrics for different quantifiable attributes of seagrass meadows, with exchange rules

- *Determine a metric following the guidelines offered in the previous case study which suggested including a range of ecologically-relevant parameters such as [% cover x mean height x area], with precise definitions for each of these parameters, and with species composition, epiphyte load and number of reproductive structures, addressed in exchange rules.*

Temporal equivalence [i.e. accounting for time lags to offset maturation]

- *Best addressed by delivering an advanced offset which should take 1-2 years to mature*
- *Or use a time discounting factor to account for the temporal loss (e.g. would reduce dugong habitat and hence potentially their population viability until the offset is mature)*

Spatial equivalence

- *Replant in a stakeholder-agreed regional priority zone, if available; or*
- *Replant within a stakeholder- agreed local geographical area e.g. the same GBR bioregion and within feeding home ranges of local dugong populations (which is about 100 km)*

Equivalence of amount

- *Addressed in the basic metric of [% cover x mean height x area], but recognising the large differences in biomass between different species*

Addressing uncertainty

- *Address the measurement risk of losses, including the ephemeral nature of seagrass occurrence, by independent expert review*
- *Address the measurement risk of offset gains by a uncertainty multiplier as applied by the EPBC Policy*
- *The risk of long-term persistence is inherent in seagrass ecology, so not included in the metrics or exchange rules*

Additionality and baselines

- *Choose an offset area where naturally regeneration is unlikely, or use a baseline reflecting the probability of regeneration at the site over time*

Trading-up?

- *No trading-up options have been agreed by expert consensus. However, restoring within a 'green' protected area (where no risk of trawling) could be considered as trading-up, as long as additionality can be demonstrated.*

2. Equivalence in offsetting impacts of dredging and spoil disposal

This case study is based on increased fine suspended sediment, caused by dredging and/or dumping, impacting seagrass and other phototrophic benthic ecosystems through loss of light for photosynthesis. This impact is offset by a reduction of suspended sediment inflows from the adjacent river catchments through improved management practices in grazing lands, stream bank fencing and other actions to reduce erosion.

Equivalence analysis

Character and quality equivalence = like-for-like equivalence of biodiversity value or impact type

- *Use tonnes of suspended sediment as an ecologically appropriate proxy for impacts on photic depth*
- *Assume a tight relationship between tonnes of fine sediment and photic depth (see Fabricius et al. 2014)*
- *Measure impact and offset using the same methods in tonnes of fine sediment*
- *Consider options and issues for specific particle sizes e.g. <15.6µm.*

Temporal equivalence [i.e. accounting for time lags to offset maturation]

- *No advanced offsets are available and unlikely these can be provided in the next few years.*
- *Determine a discounting rate – the UK 3.5% annual rate seems reasonable over e.g. 10 years to maturity.*
- *Note that the impact from a dredging campaign is likely to be temporary with much reduced impact after two years, whereas the offset lasts much longer (but not permanent as that requires ongoing maintenance).*
- *Because of the time lags for offset actions in the catchments to deliver reduced sediment loading, temporal equivalence would not be achieved.*

Spatial equivalence

- *Locate the offset within the catchment of a river which discharges within 100 km of the impact (100 km is based on the maximum potential spread of suspended sediment from dredging including deposition-resuspension events).*

Equivalence in amount

- *Use the same methods to quantify the impact and offset in tonnes of fine sediment.*

Addressing uncertainty

- *Address the measurement risk of losses, including the ephemeral nature of seagrass occurrence, by independent expert review*
- *Address the measurement risk of offset gains by a uncertainty multiplier as applied by the EPBC Policy*
- *The risk of long-term persistence is an issue which will need auditing and agreement on the duration of persistence for which the proponent is responsible.*

Additionality and baselines

- *There are significant issues around additionality and baselines which will require explicit guidance from Reef Trust.*

2 Determining financial offset contributions

This section assesses the issues to be considered in developing a process to determine the costs for proponents to pay a financial contribution to the Reef Trust to deliver their offset requirements. It does not assess the mechanisms for payments to or from the Reef Trust. It also does not assess the transaction costs. A review of costed examples suggests that overall transaction costs incurred by the offset provider (including site selection, management planning, project management and monitoring) are likely to add around 30% to the costs of the work completed, and that separate provisions for regulating the system are likely to add up to 10% to the overall costs (GHK 2011).

2.1 Options and criteria

Financial offset contributions are usually determined using a three-step process:

1. quantification of the losses (or impacts), based on the environmental impact assessment;
2. determination of the gains required (to achieve no net loss or net gain), informed by the policies and guidelines discussed in the preceding section to ensure acceptable ecological equivalence;
3. determination of the costs needed to deliver the gains required.

Some possible options for determining financial costs include:

i. A scaled fee based on the project budget;
ii. A scaled fee based on the development footprint;
iii. Economic value per ha lost;
iv. Valuation study of loss for each project;
v. Cost of advanced offsets;
vi. Cost of anticipated offsets; and
vii. [Proponent-managed implementation of direct offsets outside the Reef Trust.].

Note that options i, ii, iii and iv omit the second step, and determine the financial offset contributions solely on the basis of losses or impacts, with no reference to required gains. Bos *et al.* (2014) reviewed a further option of 'spatial equivalence' which determines the size of the impacted area, and then a separate calculation is required to determine the cost.

Options i to vi are then assessed against the following criteria:

1. Alignment with existing **regulation** (EPBC Act; Queensland Offsets Policy) and international best-practice (BBOP);
2. **Accuracy** in estimating the full cost (of achieving maintenance or improvement in viability) without overcharging;
3. **Transparency** and governance to ensure stakeholder comfort and support;
4. **Flexibility** for strategic investment; and
5. **Simplicity** and minimising transaction costs (e.g. relating to data collection by proponents, developing models and metrics, proposal assessment by regulators, and monitoring).

2.2 Assessment of potential options and their applicability to specific biodiversity values

The six options listed above are discussed in more detail, with particular reference to the four criteria listed above. Table 6 provides a summary of the options for determining financial offset contributions.

i. Project budget

This is a scaled fee based on the project budget, as investigated by Bos *et al.* (2014). Development costs are not necessarily correlated with the scale of impact or the cost of offsetting the residual impacts. This option is not consistent with the EPBC Policy, notably the objective to 'improve or maintain the viability' of the impacted value.

- e.g. Under Brazilian law, an ecological Value Added Tax (ICMS-Ecológico) is charged to the budget of development projects for protected area and watershed conservation

Conclusion: Not suitable for use in the GBR.

ii. Development footprint

This is a scaled fee based on the development footprint, as discussed by Bos *et al.* (2014). The footprint size can be difficult to determine in marine projects, and is not necessarily correlated with the cost of the offsetting the residual impacts. This option is also not consistent with the EPBC Policy.

- e.g. the Qld government Financial Settlement Offset Calculation Methodology 1.0 offers financial payments under certain conditions, based on the formula:
  offset payment = land value + administration costs + management costs
  (For marine offsets, land value is $30-50,000/ha, with discounts for large areas and a 4x multiplier for certain values, plus a 25% administration cost and zero management costs).

Conclusion: Not suitable for use in the GBR.

iii. Economic value per ha lost

As investigated by Bos *et al.* (2014), 'Economic value per ha lost' is when costs are determined as a proportion of the total GBR value lost. This is highly sensitive to the choice of 'total GBR value', which will usually be only a partial estimate as many values are not taken into account. Two valuation methods were considered by Bos *et al.* (2014): Costanza *et al.* (1997), now updated as Costanza *et al.* (2014), and the Deloitte Access Economics series which omits a subset of the total economic value of the area e.g. existence values, bequest values, options values (DAE 2013). Both of these methods and their results remain controversial (e.g. Sagoff 2009; Salles 2011). This option would not account for spatial variation, possibly overestimate liability to one subset of values (tourism, fishing, recreation and scientific research), and omit liability for the numerous values excluded from the valuation methods. Again, the calculated costs are not directly related to the cost of the offsetting the residual impacts, and this option is not consistent with the EPBC Policy.

- e.g. the now superseded Qld Fish Habitat Offset Package Calculator (DAFF 2012) valued fisheries-specific ecosystem services at 11% of Costanza *et al* (1997)'s total ecosystem services value for estuaries. The 11% was a midpoint of (1) Costanza *et al* (1997) valuation of the fish habitat and fisheries-specific components at 7% of the global total ecosystem services value for estuaries, and (2) valuations by five recent Qld development project assessments of the fish habitat and fisheries specific components at 15% of Costanza *et al.* (1997)'s total estuaries value. The policy noted that this approach should be reviewed as models of fish habitat value per hectare and/or evidence of a non-linear relationship between fish habitat and fisheries productivity in Queensland become available.

Conclusion: Not suitable for use in the GBR.

iv. Valuation study of loss for each project

This option was assessed by Bos *et al.* (2014) as generating costs which are contentious because they are highly sensitive to valuation method and other research choices. In particular, valuation studies of specific species and ecosystems of the GBR give highly variable results depending on whether or not non-market values are included. This is also a time-consuming and expensive method. There are few real-world examples and this option is not consistent with the EPBC Policy.

Conclusion: Not suitable for use in the GBR.

v. Cost of advanced offsets

In advanced offsets, the ecological outcomes are fully demonstrated. If these outcomes match the offset requirements, it is straightforward and transparent to determine the cost of delivering these requirements. This cost is based on a loss-gain calculation and usually determined by the market demand and availability. In cases where the market is distorted or immature, regulators might need to guide or fix the price. Advanced offsets reduce the governance risk that in lieu fees are directed to inappropriate or inadequate actions (Wilkinson 2009; BenDor and Riggsbee 2011). For example, advanced offsets are sold at a market price in the Victorian BushBroker system, and planned for the NSW BioBanking system.

Conclusion: Suitable for future use in the GBR but because advanced offsets have not yet been produced in the GBRWHA or GBRC, this option is not immediately implementable.

vi. Cost of anticipated offsets

This is the method most commonly used by regulators. The offset delivery party is often called an offset or mitigation bank, but in this case will be the Reef Trust. This method is similar to the use of advanced offsets but the costs have to be estimated for each case based on a loss-gain calculation, the regulatory requirements and its experience in delivering offsets. Compared to advanced offsets, there is more ecological risk, but offsets can be delivered more strategically to meet evolving needs. US Wetland Banking proponents are required to provide additional offsets for temporal losses if it uses an in-lieu fee program which does not have the sufficient number and type of offset credits available, and there is a cap on the number of advance credits that can be sold (DOD and EPA 2008; Wilkinson 2009). In the absence of strong regulation and compliance monitoring, many delivery parties under-estimate costs as proponents usually buy the cheapest option on the market, and risk not delivering the required ecological outcomes (Wilkinson *et al.* 2006; Wilkinson 2009); e.g. most transactions under US Wetland Banking legislation (DOD and EPA 2008).

Conclusion: Suitable for current and future use in the GBR.

The assessment of options for determining financial offset contributions is shown in Table 6.

Table: 6. Summary table of options for determining financial offset contributions.

Option	Example	Regulation	Accuracy	Transparency	Flexibility	Simplicity	Viable ?
Project budget	Brazilian ecological Value Added Tax (ICMS-Ecológico)	X	X	✓✓	✓	✓✓	X
Development footprint	Qld Financial Settlement Offset Calculation Methodology	X	X	✓	✓	✓✓	X
Partial economic value per ha lost	Qld Fish Habitat Offset Package Calculator	X	X	✓	✓	-	X
Valuation study of loss for each project	-	X	X	✓	✓	-	X
Cost of advanced offsets	Victorian BushBroker	✓	✓✓	✓✓	✓	✓✓	✓
Cost of anticipated offsets	US Wetland Banking	✓	✓	✓✓	✓	✓	✓

Only the last two options, using the cost of advanced offsets and the cost of anticipated offsets, are consistent with the EPBC Policy, and are considered to be acceptable. They are also more transparent than the other options, but using the cost of advanced offsets is less flexible because these offsets need to be initiated potentially many years in advance. The fairest and simplest option for proponents, regulators and ecological outcomes is to use the cost of advanced offsets where suitable advanced offsets are available on the market from biobanks.

However, as discussed in the background section on advanced offsets, there are significant cost and process considerations in developing a functional biobanking system to deliver advanced offsets. As discussed on the background section on baselines and additionality, the determination of additionality is significantly more complex, especially for the GBR in which a variety of incentives has existed for some time to encourage practice change. This report identifies the technical advantages to using advanced offsets. The Reef Trust should consult with regulators who have established and operated functional biobanking schemes (e.g. NSW and Victoria State governments and, preferably, the more mature biobanking systems in the USA) to learn from their experiences. The Reef Trust should then consider whether it is practical and cost-effective to develop the necessary market infrastructure, including regulations and processes, and to otherwise facilitate the establishment of a biobank.

Recommendation: Consider developing the market infrastructure, including regulations and processes, and facilitating the establishment of a biobank of advanced offsets.

Where advanced offsets are unavailable, the only other appropriate option is to use the cost of anticipated offsets. In keeping with best-practice and sound governance, costs should be modelled by an independent body or by the Reef Trust with an independent review, based on pre-existing cost data. Cost data should account for key differences in the type of investment represented by an offset exchange and other previous and ongoing investments in practice change in GBR catchments. In particular, actions should be fully costed, without the expectation that offset providers will contribute in-kind. However, most sediment-load reduction offsets should use the already tried and tested (and costed) methods of erosion control already being implemented under programs such as Reef Rescue in the GBR Catchment. The Reef Trust should consider whether to develop cost models for the most common offset scenarios to ensure standardisation and improve governance, and to serve as examples for other scenarios. All cost models need to explicitly include applicable indirect costs such as preparing models and estimates, auditing delivery, monitoring, evaluation and reporting. It is also appropriate to charge for the relevant administration costs of Reef Trust and any offset delivery agency. The regulator might also wish to include cost elements for education or outreach and research, which also need to be added to the final offset cost.

Recommendation: Consider developing cost models for the most common offset scenarios.

Recommendation: Where possible, ensure that advanced offsets are purchased, at the market price.

Recommendation: Where advanced offsets are unavailable, ensure that costs are modelled by an independent body or by Reef Trust with an independent review, based on pre-existing cost data.

Recommendation: Ensure that offset costs include monitoring, reporting and other indirect costs; viz, = costs of direct action x any uncertainty multipliers + costs of preparing models and estimates + costs of auditing delivery + costs of monitoring and evaluation + admin costs of Reef Trust and delivery body [+ any education / outreach + any research]

Recommendation: Ensure that providers of offset benefits through the Reef Trust seek the full cost of provision.

Recommendation: Ensure that such 'fully funded' actions do not crowd out applications for other works under the Reef Trust and other existing or planned incentive schemes where an in-kind contribution from the landholder may be expected.

2.3 Comparison with proponent-driven direct offsets

As noted previously, proponent-driven direct offsets are an allowed form of offset delivery; but would not be delivered via the Reef Trust process. If costs are similar, proponents are likely to favour delivery through the Reef Trust over proponent-driven offsets because offset requirements can be resolved quickly and with certainty through a single payment which sheds their liability for the offset. Delivery through the Reef Trust would potentially allow more strategic conservation outcomes, through consolidating a number of offsets into a large contiguous site with higher conservation values; and offer efficiencies via economies of scale and reduced transaction costs.

Case studies for determining financial costs

Determining the financial costs for impacts on marine assets is challenging. It is not possible to create a simple calculator for all types of impacts and offsets. Unlike terrestrial calculators, marine impacts cannot be simplified to an area impacted, and marine offsets cannot easily be simplified to dollar restoration cost per unit area offset. However, it would be possible to create a simple calculator, with independent expert input and review, for specific impacts and offsets likely to be commonly encountered (e.g. ha of seagrass meadows destroyed and replanted; or tonnes of sediment suspended and discharge from catchments averted). It would also be desirable where possible to estimate a range of sample costings offered to give stakeholders an idea of the likely offsetting costs using such a calculator.

As an underlying principle to ensure accuracy in determining costs, the modelling should be done by an independent body or by Reef Trust with an independent review. Furthermore, offset costs must include monitoring (see next section), modelling, reporting and other indirect costs; viz offset costs = (costs of direct action x any uncertainty multipliers) + costs of preparing models and estimates + costs of auditing delivery + costs of monitoring and evaluation + admin costs [+ any education / outreach + any research].

In the case of advanced offsets, the costs are pre-determined because the offsets have been delivered. However, there are no advanced offsets currently available in the GBRWHA, so the costs of retrospective offsets will need to be estimated. Two examples are provided below to identify some of the key considerations in this kind of assessment.

1. Determining financial payments for direct impacts on seagrass

Local-scale seagrass restoration in the GBR could potentially be successful in areas where seagrass has existed in the past, but a transient impact has resulted in loss. The most cost-effective method is using seed, and in most cases success is determined by site-specific factors such as temperature, depth, water quality, currents and mobility of substrate (see Appendix 2). Maintenance of genetic diversity is also critical for surviving disturbances, such as intense grazing events, temperature stress, and algal blooms (Hughes and Stachowicz 2004, 2011; Reusch et al. 2005; Reynolds et al. 2012).

Restoration in the GBR will take research to develop methods that deliver real on-the-ground success. Previous costs for restoration have started at around $34,000/ha in Australia with volunteer assistance but *more typically $500,000 to $1,000,000 in overseas projects without volunteers (e.g. Busch et al. 2010; Irving et al. 2010). Therefore, an offset provider would need to start with a 2-3 year investigation into methods, feasibility and success. It is estimated that establishment and investigation of a 2-hectare rehabilitation trial is likely to cost in the order of $900,000 to be effective ($450,000/ha for the rehabilitation trials including genetics, monitoring transplant success, seed harvesting and seed germination trials) (C. Collier, pers. comm.). It is likely that over time the cost as well as success rate could be improved, particularly as the methodology becomes routine enough for volunteers (including traditional owners) to assist.*

2. Determining financial payments for impacts of dredging and spoil disposal

When extrapolating recent historical costs to future costs, large changes in costs are unlikely for current management practices. However, where other programs (notably Reef Rescue and other offsets) have already targeted the cheapest / most efficient options, more expensive management practices are needed to achieve diminishing returns (e.g. gully repair), and costs per tonne of sediment will increase.

The existing Reef Rescue databases managed by the regional NRM regions and the Paddock to Reef Program could be used to model costs of management practice changes, supported by a benefit/cost analysis (e.g. INFFER). Analysis from the existing and ongoing Water Quality Improvement Plans can provide the foundation to these assessments, but note that the farmer contribution to project costs (c. 50 – 70% of the total) must be added to arrive at the 'real' cost of sediment mitigation on-ground works. Therefore offset costs = 100% of the modelled costs disregarding any financial contribution offered by landowners. It could be anticipated that landowners would contribute as they will derive benefits; however this money needs to be spent on additional outcomes instead of reduced offset costs.

However, great difficulties remain in the prediction of the cost effectiveness of catchment erosion control methods from a water quality improvement perspective. The estimates of reducing loading of suspended sediment by one tonne across the different NRM regions range from $40 to $3,000 for similar practice change or on-ground works in rangeland grazing areas (data from the Department of the Environment collected from Reef Rescue auditing). Star et al. (2012) estimated the potential costs of abatement of sediment across multiple land types, tree coverage, starting conditions, and pasture utilisation rates across the GBR catchments, and found that:

- *For land with a "C" starting condition, costs ranged from less than $1/tonne to about $140/tonne. Many estimates were around $20-40/tonne.*
- *For land already in "B" condition, costs tended to be higher as the trade-offs between production and conservation outcomes are greater, and ranged from about $1/tonne to $811/tonne. Crude analysis suggests that the average was $20-40/tonne; however detailed considerations would be required for specific locations.*

Considerably more research and analysis of these costs will be needed before reliable predictions of costs can be made.

Monitoring and evaluation arrangements could be made through agreements between Reef Trust and *existing programs, for example the current Paddock to Reef Program, given their expertise in catchment monitoring and modelling (modelling may be required, although proxies such as ground cover could be monitored directly).*

The issue of timing is significant due to potentially long time lags in fully realising sediment reduction goals up the catchment. Offsets such as pasture management which are unlikely to deliver full gains for decades (see Appendix 3) may need time discounting, whereas if the offset has to be delivered concurrently with impact (which may be possible e.g. active vs passive gully remediation), costs may be very much higher (e.g. the costs of reducing one tonne of sediment loss via gully remediation are considerably higher than through pasture management methods).

3 Monitoring, auditing and reporting of offsets

There have been no major assessments of offset compliance or effectiveness in Australia. Assessments of non-Australian offset programmes have found high rates of non-compliance, often greater than 50%, perhaps incentivised by inadequate regulation for project monitoring and inadequate resourcing for compliance monitoring (Harper and Quigley 2005; Quigley and Harper 2006; Burgin 2008; Matthews and Endress 2008; Brownlie and Botha 2009; Norton 2009; Walker *et al.* 2009; Wilkinson 2009; Burgin 2010). Some significant GBR and Reef Trust stakeholders are likely to be critical of biodiversity offsets and expect rigorous and transparent monitoring and reporting.

Monitoring and auditing need to cover a wide spread of issues related to offset effectiveness, including review of the plans for offset works, surveys to ensure correct delivery of inputs (management practices) and observing that these activities are effective (e.g. fences are functional), and eventually that this effectiveness flows to benefit the impacted MNES. Evaluation, reporting and review need to be incorporated into the auditing and monitoring. There are limited conceptual options available for monitoring and auditing; these follow the basic model of measuring compliance or progress towards a pre-agreed set of outcomes. Best-practice will encompass several elements, including:

- Defining the objectives of the auditing program, including:
    - whether the offset met the approval conditions;
    - trends in key aspects of biodiversity (e.g. viability of an MNES);
    - early warning of problems that might later be difficult or expensive to reverse; and
    - informing adaptive management (Lindenmayer *et al.* 2012).
- Analytic models and tools; statistical certainty; sample size; periodicity;
- Explicit investigation of the power of proxy measures;
- Independent and transparent governance (noting that the current default option is for the Australian and Queensland governments to be responsible for M&E of Reef Trust); and
- Minimisation of cost as feasible while maintaining adequate quality and sample sizes to meet the objectives, and ensure operator health and safety.

Monitoring offsets should also include the parameters used in any equivalency metrics. For example, if impacts on seagrass meadows are being offset by reducing suspended river sediments, then suspended sediment (or turbidity or clarity) at the seagrass site needs to be measured. However, if the impacts are offset by replanting seagrass, then measures such as % cover, mean height, area, species composition, epiphyte load and number of reproductive structures need to be measured.

The duration of monitoring is determined by its objectives.

Given that the primary objective is to demonstrate whether the offset was effective and meets the approval conditions, which is a regulatory question, the Reef Trust should consider developing explicit guidelines on monitoring requirements. These could guide the offset provider on what degree of certainty is required in demonstrating compliance, and the duration of monitoring needed. For the common scenarios of offset type, the guidelines could offer prescriptive methods which use standard methods (see below for an example from the P2R Program) and give standard quantitative measures of, for example, load reductions with uncertainty estimates. Uncertainty in estimates of the cost per tonne of reducing sediment loads in grazing lands are large, with current estimates of $40 to $3000 per tonne (data from the Department of the Environment drawn from analysis of individual NRM regional estimates). This will be a major impediment in estimated the costs of sediment reductions in the offsets program. Considerably more research is needed to be able to explain the difference in the estimates for similar management practice change in different regions.

Recommendation: Develop explicit guidelines on monitoring requirements.

To ensure good governance, the monitoring should be undertaken by a team independent of the offset provider. Bos *et al.* (2014) recommend that "monitoring of the efficacy of offsets is separate to but coordinated with regional monitoring programs for ecosystem health, and monitoring data are made publicly available".

Currently auditing, monitoring and eventual evaluation of the effectiveness of Reef Plan (Reef Rescue) on-ground works are carried out by the particular NRM bodies (e.g. Terrain NRM) through which the grant was managed (auditing), while 'monitoring' is carried out using the Source Catchments modelling process by the Paddock to Reef Integrated Monitoring and Modelling Program (P2R Program) (see Carroll *et al.* 2012). The modelling uses aggregated management practice change data resulting from the on-ground works program to estimate pollutant reductions due to the works (Waters *et al.* 2014). The overall progress evaluation of Reef Plan, both annually and cumulatively, has been reported annually in the Report Cards (e.g. Queensland Government 2014). Note that the improved water quality due to on-ground works and improved management practices are assumed to take effect immediately with no time-lags.

Improved practices and on-ground works funded under an offsets program could be evaluated for effectiveness and load reduction using identical methodology with the caveat again that time-lags are ignored when using this methodology.

Seagrass monitoring is also carried out under the Marine Monitoring Program component of the P2R Program (in association with the SeagrassWatch Program) at selected sites throughout the GBRWHA (and elsewhere in Queensland) (e.g. Coles *et al.* 2014). The overall results are also reported in the Report Cards. The methodology used is also quite suitable, in general, to assess the success of replanting schemes for seagrass such as under an offsets program but would need tailoring for individual sites and circumstances.

Case studies

1. Direct restoration of seagrass

The challenges in re-establishing seagrass meadows in a GBR context are detailed in Appendix 2.

The first step of the auditing process will be to review the planning (including, for example, species mix and the site characteristics), methodology (for example, provision and source of seeds if seeding is the chosen method) and timing (summer/winter, wet season/dry season and likely wind conditions). Auditing in this case will involve a relatively simple checking process that the planting/seeding process has occurred.

The primary objective of monitoring could be to demonstrate whether the offset had met its objectives, e.g. to improve or maintain the viability of the impacted MNES. This could be demonstrated by the loss-gain metric. The parameters likely to be used in loss-gain metric can be measured using well-established standard methods used in the P2R and Seagrass Watch programs in Queensland (McKenzie et al. 2007, 2010). In a typical monitoring program (McKenzie et al. 2012), sites are monitored for seagrass cover, species composition, canopy height, macro-algae cover, epiphyte cover, number of reproductive structures (spathes, fruits, flowers) and leaf tissue nutrients. A similar set of techniques are entirely suitable to assess the success of replanting seagrass but would need specific tailoring for the individual site circumstances.

A secondary objective of monitoring could be to give an early warning of problems such as non-establishment of the seagrass. To address this objective, the offset might be monitored much earlier and more frequently for simple parameters of seagrass establishment.

Another secondary objective of monitoring could be to inform adaptive management of the offset. To address this objective, the offset might be designed with an experimental component, and the different experimental regimes monitored for simple parameters of offset success.

The sample size and periodicity of monitoring are dependent on the chosen analytic models and tools, and the desired statistical certainty. In this case, as the analysis is a very simple demonstration of seagrass cover, height and area, it is suggested that the methods follow, or are derived from, the P2R and Seagrass Watch programs in Queensland (McKenzie et al. 2007, 2010). The duration of monitoring needed to establish that the seagrass has successfully established and therefore the offset was a success should be of the order of three years. After that period loss of the meadow is likely to be due to external factors not associated with the original development or the replanting process.

2. Reducing sediment load in catchments

Auditing will start with reviewing the planning in terms of location of on-ground works, the type of works envisaged (e.g. gully remediation, stream bank revegetation, pasture management, land retirement) and the arrangements with landholders as to the timing and input deliverables of the works. For monitoring, modelling will be a critical element given time-lags to effectiveness (Appendix 3). Monitoring is complicated in grazing lands by long time-lags to improvements (Appendix 3) hence monitoring may need to occur over periods >5 years. This is particularly the case for pasture management to reduce hillslope erosion, and *riparian fencing and riparian restoration to reduce stream bank erosion. On the other hand, mechanical gully restoration can have quick effects in less than two years and hence is more tractable to monitor.*

All offset sites can be modelled for efficacy using existing models (GRASP, APSIM, HowLeaky?, Source Catchments). In addition, a subset of offset sites should be actively monitored to provide adequate validation for modelling as occurs in the current Reef Plan Paddock to Reef Integrated Monitoring and Modelling Program (P2R) (Carroll et al. 2012). The costs of monitoring and modelling either at paddock-scale or (sub)catchment-scale are well-established from the current P2R program. Individual sites to be monitored will be very case specific. Designing a monitoring program is complex and there are no 'off the shelf' design tools available. However in the particular case there are many examples of current and past monitoring of 'demonstration/experimental' sites from which such design elements can be drawn.

Currently the Paddock to Reef IMP is run by government agencies and research organisations such as Queensland Government agencies, CSIRO, AIMS and universities. In this way, the costs are subsidised. One of the forms of 'subsidy' is that the intellectual property in the results of the P2R program is shared between the governments and the research and monitoring providers and thus the results are publishable by the research and monitoring providers. This could also be the case for the offsets monitoring but would have to be a special arrangement through contracts as, in general, most compliance monitoring programs do not provide for shared IP. Otherwise, offsets monitoring might be charged at a higher (unsubsidised) rate by for-profit consultancies or consulting contracts by non-profit institutions.

An important consideration is demonstration of additionality – i.e. the task of separating the effects of the offsets actions from the effects of the Reef Rescue (government and land-holder) actions. This can only be done by using small-scale monitoring and modelling, i.e. not by end-of-catchment monitoring.

3.1 Potential options for the Reef Trust

The best option to evaluate the effectiveness of projects carried out under an offsets program will be to use the tried and tested methods currently used in the P2R Program. For sediment load reductions due to on-ground works (e.g. riparian vegetation restoration), improved pasture management practices or reduced tillage in cropping systems standard algorithms used in the P2R Program will be entirely appropriate for use to evaluate the effectiveness of similar projects funded out of an offsets program. One issue is that the algorithms are being improved over time, based on new research results from practice trials. An issue of 'shifting baselines' may result when using newer algorithms on a project set up using predicted results from an older algorithm. In general the algorithm on which the effectiveness was estimated at the commencement of the project should be used throughout the project. Another issue related to this is, as mentioned earlier, the highly variable costs of reducing sediment loading estimated from the different NRM regions. It may be that a fixed 'cost effectiveness' estimate is used throughout a single offsets funded project to once again avoid the 'shifting baseline' phenomenon.

4 Synthesis of findings and recommendations

The Reef Trust needs to address some significant technical and political challenges to deliver a functional offsets system. The technical issues related to ecological equivalence, determining financial contributions and audit/monitoring are discussed in this report with a number of technical recommendations. These recommendations could be summarised as a single recommendation – to develop prescriptive guidance to improve certainty for proponents, other stakeholders and ecological outcomes.

Guidance on ecological equivalence needs to balance the tension between tighter definitions of equivalence, which enable offsets to compensate more precisely for the impacts, and looser definitions which increase the offset options, with consequent savings in financial cost and administrative complexity. This guidance would be consistent with the EPBC Policy but in places more prescriptive. This type of guidance has been developed for a number of terrestrial offset systems such as those used by the States of NSW and Victoria, and embedded into the methods manuals and calculators for these systems. However, these methods manuals and calculators are relatively complex and regularly updated, indicating that even for these better-known terrestrial systems and better-developed offsets systems, it is challenging to develop functional systems. To balance ecological rigour against the practicalities of workable systems, the Reef Trust might need to develop this prescriptive guidance as an iterative process.

The most significant technical recommendation related to determining financial contributions is for the Reef Trust to consult more widely regarding the challenges inherent in establishing a biobank. This is a key decision which needs to be informed by the lessons from at least the State governments of NSW and Victoria and, preferably, from the more mature biobanking systems in the USA. The second most significant recommendation is for the Reef Trust to consider developing cost models for the most common offset scenarios. Provision of these models could mitigate some of the political risk around determining offset costs.

Prescriptive guidance can be developed to address ecological equivalence, determining financial contributions and monitoring, but it also needs to address the political context and reputational risk. To be politically acceptable, any guidance is expected to be stable and predictable, to require relatively low transaction costs and timings, and to deliver cost-efficient offset solutions. The Reef Trust must consider resourcing this guidance from governmental funds rather than imposing additional developmental costs onto the first offset transactions. It must also consider developing this guidance promptly, before proponents investigate new projects which might have residual impacts on the GBR.

The Reef Trust is a new entity that is yet to develop its reputational credentials. Biodiversity offsets are a relatively new and evolving tool which are held in poor regard by many stakeholders across the spectrum from proponents to environmentalists. There is a concern among some stakeholders that the Reef Trust risks compromising its actual and perceived independence by being too closely directed by government. Furthermore, it risks a conflict of interest if it has the roles of both regulator and offsets provider. It is recommended that the Reef Trust's decisions and process to develop an offsets system are undertaken with close awareness of these risks. A number of the technical recommendations highlight the need for stakeholder-endorsed or independently-reviewed processes, and these principles should apply to all of the Reef Trust's actions.

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Appendix 1: Details of offset principles and policies

The EPBC Policy states that suitable offsets must:

- deliver an overall conservation outcome that improves or maintains the viability of the aspect of the environment that is protected by national environment law and affected by the proposed action
- be built around direct offsets but may include other compensatory measures
- be in proportion to the level of statutory protection that applies to the protected matter
- be of a size and scale proportionate to the residual impacts on the protected matter
- effectively account for and manage the risks of the offset not succeeding
- be additional to what is already required, determined by law or planning regulations or agreed to under other schemes or programs (this does not preclude the recognition of state or territory offsets that may be suitable as offsets under the EPBC Act for the same action, see section 7.6)
- be efficient, effective, timely, transparent, scientifically robust and reasonable
- have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced.

In assessing the suitability of an offset, government decision-making will be:

- informed by scientifically robust information and incorporate the precautionary principle in the absence of scientific certainty
- conducted in a consistent and transparent manner.

The Queensland Government Environmental Offsets Policy principles are:

- Offsets will not replace or undermine existing environmental standards or regulatory requirements, or be used to allow development in areas otherwise prohibited through legislation or policy.
- Environmental impacts must first be avoided, then minimised, before considering the use of offsets for any remaining impact.
- Offsets must achieve a conservation outcome that achieves an equivalent environmental outcome.
- Offsets must provide environmental values as similar as possible to those being lost.
- Offset provision must minimise the time-lag between the impact and delivery of the offset.
- Offsets must provide additional protection to environmental values at risk, or additional management actions to improve environmental values.
- Where legal security is required, offsets must be legally secured for the duration of the impact on the prescribed environmental matter.

However, this policy does not apply to a handful of stated conditions including development that is a significant project declared under section 26(1)(a) of the State Development and Public Works Organisation Act 1971.

This policy also does not apply to State significant biodiversity values which are offset by another Queensland Government offset policy such as Mitigation and Compensation for Works or Activities Causing

Marine Fish Habitat Loss: Departmental Procedures, Fish Habitat Management Operational Policy, Queensland Department of Primary Industries (Fisheries Act 1994).

Bos *et al.* (2014) offered nine principles for effective GBR offsets:

- Mitigation hierarchy: offsets should be considered only after impacts are avoided and mitigated.
- Offsetability: the offsetability risk profile should be considered before offset design.
- Net benefits: offsets should aim to achieve net benefits to all affected values measured against the counterfactual baseline.
- Third-party implementation: offsets should be designed and implemented by specialist third-party entities.
- Direct and specific action: offsets should be direct and specific to the impacted values.
- Strategic sites: offsets should be consolidated into regionally strategic implementation sites with long-term legal protection.
- Temporal strategy: offset strategies should minimize the time to achieve net benefits and maintain net benefits in perpetuity.
- Financial liability: financial liability for offsets should be determined by the costs to achieve and maintain net benefits in perpetuity.
- Monitoring and adaptation: offsets should be subject to monitoring and adaptive implementation over appropriate durations.

Appendix 2: Issues in restoring coral, seagrass and mangrove habitats

Key messages

- Restoration options for coral reef, seagrass and mangrove ecosystems in the GBR are not well established and are likely to be expensive.
- Although restoration can enhance conservation efforts, restoration is always a poor second to the preservation of original habitats.
- Consider restoration not as a one-off event but as an ongoing process over a time-scale of years which is likely to need adaptive management.
- There are many factors that affect the success of restoration projects resulting in a high risk of failure; a majority of ecosystems cannot be restored or replaced to full capacity.

Coral restoration

Would it work in the GBR?

Coral reef restoration is in its infancy; there have been limited attempts to undertake coral reef restoration in Australia, with only a few case studies or trials in the GBR (e.g. Harriott and Fisk, 1988). There are many studies around the world that have attempted to carry out coral reef restoration projects including several examples in Hawaii, Maldives, Fiji, Philippines and French Polynesia. However, active coral reef restoration has been carried out with some success at scales of up to a few hectares only. Detailed guidelines (e.g. Edwards and Gomez, 2007), handbooks (e.g. Precht, 2006) and manuals (e.g. Job et al., 2003) are now available to guide coral reef restoration projects. The options described below do not take into account current permitting issues within the GBR Marine Park which are also likely to have significant influence on the viability of various options. Physical restoration techniques include triage and repair of damaged reefs, and artificial reef creation (Edwards and Gomez, 2007). Rapid structural 'repair' of a reef after a disturbance can be very cost-effective and can be carried out by competent divers. This is most relevant to structural damage and may involve cementing or epoxying large cracks in the reef framework, righting and reattaching coral, sponges and other reef organisms or storing organisms in a safe environment until they can be reattached. Large limestone boulders can provide an effective and relatively low-cost way of restoring stability and topographic complexity to rubble fields in less exposed environments. The use of artificial reefs in restoration needs to be considered carefully and critically in terms of need, ecological impact, cost-effectiveness and aesthetics but can be successful if well-designed.

How much would it cost?

The suitability of these options depends on the cause of the coral loss, and the environmental, social and economic characteristics of the location. Major physical restoration of reefs costs in the order of US$100,000 -1,000,000s per hectare (Edwards and Gomez, 2007). Low-cost transplantation appears to cost about US$2000 -13,000 per hectare. With more ambitious goals this rises to about $40,000 per hectare. For comparison, a global approximate estimate of the average total annual value of coral reef goods and services is US$6,075 per hectare (Edwards and Gomez, 2007). Some physical restoration may be a prerequisite for any chance of successful biological restoration.

Transplantation of hard corals as a means of accelerating the regeneration of damaged coral reefs, or as a way of establishing reef areas where none exist naturally, has been tested in many parts of the world (Harriot and Fisk, 1995). The transplantation is generally successful from a biological point of view, with survival rates in most cases ranging between 50% and 100%, when corals are transplanted into similar habitats to those from which they were collected. However, coral transplantation is a very expensive process and generally would be considered as a valid option only in areas of high commercial, recreational or aesthetic value.

The cheapest route is to collect corals directly from the reef and transplant to the degraded area. However, to obtain good survival, individual transplants need to be quite large (>5-10 cm). Smaller fragments (2-3 cm) can be successfully cultured in the sea in mid-water or benthic nurseries until large enough to survive. This can be expensive but makes better use of coral material. Very small fragments can also be cultured but costs continue to increase with these more intensive processes. Planktonic coral larvae can also be cultured, settled onto pieces of substrate, and grown up in mid-water cages, for 6-12 months until large enough to have a reasonable chance of surviving on the reef.

Is it suitable for GBR offsets?

At present there is limited capacity and knowledge for such restoration interventions in the GBR, and little knowledge of the potential risks (GBRMPA, 2014). Investment in significant research and development would be required to develop the expertise for such interventions in a timely and environmentally responsible manner.

Seagrass restoration

Would it work in the GBR?

Seagrass restoration projects have not been undertaken in the GBR. However, seagrass restoration in other parts of the world, such as the US and southern Australia, have shown that it can be successful (e.g. Reynolds et al., 2012; reviewed in Statton et al., 2012; Irving et al., 2010). Various trials have indicated that the success of restoration activities can be limited in areas where seagrass did not exist previously, or the long-term cause of impacts had not been alleviated (e.g. chronic poor water quality). It has been demonstrated that where restoration attempts are made in areas of marginal water quality, stresses and disturbances are likely to reduce plant growth and survival (Reynolds et al., 2012). In such cases, initial protection of seagrass is far more cost effective. For the GBR, seagrass restoration could potentially be successful in areas where seagrass has existed in the past but a short-term impact has resulted in loss. For example, areas affected by cyclones have had seeds and mature plants physically removed resulting in slow recovery rates.

Restoration by direct planting was traditionally the more common technique with a moderate success rate, however, it is expensive largely due to the labour intensive nature of plant collection and transplantation (see

Busch et al. 2010 for examples). Attempts have been made to automate some of these methods by utilising mechanised planting and underwater harvesting machines to accommodate large-scale projects. Direct planting is still used where it is the only option, however, the success of anchoring the new plants is highly dependent on the hydrodynamics of the area and substrate stability can be a major issue.

The more cost-effective way of restoration is by seed, and for Zostera marina in the United States which seeds abundantly, there has been some success in harvesting and transplanting (eg. Ort et al., 2014 San Francisco Bay; Reynolds et al., 2012 Virginia Coastal Bays; Busch et al., 2011 Chesapeake Bay). Techniques for sourcing seeds have also been investigated, highlighting important factors for success such as maintenance of genetic diversity which is critical for surviving disturbances, such as intense grazing events, temperature stress, and algal blooms (Hughes and Stachowicz 2004, 2011, Reusch et al. 2005; Reynolds et al., 2012). Trials of seedling culture and outplanting, and recruitment facilitation in South Australia were moderately successful in the shorter term but were limited by several factors including mobility of substrate (Irving et al., 2010).

It is possible that seeding techniques may be successful for Zostera muelleri in the GBR, but it has not been trialed, and is most relevant in the southern GBR (including Gladstone) where it occurs abundantly. For more northern species (Halodule, Cymodocea, Thalassia and Enhalus spp), the seeding technique raises a lot of complications, including how to obtain and harvest seed as these species don't seed prolifically and the seeds are more cryptic. There may be a way to promote seed production using aquaculture, or direct transplantation might be an option for these northern GBR species if costs can be managed.

How much would it cost?

Previous costs for restoration have started at around $34,000/ha in Australia with volunteer assistance but more typically reaches $500,000 to $1,000,000 in overseas projects and without volunteers (e.g. Busch et al., 2010; Irving et al., 2010).

Is it suitable for GBR offsets?

The successful seagrass restoration programs have taken some time to set up and get running due to the large research and development component. Restoration in the GBR will also take some time to develop into a program that delivers real on-the-ground success; it is not a suitable, reliable option for GBR offsets at this time. The region is, however, in the position to benefit from the trials and lessons of these other programs established previously.

Relevant examples of seagrass restoration

1. As described in the paper: Ort, B. S., Cohen, C. S., Boyer, K. E., Reynolds, L. K., Tam, S. M., & Wyllie-Echeverria, S. (2014). Conservation of Eelgrass (Zostera marina) Genetic Diversity in a Mesocosm-Based Restoration Experiment. PloS One, 9(2), e89316.

The technique, called Buoy-Deployed Seeding (BuDS), uses pearl nets filled with seed-containing spathes which are like peas in pods. The spathe-filled pearl nets are attached to a buoy anchored to the substrate so that the net sways with the tides. The seeds in the spathes develop naturally and drop to the floor as they ripen. This is closer to what happens in nature compared to other artificial seeding methods that broadcast mature seeds at once.

The study found that BuDS is especially effective for preserving genetic diversity. The method was tested in tanks filled with water from San Francisco Bay and with seed-filled nets floating in each. The seeds fell from the nets and started to grow as they matured, and the researchers compared the genetic diversity of these seedlings to that of the natural environment where the seeds were collected. They found the resulting crop of eelgrass was just as genetically diverse as the beds where they came from.

Genetically diverse ecosystems, in relation to homogeneous ones, are better able to survive through stressful situations since a wide variety of genes allow for more flexible adaptive responses. Likewise, genetically diverse patches of seagrass tend to be better at withstanding heat and grazing by geese, increasing the likelihood that restoration will succeed.

Several years ago, BuDS was used for a project to restore a meadow that had suddenly died a few years earlier. Currently, this method is used as part of the Living Shorelines Project in the San Francisco Bay area, which aims to protect shorelines with sustainable resources and natural vegetation in lieu of conventional shoreline reinforcement methods that degrade wildlife habitat.

2. As described in the paper: Statton, J., Dixon, K.W., Hovey, R.K., Kendrick, G.A. (2012). A comparative assessment of approaches and outcomes for seagrass revegetation in Shark Bay and Florida Bay. Marine and Freshwater Research 63: 984–993.

The literature is reviewed to evaluate seagrass revegetation projects focused on Posidonia australis and Amphibolis antarctica, the main affected species in Shark Bay, Western Australia and Florida Bay, United States. The investigation assessed the effectiveness of anchoring planting units, plant-unit density and size on planting-unit survival. No positive trends were found in the assessment, suggesting that there is no discrete technique, approach or technology that could be used with confidence to deliver cost- effective, scalable revegetation.

3. As described in the paper: Busch, K.E., Golden, R.R., Parham, T.A., Karrh, L.P., Lewandowski, M.J., Naylor, M.D. (2010). Large-Scale Zostera marina (eelgrass) Restoration in Chesapeake Bay, Maryland, USA. Part I: A Comparison of Techniques and Associated Costs. Restoration Ecology 18: 490-500.

Reported costs of Z. marina transplanting efforts have varied widely, ranging from approximately $4,000 to $63,000/ha. Manual and mechanical transplant projects involving other species have ranged from approximately $16,000 to $3,387,000/ha, with total project costs dependent on transplant method and density.

Mangrove restoration

Would it work in the GBR?

Small scale restoration projects have demonstrated the extreme difficulty of scaling up to effective large scale restoration projects (Duke and Larkum, 2008).

Direct manual planting of mangrove seedlings or propagules is the most common method of restoring mangroves. However, this approach is not often successful, especially when the reasons for mangrove degradation were not removed prior to planting new seedlings or propagules. On exposed shorelines, wave action and erosion are among the most important factors that affect mangrove seedlings survivorship (Duke et al., 2007). Fringe mangrove seedlings can be uprooted and washed away by strong waves and currents. Furthermore, erosion can alter the morphology of the site and hence the inundation regime. The low wave-energy climate which is suitable for mangrove to establish its roots could be provided by a barrier (i.e. coastal structure). There may even be a large capital investment in growing mangrove seedlings in a nursery before existing stress factors at a proposed restoration site are assessed. This often results in major failures of planting efforts (Elster, 2000; Erftemeijer and Lewis, 1999; Lewis, 2005). However, a successful mangrove restoration project may not necessarily include a planting phase (Kamali and Hashim, 2011). When the stressors are removed and suitable environmental conditions are provided, such as correct hydrology and calm area, particularly on exposed coasts, natural regeneration processes could recover mangroves from degradation.

How much would it cost?

There is limited detailed information on the success and cost of mangrove restoration projects in the GBR.

Is it suitable for GBR offsets?

It is likely that mangrove restoration would be a suitable GBR offset, and small scale projects are already in place under the Queensland Fisheries Act 1994 and EPBC Act 1999 (e.g. Hay Point, Mackay; Kaveney, 2010). However, further information is required on the costs associate with mangrove restoration and options for large scale restoration activities.

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Appendix 3: Time lags in catchment management

Time lags in the GBR system can have a marked effect on the ability to measure change as a result of management actions. These time lags can be associated with material transport within catchments and into the GBR lagoon, and between catchment management actions and the resultant changes in water quality at varying downstream catchment scales. In addition, time lags will vary depending on what water quality parameter is being measured. For instance, sediment lag times may be much longer than reductions in dissolved inorganic nitrogen or pesticide concentrations in waterways. For example, optimisation of herbicide application through the use of new technologies such as shielded sprayers may result in reductions in concentrations within a period of months to three years (as shown in Table 1). It is critical to acknowledge that the first detectable changes towards water quality improvement will be attributed to management practice change and the longer-term response will relate to load outputs. This highlights the importance of innovative monitoring and modelling techniques, and an improved understanding of system dynamics to inform management decisions relating to water quality management in the GBR.

Time lags and offsets timing

Increased suspended sediment river loads lead to immediate (within the current year) increases in inshore turbidity (Fabricius *et al.* 2014; Logan *et al.* 2014). From the results of these studies, catchment management works which produce an immediate reduction in sediment loading can be expected to have an effect on reducing inshore turbidity within one year. However there are very long time lags between implementing catchment works and having the works actually start to reduce erosion. In Table 1 time lags are estimated for erosion control and sediment reduction works. In Table 2 time lags are estimated for other pollutants including nutrients and pesticides.

Table 1: Time lags and costs of different sediment reduction works.

Works	Time lag cause	Possible time lag
Riparian vegetation replanting	Time after tree planting for trees to establish and grow to a size to be effective in bank stabilisation	10 years
Riparian fencing to exclude or manage cattle	Time for trees to naturally seed and recruit to area, establish and grow to a size to be effective in bank stabilisation	15 years - 5 years longer than actively planted trees
Pasture management through rotational spelling	Pasture to recover to >80% cover	10 years
Gully remediation through preventing cattle access and pasture management	Time for trees and grasses to seed and re-establish	15 years
Gully remediation through engineering works	Time for restored former gully area to stabilise	3 years

In theory, catchment works would need to begin several years before commencement of dredging so that reductions in sediment discharge from rivers coincides with the actual period dredging is occurring and increased turbidity results. However, since this unlikely to be practical, the best that can be done is to start catchment management as soon as possible.

Table 2: Timeframes for water quality changes as a result of management actions to be detected for three example parameters at varying spatial scales from paddock to reef.

Timeframe of water quality trends/signals being detected at different spatial scales			
Management actions/ remedial activity	Water Quality Parameter		
	Suspended sediment (Burdekin Rangelands)	Dissolved inorganic nitrogen (lower Burdekin)	Herbicides (the Tully floodplain)
	Erosion control mechanisms for grazing lands e.g. riparian fencing and wet season spelling	Reduction of fertiliser use in cropping lands e.g. implement Six Easy Steps	Minimise/optimise pesticide use through new technologies e.g. shielded sprayers, control traffic
Paddock/Plot Scale	Likely 2–3 wet seasons e.g. Virginia Park Station	Months – 3 years; depends on the nitrogen stored in the system (e.g. soil, organic matter) e.g. BRIA paddock	Months – 1 year; depends on previous usage and residuals in the system. e.g. Tully paddock
Local Scale e.g. immediate drainage line/ local waterway	Likely to be detected within 5-10 years depending on system noise e.g. Weany Creek	Likely 1-3 years; depending on rate of adoption within local area and system noise e.g. local cane drain	Likely < 1 year due to relatively short half-life (e.g. diuron half-life in soil is 90 days) e.g. local cane drain
Sub-catchment Scale	> 5 years; even for major scale land management interventions across the sub-catchment e.g. Fanning River	Likely <10 years if sugarcane is dominant catchment land use and management change is widely adopted; particularly if detailed pre-monitoring data are available e.g. Upper Barratta Ck	< 2 years if sugarcane is dominant catchment land use and management change is widely adopted; particularly if detailed pre-monitoring data are available e.g. Davidson Ck
End-of-catchment Scale	Likely > 10 years (major erosion control management intervention across the Burdekin); dilution of signal as only small % of total catchment area under improved management at any one time, and hydrological variability or noise is high. e.g. Burdekin R (Inkerman)	Likely < 10 years if sugarcane is dominant catchment land use and management change is widely adopted; particularly if detailed pre-monitoring data are available e.g. Barratta Ck (Bruce Hwy)	< 2 years, however may be dilution effect depending on amount of cane in catchment, and proportion of uptake by the industry within this catchment e.g. Tully River (Euramo)

Timeframe of water quality trends/signals being detected at different spatial scales			
Estuarine & Marine Scale e.g. coastal waters within adjacent bay	Likely > 10 years before change in turbidity; limited likelihood of detecting signal from this management action due to size of catchment. e.g. Upstart Bay	< 20 years for chlorophyll from major nitrogen fertiliser reduction across the lower Burdekin sugar lands with variability due to other sources of nutrients (e.g. Burdekin plume), seasonal variations in nitrogen cycling and sea water mixing. e.g. Bowling Green Bay	< 2 years in the floodplume, however may be difficult to detect if the coastal waters are also influenced by larger river flood plumes (e.g. Herbert or Murray Rivers) e.g. Dunk Is. & Family Is. Group

Source: Bainbridge et al. (2009a).

Appendix 4: Authors

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- Principal Consultant, The Biodiversity Consultancy, 2011 -
- Technical biodiversity offsets consultant to governments (e.g. co-author of New Zealand's Offsets Accounting Framework), banks (e.g. advising International Finance Corporation on hydropower offset policy) and corporations (e.g. advising corporate offsets policy, creating biodiversity metrics, calculating No Net Loss requirements, designing specific offsets, designing M&E plans)

Leon Bennun

- Technical Director, The Biodiversity Consultancy, 2014-
- Director of Science, Policy and Information, BirdLife International, 2002-2014
- Technical advice on offsets to IUCN and Rio Tinto via the Net Positive Impact Protocol and Review Panel. Developed Integrated Biodiversity Assessment Tool (IBAT) as information base for Mitigation Hierarchy application. Guided BirdLife strategic corporate partnerships and policy and positions on biodiversity offsets.

Martine Maron

- Associate Professor in Environmental Management, The University of Queensland, 2008-
- ARC Future Fellow 2014-2018; Director of BirdLife Australia 2011 - and Chair of their Research and Conservation Committee 2013-2014; Member of IUCN working group on biodiversity offsets policy 2014-
- Environmental offsets policy design and review for several governments (example products: EPBC Act Offsets Assessment Guide; New Zealand's Offsets Accounting Framework)

Jon Brodie

- (Chief) Research Scientist, Centre for Tropical Water & Aquatic Ecosystem Research, James Cook University, 2001 –
- Director, Research and Monitoring Section and then Director, Water Quality and Coastal Development Section, Great Barrier Reef Marine Park Authority, 1990 – 2001
- Lead author of the Scientific Consensus Statement for Water Quality in the GBR (2008, 2013), with 50 leading scientists, for the Queensland Government

Melissa Bos

- Researcher, Marine Conservation Finance and Marine Offsets, Centre of Excellence in Coral Reef Studies and School of Business, James Cook University, 2012-

- Project Manager, Sustainable Funding and Social & Economic Sciences, Great Barrier Reef Marine Park Authority, 2012-2013, including Great Barrier Reef offset analysis, policy, and systems
- Director, Hawaii Fish Trust and Global Marine Partnership Fund, Conservation International, 2007-2012, including compensatory mitigation (offset) policy and design for Hawaii and Micronesia

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- Research Fellow - Catchment to Reef Processes, Centre for Tropical Water & Aquatic Ecosystem Research, James Cook University, 2009 –
- Partner & Senior Scientist, C2O Consulting, 2004 –
- Coordinator, Wet Tropics Water Quality Improvement Plan 2013/14 and Burdekin Water Quality Improvement Plan 2014/15

Appendix 5: Stakeholder consultation

This report was written based on the published literature and the theoretical and practical experience of the authors. A summary was presented to a stakeholder consultation workshop in Brisbane on 14 October 2014. This workshop discussed some key issues around additionality, ecological equivalence and costing for uncertainty. The following stakeholders participated in the workshop:

- Adam Knapp, Queensland Farmers' Federation
- Ailsa Kerswell, Eco Logical Australia
- Ami McGrath, Department of the Environment
- Andrew Duncan, Qld Department of Environment and Heritage Protection
- Andrew O'Neill, Water by Design
- Chris Johnson, Qld Department of Environment and Heritage Protection
- Claire Gronow, Ashgrove Environmental, representing EIANZ
- Craig Hempel, Qld Department of Environment and Heritage Protection
- David Calvert, Department of the Environment
- Georgina Newton, Department of the Environment
- Jim Binney, Mainstream Economics;
- Kat Miller, Department of the Environment
- Michael Allen, Qld Office of the Coordinator General
- Michael Berkman, Environmental Defenders Office Queensland
- Mike Berwick, Queensland Regional Groups Collective
- Miranda Lello, Department of the Environment
- Nicola Garland, Queensland Resources Council
- Paul Doyle, North Queensland Bulk Ports Corporation
- Sean Hoobin, WWF
- Stuart Whitten, CSIRO

- Guy Dutson, report lead author, The Biodiversity Consultancy;
- Jon Brodie, report author, James Cook University
- Martine Maron, report author, University of Queensland