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A review of New Zealand studies into the cost of degradation of freshwater ecosystems

New Zealand Government

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1. Overview

Introduction

This report provides an overview of the ecological, cultural, social and environmental costs of degradation of freshwater ecosystem health in Aotearoa New Zealand. It assesses the evidence on current and historical costs of degradation of freshwater ecosystems. Such information can help with:

- motivating policy interventions (understanding the cost of the status quo)
- understanding the nature of the problem that exists
- helping inform the likely benefits of intervention given current and historical value obtained from freshwater ecosystems.

Potential future research directions that emerge are highlighted. The report uses a literature review to identify and summarise significant studies, rather than conducting a systematic literature review of all studies.

This report is divided into three sections:

- Section 1 outlines the purpose and method
- Section 2 summarises the findings of the review
- Section 3 discusses the findings in more detail including a table describing the studies included in the review.

Scope of review

The focus of the review is on the level and range of values supported by freshwater ecosystems and how these are affected by degradation, either at present or historically. Thus, this report considers the overall costs of degradation; assessing benefits associated with activities that cause degradation are outside of scope.

Level of value supported by freshwater ecosystems can be expressed in monetary or non-monetary terms. In the latter case, these terms can be quantitative or qualitative, and relate to any measure or understanding of value derived from freshwater ecosystems within the four categories of values of interest. For example, number of angler days is a quantitative non-monetary measure of the flow of a social value from an ecosystem, whereas a qualitative measure could be on a scale of D- to A+ for quality and utilisation of fishing (Hughey and Taylor, 2008; Williamson, Quinn, Williams and van Schravendijk-Goodman, 2016).

Marginal changes in values relative to the status quo is not the focus of this report, although this approach is the most common in economic studies of market and non-market values (Farley, 2008). It is also important to note this report covers the effects of environmental

degradation in the past or present. Projections of future scenarios are outside of scope, and where studies that are relevant to this review also included future projections, these parts of the studies were excluded from the review.

Selection of studies

Studies were selected for inclusion in the review primarily through scanning reference lists and citing papers, starting from two highly detailed and relevant recent studies and progressing from there. Relevance was determined on the basis of the report's main focus, with priority given to studies that integrate assessments of values across all four categories of ecological, cultural, social and economic.

The two initial papers that were identified were Scion (2012) and the Technical Leaders Group for Healthy Rivers/Wai Ora (2016). Additional material for reference list scanning on environmental degradation was provided by a library at the Ministry for the Environment and several regional councils.

Due to time constraints, the review continued until signs of literature saturation started to show, such as lack of new papers showing in reference list scanning and additional papers starting to fit less well with the focus of this report.

The review table

The review table at the end of the report has 12 columns. The first eight are as follows:

1. Study citation
2. Purpose, such as regional policy, national policy, catchment management or research
3. Source, such as report or journal article
4. Location of focus
5. Approximate time period in the past or present from which the data is collected
6. The main environmental state that impacts the values
7. Brief summary of the analytical framework and method used to identify the state of the four categories of values
8. An overall picture of the extent to which the study discusses causality from the ecosystem condition to the state of the values. It is beyond the scope of this report to make a judgment as to how robustly the study identified causality. The column only identifies whether it was discussed to a low, medium or high extent.

The last four columns summarise one or several headline findings from the studies regarding ecological, cultural, social and economic values. If a value was not covered in any significant sense, the relevant column is left blank.

2. Summary of main findings

The main findings emerging from a reading of the literature in this review are:

1. Overall, there is enough previous research available to provide a general qualitative assessment of the costs of degradation. This previous research shows the strong correlations between the state of freshwater ecosystem attributes and the state of the values (ecological, cultural, social and economic) that flow from freshwater ecosystems. It also points to high levels of degradation, which means a high level of cost across the categories of values.

2. If a more detailed assessment of the costs of degradation is desired, research needs to be undertaken at a catchment or local level. Such research should include information from the relevant local communities. This information could be collected from a survey, in collaboration with researchers and policy makers, by interviews with representatives from the local community or through deliberation by experts that are highly familiar with the local communities.

3. To integrate information on the costs of degradation with policy modelling in a catchment, there needs to be a clear relationship between the metrics for the state of the environment and the metrics for the values. This integration can be achieved with a quantitative measure of value, such as monetary valuation of ecosystem services (Yao and Velarde, 2014), or qualitative measures of value that provide an ordering, such as rating the state of a value between D- and A+ D- (Williamson et al, 2016), from 0 to 1 (Warmenhoven et al, 2014) or from very poor to very good (Ministry for the Environment and Stats NZ, 2017).

   Future research could focus on refining estimates of such relationships and integrating them into policy projections. See for example the scenario analysis undertaken by Yao and Velarde (2014) and Warmenhoven et al, (2014).

3. Discussion

The studies reviewed here show there is a high level of value obtained from freshwater ecosystems. They also point to many areas where there is a high level of degradation. Given the high value from healthy freshwater ecosystems, and the high levels of degradation, costs of degradation are also high. However, the studies are undertaken in places with high values placed on freshwater ecosystems, and high levels of degradation. Places with pristine ecosystems are less relevant from a research perspective when looking at the costs of degradation.

The papers reviewed here provide a good overall breadth and depth of information about the costs of degradation. As shown in Gluckman et al (2017, p. xxxi), there is enough current research to provide a national-level qualitative rating of the state and trends of the major freshwater values.

Costs of degradation

Costs of degradation that are identified in the studies reviewed here include, for ecological values:

- loss of ecosystems, such as wetlands
- loss of biodiversity, such as for native braided river birds and fish.

For cultural values:

- mahinga kai, mana kaitiaki, taonga species very degraded from a historical perspective.

For social values:

- mixed experiences with recreation – some places are good, some places are poor due to, for example, mud, risk of picking up stomach bugs or decline in fish.

For economic values:

- flood protection is lost or replaced by costly infrastructure where natural flood protection has been removed
- ongoing erosion is reducing stocks of productive soil
- degradation from land use means more restrictions on future land use.

Assessment of literature

While there is enough research to support high-level conclusions on the costs of degradation, there is a general scarcity of detailed studies that fit the criteria for this review well. Hughey and Taylor (2008), Scion (2012), Warmenhoven et al (2014) and Williamson, Quinn, Williams and van Schravendijk-Goodman (2016) are the studies that best fit the criteria, whereby the historical and current costs of degradation of ecological, cultural, social and economic values

are studied in an integrated and detail manner. These studies cover Te Waihora-Lake Ellesmere, Waiapu and Waikato-Waipa.

Beyond these studies the papers identified become more specifically focused on one category of value or one type of ecosystem, or more focused on current value rather than costs of degradation.

Links between state of ecosystems and costs

There is a strong link between the state of freshwater ecosystems and the costs of degradation. In general, the state is getting worse over time, leading to higher costs over time. This general summary is consistent with Gluckman et al (2017), however the picture is complex as there is a mixture of freshwater bodies that are still relatively pristine (particularly upland) and severely degraded water bodies.

The term 'costs of degradation' implies a line of causality from degraded freshwater ecosystems to negative impacts on values. However, establishing a causal link between freshwater ecosystems and the state of social, cultural and economic values in a community is not clear cut. Freshwater ecosystems are strongly linked with social, cultural and economic systems, and the feedbacks between the systems (causation) go both ways.

Tipa and Tierney (2006) note the high correlation between physical measures of ecosystem health and cultural health. But they also note that a Māori perspective aligns with a more holistic view. While this report takes a more holistic approach than the purely technical stream health indicators approach that Tipa and Tierney (2006) highlight, this report still does not fully encapsulate the idea of ki uta ki tai (mountains to sea). 'Costs of degradation' is limited in a sense to considering freshwater ecosystem health (cause) and the impact of declines in this health on social, cultural and economic values (effect). The framing of this report provides focus, but its limitations should be noted and understood.

Diversity in values across catchments

What these studies do show is a diversity in values derived from freshwater ecosystems, which flow from a diversity of attributes of freshwater ecosystems. Studies included could measure value using quantitative or qualitative means, and any methodology (except a marginal analysis, as favoured in economics), as outlined in the introduction of this report.

While there are plenty of commonalities around the country, each catchment can be seen as a collection of some of the values or freshwater attributes that are present nationally. But each catchment will have only some of these values and attributes as important and others as less important or not present. For example, sediment is a large problem in Waiapu due to the nature of the land, the local climate and the type of degradation on the land within the catchment. Cultural values are particularly important there too, given the high Māori population and the importance of the catchment to Ngāti Porou.

On the other hand, the Waikato-Waipa catchment, based on the studies reviewed here, has a wider range of types of degradation that are shown to be important, and supports a wider range of types of values. Stressors such as nutrients and E. coli are important in this catchment.

Thus, it seems each catchment could be assessed against a comprehensive set of national criteria in terms of ecosystem state and values, but the picture of what is important and significant in each catchment will look different. An interesting example of a national level assessment of freshwater ecosystems in terms of the conservation value supported in each catchment is provided by West, Leathwick and Dean-Speirs (2019). An example of collection of national data on cultural health is Ministry for the Environment and Stats NZ (2017).

Based on the studies identified in this report, it seems more work could be done to map the data on freshwater ecosystems and the values they support, catchment-by-catchment, around the country.

Non-substitutability

In addition, each catchment has a degree of non-substitutability, particularly for cultural values (Satterfield, Gregory, Klain, Roberts and Chan, 2013).

The state of the Waiapu is important to Ngāti Porou, other locals and visitors. If the state of the Waikato improves, there is a limited extent to which that would substitute for the state of the Waiapu. Indeed, for certain values related to the Waiapu, there is no substitute, demonstrated by the place of the Waiapu in the pepeha of Ngāti Porou – "Ko Hikurangi te Maunga, Ko Waiapu te Awa, Ko Ngāti Porou te Iwi" (Scion, 2012, p 193). Ecological, social and economic values, especially from the point of view of local communities, will also have limited substitutability over space.

Current and future research methods

Collaborative local assessment

Ideally, to understand costs of degradation in more detail for a specific place, a detailed assessment at a local level should be done. This assessment requires information from the local community and could be in the form of:

- a survey, for example to assess non-market values in monetary terms
- interviews or participatory research processes.

Some of the integrated studies reviewed here involved some aspect of communities developing their aspirations for the freshwater ecosystem, and then assessed each value of interest against the aspirations of the community (Tipa and Teirney, 2006; Warmenhoven et al, 2014; Williamson et al, 2016). These studies highlight the importance of talking to communities as part of assessing community values for freshwater ecosystems.

The studies reviewed here also serve as a reminder of the information held within communities. A purely expert-led scientific assessment may have blind spots, even in relation to bio-physical assessments. Therefore, communities also have a potential role in understanding ecosystem health, through integrating mātauranga Māori (eg, NIWA, 2010) and gathering other knowledge they hold.

Citizen science is another avenue where future data on ecosystem health can be collected. Additionally, the role of communities in resource management is an area to consider that is

beyond the scope of this review, but there are potential cross-overs between gathering community knowledge to understand costs of degradation, and collaborating with communities to manage freshwater resources.

The benefit transfer method

The studies provide insight into the types and nature of costs of degradation that are being faced in catchments around the country. Therefore, for a given catchment, it is possible to compile a likely list of costs of degradation, given the information held about that catchment. Such an exercise may be motivated by a lack of time and budget to do a more in-depth assessment. For such an assessment, the state of the catchment's attributes and the area's population could be compared to similar catchments where primary research has been done. This information could help define the problem and provide motivation for intervention. It could also underpin modelling of future costs of degradation with no intervention, and benefit-cost analysis of proposed interventions.

A process of taking a place and a population without existing primary data and estimating value flowing from that place to that population has been formalised in economics with the well-established benefit transfer method. This method estimates the value of an environmental resource to a population in one location by using existing survey data on monetary non-market values from other locations (Treasury, 2015; US Environmental Protection Agency, 2014).

The concept has potential to be explored as a way of transferring estimates of non-monetary measures of value from one location to another. However, more work would need to be done to test the idea, particularly for the cultural values, given it may not fit within a Māori cultural context.

Measuring values

The assessment of the state of values and costs of degradation can be undertaken using a common method and metric such that catchments can be compared nationally. These assessments require either a quantitative measure, such as monetary values (Yao and Velarde, 2014), or a qualitative rating, such as the D- to A+ scale (Williamson et al, 2016).
If comparability is desired, a common method is important, as variance in method could affect measures.

It is difficult to compare types of values (to contrast them and allow for trade-offs) unless they are in a common metric, such as money. Some would argue that it is necessary to convert all values to monetary ones to do a robust benefit-cost analysis. Others argue it is an unsound approach as converting ecological, cultural and social values into monetary values is inappropriate. It may be that only some form of democratic decision-making process can resolve difficult trade-offs between competing but distinctive values (Bertram and Terry, 2013; Raz, 2009; Tietenberg and Lewis, 2016). The other approach is creating an index value, though that requires a decision on weighting components, and in the studies reviewed here using index measures still separated types of values to some extent (Tipa and Teirney, 2006; Warmenhoven et al, 2014).

Baseline and future projection

One important decision that needs to be made when assessing costs of degradation is to define the baseline. The aforementioned aspirational approach implicitly makes the baseline, or point of comparison, at the point of the desired state of the values. Tipa (2013) takes a historic view, comparing contemporary ecosystem health with the ecosystem health in 1873. Data availability constrains how far back a baseline can be set, although difference from a pristine ecosystem is one approach. An estimate of future costs of degradation could set the baseline as the current ecosystem state.

Finally, to better understand how costs vary by time and space, it is important to have a clear link between the state of a freshwater ecosystem and the values the ecosystem supports. This would allow variation in costs of degradation over space and time to be more clearly understood. Thence, tracking progress and modelling future policy in terms of impacts on values would be more possible. This exercise has been undertaken to some extent in the studies reviewed, including Warmenhoven et al (2014), who project how the values supported by the freshwater ecosystem change with climate change. To what extent this can be used to better understand variation over space and time, and indeed project changes forward, is still an open question.

Future research should look at refining our understanding of these relationships. We should test how well we can project changes in values around the country, and in future scenarios. This includes better understanding the extent to which this modelling must be done on a catchment level, versus modelling scenarios at a more aggregated, national level.

Table 1 Summary of papers

Study	Purpose	Source	Location	Time period	Environmental state	Analytical framework and methods	Discussion of causality	Ecological values	Cultural values	Social values	Economic values
Barns, Henry & Reed 2013	Regional policy	Report	Waikato and Waipa	Early 2010s	Water quality	Focus groups, surveys on values, uses of water and perceptions of quality. Document review. Qualitative and quantitative data	Medium		Māori reported higher usage of waterway than other ethnicities, for recreation and food	Users (64% of surveyed) assessed water quality in the Waikato region as good (31%), neutral (36%), poor (29%)	
Clarkson, Ausseil & Gerbeaux 2013	Research	Book chapter	Around New Zealand	Last few decades	Wetland ecosystem health	Total economic value of ecosystem services. Literature review	High	NZ wetlands provide habitat ecosystem services worth $1,175 /ha/year (2012)	NZ wetlands provide cultural ecosystem services worth $6,054 /ha/year (2012)	Manawatu-Wanganui region wetlands provide provisioning ecosystem services worth $17,026 /ha/year (2006)	NZ wetlands provide regulating ecosystem services worth $45,217 /ha/year (2012)
Department of Conservation 2007	National policy	Report	Whangamarino wetland	Last few decades	Wetland ecosystem health	Ecosystem services. Monetary value of flood control, mostly qualitative descriptions otherwise	High	Existence value estimated in a 1988 study at $US9.9 million a year (2003 dollars)			Whangamarino wetlands, in conjunction with Whangamarino control gates, prevented $5.2 million of flood damage (2007 dollars) from

Study	Purpose	Source	Location	Time period	Environmental state	Analytical framework and methods	Discussion of causality	Ecological values	Cultural values	Social values	Economic values
											1998 flood event
Field & Tunks 2010	Regional policy	Report	Bay of Plenty	2011	Turbidity, nitrogen, phosphorous, *E. coli*.	Social and economic impact assessment (for policy proposal). Literature, secondary quantitative, submissions, primary interviews. Focus on Māori and other vulnerable communities	Medium	Declining quality of many rivers and streams between 1998 and 2008	Concerns expressed about the loss of food resources for Māori due to degradation of water quality	Mud accumulation from dam has impacted recreational opportunities. Skin infections and stomach bugs increasing from swimming	Income from land use need to be weighed against environmental policy. Some concern over insecurity of access to water for irrigation etc
Gluckman et al 2017	National policy	Report	National	Recent	Quantity and quality of water nationwide	Qualitative summary of assembled evidence	High	Native braided river birds declining, some native fish at risk/declining, some increasing	Mahinga kai, mana kaitiaka, taonga species generally very degraded in a historical perspective, likely worsening in many places	Swimming values declining or static, fishing mostly declining, particularly in lowland areas	
Hughey & Baker 2010	National and regional policy	Report	National, with several case studies	Around 2010	Water quality, environmental suitability for recreation	River Values Assessment System (RiVAS), which can assess all river values using multi-	Low			Rivers and swimming spots in cases studies ranked for significance for certain recreational	

Study	Purpose	Source	Location	Time period	Environmental state	Analytical framework and methods	Discussion of causality	Ecological values	Cultural values	Social values	Economic values
						criteria analysis (MCA). Rivers are scored and ranked on certain criteria				uses. These data can inform prioritisation	
Hughey & Taylor 2008	Catchment management	Report	Te Waihora/Lake Ellesmere	Approx 1993 to 2009	Ecosystem health	Comprehensive study, including cultural health index, assessment of recreational values	High	Trends for water quality measures and wildlife are mixed	Ngāi Tahu cultural values are declining	Value of recreational opportunities and experiences generally increasing	Commercial fishing has declined steadily. Currently catch value $636,500/year
Krausse, Eastwood & Alexander 2001	Research	Report	National	1998	Erosion	Estimate financial costs of erosion where data is available (eg. from organisations), namely for damage and prevention costs.	High				Economic cost of erosion is $127 million per annum (1998 dollars)
Ministry for the Environment & Stats NZ 2017	Environmental reporting	Webpage	National (41 sites)	2005 to 2016	Quantity and quality of water	Review of data from Cultural Health Index site measurements nationwide	Low	Mahinga kai status was poor or very poor at 28 sites, moderate at 12, good at 2 of 39 sites	Cultural health index was poor or very poor at 9 sites, moderate at 21, good or very good at 11 of 41 sites		

Study	Purpose	Source	Location	Time period	Environmental state	Analytical framework and methods	Discussion of causality	Ecological values	Cultural values	Social values	Economic values
NIWA 2010	Regional policy	Report	Waikato River	Recent	Health and wellbeing (mauri) of river	Integration of mātauranga Māori and science. Report cards rating against aspirations (A to E). Data collection through hui, stakeholder meetings, expert judgement for sparse data	High	Taonga species, ecological integrity rated poor to very poor (D to E)	Integrity of significant sites and protection of spiritual values rated fair to poor (C to D)	Recreation and protection of human health rated fair (C)	
Te Rūnanga o Arowhenua, Pauling & Norton 2010	Regional policy	Report	Ō Tū Wharekai / Ashburton Lakes area	2010	Water quality and ecosystem health	Takiwā, Cultural Health Index, water quality measurements, fishing surveys. Takiwā records site observations of rūnanga/iwi members	High		Overall assessment of cultural health of the area is moderate		
Schallenberg et al 2013	Research	Book chapter	National lakes	Recent decades	Ecosystem health	Ecosystem services assessment, with overall qualitative score. Information from literature review	High	Biodiversity in lakes poor, declining	Tuna populations in lakes fair, declining	Contact recreation in lakes fair, declining	Drinking water from lakes poor, declining

Study	Purpose	Source	Location	Time period	Environmental state	Analytical framework and methods	Discussion of causality	Ecological values	Cultural values	Social values	Economic values
Scion 2012 (particularly chapter 6)	Regional policy – iwi focus	Report	Waiapu River Catchment (Ngāti Porou)	1840 to 2011 2008 to 2011 as a contemporary benchmark	Erosion. Present sediment yield is 20,520 t/km^2/year (3 to 500 times greater than other selected rivers)	Bi-cultural approach to develop framework of aspirational indicators. Demographic analysis Natural capital and ecosystem services. Interviews with kaumatua; kōrero and hui with iwi groups to identify 10 aspirations and indicators for these. Estimates of monetary value of lost ecosystem services (soil production, flood protection)	Medium	Reduction of fish and plant production in waterways, estuaries and wetlands. River flow impeded	Degradation of natural capital has likely contributed to reduced cultural identity and expression	Population has declined in the area from 1986–2006 and the catchment is within the 8 to 10 decile on the NZ Deprivation Index. Degradation of natural capital has likely contributed to depopulation, economic deprivation, decreased wellbeing	Lost productivity from erosion is estimated at $855,000 per annum
Sharp & Kerr 2005	Regional policy	Report	Waitaki catchment	Early 2000s	Water quality and quantity	Total economic value (monetised) estimated through review of non-market valuation	Medium			Recreational use value of the lower Waitaki valued at $2 million per year.	

Study	Purpose	Source	Location	Time period	Environmental state	Analytical framework and methods	Discussion of causality	Ecological values	Cultural values	Social values	Economic values
						studies – direct and benefit transfer				Preservation of current state of Rakaia and Waimakariri valued at mean of $42 to $43 per household per year	
Technical Leaders Group for Healthy Rivers/Wai Ora 2016	Regional policy	Report	Waikato	Recent years	Water quality	Integrated assessment of indicators on environmental, cultural, social and economic – both quantitative and qualitative	Medium	Less than 20% of original wetlands remain in the lower Waikato	Koura are in relative abundance in Waikato River tributaries from Karāpiro to Ōhakuri, and Waipa tributaries. They are scarce elsewhere	69% of people visited a waterbody in the past year in the Waikato. Higher water clarity, more likely to visit, travel cost less likely	Median weekly income in Waikato is below national average – $800 vs $860 (in 2014)
Tipa 2013	Research	Journal article	Waitaki catchment	Approx 1879 and recent	Food species	Historical and contemporary assessment of traditional food sources, historical documents and files	Medium		Tuna was gathered at 69% of sites pre-European settlement. Currently, tuna are in decline and there are few opportunities to pass on knowledge		
Tipa & Teirney 2006	Regional policy	Report	Taieri, Kakaunui,	Approx 1999 to 2005	Water quality and quantity	Combination of cultural health	Medium		High correlation between	High correlation between	

Study	Purpose	Source	Location	Time period	Environmental state	Analytical framework and methods	Discussion of causality	Ecological values	Cultural values	Social values	Economic values
			Hakatere and Tukituki rivers			index (CHI) through interviews and surveys, and scientific measures of water quality			scientific quality measures and cultural values eg, mahinga kai	scientific quality measures and social values eg, swimming	
Unwin 2016	Environmental reporting	Report	National	1994 to 2015	Ecosystem composition and health	Data on usage of angling licences, random phone survey of licence holders. Results correlated with freshwater data	Medium			Declining trend in usage of fisheries in catchments dominated by cropland or pasture	
Warmenhoven et al 2014	Regional policy – Iwi focus	Report	Waiapu River Catchment (Ngāti Porou)	Recent data (last decade or so)	Holistic – no single focus	Sustainable livelihoods approach (SLA). Six capitals measured, including through Montreal Process Criteria and Indicator framework: (95 aspirational values, 0-1 weighted scale for each capital). Secondary	Low	Noticeable decline in mahinga kai. Indicator of 0.29 (out of 1)	High effort maintains cultural knowledge, but outward migration is a pressure on this. Indicator 0.57	Ngāti porou is the second largest iwi, but highly dispersed. High level of community activity eg. at marae. Indicators of 0.82 (social), 0.56 (human and/or political)	High cost of engineering works for river management due to degradation Asset rich (land) but low income. Indicators of 0.36 (physical), 0.41 (financial)

Study	Purpose	Source	Location	Time period	Environmental state	Analytical framework and methods	Discussion of causality	Ecological values	Cultural values	Social values	Economic values
						quantitative, primary interviews					
Williamson et a 2016	Regional policy	Report	Waikato and Waipa Rivers	2012-2014	Water quality and quantity	Report card summarising current state of water bodies under various criteria using recently collected data	Medium	Overall grade for all criteria is C+. Water quality is C-, water security is C+, ecological integrity C+	Kai overall grade is C	Experience with the waters overall grade is C	Economic score (socially focus criteria eg. employment, housing, equality) for the region is B+
Yao & Velarde 2014	Research	Report	Ōhiwa catchment	Recent data.	Land use (including wetlands and mangroves)	Ecosystem services. Approximate an indicative value for each one using secondary data and/or estimate using spatial economic model	High	Wetlands and mangroves provide $11,721/ha/year of waste treatment and $494/ha/year of species conservation		Wetlands and mangroves provide $1,978/ha/year of recreational value	Wetlands and mangroves provide $12,737/ha/year of avoided erosion and flood disturbance

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