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A New Approach to Environmental Valuation for New Zealand

Abstract

New Zealand's Resource Management Act is frequently criticised for the costs and delays it imposes on activities, but less attention is given to the consistency of values it applies to environmental effects through its decisions. The wide variety of parties who exercise decision roles under the act lack guidance on the economic value of the environment, and non-market valuation studies are too costly to be widely used and too few and varied to infer reliable generic values. Drawing on experience in estimating the public value of safety improvements, this article proposes an alternative approach that measures people's aversion to the risk of environmental impacts of different scales and severity which could yield values sufficiently generic to be widely used, and outlines its uses both within and beyond the RMA applications.

Keywords Resource management, non-market valuation, risk, environmental accidents

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While the Resource Management Act 1991 (RMA) attracts frequent criticism for imposing costs and delays on activities, less attention is paid to whether it consistently accounts for the environmental effects of its decisions across the country. Could a more coherent approach be adopted, rather than relying on the vagaries of particular councils, courts or individual decision makers? Our answer is 'yes' – by applying the approach proposed and developed in this article, which avoids the limitations of current evaluation approaches.

Although the RMA's purpose includes providing for 'economic well-being' (section 2), the idea that environmental condition is part of the 'consumption set' that determines peoples' well-being is not commonly considered in economic terms within the act's evaluation processes. These are legislated by politicians, administered by planners and adjudicated by courts which emphasise legalistic and scientific aspects, with economic assessments largely focused on job creation and economic growth. Hence, the environment is valued in an ad hoc manner, implied through project approvals and other decisions.

This is unlikely to result in an optimal level of environmental protection across New Zealand since it leaves unanswered the economic question of how much is it worth to avoid adverse environmental effects?

The new and alternative approach combines the principles of environmental and safety valuation to deliver a flexible mechanism for environmental decision making, applicable not just to RMA decisions, but to other processes, such as biosecurity assessments, that consider environmental values. We term this a VMAEE (value of a major adverse effect on the environment), the reasons for which are considered below.

The VMAEE sits within a wider context of economists' varied attempts to place monetary value on things which do not have prices revealed in market trades. The natural environment has numerous 'missing markets', sometimes because it is impractical to regulate the use of environmental resources (like the quality of the air we breathe) and sometimes because of what might be called 'administrative failure' to define and enforce entitlements to use resources that could reveal value through trade. Markets can be created for some resources: tradable quotas for commercial fishing, for example, and emissions trading to tackle climate change. However, many environmental effects are too diffuse to enable well-functioning markets to be established.

Various methods have been devised to address this problem – e.g. non-market valuations of environmental resources – which have sometimes influenced resource use decisions (see, for instance, Harris and Meister, 1983). But applications of such methods can be time-consuming and costly, they address particular clients' concerns, and in New Zealand at least there are too few estimates employing too widely varying methods to infer generic values for environmental resources such as water quality, biodiversity or natural settings. The cost of generating bespoke values has been prohibitive, so decisions will often be taken with no explicit economic values attached to environmental impacts. In such cases, economic values are implied by the decisions taken: for example, if a decision causes an environmental resource to contract, that resource is implicitly valued less than the opportunity cost of forgoing the project that alters it. Leaving decisions to be made without explicit focus on economic value by a variety of decision makers is not a recipe for efficient resource use.

These issues are not unique to New Zealand and can be placed in a wider context. Since the 1990s international agencies such as the World Bank, the OECD and the United Nations have steered a more consistent approach to placing values on the natural environment, driven by the premise that in the absence of a monetary value, the natural environment may not be properly taken into account in public policy deliberations at national or regional level, nor in private corporate decision making. The World Bank has developed frameworks for comprehensive wealth, inclusive wealth and genuine savings indicators which treat the environment as a source of natural capital to be measured alongside the produced capital of machinery and infrastructure, human capital (capabilities and skills), institutional capital (laws and governance) and net foreign assets.

In parallel with this, the United Nations has developed a System of Environmental Economic Accounting (SEEA), which sets standards for preparing natural resource accounts consistent with (but not part of) its System of National Accounts which records national economic aggregates like GDP. Its latest SEEA guidelines issued in 2012 included a core framework covering resources that give rise to marketable goods (such as hydrocarbon and mineral stocks) and an experimental framework that covers non-market resources (like recreation space and biodiversity). Statistics New Zealand has prepared satellite accounts using SEEA's core framework, on energy and minerals, water, fisheries and forestry (recently updated in Statistics New Zealand, 2018).

More recently, the notion of ecosystem services has received prominence through the UN-initiated Millennium Ecosystem Assessment in 2005, and the United Kingdom's National Ecosystem Assessment in 2011. The ecosystem services framework draws direct links between the condition of the natural environment's ecosystems and the beneficial services of value it supplies to human activities, under four distinct categories of service: provisioning (supply of materials and energy), regulating (such as carbon sequestration and water flow moderation), cultural (settings for recreation, tourism and cultural heritage) and supporting (nutrient cycling and pollination).

> The [value of a major adverse effect on the environment] is primarily aimed at deriving marginal values that can inform decisions at individual project or policy change level.

The UN's SEEA, capital accounting and ecosystem services frameworks are all attempts at a more interdisciplinary approach to economic valuation, but integration of science and economics is not yet fully resolved. All have received official endorsement and are being implemented by governments to varying degree, but they are primarily oriented towards measuring stocks of natural resources, rather than the changes in environmental condition and flows of effects that result from individual policies, plan changes or consenting decisions. A further limiting feature is that the average values inferred from them are not the marginal values needed to assess individual policy changes or projects, which will vary with the conditions of abundance or scarcity in each situation. The principal use of these aggregate stock measures is in comparing periodic snapshots of the position of natural resources in the national economy, rather than in assessing whether a particular project or plan change would produce benefits in excess of its full social costs, including costs of environmental changes.

The VMAEE is primarily aimed at deriving marginal values that can inform decisions at individual project or policy change level. It complements and serves a different purpose to the valuation of aggregate stocks in the SEEA.

Valuing the seemingly priceless: the conceptual underpinnings of the VMAEE framework

The VMAEE combines two pre-existing economic frameworks: the total economic value (TEV) model of natural environmental resources with public good characteristics, which includes current use values, future use (or option) values and non-use (like existence and bequest) values;[1] and the value of preventing a fatality (VPF) approach[2] to valuing safety improvements in public sector projects.

However, while we retain the essence of the TEV approach, we avoid the most trenchant criticism of environmental valuation studies – in New Zealand[3] and elsewhere – which have focused on specific species or habitats, resulting in a myriad of site-specific values generated from one-off (costly) studies that risk overstating value in one context by under-accounting in others, and which sometimes have (mistakenly) been applied to valuing the current stock.[4] VMAEE achieves this by adopting a multi-site approach, mirroring the VPF approach currently applied in transport appraisal of the value of preventing fatalities, which provides a utility-theoretic measure for safety.

In that approach, safety has a clear unit of measure, whereby the VPF is the aggregate willingness to pay, summed over a large group of individuals, for small reductions in each individual's risk of premature death, where the risk reductions are such that they will reduce the expected number of premature fatalities in the affected group by one and hence prevent one 'statistical fatality' in the forthcoming period. Applying the VPF means that the benefit of avoiding fatalities can be directly compared to its marginal costs, unlike in environmental assessment where the benefits of reducing the risk of environmental harm are only implicitly considered, or, worse, effectively valued at zero.

The VPF is portable across any policy domain that has an impact on human safety. This is a particularly useful feature and provides the rationale for incorporating it as the second stage of our framework. It is conceptually simple in respect of how it treats the policy output – the prevention of a fatality – as no effort is made to distinguish between different accident types or different ways of dying in such an accident. This contrasts with environmental valuation, which often has multiple, diverse units of output measures – for example, particular species saved from extinction, characteristics of water quality, ill-defined 'amenity' of landscapes – making it difficult to generalise any damages away from a specific site.

Although the VMAEE framework is pitched at a higher level than individual species, sites or attributes, it also has an inbuilt flexibility that can accommodate differing severities of environmental harm.

VPF also permits public preferences to be incorporated into appraisals in a transparent manner, consistent with economic theory. This contrasts with current RMA process, under which, even if the public is consulted, it is unclear how these consultations affect the final decision.

The final distinguishing feature of the VPF is its integral treatment of risk. It is reduction in the risk of a fatality that is valued, not the certain death of an identified person. Our framework incorporates this principle, unlike standard environmental valuation, which often posits (certain) changes in environmental attributes.

The distinction made above between a multi-layered, complex environment and simpler preferences for protecting human life should not preclude the adoption of a VPF-style approach to environmental valuation. A VPF is a single clear entity which becomes a benchmark value which can be adjusted for use in other contexts. In environmental matters, there is no such benchmark value except in rare cases such as global carbon credits, leaving councils, Environment Court judges and even sometimes central government policymakers without guidance on economic value when deciding what weight to place on protecting or allowing change in the natural environment. In many situations, it is difficult to build up a tailored layer cake of values that reflect all the facets of environmental change, without resorting to values transferred from elsewhere or averages that do not accurately reflect the marginal choices. Seeking public preferences to avert the risk of different scales of impact, without being precise on details, may have its limitations, but does have the advantage that it replaces the zero price implicitly applied to environmental change in much RMA decision making, which must surely be a gross underestimate. At the very least it removes the current anomaly in New Zealand whereby the transport sector explicitly values the protection of humans and directly embeds it into policy while environmental protection remains unquantified.

Value of a major adverse effect on the environment (VMAEE) framework

Although the VMAEE framework is pitched at a higher level than individual species, sites or attributes, it also has an inbuilt flexibility that can accommodate differing severities of environmental harm. It explicitly recognises that, for some aspects of environmental value, protection of existing features may be mission-critical (e.g. habitat essential for species survival), but for others some level of change may be acceptable because of substitution possibilities (e.g. recreation transferring from native to planted forests). It also requires a bridge between the valuation both of safety and of environmental impacts. This is provided by the concept of a major accident to the environment (MATTE), which underpins the Control of Major Accident Hazards (COMAH) Regulations 1999 in the UK,[5] but has no equivalent in New Zealand. In RMA language it might be termed a major adverse effect on the environment (MAEE). An MAEE would be flexible enough to cover both the risk of immediate catastrophic loss and the 'accident by stealth' of continued exposure to risk of degradation.

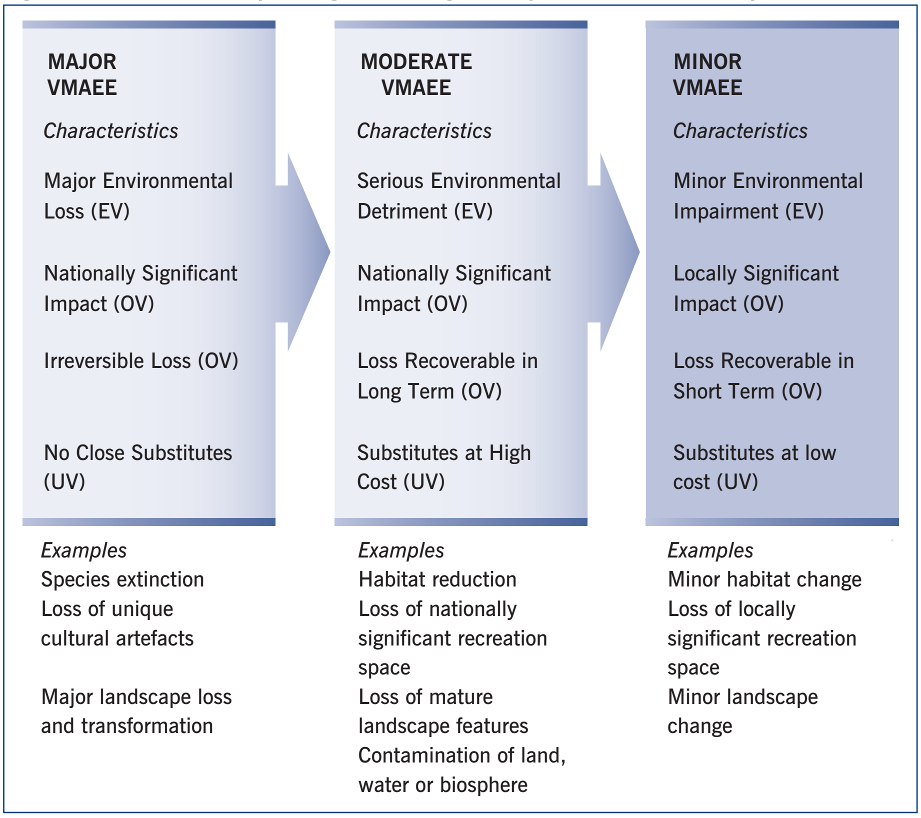
Applying the MAEE

Defining major environmental 'accident' scenarios in terms of scale, long- and short-term effects and the extent of impact on human population centres or natural areas allows non-market valuation techniques to be applied to establish people's preferences for reducing the risk of different combinations of effects at a range of prices, thus capturing the reduction in TEV from an MAEE. The arguments for and against different valuation methods and the often-voiced reservations about their validity are well rehearsed elsewhere and are not repeated here (see, for instance, NZIER, 2010; Pearce, Atkinson and Mourato, 2006). This does not negate the conceptual framework underpinning VMAEE elicitation but will undoubtedly have an impact on its empirical application. A VMAEE elicited using state-of the-art methods will clearly be less prone to error and bias than one elicited under outdated practices.

Operationalising the VMAEE

The VPF is the value of reducing the risk of the most severe life 'event', death, but reducing the risk of non-fatal injuries of varying severity is also used in regulatory analysis, requiring a value of preventing injury (VPI).[6] Likewise, our framework also accommodates adverse environmental effects of differing severity. Thus, an MAEE might be so serious that any environmental losses are irreversible

Figure 1: A VMAEE incorporating decreasing severity of environmental impact



(e.g. global extinction of a species, or the extinction of a keystone species in a habitat of national significance), but others might have a different scale and significance – e.g. serious but without the irreversibility of potential losses (localised extinction of a species abundant elsewhere). Quantifying the VPF is straightforward: it is calculated by dividing mean willingness to pay by the risk reduction.[7] The environmental analogue value – the VMAEE – would be calculated in similar manner, with less serious adverse effects scaled accordingly.

Defining a VMAEE requires overlaying the VPF concept with the components of TEV. As an illustrative, not prescriptive, example, Figure 1 delineates a VMAEE in terms of the degree of severity of environmental damage, and demonstrates how each environmental outcome maps to value. We restrict this to three types of MAEE, although more could be included and gradations could exist between these three types: for instance, an effect with characteristics of a major VMAEE except for the availability of close substitutes elsewhere would attract lesser value than a full major VMAEE, but perhaps higher value than the moderate VMAEE. In simple terms, environmental degradation that has a negative impact on human well-being reduces one or more of option value (OV), existence value (EV) or use value (UV). The value of reducing the risk of MAEEs of different severities is captured by the public's willingness to pay (in the same way as VPF is calculated). This will result in a range of indicative values for differing environmental effects and how the values change at the margin.

This differs crucially from existing approaches to project appraisal. Rather than having to determine the weight to be applied to individual environmental effects, the impact of these adverse effects is combined and assigned to varying categories of severity, determined by scientific/ecological characteristics. Economics can also inform this categorisation: for instance, scarcity and irreversibility enhance value, whereas abundance, availability of substitutes and ease of reproduction have the opposite effect. But the VMAEE is inherently interdisciplinary in approach. Economists need to draw on other disciplines' experts in characterising the nature and probabilities of accidental outcomes for the environment in the different severity scenarios, but once the values have been estimated they can be entered into the wider policy process, which includes both

Figure 2: An Example VMAEE Choice Set

ATTRIBUTE	CHOICE A	CHOICE B	STATUS QUO
Risk: Habitat loss	Reduced by 10%	No change	High
Risk: Landscape Change	increased by 2%	Increased by 5%	Low
Risk: Contamination	No Change	Reduced by 10%	Medium
Recreation	Improved trails (10%)	Improved trails (15%)	No improvement
Location	100 km away	1 km away	50 km away
Cost	NZ$30	NZ$50	NZ$0

Note: Risk reductions could be presented as 1/100, for example
Location can be expressed in distance bands to a site for a representative New Zealand

economic and non-economic considerations.

Deriving and applying a VMAEE in resource management

Derivation

Here we illustrate a hypothetical application of the framework at national level, although it could be amended to a smaller operational scale. Under this scenario, the government, through the RMA, sets the frame for regulating environmental harm (or preservation) across the country. A priori, it is unknown which particular site will be affected; instead there is a small risk at all sites. Thus, any value which reflects this risk can be applied to any proposed project (or to any site that might be vulnerable to adverse effects).

To be applicable at the national level we assume that at least some people derive existence value and/or some people would adopt an altruistic stance (Aldred, 1994), and hence be prepared to contribute to the prevention or reduction in the risk of an MAEE elsewhere in the country as well as in their immediate neighbourhood. This allows us to draw directly on the conceptual framework in Appendix 1 to inform the design of any empirical study to estimate a VMAEE.[8]

Willingness to pay values could be derived from various methods: e.g. hedonic pricing methods, random utility travel cost models, contingent valuation or choice modelling (Freeman, Herriges and Kling, 2014). We develop our example in the context of a choice experiment (based on Lancaster's (1966) model of consumer preferences and widely applied in health (Ryan et al., 2006), transportation (Hensher and Rose, 2005) and the environment (Adamowicz et al., 1998)). This could be informed by deliberative processes or focus groups which examine potential trade-offs in depth, and which can be used to refine the questions before applying them to a wider sample survey representative of the population at large.

In a VMAEE context, people's utility is a function of the different environmental attributes and the reduction in risk to these attributes. To facilitate generalisability and avoid the site-specificity problems discussed above, broad sets of attributes at risk of damage are defined in TEV terms. Respondents would first be made aware of the current conditions with respect to biodiversity significance, recreational opportunities and so on. They would then face a series of choice sets (see example in Figure 2) consisting of two or more differently specified, but related, sets in which they indicate their most preferred option.[9] By varying the attributes, levels of risk and price across choice sets, marginal values for each attribute can be recovered directly via econometric procedures (Freeman, Herriges and Kling, 2014), while estimates of overall welfare gains from the intervention as a whole can also be estimated (indirectly).

Moving forward, assume that a mean willingness to pay for a reduction in a risk to the environment has been estimated from a sample of New Zealand households. Appendix 2 considers a simple example of reducing the risk of an MAEE by 1 in 100,000 per site and shows how this can be aggregated into a societal value for this risk reduction – i.e. a VMAEE. This ex ante measure assumes that at the time of enactment the policy will be expected to prevent one adverse event in the forthcoming period, although in some periods more than one adverse event may be prevented and, in some periods, none. This mirrors the VPF, which is the value of preventing one fatality on average in the next period.

A VMAEE in this form could complement rather than supplant other forms of environmental valuation, by indicating public value of protection against the risk of adverse effects that cannot be valued in other ways. This is similar to the VPF, which is sometimes called the human cost of accidents, and combined with other accident cost estimates such as the cost of property damage, emergency services attending the scene, policing, and justice system costs that may follow if fault is established. Thus, the VMAEE would not preclude the use of biodiversity offsets as a means of mitigating the environmental impacts: if a choice set includes offsets, the reduction in risk to biodiversity would be assigned a less major VMAEE than it would if offsets were not feasible.

Applications

We now consider how the VMAEE approach could inform decisions made on biosecurity, freshwater management, the RMA and national living standards.

Ecosystems

In biosecurity, a key issue is what value should be placed on avoiding risks to species or habitats that are unique to New Zealand. There are periodic incursion risks, such as myrtle rust which threatens indigenous trees such as mānuka and the red-flowering pōhutukawa. There are also chronic risks from established introduced predators like stoats and possums, against which the government has granted initial funding of $28 million towards making New Zealand predator-free by 2050. Diminishing returns and increasing marginal costs may make eradicating the last breeding specimens prohibitively expensive, but policymakers are still interested in how much the public is willing to pay for more intensive predator management than is currently achieved.[10]

Protecting more habitats and wildlife communities lowers the probability of their being driven to extinction. A VMAEE could help infer societal values for risk and help prioritise how much habitat to protect and where, informing the trade-off between social and scientific objectives, although in some cases, such as risks involving pivotal keystone species, scientific considerations may continue to dominate. For example, in a New Zealand context, the Department of Conservation may have some scientifically determined bottom lines in terms of the portfolio of sites it needs to secure the survival of species, a representative diversity of habitats and the supply of ecosystem services. But the VMAEE could show the relative public value of securing environmental condition above those levels, which could assist the department with its priority setting and in demonstrating public value from extra investment funding.

Freshwater management

Deteriorating freshwater quality has recently risen in public awareness, due partly to agricultural intensification, which increases nutrient discharges to the environment, and partly to one-off events like the 2015 gastroenteritis outbreak in Havelock North, attributed to intrusion of faecal matter from sheep pastures into bores during rainstorms. These raise questions about the value of protecting surface water quality and groundwater against contamination, reducing the risk of infection from contact with water.

The question is whether the costs of so doing are justified by the benefits of reducing the frequency of such contamination. Risk of contamination varies with localised factors, such as the depth of aquifers, the location of recharge areas and the population potentially at risk – all matters which could be reflected in a VMAEE. Where water contamination has wider ramifications – e.g. affecting New Zealand's reputation as a tourist destination – a VMAEE could be informative in considering national assistance to poorer communities to enable them to reach a higher basic standard.

A VMAEE could also inform the National Policy Statement for Freshwater Management, which in 2014 set a national objective of improving the quality of all freshwater bodies to safely 'wadeable'. This was amended in 2017 with a new target of 90% of all rivers and lakes being safely 'swimmable' by 2040 (Ministry for the Environment, 2017). At what point would the costs incurred exceed the benefits gained? A VMAEE could help determine this by providing a comparable monetary value of benefits to assist in identifying where to prioritise improving water quality.

The VMAEE framework developed in this article combines the existing frameworks of TEV and the VPF applied to safety and adapts them to derive valuations of public aversion to risks to the environment.

The RMA

The RMA has come under increasing scrutiny over whether it appropriately balances the needs of development and environmental protection. Since coming into force, there have been 21 amendment acts and 34 regulations issued to give direction for more consistent implementation by the 16 regional authorities and 68 district and city councils that exercise powers under the act. Disputes under the act have recourse to the Environment Court, whose decisions can be appealed in the High Court, so the judiciary also influences implementation.

There are unavoidable trade-offs between environment and economic outcome in every decision under the act, but little guidance exists on how to make these trade-offs in economic terms. For RMA applications for local plan changes or consents for new land uses or discharges into air and water, the decision makers are left to weigh the benefits of approval against the localised environmental changes and an overlay of national priorities. Experts on ecology, visual amenity and recreation may assess the significance of an affected site from their own perspectives, but consideration of economic consequences is often limited to potential impacts on jobs and incomes, not the potential losses people face from changes in the environment and their willingness to pay to reduce the risk of loss, as captured by TEV. This can result in perverse outcomes: for instance, authorising the destruction of very rare habitats to enable a project that would create jobs and outputs that could be readily replicated by relocating the activity elsewhere.[11] A VMAEE would provide objective guidance on the relative value of different potential losses and improve consistency of decisions.

The government

The Treasury could adapt the VMAEE approach to its Living Standards Framework to place monetary values on natural capital (see van Zul and Au, 2018) and changes in environmental outcomes over time. The VMAEE approach could also be used to provide a monetary overlay to the initiatives of Ministry for the Environment and Statistics New Zealand in environmental reporting (see Ministry for the Environment, 2015), and be a step towards more explicit consideration of the economic value of (changes in) natural stocks than the natural resource satellite accounts prepared using the UN SEEA guidance for fisheries, forests, minerals and water (see Statistics New Zealand, 2018). The approach can also be used by other government departments, e.g. the Ministry for Primary Industries and agencies wherever there are environments at risk of degradation, and to which measures can be applied that affect the probability of adverse effects occurring.

Concluding comments

The VMAEE framework developed in this article combines the existing frameworks of TEV and the VPF applied to safety and adapts them to derive valuations of public aversion to risks to the environment. It complies with the economic principle of marginal values, but also meets policymakers' needs for flexibility, consistency and transparency. It can generate a small number of values that can be applied in any domain, ensuring that environmental resources are given the same weight across different sectors, while acknowledging that some Department of Conservation preservation activities with hard-to-ascertain probabilities and involving potentially irreversible outcomes can still be determined separately. In providing such a framework, we place the environment at the heart of, rather than adjunct to, economic decisions over natural resources in New Zealand.

The VMAEE serves a different purpose from the valuations of stocks in the SEEA. But it has some overlap with the ecosystem services approach, which provides a typography for identifying services from the natural environment that can be valued and mapped against TEV (as in Appendix 1). There is potential to develop this linkage in future as both the VMAEE and ecosystem services approaches evolve.

The advantages of the VMAEE are that it generalises the object of valuation around the scale and characteristics of environmental risks, rather than valuing specific environmental features, which may affect the non-market valuation responses (for example, charismatic 'mega-fauna' attract higher survey response values than do less visible but rarer species more pivotal in ecosystem functioning). It would be less prone to 'focus illusion', which lifts the values of subjects by bringing attention to them, and which also contributes to the widely reported 'part–whole bias', in which respondents indicate similar value for environmental attributes of greatly different scale and significance. And having a single suite of values for effects of different severity derived by a common method would be more widely applicable, and ultimately less costly to obtain, than the assortment of current ad hoc valuation estimates of specific issues.

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1 Built on ideas attributed to Krutilla, 1967.

2 VPF is equivalent to the value of statistical life (VSL) seen in some literature. We use VPF here following practice in the UK, where it is considered a more accurate description of what it does: see Clough, Guria and Bealing (2015).

3 For example, Lincoln University hosts a New Zealand non-market valuation database with summary details of over 150 empirical studies applying various methods to recreation, pollution, aesthetics, risk, transport and environmental protection; however, these provide insufficient estimates on particular topics to infer reliable generic estimates.

4 An example of this, which combines environmental consumer surplus values with GDP without adjusting for consumer surpluses on non-environmental consumption, is Costanza et al. (1997). While this approach allows society to track the value of stock over time, it is not appropriate to the type of natural resource management addressed in this article.

5 The mechanism by which the UK implements the Seveso Directive (82/501/EEC).

6 For example, the NZ Transport Agency values the reduction in risk of serious injury (requiring hospitalisation) at 10% of the VPF.

7 For instance, if the average willingness to pay to reduce the risk of fatality by 1 in 100,000 is $20, society's willingness to pay to avoid one anonymous fatality, the VPF, is $20÷0.0000001=$2 million (Lindhjem and Navrud, 2010).

8 Further assumptions would be required to enable the VMAEE to be used in economic regulation, although we do not develop them formally here. As in the VPF, we assume financial risk aversion and prudence with respect to current wealth. The environment is considered a normal good, so a person places higher value on a larger than a smaller reduction in a particular environmental hazard.

9 Following standard practice, such surveys are subject to extensive pre-testing and piloting to ensure that respondents understand the information and tasks, while retaining their scientific validity.

10 By comparison, in 2014 the Department of Conservation spent $31 million on pest control, mainly on reserve areas, and Operational Solutions for Primary Industry (OSPRI) spent $47 million on control of bovine Tb vectors on farmland and interstitial bush areas. The cost of ridding the country of introduced predators has been estimated at between $9 billion and $31 billion.

11 For example, on the Escarpment mine on the Denniston Plateau, the Environmental Court granted consent for an opencast coal mine that would destroy habitats that ecological experts for both sides agreed were extremely rare, although the economic benefits of jobs and incomes could be obtained from extraction elsewhere, as coal is not scarce in the region.

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Appendix 1: Total Economic Value And Ecosystem Services

Total Economic Value approach

Value Category	*Sub-Category*	*Value from...*
Non-use Value	Existence value	Retaining species, sites, habitats for their own sake
	Bequest value	Retaining unique natural features for future generations
	Scientific value	Potential for new scientific and educational understanding
	Spiritual/culture value	Deeper experience of a place that transcends amenity, associative and commemorative values
	Commemorative value	Connections with a significant event, idea or person
	Associative value	Essential element of wider identity
	Amenity/aesthetics	Visual qualities of physical attributes
Future Use Value	Quasi-option value	Retaining potential until better informed
	Option value	Retaining potential to use in future
Current Use Value	Indirect use value	Use supports other activities
	Direct use value	
	Non-consumptive	Use does not deplete resource
	Consumptive use	Use extracts or depletes resource

Ecosystem services	
Cultural services Non-material services obtained from ecosystems	Supporting services underpinning all other ecosystem services
Regulatory services Benefits from regulating services of ecosystems	
Provisioning services Products obtained from ecosystems (food, materials, energy, water)	

Appendix 2: Calculating And Applying A VMAEE For Policy

Aggregate annual WTP = $V x 1.47 x 106 (1)

∴Discounted present value of aggregate WTP over 20 years at public sector discount rate of 4% per annum

$= \$V \times 1.47 \times 10^6 \times 14.2$ (2)

$= \$V \times 20.9 \times 10^6$ (3)

Expected number of MAEE prevented over 20 years as a result of risk reduction

$= 1000 \times (10^{-4} - 10^{-6}) \times 20$ (4)

$= 1000 \times (99 \times 10^{-6}) \times 20$ (5)

$= 1.98$ (6)

This is typically referred to as the prevention of 1.98 "statistical" MAEE. Hence from (3) and (6) the aggregate WTP-based value per statistical MAEE prevented =

$$\frac{\$V \times 20 \times 10^6}{19.8} \quad (7)$$

$= \$V \times 10.1 \times 10$ (8)

However, the overall reduction in risk per MAEE site

$= (10^{-4} - 10^{-6}) \times 20$ (9)

$= 99 \times 10^{-6} \times 20$ (10)

$= 1.98 \times 10^{-3}$ (11)

Hence the WTP-based value of the 20 year reduction in risk per MAEE site

$= (\$V \times 10.1 \times 10^6) \times 1.98 \times 10^{-3}$ (12)

$= \$V \times 0.020 \times 10^6$ (13)

$= \$V \times 0.020$ million (14)

It is then easy to calculate the value of a 20 year risk reduction for a MAEE site for different mean WTP amounts. If mean annual WTP per household was $2.50 a VMAEE would be $51,900 while a $200 mean annual household WTP would generate a VMAEE of over $4.0 million. Table A1.1 contains implied VMAEES for WTP amounts between these two values. Note that this value applies to *each* MAEE site.

Table A2.1 Implied VMAEES for Different Household Mean WTP

Mean annual household willingness to pay	Value of 20 year risk reduction per MAEE site $'000
$2.50	51.9
$5.00	103.9
$10.00	207.8
$20.00	415.5
$50.00	1,038.8
$100.00	2,077.7
$200.00	4,155.4