9.2 Saltmarsh quality and extent

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Preamble: 'Salt marsh' is a collective term that refers to the many species of salt tolerant plants that are found in bays, lagoons, estuaries, river mouths and sheltered coastal areas, usually at or above the high tide mark [2]. They are also characterised by the absence of species that are not salt tolerant [31].

Also note that we have encompassed salt marsh 'extent' under salt marsh 'quality' given extent is one indicator of wetland condition as per [31].

State of Knowledge of "Saltmarsh quality and extent" attribute: Good / established but incomplete – general agreement, but limited data/studies

Overall, we consider the state of knowledge for the salt marsh quality and extent attribute to be 'good / established but incomplete'. Internationally and nationally, there is excellent and good evidence, respectively, relating salt marsh quality (including extent) to ecological integrity. However, NZ-specific data that quantifies stressor impacts on 'quality' and associated ecosystem services are limited, and data on tipping points are lacking. Nationally, there is a standardised protocol for monitoring, and management interventions are well known. However, monitoring of salt marsh quality is not routinely carried out across the country, leading to a lack of national-scale data and baselines for comparison.

Part A—Attribute and method

A1. How does the attribute relate to ecological integrity or human health?

There is excellent evidence globally and good evidence in Aotearoa New Zealand (hereafter Aotearoa) to show that salt marsh quality is closely tied to ecological integrity. Salt marshes are highly productive biogenic habitats that support biodiverse communities; these habitats are often comprised of various specialised plant and animal species that contribute to complex food webs, nutrient cycling processes and carbon storage [see review by [1,73,74]]. Salt marshes are naturally found along coastlines throughout Aotearoa. Their existence at the land-sea interface makes them important for terrestrial, freshwater, estuarine and nearshore coastal ecosystems.

Nationally, salt marshes support various threatened or at-risk plant and animal species including birds[2; 3, 4, 5, 6, 7, 8]. They can also provide habitat and foraging opportunities for native fish species[1, 9]. Salt marshes serve several physical functions, such as shoreline protection to control terrestrial erosion and natural wastewater treatment, improving water quality by trapping sediments and pollutants (e.g., excessive nutrients) from runoff[10; 11]; the latter of which helps prevent the contamination of coastal waters and may reduce the risk of harmful algal blooms. Furthermore, salt marshes sequester carbon dioxide, mitigating climate change by storing carbon in plant biomass and sediments [e.g., [12, 13]].

A2. What is the evidence of impact on (a) ecological integrity ~~or (b) human health~~? What is the spatial extent and magnitude of degradation?

Globally and nationally, there is good evidence of the impact of degraded salt marsh quality on the ecological integrity of coastal systems [e.g., for Aotearoa, [1]; globally, [14]]. Fragmentation and loss of salt marsh from stressors like coastal development, recreation, and livestock grazing / trampling has led to reduced filtering capacity, release of carbon, and decreased shoreline protection[11,12,15,16,17]. Notably, this has impacted the national-scale loss or severe reduction of salt marsh habitat for various threatened and at-risk bird species, the impacts of which can be seen in reduced population trends[18]. In addition, the incursion of invasive, weedy species (e.g., *Spartina* spp.) have displaced and/or outcompeted indigenous salt marsh flora[19]. However, it is worth noting that introduced plants can still carry out key ecosystems services such as wave attenuation[16] and / or carbon storage and sequestration[20].

A3. What has been the pace and trajectory of change in this attribute, and what do we expect in the future 10 - 30 years under the status quo? Are impacts reversible or irreversible (within a generation)?

Salt marsh quality in Aotearoa has declined over time, particularly due to habitat loss as a result of historic land reclamation [e.g., for agriculture and/or development,[1, 2, 21, 22, 23]]. At least 31 threats have been identified for salt marsh habitat in Aotearoa. Threats deemed to have extreme effects on salt marsh are further land reclamation and sea level rise, both of which have the capacity to eliminate existing salt marsh habitat[24]. Threats that can have a major impact on salt marsh are causeway construction, increased sediment loading on rivers, and oil pollution[24]. The interactions among sustained stressors continue to reduce habitat suitability, and thus salt marsh quality, for key indigenous saltmarsh-forming species [e.g., [1, 25]]. Furthermore, lag times between management actions and stressor reduction remain for some cases (see Section B5). While these multitude of stressors are actively interacting to reduce salt marsh quality (to varying magnitudes based on location), most can be considered reversible. However, natural salt marsh recovery is generally slow (up to 40 years) and may not fully recover without additional interventions[26, 27]. This means that retaining or improving salt marsh quality will be heavily dependent on effective legislative action that affords salt marshes adequate protection, monitoring, risk mitigation, and restoration where needed [22, 28, 29].

Climate change is also predicted to impact salt marsh quality and stressors associated with this are expected to exacerbate over the next 10-30 years[24, 30]. See Section D3 for climate change impacts and management actions.

A4-(i) What monitoring is currently done and how is it reported? (e.g., is there a standard, and how consistently is it used, who is monitoring for what purpose)? Is there a consensus on the most appropriate measurement method?

To our knowledge, there is no routine monitoring or reporting of salt marsh quality (beyond extent), *per se*, on a national scale for Aotearoa. As a result, there is consensus lacking on the most appropriate measurement method for assessing this attribute in Aotearoa. A standardised monitoring protocol for measuring wetland condition, based on both broad- and plot-scale data collection and applicable to salt marsh, was developed by [31]. This 'wetland condition index'[1] does not appear to be routinely used in Aotearoa for state of the environment (SOE) monitoring of salt marshes, although some councils have applied it in individual cases [see [32,33]].

Data on salt marsh extent (including dominant vegetation types), which is relevant to salt marsh quality, is routinely collected through SOE estuary habitat mapping by councils e.g., following the National Estuary Monitoring Protocol [NEMP] broadscale methods[34]. Historical loss in salt marsh area is also often reported during broadscale estuary SOE monitoring where this information is available (e.g., indicator called '% of historical remaining')[35]. A recent scoping review of the current NEMP outlines a conceptual approach for future salt marsh monitoring that includes 'condition' in respect to factors such as erosion, vehicle damage and weed incursion[36]. National-level monitoring of saline wetland extent (which includes salt marsh and mangroves) is reported in a Stats NZ environmental indicator called "Wetland Area"[2]. However, this assessment does not capture small wetlands less than 0.5 ha in area that are known to have important ecological value, e.g., [21].

Some salt marsh quality data are present for Aotearoa across a number of scattered sources. Some of these data are gathered for individual studies or research, e.g., impacts of livestock grazing, [37]; vehicle use [29]. Some of it will also likely result from resource management act (RMA) related processes. Additional information on the presence of non-indigenous plant species (e.g., the invasive weed *Spartina* spp.) is being collected by councils and / or other government organisations such as Department of Conservation (DOC) to inform eradication activities, for e.g., as part of regional council pest management plans [38]. Data on the number / type of non-indigenous species trapped (e.g., for pest mammals) or eradicated (e.g., for *Spartina*) along with biodiversity indicators (e.g., indigenous bird abundance), is likely to be collected and stored haphazardly by various community groups[3] and governmental organisations like DOC.

A4-(ii) Are there any implementation issues such as accessing privately owned land to collect repeat samples for regulatory informing purposes?

Current salt marsh quality monitoring methods require on-the-ground fieldwork. Access is a key consideration given that some salt marshes are located on private land and are therefore subject to

[1] The 'wetland condition index' encompasses five wetland condition indicators: change in hydrological integrity, change in physicochemical parameters, change in ecosystem intactness, change in browsing, predation and harvesting regimes, and change in dominance of indigenous plants.
[2] https://www.stats.govt.nz/indicators/wetland-area/
[3] For example, Tasman Environmental Trust's 'Battle for the banded rail' project. https://www.tet.org.nz/projects/battle-for-the-banded-rail/

the landowner's property rights. The safest and / or most cost-effective site access option may require travel over private (including Māori-owned) land in some cases. Accessing private property without the owner's consent can be considered trespassing, so clear communication, establishing good relationships, and addressing any concerns or impacts on the landowner's property or operations will be necessary. Formal access agreements or contracts may need to be established. It is possible that some salt marshes are not able to be accessed during certain times of year due to ecological factors such as nesting of rare birds. Some salt marshes may also be in or nearby culturally significant areas.

Various health and safety factors also need to be considered in relation to fieldwork. These include access to the marsh in respect to presence of any channels of water and whether a 4-wheel drive vehicle or a boat is required for transport. Depending on the monitoring method being used, technical expertise such as plant species / taxa identification and mapping / GIS skills may also be required. Aerial imagery of the salt marsh, of suitable quality, taken with no cloud cover and likely within a certain season or month, is also required for mapping habitat extent. This imagery can be collected by aeroplane, drone or satellite. Additionally, monitoring may need specialised scientific equipment such as field pH and/or conductivity meters depending on the method being used.

A4-(iii) What are the costs associated with monitoring the attribute? This includes up-front costs to set up for monitoring (e.g., purchase of equipment) and on-going operational costs (e.g., analysis of samples).

We anticipate that the main cost to undertake monitoring of the five indicators encompassed under the wetland condition index by [31] is paying field staff for their time. However, other costs include laboratory analysis of various parameters within soil samples. There are also a number of required equipment items although most of these are relatively inexpensive except for field meters to measure pH and conductivity (which could cost approximately $6000 combined) and GPS (see following section). Refer to the attribute template for the 'Wetland condition index' for further detail.

As an example, in 2002, the approximate cost to survey one estuary (for all substrate and vegetation types) for salt marsh extent (i.e., one indicator of quality) following NEMP was estimated to be between $15,000 to $30,000 [34]. However, this cost was dependent on the size of estuary and whether suitable aerial photographs were available or needed to be obtained for the survey. The approximate cost now will likely differ e.g., to account for inflation and technological advances. Most costs related to personnel time spent collecting data and reporting results, however, key equipment includes GPS ($300 - $800) and ARC GIS or equivalent software ($100 - $3800). New, more cost-effective techniques, such remote mapping and machine learning e.g., [39], may be used in the future but this will need to gather the relevant information required to inform salt marsh quality [e.g., as per [31]].

Monitoring frequency will also dictate costs over time. For mapping extent, for example, the NEMP recommends broadscale monitoring every 5 years.

A5. Are there examples of this being monitored by Iwi/Māori? If so, by who and how?

There are te ao Māori based indicators for wetland monitoring, as outlined by [31]. To our knowledge monitoring of these indicators has not been carried out on a regular (or even infrequent) basis for salt marshes in Aotearoa. The “Ngā Waihotanga Iho – The Estuary Monitoring Toolkit”[1] provides tools to measure environmental changes that occur in estuaries over time. Among other things, this involves flora identification (broadly for estuaries), but again we are unsure whether it has been implemented.

Environmental-based indicators including cultural health indicators, have been co-developed for monitoring and management of local wetlands and some estuaries. An example is development of cultural health assessments by Te Rūnanga o Ngāi Tahu for Te Ihutai/Avon-Heathcote Estuary to ensure their values are included [40]. It is noted that within the assessment were observations related to modifications of vegetation communities regarding the incursion of invasive species [40]. Another example of iwi-led estuarine monitoring methods that includes salt marsh is outlined by [41] for Whakatū/Nelson, however, we are unsure whether this monitoring has been implemented.

A6. Are there known correlations or relationships between this attribute and other attribute(s), and what are the nature of these relationships?

Salt marshes that are part of larger, continuous coastal habitats and have unobstructed hydrological connections tend to have higher habitat quality and ecological functions than isolated or fragmented marshes, all of which relates to ‘landscape connectivity’. Salt marshes that offer limited ‘access to natural areas’ (specifically in relation to human disturbance) also often have higher habitat quality and support more diverse ecological communities. However, this does not exclude the potential impacts of pollution on salt marsh quality from ‘microplastics’ and ‘heavy metals’, which can come from distant sources. Additionally, salt marshes often occur in areas with significant mud deposition from tidal action, meaning ‘mud extent’ and characteristics of mud or tidal flats (e.g., ‘soil bacteria composition’, ‘soil carbon’, ‘surface erosion/runoff control’) can influence the establishment, distribution, and quality of salt marsh and associated habitats, e.g., mangroves and seagrass[1].

Salt marshes are transitional habitat found between multiple ecosystems, meaning there will likely be a crossover in monitoring methods with the quality and extent of habitats such as dunes, seagrass, and mangroves. In addition, the ‘wetland condition index’ is applicable to other wetlands besides salt marshes. Provided there is sufficient data resolution to assess salt marsh quality (i.e., that can suitably measure indigenous vs non-indigenous species), methods for monitoring ‘indigenous plant dominance’ in the terrestrial domain may also overlap with those used to measure salt marsh quality.

Part B—Current state and allocation options

B1. What is the current state of the attribute?

There is good evidence that salt marshes have been lost nationally over time[22, 21], although historical baselines aren’t necessarily known. The current state of remaining salt marsh quality is not well understood at the national and local level. There is information available from estuaries around the country on salt marsh extent based on habitat mapping. However, in general, current knowledge and reporting of the overall quality of existing salt marsh habitats in Aotearoa are poor.

[1] https://niwa.co.nz/te-kuwaha/tools-and-resources/ng%C4%81-waihotanga-iho-the-estuary-monitoring-toolkit

B2. Are there known natural reference states described for New Zealand that could inform management or allocation options?

Salt marsh systems that have retained their historical extent and have limited to no introduced plant species or evidence of human-induced impacts (e.g., vehicular trampling, pollution, livestock grazing) could be considered a reference state with respect to quality. Salt marshes found in remote, protected locations such as national parks may best serve as examples of natural states with limited impact from human-induced stressors. However, sites within remote, protected areas may still contain stressors like introduced weeds and mammals and be subject to climate change impacts.

Information regarding historical reference state could also be gathered through methods such as sediment coring under existing and former salt marsh habitats, which can avail reference states via analysis of pollen, plant remains, and geochemical indicators [e.g., [42, 43]].

B3. Are there any existing numeric or narrative bands described for this attribute? Are there any levels used in other jurisdictions that could inform bands? (e.g., US EPA, Biodiversity Convention, ANZECC, Regional Council set limit)

Guidelines for allocating scores, on a scale of 0–5, to the various indicator components of the 'wetland condition index' are outlined in [31]. Additional, quantitative limits to maintain the ecological integrity of *freshwater* wetlands are detailed in [44]. These are based on attribute states ranging from A (excellent condition) to D (poor condition). There is at least one example where these freshwater wetland attribute states have been applied to salt marshes [e.g., [32]].

B4. Are there any known thresholds or tipping points that relate to specific effects on ecological integrity?

International thresholds / tipping points for salt marsh quality have been reported, but data for Aotearoa is lacking. The thresholds / tipping points depend on salt marsh type and local structure of associated salt marsh floral and faunal communities. For example, shifts in characteristics of nekton and vegetation communities from a natural state (e.g., indigenous plant and fish dominated communities) to impacted states (e.g., invasive plant and invertebrate dominated communities) can signal ongoing degradation[45]. Slowed salt marsh recovery rates, increased similarity in saltmarsh quality (i.e., low quality) across time and sites, increasing variability in seasonal salt marsh state, and increased variability in data structure (i.e., increased data skewness) have also been related to tipping points in salt marsh states[46].

B5. Are there lag times and legacy effects? What are the nature of these and how do they impact state and trend assessment? Furthermore, are there any naturally occurring processes, including long-term cycles, that may influence the state and trend assessments?

Lag time between stressor and impact on salt marsh quality will be site- and stressor-dependent. For example, there may be no lag time in cases of direct and severe physical damage, such as shoreline hardening for coastal development. Alternatively, lag times are expected from the impacts of stressors / factors such as contaminant incursion, droughts and land-based nutrient and sediment runoff [e.g., [47, 48, 49]]. In terms of the impact of non-indigenous plant species, there will be a time when these exist as seeds / seedlings before becoming established and spreading.

Plant growth and recovery of species interactions can be highly influenced by legacy effects following historic land reclamation, coastal development[1], drainage [50], nutrient enrichment[51], and fires[28].

B6. What tikanga Māori and mātauranga Māori could inform bands or allocation options? How? For example, by contributing to defining minimally disturbed conditions, or unacceptable degradation.

Mātauranga Māori is place-based and so the local context is important. Salt marsh and coastal wetlands are highly valued by Māori as important systems that provide resources for cultural practices [e.g., weaving, construction, 51], as habitat for taonga species and mahinga kai species [e.g.,53]. Understanding Indigenous-based indicators (i.e., specific tohu and/or taonga species, see Section A5) with whānau, hapū and iwi could be used to inform bands/allocation options.

Part C—Management levers and context

C1. What is the relationship between the state of the environment and stresses on that state? Can this relationship be quantified?

In cases where salt marsh is destroyed, such as shoreline hardening, there is obviously a direct detrimental relationship between the stressor and salt marsh quality. Furthermore, there is also some information for Aotearoa documenting the relationship between salt marsh quality and other physical stressors such as livestock grazing and trampling and vehicle damage [e.g., 29, 37]. However, there are still challenges associated with disentangling interactions among multiple stressors, respective lag times, additional legacy affects, and overall salt marsh quality. In addition, the impact of stressors on ecosystems is usually highly context-specific (i.e., place and history are very important) and so effective management and needs to understand and allow for that context.

C2. Are there interventions/mechanisms being used to affect this attribute? What evidence is there to show that they are/are not being implemented and being effective?

Key management interventions include salt marsh protection and the elimination or reduction of stressors. From a policy perspective, the RMA (1991) is a key piece of legislation that sets out how we should manage our environment. In addition, the New Zealand Coastal Policy Statement[54] guides councils in their day-to-day management of the coastal environment. There are various other relevant government-related directions and management implementations, for example for freshwater, biosecurity, fisheries, wildlife, climate change, threatened species and national parks. Despite this, [22] and [55] outline how government management is still failing to fully protect wetland / salt marsh habitats in Aotearoa.

Salt marsh restoration is another management intervention that can be carried out to improve quality of degraded salt marsh by government, iwi/hapū, community groups or others interested in recovering estuarine habitat [e.g., 56]. Salt marsh species are grown in some commercial nurseries and so are widely available for restoration projects, and there have been several studies on survival and growth of various species used in salt marsh restoration that can inform restoration efforts [e.g., see review by 1].

C2-(i). Local government driven

Local governments can take action to protect (e.g., through policy / plans) and restore salt marsh at the regional level. A number of local government-driven initiatives are present throughout Aotearoa aimed at restoring salt marsh habitat. Some examples include the restoration of endemic salt marsh species such as oioi (Salt marsh Ribbonwood, *Apodasmia similis*) at sites along the Taranaki coastline; salt marsh and adjacent habitats at Charlesworth Reserve, Christchurch; and the restoration of Wainono Lagoon, Canterbury. Additional projects can be found at the DOC Restoring Estuaries Map[56].

C2-(ii). Central government driven

Central government can provide key funding for the protection, conservation and restoration of salt marshes. For example, for relevant DOC activities, projects under the Freshwater Improvement Fund and MfE's 'At risk' catchments programme such as the Te Hoiere / Pelorus Catchment Restoration Project. There is also potential to consider salt marsh restoration for carbon credits, for example within the Government's Emissions Trading Scheme [12, 57].

C2-(iii). Iwi/hapū driven

Indigenous taonga and their ecosystems are protected under Te Tiriti o Waitangi. Hapū and iwi are driving the Hinemoana Halo project alongside Conservation International [75], which includes supporting nature-based solutions including restoration of coastal wetlands, which holistically can support supporting saltmash habitats. There are many examples of the suite of tools that hapū and iwi have towards supporting ecological health [76]. In addition, in terms of research to inform management interventions, a project on potential estuarine thresholds and indicators, included collaboration with iwi, has aimed to achieve impact by combining knowledge streams to inform catchment-based solutions that lead to improved mauri of catchments and estuaries[58]

C2-(iv). NGO, community driven

A number of community-driven wetland restoration projects exist throughout Aotearoa. Some examples include the Manawatū Estuary Trust, the Cobden Aromahana Ecological Restoration Group, and the Waimea inlet restoration project, to name a select few. Additional projects can be found at the DOC Restoring Estuaries Map[56]. There is also potential to consider salt marsh restoration for carbon credits including through voluntary offset schemes e.g., as is being explored by The Nature Conservancy (an NGO) for Aotearoa[59].

C2-(v). Internationally driven

Internationally-driven obligations relevant to the protection of salt marsh quality include the Ramsar Convention of which Aotearoa is a signatory meaning it plays a part in the international effort to conserve wetlands[60]. There are multiple Ramsar sites around the country that contain salt marsh habitats. Under the Convention to Biological Diversity (CBD), Aotearoa is required to have a national biodiversity strategy and action plan through which obligations under the CBD are delivered. Aotearoa also has international climate change obligations such as those under the Paris Agreement. We understand that Aotearoa has also signed other international agreements (e.g., Free Trade) that require conditions around environmental management and climate change to be upheld. Restoring the vitality of degraded systems (which include salt marsh ecosystems) is crucial for fulfilling the UN Sustainable Development Goals and for meeting the targets of the UN Decade (2021-2030) on Ecosystem Restoration (UN-DER).

Part D—Impact analysis

D1. What would be the environmental/human health impacts of not managing this attribute?

Failing to manage salt marshes poses a significant threat to coastal environments, triggering a cascade of ecological problems. For example, the degradation of salt marsh quality can lead to a reduction or loss of salt marsh nursery functions, which is reflected in the decline of bird populations [1]. Additionally, impacted salt marshes may lose their ability to filter pollutants and excess nutrients from runoff water before it reaches the ocean leading to increasingly polluted coastal areas. This influx of pollutants may disrupt the delicate balance of marine life and can trigger harmful algal blooms and oxygen depletion zones. Reductions in salt marsh quality can sever vital links in the marine food web, which can have cascading impacts on the overall health and biodiversity of coastal ecosystems. Reduction in salt marsh quality may also lead to increased erosion of shoreline habitats. Overall, impacts on marine ecological health and biodiversity have a detrimental flow-on effect for mauri, cultural practices and mātauranga such as those interconnected with mahinga kai (site, species and habitats).

D2. Where and on who would the economic impacts likely be felt? (e.g., Horticulture in Hawke's Bay, Electricity generation, Housing availability and supply in Auckland)

The economic impacts of salt marsh degradation / loss are likely to be felt among fisheries, coastal infrastructure development, and tourism sectors. Reductions in salt marsh quality could lead to a loss of habitat for commercially-important species[1, 9, 61]. Similarly, reductions in salt marsh quality can limit the suitability for threatened and endangered bird species, which limits coastal tourism opportunities for certain groups (e.g., birders) and local businesses[62]. Reduced salt marsh quality causing poorer water quality, can lead to various detrimental implications for commercial activities such as aquaculture, fishing, tourism, and recreational industries such as water-sports events. Reductions in salt marsh quality can also limit their protective capacity as natural buffers that absorb wave energy and lessen the impact of storm surges[63]. The loss of salt marsh exposes coastlines to increased erosion, leading to a retreat of beaches and a heightened risk of damage to coastal infrastructure[64].

D3. How will this attribute be affected by climate change? What will that require in terms of management response to mitigate this?

Sea level rise and increased storm frequency is expected to lead to the erosion and loss of existing salt marsh [e.g., from 'drowning', [30, 65, 66]]. Sea level rise may also result in reduction in salt marsh extent (and therefore quality) due to 'coastal squeeze' if suitable space is not available for it to migrate to due to the presence of roads, urban areas, stopbanks, or agricultural land directly inland from current salt marsh[67, 68]. Increased storm frequency will likely lead to increased run-off of sediment, nutrients and contaminants. Although note that sediment supply is key for salt marsh vertical accretion, which can improve marsh resilience to sea level rise[69]. Alterations to water quality, which includes changes in salinity, can alter salt marsh community structure and lead to further incursion of invasive species. Increasing temperatures due to climate change is already leading to range shifts of indigenous and invasive species. Increased frequency of fires as a result of climate related issues, such as drought poses an additional risk as many salt marsh species, overseas at least, are shown to be not well adapted to wildfire regimes and demonstrate even slower recovery after burns compared to non-burned salt marshes [e.g., [70]]. However, increasing temperatures may yield some-short term benefits for certain salt marsh vegetation species, such as increased biomass[71].

Reducing / stopping anthropogenic greenhouse gas emissions is crucial for mitigating climate change impacts. Besides this, management actions to reduce climate change impacts on salt marsh include providing a habitat buffer along current salt marsh margins to provide sufficient space for this habitat to migrate inwards. This can be accomplished through the removal of any hard structures such as seawalls and roads, to reduce impacts of 'coastal squeeze'[68, 72]. Resilience of salt marsh habitats to climate change can be further improved by reducing impacts from other stressors, such as catchment sediment and nutrient runoff and protection from livestock grazing and development. The quality of salt marsh habitats that are currently degraded can also be improved through actions such as increased protection and restoration.

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