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Elevating and Recognising Knowledge of Indigenous Peoples to Improve Forest Biosecurity

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Current forest biosecurity systems and processes employed in many countries are, in large, constructs of Western principles, values and science knowledge that have been introduced and integrated internationally. They are often devoid of knowledge, and of the values and principles, held by indigenous people, even those who have an intimate and enduring relationship with their forests. Indigenous people are also often overlooked in policy and decision-making processes, yet are often most affected by biosecurity pests and pathogens that impact native plant species that they may rely on for sustenance, cultural or spiritual purposes. By adopting an inclusive approach, scientists and indigenous people can achieve more comprehensive and robust biosecurity outcomes through a shared diversity of knowledge and at the same time serves to elevate and recognise the importance of indigenous knowledge. A co-innovation approach can also result in more widespread adoption of tools or practices by end-users including indigenous people. Understanding New Zealand Māori and their unique knowledge base can help improve forest biosecurity systems and practices, as can discussions of barriers that can and have prevented adoption of inclusiveness. Here we outline key principles behind indigenous engagement, specifically the need to develop enduring relationships.

Keywords: traditional indigenous knowledge, indigenous engagement, kauri dieback, myrtle rust, New Zealand Māori

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INTRODUCTION

Indigenous people have a time-acquired intimate knowledge of ecosystem functions, distribution of resources and an interconnectedness between the environment and their culture. This is common for indigenous peoples across the globe, who account for less than 5% of the world's population but hold almost 20% of the earth's landmass (United Nations Department of Economic and Social Affairs, 2009), which has enabled them to endure centuries of living and harvesting from the land. This is referred to as traditional ecological knowledge, the knowledge that is acquired through extensive and long-term coexistence with the environment they inhabit (Berkes et al., 2000). Much of this knowledge is intergenerational observation of people, place and species, which is passed down through generations (McGregor, 2002; Ramstad et al., 2007). Based on indigenous observations of the natural environment, and the reoccurring way in which they occur, hypotheses can be made about how natural systems work. These can be interpreted in a cultural context and used in environmental management practices and ecological preservation. Traditional ecological knowledge is often transmitted via oral traditions of storytelling and song, so can give insight on past ecological states; this can be useful for scientists who are trying to understand the current ecology of ecosystem populations and landscapes (Ramstad et al., 2007).

Indigenous knowledge of the environment can be attributed to indigenous peoples' reliance on the environment as a provider and their experiences of hardship that have led to sustainable management techniques derived from adaptation to their unique environment. This level of knowledge and understanding of environmental indicators needs to be empowered and elevated in contemporary science as their insight on interconnectedness and interdependence of ecosystem components gives rise to a distinctive perspective on underlying ecosystem structures. Involvement of indigenous values can also result in meaningful community involvement and greater chance for long-term success and indigenous groups can see benefits from early and on-going involvement in incursion response; or long-term management of forest pests and pathogens in the form of economic returns or reinforcements of cultural values (Wehi and Lord, 2017).

Whilst the inclusion of indigenous people in policy and decision-making processes is defined by individual country governance, the ability to include an indigenous perspective and their knowledge into research is in the hands of scientists. New Zealand Māori have often been described as pioneers in forging new pathways for indigenous peoples across the globe (Amoamo et al., 2018; McClure, 2021). In this paper, we show how traditional ecological knowledge can help improve forest biosecurity systems and practices. We will explore the barriers that have and can hinder relationships between scientists and indigenous communities, and outline key principles to engage people and communities for development of co-innovation approaches.

INDIGENOUS TRADITIONAL ECOLOGICAL KNOWLEDGE

Traditional ecological knowledge, sometimes described as intergenerational knowledge, can provide an important contribution to scientific knowledge (Stevenson, 1996). Although traditional knowledge or practices may not be expressed in biosecurity terms, there are numerous examples of how knowledge could be incorporated across the biosecurity system, in many cases the practices and outcomes are relevant (Lambert and Mark-Shadbolt, 2021; Maclean et al., 2021). Environmental management practices and worldviews of indigenous societies across countries are different but key principles of their relevance and how they can be included to provide insight on how to manage current and future environmental issues is comparable.

For many indigenous peoples, traditional ecological knowledge is often incorporated into storytelling and oral histories and frequently describes a holistic and spiritual connection (Lefale, 2010; Chao and Hsu, 2011; Yuan et al., 2014). The use of prayer and spiritual practices such as the recognition of gods can be an acknowledgement or pay homage to the provider(s) who are the deities over that realm. Hence, understanding the interconnectedness of the knowledge held in respect to its cultural and spiritual significance is important. This can also help understand why certain contemporary science practices or proposed methodologies may be unacceptable or contravene traditional beliefs.

Mātauranga Māori is a large body of knowledge of Polynesian origin, derived and translated through each generation (Hikuroa, 2017; Mercier, 2018). An interconnected knowledge system incorporating both the observed and learned knowledge, which can be both contemporary and traditional. This is a practice that incorporates the seen and the unseen, utilising cosmology and theology, ecology ethics and science.

Understanding ecological environmental impacts caused by biosecurity disruptions will impact on the ability of a community to interact with that environment for traditional or cultural purposes. However, these limitations do not detract from the need to preserve these environments for the intergenerational benefit of those connected to the whenua (land) and those with the responsibility of kaitiakitanga (stewardship) (Kennedy, 2017). This knowledge accumulated by Māori according to their experiences, history, worldview, culture and aspirations can reflect a range of values, concepts, principles and practices that define Māori as a distinct social group but is also knowledge localised to specific iwi (tribes), hapū (sub-tribes), and whanau (families). This interconnectedness that binds generations to the land with the knowledge that the mātauranga will aid the restoration of highly disturbed or affected areas (Lambert and Mark-Shadbolt, 2021). An integral part of mātauranga Māori is pūrākau, Māori cultural narratives, stories and myths shared through generations as a tool to recall culture, history and knowledge (Henare, 2001) and are deliberately constructed to encapsulate and condense the realities of Atua (gods), the universe and humanity, and ultimately Te Ao Māori (Māori world view) (Hikuroa, 2017). Pūrākau is an embodiment of strong cultural roots that foster growth, learning and development (Henare, 2001).

This knowledge, traditional or contemporary, indigenous or western is not unique to the New Zealand Māori but common for most indigenous peoples across the world. Here we provide some brief and selected examples of traditional knowledge and practices of Aboriginal Australians, Aboriginal Canadians and Polynesians that could be used or are relevant management options for forest biosecurity. These are followed by a more in depth case study of New Zealand Māori. In all cases, indigenous knowledge extends substantially beyond the examples provided.

Aboriginal Australians

Aboriginals are the indigenous people of Australia with long-term ecological and environmental management knowledge with the potential to be utilised in the contemporary management. This knowledge has helped nurture these people for thousands of years providing a safe, secure supply of food able to sustain many generations. Regarded as a nomadic race, there was a purpose for this type of subsistence (Crabtree et al., 2019).

Aboriginal Australian groups have extensive seasonal knowledge, which provides a temporal framework for resource management. Traditional management practices include, but are not limited to, regulation of resources due to customary rules, seasonal timing, frequency, intensity and long-term patterning of usage. For instance, Uninggan people practise planned rotational harvests, this involves moving to new locations before depleting the land of resources in order to maintain long-term productivity of that area (Prober et al., 2011). Wiradjuri people practise burning rituals, where selected areas of the plains are burnt during weeitt (autumn). This encourages the growth of fresh grass for the following spring, as well as, forcing animals to the foothills, ensuring a food source in winter campsites (Prober et al., 2011).

Whilst not framed as forest biosecurity, both have direct application to forest biosecurity and the recent devastating fires across Australia have highlighted how traditional burning practices that are specific and tailored to the ecosystems can be advantageous over contemporary methods (Bird et al., 2018). Often referred to as “cool burning” this method was a way of reducing build-up of litter accumulated over time through dead and dying leaves, branches and trees (Skiba, 2020). By burning this litter, it removed the risk of bone dry tinder either becoming combustible or adding to the fuel of a fire.

Aboriginal Canadians

Similar to the Aboriginal Australians, fire was an important part of forest ecosystem management for Aboriginal Canadian communities. With fire as a regular and natural component of Canadian forests, including for a number of fire-dependent species, the Anishnaabe tribe used fires to create disturbances in the forest canopy, often to provide successional management (Berkes and Davidson-Hunt, 2006). It also offered ways to provide natural fire breaks through placement of green vegetation and reduce forest floor fuel loads. Forests were managed both at site scale and the landscape scale to meet multiple and integrated objectives and values. A key principle was maintaining habitats and species to ensure the full suite of plant species for the future (Berkes and Davidson-Hunt, 2006).

These practices are likely to have contributed to maintaining a balance in pest and pathogen control (Parker et al., 2006), and although not expressed as contemporary scientific practices, traditional practices offer a diversity of methods and ways to manage forest biosecurity issues.

Polynesians

Pacific Island societies have vast knowledge systems and possess specific management tools for their local ecosystems. Indigenous Pacific Islanders are recognised as key resources for the development of adaptation strategies (Pearson, 2020).

Tapu is a practice in Polynesian societies and signifies things are forbidden or sacred. This can be used to forbid certain behaviors or access to a geographic area and defines what is considered sacred and what is expected to maintain sacredness (Percival, 2008). In Micronesia, there is a tradition system called “mo,” which designates parts of land, a whole island or reef area as restricted (Percival, 2008). In the Cook Islands, ra’ui is a customary prohibition for a defined period of time, often seasonally, and was traditionally used on land (Te Ava and Page, 2020). Examples of practices such as ra’ui are common across Polynesian countries. Some examples of traditional Polynesian adaptation practices include: the use of traditional farming techniques for crop diversification, minimising the risk of harvest failure; change in food habits when crops are not producing good harvests, people revert to another sources of food; and changes to the environment, for example when customs of planting crops or trees are no longer related to the phases of the moon/tidal patterns (Percival, 2008).

NEW ZEALAND MĀORI CASE STUDY

When Māori migrated to New Zealand, the people had to adjust to the different temperatures, seasonal rhythms and to discover new resources. Interacting with the new environment and its processes allowed Māori to learn and develop detailed environmental knowledge over the centuries (King et al., 2008). Through this experience-based understanding of the environment, Māori inherited the ability to live, work and navigate their lives successfully and harmoniously; Māori ancestors established a philosophy of preservation and conservation, which is a foundation for future generations to learn from Harmsworth and Warmenhoven (2002). Māori possess local environmental knowledge, gained through personal experiences and ongoing interactions with their local ecosystems. By understanding the sensitive balance between people and the environment, it enabled Māori to navigate their resources sustainably by living in harmony with all natural elements.

According to Māori traditions, Tāne-mahuta (God of the Forests) is the founder of humankind who fashioned the first woman, Hineahuone, from the soil at Kurawaka (Royal, 2005). Tāne-mahuta assembled Hineahuone of the raw material of Papatūānuku (Earth Mother), he then sneezed into her physical body giving her life and imbued her with mauri (life essence). Hence, the phrase “tihei mauri ora” – the sneeze of life (Roberts et al., 1995). Tāne-mahuta created the perfect being; her tinana (body) is ingrained with mauri, her wairua (spirit) is from the sacred ochre of Papatūānuku, and her hinengaro (mind) is imbued with three baskets of knowledge from the upper-most realm of the heavens (Walker et al., 2019).

This creation story is a source of knowledge that has fashioned the concepts and interconnections Māori have with the environment (Henare, 2001; Harmsworth and Awatere, 2013). This relationship is derived from the notion that humankind has descended from Papatūānuku (Earth Mother) (Higgins, 2004). By mapping kinship relationships with ancestors and their associated environments, Māori created culturally appropriate ways of acting (Forster, 2019). These actions are tabulated through a set of inherited obligations and responsibilities to ancestors, taonga (treasured) sites and for future generations (Forster, 2019).

Kaitiakitanga (guardianship, stewardship) lays down the basis of what constitutes a communal balance; it creates a unique role for each branch within the community in maintaining balance when managing resources (Roberts et al., 1995). Kaitiakitanga is the management of the environment based on Te Ao Māori (the Māori world view) that is: all life is connected and no creature is superior to the natural world but is part of the network or fabric of life. This is the overarching Māori environmental principle to protect and preserve ancestral lands and waters to pass along to subsequent generations (Kennedy, 2017). Māori maintain their relationship to the environment through this practical philosophy of environmental guardianship. There is interdependency between humans and ecosystems, which is expressed in this narrative giving rise to manaaki whenua (caring for the land) and manaaki tangata (caring for the people) (Rameka, 2018). Māori seek to understand the entire ecosystem; this stems from the ideology that biodiversity is embellished through the interrelationships of all living things, which are dependent on each other (Harmsworth and Awatere, 2013). The holistic Māori world view supports the view that ecosystems are made up of many dynamic organisms as a functional unit (Harmsworth and Awatere, 2013), including humans. Ecosystem survival relies on interdependency rather than organisms being indifferent to it.

Philosophically, Māori do not consider tangata (people) to be separate from nature; instead, humanity and nature are direct descendants from mother earth (Henare, 2001; Harmsworth and Awatere, 2013), which reinforces the belief that earth does not belong to humanity, but humanity belongs to the earth. Te Ao Māori is seeking to ensure Papatūānuku and tangata whenua (people of the land) activities are managed in harmony and balance (Wakefield et al., 2006). The kaitiakitanga approach to managing ecosystems is informed by generations of mātauranga passed on and refined over time. It is also founded on, and informed by, a particular belief system or world view deeply grounded in mātauranga developed by physical and spiritual experience.

Indigenous Biosecurity in Action

The word "whenua" typically translates to land; however, it also translates as the placenta. This is significant to Māori because the land is the nurturing source of human existence, just as the placenta is for the newborn child (Henare, 2001). Thus, humanity has obligatory roles to the placenta that nourishes them (Henare, 2001). Papatūānuku must be protected to ensure the continued survival of her many offspring; considering the health and well-being of Māori are inextricably linked to the health of our environment, which is described by the following whakatauki (proverb):

Te Takahi i te tapu o Papatūānuku, Te takahi i te tapu o te Tangata.

If the sacredness of our Earth Mother is trampled, then the sacredness of people is also adversely affected (Wakefield et al., 2006).

Māori groups have been involved in issues surrounding *Phytophthora agathidicida*, a soil-borne pathogen responsible for the dieback of kauri (*Agathis australis*) (Lambert et al., 2018; Lambert and Mark-Shadbolt, 2021). Kauri trees are the centrepiece of Māori cultural and spiritual beliefs. Tāne-Mahuta, the largest known kauri tree, is in an infected forest; the health of this forest is inextricably linked to the mauri (life essence) and mana (prestige) of the local Māori. Māori knowledge has been a big part of kauri conservation, outlining rationale and frameworks entirely based on mātauranga Māori. Using holistic approaches based on the domains of Atua, Māori have been able to recommend the inclusion of the monitoring of other species within the kauri forest, the surrounding environmental conditions, and the proximity of significant water bodies, levels of sunlight, human activities and tree condition. Through partnering with contemporary scientists, these attributes have been included in projects and programmes of research via co-design from the outset. Traditional knowledge has also been used to develop different types of control methods, for example trialling of whale oil in the treatment of diseased kauri trees based on the traditional relationship between whales and kauri bark and the use of vibration as a physical treatment, and to improve selection and potential efficacy of control methods by incorporating traditional ecological knowledge (Harrison, 2018; Lawrence et al., 2019; Smith and Mark-Shadbolt, 2020). Other mātauranga management practices implemented have included rāhui, the restriction of access to an area of land to allow recovery; tohu, the monitoring of the signs and sentinels of health or illness and possible paths to increase mauri; rongoa (traditional treatments), companion planting, elimination of (pathogen) carrier plants, use of barrier protection and physical treatments (Lambert et al., 2018; Bradshaw et al., 2020; Lambert and Mark-Shadbolt, 2021).

Similarly, Māori involvement, co-design and co-innovation has been an integral component of the myrtle rust (causal agent *Austropuccinia psidii*) response in New Zealand. Myrtle rust was first detected in New Zealand in 2017 and threatens many native Myrtaceae species such as the pōhutukawa (*Metrosideros excelsa*), rātā (*Metrosideros* spp.), ramarama (*Lophomyrtus bullata*) and mānuka (*Leptospermum scoparium*) (Sutherland et al., 2020; Toome-Heller et al., 2020). During the incursion, response training of Māori technicians allowed regional deployment during surveillance but subsequently has meant Māori, who oversee large tracts of native forest, are informed and knowledgeable leading to more effective and widespread management and involvement (Lambert et al., 2018). Co-development of surveillance protocols has increased and improved the range attributes measured and its applicability to a wider range of end-users, as has design of a platform for live reportings of their suspected findings (Scion, 2017).

Practices and management techniques developed by Māori tribes (iwi) to deal with the threat of myrtle rust include monitoring indicator species such as the highly susceptible ramarama, as well as weather patterns, bird behavior (timing population, presence) and flowering, to be able to understand the presence, spread, and behaviour of myrtle rust, as well as the tohu (signs) and symptoms. Bird behaviour and flowering also allow Māori kaitiaki (Māori guardians) to recognise issues of food reserves and time of harvest of culturally connected resources. Saving seed, replanting, transplanting to another environment and rāhui (exclusion from locations for a period of time) are all considered essential to protect these susceptible species and have been undertaken in regions across New Zealand. In particular, seed collection has highlighted a success story between contemporary science and indigenous inclusion, where resources on how to collect and process seed for long-term storage, as well as units to store seed, were sourced from Kew Gardens, United Kingdom (Biological Heritage, 2018). This resulted in substantial amounts of seed collected from across Myrtaceae ecosystems in New Zealand and will provide a valuable resource for the future conservation and restoration.

The incorporation of traditional ecological knowledge has enriched the quality and diversity of contemporary science, and has also included and upskilled those who have an interest and enduring relationship with forests but may not have previously had the opportunity or resources for involvement. Whilst the above highlights some positive examples of how indigenous Māori knowledge and participation can strengthen and extend forest biosecurity practices, the authors acknowledge Māori still struggle to be involved in forest biosecurity from the outset, to get their management strategies recognised and implemented, and to obtain adequate resources to do so (Teulon et al., 2015; Lambert et al., 2018; Lambert and Mark-Shadbolt, 2021).

BARRIERS TO ENGAGEMENT

In many incursions and research programmes related to forest biosecurity, indigenous people are often excluded and under-recognised despite their vast amount of knowledge. Cultural values are infrequently used in goals and priorities across the biosecurity pipeline (Lambert and Mark-Shadbolt, 2021), and often there is failure to recognise ceremonial and medicinal harvesting of plants and of basic food requirements (Wehi and Lord, 2017). Collaboration between indigenous communities, scientists and resource managers on research and management projects is a constructive pathway to bridge science and indigenous knowledge. Inclusion at the science level could also serve to provide exposure for their inclusion at government level.

When scientists engage with indigenous people they bring their scientific knowledge for discussion. Inevitably, there are differences in the two approaches but both groups are wanting to achieve similar goals; the preservation of ecosystems from pest or pathogen threats. A typical issue is that contemporary science knowledge "goes over the heads" of indigenous people as it comes across in unfamiliar terms. Conversely, scientists are generally very unfamiliar with indigenous approaches to ecosystem management, the concepts involved and the language used. Furthermore, when discussed in terms of spirituality or mythology are often dismissed as being non-scientific. There is a barrier or gap between the two groups that can cause projects to stall or for local knowledge never to be brought to bear alongside the scientific knowledge scientists bring to a project. A challenge for the science community is to: understand the world view of the indigenous people whose land or plants they may work with; have a real knowledge of how indigenous people approach forest stewardship; communicate their own knowledge and terms in a way that is familiar and understandable; and be able to engage in meaningful discussions with indigenous people that draws out their traditional ecological knowledge.

A major obstacle for indigenous people is the lack of resources and opportunities for engagement and capacity building (Taiepa et al., 1997). There is an inherent expectation that indigenous people can meet during working hours, when often they have their own jobs. There is also an expectation they can fund travel for themselves and that voluntary participation is acceptable. Conversely, the scientist has a paid position, funds to travel and the research undertaken can lead to secure long-term funding. There can also be a reluctance to formally include indigenous people in scientific publications or research projects beyond engagement. Often this can be directly related to resources but means the scientific community needs to anticipate and include funds in research proposals. Institutional inertia (being passive, inactive) can often provide a barrier for scientists themselves within their organizations but this is not insurmountable.

A lack of reciprocity can be a major barrier and can cause long-term mistrust. This occurs when scientists engage with indigenous groups but end up extracting the information required and moving on without any form of enduring reciprocity. Information and data can be used and published without permission or appropriate acknowledgement of its origin. Often this can lead to further funding for science groups, providing a monetary incentive; however, this does not extend to the indigenous groups themselves who have contributed knowledge. The development and implementation of a strategy that incorporates cross-community and cross-disciplinary collaboration that acknowledges the unique status and contribution of indigenous groups is important. This can also help prevent misinterpretation of values or their dilution to metrics, such as monetary worth (Harmsworth and Awatere, 2013).

OVERCOMING BARRIERS TO WORKING WITH INDIGENOUS PEOPLE

In terms of practical engagement, the importance of relationships and trust is emphasised for a successful project (Thornton and Scheer, 2012). Scientists often note the importance of ongoing relationships between themselves and the community, "*Trust and respect for each other were the most fundamental and time consuming to establish and demonstrate*" (Thornton and Scheer, 2012). This level of importance in a relationship is also reflected across national and international collaborations between science groups and relationships with industry (Orecchini et al., 2012; Kraut et al., 2014). Strong robust relationships built on integrity and trust are forged by having open and honest conversations. The same needs to apply to indigenous people, working with them as a separate group and not including them as part of the "community," because their knowledge and intrinsic and enduring relationship with their local environment is what sets them apart.

Here we highlight four key aspects to engaging with indigenous people:

1. **Early engagement.** Involve indigenous groups very early in biosecurity project development to gain trust and feedback.
2. **Speak the language.** Learn basic greetings and introductions as well as understand words that can help to explain concepts or values.
3. **Co-develop a framework.** This could include how indigenous groups could be involved in co-design the of research projects and have direct input into its implementation, opportunities for capacity building and further involvement in research opportunities if possible, and provide a mechanism for future dialogue to maintain an ongoing relationship.
4. **Establish agreements**. Recognise and formally acknowledge the contribution of traditional ecological knowledge to the research process; agree on protections over the traditional indigenous knowledge shared –

FIGURE 1 | Māori indigenous engagement model developed as a framework of how to engage and work with Māori. The framework is based on the traditional Māori process of removing toxins from karaka *(Corynocarpus laevigatus)* kernals prior to eating, as a model for successful engagement. If one step is missed, the toxins will not be removed from the resulting kernals; similarly, if we take short cuts in the engagement process then we will not remove all doubt and suspicion. This framework was developed by Alby Marsh, Jenny Green, Hone Ropata, Bob Fullerton (The New Zealand Institute for Plant and Food Research Limited) and Matua Grant Hawke (Ngati Whatua Ki Orakei).

namely over how the information provided can be used and communicated by each party, published or publicised, used or not in commercial applications, how rights to such applications are handled, and preserve the right of the indigenous people to withdraw access to information.

When working alongside indigenous people, emphasis must be placed on the need for innovative methods to build trust and explore common ground and differences, for example, meeting at traditional meeting places to establish guiding principles, dialogue and creating a collective symbol as a metaphor for co-management (Taiepa et al., 1997). Similarly, development of frameworks based on principles, processes and concepts that are familiar with indigenous groups is important. Here we show a framework developed for engagement with New Zealand Māori that is based on the steps required to remove toxins from karaka (*Corynocarpus laevigatus*) kernels, which make them highly poisonous, so they can be safely eaten (**Figure 1**). We also show how the fundamental principles of this framework can easily be adjusted and tailored to other indigenous groups (**Figure 2**). In this case, the framework developed for Aboriginal people in Australia was based on the preparation of cakes from cycad

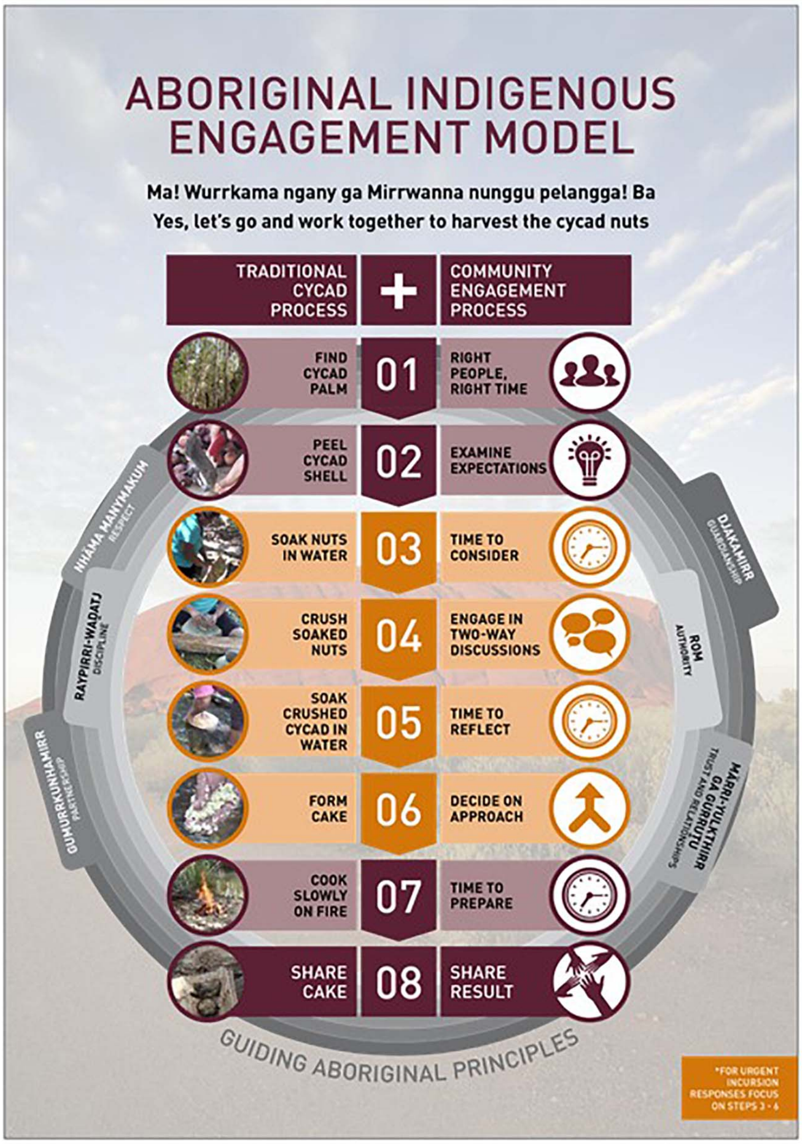

FIGURE 2 | Aboriginal indigenous engagement model developed as a framework of how to engage and work with Australian Arborgines. The framework is based on the traditional Aboriginal process of removing toxins from cycad (*Macrozamia* spp.) nut kernals prior to eating, as a model for successful engagement. In this framework, essential steps have been identified for urgent incursion responses. If one of these steps is missed, the toxins will not be removed from the resulting nuts; similarly, if we take short cuts in the engagement process then we will not remove all doubt and suspicion. This framework was developed by Linda Ford, Ruth Wallace, Kathy Guthadjaka, Pawinee Yuhun, Chloe Ford and Johanna Funk (Charles Darwin University).

(*Macrozamia* spp.) nuts, which, similarly to karaka, also contain toxins that need to be removed before they can be consumed (Beck, 1992).

Establishment of frameworks and agreements that involve indigenous people and clearly demonstrate respect, dialogue and negotiation at the borders of knowledge systems can enrich knowledge, research and outcomes, and also allow focus on shared goals that can be mutually beneficial. This manuscript provides a context for understanding the relationship indigenous people have with their environment, how their traditional ecological knowledge can enhance and benefit contemporary knowledge and provides tools for scientists to engage with indigenous people on forest biosecurity in a way that is culturally appropriate.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

RK reviewed literature, compiled information including traditional knowledge, and wrote an initial report. AM developed the frameworks, provided information and narratives including traditional knowledge. BG drafted the manuscript based on the initial report. All authors contributed to the background and discussion, and have edited and read the full manuscript.

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