31 Where to invade next: Inaction on biological invasions threatens sustainability in a small island developing state of the tropical South Pacific

Marie-Isabell Lenz[1,2,7], Stephen Galvin[2], Gunnar Keppel[3], Sunil Gopaul[2,4], Matthias Kowasch[5], Michael J. Dyer[3,2], Dick Watling[6], Sherri Lodhar[2], Geon C. Hanson[2], Stefan Erasmi[7], Hans Juergen Boehmer[2,8,*]

[1]*United Nations University (UNU-EHS), Bonn;* [2]*School of Geography, Earth Science and Environment, University of the South Pacific (USP), Suva;* [3]*School of Natural and Built Environments and Barbara Hardy Institute, University of South Australia, Adelaide;* [4]*Forest Monitoring Division, Guyana Forestry Commission;* [5]*Department of Geography and Regional Science, University of Graz;* [6]*NatureFiji-Mareqeti-Fiji;* [7]*Department of Geography, University of Goettingen;* [8]*Institute for Applied Ecological Studies (IFANOS), Nuremberg.*

*Corresponding author: juergen.boehmer@usp.ac.fj; http://orcid.org/0000-0002-9176-4836

Keywords

Biodiversity conservation; CBD; Convention on Biological Diversity; Fiji; forest reserve; *Iguana iguana;* island biogeography; invasive alien species; Mahogany plantation; nature conservation; *Pinanga coronata*; SIDS; sustainable development; terrestrial biodiversity; tropical rainforest

Abstract

Oceanic island ecosystems contain a disproportionate number of Earth's terrestrial species, many of them endemic or indigenous to only one or a few islands. Consequently, the importance of islands in the quest to protect terrestrial biodiversity has been increasingly recognised and included in global environmental agreements. Nevertheless, oceanic island ecosystems remain extremely vulnerable to anthropogenic disturbance and its impacts, particularly in terms of the uncontrolled spread of introduced species, so-called biological invasions, leading to substantial biodiversity loss and fundamental changes in ecosystem functioning and structure. The South Pacific region is a hotspot of biodiversity but also has the world´s highest concentration of invasive alien plant species. Although the issue of biological invasions has been increasingly acknowledged by local governments and international agreements, invasive alien species are often not monitored properly on Pacific islands. Furthermore, knowledge of the potential impact of invasive alien species regularly does not result in on-the-ground action, adding to the growing extinction threat. This inaction persists despite international and national efforts for sustainable use and nature conservation of terrestrial biodiversity in the region's Small Island Developing States. We illustrate this problem with two relatively recent biological invaders in Fiji: the ivory cane palm (*Pinanga coronata*) and the green iguana (*Iguana iguana*). We use these examples to examine the potential consequences of continuing inaction, despite awareness in relevant government departments, for native forest biodiversity and human livelihoods. Through an examination of the institutional background, we discuss steps towards good governance and sustainable development of terrestrial biodiversity in the Small Island Developing States of the tropical South Pacific, where on-the-ground action to control, eradicate and prevent invasive alien species is desperately needed.

31.1 SUSTAINABLE DEVELOPMENT, ISLAND BIODIVERSITY, AND BIOLOGICAL INVASIONS

In late 2017, global attention was focused on the South Pacific region and its Small Island Developing States (SIDS) during the 23rd Conference of Parties (COP 23), jointly hosted by Fiji and Germany, at the World Climate Conference in Bonn, Germany. As did previous events of this kind, this Conference highlighted the position of South Pacific islands at the forefront of climate change with wide-ranging discussions on climate change mitigation and adaptation. However, the South Pacific region is also at the forefront of biodiversity loss due to the inherent vulnerability of island ecosystems (Keppel *et al*., 2014) and the ineffectiveness of conservation actions (Keppel *et al*., 2012; Brodie *et al*., 2013). In this chapter we will highlight how insufficient management of invasive alien species is threatening native biodiversity and human livelihoods in the Pacific, and will illustrate this with the case studies of two emerging invasive alien species that are having devastating impacts on native rainforest ecosystems in Fiji.

The need to halt the alarming rate of global biodiversity loss is addressed by the United Nations' Sustainable Development Goals (SDGs) to be accomplished by 2030 (IAEG-SDGs, 2016). Target 15.5 highlights the need to reduce the degradation of natural habitats, to halt the loss of biodiversity and to protect and prevent the extinction of threatened species. Tropical oceanic islands have high, often endemic biodiversity (Kier *et al*., 2009; Keppel *et al*., 2016), and therefore play a key role in the protection of Earth´s terrestrial biodiversity (e.g. Genovesi, 2011; Kueffer *et al*., 2014). In the topical South Pacific, the French territory of New Caledonia, the East Melanesian Islands, and Polynesia/Micronesia are recognised global biodiversity hotspots (Mittermeier *et al*., 2005). Islands therefore provide opportunities for formulating new strategies for biodiversity conservation and the sustainable use of marine, freshwater, and terrestrial ecosystems (SCBD, 2005; Clout and Williams, 2009). Furthermore, islands remain essential testing grounds for the development of theoretical and practical methods in the fields of evolution, invasion biology, ecology, biogeography, and conservation (e.g. MacArthur and Wilson, 1967; Vitousek, 2004; Pungetti, 2012; Kueffer *et al*., 2014; Fernández-Palacios *et al*., 2015).

Oceanic island ecosystems are highly vulnerable to human disturbances and their impacts, particularly biological invasions (e.g. Kier *et al*., 2009; Kueffer *et al*., 2010; Keitt *et al*., 2011; Clout and Veitch, 2011; Genovesi, 2011; Meyer, 2014; Van Kleunen *et al*., 2015). In New Caledonia, 83% of the endemic plant species are considered threatened (Pouteau and Birnbaum, 2016). Invasion by non-indigenous species is one of the most pressing issues in applied ecology, second only to habitat destruction as a primary cause of biodiversity loss (Enserink, 1999; Boehmer, 2011a). Management of invasive alien species (IAS) is mandated for all signatories in Article 8 (h) of the Convention on Biological Diversity, which declares that parties shall 'prevent the introduction of, or control or eradicate, those alien species which threaten ecosystems, habitats or species' (SCBD, 2005, p. 133). This multilateral environmental agreement is 'the only globally applicable, legally binding instrument to address generally alien species introduction, control and eradication across all biological taxa and ecosystems' (Shine *et al*., 2000, p. 14).

The Pacific islands have experienced great biodiversity losses since human colonization, with invasive alien species contributing considerably (e.g. Smith, 1985; Denslow, *et al*., 2009; Keppel *et al*., 2014). Some alien species can cause fundamental changes in indigenous ecosystems, including the extirpation of native species (Nishida and Evenhuis, 2000; SCBD, 2001; Mueller-Dombois, 2006). Oceanic islands harbour more naturalised alien plants than similarly sized mainland regions, and Pacific islands show the steepest increase in the cumulative number of naturalised species per unit area on Earth (Van Kleunen *et al*., 2015).

Several introduced plant species are now dominant elements of Pacific forests (see e.g. Meyer *et al*., 2008; Boehmer and Niemand, 2009; Minden *et al*., 2010a, 2010b; Mueller-Dombois *et al*., 2013).

Plants, at 89%, are the most frequently introduced species in the Pacific region (UNEP-WCMC, 2016). The Pacific Islands Ecosystems at Risk (PIER) database lists, as of September 2018, 1,930 invasive alien plant species (Denslow *et al*., 2009; PIER, 2018a), a notable increase on the 1,132 identified four years previous (Meyer, 2014). Of those 1,930 species, 597 have been recorded from Fiji (PIER, 2018b). Only 12 of the species identified in the PIER database have been comprehensively examined, with study sites predominantly in Hawaii and the Galapagos Islands (Meyer, 2014). This illustrates the dearth of knowledge about IAS on Pacific islands and suggests that many invasive alien species on South Pacific islands remain undocumented.

The ecological impacts of invasive alien plants have severe consequences for the more than 50 million people who live in SIDS (Reaser *et al*., 2007). This is particularly relevant where forests provide significant livelihood opportunities for people in rural areas (FAO, 2014), as is the case in the South Pacific (Mohamed and Clark, 1996). The livelihoods of these biodiversity-dependent people are under increasing pressure, as invasive alien plants are a major factor in the loss of ecosystem goods and services (Kueffer *et al*., 2010). Safeguarding island forests from invasive alien plants is, therefore, critical in order to ensure the lasting protection of natural resources, and that future generations have access to these goods and ecosystem services.

Management of invasive alien species in Pacific SIDS is hampered by their geographic and economic circumstances, which place constraints on suitable options for the monitoring, documentation, and risk assessment of invasive species taxa (SCBD, 2005). The vast geographic dispersion complicates close collaboration among Pacific Island countries and territories (Meyer, 2014), and funding for conservation remains limited and mostly tied to short funding cycles (Keppel *et al*., 2012). These limitations also restrict the ability to determine the species that have the greatest actual and potential impact in the region, and therefore require immediate action (Tye, 2009). Furthermore, most land is under indigenous tenure (e.g. Jupiter *et al*., 2014; SPREP, 2016a), making the nation-wide implementation of action plans more challenging (DoE, 2007; SPREP, 2016a; GoF, 2017). For example, in Fiji, more than 87% of the land, and 90% of the forest, is under customary (*iTaukei*) ownership.

31.1.1 The trans-disciplinary nature of managing biological invasions: International agreements

Economic development, anthropogenic disturbance, and habitat diversity influence invasive alien plant species richness on oceanic islands (Daehler, 2008; Tye, 2009; Kueffer *et al*., 2010). Denslow *et al*. (2009) illustrate that economic and transportation development can increase the number of invasive alien species, suggesting that, on average, the presence of an airport with a paved runway adds 108 PIER-listed invasive alien species to an island. Accordingly, invasion biology cuts across several academic disciplines and is an integrative interdisciplinary and transdisciplinary research field (Boehmer 2011a).

The 9th CBD Conference prioritized IAS, highlighting that ‘the significant adverse ecological and economic effects of certain alien species on biological diversity and human health’ should be addressed (SCBD, 2005, p. 504). In this context, ‘alien species’ include alien invasive species and pathogens that carry vector-borne diseases spreading across biogeographic boundaries. The impacts of these ‘alien species’ are forecast to be exacerbated by climate change (Settele *et al*., 2014). The conference further emphasised the trans-disciplinary nature of the field, highlighting the need for a comprehensive and interdisciplinary approach instead of a sectoral approach (Perrings *et al*., 2010).

To address remaining gaps and inconsistencies in this international framework (Clout and Williams, 2009), relevant issues for managing IAS were included in the 2010 Biodiversity Targets (CBD, 2013) and the Aichi Biodiversity Target 9, as part of the CBD's Strategic Plan for Biodiversity 2011-2020 (Butchart *et al*., 2010; CBD, 2013). For the Aichi Targets to be met, contracting parties of the CBD are urged to work together in a coordinated manner and with collective action (SCBD, 2005) to enhance the 'detailed knowledge of native biodiversity and of potential inter-actions between invading non-native species and native species' (Baur and Schmidlin, 2007, p. 257).

Despite these efforts, implementation of many objectives remains problematic. This is due to the diversity of CBD members, the broadness and non-binding character of the policies, a lack of concrete enforcement mechanisms, and the lack of concrete penalties or sanctions (Perrings *et al*., 2010; Genovesi, 2011; Andresen *et al*., 2012). Only a few objectives have binding value; for example, the aforementioned Article 8 (h) is, in reality, merely a 'broadly phrased obligation' to manage IAS (Shine *et al*., 2000, p. 14). Instead, contracting parties are called upon to formulate their own action plans and to choose appropriate measures to preserve and protect biodiversity. Implementations of the broad and highly interpretable goals remain under the contracting parties' own evaluation and responsibility (Shine *et al*., 2000). While protocols potentially offer more binding regulations (Andresen *et al*., 2012), only two have been adopted: the Cartagena Protocol on Biosafety (Perrings *et al*., 2010) and the Nagoya Protocol (Andresen and Rosendal, 2014), neither of which have been ratified by many countries.

IAS have also been incorporated into Target 15.8 of the Sustainable Development Goals (IAEG-SDGs, 2016). However, the SDGs do not explicitly acknowledge that invasive alien species management requires a trans-disciplinary approach to prevent negative social, economic, and environmental impacts. Those impacts, in turn, would reduce the success of sustainable development, economic growth, biodiversity conservation, the provision of ecosystem services, food and water security, poverty alleviation, and health (Jupiter *et al*., 2014; GEF, 2016).

31.1.2 Regional biodiversity policies in the South Pacific

Reaser *et al*. (2007) and Meyer (2014) emphasise that globalisation is a central factor in the spread of invasive alien plants. This makes close international cooperation essential for successful invasive alien species management in the South Pacific. The CBD supports this notion. It acknowledges, in its Guiding Principles for the Implementation of Article 8 (h), the extraordinary situation that SIDS are facing in dealing with invasive alien species. The CBD also highlights that the situation requires further support and allocation of resources (SCBD, 2005).

Although ecosystem functioning and biodiversity sustain human well-being, health, culture, and the economy in Pacific island communities (Jupiter *et al*., 2014), the 'coverage of the land and seas of Oceania by protected areas is low' (SPREP, 2016a, p. 44). Invasive alien species constitute a tremendous and increasing threat to ecosystem functioning and biodiversity in the Pacific (Daigneault and Brown, 2013; Meyer, 2014). Despite these strong ecological impacts that degrade livelihoods, research and policies have primarily focused on species that affect national economic interests – including plant pests – and/or human health (DoE, 2007, 2014).

The CBD advises that, for the successful abatement of invasive alien species, the legal framework for biodiversity conservation and mitigation of the threat of invasive alien species needs to be internationally constituted. Regional organizations can function as connectors and coordinators, defining and utilising national priorities, such as capacity-building, guidance, specific implementation, and management strategies (Sherley *et al*., 1999; Perrings *et al*., 2010; Andresen *et al*., 2012). The development of mechanisms for trans-boundary, regional,

and multilateral cooperation (Reaser *et al*., 2003) has allowed particular gaps in the international regulatory framework to be filled (Clout and Williams, 2009). Joint collaboration of regional networks and national policies may help countries by formulating mutual standards in research, management measures, and key policy tools, each of which is essential for successful and cost-effective alien species management (Shine, 2006). Furthermore, the promotion of structure-building facilitates the exchange of information, and technical expertise gained from experience, early warning systems, and the identification of common priorities and threats are crucial (Perrings *et al*., 2010).

Several of the South Pacific's regional projects, organizations, and networks have addressed the conservation of biodiversity and non-native contaminants with a range of policies and legislative measures on various spatial scales (Jupiter *et al*., 2014). The South Pacific Regional Environment Programme (SPREP), the Secretariat of the Pacific Community (SPC), the Pacific Invasive Initiative (PII), and the Pacific Invasive Learning Network (PILN) are the main regional agencies tackling the issue of invasive alien species (Tye, 2009). A set of regional guidelines for invasive species management in the Pacific were endorsed in 2009 by the 26 member countries and territories of SPREP. The objectives and strategic plans are to provide information, awareness, infrastructure, protocols, legislation, funding, and linkages (Sherley *et al*., 1999; Tye, 2009) necessary for protecting the ecosystems of Pacific island countries and territories from invasive alien species (Tye, 2009; Perrings *et al*., 2010; Jupiter *et al*., 2014). 'An ideal future scenario for invasive species management will include ecosystem-based adaptation at island and national scales, involve local communities, build capacity, use a multi-partner approach, and communicate successful strategies and tools' (SPREP, 2016b, p. 12).

Another SPREP initiative is the Framework for Nature Conservation and Protected Areas in the Pacific Islands Region (2014-2020). The framework offers guidance to help accomplish the CBD Aichi Targets through the implementation of National Biodiversity Strategy and Action Plans (NBSAPs). Each signatory of the CBD is required to implement the NBSAP goals on a national and supra-national level, in addition to various other international, regional, and local conservation initiatives (SCBD, 2005; Jupiter *et al*., 2014; SPREP, 2014, 2016a; GoF, 2017). Of the region covered by SPREP, 14 countries are signatory parties to the CBD, and 12 of these have a National Biodiversity Strategy and Action Plan (SPREP, 2016a). SPREP further coordinates the Regional Invasive Species Programme, which was created to produce a regional invasive alien species strategy for the Pacific islands and was formalised in 2005 (Tutangata, 2000; Reaser *et al*., 2003).

31.1.3 Challenges for regional cooperation

The situation of SIDS in the Pacific is particularly complex. The Pacific Ocean encompasses one-third of the globe, as much as the Indian, Atlantic, and Arctic oceans combined, and is the planet's largest single geographical feature (GEF, 1993). The extensive dispersion of islands within nations and territories, as well as the vast oceanic distances between them, make many islands relatively inaccessible (Meyer *et al*., 2008), thus complicating management of IAS and adding to the extinction problem faced by the region. This situation creates issues for regional cooperation (Tye, 2009) owing to a general lack, and uneven distribution, of regional biological information and data relating to native and non-native species and groups (Ash and Vodonivalu, 1989 in DoE, 2007).

Amid a multitude of frameworks, agreements, stakeholder networks, financial mechanisms, and databases, the region has implemented a number of regional projects. One example is the recently completed GEF (Global Environment Facility)-IAS Project (2011-2016), which produced guiding publications on key invasive species issues and a Battler Resource Base, with up-to-date information on invasive alien species, aiming to improve the capacities of Pacific islands (SPREP, 2017). Another example is the Pacific Invasive Species

Guidelines Reporting Database, initiated in 2016, containing national, territorial, and regional progress. This was established to help implement the 2009 Guidelines for Invasive Species Management in the Pacific (SPREP, 2017). Significant implementation (addressing eradication but also control, biosecurity, and associated capacity-building) has been delivered by BirdLife International and Island Conservation.

However, to effectively manage invasive alien species, Pacific islands must improve central governance capacity for implementing laws, regulations, and management measures (Jupiter *et al*., 2014). Shine (2006) mentions that trained personnel, adequate quarantine measures, risk assessment facilities, necessary funding, and political will are still lacking. Existing legislation and policies are often weak and do not comprehensively address the impact of invasive alien species on biodiversity (Sherley *et al*., 1999). In addition, legislation and policies are inadequately implemented, monitored, and enforced, with the focus often being on the economic impact rather than biodiversity conservation (SBSTTA, 2005 in Shine, 2006; Jupiter *et al*., 2014).

Even though the majority of Pacific SIDS states have national policies addressing IAS, only nine have adopted laws concerned with IAS (SPREP, 2014). Furthermore, effective invasive alien species management requires monitoring of potential or known invaders, early warning systems to prevent the spread of certain species, and the identification of common priorities and threats (Perrings *et al*., 2010). However, only the Federal State of Micronesia and the Solomon Islands used their National Biodiversity Strategy and Action Plan (NBSAPs) or National Invasive Species Action Plans (NISAPs) to highlight the need to monitor the spread of IAS (PII, 2010).

31.2 MANAGEMENT OF INVASIVE ALIEN SPECIES IN FIJI

In Fiji, the Department of Environment (DoE) is the chair of the Biodiversity Steering Committee (BSC). This board is responsible for the coordination and implementation of the National Biodiversity Strategy and Action Plan (DoE, 2007). IAS are defined as one of seven thematic fields for the implementation of biodiversity conservation through the plan (DoE 2014). In 2009, a meeting of the Species Management Committee, along with other groups and stakeholders, in Suva assessed major threats to native biodiversity caused by IAS and investigated necessary measures for the mitigation of these threats by creating an implementation framework for species conservation (DoE, 2014). This meeting resulted in current efforts for the prevention of new introductions, management of established species in key biodiversity areas, and the eradication of specific species on small islands (DoE, 2014).

Unlike five other Pacific SIDS (PII, 2010), Fiji does not, to date, have a National Invasive Species Action Plan in place. However, within its current NBSAP (2017-2024), objectives have been formulated for action to improve national legislation, policies, and strategies regarding the management of IAS. Those objectives include plans for a legislative review and gap analysis, the development of a National Invasive Species Strategy and Action Plan (NISSAP), and the support and strengthening of its previously established Fijian Invasive Species Task Force (GoF, 2017), which manages invasive alien species as part of Fiji´s National Biodiversity Strategy and Action Plan (DoE, 2014). In a policy document for the CBD, the government further announced the creation of an Emergency Response Plan. The aim of this plan is to alleviate and manage the risks posed by IAS and pest outbreaks, with the intention of incorporating it into Fiji's National Disaster Management Programme (CBD, 2008).

However, it is questionable whether the government authorities in Fiji have the capacity and resources to conserve biodiversity or monitor and manage invasive alien species (Keppel *et al*., 2012; Jupiter *et al*., 2014), although the CBD requires signatories to carry out risk assessments as an empirical tool to estimate possible risks posed by invasive alien species (Daehler *et al*., 2004; SCBD, 2005). This activity would support and expand the effects of

environmental impact assessments (EIAs), which are legally obligatory, and mandate government authorities to undertake a biosecurity risk assessment of incoming regulated articles and products (Jupiter *et al*., 2014). However, undertaking such risk assessments is often difficult to implement, given that relevant government departments are generally under-staffed and under-funded, and are focused on resource exploitation rather than environmental conservation (Keppel *et al*., 2012, Jupiter *et al*., 2014).

In recent years, emphasis has been placed on capacity-building (UNEP-WCMC, 2016) and better control over the import of IAS at national borders of South Pacific countries, which is a difficult task without additional human and financial resources (King 2007). As is the case with the conservation sector in the Pacific (Keppel *et al*., 2012), the focus has been on developing management concepts, policy guidelines and data-sharing initiatives in meetings and workshops: 'However, this strategy may underemphasise the importance of enhancing internal biosecurity measures. The major challenge now is not only to prevent new introductions … but also to control populations of existing invasive species' (Aalbersberg *et al*., 2012, p. 123). Controlling IAS, therefore, will require on-the-ground implementation, starting with applied research, on-the-job training, enforcement and well-directed action.

The following two case studies of IAS in Fiji, the ivory cane palm (*Pinanga coronata*) and the green (or 'American') iguana (*Iguana iguana*), highlight the urgency of on-the-ground action to control existing populations. Both species are recent, emerging IAS, with potentially devastating consequences for native biodiversity and sustainable livelihoods. Each biological invasion is a unique process and has to be assessed in detail, in particular when it comes to predictions of the potential impact on native biodiversity and ecosystems, and the development of appropriate management strategies (Boehmer *et al*., 2001; Fischer *et al*., 2009; Kowarik *et al*., 2011).

31.2.1 Case study 1: The rapid spread of ivory cane palm in Fiji´s forests

About 50% of Fiji's land area is composed of tropical lowland rainforest (Mueller-Dombois and Fosberg, 1998). Biodiversity in these forests is extremely high and more than half of the species are endemic to the archipelago (Keppel *et al*., 2010). The number of endemic species is surpassed only by New Caledonia and the 'Australian wet tropics' (Ibanez *et al*., 2018). Fiji's rainforests are the nation's most diverse terrestrial ecosystem (Keppel, 2014) and contain over 99% of the national endemic flora and fauna (Olson *et al*., 2010; DoE, 2014). The DoE (2014) describes native forests as being of essential importance for Fiji's biodiversity conservation, and they provide important genetic resources, as well as cultural and economic value, supporting the livelihoods of many Fijians (DoE, 2007; SPREP, 2016a). Yet primary forest coverage decreased by 21% between 1991 and 2007 (DoE, 2014).

The ivory cane palm is native to Java and Sumatra (Kimura and Simbolon, 2002; Witono *et al*., 2002; Witono, 2003; Witono and Rondo, 2006; Keppel and Watling, 2011). In Indonesia, it is one of the dominant species in rainforests, extending from sea level to 1,800 meters a.s.l. (Witono *et al*., 2002; Witono, 2003). The natural tendency to form mono-dominant stands implies that *P. coronata* can outcompete and displace other understory species (Watling, 2005; Daehler and Baker, 2006). The palm was brought to Fiji for ornamental purposes in the 1970s and started spreading from gardens close to the Colo-i-Suva forest reserve on Fiji's main island of Viti Levu (Keppel and Watling, 2011). Its invasive potential was first recognised in the early 1990s (Watling and Chape, 1992). Today, it is rapidly spreading, forming dense stands in the mahogany plantations of Colo-i-Suva and neighbouring native forests, where it is displacing native species (Dyer 2017, Dyer *et al*., accepted; Dyer *et al*., in press).

We used an assessment questionnaire, the Alberta Risk Assessment Tool, which ranks the potential invasiveness (i.e. potential to invade) of a species via 58 questions in three categories (environmental, economic, and social) (IASWG, 2008), to carefully examine the

potential risk to native biodiversity in Fiji's rainforests (Lenz, 2016). The risk assessment tool highlighted the rapid growth and regional dispersal abilities of *P. coronata* as a particular concern. The species has the potential to disperse up to several kilometres in a single event, in addition to possibly doubling its population in less than 10 years (Hanson, 2017). *Pinanga coronata* is already abundant in the Colo-i-Suva forest reserve, utilising anthropogenic and natural pathways, which facilitate continuous re-introduction of the species into the area (Dyer *et al*., accepted; Dyer *et al*., in press). In addition, the entire forest reserve provides suitable habitat and climate for the spread of *P. coronata*. Other indicators of its ability to rapidly invade are its adaptability and tolerance to a broad range of environmental conditions and its efficient reproduction (Hanson, 2017).

There is a clear research deficit regarding the environmental impacts of ivory cane palm. It has been demonstrated that *P. coronata* has significant negative relationships with native tree fern species (*Cyathea* spp.) and herbs (Mathieu, 2015; Dyer *et al*., in press), and the palm is therefore likely displacing these species of the forest understorey. However, little is known about how the cane palm outcompetes native species, its potential as a vector or host of diseases, or its ability to hybridise with native palm species. It also impacts aspects of the ecosystem, such as light availability, nutrient cycling, and the ability of indigenous plant species to regenerate (Gopaul, 2018). Many of these documented effects of *P. coronata* are similar to those associated with kahili ginger (*Hedychium gardnerianum*) in Hawaii (Minden *et al*., 2010a, 2010b). Environmental effects received the highest result of the three categories evaluated using the risk assessment tool.

The economic impacts of *P. coronata* on agriculture and livestock are also largely unknown. To date, industries such as aquaculture, tourism, and energy do not appear to be impacted. Due to the palm's re-sprouting ability, it may increase the efforts required by rural farmers to prepare forested land for planting in shifting agriculture systems (where an area is cleared, cultivated for a few years, and then abandoned for a new area until fertility has been naturally restored). Within forestry, the predicted losses are 3-4% because it is assumed that dense ivory cane palm populations bind nutrients and reduce tree growth in the vicinity (IASWG, 2008). This impact is yet to be quantified, and more severe long-term consequences could exist. For example, dense cane palm cover may prevent the regeneration of timber species, reducing the density and hence yield of timber species. Research on tree growth and regeneration in areas affected by *P. coronata* is therefore urgently required.

The social effects of the invasive alien species are diverse and ambiguous. In addition, some aspects, such as the potential loss of food supplies, particularly important for the subsistence lifestyle in Fiji, remain unknown. However, there appears to be no effect on human health and well-being, recreational activities, and the urban environment, with perhaps only a mild effect in terms of aesthetic or traditional/cultural values. In contrast, the species influence on the perception of natural values has been categorised as severe because of its potential impact on biodiversity. The social effects have the lowest assessed score, which is insignificant when compared with the sum of the economic effects (Lenz, 2016). These impacts increase as the species aggressively spreads and expands throughout the area and into adjacent areas. In 2016, the palm's populations in CIS and Savura already covered more than 1,500 hectares (Dyer *et al*., accepted).

In summary, the ivory cane palm has considerable potential to reduce native biodiversity, to change the structure and dynamics of forests, and to affect the overall ecosystem functioning. In addition, a general negative impact upon Fiji's forestry can be expected. Despite these obvious threats, nothing has been done to contain the species. This invasion may have been prevented entirely, if action had been taken when the ivory cane palm was first identified as invasive with serious ecological threats in 1992 (Watling and Chape, 1992) or when it was reported to be forming dense populations and dominating parts of the forest understory of south-east Viti Levu in 2005 (Watling, 2005). Furthermore, Keppel and Watling

(2011) recommended immediate eradication of the palm eight years ago, when the species was first observed in a native forest reserve.

In spite of this, remedial actions of eradication or control have not been implemented, and apparently have not even been discussed. The only two invasive alien plant species that have been formally acknowledged as a major threat to the genetic resources of Fiji's forests are the African tulip tree (*Spathodea campanulata*) and Mission grass (*Pennisetum polystachion*) (FAO, 2010; Brown and Daigneault, 2014), and even the ecological impacts of these species have not been researched. Despite repeated efforts by local experts over the last 25 years, there remains a need for the political authorities to address the growing *P. coronata* invasion problem. Worse still, the Pacific Island Ecosystems at Risk project database does not include *P. coronata* among the list of the region's high-risk invasive alien palms (Meyer *et al*., 2008; PIER, 2013).

31.2.2 Case study 2: Green iguanas eating local livelihoods

The green iguana is an invasive alien animal species with well-known economic and ecological impacts. It is native to parts of Central and South America but has established feral populations on several islands (e.g. Puerto Rico and Hawaii) and parts of continental mainland United States (e.g. Florida), where its populations reach high densities (Falcón *et al*., 2013). The species poses considerable threats to native biodiversity and is displacing the critically endangered, congeneric *Iguana delicatissima* in some of the Lesser Antilles (van den Burg et al., 2018). As a predominantly herbivorous, but potentially opportunistically omnivorous, species, the iguana poses threats to the native flora and fauna (Falcón *et al*., 2013). In addition, the green iguana has been shown to eat important food and commercial plants (Falcón *et al*., 2013; CI-Pacific, 2013). Furthermore, the species is impacting air and car traffic due to very high population densities on Puerto Rico (Falcón *et al*., 2013).

In Fiji, the green iguana was illegally introduced and released on a single property on the island of Qamea in the year 2000 (CI-Pacific, 2013), and was positively identified and reported on the same island in 2008. It has since also been observed on the islands of Koro, Laucala and Taveuni (Thomas *et al*., 2011). The initial response to this potentially harmful invasive alien species was swift and driven by the local non-profit organization NatureFiji-MareqetiViti and the Fijian government. An initial risk assessment, which included scientific research and creating community awareness, was undertaken (CI-Pacific, 2013). The government introduced legislation that made moving green iguanas between islands illegal and punishable by high fines through the Biosecurity Authority Fiji (at the time named the Fiji Department of Biosecurity Services) in March 2010, and funded an eradication plan through the Fiji Ministry of Primary Industries (Thomas *et al*., 2011).

Although strongly supported by the government, these initial management actions were mainly carried out and implemented by NatureFiji-MareqetiViti. However, after producing a preliminary environmental management plan together with the Biosecurity Authority of Fiji (BAF), NatureFiji-MareqetiViti withdrew from leading Fiji's response to enable BAF to take the lead in 2011. Since then, there have been only a few management efforts. As of September 2018, the only on-the-ground action was in early 2015, when the Fiji army dispatched more than 100 soldiers to affected islands and killed 40 iguanas (Radio New Zealand, 2015). This, of course, is insufficient to control an agile, quickly spreading invasive animal which, in the meantime, has reached Fiji's second largest island, Vanua Levu (Fiji Broadcasting Commission, 2017; see also Falcón *et al*., 2013).

Therefore, despite the well-established threat that this invasive alien species poses to native biodiversity and local livelihoods, little has been done on the ground to prevent increasing population sizes and the continuing spread of the green iguana. The results of this inaction could be catastrophic. Fiji has several endemic iguana species in the genus *Brachylophus* (Fisher *et al*., 2017), which could potentially be displaced by the invasive alien

iguana, while the subsequent impacts on native plant species through potential grazing of adults and seedlings remain unstudied. More importantly, livelihoods could be affected as the green iguana has been reported feeding on the commercial food crops taro (*Colocasia esculenta*) and Pacific spinach (*Abelmoschus manihot*) (CI-Pacific, 2013).

31.3 REASONS FOR INACTION ON INVASIVE ALIEN SPECIES

Like many other Pacific island countries and territories, Fiji has ratified the CBD (1993/2) and has been a member of the Convention since 1993/12. However, there is currently no framework in place to target the management of invasive alien species to meet Fiji's obligations under Article 8 (h) of the CBD. Fiji's Forest Decree No. 31 of 1992 (GoF, 1992) fails to provide a plan or requirement for invasive alien species management. It simply enables the Department of Forests to undertake management, such as silviculture in the country's reserves. Since 2008, the Biosecurity Authority of Fiji has been the country´s entity that intercepts exotic pests, plants, diseases, and animals assessed to be dangerous to agriculture, forestry, and livestock industries.

A review of the most important IAS in Fiji shows a list dominated by pests, animal diseases, and animals, with only two invasive alien plant species included (Wainqolo and Timote, 2005; FAO, 2010). Clearly invasive alien plants and, in particular, invasive alien palms are not prioritised for management even though their threats have been brought to the attention of national and local authorities. There seems to be some disconnect between highly active international agencies who rely on information provided by national agencies for developing appropriate strategies, and the reality on the ground. It is safe to say that, considering the volatile nature of invasive alien plants, Fiji's strategy to combat their spread is insufficient. Given the lack of legislative procedure and institutional structures, there is a need for Fiji to support existing regional frameworks for invasive alien species management.

The Guidelines for Invasive Species Management in the Pacific have been in place since the 2000s. These guidelines were developed in partnership with SPREP and the Secretariat of the Pacific Community (SPC). The SPREP strategy presents a logical framework for managing the threat of IAS by generating support and building capacity among concerned stakeholders. This should be achieved through baseline risk assessments as well as the implementation of strategies such as eradication, border control, containment, chemical control, and, finally, restoration programmes (Tye, 2009). So far, however, implementation has been minimal.

The number of invasive alien species in Fiji and, indeed, the South Pacific is steadily rising. Fiji's tropical setting and ease of accessibility from throughout the Pacific make it a favoured travel destination. The country is continuously harbouring cruise and cargo ships, and has a particularly notable number of important economic and political international organizations. Therefore, IAS continue to be introduced and establish themselves, with some of them going on to spread through the island network (DoE, 2014). Furthermore, the lack of adequate legislation, the inefficiency of current strategies, and the apparent reluctance to implement on-the-ground eradication efforts are preventing successful management of IAS in Fiji.

31.4 CONCLUSION

Sharing of knowledge regarding successful management measures and research efforts for IAS on Pacific islands needs to be strengthened, as it constitutes an important showcase for future conservation strategies and the mitigation of the impacts of invasive alien species. Furthermore, climate change will intensify irreversible ecological changes in ecosystems (Wardell-Johnson *et al*., 2011) and facilitate the establishment and spread of alien species (e.g. Taylor and Kumar, 2016). Collaboration and effective knowledge exchange among

Pacific SIDS is particularly important, as responses of IAS on islands to climate change are difficult to predict (e.g. Boehmer and Niemand, 2009; Boehmer, 2011b, 2011c; Mueller-Dombois *et al*., 2013) and likely to differ with geographical context (Bellard *et al*., 2014; Malcom *et al*., 2006).

Increasing awareness and understanding in the Pacific cultural context (e.g. Raynor and Kostka, 2003; Weeks and Adams 2018) and capacity-building (Keppel *et al*., 2012) is an important component for successful IAS mitigation (Sherley, 2000). Given the importance of customary land tenure in Fiji and other SIDS of the South Pacific, it is vital to increase public awareness of the issue of IAS, particularly among *iTaukei* villagers and forestry staff (e.g. Keppel *et al*., 2012). The task of making people at all levels aware of biodiversity loss and the risks presented by IAS could be addressed with education for sustainable development (ESD), which stresses 'the significance of all forms of education in teaching and learning for a more sustainable future' (Bagoly-Simó, 2013, p. 57).

However, capacity-building and the development of policy guidelines and eradication plans, while important, will not contain an IAS. Effective management also requires on-the-ground action, which has been neglected in our two case studies. As a result, the invasions of the cane palm and the green iguana are now impending ecological, and possibly economical, disasters that become increasingly difficult to avert as both species continue to spread. An apparent lack of legislation and impetus to control potentially harmful IAS in Fiji is further compounding the escalating situation. On-the-ground action to control, eradicate, and prevent IAS is desperately needed; awareness and education are not enough, as they will not stop these threats spreading through Fiji's islands, nor will they reverse the biodiversity loss where intervention is needed now.

The case studies show that IAS are posing a serious threat to forest biodiversity and human sustainability in Fiji. While successful management (i.e. control and eradication) of these silent invaders would have been entirely feasible at the early stages of their invasion, it is becoming increasingly difficult as the two species are continuing to spread. Without national support through legislative measures, funding, and cross-sectoral integration, combating the spread of IAS in Fiji will remain an insurmountable challenge. Mandated government agencies and interested non-government organizations are needed to establish and implement interventions on the ground. These should be supported by the facilitation of upskilling and applied research as well as monitoring, evaluation, legislation, enforcement, awareness, and education.

Given the limited resources and geographic dispersion, Pacific SIDS must focus on the most harmful invaders, target the most vulnerable regions, and increase potential and quick reaction capabilities for dealing with biological invasions (Genovesi, 2007; Denslow *et al*., 2009). These planning activities must be supported by on-the-ground management actions, owing to the fact that species can efficiently spread within an island state network (Wittenberg and Cock, 2001), as illustrated by the examples of the ivory cane palm and the green iguana in Fiji. Otherwise, the future of terrestrial biodiversity, ecosystem services and sustainability in the Small Island Developing States of the South Pacific will be at risk.

ACKNOWLEDGEMENTS

The authors would like to thank the Research Office of the University of the South Pacific (USP), the European Commission (Education, Audiovisual and Culture Executive Agency, EACEA), the Australian Government (Department of Foreign Affairs and Trade), and the German Academic Exchange Service (DAAD) for financial support. Marika Tuiwawa, Alifereti Naikatini, Isaac Rounds, Sainivalati Vido, Jean-Benoit Mathieu, Kevin Sese, and Joshua Kera assisted in fieldwork and identification of species. Comments by Russell Sinclair (School of Biological Sciences, Department of Ecology and Environmental Science,

University of Adelaide), Stephen E. Williams (College of Science and Engineering, James Cook University, Townsville), Steve Cranwell (BirdLife International), and an anonymous reviewer helped to significantly improve the manuscript.

REFERENCES

Aalbersberg, B., Avosa, M., James, R., Kaluwin, C., Lokani, P., Opu, J., Siwatibau, S., Tuiwawa, M., Waqa-Sakiti, H. and Tordoff, A. W. (2012) *East Melanesian Islands Biodiversity Hotspot: Suva, Fiji*. University of the South Pacific, on behalf of Critical Ecosystem Partnership Fund, 237pp.

Andresen, S., Boasson, E. L. and Hønneland, G. (2012) *International Environmental Agreements: An Introduction*. London, Routledge, 119pp.

Andresen, S. and Rosendal, K. (2014) Complexity in international regimes: implications for biodiversity and climate change. Paper presented at Earth System Governance Norwich Conference, 3 July.

Bagoly-Simó, P. (2013) Tracing sustainability: an international comparison of ESD implementation into lower secondary education. *Journal of Education for Sustainable Development*, **7** (1), 91-108.

Baur, B. and Schmidlin, S. (2007) Effects of invasive non-native species on the native biodiversity in the River Rhine. In Nentwig, W. (Ed.), *Biological Invasions (Ecological Studies*, vol. 193), 257-274. Berlin, Heidelberg, and New York, Springer-Verlag.

Bellard, C., Leclerc, C., Leroy, B., Bakkenes, M., Veloz, S., Thuiller, W. and Courchamp, F. (2014) Vulnerability of biodiversity hotspots to global change. *Global Ecology and Biogeography*, **23**, 31-38.

Boehmer, H. J. (2011a) Biologische Invasionen: Muster, Prozesse und Mechanismen der Bioglobalisierung (Biological invasions: patterns, processes and mechanisms of bioglobalization). *Geographische Rundschau*, **3**, 4-10.

(2011b) Vulnerability of tropical montane rainforests to climate change. In Brauch, H. G., Spring, Ú. O., Mesjasz, C., Grin, J., Kameri-Mbote, P., Chourou, B., Dunay, P. and Birkmann, J. (eds.), *Coping with Global Environmental Change, Disasters and Security: Threats, Challenges, Vulnerabilities and Risks*. Hexagon Series on Human Environmental Security and Peace, vol. 5, 789-802. Berlin, Heidelberg, and New York, Springer-Verlag.

(2011c) Stoerungsregime, Kohortendynamik und Invasibilitaet zur Komplexitaet der Vegetationsdynamik im Regenwald Hawaiis (Disturbance regimes, cohort dynamics, and invasibility: on the complexity of vegetation dynamics in Hawaii's rainforests). *Laufener Spezialbeitraege*, **2011**, 111-117.

Boehmer, H. J., Heger, T. and Trepl, L. (2001) *Case Studies on Alien Species in Germany. Robinia pseudoacacia, Reynoutria japonica, Senecio inaequidens, Dreissena polymorpha, Ondatra zibethicus, Mustela vison*. Berlin, Umweltbundesamt UBA-Texte 13/01, 126pp.

Boehmer, H. J. and Niemand, C. (2009) Die neue Dynamik pazifischer Wälder. Wie Klimaextreme und biologische Invasionen Inselökosysteme verändern (The new dynamics of Pacific forests: how climatic anomalies and biological invasions change island ecosystems). *Geographische Rundschau*, **61**, 32-37.

Brodie, G., Pikacha, P. and Tuiwawa, M. (2013) Biodiversity and conservation in the Pacific islands: why are we not succeeding? In N. S. Sodhi, L. Gibson and P. H. Raven (Eds.), *Conservation Biology: Voices from the Tropics*, pp. 181-187. Oxford, Wiley.

Brown, P. and Daigneault, A. (2014) Cost-benefit analysis of managing the invasive African tulip tree (*Spathodea campanulata*) in the Pacific. *Environmental Science and Policy*, **39**, 65-76.

Butchart, S. H., Walpole, M., Collen, B., van Strien, A., Scharlemann, J. P., Almond, R. E., Baillie, J. E., Bomhard, B., Brown, C., Bruno, J., Carpenter, K. E., Carr, G. M., Chanson, J., Chenery, A. M., Csirke, J., Davidson, N. C., Dentener, F., Foster, M., Galli, A., Galloway, J. N., Genovesi, P., Gregory, R. D., Hockings, M., Kapos, V., Lamarque, J. F., Leverington, F., Loh, J., McGeoch, M. A., McRae, L., Minasyan, A., Hernández Morcillo, M., Oldfield, T. E., Pauly, D., Quader, S., Revenga, C., Sauer, J. R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S. N., Symes, A., Tierney, M., Tyrrell, T. D., Vié, J. C. and Watson, R. (2010) Global biodiversity: indicators of recent declines. *Science*, **328** (5,982), 1,164-1,168.

CBD (Convention on Biological Diversity) (2008) Bioinvasion and global environmental governance: the transnational policy network on invasive alien species: Fiji's actions on IAS. https://www.cbd.int/invasive/doc/legislation/Fiji.pdf

(2013) Quick guides to the Aichi Biodiversity Targets, 2nd version. Montreal, Canada, CBD, 42pp.

CI-Pacific (Conservation International Pacific Islands Programme) (2013) *Biodiversity Conservation Lessons Learned. Technical Series 12: Emergency Response to Introduced Green Iguanas in Fiji.* Apia, Samoa, CEPF and CI-Pacific, 168pp.

Clout, M. N. and Williams, P. A. (2009) *Invasive Species Management: A Handbook of Principles and Techniques*. Oxford, Oxford University Press, 308pp.

Clout, M. N. and Veitch, C. R. (2011) Turning the tide of biological invasion: the potential for eradicating invasive species. In C. R. Veitch, M. N. Clout and D. R. Towns (Eds.), *Island Invasives: Eradication and Management*. Proceedings of the International Conference on Island Invasives (Preface), pp. 1-3. Gland, Switzerland, IUCN, and Auckland, New Zealand, CBB.

Daehler, C. C. (2008) Invasive plant problems in the Hawaiian Islands and beyond: insights from history and psychology. In B. Tokarska-Guzik, J. H. Brock, G. Brundu, L. Child, C. C. Daehler and P. Pyšek (Eds.), *Plant Invasions: Human Perception, Ecological Impacts and Management*, pp. 3-20. Leiden, Netherlands, Backhuys Publishing.

Daehler, C. C., Denslow, J. S., Ansari, S. and Kuo, H.-C. (2004) A risk-assessment system for screening out invasive pest plants from Hawaii and other Pacific islands. *Conservation Biology*, **18** (2), 361-368.

Daehler, C. C. and Baker, R. F. (2006) New records of naturalized and naturalizing plants around Lyon Arboretum, Mānoa Valley, O'ahu. In N. L. Evenhuis and L. G. Eldredge (Eds.), *Records of the Hawaii Biological Survey for 2004-2005*. Bishop Museum Occasional Papers **87**, 3-18.

Daigneault, A. and Brown, P. (2013) Invasive species management in the Pacific using survey data and benefit-cost analysis. Paper presented at the 57th AARES annual conference, 5-8 February, Sydney, Australia.

Denslow, J. S., Space, J. C. and Thomas, P. A. (2009) Invasive exotic plants in the tropical Pacific islands: patterns of diversity. *Biotropica*, **41** (2), 162-170.

DoE (Department of Environment) (2007) *Implementation Framework 2010-2014. For the National Biodiversity Strategy and Action Plan 2007*. Suva, Fiji, CBD, 129pp.

(2014) *Fiji's Fifth National Report to the United Nations*. Suva, Fiji, CBD, 102pp.

Dyer, M. J. B. (2017) *Distribution of the invasive palm* Pinanga coronata *and its effects on native tree ferns in the Colo-i-Suva area, Viti Levu, Fiji*. University of the South Pacific, Faculty of Science, Technology and Environment, and University of South Australia.

Dyer, M. J. B., Keppel, G., Watling, D., Tuiwawa, M., Vido, S. and Boehmer, H. J. (accepted) Using expert knowledge and field surveys to guide management of an invasive alien palm in a Pacific island lowland rainforest. In C. R. Veitch (Ed.), *Island Invasives: Stepping Up to the Challenge. Proceedings of the 14th Ecology and Management of Alien Plant Invasions (EMAPI) World Congress 2017*. Gland, Switzerland, IUCN, and Dundee, Scotland.

Dyer, M. J., Keppel, G., Tuiwawa, M., Vido, S. and Boehmer, H. J. (in press) Invasive alien palm *Pinanga coronata* threatens native tree ferns in an oceanic island rainforest. Australian Journal of Botany.

Enserink, M. (1999) Biological invaders sweep in. *Science*, **285** (5,435), 1,834-1,836.

Falcón, W., Ackerman, J. D., Recart, W. and Daehler, C. C. (2013) Biology and impacts of Pacific island invasive species. 10. *Iguana iguana*, the green iguana (Squamata: Iguanidae). *Pacific Science*, **67** (2), 157-186.

FAO (Food and Agriculture Organization of the United Nations) (2010) *The State of the World's Forest Genetic Resources: Republic of Fiji Country Report*. Suva, Fiji, Secretariat of the South Pacific, 60pp.

(2014) *The State of the World's Forest Genetic Resources*. Rome, FAO, 277pp.

Fernández-Palacios, J. M., Kueffer, C. and Drake, D. R. (2015) A new golden era in island biogeography. *Frontiers of Biogeography* **7** (1), 14-20.

Fiji Broadcasting Commission (2017) BAF officers create awareness. http://www.fbc.com.fj/fiji/50130/baf-officers-create-awareness

Fischer, L. K., von der Lippe, M. and Kowarik, I. (2009) Tree invasion in managed tropical forests facilitates endemic species. *Journal of Biogeography*, **36**, 2,251-2,263.

Fisher, R. N., Niukula, J., Watling, D. and Harlow, P. S. (2017) A new species of iguana *Brachylophus* Cuvier 1829 (Sauria: Iguania: Iguanidae) from Gau Island, Fiji Islands. *Zootaxa*, **4,273** (3), 407-422.

Genovesi, P. (2007) Limits and potentialities of eradication as a tool for addressing biological invasions. In Nentwig, W. (Ed.) *Biological Invasions (Ecological Studies*, vol. 193), 385-402. Berlin, Heidelberg, and New York, Springer-Verlag.

(2011) Are we turning the tide? Eradications in times of crisis: how the global community is responding to biological invasions. In C. R. Veitch, M. N. Clout and D. R. Towns (Eds.), *Island Invasives: Eradication and Management. Proceedings of the International Conference on Island Invasives*, pp. 5-8. Gland, Switzerland, IUCN, and Auckland, New Zealand, CBB.

GEF (Global Environment Facility) (1993) *Regional: South Pacific Biodiversity Conservation Programme*. Apia, Samoa, SPREP, 60pp.

(2016) *GEF-6 Project Identification Form. Strengthening National and Regional Capacities to Reduce the Impact of Invasive Alien Species on Globally Significant Biodiversity in the Pacific*. UNEP, 29pp.

GoF (Government of Fiji) (1992) Forest Decree 1992/No. 31, 17pp.

(2017) *National Biodiversity Strategy and Action Plan [2017-2020]*. Suva, Fiji, GoF, 80pp.

Gopaul, S. (2018) Abiotic effects of the invasive alien palm *Pinanga coronata* in the Colo-i-Suva Forest Reserve, Fiji. Suva, Fiji, University of the South Pacific, Faculty of Science, Technology and Environment, 162pp.

Hanson, G. (2017) *Population Structure, Allometry, and Spread of Alien Ivory Cane Palm,* Pinanga coronata, *in a Protected Forest Landscape on Viti Levu, Fiji*. Suva, Fiji, University of the South Pacific, Faculty of Science, Technology and Environment, 170pp.

IAEG-SDGs (Inter-Agency and Expert Group on SDG Indicators) (2016) *Final List of Proposed Sustainable Development Goal Indicators*. United Nations Statistical Commission/United Nations Economic and Social Council, 39pp.

IASWG (Invasive Alien Species Working Group) (2008) Alberta Invasive Alien Species Risk Assessment Tool Version 3. Edmonton, Canada, Alberta Ministry of Agriculture and Forestry, 64pp.

Ibanez, T., Blanchard, E., Hequet, V., Keppel, G., Laidlaw, M., Pouteau, R., Vandrot, H. and Birnbaum, P. (2018) High endemism and stem density distinguish New Caledonian from other high-diversity rainforests in the Southwest Pacific. *Annals of Botany*, **121**, 25-35.

Jupiter, S., Mangubhai, S. and Kingsford, R. T. (2014) Conservation of biodiversity in the Pacific islands of Oceania: challenges and opportunities. *Pacific Conservation Biology*, **20** (2), 206-220.

Keitt, B., Campbell, K., Saunders, A., Wang, Y., Heinz, R., Newton, K. and Tershy, B. (2011) The Global Invasive Vertebrate Eradication Database: a tool to improve and facilitate restoration of island ecosystems. In C. R. Veitch, M. N. Clout and D. R. Towns (Eds.), *Island Invasives: Eradication and* Management. Proceedings of the International Conference on Island Invasives, pp. 74-77. Gland, Switzerland, IUCN, and Auckland, New Zealand, CBB.

Keppel, G. (2014) The importance of expert knowledge in conservation planning: comment to an article by C. J. Klein *et al*. *Marine Policy*, **48**, 202-203.

Keppel, G, Buckley, Y. M. and Possingham, H. P. (2010) Drivers of lowland rain forest community composition, diversity and structure on the islands of the tropical South Pacific. *Journal of Ecology*, **98**, 87-95.

Keppel, G. and Watling, D. (2011) Ticking time bombs: current and potential future impacts of four invasive plant species on the biodiversity of lowland tropical rainforests in south-east Viti Levu, Fiji. *South Pacific Journal of Natural and Applied Sciences*, **29** (1), 43-45.

Keppel, G., Morrison, C., Watling, D., Tuiwawa, M. V. and Rounds, I. A. (2012) Conservation in tropical Pacific island countries: why most current approaches are failing. *Conservation Letters* **5**, 256-265.

Keppel, G., Morrison, C., Meyer J.-Y. and Boehmer, H. J. (2014) Isolated and vulnerable: the history and future of Pacific island terrestrial biodiversity. *Pacific Conservation Biology*, **20** (2), 136-145.

Keppel, G, Gillespie, T. W., Ormerod, P. and Fricker, G. A. (2016) Habitat diversity predicts orchid diversity in the tropical Southwest Pacific. *Journal of Biogeography*, **43** (12), 1-11.

Kier, G, Kreft, H., Lee, T. M., Jetz, W., Ibisch, P. L., Nowicki, C. Mutke, J. and Barthlott, W. (2009) A global assessment of endemism and species richness across island and mainland regions. *Proceedings of the National Academy of Science of the United States of America*, **106** (23), 9,322-9,327.

Kimura, M. and H. Simbolon (2002) Allometry and life history of a forest understory palm *Pinanga coronata* (Arecaceae) on Mount Halimun, West Java. *Ecological Research*, **17**, 323-338.

King, P. (2007) *Regional: Mainstreaming Environmental Consideration in Economic and Development Planning Processed in Selected Pacific Developing Member Countries. Technical Assistance Consultant's Report for the Asian Development Bank – Country Environmental Analysis: Vanuatu*. Manila, Philippines, Asian Development Bank, 75pp.

Kowarik, I., Jaeger, H., Fischer, L. and Von der Lippe, M. (2011) Auf den Einzelfall kommt es an! Unterschiedliche Auswirkungen derselben invasiven Art auf ozeanische Inseln.

(The individual case matters! Different impacts of the same invasive plants on oceanic islands). *Geographische Rundschau*, **3**, 48-53.

Kueffer, C., Daehler, C. C., Torres-Santana, C. W., Lavergne, C., Meyer, J.-Y., Otto, R. and Silva, L. (2010) A global comparison of plant invasions on oceanic islands. *Perspectives in Plant Ecology, Evolution and Systematics*, **12** (2), 145-161.

Kueffer, C., Drake, D. R. and Fernández-Palacios, J. M. (2014) Island biology: looking towards the future. *Biology Letters*, **10**, 1-4.

Lenz, M.-I. (2016) *Risk Assessment of the Invasive Alien Ivory Cane Palm (*Pinanga coronata*) in the Forests of Colo-i-Suva Forest Reserve, Viti Levu, Fiji*. Goettingen, Germany, Georg-August-University-Goettingen, 94pp.

MacArthur, R. H. and Wilson, E. O. (1967) *The Theory of Island Biogeography*. Princeton, NJ, Princeton University Press, 203pp.

Malcolm, J. R., Liu, C.-R., Neilson, R. P., Hansen, L. and Hannah, L. (2006) Global warming and extinctions of endemic species from biodiversity hotspots. *Conservation Biology*, **20**, 538-548.

Mathieu, J.-B. (2015) Diversity of understory vegetation in a submontane tropical rainforest under impact of an invasive alien palm species. Suva, Fiji, University of the South Pacific, Faculty of Science, Technology and Environment, and Quebec, Canada, University of Laval, 42pp.

Meyer, J.-Y. (2014) Critical issues and new challenges for research and management of invasive plants in the Pacific islands. *Pacific Conservation Biology*, **20** (2), 146-164.

Meyer, J.-Y., Lavergne, C. and Hodel, D. R. (2008) Time bombs in gardens: invasive ornamental palms in tropical islands, with emphasis on French Polynesia (Pacific Ocean) and the Mascarenes (Indian Ocean). *Palms*, **52** (2), 71-83.

Minden, V., Hennenberg, K. J., Porembski, S. and Boehmer, H. J. (2010a) Invasion and management of alien *Heydchium gardnerarium* (kahili ginger, Zingiberaceae) alter plant species composition of a montane rainforest on the island of Hawai'i. *Plant Ecology*, **206**, 321-333.

Minden, V., Jacobi, J. D., Porembski, S. and Boehmer, H. J. (2010b) Effects of invasive alien kahili ginger (*Hedychium gardnerianum*) on native plant species regeneration in a Hawaiian rainforest. *Applied Vegetation Science*, **13**, 5-14.

Mittermeier, R. A., Gil, P. R., Hoffman, M., Pilgrim, J., Brooks, T., Mittermeier, C. G., Lamoreux, J. and da Fonseca, G. A. B. (2005). *Hotspots Revisited: Earth's Biologically Richest and Most Threatened Terrestrial Ecoregions*. Chicago, IL, University of Chicago Press, 392pp.

Mohamed, N. and Clark, K. (1996) *Forestry on Customary-owned Land: Some Experiences from the South Pacific*. Rural Development Forestry Network (RDFN), Network Paper 19a. Overseas Development Institute, Regent´s College, London, 33pp.

Mueller-Dombois, D. (2006) Pacific island forests: successionally impoverished and now threatened to be overgrown by aliens? *Pacific Science*, **62** (3), 303-308.

Mueller-Dombois, D. and Fosberg, F. R. (1998) *Vegetation of the Tropical Pacific Islands. (Ecological Studies*, vol. 132). New York, Springer-Verlag, 733pp.

Mueller-Dombois, D., Jacobi, J. D., Boehmer, H. J. and Price, J. P. (2013) *'Ōhi'a Lehua Rainforest. The Story of a Dynamic Ecosystem with Relevance to Forests Worldwide*. Honolulu, HI, Friends of the Joseph Rock Herbarium, 278pp.

Nishida, G. M. and Evenhuis, N. L. (2000) Arthropod pests of significance in the Pacific: a preliminary assessment of selected groups. In G. Sherley (Ed.), *Invasive Species of the Pacific: A Technical Review and Draft Strategy*, pp. 115-129. Apia, Samoa, SPREP.

Olson, D., Farley, L., Patrick, A., Watling, D., Tuiwawa, M., Masibalavu, V., Lenoa, L., Bogiva, A., Qauqau, I., Atherton, J., Caginitoba, A., Tokota'a, M., Prasad, S., Naisilisili, W., Raikabula, A., Mailautoka, K., Morley, C. and Allnutt, T. (2010)

Priority forests for conservation in Fiji: landscapes, hotspots, processes. *Oryx*, **44**, 57-70

Perrings, C., Mooney H. and Williamson, M. (Eds.) (2010) *Bioinvasion and Globalization: Ecology, Economics, Management, and Policy*. Oxford, Oxford University Press, 267pp.

PIER (US Forest Service, Pacific Island Ecosystems at Risk) (2013) Plant threats to Pacific ecosystems. Pacific Islands Ecosystems at Risk. http://www.hear.org/pier/index.html

(2018a) All PIER species listed by scientific name. http://www.hear.org/pier/scientificnames/

(2018b) PIER plant species present in Fiji listed by scientific name. http://www.hear.org/pier/locations/pacific/fiji/specieslist.htm

PII (Pacific Invasives Initiatives) (2010) *Invasive Species Management in the Pacific: A Review of National Plans and Current Activities*. Auckland, New Zealand, PII, 26pp.

Pouteau, R. and P. Birnbaum (2016) Island biodiversity hotspots are getting hotter: vulnerability of tree species to climate change in New Caledonia. *Biological Conversation*, **201**, 111-119.

Pungetti, G. (2012) Islands, culture, landscape and seascape. *Journal of Marine and Island Cultures*, **1**, 51-54.

Radio New Zealand (2015) Fiji military in major iguana-culling operation. https://www.radionz.co.nz/international/pacific-news/267169/fiji-military-in-major-iguana-culling-operation

Raynor, B. and Kostka, M. (2003) Back to the future: using traditional knowledge to strengthen biodiversity conservation in Pohnpei, Federated States of Micronesia. *Ethnobotany Research and Applications*, **1**, 55-63.

Reaser, J. K., Yeager, B. B., Phifer, P. R., Hancock, A. K. and Gutierrez, A. T. (2003) Environmental diplomacy and the global movement of invasive alien species: a U.S. perspective. In G. M. Ruiz and J. T. Carlton (Eds.) *Invasive Species. Vectors and Management Strategies*, pp. 362-381. Washington, DC, Island Press.

Reaser, J. K., Meyerson, L. A., Cronk, Q., De Poorter, M., Eldrege, L. G., Green, E., Kairo, M., Latasi, P., Mack, R. N., Mauremootoo, J., O'Dowd, D., Orapa, W., Sastroutomo, S., Saunders, A., Shine, C., Thrainsson, S. and Vaiutu, L. (2007) Ecological and socioeconomic impacts of invasive alien species in island ecosystems. *Environmental Conservation*, **34** (2), 98-111.

SCBD (2001) Assessment and management of alien species that threaten ecosystems, habitats and species (CBD Technical Paper 1). Montreal, SCBD, 146pp.

(2005) *Handbook of the Convention on Biological Diversity*, 3rd ed. Montreal, CBD, 1,493pp.

Settele, J., Scholes, R., Betts, R., Bunn, S., Leadley, P., Nepstad, D., Overpeck, J. T. and Taboada, M. A. (2014) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White (Eds.). Cambridge and New York, Cambridge University Press, 1,132pp.

Sherley, G. (ed.) (2000) *Invasive Species in the Pacific: A Technical Review and Draft Regional Strategy*. Apia, Samoa, SPREP, 190pp.

Sherley, G., Timmins, S. and Lowe, S. (1999) Draft invasive species strategy for the Pacific islands region. Nadi: Regional Invasive Species Workshop. In G. Sherley (Ed.) (2000) Invasive Species in the Pacific: A Technical Review and Draft Regional strategy, pp. 1-6. Apia, Samoa, SPREP.

Shine, C. (2006) *Overview of Existing International/Regional Mechanisms to Ban or Restrict Trade in Potentially Invasive Alien Species*. Strasbourg, Council of Europe, 28pp.

Shine, C., Williams, N. and Guendling, L. (2000) *A Guide to Designing Legal and Institutional Frameworks on Alien Invasive Species*. Gland, Switzerland; Cambridge, UK; and Bonn, Germany, IUCN.

Smith, C. P. (1985) Impact of alien plants on Hawaii's native biota. In C. P. Stone and J. M. Scott (Eds.) *Hawaii's Terrestrial Ecosystems: Preservation and Management*, pp. 180-250. Honolulu, HI, Cooperative National Park Resources Unit, University of Hawaii.

SPREP (Secretariat of the Pacific Regional Environment Programme) (2014) *Framework for Nature Conservation and Protected Areas in the Pacific Islands Region 2014-2020*. Apia, Samoa, SPREP, 32pp.

(2016a) *State of conservation in Fiji: Country report 2013*. Apia, Samoa, SPREP, 74pp.

(2016b) *Battling Invasive Species in the Pacific: Outcomes of the Regional GEF-PAS IAS Project: Prevention, Control and Management of Invasive Species in the Pacific Islands*. Apia, Samoa, SPREP, 40pp.

(2017) *SPREP Annual Report: 2016*. Apia, Samoa, SPREP, 70pp.

Taylor, S. and Kumar, L. (2016) Will climate change impact the potential distribution of a native vine (*Merremia peltata*) which is behaving invasively in the Pacific region? *Ecology and Evolution*, **6** (3), 742-754.

Thomas, N., Surumi, J., Macedru, K., Mataitoga, W., Qeteqete, S., Naikatini, A., Niukula, J., Heffernan, A., Fisher, R. N. and Harlow, P. S. (2011) *Iguana iguana*: a feral population in Fiji. *Oryx*, **45**, 321-323.

Tutangata, T. I. (2000) Sinking islands, vanishing worlds. *Earth Island Journal*, **15** (2), 44.

Tye, A. (2009) *Guidelines for Invasive Species Management in the Pacific: A Pacific Strategy for Managing Pests, Weeds and Other Invasive Species*. Apia, Samoa, SPREP, 20pp.

UNEP-WCMC (United Nations Environment Programme – World Conservation Monitoring Centre) (2016) *The State of Biodiversity in Asia and the Pacific: A Mid-term Review of Progress towards the Aichi Biodiversity Targets*. Cambridge, UNEP-WCMC and IUCN, 103pp.

van den Burg, M., Breuil, M. and Knapp, C. (2018) *Iguana delicatissima*. The IUCN Red List of Threatened Species 2018. e.T10800A122936983. http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T10800A122936983.en. Downloaded on 7 September 2018.

Van Kleunen, M., Dawson, W., Essl, F., Pergl, J., Winter, M., Weber, E., Kreft, H., Weigelt, P., Kartesz, J., Nishino, M., Antonova, L. A., Barcelona, J. F., Cabezas, F. J., Cárdenas, D., Cárdenas-Toro, J., Castaño, N., Chacón, C., Chatelain, C., Ebel, A. L., Figueiredo, D., Fuentes, N., Groom, Q. J., Henderson, L., Inderjit, Kupriyanov, A., Masciadri, S., Meerman, J., Morozova, O., Moser, D., Nickrent, D., Patzelt, A., Pelser, P. B., Baptiste, M. P., Poopath, M., Schulze, M., Seebens, H., Shu, W., Thomas, J., Velayos, M., Wieringa, J. J. and Pyšek, P. (2015) Global exchange and accumulation of non-native plants. *Nature*, **525**, 100-103.

Vitousek, P. M. (2004) *Nutrient Cycling and Limitation: Hawai'i as a Model System*. Oxford, UK, and Princeton, NJ, Princeton University Press, 223pp.

Wainqolo, I. and Timote, V. (Fijian Forestry Department and Fiji Quarantine Inspection Service) (2005) Forest invasive species: country report: Fiji. In P. McKenzie, C. Brown, S. Jianghua and W. Jian (Eds.), *The unwelcome guests. Proceedings of the Asia-Pacific Forest Invasive Species Conference*, 17-23 August, Kunming, China. http://www.fao.org/docrep/008/ae944e/ae944e00.htm

Wardell-Johnson, G. W., Keppel, G. and Sander, J. (2011) Climate change impacts on the terrestrial biodiversity and carbon stocks of Oceania. *Pacific Conservation Biology*, **17**, 220-240.

Watling, D. (2005) *Palms of the Fiji Islands*. Suva, Fiji, Environmental Consultants Fiji, 192pp.

Watling, D. and Chape, S. (1992) *Fiji: State of the Environment Report*. Gland, Switzerland, IUCN, 154pp.

Weeks, R. and Adams, V. M. (2018) Research priorities for conservation and natural resource management in Oceania´s small-island developing states. *Conservation Biology*, **32**, 72-83.

Wittenberg, R. and Cock, M. J. W. (Eds.) (2001) *Invasive Alien Species: A Toolkit of Best Prevention and Management Practices*. Wallingford, UK, CAB International, 228pp.

Witono, J. R. (2003) Phenetic Study on Clustered *Pinanga* of Java and Bali. *Biodiversitas*, **4** (1), 38-42.

Witono, J. R., Mogea, J. P. and Somadikarta, S. (2002) *Pinanga* in Java and Bali. *Palms*, **46** (4), 193-202.

Witono, J. R. and Rondo, K. (2006) Genetic analysis of some species of *Pinanga* (Palmae) by using ISSR markers. *Berita Biologi*, **8** (1), 19-26.