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Mitigating the threat of invasive marine species to Fiordland: New Zealand's first pathway management plan

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Abstract

Multiple human-mediated pathways in the marine environment provide ample opportunities for new and potentially harmful species to spread into high-value natural areas. Often, these areas are remote and reactive measures to an invasion prove to be difficult, therefore a more precautionary and proactive approach is necessary. The Fiordland Marine Area (FMA) is largely unmodified and has a unique and productive underwater environment. Following an amendment in 2012 to the Biosecurity Act 1993 the Fiordland Marine Guardians and an inter-agency government group worked to develop and implement the Fiordland Marine Regional Pathway Management Plan (FMPP), whose overarching objective is to prevent the introduction and spread of invasive marine species to the FMA. The plan involves three key elements to manage invasive species vectors: (1) that vessel owners and operators hold a current Clean Vessel Pass for their vessel; (2) that the vessel meets clean vessel standards including hull biofouling, gear biofouling and residual seawater requirements; and (3) that owners and operators maintain and can present records on the steps taken to meet the clean vessel standards. The plan was made operative in 2017, and to date, uptake has generally been positive with only a small number of compliance issues. The adoption of this plan is largely due to an integrated iwi, community and agency management approach which has encouraged engagement and participation from the Fiordland stakeholders. The ongoing success of this programme will rely on the commitment from the partnering central and local government agencies to improve and refine the plan, and on a general elevation in the importance of marine biosecurity management nationwide. Ideally, the plan will significantly reduce the risk of further marine bioinvasions within the FMA.

Key words: Fiordland Marine Guardians, biofouling, vessels, vectors, proactive management

Introduction

The establishment of invasive species threatens biodiversity and has the potential to cause major social, environmental and economic consequences

(Vitousek et al. 1996; Pimentel et al. 2000; Bax et al. 2003; Early et al. 2016; Paini et al. 2016). Global connectivity driven by the need for international and regional trade has opened significant pathways for the transport of non-indigenous species which can go on to become invasive (Carlton 2000; Hulme 2009). In marine and estuarine systems vessel movement is the primary pathway to transport marine species to areas outside of their "home range". The management of vectors to prevent the transport of marine species in conjunction with early detection and rapid response capability are important components of biosecurity systems (Hewitt et al. 2004; Wotton and Hewitt 2004; Hewitt and Campbell 2007).

Effective biosecurity management is critical to protect New Zealand's unique fauna and flora and growing primary industries. New Zealand is world-leading regarding its biosecurity system including terrestrial, freshwater and marine environments, and a coordinated and proactive biosecurity approach is utilised including managing risk offshore to controlling species within the country (Hewitt et al. 2004; Champion 2018). In short, New Zealand has developed a biosecurity system with effective and proactive legislation and policy supported by science to manage invasive species (Champion 2018). The Biosecurity Act 1993 provides the legal framework for management agencies to prevent the establishment, respond and eradicate or control established harmful organisms. This framework encourages national and regional government agency collaboration and engagement with affected parties and stakeholders.

The system itself is well set up for invasive terrestrial species management, however, it cannot always be directly applied to the marine environment and the tools for mitigating the spread of invasive marine species in a global context have shown only minor advancements (Hewitt and Campbell 2007; Goldson et al. 2015). Proactive management focusing on invasion pathways (e.g. shipping) is needed in order to reduce the risk of invasive marine species establishing in new areas. The primary vectors of ballast water and biofouling have recently become regulated in some areas by international policies and border regulations such as the International Convention for the Control and Management of Ships Ballast Water and Sediments (IMO 2004 ratified September 2017) and New Zealand's Craft Risk Management Standard (CRMS) for the biofouling on vessels arriving to New Zealand (MPI 2018). Such regulation is relatively new, and only deals with vessels entering New Zealand waters. There is a need to also focus on the secondary (domestic) human-mediated spread of invasive marine species within New Zealand waters, and to protect areas of high natural, social and commercial value. There are significant efforts nationwide through the Marine Pest High Risk Site Surveillance (Woods et al. 2018) and recent, regional or area-specific marine biosecurity programmes in Northland, Auckland, Bay of Plenty, Waikato, Hawkes Bay, the Top of the South (Forrest 2019), the Chatham Islands and

Southland all aiming to reduce the domestic spread of marine invasive species (New Zealand Government 2019; Top of the North Marine Biosecurity Partnership 2019).

Until 2012, the domestic spread of harmful organisms was managed through species-specific pest management plans. In 2012 the Biosecurity Act 1993 was amended to allow for national and regional pathway management plans which enable management agencies to declare invasive or harmful species as "pests" and place rules on the vectors of spread rather than species-specific rules. This change in legislation authorises proactive measures which have advantages over traditional reactive approaches i.e. preventing invasive species establishment rather than taking costly and potentially ongoing remedial action once an invasive species is detected. Risk-reduction mechanisms should underpin marine biosecurity due to the difficulties of incursion responses in the marine environment. The provision for pathway management plans is a major step forward in marine biosecurity management in New Zealand. At present, several national and regional partnerships are considering their implementation or at least a more vector-focused approach to marine biosecurity. The Fiordland Marine Area was the first area of the country for which a domestic pathway management plan was considered and implemented – the Fiordland Marine Regional Pathway Management Plan (FMPP, Environment Southland 2017a). The process was driven by a community-based, multi-stakeholder and government agency partnership.

This paper reviews the process that led to regulatory marine pathway management for Fiordland and why this represented an important step forward for marine biosecurity in New Zealand. We first provide a broad overview of marine vectors and their management. We then discuss the Fiordland Marine Area, the threat of invasive marine species and the importance of pathway management in this context. Finally, we review the process that led to the development and the implementation of the FMPP 2017 and the early learnings from this programme.

Marine pest pathways and their management

Species-specific management is useful in some circumstances, however, there is a need for vector focused approaches to limit the introduction of unknown invasive species and their domestic spread (Ojaveer et al. 2014). Successfully managing pathway risks greatly lowers the chance of an invasive species, disease or pathogen establishing (Ruiz and Carlton 2003), and this is critical both pre- and post-border. By including strategic pathway management for harmful organisms with early detection and rapid response tools, natural areas and industries can be particularly resilient to the damaging effects from invasive species.

The greatest pathway risks are by vessel movements that can transport species in different ways (Coutts and Dodgshun 2007; Acosta and Forrest

2009). These include ballast water, external hull fouling and fouling in niche areas but also water and sediment from other internal spaces (e.g. bilge), anchors, fishing and dive gear and associated equipment. These vectors can all be managed to reduce the risk of such activities resulting in the spread of invasive marine species (Carlton and Geller 1993; Ruiz et al. 1997; Coutts and Taylor 2004; Ashton et al. 2006; Coutts and Dodgshun 2007; Acosta and Forrest 2009; Fletcher et al. 2017).

Regular hull maintenance practices including the application of antifouling coatings are crucial for preventing the transport of marine invasive species on the hulls of vessels. It is equally important that the antifouling coatings used are regularly applied (as per manufacturers' guidelines) as the age of the coating is a critical factor for the settlement of biofouling (Floerl and Inglis 2005; Floerl et al. 2005). It is also important that the type of coating (e.g. fouling release, self-polishing, soft ablative and hard non-ablative coatings) is suitable for the type of vessel (Piola et al. 2009). Applying antifouling coatings is not enough on its own to reduce biofouling sufficiently. Poor application of antifouling coatings and damage to hull surfaces can facilitate the recruitment of biofouling taxa (Piola et al. 2009). Further, some areas of hull surfaces can be difficult to antifoul. Therefore, regular inspection of the coatings condition and for the presence of biofouling taxa is important to ensure vessels remain a low risk of transporting marine species to new areas. Depending on the results of such inspections, vessel haul-outs and dry-docking may be necessary to remove risk-biofouling.

The movement of fouled marine equipment is a risk, and this has been highlighted in the aquaculture industry (Fitridge et al. 2012). Also, the establishment of permanent moorings or barges, and movement of fishing gear can facilitate domestic spread. Invasive biofouling species including *Undaria pinnatifida* (Harvey) Suringar, *Sabella spallanzanii* (Gmelin, 1791), *Styela clava* Herdman, 1881 and *Didemnum vexillum* (Kott, 2002) have been associated with moveable aquaculture gear and debris (Forrest and Blakemore 2006; Locke et al. 2007; Fletcher et al. 2013a, b; James and Shears 2016; Campbell et al. 2017; South et al. 2017), which has contributed to their domestic spread in New Zealand and can be a nuisance/cost to the aquaculture industry. To reduce the risk of transporting invasive species on equipment, a number of treatment options can be used (Georgiades et al. 2016). This includes the physical removal of visible biofouling, treatment with chemicals such as chlorine (Morrisey et al. 2016) and acetic acid (Forrest et al. 2007), the use of heat and steam (Wotton et al. 2004; Forrest and Blakemore 2006; Cahill et al. 2019) and desiccation (Hopkins et al. 2016).

Water held on and within vessel compartments is another vector, particularly for microscopic life stages. Ships use ballast water to maintain stability while transporting cargo and passengers, however ballast water also contributes to the dispersal of invasive marine species (Carlton and

Geller 1993; Drake and Lodge 2007). Bilge water is considered a significant vector in this context, with a number of hardy taxa maintaining viability through the bilge water uptake, transport and release process (Fletcher et al. 2017). Additionally, other uses of water such as holding tanks for rock lobster and wells of on-board water are controllable vectors. Reducing the risk of on-board water can be achieved by discharging bilge and ballast in open water such as blue water exchange or prior to departure, avoiding the discharge of seawater in high value areas or treating the water with chemicals, heat or UV (Tsolaki and Diamadopoulos 2010; Stehouwer et al. 2015).

Pathway management is particularly important for high-value and remote marine areas (Campbell and Hewitt 2013) as in many instances these places are relatively unmodified, may contain sensitive species, and have strong social and cultural significance along with high economic and environmental values (Cocklin et al. 1998; MacDiarmid et al. 2013; McCarthy et al. 2014). Pathway management initiatives have been introduced in several global locations to date. For example, in response to increasing vessel traffic, local authorities in the Galapagos Islands, Ecuador, inspect international vessels on arrival for biofouling and direct them to leave for cleaning if they are transporting fouling species (Carlton et al. 2019). The Department of Land and Natural Resources is working towards inspection and enforcement procedures for ballast water and biofouling management in Hawaii (Department of Land and Natural Resources 2007; Davidson et al. 2014; DLNR Division of Aquatic Resources 2019). New Zealand is home to several high value marine areas that would benefit from protection via pathway management regulation.

The Fiordland Marine Area and pathway management

Fiordland is an area in the southwest of New Zealand's South Island characterised by a spectacular mountainous landscape, dense indigenous forest, high rainfall, and glacial carved fiords extending out to a rugged coastline (Figures 1 and 2; Fiordland Marine Guardians 2017). Human activity within Fiordland has been limited until recent times. Few Māori permanently resided in Fiordland, but the region was used seasonally for food gathering. European settlement first occurred in 1773 but it wasn't until the mid-19th century that explorers, prospectors and surveyors penetrated the area. The establishment of mines, timber mills and agriculture however did not last, and the Fiordland National Park was officially constituted in 1952, becoming an UNESCO World Heritage Area in 1986. The area is still relatively isolated by today's standards and it is one of the few remaining true wilderness areas. The marine environment holds outstanding natural values including diver-accessible black coral, red coral and sea pens, as well as productive commercial and recreational fisheries in the outer fiords and coast (Grange 1985, 1991; Fiordland Marine Guardians 2017). The marine flora and fauna are highly diverse, and the inner fiord

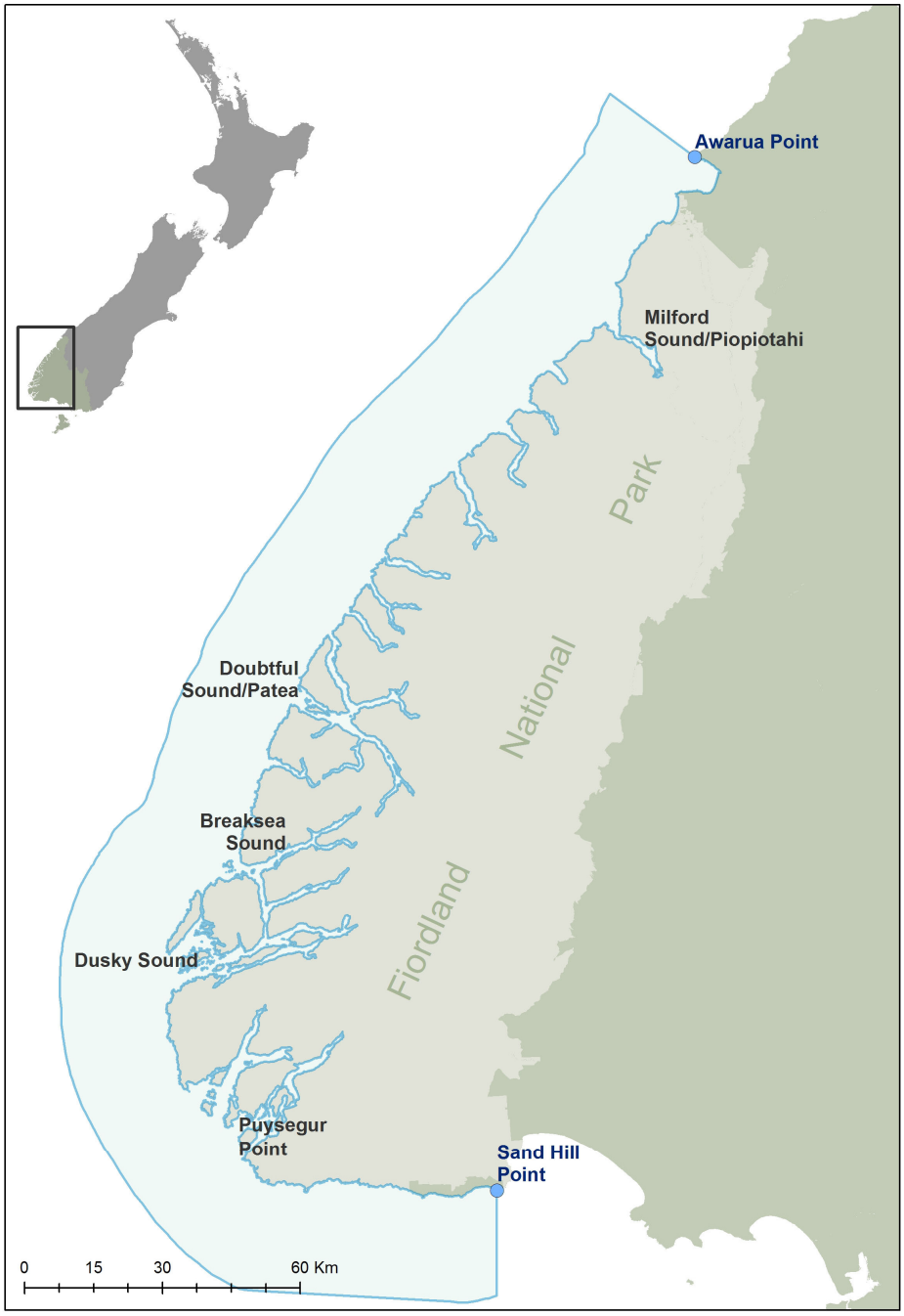

Figure 1. The southwestern New Zealand Fiordland region highlighting the national park and the Fiordland Marine Area (FMA) from Awarua Point in the north to Sand Hill Point in the south. The FMA extends 12 nautical miles from the coast (light blue).

marine ecology is globally unique (Figure 2). As technology has improved, Fiordland has become more accessible and this can lead to an overall degradation of the environment through mounting pressure on fish stocks, increasing biosecurity risk and potential pollution from development. The areas' remoteness and high natural value require protection and effective resource management.

An integrated iwi/community/agency led approach to resource management underpins the future sustainability of the FMA. In 1995, a group of stakeholders formed the Guardians of Fiordland's Fisheries Inc

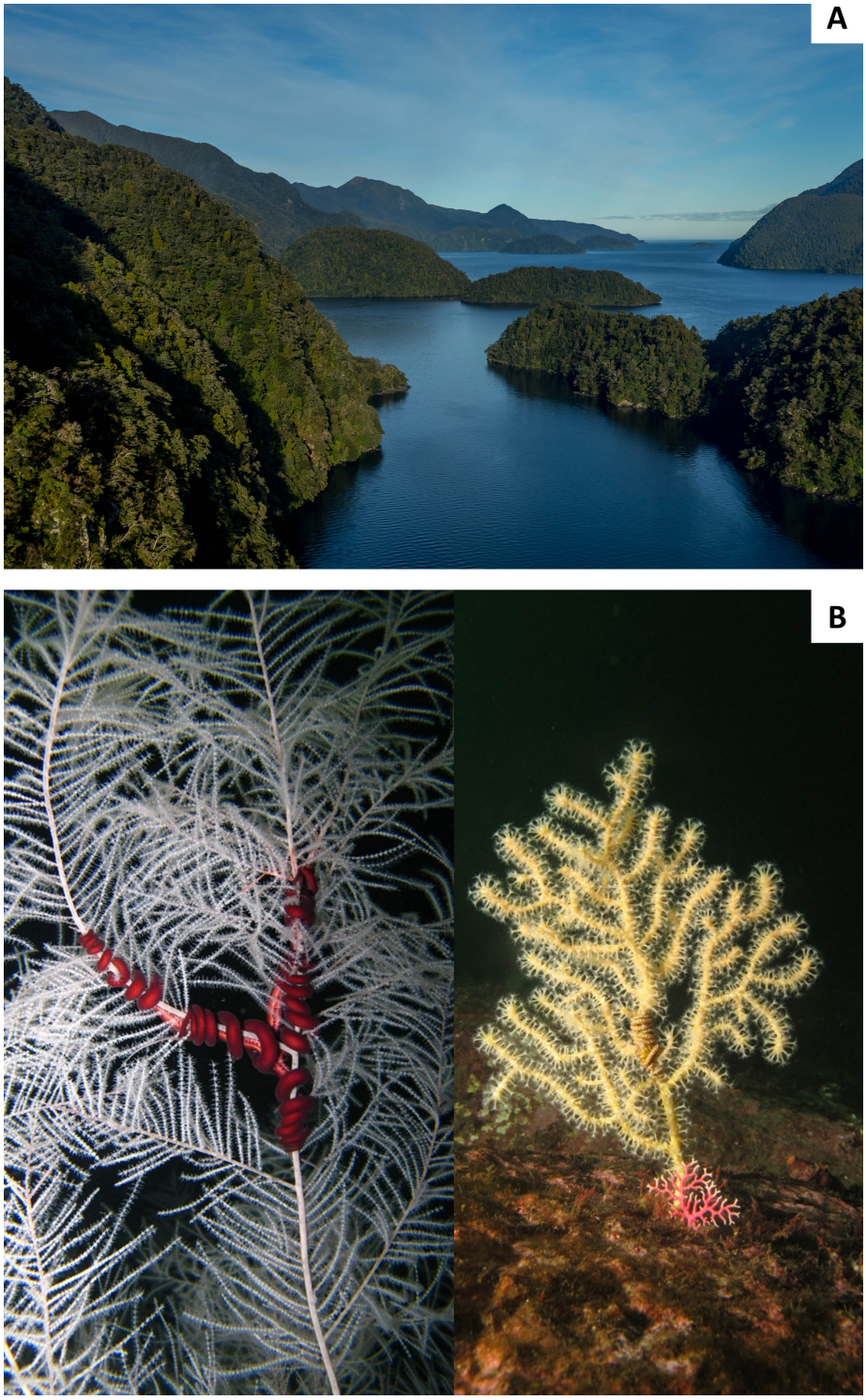

Figure 2. A – The Fiordland coastal landscape in Breaksea Sound and B – some of the abundant coral species that can be found at diving depths sometimes as shallow as 3–5 m (image A provided by S. Cunningham; images B provided by R Kinsey of the Department of Conservation).

(now referred to as the Fiordland Marine Guardians, from here on "Guardians") in response to growing concern regarding the mounting pressure on the Fiordland marine environment via fishing, tourism and development. The Guardians vision was and remains "that the quality of Fiordland's marine environment and fisheries including the wider fishing

experience, be maintained or improved for future generations to use and enjoy". The work of the Guardians led to the development of the Fiordland Marine Conservation Strategy 2003 (Guardians of Fiordland's Fisheries & Marine Environment Inc. 2003) which prioritised major conservation issues for the area. The strategy was presented to the Minister of Fisheries and the Minister for the Environment and led to the development of special legislation – the Fiordland (Te Moana o Atawhenua) Marine Management Act 2005. The result was a package of negotiated measures including amended non-commercial fisheries rules, the exclusion of commercial fishing from large areas of the internal reaches of the fiords, the protection of areas of unique and fragile biodiversity (known as "china shops"), the establishment of eight of the ten Fiordland marine reserves and several other non-legislative measures (Townsend 2008). The Guardians are appointed by the New Zealand Government and collectively represent tangata whenua (indigenous people of this region) together with commercial and recreational fishers, tourism interests, recreational users, marine science, conservation and the local community supporting kaitiakitanga or stewardship. The tangata whenua, or iwi of the wider region is Ngāi Tahu with the Ōraka-Aparima Rūnaka Inc having the stewardship role for the FMA. The Guardians are responsible for the integrated management of the FMA, and as a component of this, they provide advice to the multiple government agencies involved in Fiordland's management. The collaborative foundation of the Guardians has led to multiple governing agencies being advised by local experts, who work together and pool resources to sustain and enhance the marine values in Fiordland. This is a unique approach to environmental management in that the Guardians play a role normally reserved for government agencies.

In early discussions, the impacts of invasive marine species (along with pollution and overfishing) were recognised as one of the biggest threats to the FMA (highlighted in the Fiordland Marine Conservation Strategy 2003) and subsequent user surveys have shown this concern too (Booth et al. 2007; Booth and Espiner 2010). Following on from the Conservation Strategy, systems were continually developed to improve marine biosecurity. This involved a Fiordland Marine Biosecurity Plan and joint management agency response agreement (between central and local government agencies) for considering incursion response in the FMA (MPI 2015, 2016). This agreement would ensure the management agencies investigate marine incursions, outlining the decision-making process and cost-sharing arrangements for an initiated response.

In 2010, the invasive seaweed *Undaria pinnatifida* (Harvey) Suringar was discovered in Sunday Cove, Breaksea Sound, Fiordland, which initiated a joint-agency local eradication response, and this continued for seven years (Environment Southland 2017b). Monthly, teams of divers were deployed in Sunday Cove to search and manually remove

sporophytes from natural and artificial substrates. In conjunction with the removal programme, annual and semi-annual wider surveillance for *U. pinnatifida* took place and the hulls of vessels that frequently departed Bluff Harbour and the Oban area (Stewart Island) for Fiordland were inspected on a monthly basis, under a programme led by the Ministry for Primary Industries (MPI). The response continued with an eradication objective until April 2017 when further populations of *U. pinnatifida* were found to be widespread in Breaksea Sound. Management of the invasive seaweed carries on with a containment goal, however, the spread of *U. pinnatifida* has continued and there is ongoing concern over further spread or renewed introductions (Environment Southland 2017c, 2019). The operational team likely succeeded or came very close to complete eradication of *U. pinnatifida* within Sunday Cove with less than 10 juvenile sporophytes detected and removed annually over the final 3 years of the response. However, a subsequent invasion outside of the initial incursion area ended the chance of complete eradication of *U. pinnatifida* from Fiordland. Despite the outcome of the response, several significant initiatives came out of the process, including the importance of preventing marine bioinvasions, learnings for future incursions and the strengthening of the stakeholder and government partnership to tackle these issues as they arise. The willingness of the partnering agencies (with strong support from the Guardians) to undertake and resource this local eradication attempt ultimately laid the working foundation for the prioritisation of pathway management and a strengthened marine biosecurity capability in Fiordland.

Following the 2012 amendment to the Biosecurity Act 1993 and considering the invasion of *U. pinnatifida* in Breaksea Sound, there was a large push from the Guardians to consider pathway regulations for Fiordland. Pathway management plans were regarded as an ideal tool for the FMA because of the increasing vessel movements out of other NZ ports where potential invasive marine species were present. A steering group was formed to develop a proposal, and a collaborative approach was taken involving representatives from the Guardians, Te Rūnanga o Ngāi Tahu, and government agencies Environment Southland (ES), MPI, the Department of Conservation (DOC), and other relevant stakeholders. The process to develop a pathway management plan for Fiordland (Figure 3) was an extension of the integrated iwi/community/agency approach that was implemented to develop the Fiordland Conservation Strategy back in 2003 (L. Teirney *pers. comm.*, July 2019).

Regional pathway management plans are made through Part 5 of the Biosecurity Act 1993 and must align with the National Policy Direction for Pest Management 2015 to ensure national consistency. There are several steps councils must follow before implementing a plan with enforceable rules including demonstrating that the benefits of a plan will outweigh its costs and that formal consultation takes place with those that may be affected

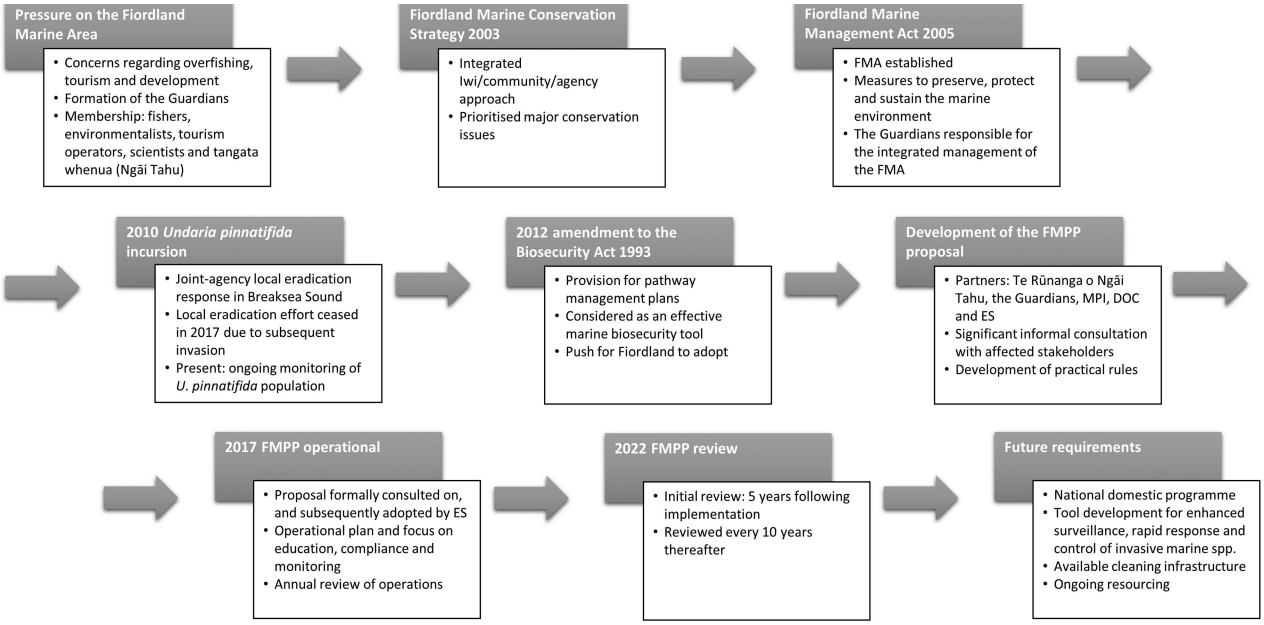

Figure 3. A summary of the process that led to the development and implementation of the Fiordland Marine Regional Pathway Management Plan.

by the new rules. Subject matter experts were engaged as required, and public informal and formal consultation was also conducted to ensure that the proposed solution was going to be effective and practical/workable. The level of informal consultation was pivotal to achieve final approval of the plan and support from Fiordland users once it became operational, however, this added consultation is not a requirement of the Biosecurity Act 1993. Environment Southland are the lead agency enacting the plan, and in 2017, the Environment Southland Council formally adopted the FMPP – a major advancement for marine biosecurity management and the first of its kind in New Zealand.

The elements of the pathway plan

The development approach was grounded in education and self-responsibility, and the proposed management of invasion pathways to Fiordland intended to be practical and easy to understand consisting of only three rules. The first rule was that all boats within 1 nautical mile of the landward boundary of the FMA would have to apply and hold a current Clean Vessel Pass (CVP) which is currently of no charge to the applicant. The CVP is a declaration that the vessel will be clean and will meet specific biofouling and residual seawater standards set out in the second rule of the plan. The CVP rule creates a system for ES to directly communicate with users of the FMA and gather information on where vessels are coming from and where they are going to within Fiordland, and this includes details on the types of vessels and times of year vessels are operating in Fiordland. Being able to communicate directly with a target audience and collect this type of information is important for the planning and timing of communications and compliance, and surveillance for invasive

marine species. It is worth noting that Rule 1 of the FMPP may not directly apply to cruise ships as they can meet this rule by agreeing to Environment Southland's revised Cruise Ship Deed of Agreement. Rules 2 and 3 of the FMPP apply to cruise ships as they do for all other vessels.

The second rule of the FMPP requires that all vessels entering within one nautical mile of the landward boundary of the FMA to have hull biofouling meet a standard of "no more than a slime layer and goose barnacles" (including niche areas), that any gear associated is clean, treated and dry, and that residual seawater such as live holding tanks for rock lobster are visibly clean and treated. These rules are not pest specific, however, they focus on the key vectors many marine invasive species utilise to reach a new destination. Therefore, if vessel operators minimise the amount of fouling or contamination by marine organisms the chance of an invasive species being transported and establishing in Fiordland is greatly reduced.

The third rule is that records must be held to show that steps have been taken to adhere to the standards in Rule 2 of the FMPP, and that these are made available on request to ES. This rule is important as not all vessels can be fully inspected and evidence of best practice, such as a combination of evidence of recent antifouling coating and/or in-water hull inspection prior to entering Fiordland is a useful method to assess the risk of vessels.

Following the development of the proposal, extensive informal consultation with affected stakeholders, testing the plan through the Biosecurity Act 1993 and National Policy Direction, and acceptance by the Environment Southland Council, the FMPP became operative in April 2017. The plan itself consists of several components to help it succeed: a robust communications strategy, regular compliance and monitoring for invasive species, committed resourcing and community support – all of which are essential for this programme to continue well into the future.

Plan implementation and early lessons

Effective communication ensures the opportunity for voluntary compliance with marine biosecurity requirements and encourages vessels to stay in a clean state regularly. Behaviour change is the most important aspect of the FMPP, and education is the best tool to prevent non-compliance. On the other hand, enforcement is an important backstop, and if rules aren't enforced, over time non-compliance will occur (Shimshack and Ward 2005). Compliance activities on their own are also a very powerful communication tool. Lastly, monitoring is needed to test the effectiveness of the FMPP by assessing whether its rules are enough to mitigate biosecurity risk or if the programme is being implemented at full capacity. An annual review of the operations gives the Council the opportunity to continually adapt and improve implementation. The FMPP must be re-evaluated initially after five years (first review 2022) and thereafter every 10 years.

Vessels originating from several ports domestically and internationally visit Fiordland including commercial fishing and tourism vessels, cruise

ships and recreational yachts and powerboats capable of covering long distances. These predominately in-water vessels (i.e. only leave the water for maintenance purposes) are the greatest risk and are the key audiences of the FMPP. The partnering agencies need to continue to communicate with these stakeholders to encourage compliance. Currently, to achieve this, a variety of print and web media along with in person workshops and on-water compliance trips are used to deliver the key messages. Communications are delivered by various local and central government agencies and marine stakeholders. Communications are not just limited to being pathway and Fiordland specific, but include invasive species identification and steps to ensure vessels are of as low biosecurity risk as possible. Management agency cooperatives elsewhere in the country, including the Top of the North and Top of the South marine biosecurity partnerships, encourage best practice biofouling management through education, compliance and monitoring for marine pests in other regions of the country and this continually helps to raise the awareness of vessel owners (MPI 2019). The overall increase in the profile of marine biosecurity nationally will continue to encourage best practice by vessel owners visiting the FMA and other high-value natural areas in New Zealand.

Data from CVP applications in 2017–18 (April 2017–June 2018) and visits by cruise ships to the FMA estimate that the number of vessels visiting Fiordland is approximately 320 individual vessels with many making multiple visits to the area in a year. This number is calculated from 290 individual CVPs issued by Environment Southland (Environment Southland 2018) and information from the New Zealand Cruise Association on the 2017–18 cruise season which reports that 27 individual cruise ships entered the FMA with a total of 97 cruises through the area (NZCA 2019). This total number of vessels visiting Fiordland is thought to be underestimated as it is unlikely all vessels visiting the area apply for a CVP.

Bi-annual Fiordland-wide surveillance and compliance trips take place focussing on random inspections checking compliance with the three FMPP rules, and diver surveys of mooring areas for the detection of invasive species. To date compliance with the biofouling rules of the FMPP has been good, with only five instances requiring enforcement action out of over 100 on-water random inspections since the plan's inception. Enforcement has been a combination of cost-recovering inspection costs for minor infringements to the full recovery of inspection, sample collection, removal and organism identification costs and the legal direction to leave the FMA for vessel haul out and clean. The uptake of applying for a CVP has been slow and adherence to this rule is at a lower rate. However, even vessels inspected without a CVP were found to have met the requirements of Rule 2 of the FMPP and presented a low biosecurity risk. During the initial implementation period, the operational programme has focussed primarily on education and inspections rather

than formal compliance for minor infringements (e.g. failing to produce a CVP but not breaching the standards in Rule 2). Since the beginning of the 2018–19 season, compliance using the cost-recovery powers of the Biosecurity Act 1993 for vessel inspection costs has been implemented for most minor breaches of the FMPP. The continued combination of education and the ability of Environment Southland to take enforcement action where appropriate will lead to greater compliance rates in the future.

Compliance monitoring is important to assess whether key messages are being communicated effectively and can inform any need for changes in operations (e.g. revising the communication strategy or stricter penalties and more frequent inspections) if rules are continually being breached. The rate of new incursions to Fiordland is another way to test the effectiveness of the plan. To date, the only surveillance methods employed have been diver surveys of well used mooring and anchoring areas and vessel hubs such as Milford and Doubtful Sound. Due to the remoteness and size of Fiordland, the sole use of divers lacks early detection sensitivity and is resource intensive over large areas. Other species or taxa-specific methods such as traps, grabs and dredges could prove to be useful and passive approaches such as the deployment and retrieval of settlement plates would improve surveillance capability (Tait et al. 2018). However, morphological taxonomy methods may fail to detect early and cryptic life stages of invasive species and therefore the parallel use of novel molecular technologies would improve surveillance sensitivity (Pochon et al. 2015; Zaiko et al. 2016; Wood et al. 2017; von Ammon et al. 2018).

However, the major limiting factors are the increasing pressure by visiting vessels from risk ports, availability of vessel cleaning and maintenance facilities, the difficulty of operating in such a remote and hard to access location, and ensuring resourcing is available to carry out compliance, surveillance and education.

Methods to assess compliance need to be continually developed and adopted (Zabin et al. 2018). To date, protocols for inspection have not been developed. The Regional Coastal Plan for the Kermadec and Subantarctic Islands 2017 in New Zealand and the inspection, sampling and reporting protocols therein are based on the Floerl et al. (2005) standardised Level of Fouling (LoF) rank scale and include guidance diagrams for hull inspections as well as reporting forms for inspection results, vessel operational history and biofouling maintenance (Floerl et al. 2010). A similar approach could be adopted for the FMPP and should be encouraged as best-practice for vessels prior to entry to the FMA. For random compliance inspections this approach is likely too onerous for most vessels intercepted and inspected that are operating and visiting the area. A simpler and more rapid standardised assessment should be developed and other technologies such as ROV and video should be explored and trialled (Zabin et al. 2018). Technical guidance on biofouling management for vessels arriving into

New Zealand is available to assist compliance with New Zealand's CRMS (Georgiades et al. 2018). The biofouling standard of the FMPP and the long-stay standard for the CRMS are identical – no more than a slime layer and goose barnacles, therefore, this guidance could easily be adopted to inform vessels intending to operate in Fiordland, and many international vessels should be familiar with the biosecurity requirements due to the consistency between the two separate regulations. Guidance is also available for how to treat equipment from MPI, however, protocols for the discharge and treatment of residual seawater including bilge and domestic ballast water discharge need to be further refined as assessing non-compliance can be difficult, and chemical treatments need testing and further approvals by the relevant authorities (Sinner et al. 2013).

As national level guidance increases, and more regional authorities include invasive marine species management into their biosecurity programmes, rules will become more stringent for vessels moving within New Zealand. Including steps to make voluntary compliance with rules easier will be beneficial. For areas like Fiordland, a greater level of environmental stewardship is expected, and its users are likely more willing to be proactive in regard to this. However, around New Zealand there is a current lack of infrastructure and tools (e.g. available haul out facilities) for vessels to meet biofouling standards, therefore, future investment in this space would likely lead to greater compliance. Additionally, where enforcement may be used, inspection processes will need to be standardised nationally (e.g. inspections by divers or ROV) so that regional authorities can readily assess and communicate biosecurity risks of vessels moving between coastal management areas.

Conclusion

On its own, pathway management is not enough to maintain very low risk of marine bioinvasion. The major limiting factors of the FMPP are the increasing pressure by visiting vessels from risk ports, availability of vessel cleaning and maintenance facilities, the difficulty of operating in such a remote and hard to access location, and ensuring resourcing is available to carry out compliance, surveillance and education. To strengthen the overall marine biosecurity system, efforts must continue to identify opportunities to manage risks offshore and domestically, as well as enhancing our ability for early detection and rapid response to invasive marine species capable of impacting New Zealand's coastal values. When compared to terrestrial biosecurity, the marine environment lacks cost-effective surveillance and control tools, and resourcing. Methods for better biosecurity surveillance such as the use of environmental DNA detection methods, capability to treat high risk vessels quickly and effectively and control tools need to be further developed and adopted into marine biosecurity management by government agencies and industry partners.

Several human-mediated pathways can spread harmful organisms, and therefore, pathway management approaches can prevent or reduce the risk of these organisms establishing in high-value coastal marine areas. Successful eradication or long-term containment of established invasive marine species from natural environments is a substantial challenge and technically and financially difficult in remote areas (Meyerson and Reaser 2002; Coutts and Forrest 2007). If an incursion is detected early and rapid response can take place, or the benefits of control clearly outweigh the costs required to minimise the impact of an established invasive species, then reactive management can be justified. However, prevention is the best insurance, and this includes understanding and controlling the pathways of introduction to mitigate invasion and prevent new introductions. Pathways need to continue to be managed at the border and within New Zealand focusing on domestic transfers among ports, marinas, aquaculture installations and important marine areas such as the Fiordland Marine Area and offshore islands such as the Kermadec and Subantarctic Islands. The marine biosecurity regional partnerships that have developed in some areas of New Zealand including the Top of the North and Top of the South marine biosecurity partnerships (MPI 2019) have resulted in more effective domestic marine biosecurity management and leadership in this area which will likely contribute to a national scale domestic programme in the future.

Effective management of biosecurity relies on interagency and stakeholder collaboration and engagement (Champion 2018). The Fiordland marine biosecurity partnership described throughout this article highlights the importance of an integrated iwi/community/agency approach and this was the primary driver behind a pathway management plan becoming operative to help protect the FMA from bioinvasions. This inclusion of regulatory vector management is a major advancement and provides significant benefits to a valuable and largely unmodified marine area. The plan and its outcomes will inform marine biosecurity management in other areas of New Zealand and globally.

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