Pathway Management Plan

Assessing the benefits and costs of implementing a Pathway Management Plan is a requirement under the Biosecurity Act 1993. A national guiding document released in 2015 accompanying the National Policy Direction provides the relevant components required for cost benefit analysis and assessment of implementation costs.

The analysis of benefits and costs associated with the pathway plan were assessed using a benefit-cost model originally developed for Top of the South (which compromises the three Top of the South councils, MPI, local ports, the aquaculture industry, tangata whenua and other regional stakeholders in marine biosecurity). The model was further developed and refined by Cawthron Institute to better fit Northland and the pathway management scenario of reducing hull bioufouling to a low level.

The model is a four-step risk management process (risk identification, risk assessment, analysis of the risk treatment options, and risk evaluation) designed to assess risk according to the likelihood of marine pest introduction and spread with and without pathway management, and the consequences of their impact on regional values. Benefits are determined, in dollar terms, as the difference between unmanaged and managed risk.

Aquaculture

Description	Aquaculture (or marine farming) is the breeding and growing of animals and plants in the water for profit. It can take place on land or in ponds or tanks, but most aquaculture in New Zealand occurs in the sea. The main commercial species farmed in New Zealand are green lipped mussels and pacific oysters. Green lipped mussels are grown on lines suspended from floats on the surface, while Pacific oysters are grown on inter-tidal racks. Other species farmed include chinook salmon, paua, snapper and kingfish.
Risk	Aquaculture is a known vector for the spread of marine pests and diseases. The spread of these pests is usually associated with biofouling species and the movement of aquaculture equipment and stock between marine farms. Marine pest impacts are largely related to the fouling of marine farms which can result in the loss of stock, reduced growth rates and increased costs associated with handling and cleaning. In addition, once established, marine pests are more likely to spread to the adjacent environment which can result in adverse effects on the surrounding natural habitat. In some instances the species being farmed can escape into the surrounding environment, becoming invasive.
Ability to move organisms	It is common practise within the aquaculture industry to share and reuse gear or move stock between farms and other regions. If the gear is not clean or treated prior to relocation - 'hitchhiking' marine pests can be transferred between marine farms. Similarly, the movement of stock, in particular spat, which must be kept alive, also favours 'hitchhiking' marine pests. Should transfers occur between regions, gear should be thoroughly cleaned and details of the transfer kept.
Regional distribution	Northland is one of New Zealand's major marine farming regions, producing nearly half the country's exports of Pacific oysters and three-quarters of its mussel spat. The oyster farming industry is concentrated in the Bay of Islands, Parengarenga, Houhora, Whangaroa and Kaipara harbours. There are approximately 120 developed marine farms with ongoing interest in the development of additional oyster growout farms in the Far North harbours, and in oyster spat catching in the Kaipara. Northland has 841 hectares of consented marine farm area - although only approximately half of this is actually developed. On land, there is the National Institute of Water and Atmospheric Research (NIWA) fin-fish aquaculture research facility and a commercial abalone farm owned by OceaNZ Blue, both are located at Bream Bay near the entrance to Whangarei harbour.
Current controls	- An organism new to New Zealand is managed by MPI until its identified. - MPI has protocols in place to reduce the risk of marine pest spread associated with aquaculture activities. - Codes of practise have been developed by oyster, mussel and salmon producers which are aimed at reducing biosecurity risks associated with their operations.

	- A notice of direction can be given to a marine farm that is found to be harbouring a pest that is identified in the RPMS. - A notice of direction can be given under Section 122 of the Biosecurity Act for any unwanted organism. - An infringement notice can be given to a marine farm that is found to be harbouring/ releasing any 'exotic organism' in Northland under the Regional Coastal Plan for Northland. - Air drying and/ or waterblasting are the two most common forms of treatment for biofouling marine pests on aquaculture gear. - Biosecurity management plans have been developed by some marine farms although this approach is voluntary and hasn't been implemented industry wide. The Ministry of Fisheries (now MPI) was responsible for monitoring compliance of marine farmers with leases and licences for marine farming issued under the Marine Farming Act 1971. Responsibility for approving and monitoring marine farms has now passed to regional councils under the Resource Management Act 1991, although in the case of derelict or abandoned marine farms, any forfeiture action begun by the Ministry of Fisheries under the Marine Farming Act will be concluded. Upon the granting of a coastal permit for a marine farm, MPI must make an aquaculture decision. This involves MPI making a formal assessment on whether the proposed aquaculture activity will have an undue adverse effect on customary, recreational or commercial fishing.
Benefits	Aquaculture is one of the fastest growing primary industries and holds significant commercial, ecological and cultural value. In 2011 approximately 3000 people were employed nationally by the industry, generating over $400 million in revenue with a goal of reaching $1 billion in sales by 2025.

The Northland Scenario

In 2013, aquaculture in Northland was estimated to have produced over $18.5m in regional gross domestic product and directly employed more than 380 people. In addition to aquaculture activities, spat collection from Northland significantly supports aquaculture activities in other parts of New Zealand. Mussel spat collected from seaweed at Ninety Mile Beach supplies over 75% of seed to mussel farms throughout New Zealand. Kaipara Harbour provides oyster spat.

Aquaculture has the potential to be an increasingly important contributor to the social, economic, and cultural wellbeing and health of Northland, especially in the more remote parts of the region.

Pacific oysters (Crassostrea gigas) and Green-lipped mussels (Perna canaliculus) are the two main species grown in Northland. There is currently 841 hectares of consented marine farm area - although approximately only half of this is actually developed. Currently, approximately 120 developed marine farms are located in 10 of the region's 15 harbours, utilising the extensive intertidal flats, warm waters, and generally high water quality of the coastal marine area.

Aquaculture has recognised potential for expansion in the Northland region, subject to the identification and use of suitable and appropriate sites and the adoption of management controls.

To date, *Eudistoma elongatum, Didemnum vexillum* and *Styela clava* have been found on marine farms in Northland.

Common aquaculture stock transfers in and out of Northland:

- Wild mussel spat collected from 90 Mile-Beach and transferred to various marine farms throughout New Zealand;
- Wild oyster spat collected from sites such as the Kaipara harbour and transferred to marine farms within the upper North Island; and
- Oyster spat from Nelson and Marlborough Sounds transferred to Northland.

Species risk assessment

Organism	Suitability for translocation via aquaculture	Current status	Potential to become a pest if introduced	Potential financial implications	
				Potential economic loss	Potential cost of management
Asian clam	More likely via ballast water than aquaculture	Unwanted Organism Not established Notifiable organism	Strongly inferred impact on both economic values and biodiversity. Thought to be responsible for the collapse of commercial fisheries and the decline of biodiversity in California. Can live in fresh and salt water and is highly resistant to changes in salinity and temperature. In San Francisco Estuary average densities average 2,000/m2. Feeds at multiple levels in the food chain, can place pressure on native organisms and significantly disturb surface sediment layers	High	High
Caulerpa seaweed	Most likely way of arriving in New Zealand is through importation for use in aquariums and subsequently released into the marine environment	Unwanted Organism Not established Notifiable organism	A rapidly growing saltwater weed that can cause major ecological and economic damage. Ability to live in a wide range of temperatures, depths and substrates. Forms dense fields and can prevent the establishment of native seaweeds. Can cause reduction of fishing catches due to elimination of fish habitat.	Medium	Medium
Chinese mitten crab	Juveniles could be transported through oyster aquaculture	Unwanted Organism Not established	Potential to undermine the integrity of stream banks through burrowing, accelerating erosion. Ability to live in both fresh and salt water with a wide diet, infers a significant impact	High	Medium

Organism	Suitability for translocation via aquaculture	Current status	Potential to become a pest if introduced	Potential financial implications	
				Potential economic loss	Potential cost of management
		Notifiable organism	on ecosystems. Can affect human health as a host for parasitic lung flukes. In Europe, high densities have damaged commercial fishing nets and catches.		
European shore crab	Juveniles could be transported through oyster aquaculture. Tolerates a wide range of salinities and temperatures	Unwanted Organism Not established Notifiable organism	Voracious predator, can negatively impact shellfish population including those being farmed. Significant potential impact on both economic values and biodiversity. May out-compete native crabs and cause decline in native shellfish populations Ability to spread – first recorded in Port Phillip Bay, Victoria in 1900 and now occurs widely in Southeast Australia.	Medium	Medium
Mediterranean fanworm	Can be transported via aquaculture Is known from mussel farms in the Waikato and Auckland Regions	Unwanted Organism Notifiable organism Well established in Auckland harbour. Present in some areas of Whangarei harbour.	Highly invasive species, can form dense groups that could affect native species by competing for food and space. Can filter large amounts of water which could affect nutrient flow.	High	High
Northern pacific Seastar	Juveniles could be transported through aquaculture	Unwanted Organism Not established Notifiable organism	Strongly inferred impact on biodiversity and shellfish farming. Is a voracious predator and can multiply rapidly. Has potential to cause major problems for local communities and commercial shellfish operations.	High	High

Organism	Suitability for translocation via aquaculture	Current status	Potential to become a pest if introduced	Potential financial implications	
				Potential economic loss	Potential cost of management
Asian paddle crab	Juveniles could be transported through aquaculture	Widespread in the Hauraki Gulf, has been detected in Whangarei harbour and Opua/Waitangi.	Aggressive crab, potential to compete with native crabs, preys on shellfish and as such can threaten marine farming. Not reported to be a pest in its native habitat or in other countries.	High	Medium
Didemnum sea squirt	Can be transported via aquaculture	Established in Marlborough Sounds, Whangamata and Tauranga.	Strongly inferred impact on marine farming. Can smother man made structures including mussel lines, and spreads easily.	High	High

What pests already existing may have been introduced by aquaculture?

As outlined in the above Species Risk Assessment Table, all but Caulerpa Seaweed and Asian clam could be introduced via aquaculture.

To date, *Eudistoma elongatum, Didemnum vexillum* and *Styela clava* have been found on marine farms in Northland.

Mediterranean fanworm has become established in Whangarei Harbour (Northland Regional Council in conjunction with the Whangarei Marine Biosecurity Charter Group, 2013. *Whangarei Marine Biosecurity Charter*), although this has occurred through hull biofouling there is the potential for it to be spread via aquaculture.

Styela clava can now be found in the Bay of Islands, Whangarei and the Houhora harbours; *Eudistoma elongatum* is found in the Parengarenga, Rangaunu and Hohoura harbours as well as in the Bay of Islands; *Didemnum vexillum* is found in Whangarei and Houhora harbours; Pyura sea squirt is in Russell and Oronga Bay in the Bay of Islands, Hokianga, and the far north; Undaria is found in Houhora and Rangaunu harbours.

Ballast water

(referenced: Cawthron reports part A and B (2013), Convention for the control and management of ships ballast water and sediments(2004), and Vessel movements within NZ (MAF 2008))

Description	Ballast water is used by vessels to increase the draft, change the trim or regulate stability. If a vessel is unladen it will usually be ballasted and will discharge its ballast water to account for the amount of cargo being loaded. When taken on, ballast water may include sediments and biological constituents which may then be discharged with the water in a different port. Ballast water is discharged by both domestic and foreign vessels in New Zealand ports.
Risk	Ballast water can potentially carry unwanted marine organisms and discharge them, live, in to a new country or region. Due to the process of taking on and discharging ballast, it is most likely that marine organisms would be transported as larvae, spores or fragments. Ballast water can also introduce algal blooms. Once introduced to a new environment these organisms can establish quickly and affect marine biodiversity. Ballast water is recognised as a mechanism of spread for marine organisms.
Ability to move organisms	The translocation of marine organisms via ballast water is dependent on the volume of water being taken on and expelled, the number of marine organisms in the port of origin and the ability of any organisms to survive in the receiving environment, season and lifecycle of the organism, and transit time.
Regional distribution All data, excluding that on cruise ship movements, is referenced is from MPI Technical paper No 2014/04 'Vessel Movements within New Zealand' June 2009	Ballasted vessels are constantly travelling throughout New Zealand and being received from overseas. The majority of movements of large merchant vessels between NZ ports between January 2000 and December 2005 were either lightly or moderately ballasted, with 21.3% being heavily ballasted. Whangarei exceeds this national average, with 55% of vessels being heavily ballasted, and 43.6% moderately ballasted (see appendix 1). This is due to the higher than average number of bulk carrier vessel arrivals in Whangarei (see appendix 2). There is little seasonal variation in large vessel movements. The majority of movements of ballasted vessels occur on the Eastern coast of New Zealand, from Whangarei to Bluff, including the ports of Auckland, Tauranga, Gisborne, Napier, Wellington, Picton and Nelson, Lyttelton, Timaru, and Dunedin. New Plymouth is the only port on the West Coast to have significant movement of large vessels. Between January 2000 and December 2005 there was an average of 7,210 movements of large merchant vessels between New Zealand ports each year. Analysis of mean annual vessel movements of vessels greater than 99 tonne show that the majority of domestic movements *to* Whangarei originate from Tauranga (30 – 82 annual movements) followed by Auckland, Napier, Wellington, Lyttelton, Dunedin and New Plymouth (8 – 29 annual movements for each). The majority of movements *from* Whangarei are to Tauranga (83 – 198 annual movements) and Auckland (30 – 82 annual movements). Data on international vessels is limited, however mean annual movements to and from Whangarei (see appendix 3) show that there were a greater number of large vessels leaving Whangarei for domestic ports than those arriving from domestic ports, indicating that there were a greater number of arrivals from international ports than departures to international ports. This discounts Whangarei as a 'last port of call' location. The other main port of arrival and departure of international vessels in Northland is Opua and the Bay of Islands. The majority of the vessels arriving and departing from Opua marina are recreational and not likely to be ballasted. Cruise ships visiting the Bay of

	Islands are most likely to be arriving from or departing to a domestic location with approximately 26% of cruise ships during the last high season arriving from an international location, and approximately 17% departing to international locations (see appendix 4). This discounts the Opua and the bay of Islands as primarily being a 'last port of call' for large vessels.
Current controls	Central government is responsible for the control of ballast water discharge from international vessels or vessels that have been outside NZ territorial waters, and manages this under section 22 of the Biosecurity Act through the Import Health Standard for Ballast Water (2005). This requires that if not freshwater, the ballast must have been either exchanged en route, treated, or discharged to an onshore treatment facility. There are few, if any, restrictions on ballast water domestically.
Benefits	Ballast water provides an effective way to ensure that ships can travel safely between ports with little or no cargo on board.

The Northland scenario

As ballast water is generally only required by large merchant vessels, the East coast of Northland is at the greatest risk due to the operation of the port of Whangarei, and visiting cruise ships in the Bay of Islands.

Vessels servicing the cement works in Whangarei travel to the upper reaches of the harbour where they will discharge 1800 tonnes of ballast water approximately 90 time a year. Half of the time, this water is taken up in Auckland. Northport, at the mouth of the harbour, receives a higher volume of shipping traffic, with domestic movements predominantly coming from the top of the South Island and the East Coast of the North Island.

Domestic coastal tankers at Marsden Point Refining Company make approximately 120 visits, and discharge 18,000 tonnes of seawater, taken up from various locations between Auckland and Bluff.

Over 50 cruise ship arrivals are expected to visit the Bay of Islands in the high season from October 2015 – May 2016. While some of these vessels arrive from outside of New Zealand territorial waters and are held by national standards for ballast water, the majority arrive from other areas in New Zealand.

Species risk assessment

A preliminary assessment of the risk that ballast water presents based on species that are currently included in the Northland Marine Pest Management Strategy, the majority of which are not currently in New Zealand, and are capable of being transported via ballast water.

Organism	*Suitability for translocation via ballast*	*Current status*	*Potential to become a pest if introduced*	*Potential financial implications*	
				Potential economic loss	*Potential cost of management*
Asian clam	Larvae of Asian clam can be transported in ballast water. Able to survive in both salt water and fresh water, risk of being	Unwanted Organism Not established Notifiable organism	Strongly inferred impact on both economic values and biodiversity. Thought to be responsible for the collapse of commercial fisheries and the decline of biodiversity in California. Can live in fresh and salt water and is highly resistant to changes in salinity and temperature.	High	MPI lead agency

Organism	*Suitability for translocation via ballast*	*Current status*	*Potential to become a pest if introduced*	*Potential financial implications*	
				Potential economic loss	*Potential cost of management*
	introduced in fresh ballast water.		In San Francisco Estuary average densities average 2,000/m2. Feeds at multiple levels in the food chain, can place pressure on native organisms and significantly disturb surface sediment layers		
Caulerpa seaweed	Most likely way of arriving in New Zealand is through importation for use in aquariums and subsequently released into the marine environment.	Unwanted Organism Not established Notifiable organism	A rapidly growing saltwater weed that can cause major ecological and economic damage. Ability to live in a wide range of temperatures, depths and substrates. Forms dense fields and can prevent the establishment of native seaweeds. Can cause reduction of fishing catches due to elimination of fish habitat.	High	MPI lead agency
Chinese mitten crab	Larvae and juveniles can be transported in ballast water. Post-larval stages can survive in both salt and fresh ballast water. Larvae are planktonic for 1 – 2 months.	Unwanted Organism Not established Notifiable organism	Potential to undermine the integrity of stream banks through burrowing, accelerating erosion. Ability to live in both fresh and salt water with a wide diet, infers a significant impact on ecosystems. Can affect human health as a host for parasitic lung flukes. In Europe, high densities have damaged commercial fishing nets and catches.	High	MPI lead agency
European shore crab	Larval and juvenile stages of the crab can be transported in ballast water. Tolerates a wide range of salinities and temperatures	Unwanted Organism Not established Notifiable organism	Voracious predator, can negatively impact shellfish population including those being farmed. Significant potential impact on both economic values and biodiversity. May outcompete native crabs and cause decline in native shellfish populations	High	MPI lead agency

Organism	*Suitability for translocation via ballast*	*Current status*	*Potential to become a pest if introduced*	*Potential financial implications*	
				Potential economic loss	*Potential cost of management*
			Ability to spread – first recorded in Port Phillip Bay, Victoria in 1900 and now occurs widely in Southeast Australia.		
Mediterranean fanworm	Can be transported in ballast water as larvae, although most likely to be transported via hull biofouling.	Unwanted Organism Notifiable organism Well established in Auckland harbour. Present in some areas of Whangarei harbour.	Highly invasive species, can form dense groups that could affect native species by competing for food and space. Can filter large amounts of water which could affect nutrient flow.	High	High
Northern pacific Seastar	Can be transported in ballast water as larvae.	Unwanted Organism Not established Notifiable organism	Strongly inferred impact on biodiversity and shellfish farming. Is a voracious predator and can multiply rapidly. Has potential to cause major problems for local communities and commercial shellfish operations.	High	MPI lead agency
Asian paddle crab	Can be transported in ballast water as larvae. Larvae can float in the water for 3 – 4 weeks.	Widespread in the Hauraki Gulf, has been detected in Whangarei harbour and Opua/Waitangi.	Aggressive crab, potential to compete with native crabs, preys on shellfish and as such can threaten marine farming. Not reported to be a pest in its native habitat or in other countries.	Medium	Medium
Didemnum sea squirt	Can be transported as fragments in ballast water. Releases tailed larvae into the water column.	Established in Marlborough Sounds, Whangamata and Tauranga.	Strongly inferred impact on marine farming. Can smother man made structures including mussel lines, and spreads easily.	Medium	Medium

What pests already existing may have been introduced by ballast water?

As outlined above in the Species Risk Assessment Table, all but Caulerpa seaweed, could be introduced via ballast water.

Mediterranean fanworm has become established in Whangarei Harbour (Northland Regional Council in conjunction with the Whangarei Marine Biosecurity Charter Group, 2013. *Whangarei Marine Biosecurity Charter*), although this has occurred through hull biofouling there is the potential for this to occur via ballast water.

Styela clava can now be found in the Bay of Islands, Whangarei and the Houhora harbours; *Eudistoma elongatum* is found in the Parengarenga, Rangaunu and Hohoura harbours as well as in the Bay of Islands; *Didemnum vexillum* is found in Whangarei and Houhora harbours; Pyura sea squirt is in Russell and Oronga Bay in the Bay of Islands, Hokianga, and the far north; Undaria is found in Houhora and Rangaunu harbours.

Appendix 1

Table 10: 'Vessel movements within NZ'

Arrival port	Light	Medium	Heavy	Fishing	Slow	Total
Whangarei	22	833	1051	4	1	1911
Total of NZ ports % of NZ total	16 836 38.9%	15 846 36.6%	9 200 21.3%	1 274 2.9%	106 0.2%	43 262

Appendix 2

Table 11: 'Vessel movements within NZ'

Arrival port	Container	Cargo	Bulk	VPL	Tanker	Fishing	LNG/LPG	Other	Dredge	Bulk/oil	Total
Whangarei	20	472	1 043	2	361	4	1	1	1	6	1 911
Total of all ports % of total	15,540 35.9%	10,215 23.6%	7,210 16.7%	3,807 8.8%	3,594 8.3%	1,275 2.9%	1,030 2.4%	214 0.5%	31 0.1%	16 0.0%	43,262

Appendix 3

Table C23: 'Vessel movements within NZ'

Mean annual movements in and out of Whangarei

From Whangarei					
Total	Heavy	Medium	Light	Fishing	Slow
225.5	109.2	112.7	3.2	0.3	0.2

To Whangarei					
Total	Heavy	Medium	Light	Fishing	Slow

192.0	89.3	101.7	0.7	0.2	0.2

Appendix 4

2014/2015 Expected cruise ship arrivals, Bay of Islands

New Zealand Locations

	Auckland	New Plymouth	White Island	Tauranga	Fiordland	Wellington	Domestic Total
Arriving from	21	1	1	1	0	0	24
Departing to	15	0	0	4	5	2	26

International Locations

	Norfolk Island	Fiji	New Caledonia	Sydney	Rarotonga	Pitcairn Islands	International Total
Arriving from	1	1	2	3	2	0	9
Departing to	3	0	0	2	0	1	6

Biofouling

Description	Hull biofouling is the accumulation of aquatic organisms on vessel surfaces (including attachments, pontoons, hull surfaces, internal sea-water systems, niche areas; excluding ballast tanks) immersed in, or exposed to, the aquatic environment (Inglis, G., Floerl, O. and Woods, C., for MAF, 2012. *Scenarios of Vessel Bioufouling Risk and their Management).* Biofouling on vessel hulls is a known mechanism for the movement and introduction of marine organisms including marine pests from one place to another.
Risk	Vessels with an accumulation of hull biofouling are susceptible to marine pest attachment and infestation. In addition to the risk presented by biofouling on the smooth surfaces of the hull , there is a significant biofouling risk associated with the niche areas of vessels which are often overlooked. Niche areas are the non-hull submerged areas of the hull (including rudders, propellors, seachests, intakes etc)that due to their nature, position and/or structure are difficult to antifoul, clean and inspect In Northland both recreational and commercial vessel movements have been identified as primary mechanisms for the transport of marine pests (Northland Regional Council, 2015. *Immediate Options for Marine Pathways Management - A scoping document prepared by the Northland Regional Council on behalf of the Domestic Marine Pathway Management Project Working Group.).* Vessels that have long lay-up periods and slow voyages (barges and pleasure boats) often have proportionally higher levels of biofouling and pose a higher risk of introducing non-indigenous species to new locations. Whereas commercial vessels often have more incentive to maintain clean hulls to minimise drag and increase fuel efficiency however they have a larger surface area and more niche areas which are vulnerable to biofouling *(Ministry of Agriculture and Forestry, 2011. Risk Analysis: Vessel Biofouling.)* Once introduced to a new environment these organisms can establish quickly and have the potential to impact on the region's economy, environment, human health, and indigenous values. As biofouling, they can also interfere with vessel performance by causing drag - requiring more power and fuel, and block essential seawater and cooling systems. Northland receives a high volume of international traffic particularly visiting pleasure boats from the south pacific - however the risk associated with international traffic is primarily the responsibility of Ministry of Primary Industry (MPI), and will be managed by the introduction of the Craft Risk Management Standard, which will be in force by 2018. This will set 'clean hull' requirements for visiting vessels at the border with thresholds around what is considered a 'clean hull' that are dependent upon the length of stay of the vessel. Overall this will ensure a high standard of hull cleanliness for all international vessels (commercial and recreational) including those entering Northland. Not only the movements of vessels *entering* Northland pose a risk of introducing marine pests to new areas. Northland has a number of established marine pest species that are of concern to other regions. Customs data demonstrating that most international vessels arriving in New Zealand in 2009-10 cleared customs in Opua or Whangarei, and continued on to visit more than one other port during their stay (Inglis, G., Floerl, O. and Woods, C., for MAF, 2012. *Scenarios of Vessel Bioufouling Risk and their Management).* There are also strong connections between Northland and other recreational vessel hubs like Tauranga and Auckland. Vessels

	travelling from Northland, particularly those that have been laid up in Northland for extended periods and not regularly maintained, pose a significant risk of transferring unwanted marine organisms to new areas as biofouling.
Ability to move organisms	Each time a vessel moves from one port to another it presents a risk of transferring any species that may be associated with, or attached to the hull. Although if the hull and niche areas are well maintained and kept clean of any fouling this risk is virtually non-existent. The translocation success of marine pests via hull biofouling is also dependent on a number of factors: 1) the number of non indigenous marine organisms present at the vessels' place of origin or berth, 2) the ability of the organisms to survive in the receiving environment, 3) season and life cycle of the organisms, and 4) vessel transit time. Accumulation of hull biofouling will occur: - as anti-fouling ages; - if anti-foul has been damaged or incorrectly applied; or - during extended periods of inactivity, particularly in areas of low water flow and high fouling organism density. Marine pests transported by hull biofouling can enter the receiving environment by active in-water cleaning of hulls (i.e. scraping or brushing organisms off the hull) or by passive discharge. Passive discharge includes reproductive processes and the organism being dislodged off the hull during vessel movement.
Regional distribution	Vessels are constantly entering New Zealand waters and travelling from harbour to harbour, most of these vessels will have some level of accumulated hull biofouling. Furthermore stationary vessels either on moorings or in berths often have high levels of biofouling due to inactivity and lack of maintenance; derelict or poorly maintained vessels are common in some areas of Northland and are often heavily fouled. Due to the popularity and accessibility of Northland's east coast it is at higher risk of marine pest introduction than the west coast harbours. Most of the recreational vessels visiting Northland from other parts of New Zealand will spend most of their time on th east coast. Both of the customs clearance ports in Northland are also located on the Region's east coast (Bay of Islands and Whangarei Harbour). Recreational vessels constitute the bulk of vessel traffic into Northland and models have shown that approximately 50% of these recreational vessel movements are from Auckland marinas. The greatest domestic risk associated with hull biofouling arises from vessel movements from Auckland (NIWA for Northland Regional Council, 2011. *Scoping and development of a regional surveillance plan for marine pests in Northland*.). Auckland is known as a risk node for vessel biofouling not only due to the large volume of vessel movements originating form the region but also due to the fact it has a large number of established marine pests species. Nationally more than half the annual yacht movements begin and/or conclude in one of the following marinas: Westhaven Marina (2,186), Opua (1,283), Gulf Harbour Marina (1,249), Picton (1,195), Great Barrier Island (1,178) or Westpark Marina (790). Just over half the recreational vessel movements occur in the summer months with 90% of international vessels arriving during the summer months into Opua, Whangarei, Auckland and Tauranga.; with over 86% of recreational vessel arrivals to Northland originating from other areas of New Zealand (Ministry of Primary industries for Ministry of Agriculture and Forestry, 2009. *Vessel Movements within New Zealand* (MPI Technical Paper No: 2014/04).

	Although recreational vessels make up the bulk of vessel movements; Northland still receives a number of vessels greater than 99 tonne annually. Unlike the recreational movements most of the domestic large commercial vessels that visit Whangarei originate from Tauranga (30 – 82 annual movements) followed by Auckland, Napier, Wellington, Lyttelton, Dunedin and New Plymouth (8 – 29 annual movements for each). The majority of movements of these vessels departing Whangarei are to Tauranga (83 – 198 annual movements) and Auckland (30 – 82 annual movements) (Ministry of Primary industries for Ministry of Agriculture and Forestry, 2009. *Vessel Movements within New Zealand* (MPI Technical Paper No: 2014/04). Data on the number of international large commercial vessel movements to Northland is limited, however the only receiving harbour for international bulk carriers and tankers in the region is Whangarei. On average Whangarei receives 20 large commercial vessels a fortnight, of which 60% are international in origin (*Northport August expected arrivals data* 2016). Mean annual movements to and from Whangarei show that there were a greater number of large vessels leaving Whangarei for domestic ports than those arriving from domestic ports, indicating that the shortfall must have comprised international vessels.
Current controls	- All international vessel arrivals fall under the jurisdiction of MPI to be cleared at the border. - Any new to New Zealand organism is responded to by MPI until its identified and risk assessed. - A Notice of Direction can be given to a vessel that is found to be harbouring a pest that is identified in the RPMS, this notice will direct vessel owners to remove marine pests in a manner approved by an Authorised Person. - A Notice of Direction can be given under Section 122 of the BSA for any unwanted organism even if it is not listed in the RPMS. - An infringement notice can be given to a vessel that is found to be harbouring/releasing any 'exotic organism' into or within Northland under the Regional Coastal Plan for Northland. - Heavily fouled vessels are free to move around the region providing they are not harbouring an unwanted organism or a pest identified in the RPMS (and are not in breach of maritime safety laws). - Northland Marinas - as well as all marinas on the eastern seaboard of the Coromandel Peninsula down to and including Tauranga - with regional council support, are putting in place the 'six or one' programme, requiring proof of either a new antifoul within the previous six months, or a lift-and-wash within one month of arrival. - Marine pest surveillance checks occur annually throughout Northland. In the 2014/2015 summer season over 300 hulls were dived and checked - the council intends to inspected over 1000 hulls during the 2015/2016 summer period. In 2016/2017 the number of inspections will increase to 1500.
Benefits	Nil benefits of hull biofouling.

The Northland scenario

Hull biofouling represents the greatest risk of pest incursion to the Northland coastal environment, and was almost certainly responsible for the introduction of the Mediterranean fanworm (designated as an unwanted organism) to the Whangarei Harbour, which subsequently became established. Fanworm is not the only marine pest that presents a risk. *Styela clava* can now be found in the Bay of Islands, Whangarei and the Houhora harbours; *Eudistoma elongatum* is found in the Parengarenga, Rangaunu and Hohoura harbours as well as in the Bay of Islands; *Didemnum vexillum* is found in Whangarei and Houhora harbours; Pyura sea squirt is in Russell and Oronga Bay in the Bay of Islands, Hokianga, and the far north; and Undaria is found in Houhora and Rangaunu harbours.

A high number of the Notices of direction issued by Northland Regional Council staff during the summer hull-check period were associated with biofouling of niche areas.

The east coast of Northland hosts the busy commercial shipping activities at Marsden Point and Portland. Domestic coastal tankers at Marsden Point Refining Company make approximately 120 visits, from various locations between Auckland and Bluff.

There are a number of 'high value' areas within close proximity to Northlands harbours, such as the Poor Knight Islands and Three King Islands - consideration needs to be given to the risk of incursion to such areas.

Northland is unique in that it shares the statutory management of the Kaipara Harbour with Auckland Regional Council. The jurisdiction of both councils under the Resource Management Act 1991 (RMA) ends at the boundary line within the Kaipara Harbour, meaning individual rules cannot be enforced across that boundary. However there is an opportunity to align rules pertaining to marine biosecurity so that, while the management agent will change, the rules will be similar across the boundary.

Currently there are no commercial port facilities or marinas located on the west coast of Northland. However, both Kaipara and Hokianga Harbours are the home ports for local fishing fleets.

Over 50 cruise ship arrivals are expected to visit the Bay of Islands in the high season from October 2015 – May 2016. While some of these vessels arrive from outside of New Zealand territorial waters, the majority arrive from other areas of New Zealand.

Northland's marine industry employs approximately 1000 people and contributes at least $80 million to the regional economy (NRC in conjunction with the Whangarei Marine Biosecurity Charter Group, 2013. *Whangarei Marine Biosecurity Charter*). Haul out facilities at Whangarei and Opua Harbours attract a number of international recreational vessels (and New Zealand based recreational and commercial vessels) to undergo maintenance, cleaning and repairs (Inglis, G., Floerl, O. and Woods, C., for MAF, 2012. *Scenarios of Vessel Bioufouling Risk and their Management).*

Species risk assessment

A preliminary assessment of the risk that hull biofouling presents based on species that are currently included in the RPMS, the majority of which are not currently in New Zealand, and are capable of being transported via hull biofouling.

Organism	Suitability for translocation via hull biofouling	Current status	Potential to become a pest if introduced	Potential financial implications	
				Potential economic loss	Potential cost of management
Asian Clam	Able to survive in both salt water and fresh water, not transferred as hull biofouling.	Unwanted Organism Not established in New Zealand Notifiable organism	Strongly inferred impact on both economic values and biodiversity. Thought to be responsible for the collapse of commercial fisheries and the decline of biodiversity in California. Can live in fresh and salt water and is highly resistant to changes in salinity and temperature. In San Francisco Estuary average densities average 2,000/m2. Feeds at multiple levels in the food chain, can place pressure on native organisms and significantly disturb surface sediment layers	High	High (very few succesful control measures)
Caulerpa Seaweed	Most likely way of arriving in New Zealand is through importation for use in aquariums and subsequently released into the marine environment.	Unwanted Organism Not established in New Zealand Notifiable organism	A rapidly growing saltwater weed that can cause major ecological and econimc damage. Ability to live in a wide range of temperatures, depths and substrates. Forms dense fields and can prevent the establishment of native seaweeds. Can cause reduction of fishing catches due to elimination of fish habitat.	Medium	Medium (if caught early benthic mats can be used to treat)
Chinese mitten crab	Likely pathways for introduction include live importation and ballast water however there is a risk of them being introduced amongst hull biofouling.	Unwanted Organism Not established in New Zealand Notifiable organism	Potential to undermine the integrity of stream banks through burrowing, accelerating erosion. Ability to live in both fresh and salt water with a wide diet, infers a significant impact on ecosystems. Can affect human health as a host for parasitic lung flukes. In Europe, high densities have damaged commercial fishing nets and catches.	High	Very high (Difficult to detect, no known control measures and wide habitat distribution)

Organism	Suitability for translocation via hull biofouling	Current status	Potential to become a pest if introduced	Potential financial implications	
				Potential economic loss	Potential cost of management
European shore crab	The transport vectors implicated in introduction of this species globally include, hull fouling but also: natural dispersal, solid ballast, ballast water, and contaminated packing material shipped with commercial shellfish	Unwanted Organism Not established in New Zealand Notifiable organism	Voracious predator, can negatively impact shellfish populations including those being farmed. In its introduced range in the United States it has had significant impacts on both economic values and biodiversity, to the sum of $22 million annually. It is not only a voracious predator but also aggressive competitor and may outcompete native crabs and cause decline in native shellfish populations One of its major invasive characteristic is the ability to spread – first recorded in Port Phillip Bay, Victoria in 1900 and now occurs widely in Southeast Australia.	High	Very high (Difficult to detect, no known control measures and wide habitat distribution)
Mediterra-nean fanworm	Transported via hull biofouling and as larvae in ballast water.	Unwanted Organism Notifiable organism Well established in Auckland Harbour. Established in some areas of Whangarei Harbour.	Highly invasive species, can form dense groups that could affect native species by competing for food and space. Can filter large amounts of water which could affect nutrient flow.	Medium-High	Medium (if caught early benthic mats, chemical treatments or diver removals can be used to control)
Northern Pacific Seastar	Main vectors of spread are aquaculture stock and gear, ballast and live bait tanks. Risk of being introduced amongst	Unwanted Organism Not established in New Zealand Notifiable organism	Proven impact on biodiversity and shellfish farming in its introduced ranges in Australia. Is a voracious predator and scavenger and prefers bivalve prey (including commercially important species like scallops and mussels) It has a long larval phase and can multiply rapidly and has a tendency to form	High	High (difficult and costly to control mobile species)

Organism	Suitability for translocation via hull biofouling	Current status	Potential to become a pest if introduced	Potential financial implications	
				Potential economic loss	Potential cost of management
	severe hull biofouling or in seachests.		dense aggregations. Has potential to cause major losses in both recreational and commercial shellfish harvests.		
Asian paddle crab	The three main vectors of spread are deliberate introduction, ballast water and hull/niche biofouling.	Widespread in the Hauraki Gulf, has been detected in Whangarei Harbour and Opua/Waitangi.	Aggressive crab, potential to compete with native crabs, preys on shellfish and as such can threaten marine farming. Not reported to be a pest in its native habitat or in other countries.	Low (currently already present and only causing small losses to commercial flounder fishermen)	High (difficult and costly to control mobile species)
Didemnum sea squirt	Transported via hull biofouling and contaminated shellfish stock.	Established in Marlborough Sounds, Whangamata and Tauranga. Has been detected within Whangarei and Houhora Harbours.	Strongly inferred impact on marine farming. Can smother man made structures including mussel lines, and spreads easily.	Low (few mussel farms in Northland)	Medium (there has been research done on containment and chemical controls.)

What pests already existing may have been introduced by hull biofouling?

As outlined in the above Species Risk Assessment Table, all but Caulerpa seaweed and Asian clam, could or have been introduced via hull bioufouling.

All known Mediterranean fanworm incursions in New Zealand have been traced back to a heavily infested barge located in Auckland Harbour. Mediterranean fanworm subsequently spread to Whangarei Harbour and become established (Northland Regional Council in conjunction with the Whangarei Marine Biosecurity Charter Group, 2013. *Whangarei Marine Biosecurity Charter*).

Styela clava can now be found in the Bay of Islands, Whangarei and the Houhora harbours; Eudistoma sea squirt is found in the Parengarenga, Rangaunu and Hohoura harbours as well as in the Bay of Islands; Didemnum sea squirt is found in Whangarei and Houhora harbours; Pyura sea squirt is in Russell and Oronga Bay in the Bay of Islands, Hokianga, and the far north; Undaria is found in Houhora and Rangaunu harbours.

Proposed management

Option	Programme description	Explanation of benefits	Explanation of costs	Level of risk that programme will not be successful
No regional intervention	Status quo.	Currently there are no specific rules relating to hull biofouling unless an unwanted organism or RPMS listed marine pest is present. However, the Regional Coastal Plan for Northland prohibits the intentional introduction and spread of marine pests. Sections 52 and 53 of the Biosecurity Act contain provisions to manage, reduce and eliminate marine pests - but only once they have been discovered and identified. There would be no additional costs to council if there was no pathway plan to administer. New benchmarks are being set as industries impose their own initiatives, for example, Northland marinas, have in place a 'six-or-one' programme, requiring proof of either a new antifoul within the previous six months, or a lift-and-wash within one month of arriving at marinas.	An amendment to the Biosecurity Act in November 2012 made provisions for the development of pathway management plans as a measure to help manage the spread of harmful marine organisms in New Zealand. There would be no provisions under the pathway plan to control the introduction and spread of marine pests by way of hull biofouling which is known to be one of the main ways that marine organisms, including marine pests, are moved from one place to another. Should biofouling remain unmanaged, it may cause the spread of unwanted species by human activities beyond the scope of normal species spread. The spread of these unwanted species could have a significant impact on native species diversity and the marine farming industry. Attempted control of a widely expanded populations of marine pests would be more costly than the preventative management of the current populations or populations caused by by natural spread.	High. If a pathway is not identified in the marine pathways plan the council cannot take any legal actions. By not applying rules in the pathway plan to hull biofouling, there would be no provisions to control the introduction and spread of marine pests by this vector (other than on an unwanted species basis through the current provisions in the Biosecurity Act and/ or Regional Coastal Plan for Northland).

Option	Programme description	Explanation of benefits	Explanation of costs	Level of risk that programme will not be successful
Pathway programme: Slime layer only	No more than a slime layer and goose barnacles present on all below water surfaces of vessel hull. Any vessel with more hull biofouling than this could be subject to enforcement or risk minimisation actions by the council. The definition of a 'slime layer and goose barnacles' is unambiguous and legally robust. A 'slime layer and goose barnacles' has been adopted by the International Marine Organisation (IMO) and incorporated into its guidelines as a standard that will not facilitate pest attachment. It is also consistent with the *'Craft Risk Management Standard - Biofouling Vessels Arriving to New Zealand'* , set and implememted by MPI. Environment Southland has just released the marine pathways plan for Fiordland which also requires vessels visiting Fiordland can prove they only have a slime layer and/or goose barnacles on their hull during their visit to the area.	A pathway plan would provide more effective protection from marine pests through increased education/ understanding and statutory measures. A marine pathways plan could minimise the risk of new marine pest incursions into Northland. Rather than working reactively to try to eradicate a pest once it has been detected in Northland we would be managing the vector of spread before the pest enters our region. Overall hull cleanliness would improve, reducing the likelihood of marine pests entering the region and or being spread around Northland as hull biofouling. A marine pathways plan that allowes only minimal fouling would compliment the 'six-or-one' marina driven programme to keep hulls clean, and assist with its implementation.	Pathway plans are arguably the most cost-effective and efficient way forward as they are proactive, and aimed at preventing new marine pests from entering Northland and being spread around. However allowing only minimal fouling will incur costs with vessel owners. To maintain vessels at this level of biofouling extra lift and washes and antifouling more regularly will have to occur. This increased cost to vessel owners may encourage un-authorised in-water cleaning and antifouling activities which are inconsistent with the current (and proposed) regional plan rules.	Low-Moderate. It could be difficult to enforce and would require ongoing education. The rate of voluntary compliance from vessel owners will likely be low and would require a lot of ongoing resources for continued hull inspections and also significant council resources for the follow up of enforcement procedures under both the biosecurity act and RMA.

Option	Programme description	Explanation of benefits	Explanation of costs	Level of risk that programme will not be successful
Pathway programme: Light fouling	1-5% of visible surface covered by patchy macrofouling or filamentous algae. Usually remaining area covered in slime.	'Light fouling' is very similar to Top of the Souths proposed pathway plan (their definition of light fouling is described slightly differently). A pathway plan would provide more effective protection from marine pests through increased education/ understanding and statutory measures. Supports the marina 'six or one' programme. Lower risk than the status quo. Easier to comply with, less onerous and more cost effective than 'a slime layer and goose barnacles'. Overall hull cleanliness would improve, reducing the likelihood of marine pests entering and or being spread around Northland.	Pathway plans are arguably the most cost-effective and efficient way forward as they are proactive, and aimed at preventing new marine pests from entering Northland and being spread around. There could be difficulties in interpretation by both authorities and boat owners. May encourage un-authorised in-water cleaning and antifouling activities which are inconsistent with the current (and proposed) regional plan rules. Does not completely remove the risk of marine pest incursion - council hull survey data indicates the highest risk of pest incursion occurred on hulls categorised between 'light fouling' and 'extensive fouling'.	Moderate. It could be difficult for authorities and boat owners to determine their own compliance. It could be difficult to enforce and would require education, resources for ongoing hull inspections, following up on, for example, notices of direction and abatement notices.
Pathway programme: Considerable fouling	Macrofouling clearly visible but still patchy. 6-15% of visible hull surface covered by macrofouling or filamentous algae. Usually remaining area covered in slime.	Not applicable.	Not applicable.	Equivalent to the status quo of no regional intervention.
Pathway programme: Extensive fouling	16-40% of visible hull covered in marcofouling or filamentous algae.	Not applicable.	Not applicable.	Equivalent to the status quo of no regional intervention.

Option	Programme description	Explanation of benefits	Explanation of costs	Level of risk that programme will not be successful
	Usually remaining area covered in slime.			
Pathway programme: Very heavy fouling	41-100% of visible hull surface covered by macrofouling or filamentous algae. Usually remaining area covered in slime.	Not applicable.	Not applicable.	Equivalent to the status quo of no regional intervention.
Site led programme	Site-led Pest Programme: that the subject, or an organism being spread by the subject, that is capable of causing damage to a place is excluded or eradicated from that place, or is contained, reduced, or controlled within the place to an extent that protects the values of that place. Clean vessel destination pass - specific to a vessel and is to be on that vessel at all times. Would be defined with maps.	Consistent with parts of Fiordlands proposed pathway plan. A pathway plan would provide more effective protection from marine pests through increased education/ understanding and statutory measures. There are a number of 'high value' areas within close proximity to Northlands harbours, such as the Poor Knight Islands and Three King Islands. A clean vessel destination pass would remove the risk of incursion by way of hull biofouling in such areas.	Rules relating to hull biofouling would only be applicable to craft in areas defined as 'destination areas' and could not be enforced elsewhere. Response costs should an incursion occur. Marine pests would spread elsewhere. A partnership approach with the Department of Conservation would be required.	Low - as action would take place in specific destination/ high value places making use of limited resources.
Preferred option:	**Pathway programme - Light fouling + movement** In relation to NPD considerations (section 6(1) outlines four criteria) a **medium-level analysis** was deemed appropriate for the marine pathway plan. In terms of alternative approaches assessed, under <u>no regional intervention</u> (or do nothing) three types of hull fouling were considered; Considerable, extensive and heavy fouling. Reducing the risk of transporting marine pests(identified or otherwise) by reducing hull biofouling would be a voluntary measure. Control over reducing the risk of transportation of marine pests in Northland via biofouling on moving vessels would be negligible. This would be unacceptable for many users of the marine environment with high political and stakeholder fallout anticipated.			

<table>
<tr><th>Option</th><th>Programme description</th><th>Explanation of benefits</th><th>Explanation of costs</th><th>Level of risk that programme will not be successful</th></tr>
<tr><td></td><td colspan="4">Due to the difficult nature of controlling and managing marine pests consideration of a site led programme in the form of a 'clean vessel pass' was considered. However this targeted approach would see marine pests spread outside of the high value defined areas and this approach would not yield the same benefits as a Northland wide pathway plan approach. There would be no guarantee of outcomes in the selected areas.

A hull biofouling level of a 'slime layer only' for vessels in Northland was considered but was deemed to be an unrealistic provision both technically and economically, the cost to the vessel owner of maintaining a 'slime layer only' would be unsustainable. Even though this option would reduce the risk of transportation of marine pests in Northland to the lowest level, the result in positive outcomes would be outweighed by a high socio-political risk.

Light fouling + movement, offers the best and most practicable option as it is likely to; be easily identified by vessel owners, be easier to comply with than a 'slime layer only' level of fouling and from previous hull surveys 60% of vessel owners are already compliant with this level of fouling. Slowing the spread of marine pests and preventing the establishment of new marine pests by setting a minimum standard for hull fouling upon movement is considered the most efficient and cost effective option. Enforcement will remain an option for exacerbators of problem situations.</td></tr>
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Quantitative analysis

The high level analysis model for the marine pathways plan was created using a benefit-cost model originally developed by Cawthron Research (Forrest and Sinner, 2016) but adapted for the Northland situation. The model was populated with a NRC staff assessment based on data collection of the current programme for managing sustained control marine pests in Northland. The model includes not only the public costs of a pathways plan such as surveillance, administration and enforcement but also the private costs to vessel owners in meeting various levels of hull biofouling. The benefits to the Northland marine environment by preventing the spread and establishment of marine pests by managing the movement of fouled vessels have been quantified by using model inputs from numerous sources, namely Marjan van der Belt and Anthony Cole (2014), Murray Patterson and Anthony Cole (2013), and Vince Kerr (2010). The benefit of the alternative programmes assessed are determined, in dollar terms, as the difference between unmanaged and managed risk.

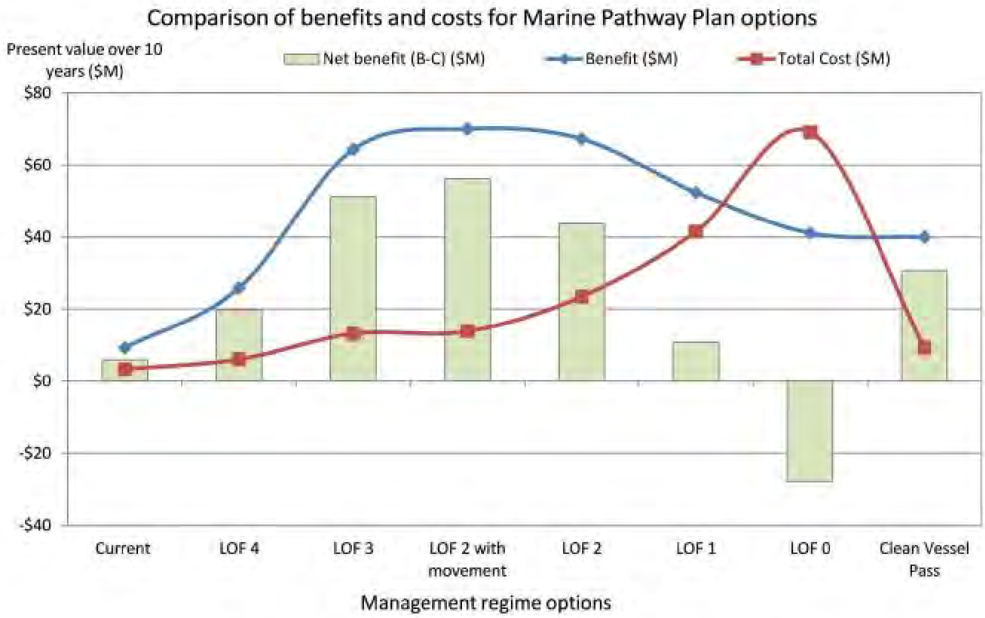
An important point of the pathway plan is that the proposed level of fouling (LOF 2) is only required when moving from one "place" to another, for example, from Whangarei Harbour to Tutukaka. It was determined that the risk imposed by a vessel which has a fouling level of more than LOF 2 is higher when moving that fouling from one place to another. A vessel staying in one location or moving within the defined place (for example Whangarei Harbour) with a level of fouling more than LOF 2 has a relatively lower risk of transferring new marine species that are not already present. This is with the exception of the sustained control species in which any vessel found with any of the sustained control species as fouling will be directed to remove these species as per the RPMP rules. A Clean Vessel Pass regime option was also analysed.

Key results

Present value of benefits and costs for a ten-year period

	Management regime							
	Current	LOF 4	LOF 3	LOF 2 movement	LOF 2	LOF 1	LOF 0	Clean Vessel Pass
Benefit ($M)	$9.2	$25.9	$64.3	$70.0	$67.2	$52.3	$41.2	$40.0
Private costs ($M)	$0.0	$1.6	$8.4	$9.0	$17.3	$31.7	$57.6	$4.0
Public costs ($M)	$3.3	$4.5	$4.7	$4.9	$6.1	$9.9	$11.4	$5.3
Total Cost ($M)	$3.3	$6.1	$13.1	$13.9	$23.4	$41.6	$69.1	$9.3
Net benefit (B-C) ($M)	$5.9	$19.8	$51.2	$56.1	$43.8	$10.8	-$27.9	$30.7
Benefit/Cost ratio	2.8	4.2	4.9	5.0	2.9	1.3	0.6	4.3

The table above and figure below summarise of key results comparing the existing species led approach for marine pest with various levels of biofouling under a potential Pathways Plan. For each management option, consideration was given to the extent to which it would reduce both the introduction and spread of marine pests in Northland. The cost increased across the options; both council costs such as administration and enforcement and private sector costs (lifting and washing, application of antifoul, etc) in meeting the LOF requirement. All but the LOF 0 option yielded a positive net benefit. The net benefit for the LOF 2 + movement management regime was the highest among the eight options considered.



The benefit cost analysis for the marine pathway plan suggests that the LOF 2 + movement management regime will produce the highest net benefit over a 10 year timeframe ($56M over 10 years). The public good in preventing new marine threat species from becoming established and current marine threat species from spreading is significant using the pathway approach. This approach will reduce the potential impacts and costs to the region in the future by preventing the need for incursions responses. The costs of redirecting the existing hull surveillance programme to compliance inspections for the biofouling levels (and continued sustained control marine species inspections) and lifting the number of vessels inspected per year returns a high positive net benefit result in terms of offsetting marine pest species risk and targeting multiple marine species, especially those not yet present in the region or identified as risk species. The combined impact of a species led and pathways plan approach is considered the most effective and efficient way of managing marine pests.

Key assumptions to the model

Calculation of risk assumptions

75%			Likelihood of marine pest being introduced in any one year					
90%			Likelihood of that introduction being attributed to hull fouling					
Efficacy 1 - Probability of treatment success								
	LOF 4	LOF 3	LOF 2 movement	LOF 2	LOF 1	LOF 0	Clean Vessel Pass	
	80%	85%	85%	90%	95%	95%	95%	
Efficacy 2 - Probability of uptake								
	LOF 4	LOF 3	LOF 2	LOF 2	LOF 1	LOF 0	Clean Vessel Pass	
	85%	75%	58%	58%	11%	4%	4%	Proportion of Northland boats in conformity based on hull survey data, i.e. at that level or below
	75%	66%	75%	50%	40%	30%	95%	Proportion on non-conformity vessels likely to move to requirement
	96%	91%	90%	79%	47%	33%	95%	Probability of uptake

Ecosystem values per/ha

	Ecosystem biome					
	Open sea/ocean	Continental shelf	Reefs	Salt marshes / wetland	Estuary / lagoon / intertidal / mangroves / seagrass	Total
Economic value ($ per ha)	112	378	4,146	15,008	1,943	
Northland area (ha)[3]	n.a.	n.a.	242,545	749	61,457	304,751
Total Northland value	n.a.	n.a.	1,005,469,635	11,240,676	119,410,982	1,136,121,293

Based on ver der Belt and Cole (2014), and follow Patterson and Cole (2013).

Value of marine environment at risk in Northland

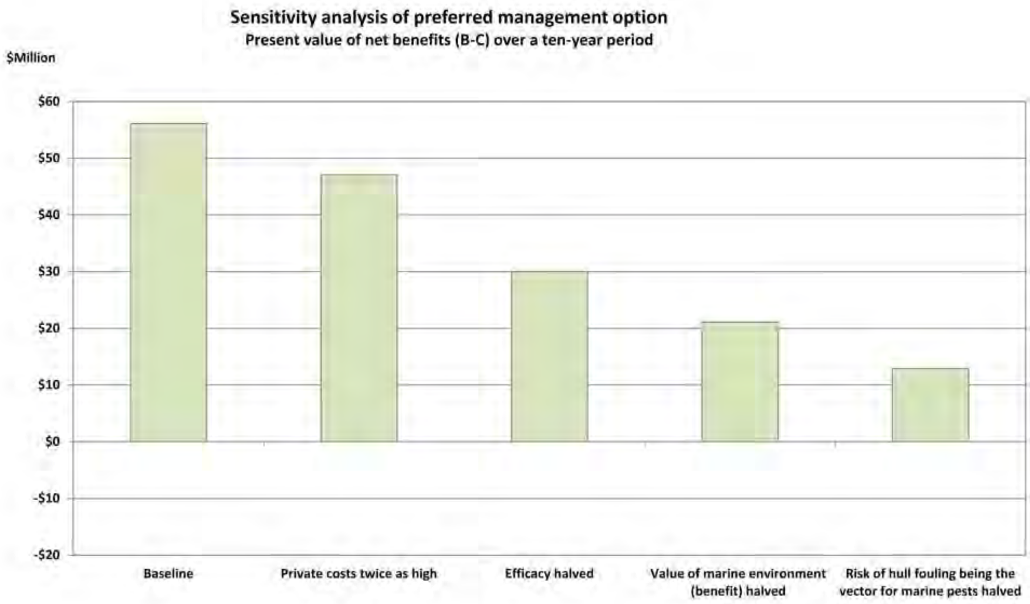
Estimation of values	
$1,100,000,000	Value of marine environment at risk

Sensitivity analysis

A sensitivity analysis was carried out to test the most uncertain values associated with the key assumptions. Four key assumptions were tested and the results in terms of the impact on the present value of net benefits are reported in the following table for the eight management options. The figure shows the impact of the changed assumptions on the net present value of the preferred management option.

Sensitivity analysis of Marine Pathway Plan options
Present value of net benefits (B-C) over a ten-year period ($M)

	Management regime options							
	Current	LOF 4	LOF 3	LOF 2 movement	LOF 2	LOF 1	LOF 0	Clean Vessel Pass
Baseline result	$5.9	$19.8	$51.2	$56.1	$43.8	$10.8	-$27.9	$30.7
Private sector costs twice as high	$5.9	$18.2	$42.7	$47.1	$26.4	-$21.0	-$85.6	$26.7
Efficacy halved (whether caused by a reduction in either treatment success and/or lower level of uptake	$5.9	-$45	$26.8	$30.0	$18.5	-$9.2	-$43.2	$15.9
Value of marine environment (benefit) being affected halved	$1.3	$6.8	$19.0	$21.1	$10.2	-$15.4	-$48.5	$10.7
Likelihood of hull fouling being the vector for marine pests reduced by half to 45%	$5.9	-$18.4	$11.5	$12.9	$2.3	-$20.9	-$51.7	$7.7



In all four cases, the preferred management option provided the highest positive net present value. The assumption that makes the biggest impact on the net present value calculation is the likelihood of hull fouling being the vector for the introduction of marine pests in any one year. Reducing the standard assumption by half - from 90% to 45% - reduces the present value of net benefit by 77% from the baseline result. A net present value of close to $0 for the preferred management scenario is calculated by the model when the likelihood of hull fouling being the vector for the introduction of a marine pest is 18%, equivalent to 20% of the baseline assumption, all other assumptions held constant.