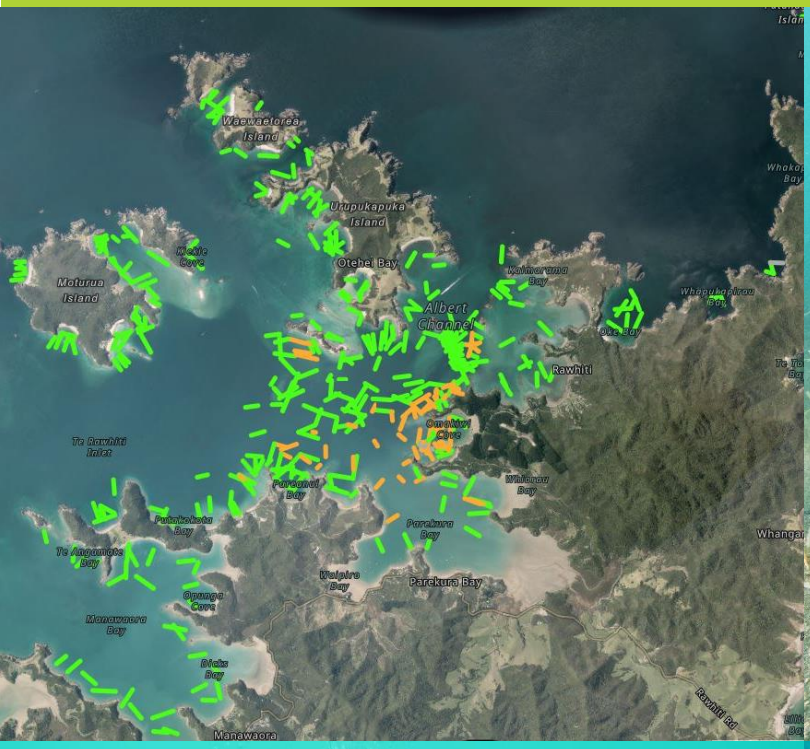
Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

Perimeter Management

Omākiwi Cove, Bay of Islands



CONTENTS

Acknowledgements

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- Bay of Plenty Regional Council Dive Team
- Commercial Dive Specialists
- Marine and Environmental Field Services
- Ministry of Primary Industries
- National Institute of Water and Atmospheric Research

Executive summary

Exotic Caulerpa (*C. brachypus* and *C. parvifolia*) was identified in Te Rāwhiti Inlet, Bay of Islands, in May 2023. Considering the ability of these species to spread rapidly, form dense monocultures, and smother and displace native species, the Ministry for Primary Industries and Northland Regional Council instigated a response to address the incursion. This document reports on one element of that response; to understand the spatial extent of exotic Caulerpa in Te Rāwhiti, and to reduce that spatial extent via the removal of infestations found in the outer regions of a Controlled Area Notice zone.

Over a 12-month period (May 2023 to April 2024), 568 delimitation survey transects were conducted. Exotic Caulerpa was found on less than 12% of these, and in one instance it was found outside the boundaries of the Controlled Area Notice zone. Infestations found close to, and beyond, the boundaries of this zone were treated with benthic mats and / or chlorine. Benthic mats that were recovered indicated this treatment method was successful in ensuring mortality of exotic Caulerpa. Methodological adjustments are discussed that would assist in improving the efficacy and recoverability of benthic mats in future.

List of figures and tables

1.Introduction

Invasion by non-native *Caulerpa* sp. has resulted in a range of negative impacts to marine species and ecosystems globally (Holmer *et al.* 2009; McKinnon *et al.* 2009; Felline *et al.* 2012). *Caulerpa* sp. can grow across intertidal and subtidal zones, down to a depth of 40m, and can establish on a diverse range of natural substrates including sand, mud, and reef, in addition to manmade structures. In favourable conditions it spreads quickly, forming dense monospecific beds that cover the sea floor, smother benthic marine life, and displace mobile species through alteration of key habitats. Invasion by non-native *Caulerpa* sp. therefore poses a significant risk to local marine species and ecosystems and subsequently to associated cultural, commercial, and recreational values and activities. As such, some non-native *Caulerpa* sp. are listed as unwanted organisms by Biosecurity New Zealand.

Two non-native species of *Caulerpa* (*Caulerpa brachypus* and *C. parvifolia*, herein collectively 'exotic Caulerpa') have been discovered in Aotearoa (Biosecurity New Zealand 2024). First identified in July 2021 at Aotea / Great Barrier Island (Blind Bay, Tryphena Harbour, and Whangaparapara Harbour; Middleton 2023), these infestations have since been subject to removal trials via various methods (suction dredging, benthic mats, and chlorine; Tait *et al.* 2024). Further surveys in 2022 led to the discovery of infestations at Ahuahu / Great Mercury Island, and in May 2023 it was identified in several locations in the Bay of Islands including Omākiwi Cove, Te Rāwhiti inlet, and into Albert Channel (Botting 2023). It has since also been discovered at Waiheke Island, Kawau Island, Mokohinau Islands, and Rākino Island (Biosecurity New Zealand 2024).

The most likely human-mediated vector for exotic Caulerpa into, and around, Aotearoa is recreational vessels anchoring with fragments entangled in anchoring equipment, as exotic Caulerpa is capable of proliferating quickly from very small fragments. Subsequently, Controlled Area Notice (CAN) zones have been introduced in several locations in the upper North Island to prevent activities such as fishing and anchoring, and subsequently reduce the risk of further spread (Biosecurity New Zealand 2024; Fig. 1).

1.1. Objectives

Considering the potential threat posed by the incursion of exotic Caulerpa in Te Rāwhiti Inlet, an agreement between the Ministry for Primary Industries (MPI) and Northland Regional Council (NRC) was instigated in August 2023 (Caulerpa Response Te Rāwhiti Treatment Trials & Perimeter Management C0035933). The intent of this agreement was to assess the feasibility of suction dredging as a method to achieve local eradication (Objective 4.1), and to conduct surveillance to better understand and reduce the spatial extent of the infestation within the bounds of the Te Rāwhiti CAN (Objective 4.2; Fig. 1). The latter objective was to be approached by removal or in-situ treatment of infestations found in the outer extent of the CAN.

This document reports on Objective 4.2. Perimeter Management of the above agreement:

> (a) To complete surveillance that improves the understanding of the spatial extent of the exotic Caulerpa infestation in the Te Rāwhiti Inlet Controlled Area Notice area.
>
> (b) To reduce the spatial extent of the exotic Caulerpa infestation in the Te Rāwhiti Inlet Controlled Area Notice area by prioritizing the removal of exotic Caulerpa located in the outer region of the Te Rāwhiti Controlled Area Notice.

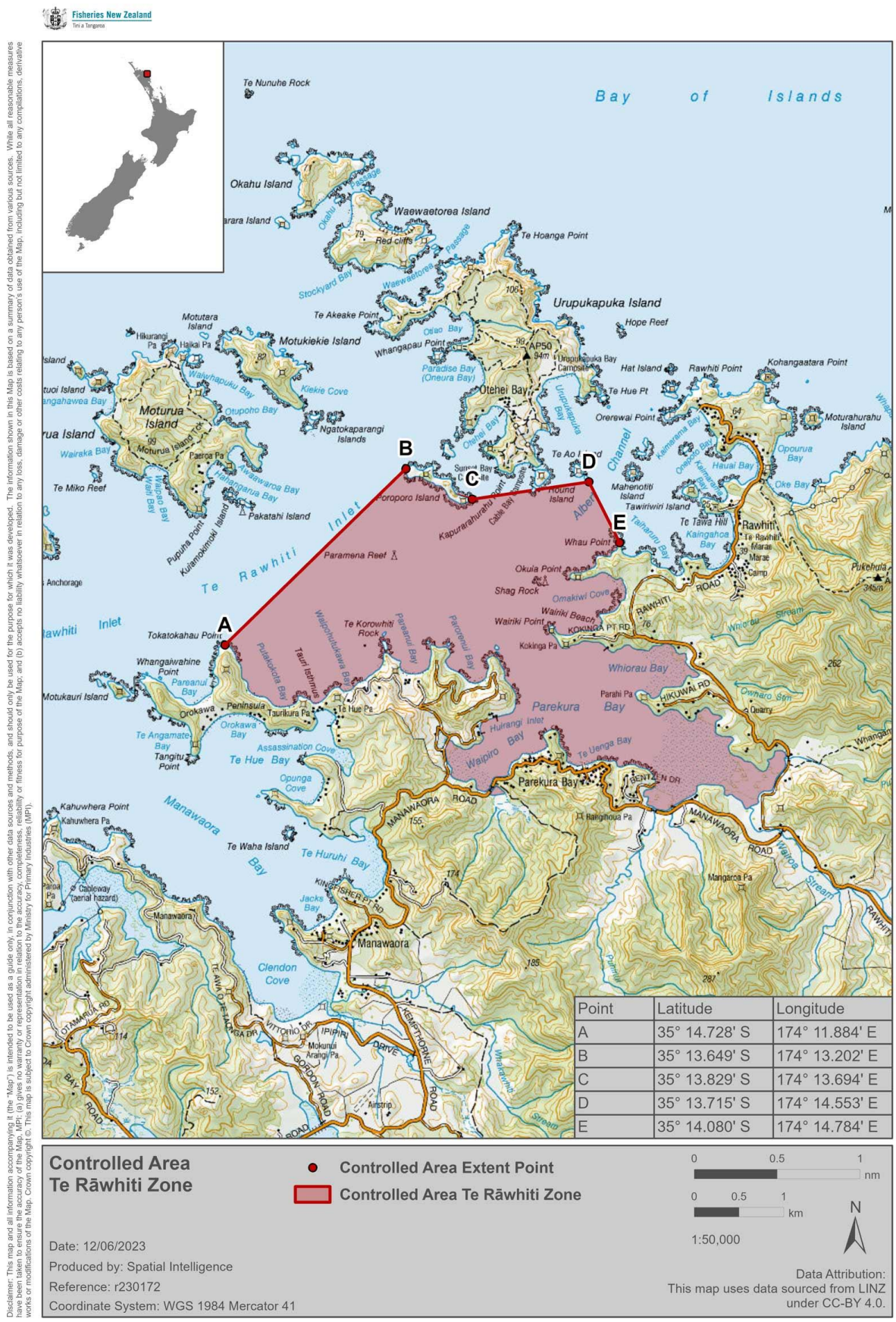

Figure 1. The Controlled Area Notice (CAN) in Te Rāwhiti Inlet, Bay of Islands. No anchoring or fishing is permitted within this zone. Source: Ministry of Primary Industries (MPI).

2.Methods

2.1. Site selection

The selection of sites at which to focus perimeter management survey efforts was strategically informed by several information sources:

- NRC vessel hull surveillance data, collected over six years from more than 10,000 vessels across Northlands' harbours, documenting anchoring behaviour in Northland.
- Active collaboration between NRC and local kaitiaki, hapū, and iwi to incorporate the vast repository of knowledge they possess regarding their rohe.
- An Envirolink-funded report, produced in partnership between NRC and the Cawthron Institute, that used network and particle tracking modelling to determine likely vessel movements from areas with known exotic Caulerpa infestations to within the Northland region, and dispersal patterns of exotic Caulerpa via surface currents (Floerl *et al.* 2023).

Analyses conducted by Floerl *et al.* (2023) indicated that Te Rāwhiti Inlet, Omākiwi Cove, and the inner Bay of Islands received 51% of potential anchoring events within the survey network. Modelling particle tracks similarly indicated Te Rāwhiti Inlet and Albert Channel were at greatest risk of receiving fragmented exotic Caulerpa via surface currents (Fig. 2). Initial survey locations were subsequently centred within the Te Rāwhiti Inlet and Albert Channel, including on the mainland and nearby islands.

The above information sources also informed priority survey sites beyond the Te Rāwhiti CAN. These locations formed the basis of a wider surveillance project conducted in April and May 2024, which covered mainland sites and islands between Whangaroa Harbour in the north and Whangārei Harbour in the south.

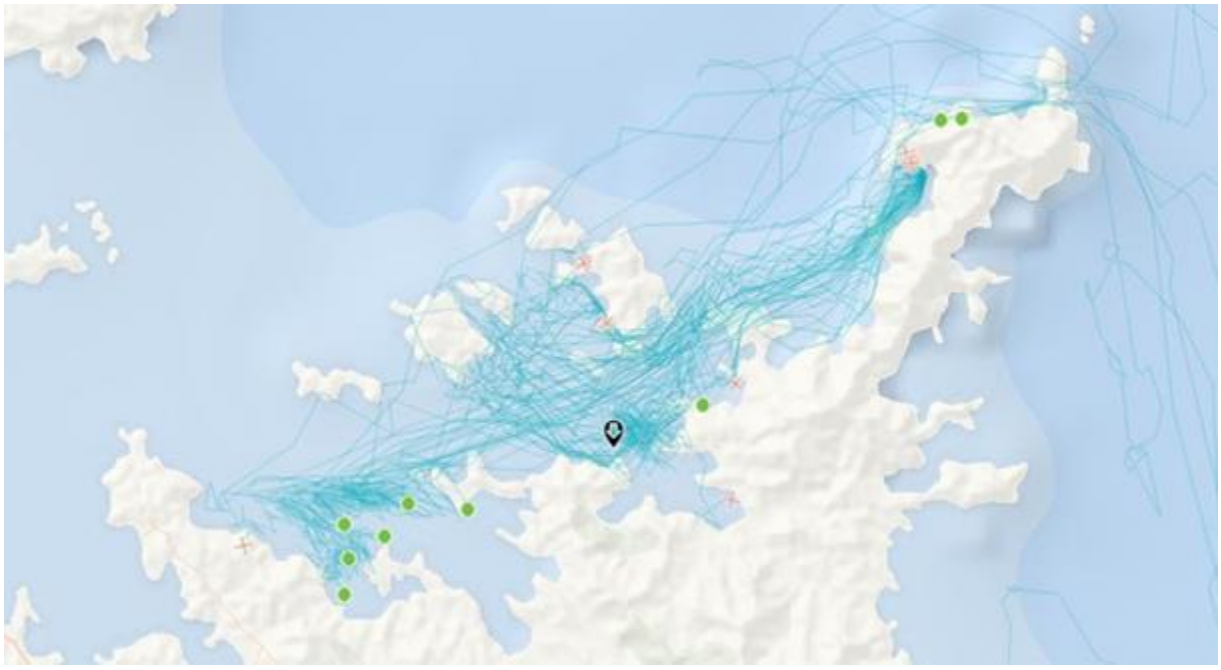

Figure 2. Modelling particle dispersal via surface currents. The black arrow indicates dispersion point. The green dots indicate likely location after 30 days. Source: Cawthron Institute.

2.2. Diver transects

To delimit the presence, and manage the spread, of exotic Caulerpa in the Te Rāwhiti CAN, diver-based delimitation surveys were conducted throughout Te Rāwhiti Inlet and Albert Channel from the time it was first detected at Omākiwi Cove in early May 2023. Surveys were conducted by various organisations, including divers from Northland Regional Council (NRC), the National Institute of Water and Atmospheric Research (NIWA), the Department of Conservation (DOC), Marine Environmental Field Services (MEFS), Bay of Plenty Regional Council dive team, and Commercial Dive Specialists (CDS).

A 15-minute bearing search technique was used to search for exotic Caulerpa. Divers followed a predetermined bearing for 15 minutes and systematically searched the substrate for exotic Caulerpa (Fig. 3A). If detected, the GPS location was recorded on the Caulerpa Infestation GIS platform via ArcGIS Fieldmaps (Fig. 3B). This was done by the diver conducting a series of pulls on a surface marker buoy to indicate to the vessel crew to record a GPS position, or with the use of underwater communications. The relatively shallow depth of anchorages in the Bay of Islands (<10m) allowed for multiple sites to be searched daily without depth limited restrictions.

Additional information recorded in the ArcGIS Caulerpa Infestation platform included start and end location of the transect, start and end depth of the transect, presence / absence of exotic Caulerpa along the transect, density of exotic Caulerpa (if present), primary and secondary substrates, and visibility (Fig. 3B). From this information the total length and search area of each transect could be calculated.

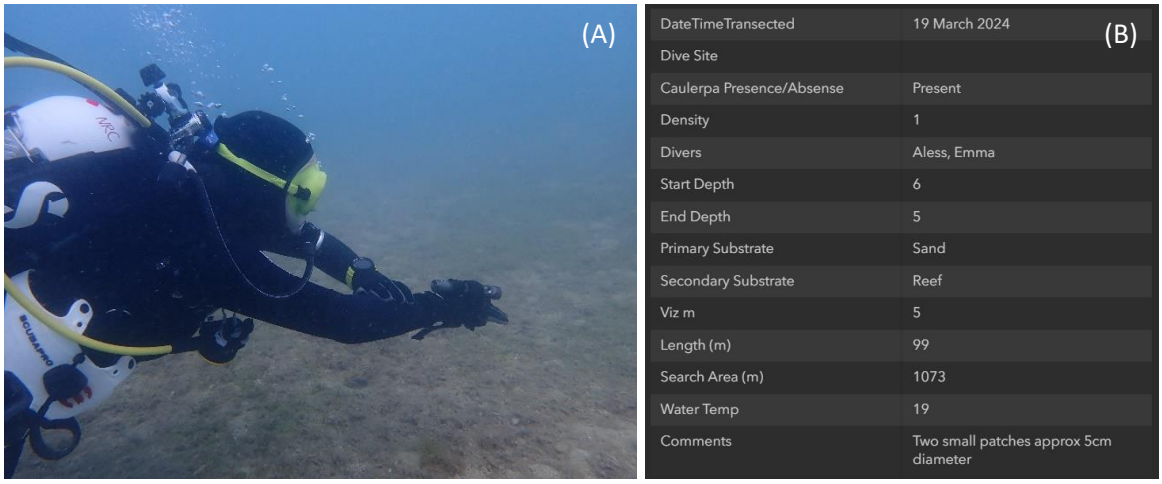

Figure 3. (A) A Northland Regional Council diver undertaking a timed-swim survey dive to search for exotic Caulerpa. (B) An example of information recorded for each transect in the Caulerpa Infestation GIS platform via ArcGIS Fieldmaps.

2.3. Benthic treatment

In locations that exotic Caulerpa was encountered during the delimitation surveys, and the size of the patch was less than 36 m^2, benthic mats constructed from sheets of plastic wrap were placed over the infestation (Fig. 4A). Benthic matting could not be used for patches greater than 36 m^2 due to consenting limitations, however no patches greater than this size were found outside of Omākiwi Cove.

Each mat was tailored onsite according to the size of the infestation found, with additional material extending beyond the perimeter of the patch to ensure it was fully contained and treated. The mats were secured to the substrate using a combination of 400mm metal stakes with a 100mm head and weighted chain or rocks. The location of the mat was recorded in the Caulerpa Infestation GIS platform via ArcGIS Fieldmaps.

In several instances chlorine tablets were also placed under the benthic mat (Fig. 4B) and, when available, weight was placed on top of the matting to reduce water flow, thereby concentrating the effects of the chlorine (Fig. 4C). Each chlorine tablet was 200g and, depending on the size of the infestation, multiple chlorine tablets were used to ensure the necessary concentration requirements were achieved. Concentration requirements were based on ~200 mg/L of free available chlorine required to successfully eliminate 99% of a *Sabella spallanzanii* infestation (Morrisey *et al.* 2016). For sites at which chlorine was used, water samples were collected from underneath the mats prior to their removal to ensure residual chlorine levels were no greater than 0.2mg/L (Fig. 4D).

Chlorine was not used for infestations found in sites of significant ecological importance, such as kaimoana beds. In these locations only benthic matting was used. In these scenarios it was necessary to leave the benthic mats in place for a duration of approximately one month to ensure mortality of exotic Caulerpa via lack of sunlight.

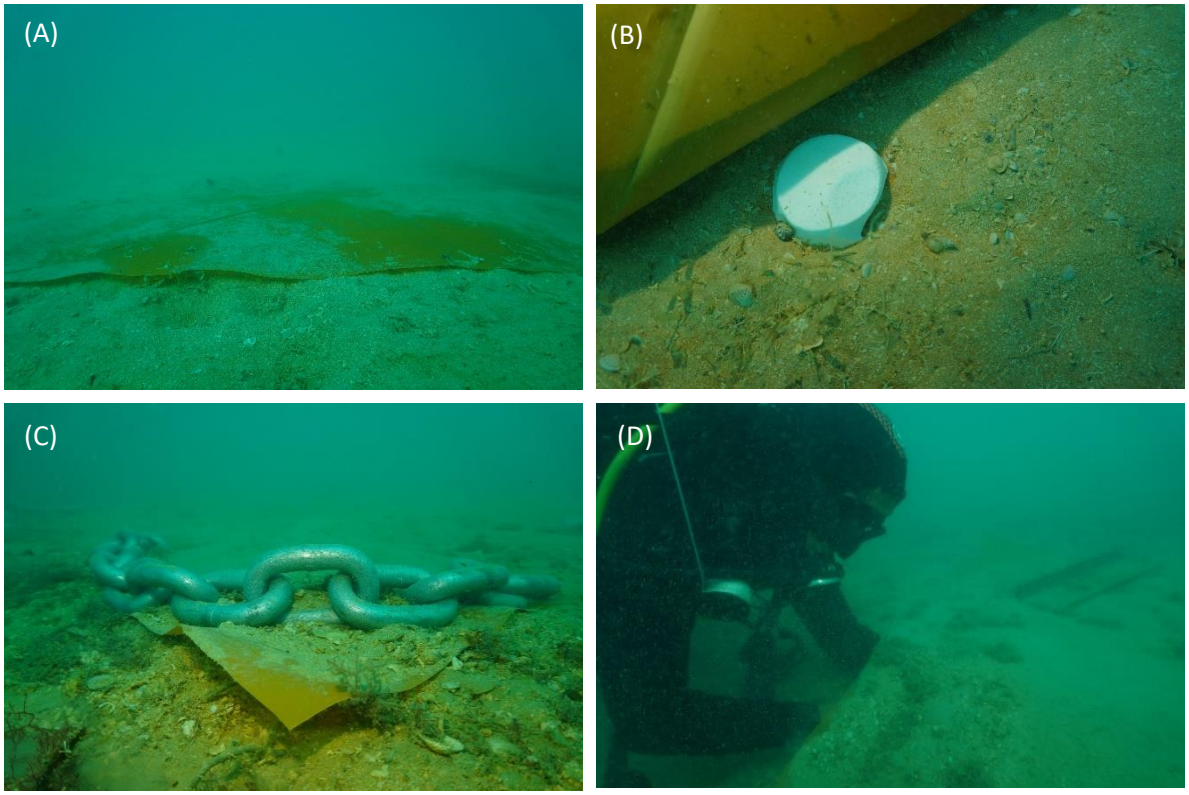

Figure 4. Use of benthic matting and chlorine tablets to address exotic Caulerpa infestations. (A) A benthic mat placed over an infestation of exotic Caulerpa. (B) A chlorine tablet underneath a benthic mat. (C) Benthic mats held in place by metal stakes and chain. (D) A Northland Regional Council diver conducts water testing for residual chlorine.

2.4. Biosecurity

All dive operations were conducted in a manner that ensured minimum contamination between dive sites to prevent the spread of exotic Caulerpa. Diving was not undertaken in areas where exotic Caulerpa was not known to be present directly after diving in known infestation areas. Additionally, after each dive day that exotic Caulerpa was detected, NIWA's decontamination protocols were followed for all dive and survey gear (soaked in a detergent and freshwater solution).

3.Results

3.1. Diver transects

From 1st May 2023 to 30th April 2024, 568 delimitation survey transects were conducted, covering a total of 122.8 km (Table 1). Of these transects, 109 were conducted under this perimeter management contract (C0035933), with the remainder being conducted under a range of additional surveillance contracts. Survey effort was concentrated in the initial months post-detection (May – August 2023; Fig. 6A-5D) in Bay of Islands, and in April 2024 (Fig. 6K) for wider surveillance.

Of the total 568 transects conducted, exotic Caulerpa was present on 11.8 % (67), the majority of which were in the vicinity of Omākiwi Cove where a large infestation is known to exist (Fig. 5). Infestations were also found near the boundaries of the CAN, including on the eastern side of Waipohutukawa Bay (surveyed in June 2023; Fig. 6B), Pareanui Bay (surveyed in June 2023; Fig. 6B), and on the southern side of Poroporo Island (surveyed in April 2024; Fig. 6K). One infestation was found outside the boundaries of the CAN (south of Mahenotiti Island; surveyed in June 2023; Fig. 6B). The primary substrates in which exotic Caulerpa was found were sand (54.6%), in addition to muddy sand and sandy gravel (12.5% and 10.94%, respectively).

Table 1. The number and length of delimitation survey transects conducted per month over a 12 period, between May 2023 and April 2024, and the presence of exotic Caulerpa found during these surveys.

Month	Transect count	Total transect length (km)	Transects with exotic Caulerpa (#)	Transects with exotic Caulerpa (%)	Transects conducted under C0035933
May 2023	94	16.3	18	19.35	42
June 2023	70	14.2	14	20	15
July 2023	50	12.3	3	6	27
August 2023	52	12.6	4	7.84	25
September 2023	0	0	0	0	
October 2023	5	1	2	40	
November 2023	7	1.5	0	0	
December 2023	9	0.8	0	0	
January 2024	18	3	2	12.5	
February 2024	14	1.8	10	71.43	
March 2024	19	1.8	10	58.82	
April 2024	230	57.5	4	1.76	
	568	**122.8**	**67**	**11.8**	**109**

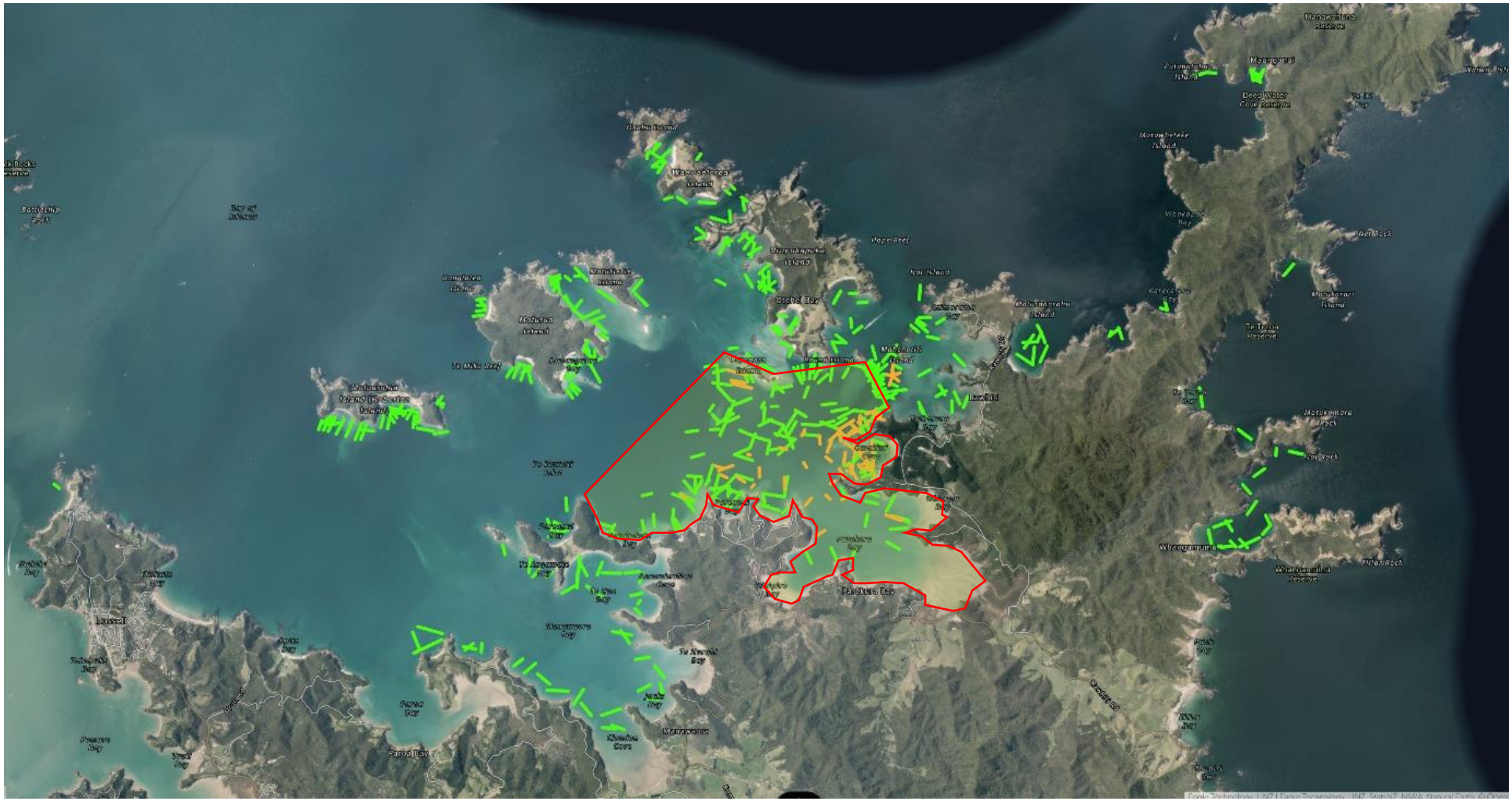

Figure 5. Exotic Caulerpa delimitation surveys conducted in the Bay of Islands from May 2023 to April 2024. Orange transects indicate presence of exotic Caulerpa. Green transects indicate no exotic Caulerpa found. CAN indicated by red outline.

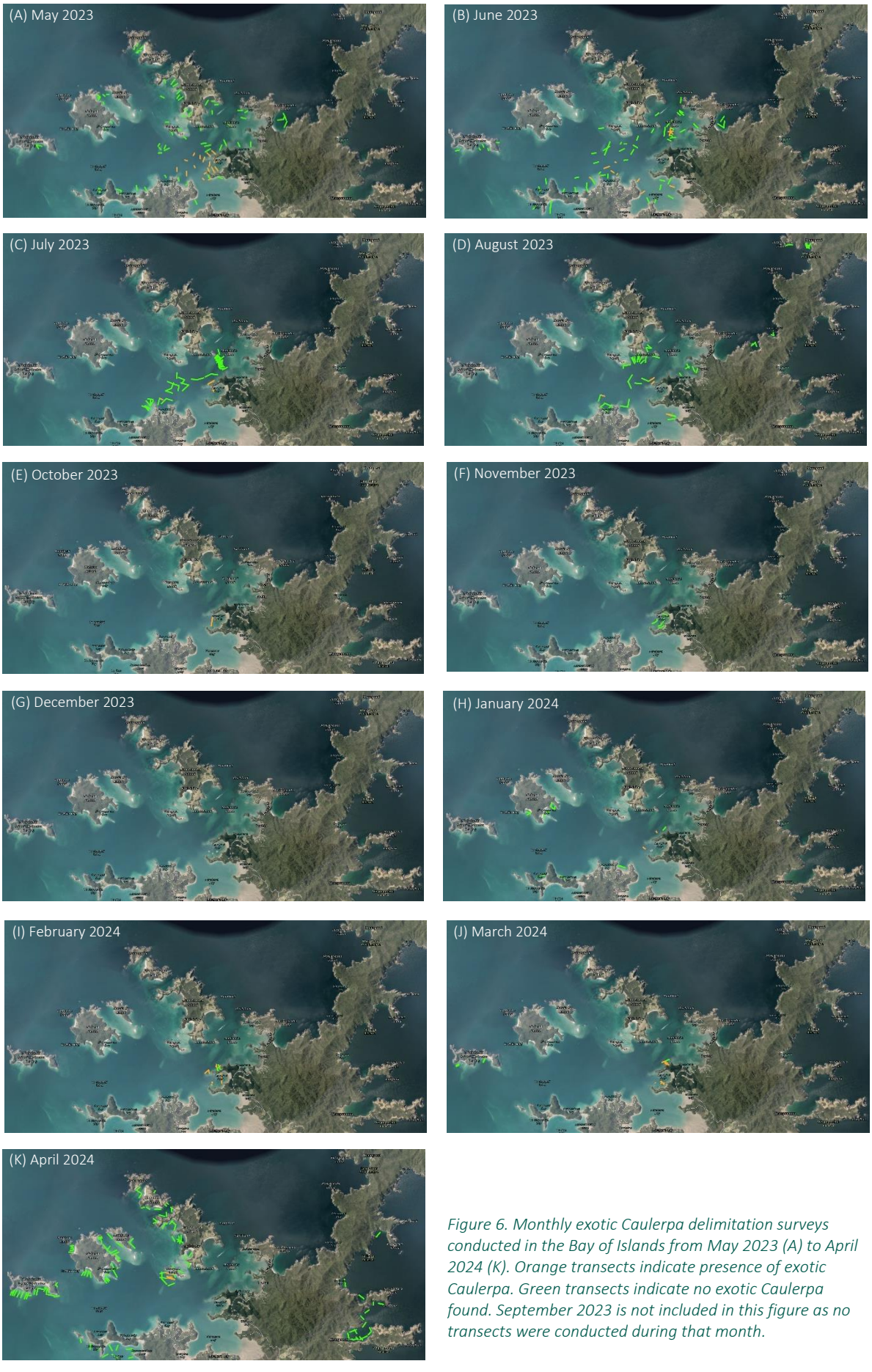

Figure 6. Monthly exotic Caulerpa delimitation surveys conducted in the Bay of Islands from May 2023 (A) to April 2024 (K). Orange transects indicate presence of exotic Caulerpa. Green transects indicate no exotic Caulerpa found. September 2023 is not included in this figure as no transects were conducted during that month.

3.2. Benthic treatment

In July and August 2023, eight infestation sites were treated (Table 2). The infestations ranged in size from 50 cm^2 to 4 m^2. In all instances benthic matting was used, and in five instances chlorine was also used. Chlorine was not used when exotic Caulerpa was found near important kaimoana sites and / or octopus. On one occasion hand removal methods were used in response to discovery of a distinct, detached ball of exotic Caulerpa. No treatments were applied to infestations found in the vicinity of Omākiwi Cove, as this site is the focus of the suction dredging trials. Infestations found on the south side of Poroporo Island in April 2024 during the wider surveillance contract (Fig. 6K) were similarly treated with benthic mats and chlorine, the results of which are reported in the wider surveillance report.

Inspection of exotic Caulerpa underneath three benthic matts was conducted approximately one week after mat placement. Mortality of exotic Caulerpa was evidenced by the bleached colouration of the fragments (Fig. 7), and water sampling indicated residual chlorine levels were at 0 ppm. The benthic mats and any residual chlorine tablets were then removed.

Several benthic mats were not recovered due to difficulties presented by low visibility and soft sediment hindering search operations. Opportunities for refining the treatment protocols to ensure recoverability of benthic mats are discussed below.

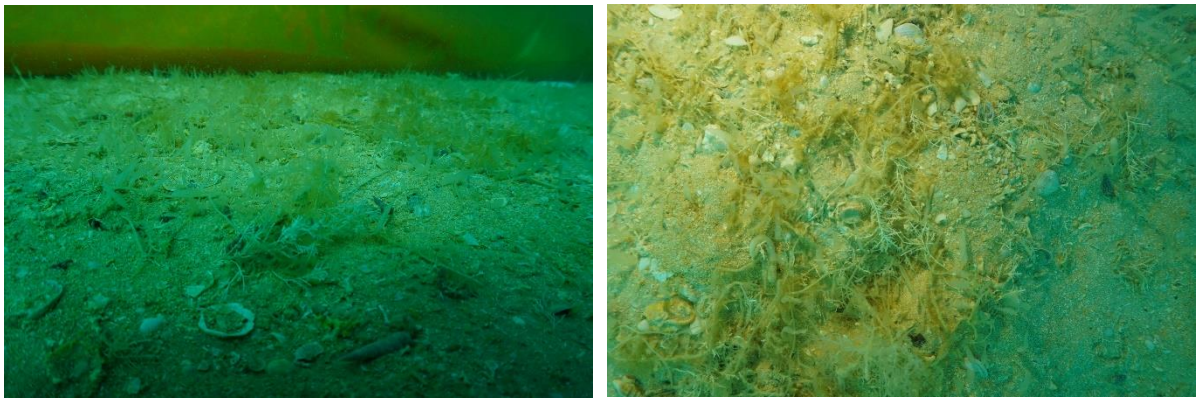

Figure 7. Mortality of exotic Caulerpa, indicated by bleaching of Caulerpa fragments, following treatment with benthic matting and chlorine tablets.

Table 2. Summary of benthic treatments undertaken for exotic Caulerpa infestations in Te Rāwhiti, Bay of Islands. Site labels correspond to Figure 8.

Site	Treatment date	Caulerpa patch size	Treatment type	Treatment quantity	Outcome	Comments
A	13/06/23	Ø 100 cm Ø 20 cm	Benthic mat Chlorine	4 x 3 m 1 x 1 m 7 x 200 g	Exotic Caulerpa eliminated. Mat removed.	Placed by MEFS.
B	30/07/23	900 cm^2	Benthic mat Chlorine	2 x 2 m 2 x 200 g		Placed by BOP.
C	31/07/23		Benthic mat Chlorine			Placed by BOP.
D	01/08/23	2,500 cm^2 50 cm^2	Benthic mat Chlorine	4 x 2 m 3 x 200 g		Placed by BOP.
E	01/08/23		Benthic mat	2 x 2 m	Mat not recovered.	Placed by BOP. No chlorine was used as an octopus' hole was observed nearby.
F	02/08/23	Ø 50 cm	Benthic mat Chlorine	2 x 2 m 1 x 200 g		Placed by BOP.
G	09/08/23		Benthic mat	4 x 4 m	Mat not recovered	Placed by MEFS & NRC. No chlorine used due to proximity to significant kaimoana site.
H	09/08/23	Ø 100 cm	Benthic mat		Mat not recovered	Placed by MEFS & NRC. Hand removal of ball of Caulerpa (<1m diameter), followed with benthic mat. No chlorine used as close proximity to kaimoana site.

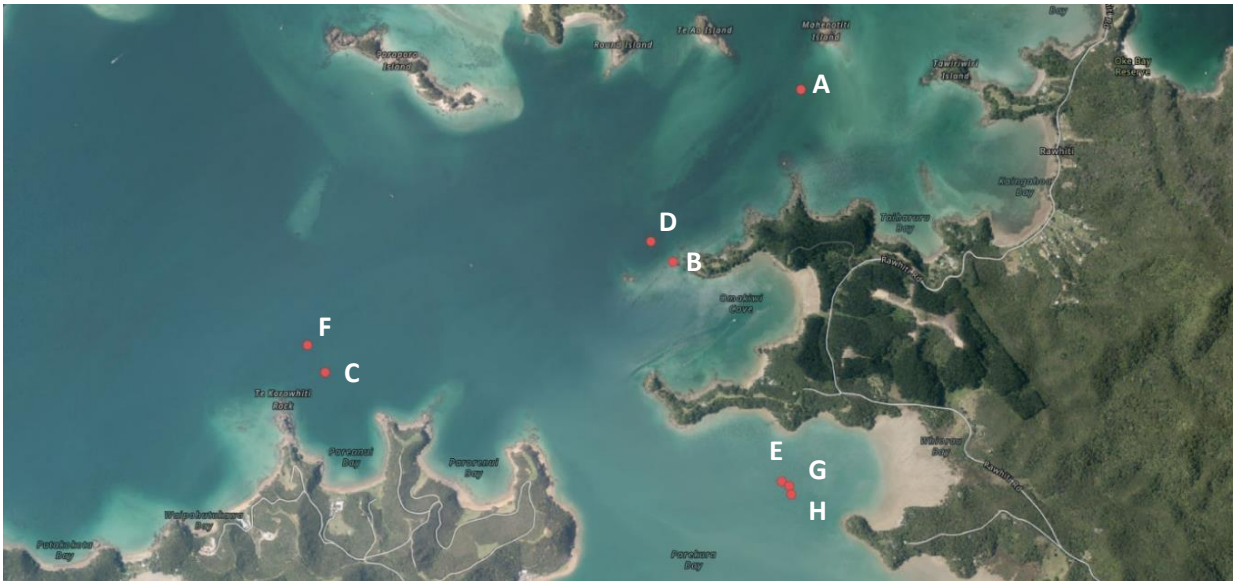

Figure 8. Sites in which exotic Caulerpa was treated in July and August 2023 in Te Rāwhiti Inlet, Bay of Islands.

4.Discussion

4.1. Surveillance of spatial extent of exotic Caulerpa

The primary objective of the perimeter management project was to conduct surveillance to improve understanding of the spatial extent of the exotic Caulerpa infestation in Te Rāwhiti Inlet. Delimitation surveys conducted over a 12 month period demonstrated that exotic Caulerpa was found predominantly in the vicinity of the large infestation in Omākiwi Cove, although smaller, distinct infestations were found in other locations close to, and in one instance beyond, the boundaries of the CAN (Fig. 5).

Considering the ease and speed with which exotic Caulerpa is able to spread, it is possible that these infestations, if not successfully treated, could spread beyond the boundaries of the CAN and further into Te Rāwhiti Inlet and the Albert Channel. However, benthic treatments undertaken here and discussed below, in conjunction with completion of the wider surveillance contract, associated treatments, and continued adherence to strict biosecurity procedures in the delivery of these projects, may assist in mitigating this risk.

4.2. Reduction of spatial extent of exotic Caulerpa

The secondary objective of the perimeter management project was to reduce the spatial extent of the exotic Caulerpa infestation in the Te Rāwhiti CAN by prioritizing the removal of exotic Caulerpa located in the outer region of the CAN. Eight infestations (including the one found outside the CAN boundaries) were treated, using a combination of benthic matting, chlorine tablets, and hand removal (Table 2; Fig. 8).

For the benthic mats that were recovered, mortality of exotic Caulerpa was evident via the bleached colouration of fragments, and thus this method proved beneficial in reducing spatial extent. It may be assumed that the additional mats not located had a similar impact upon exotic Caulerpa, however this was not able to be confirmed. Minor methodological adjustments would assist in ensuring mat recovery and thus assisting with confirmation of the reduction of spatial extent.

4.3. Efficacy of benthic mats

Several variables were identified that influenced the efficacy of benthic mats in treating exotic Caulerpa infestations, including substrate type, depth, swell, visibility, and the patch size and dynamics of the exotic Caulerpa infestations. These are discussed in conjunction with methodological adjustments that could improve this approach in future.

Substrate type. In locations where only a narrow band of soft sediment was present over harder substrates, securing the mats in place using metal stakes was challenging, and the availability of rocks to help anchor the mats could not be relied upon. This could be addressed by placing chain along the edges of the mats to better secure them.

Depth and swell. In shallow water (<6m) the mats were often affected by large swells, which could both move the mat if not fully secured and reduce the effect of chlorine by flushing the water under the mat. The latter also occurred in sites with strong currents. This could also be addressed by placement of chain along the edges of the mat to ensure the edges do not lift so substantially.

Off gassing of chlorine. The application of chlorine to the benthic community, and the subsequent biological activity, can cause large amounts of gas to concentrate underneath the benthic mat. This has the potential to lift the mat. However this could be addressed with the installation of vents to allow the built-up gas to escape (e.g. duckbill vent).

Visibility. In areas of fine sediment, placement of mats quickly disturbed the visibility and made conditions challenging to complete the placement of the mat. Further, swell and current often resulted in the mats being covered by fine sediment shortly after being placed, making them difficult to find on subsequent dives (Fig. 4A). This prevented follow up sampling of chlorine levels, inspection of the efficacy of the mats in killing exotic Caulerpa, and removal of the mats once mortality of exotic Caulerpa was confirmed. This could be addressed by marking the mats with sub-surface floats to increase their visibility, however implications for vessel navigation safety and suction dredge operation would need to be considered.

Patch size / dynamics. The procedure for placing mats was time consuming and subsequently was not considered to be an efficient method for addressing very small patches of exotic Caulerpa. Hand removal could be more effective in these scenarios; however this method is challenged by the delicate, fragmentary nature of exotic Caulerpa. There were also instances where free-floating balls of exotic Caulerpa were encountered for which, again, benthic matting was not considered the optimum response.

5. Conclusion

Delimitation surveys confirmed that the spatial extent of exotic Caulerpa in Te Rāwhiti Inlet and Albert Channel was concentrated primarily in the vicinity of Omākiwi Cove. Some distinct infestations were found adjacent to and beyond the boundaries of the Te Rāwhiti CAN, however these were targeted with a combination of benthic mats and chlorine tablets. Of the mats that were recovered, mortality of exotic Caulerpa was noted, thus this approach helped to reduce the spatial extent of exotic Caulerpa infestation in the outer region of the Te Rāwhiti CAN. Given the speed and ease with which exotic Caulerpa can spread, continued surveillance and treatment of infestations will be key to containing the spatial extent of exotic Caulerpa in Te Rāwhiti Inlet and Albert channel.

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P 0800 002 004
E info@nrc.govt.nz
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Northland
REGIONAL COUNCIL
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