

# Genetic diversity and possible origins of New Zealand populations of *Ulva*

Biosecurity New Zealand Technical Paper No: 2007/01

Prepared for Biosecurity New Zealand by  
National Institute of Water and Atmospheric Research  
ZBS2004-08

ISBN 978-0-478-29565-8 (print)  
ISBN 978-0-478-29566-5 (online)  
ISSN 1176-838X (print)  
ISSN 1177-6412 (online)

May 2007



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# Executive Summary

The genetic diversity of the green algal genus *Ulva* sensu lato in New Zealand was surveyed to identify the species present, and to assess their status as native or potentially introduced entities. Data were obtained for 581 samples collected from within the New Zealand EEZ, ranging from the Kermadec Islands to the Auckland and Antipodes Islands. Both pristine and human-modified environments were represented in the sampling sites visited.

Species recognition in *Ulva* using molecular sequencing data was achieved using the *rbcL* gene. Twenty-four genetically distinct taxa belonging to three genera were discovered in New Zealand waters – *Ulva* (19 species), *Umbraulva* (4 species) and *Gemina* (1 species). Of the 19 species of *Ulva* reported here, thirteen were able to be identified to species. The remaining 6 currently cannot be assigned to known species groups based on close homology with sequences in GenBank. These species may include undescribed, endemic taxa, or may represent cryptogenic species. The genus *Umbraulva* is recorded for the first time for the New Zealand region (and for the Southern Hemisphere) and 4 species were distinguished. One of these we consider to be introduced to the region and the other three species appear to be new and undescribed indigenous taxa. Subantarctic samples provided the first evidence of the existence of the genus *Gemina* since its description in 1952: sequence data confirmed that it is distinct from *Ulva* and *Umbraulva*. A number of the species identified in this study can be distinguished through a combination of growth form, morphological, ecological and distributional characters. However there remain considerable problems in distinguishing a number of other species by morphological characters alone.

Based on information such as distribution in New Zealand (percentage of samples occurring in highly modified environments and/or areas with much boat traffic) as well as the genetic similarity of New Zealand samples to material from overseas, we have concluded that at least 5 species have been introduced to the New Zealand region – *Ulva armoricana*, *U. californica*, *U. flexuosa*, *U. lactuca*, and *Umbraulva olivascens*.

## Overall objectives:

1. To determine the genetic diversity within the genus *Ulva* in New Zealand, collected from human modified and pristine environments, using molecular sequencing tools, and to compare these sequence data with genetic data from *Ulva* collected elsewhere (e.g. Europe, Asia, North America);
2. To analyse and map patterns of *Ulva* spp distribution based on genetic data obtained in objective 1.

## Specific objectives:

1. To obtain collections of *Ulva* populations from a range of sites within New Zealand for genetic analyses.
2. To determine the genetic diversity in New Zealand *Ulva* spp using molecular sequence data, and to relate the genetic entities distinguished by these data to preliminary morphological, habitat and distributional analysis of New Zealand material.
3. To compare New Zealand molecular sequence data for *Ulva* with genetic data from *Ulva* populations elsewhere (e.g. Europe, Asia, North America).
4. To map, using a spatially explicit GIS, the New Zealand and global distributions of *Ulva* populations analysed in this study.



## INTRODUCTION

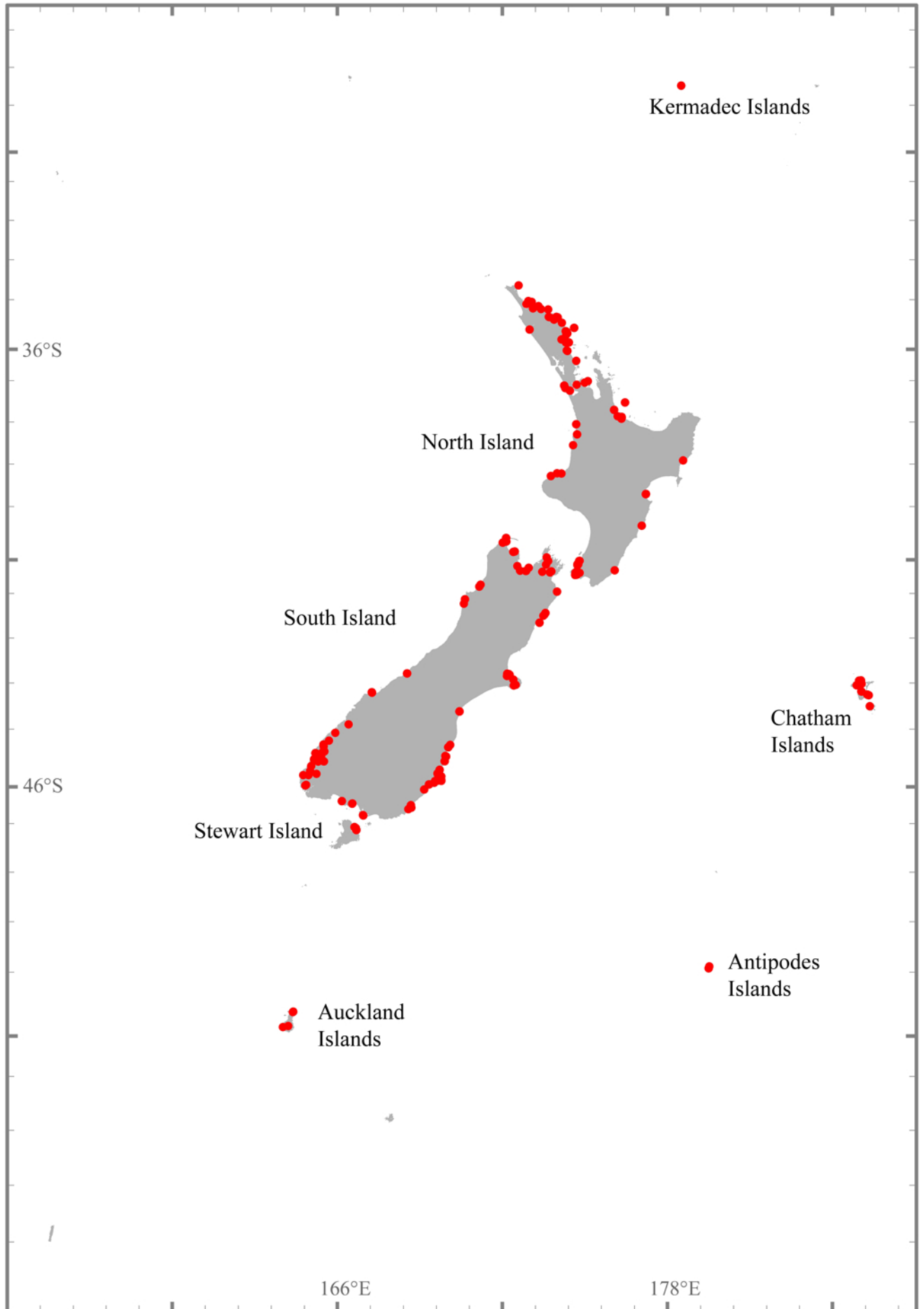
The genus *Ulva* L. (Ulviceae, Ulvales, Chlorophyta), commonly known as "sea lettuce", is found throughout the world, with many entities described. There are 307 names listed in AlgaeBase ([www.algaebase.org](http://www.algaebase.org) Guiry 2006) of which 101 are considered current. Species of *Ulva* sensu lato (including *Enteromorpha* Link) are found in a wide range of habitats and environments. Some species are tolerant of low salinity waters and are able to grow in estuarine to brackish conditions, some are present on extremely wave exposed intertidal shores, while others can be found at depths of up to 40 m on open coasts. *Ulva* species can be found in pristine marine habitats as well as in environments heavily modified by human activities. *Ulva* has been recorded in the New Zealand region from the subtropical Kermadec Islands through to the subantarctic islands, and from the high intertidal shore through to subtidal habitats of 40 m depth (Chapman 1956; Adams 1994).

Given the capacity of *Ulva* species to tolerate a wide range of conditions they are ideal candidates for human-mediated dispersal and are among the most notorious fouling organisms on ships' hulls (Schaffelke *et al.* 2006). A number of species of Ulviceae are regarded as cryptogenic, given their cosmopolitan distribution, possibly having been distributed in previous centuries by wooden sailing vessels. Shipping continues to be an important vector for the worldwide transport of macroalgal species (Schaffelke *et al.* 2006). *Ulva* species are also known for their potential for rapid, proliferous growth. A number of studies have focused on "green tide" phenomena, where species of *Ulva* produce large amounts of biomass apparently in response to human activities, such as eutrophication of the environment (e.g. Raffaelli *et al.* 1998; Malta *et al.* 1999; Taylor 1999; Blomster *et al.* 2002; Nelson *et al.* 2003; Hiraoka *et al.* 2004). In New Zealand, green tides have been studied in Tauranga and in the Avon-Heathcote estuary (Hawes *et al.* 1992; Hawes & Smith 1995; de Winton *et al.* 1998; Hawes 2001). The question arises if the *Ulva* species forming green tides are native to New Zealand, or whether they have been introduced from other parts of the world.

An important element in assessing the risks posed by introduced species is the capacity to recognize introduced and potentially invasive taxa. Consequently correct taxonomic identification must be ensured and taxonomic ambiguities need to be resolved. In the case of *Ulva* sensu lato this leads to significant problems, as *Ulva* species are notoriously difficult to identify because of their high phenotypic plasticity and the lack of morphological characters sufficient to separate many taxa. The problems in species identification are reflected in the extraordinary number of entities of *Ulva* sensu lato recorded for the New Zealand marine flora. In the only full account of the New Zealand green algal flora published to date, Chapman (1956) described many new taxa, including two new genera for ulvoid algae, *Gemina* and *Lobata*. Within the genus *Enteromorpha* Chapman distinguished 46 separate entities and within *Ulva* ca. 25. These include subspecific rankings, many of which subsequent authors have had difficulty recognising (e.g. Adams 1994).

Although it is clear that a thorough taxonomic investigation of *Ulva* in New Zealand is required in order to recognise potentially introduced species, the confused nomenclatural

Fig. 1: New Zealand - sites sampled



history and taxonomy, and the paucity of reliable morphological characters, means that a revision based solely on traditional approaches is unlikely to be satisfactory. Molecular sequencing data have been shown to be very useful in untangling relationships and clarifying morphological plasticity along ecological and environmental gradients (e.g., Tan *et al.* 1999; Hayden & Waaland 2002; Shimada *et al.* 2003).

Preliminary molecular sequencing data of samples from New Zealand indicate that some of the species concepts previously applied in New Zealand are likely to be incorrect. For example, specimens identified as *Ulva lactuca* and *Ulva rigida* based on morphology had very similar or identical *rbcL* sequences to an undescribed Chilean species and to *Ulva pertusa* from Japan, a species not previously recognized in New Zealand (L. McIvor & C. Maggs, unpublished data, pers. comm.). These preliminary data suggest that material from New Zealand routinely identified as *U. lactuca* and *U. rigida* may not belong to these taxa, and that introductions of foreign *Ulva* species to New Zealand may indeed have taken place. The objective of this project is to provide a starting point - to assess the genetic diversity of *Ulva* in New Zealand which will in turn enable the development of tools to recognise non-native species.

## **MATERIALS AND METHODS**

### **Field work**

Collections of *Ulva* (855 samples) were obtained from populations throughout New Zealand (Fig. 1, Appendix 1): 195 localities were visited (Kermadecs - 1; North Island - 75; South Island - 97; Chatham Islands - 11; Stewart Island - 5; Antipodes Islands - 2; Auckland Islands - 4); 217 sites within localities (intertidal, subtidal, drift); 324 habitats differentiated on the basis of habitat characteristics e.g. substrate, shore height/depth, channel, crevice, pool etc. Collections from the Kermadec, Antipodes and Auckland Islands were made by colleagues carrying out other research programmes, and as a consequence these areas were not as thoroughly investigated as mainland or Chatham Islands sites.

In order to maximize the opportunities to collect as wide a range of species as possible, the sites that were sampled covered a spectrum of environments, including sites with varying degrees of wave-exposure and freshwater influence, as well as intertidal and subtidal sites. Both pristine and human modified environments were specifically targeted. We attempted to get samples from as wide a geographic range as possible and some opportunistic collections were provided to us by a network of collectors carrying out fieldwork in remote locations. Because the field programme was restricted to a single year it was not possible to make seasonal collections throughout the region. However, the influence of season (i.e. temperature, daylength, spectral quality) on the presence/absence of species within localities was assessed in Wellington and Dunedin, re-sampling the same sites in spring (September - November), summer (December - February), autumn (March - May), and winter (June - August) (Wellington), and in spring, summer and autumn (Dunedin).

At collection localities *Ulva* specimens were collected from the range of accessible sites and habitats. Specimens were collected to represent populations of particular morphologies, as well as from particular habitat types e.g. high, mid and low intertidal pools, exposed vertical faces, on rocks experiencing sand abrasion, epiphytic/epiplithic growth forms. GPS coordinates were recorded for all specimens collected as part of the field programme designed for this study. Instruments used included: Etrex (Garmin), accuracy (depending on sky-view) 5-25 m; Geko 201 (Garmin), accuracy <15 m. For collections supplied from other research programmes or individuals GPS coordinates were either provided, or were subsequently estimated using TopoMapPro version2 based on field and collection information.

Specimens were scored on three scales based on assessments of the collection site:

- exposure: 1 - harbour / embayment; 2 - open coast.
- habitat/freshwater influence: 1 - subtidal / open coast; 2 - intertidal coastal; 3 - high intertidal pool / with freshwater influence; 4 - estuary; 5 - in stream or freshwater drain.
- habitat modification: 0 - pristine, very rare human visits; 1 - low volume, no boat mooring; 2 - open coasts or remote /little modified, foot traffic, small boat access; 3 - moderate e.g. tourist visits frequent; 4 - adjacent to harbour/wharf/pilings; 5 - high, wharfs and harbour installations; high traffic areas.

Samples were placed in individual plastic bags and transported to the laboratory in a chilled container. Samples were examined macroscopically and if possible, microscopically. If multiple samples showing similar morphologies were collected from the same site, a representative of these samples was chosen. Samples containing specimens of varying morphologies were separated into sub-samples. Samples that appeared to contain more than one *Ulva* species or were contaminated with other green algae (e.g. with epiphytes), and were not physically separable, were discarded as at present there are no primers that specifically target only *Ulva* species or are able to distinguish between *Ulva* species. Each sample that underwent further processing was allocated a unique number (*Ulva* project number, UPN).

From each sample with a UPN, material was taken for DNA extraction and for preparation of a herbarium voucher. Vouchers were retained as reference material for all samples included in the molecular analyses. For DNA extraction, tissue pieces of 1-2 cm x 1-2 cm of large thalli (or whole smaller thalli, or groups of very small individuals of the same morphology) were wrapped in pieces of nappy liner to avoid crumbling, and were sealed in zip-lock plastic bags, surrounded by dry silica gel. This amount of tissue was sufficient material for more than one extraction of DNA. Bags were stored away from light and excessive heat. The remainder of each sample was prepared as a herbarium voucher (Adams 1994: 16).

As part of Biosecurity New Zealand's baseline (ZBS2000/04, ZBS2005/18) and targeted surveillance (ZBS2001/01, ZBS2005/35) collecting studies of New Zealand ports and harbours, collections of *Ulva* have been retained as reference material, both as permanent

herbarium vouchers and as silica-dried subsamples to be available for molecular analyses. Eighty-five samples from these collections were included in this study and are hereafter referred to as biosecurity collections.

Dry herbarium vouchers of specimens which were identified using sequence data were lodged at the herbarium of the Museum of New Zealand Te Papa Tongarewa (WELT – Holmgren *et al.* 1990) (Appendix 2). Representative voucher specimens were scanned at 300 dpi and composite images prepared in Adobe Photoshop.

### **Morphology and anatomy**

Names used for Ulvaceae in New Zealand were summarised from general literature (Appendix 3) and from Chapman (1956) (Appendix 4). The gross thallus morphology was recorded for fresh specimens during collection and further processing (e.g., whether thalli were in the form of blades or tubes, unbranched, proliferous, broad, ribbon-like, etc). A thorough microscopic examination of fresh material was not feasible owing to the large number of samples handled, the access to field sites and the distance from a fully equipped laboratory. Cell features, where recorded, were obtained from identified dried herbarium specimens. Rehydrated material was examined in surface view and in hand-cut sections under a compound microscope (Olympus CH-2, Japan). Cells were measured at 40x and 100x magnification with an eye-piece scale, calibrated with an objective micrometer.

Historical collections including type material were examined in the herbaria of the Museum of New Zealand Te Papa Tongarewa in Wellington (WELT) and the Auckland Institute and Museum in Auckland (AK). Emphasis was placed on collections made by V.W. Lindauer, on which many of V.J. Chapman's records and new descriptions were based. Where they were able to be located, type specimens of taxa described by Chapman were examined. Herbarium specimens were examined macroscopically and microscopically. Hand sections of basal, mid thallus and upper thallus material were made to examine cell characteristics. Subsamples (ca. 1 cm x 1 cm tissue) were removed from some herbarium specimens for subsequent DNA extractions.

Literature searches of major databases and journals were carried out and an extended bibliography compiled. This includes references cited in this report as well as background taxonomic literature to the family Ulvaceae and recent literature on the ecology of *Ulva*, particularly in relation to the formation of blooms, and algal introductions.

### **Molecular biology**

#### Sample preparation

1) DNA extraction: Methods tested for the extraction of whole genomic DNA from the dried samples included Proteinase K (Hughey *et al.* 2001), ChargeSwitch (Invitrogen, California) and Chelex (Goff & Moon 1993). The Chelex method was found to be reliable, and it was also the most time- and cost-effective of the methods tested. Of the 855 freshly dried *Ulva* samples, a total of 746 were extracted with this method. The extraction of DNA from historical herbarium specimens was likewise attempted with these extraction methods, however all methods failed to extract DNA of a quality able to be amplified in

subsequent PCR reactions. Given the small samples able to be harvested from specimens, quality and quantity of DNA were assessed directly by PCR.

Around 10 mg of dry *Ulva* tissue was rehydrated in TrisEDTA buffer (10 mM Tris, 0.1 mM EDTA pH 8.0) and was roughly chopped with a razor blade. The tissue fragments were added to 180 µl extraction buffer (90 mM TrisHCL (pH 8), 50 µM EDTA, 5% w/v Chelex-100 resin) and ground for 2 minutes with a plastic pestle. After 20 minutes on ice, samples were boiled for 10 minutes. Cell debris and Chelex beads were spun down in a bench top centrifuge (10,000 g for 2 minutes). The supernatant was removed and diluted (e.g. 1:10, 1:100) with TrisEDTA buffer for PCR amplification. DNA extracts and dilutions were stored at -18°C until further processing took place.

2) Amplification: Three genes were tested to select the most informative/cost effective approach for subsequent samples: the chloroplast genes for the D1 protein of photosystem II (*psbA*) and the large subunit of ribulose-1,5-bisphosphate carboxylase/oxygenase (*rbcL*), as well as the internal transcribed spacer 1 of the nuclear ribosomal gene (ITS1).

Trials with ITS1 primers published for the genus (Blomster *et al.* 1998; Malta *et al.* 1999; Tan *et al.* 1999; Hayden *et al.* 2003) were unsuccessful. Primers did not amplify at all or produced multiple band patterns in the PCR amplification.

The *psbA* gene has not been studied in Ulvophyceae, leading to a lack of primers designed to reliably amplify this locus from *Ulva* entities. While this marker is a possible source of further information, the lack of data for comparison with known species limited its usefulness in this study.

The gene for the *rbcL*, on the other hand, was amplified successfully and provided enough variation to distinguish entities within the genus *Ulva*. Previous workers have used data from this gene to investigate species and genus relationships in the group (e.g. Tan *et al.* 1999; Hayden *et al.* 2003). Consequently, a number of *Ulva rbcL* sequences from other parts of the world are available in GenBank. Therefore the *rbcL* gene was chosen to distinguish New Zealand *Ulva* entities.

Published *rbcL* primers (Manhart 1994) were employed in the beginning of the study. However, these are known to fail to amplify certain entities, such as *Ulva rigida* (L. McIvor, personal communication to N. Barr), a species recorded from New Zealand (Chapman 1956). Therefore additional primers were empirically designed (Table 1) which successfully amplified a part of the *rbcL* gene around 1200 bp in length, for *Ulva* species including *Ulva rigida*. Candidate primers were designed by eye from available sequences, and tested empirically against extracts that had not amplified using Manhart primers. Specificity was verified by inspection of products on agarose gels and by comparison of sequences of the products with existing *Ulva* sequences. Approximately 85% of the samples were amplified using these primers.

Table 1: Amplification and sequencing primers

primer	sequence (5'-3')	direction	opposite primer	reference
RH1	ATGTCACCACAAACAGAACTAAAGC	forward	1385R	Manhart 1994
1385R	AATTCAAATTTAATTTCTTTCC	reverse	RH1	Manhart 1994
SH F1	CCGTTTAACTTATTACACGCC	forward	SH R4	this study
SH R4	TTACATCACCACCTTCAGATGC	reverse	SH F1	this study

PCR reactions of 25  $\mu\text{L}$  volume contained 1  $\mu\text{L}$  diluted DNA extract, 2.5  $\mu\text{L}$  10x reaction buffer, 1  $\mu\text{L}$  50mM  $\text{MgCl}_2$ , 0.6  $\mu\text{L}$  10mM dNTP mix, 1.25  $\mu\text{L}$  20 pmol  $\mu\text{L}^{-1}$  of each primer (Table 1) and 0.1 U recombinant *Taq*-polymerase. (Master mix developed in this study.) Most samples readily amplified at a 1:10 dilution. Chemicals were supplied by Invitrogen, California. Amplifications were performed in a Robocycler Gradient 96 thermocycler (Stratagene Corporation, La Jolla, California). The PCR protocol (developed in this study) comprised an initial denaturation step (94° C, 2 min), followed by 35 cycles of denaturation (94° C, 30 sec), annealing (40-47° C, 1 min), and extension (72° C, 2 min) with a final extension of 10 min. The presence of single bands and sufficient amounts of PCR products were assessed by agarose gel electrophoresis.

PCR products were separated from primers, unused nucleotides etc. by polyethylene glycol (PEG) precipitation: PCR reactions were mixed 1:1 with PEG solution (20% PEG, 2.5 M NaCl), were incubated at 37° C for 20 minutes to precipitate the DNA and then spun down in a bench-top centrifuge (13000 g for 25 minutes). Pellets were washed twice with 80% ice-cold ethanol and air-dried for 30 minutes. Purified DNA was re-suspended in 20  $\mu\text{L}$  TrisEDTA buffer (10 mM Tris, 0.1 mM EDTA pH 8.0). The concentration of the DNA was determined by spectrophotometry in a NanoDrop (NanoDrop Technologies, USA; operated with NanoDrop 3.0.1, Coleman Technologies Inc., USA). PCR products were mixed with 3.2 pmol primer, and water added to a final concentration of circa 2 ng  $\mu\text{L}^{-1}$  DNA, and sent to the automatic sequencing facility at the AWCGS (Allan Wilson Centre Genome Service) in Palmerston North where samples were sequenced with an ABI PRISM™ automatic DNA sequencer (Applied Biosystems USA).

Electropherograms of sequences were checked by eye and possible ambiguities edited in EditView 1.0.1 (ABI) according to IUPAC code. Complementary strands were assembled in AutoAssembler 2.0 (ABI). Partial *rbcL* sequences were obtained for a total of 581 *Ulva* samples.

#### Molecular identification

An iterative approach was taken to allow simultaneous identification of known species and of new genetic entities. An initial phylogenetic dataset was constructed in PAUP\* 4.0.b10 (Swofford 2002) containing sequences of both bladed and tubular *Ulva* entities retrieved from GenBank. Incoming sequences from New Zealand specimens were added to this dataset and were subjected to neighbour joining phylogenetic analyses, placing them in relationship to the existing sequences.

Specimens generating sequences that formed a well-supported monophyletic group with

GenBank sequences, were identified as belonging to the species named in GenBank. Sequences which were not significantly similar to GenBank sequences, i.e. which were from species without representatives in GenBank, were retained in the dataset. Sequences that formed a monophyletic group with those already in the dataset were removed to make phylogenetic analyses tractable. This framework tree served as a means of evaluating incoming sequences: sequences could be quickly identified as either novel or belonging to an existing clade, whether this clade was based on sequences from New Zealand or from elsewhere. Each clade was distinguished either by a species name or a unique clade number.

#### Phylogenetic data analyses

Sequences were aligned by eye in Se-AL version 2.0 a 11 (Rambaut 1996). The dataset included 27 sequences of Ulvaceae from other parts of the world (refer Appendix 5), with *Ulvaria fusca* Ruprecht serving as an outgroup for data analyses.

The initial data set containing 581 sequences from New Zealand specimens and 37 GenBank sequences had to be substantially reduced, due to a large number of very similar or identical sequences, in order to make phylogenetic analyses tractable. The final data set contained 51 taxa: 27 GenBank sequences including the outgroup species, and 24 sequences from New Zealand specimens. Entities were, where possible, represented by a GenBank sequence (= confirmed name) and a New Zealand specimen, or by a New Zealand specimen alone when no GenBank sequence was available. New Zealand sequences were chosen that differed most from the GenBank sample.

An appropriate model of sequence evolution for the dataset was estimated using the Akaike Information Criterion (AIC) implemented in Modeltest V3.0.6 (Posada & Crandall 1998), and this model GTR+I+ G (General time-reversible + I [= proportion of Invariable sites] + G [= shape parameter of Gamma distribution modelling the rate heterogeneity]) was used for all distance and likelihood calculations. The dataset was analysed using maximum parsimony (MP) and maximum likelihood (ML) optimality criteria, and Bayesian analysis. MP trees were estimated with PAUP\*4.0b10. MP analyses were conducted using an heuristic search strategy with 10 replicates of random-order sequence addition followed by tree bisection reconnection (TBR) branch swapping. Bootstrap support was estimated with 1000 replicates, each of 10 replicates of random order sequence addition followed by TBR branch swapping. Consistency Index (CI), Retention Index (RI) and Rescaled Consistency Index (RC) (Farris 1989) were calculated using PAUP\*4.0b10. Maximum likelihood analyses were conducted using PHYML v2.2.4 (Guindon & Gascuel 2003) under the GTR + I + G model of sequence evolution, with concurrent estimation of parameters for invariant sites and gamma-modelled rate heterogeneity. Support was estimated using 500 bootstrap replicates.

Bayesian analyses were carried out using MrBayes v3.1.1 (Ronquist & Huelsenbeck 2003) to run four chains of Metropolis-coupled Markov chain Monte Carlo (MCMC) iterations (one cold and three incrementally heated, temperature parameter = 0.2). Two independent MrBayes analyses were run under the GTR+I+ G model of sequence evolution for 1,000,000 generations. Model parameters were treated as unknown and

were estimated in each analysis. Chains were initiated with random starting trees and trees were sampled every 100 generations. Appropriate burn-in values were determined by inspection of plots of log-likelihood against generation time for each run. The likelihood scores stabilized at approximately 50,000 generations, and thus the first 500 trees were burned. The remaining trees were used to calculate a 50% majority rule consensus tree, in which each clade posterior probability (PP) value is represented by the proportion of trees containing that clade.

### **Data analyses and mapping**

A FileMaker Pro database was created to store field and laboratory data. When specimens were assigned to a species group this information was used to update records in the database. At the completion of sequencing the data were then summarized according to species/entity groupings. Data from the FileMaker database were exported to different formats to enable further summarizing and analysis. Records for each entity were summarized with respect to distribution, exposure, habitats occupied, and degree of human modification at sites. The data were summarized graphically. In addition to examination of species /entity characteristics, the seasonal collections made in the Wellington and Dunedin regions were summarized. The species composition of biosecurity collections was analysed. The spatial distribution of species was mapped using ArcMap in ArcGIS.

## **RESULTS**

### **Molecular data and phylogenetic analyses**

Of the 855 samples of *Ulva* sensu lato collected in the New Zealand region, 746 were extracted and 581 were identified by their *rbcL* sequences. In some cases, background noise or overlapping peaks in the electropherogram indicated that either the original sample might have contained more than one *Ulva* entity, might have been contaminated by another green alga, or that gene regions other than the targeted one were also amplified in the PCR. Samples that could not be unequivocally identified were discarded.

None of the historical herbarium specimens could be genetically identified due to a failure to extract amplifiable DNA from them. The 581 identified specimens could be separated into 24 distinct monophyletic entities. Of these, 19 were identified as belonging to the genus *Ulva* L., four to *Umbraulva* Bae & I.K.Lee and one to *Gemina* V.J.Chapm. Fourteen of the entities clustered with sequences from GenBank. These clusters allowed the allocation of species names to 13 entities (Table 2). A total of 11 entities did not match any sequences in GenBank. Of these, two were tentatively identified on the basis of morphology as *Gemina letterstedtioidea* and as *Ulva* species 5 "*U. ralfsii*", while the other nine remain without species names.

With 157 samples, *Ulva* species 1 was the most abundant entity, followed by *U. pertusa* (124 samples) and *U. compressa* (109 samples). Nine entities were represented only by single collections: *U. flexuosa*, *Ulva* species 4, 6 (duplicate samples), 9 and 10, and all four *Umbraulva* species ("Kermadecs" with duplicate samples).

Table 2: List of entities and numbers of samples per entity in collections analysed.  
 \*= duplicate samples

Species	No. of samples
<i>Ulva armoricana</i> Dion, de Reviere & Coat	8
<i>Ulva californica</i> Wille	3
<i>Ulva compressa</i> L.	109
<i>Ulva fasciata</i> Delile	3
<i>Ulva flexuosa</i> Wulfen	1
<i>Ulva intestinalis</i> L.	60
<i>Ulva lactuca</i> L.	3
<i>Ulva linza</i> L.	2
<i>Ulva pertusa</i> Kjellm.	124
<i>Ulva procera</i> (K.Ahlner) H.S.Hayden, Blomster, Maggs, P.C. Silva, Stanhope & Waaland	29
<i>Ulva prolifera</i> O.F.Müll.	11
<i>Ulva rigida</i> C.Agardh	17
<i>Ulva</i> species 1	157
<i>Ulva</i> species 2	27
<i>Ulva</i> species 4	1
<i>Ulva</i> species 5 " <i>U. ralfsii</i> " (Harv.) Le Jol.	10
<i>Ulva</i> species 6	2*
<i>Ulva</i> species 9	1
<i>Ulva</i> species 10	1
<i>Gemina letterstedtioidea</i> V.J.Chapm.	6
<i>Umbraulva olivascens</i> (Dangeard) Bae & I.K.Lee	1
<i>Umbraulva</i> "Kermadecs"	3*
<i>Umbraulva</i> "Northland"	1
<i>Umbraulva</i> "Auckland Is"	1

### Alignment properties

The partial alignment of the *rbcL* sequences comprised 1140 base pairs. Some sequences did not cover the whole length of the alignment. Missing data were represented by IUPAC code N. The average base composition of the reduced data set was A: 0.28755; C: 0.16531; G: 0.21547; T: 0.33167.

### Phylogenetic analyses

Trees inferred from the analyses are presented in Figures 2 A-C (A = Maximum likelihood tree, B = 50 % majority rule consensus of 32 maximum parsimony trees, C = 50% majority rule consensus of Bayesian analysis). In phylogenetic analyses, the genus *Ulva* was well supported as a monophyletic clade, with *Ulva* species 4 as the most basal entity within this genus. *Gemina* and *Umbraulva* species were positioned in the outgroup. *Gemina* was not resolved as being closely related to any other entity, and the other species resolved as a monophyletic clade with moderate bootstrap support including other *Umbraulva* species.

Figure 2A: Maximum likelihood tree for entities of *Ulva* s. l. from New Zealand inferred from *rbcL* sequences, presented in phylogram style. (GTR + I + G model,  $-\ln$  likelihood = 3875.0576; I = 0.7986; G = 1.4868; A-C = 0.3666, A-G = 3.9085, A-T = 0.4777, C-G = 0.1511, C-T = 6.6087, G-T = 1). Numbers indicate ML (left) and MP (middle) bootstrap values, and Bayesian probabilities (right). Dashes indicate that branches received a bootstrap support of 50% or less. Nodes with bootstrap values less than 50% in both analyses and bayesian probabilities below 0.9 are not labelled.







The topology of the ML tree was essentially the same as that of the tree inferred from the Bayesian analysis as well as the 32 equally most parsimonious trees produced by the MP analysis based on 133 parsimony-informative characters (length of MP trees: 414 steps; scores: CI: 0.478, RI: 0.776, RC: 0.371). However, in the MP trees, the *Umbraulva* entities were not recovered as a monophyletic group: this is likely to be an artifact as a consequence of limited taxon sampling in sister genera to *Umbraulva*. Furthermore, some entities had less support in MP bootstrap analyses e.g., the clade of WELT A027284 with *U. armoricana* received less than 50% bootstrap support. The two independent Bayesian analyses converged on a single stationary distribution of trees as assessed by average standard deviation of split frequencies. Within entities comprising more than one sample, most sequences were very similar or identical to each other and to GenBank sequences, respectively. Table 3 lists the maximal distances among sequences from New Zealand within entities and, where appropriate, the absolute distance of the representative New Zealand sequence to the GenBank sequence. Appendix 6 shows the distance matrix of absolute distances between *rbcL* sequences from GenBank specimens and New Zealand representatives included in the reduced data set.

Table 3: Maximum base pair distances between *rbcL* sequences from New Zealand specimens within single entities and absolute distance to the GenBank sequence of the representative sequence included in the reduced data set. Only entities with clusters containing more than one sample are included.

<b>Entity</b>	<b>Maximal distance [bp]</b>	<b>Distance to GenBank sequence [bp]</b>
<i>U. armoricana</i>	2	0
<i>U. californica</i>	2	2
<i>U. compressa</i>	4	2
<i>U. fasciata</i>	2	0
<i>U. intestinalis</i>	4	2
<i>U. lactuca</i>	0	2
<i>U. linza</i>	2	4
<i>U. pertusa</i>	5	0
<i>U. procera</i>	4	0
<i>U. prolifera</i>	1	0
<i>U. rigida</i>	1	0
<i>Ulva</i> species 1	4	0
<i>Ulva</i> species 2	4	n/a
<i>Ulva</i> species 5 - " <i>U. ralfsii</i> "	1	n/a
<i>Ulva</i> species 6	0	n/a
<i>Gemina letterstedtioidea</i>	2	n/a
<i>Umbraulva</i> "Kermadec Islands"	0	n/a

### **Species Treatments**

For each genetically distinguished entity a summary of information has been compiled, supplying data (where available) on the nomenclature and taxonomic status of the species, type locality, species description (from original literature), description of the specimens examined in this study, the distribution within New Zealand and elsewhere, in the latter case based largely on records in AlgaeBase (Guiry 2006). A summary of information on the habitat, a listing of voucher specimens lodged at Te Papa, additional comments on the entity and nomenclature, and the reference to the original description are provided. For each entity illustrations of scanned representative specimens are provided, with the WELT label providing a scale bar (the black horizontal line on the label is 115 mm in length). The distribution of collection sites has been mapped and a summary prepared of the habitat characteristics of each entity.

## ***Ulva armoricana* Dion, de Reviere & Coat**

Figs 3 - 5

Publication details: *Ulva armoricana* Dion, de Reviere & Coat 1998: 74

Type locality: Roscoff, Brittany, France

### SYNONYM:

probably *U. scandinavica* Bliding 1968: 554 (see Comments)

Type locality: Sweden

### SPECIES DESCRIPTION:

Blades, variable in shape, fragile, pale green colour, crumpled texture irregularly reflecting the light, tooth-like protuberances on margin of blade; lacks central cavity in stipe; basal part with longitudinal ribs containing rhizoids; mid-thallus region with polygonal cells, growing parts with quadrangular cells arranged in small longitudinal rows; in transverse sections cells in apical and middle regions rounded, non-rhizoidal cells in basal region ovate, sometimes longitudinally elongated with tapered ends. Usually 1-2 (3-4) pyrenoids per cell. (Dion *et al.* 1998)

### DESCRIPTION – NEW ZEALAND SPECIMENS:

New Zealand specimens consist either of flat sheets with toothed margins reaching 170 mm in length/width, or small blades. One sample formed a small rosette with a stiff base. The larger flat sheets were not limited to harbours or embayments, suggesting that the smaller blades might be young thalli, rather than adults stunted by environmental conditions such as exposure. Fresh specimens were of grey-green colour, dried specimens ranged from in colour from pale to dark green, with brown discolouration observed in some parts of the thalli. Tapering cells in transverse sections of the basal region confirmed the morphological identification of this entity as *U. armoricana* (WELT A027284). In surface view, cells were roundish and had usually 2 pyrenoids per cells. Cells were between 6-12 µm wide and 7-20 µm long (WELT A027284) and arranged in short rows.

### HABITAT:

*U. armoricana* occupied a variety of substrates, including growing epiphytically on Fucales, red algae, and epizoically on sponges. This species occupied a wide range of habitats and was found in tidepools in the mid intertidal as well as subtidally down to 14 m water depth, in open coast sites as well as sheltered harbour areas. It grew in estuarine as well as fully marine waters, in little modified open coast habitats as well as on wharf structures in heavily modified harbour sites.

### DISTRIBUTION – NEW ZEALAND:

Specimens were found in two distinct regions - in the north of the North Island (Bay of Islands, Cavalli Island), and in the Cook Strait region (Wellington/Marlborough Sounds/Nelson area).

### DISTRIBUTION – OUTSIDE NEW ZEALAND:

Europe: France (Guiry 2006); Japan (Shimada *et al.* 2003)

REFERENCE SPECIMENS: WELT A027284, A027285, A027290

COMMENTS:

The *rbcL* sequences of the eight specimens collected were virtually identical to each other and to the sequences of samples from France and Japan. This genetic similarity coupled with the somewhat restricted geographic range suggests this species has been introduced to New Zealand. Whether the two separate areas of distribution (Northland and Cook Strait) represent separate introduction events, will require further investigation. In Brittany, France, *U. armoricana* is considered a major component of locally occurring green tides (Dion *et al.* 1998). In New Zealand it was not found in samples analysed from the sites prone to green tides (i.e., Tauranga harbour and Avon-Heathcote estuary).

Two of the eight samples of *U. armoricana* were collected subtidally in 6 m and 14 m. Considering that in this study most areas were sampled only in the intertidal, *U. armoricana* may be artificially under-represented among the samples, i.e., could be more widespread than the data indicate.

NOMENCLATURE:

The separation of *Ulva armoricana* from *U. scandinavica* is based on morphology and is likely to be artificial. It was found using ITS sequence comparisons that samples collected in France which were identified morphologically as *U. scandinavica* had ITS sequences identical to either *U. rigida* or *U. armoricana*. The older name *U. scandinavica* would have priority. However, the relationship between these entities needs to be confirmed by sequence comparisons with material from the type locality of *U. scandinavica*. Therefore, in this context the name *U. armoricana* was chosen above *U. scandinavica* because sequences available for *U. armoricana* originated from material from the type locality while the sequences of *U. scandinavica* were based on material from England and not from the type locality in Sweden. Moreover, specimens from New Zealand showed a morphological character described for *U. armoricana*: the tapered ends of cells in transverse sections just above the rhizoidal region.

**References:**

- Coat, G.; Dion, P.; Noailles, M.-C.; de Reviere, B.; Fontaine, J.-M.; Berger-Perrot, Y.; Loiseaux-De Goër, S. (1998). *Ulva armoricana* (Ulvales, Chlorophyta) from the coasts of Brittany (France). II. Nuclear rDNA ITS sequence analysis. *European Journal of Phycology* 33: 81-86.
- Dion, P.; de Reviere, B.; Coat, G. (1998). *Ulva armoricana* sp. nov. (Ulvales, Chlorophyta) from the coasts of Brittany (France). I. Morphological identification. *European Journal of Phycology* 33: 73-80.

Fig. 3: *Ulva armoricana*

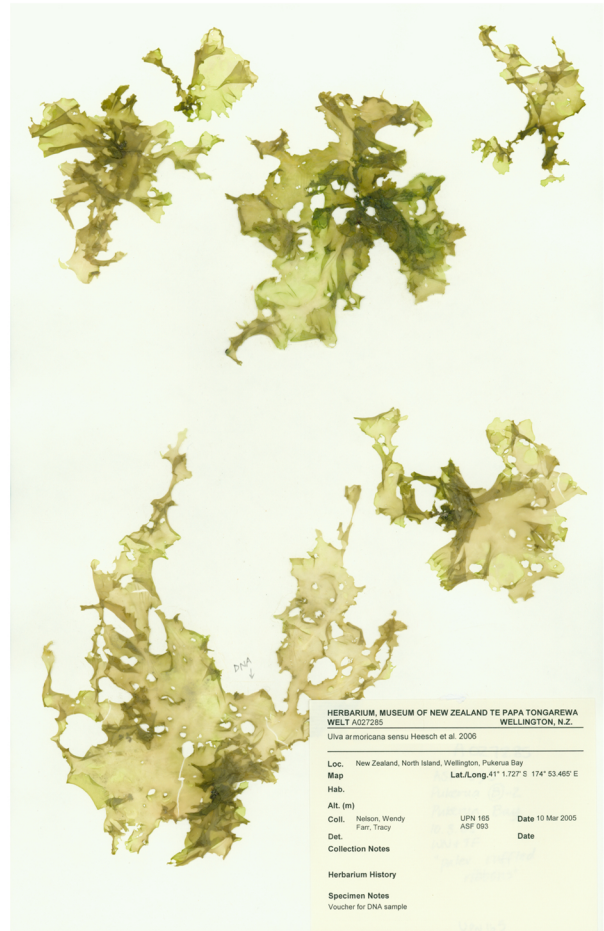


Fig. 4: *Ulva armoricana*

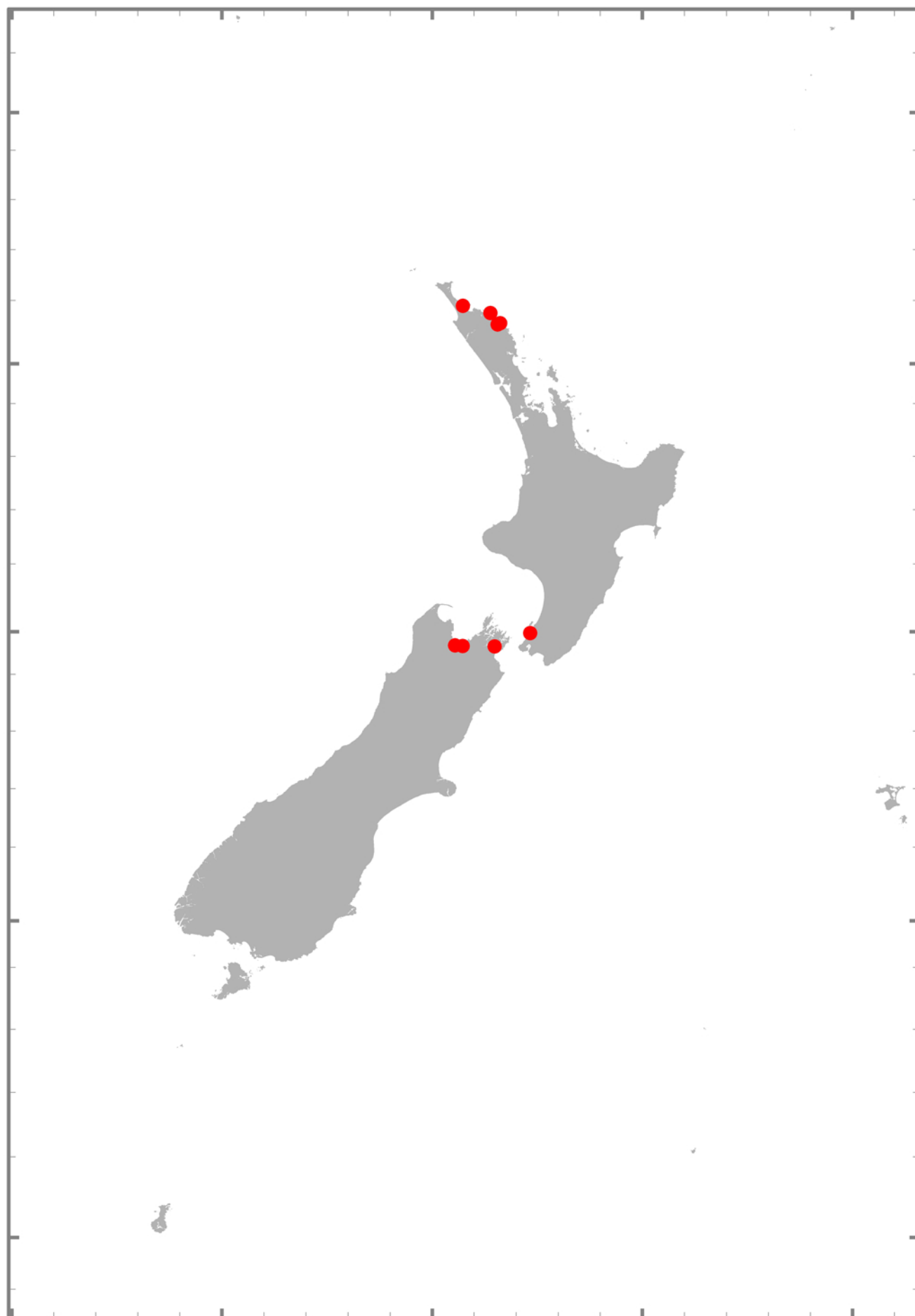
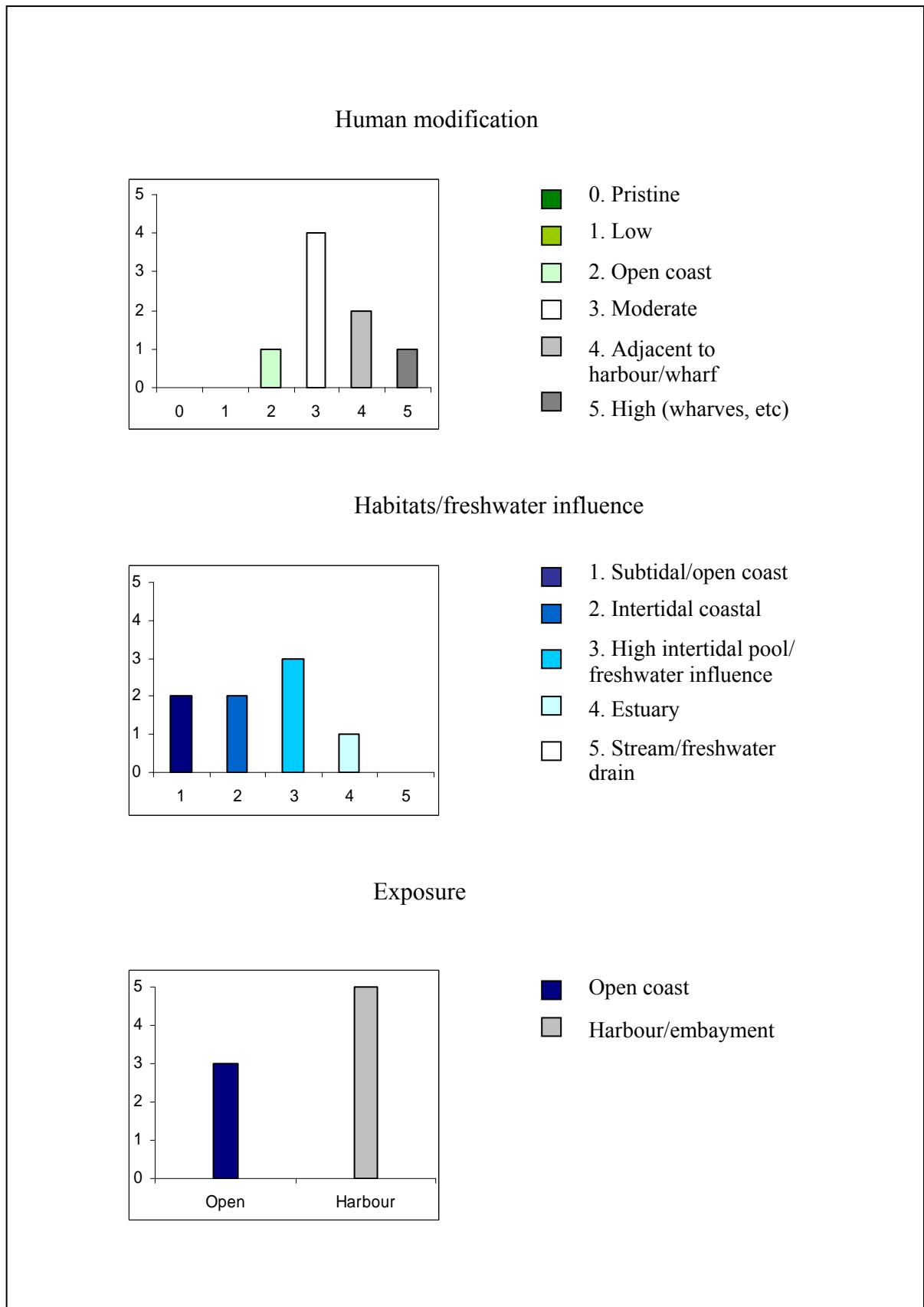


Fig. 5: *Ulva armoricana*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva californica* Wille**

Figs 6 - 8

Publication details: *Ulva californica* Wille in Collins, Holden & Setchell 1899: no. 611

Type locality: La Jolla, California, USA

**SPECIES DESCRIPTION:**

Blades mostly 15-20 mm high; cuneate to ovate to reniform, commonly much crisped, with broad attachment or slender stipe; membrane 30-35(60)  $\mu\text{m}$  thick, commonly much thicker near base; cells in surface view irregularly polygonal with rounded corners and irregular arrangement or in distinct rows; (5)10-15  $\mu\text{m}$  diam., 1-1.5 times as long as diam. anticlinally; chloroplast with 1 or 2 (4) pyrenoids. Usually in dense, turf-like stands atop rocks, occasionally epiphytic, midtidal to upper intertidal. (from Abbott & Hollenberg 1976)

**DESCRIPTION – NEW ZEALAND SPECIMENS:**

New Zealand specimens had flat lobed blades with very narrow bases and small short stipes. Fronds were broader than high, with sizes ranging from 13 x 21 mm to 18 x 30 mm. Some specimens formed frilly dishes with fringed margins, while others were not very ruffled and had a fine silky texture. The colour of dried specimens ranged from a dark green colour with olive brown margins to lighter green.

In transverse sections, cells were small and brick-like (2 times wider than tall). In surface view, cells were partially ordered (in small areas with single rows of up to 10 cells). Cells contained 1(-2) pyrenoid, and in surface view were 4-12  $\mu\text{m}$  wide and 7-17  $\mu\text{m}$  long. One sample (WELT A027343) contained fertile specimens, which sported packets of 8 meiospores per cell in areas with already released spores.

**HABITAT:**

Only three samples of *U. californica* were collected, all from intertidal sites, suggesting tolerance to some freshwater influence. The specimens from Oamaru and Wellington grew on wharf structures in sheltered harbours e.g., on a concrete slipway, while the one from Whale Bay was found in an open coast habitat with only moderate human influence.

**DISTRIBUTION – NEW ZEALAND:**

Samples were collected from Whale Bay (Raglan), Wellington Harbour and Oamaru. However, at these sites it was abundant as indicated by the numerous specimens on herbarium sheets.

**DISTRIBUTION – OUTSIDE NEW ZEALAND:**

North America: Alaska, British Columbia, California, Oregon, Washington; Africa: Senegal (Guiry 2006)

**REFERENCE SPECIMENS:** WELT A027342, A027343

**COMMENTS:**

The limited geographical spread of this species in New Zealand, in addition to the occurrence of two of the three samples in harbours on highly human modified structures, suggests that *Ulva californica* has been introduced to New Zealand. The *rbcL* sequence of the specimen from Wellington showed slight differences to the GenBank sequences and to one of the two New Zealand sequences. The question whether this may be an indication of two separate introduction events originating from different locations needs to be addressed by comparing more variable gene regions.

**NOMENCLATURE:**

When compared with sequences in GenBank, *Ulva californica* clustered with *Ulva curvata* (Kützinger) De Toni, a species recorded from Europe and the east coast of the United States. The sequences of *U. californica* and *U. curvata* were nearly identical and thus only one, *U. californica* has been included in the phylogenetic analyses here. The name *U. californica* was chosen for samples collected in this study as GenBank sequences of *U. californica* originated from material collected in California, while the *U. curvata* sequence is based on material from the east coast of the USA and not from the type locality, on the island of Rügen in the Baltic Sea (*Ulva curvata* (Kütz.) De Toni 1889: 116). The relationship between *U. californica* and *U. curvata*, and whether or not these species are the same entity, needs to be examined by using more variable genes.

**Reference:**

Collins, F.S.; Holden, I.; Setchell, W.A. (1899). *Phycotheca boreali-americana. A collection of dried specimens of the algae of North America*. Vol. Fasc. XII-XIII, Nos. 551-650. Malden, Massachusetts.

Fig. 6: *Ulva californica*



Fig. 7: *Ulva californica*

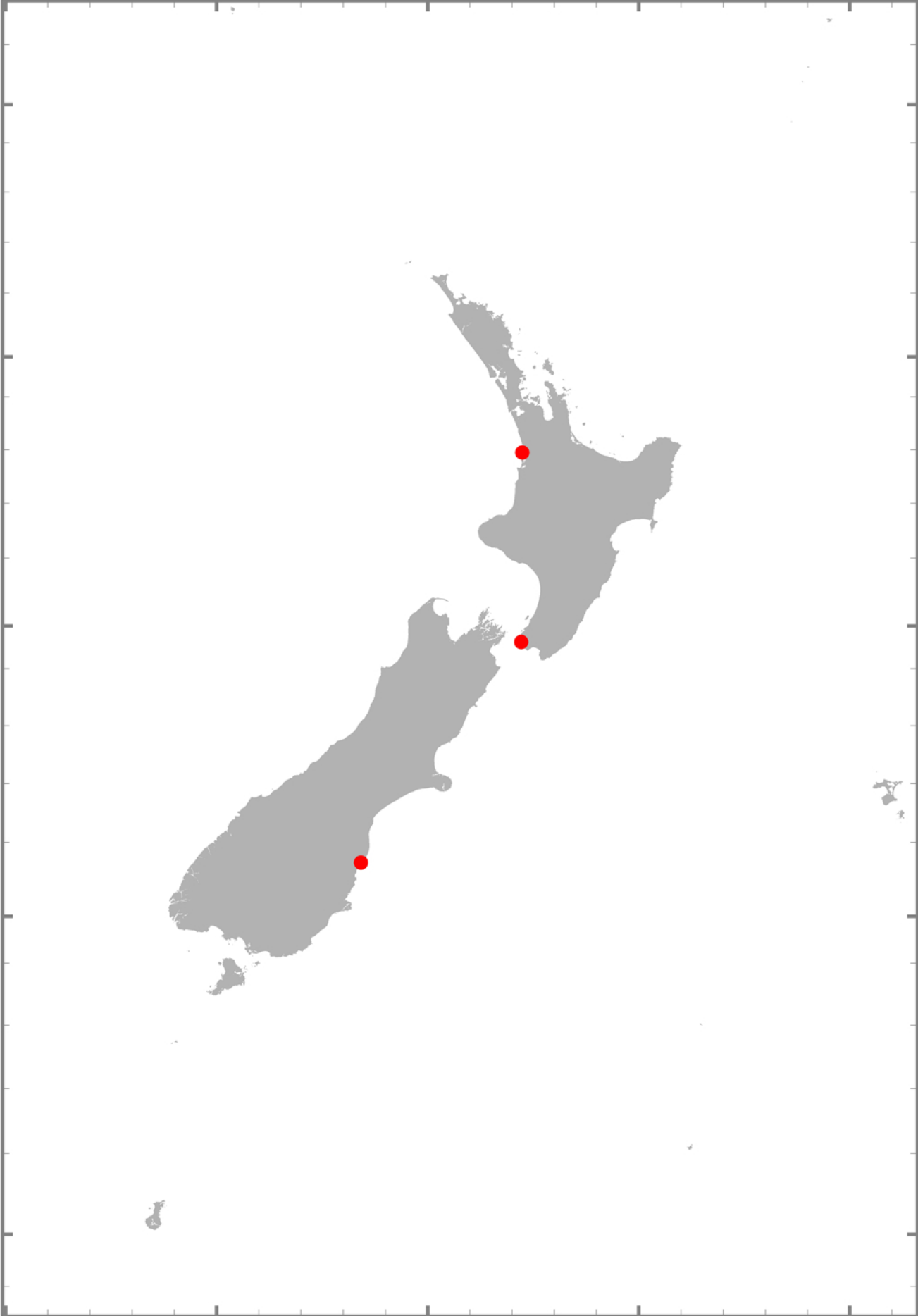
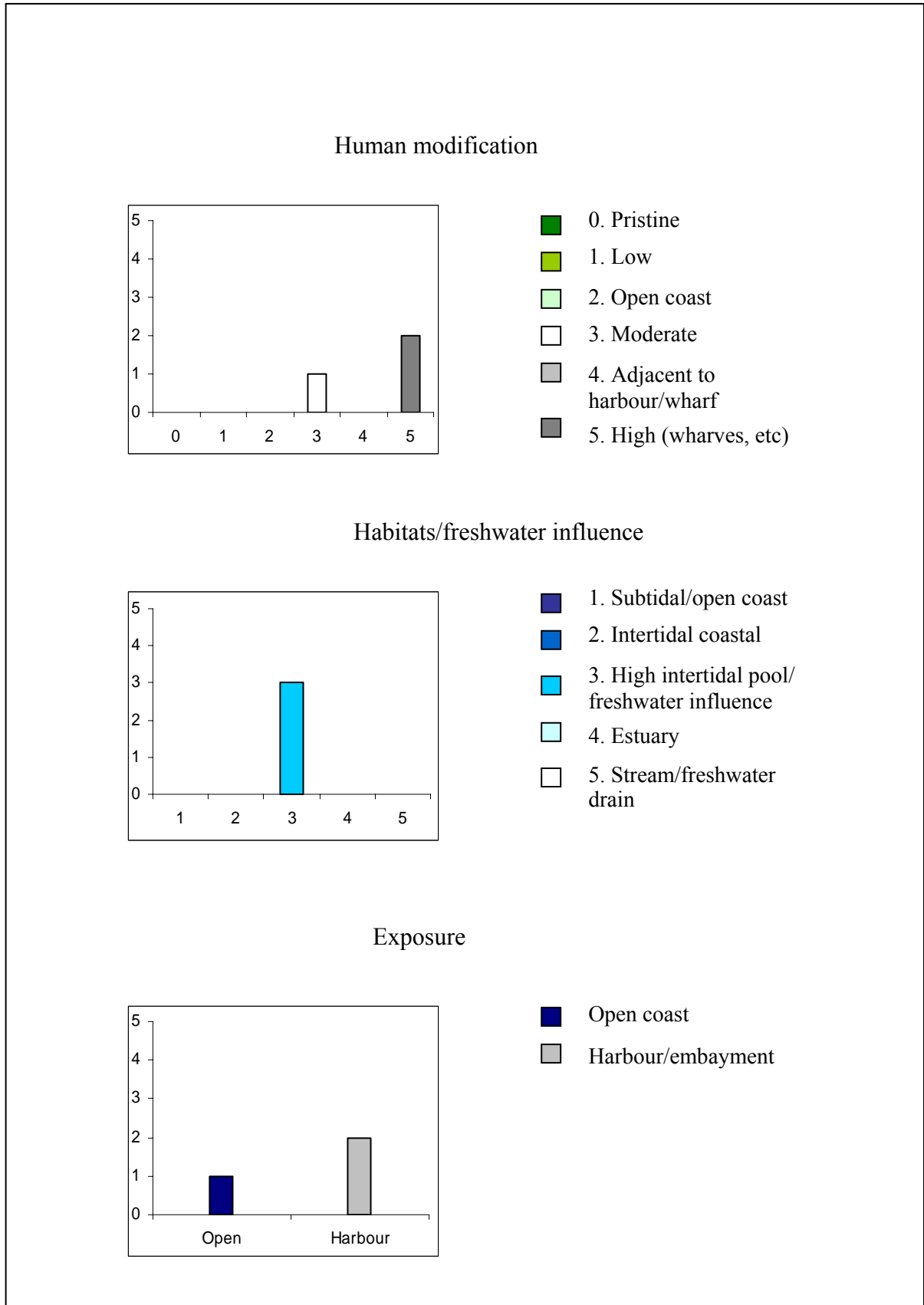


Fig. 8: *Ulva californica*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva compressa* L.**

Figs 9 - 16

Publication details: *Ulva compressa* Linnaeus 1753: 1163

Type locality: "*Habitat in Europae mari & tectis maritimis*"; [probably Bognor, Sussex, England (Hayden *et al.* 2003: 289)]

SYNONYM:

probably *Ulva pseudocurvata* Koeman & Hoek 1981: 19

Type locality: Wemeldinge, Netherlands

SPECIES DESCRIPTION:

"*ULVA tubulosa ramosa compressa*" (Linnaeus 1753)

DESCRIPTION – NEW ZEALAND SPECIMENS:

Many of the New Zealand specimens showed the much-branched tubes typical for this species, although other specimens were only sparsely branched or appeared unbranched. Branches were usually of the first order. Based on the shape and size of the tubes and amount of branching, specimens could be separated into five morphological groups:

group 1 = much branched tubes;

group 2 = slender "*Ulva intestinalis*"-like tubes with only occasional branches;

group 3 = inflated tubes;

group 4 = tiny tubes;

group 5 = a single specimen with cells in tetrads at base.

The size of the tubes ranged from less than 10 mm to 570 mm, with branches up to 80 mm long. Colours varied from bright and grassy green to dark green when fresh. The single specimen allocated to group 5 (WELT A027308) had distinct tetrads of cells in the basal region, which were not observed in any other specimen examined of this entity. In general, cells were not arranged in any specific pattern and contained 1 pyrenoid. In surface views cells were 7-12 µm wide and 9-17 µm long.

HABITAT:

Thalli were usually epilithic, also grew on mollusc shells, and occasionally on wood or epiphytically on other algae. All samples were collected in the intertidal: 42% in the low to mid intertidal, 30% in the high intertidal, and 27% in estuaries. A single sample was found in a freshwater stream. Nearly half of the specimens were from harbours or embayments, with most samples collected from sites with moderate (47%) or little (32%) influence by humans.

DISTRIBUTION- NEW ZEALAND:

*Ulva compressa* was found in most New Zealand regions, except the Kermadec Islands and the subantarctic islands.

DISTRIBUTION – OUTSIDE NEW ZEALAND:

Europe: Balearic Islands, Ireland, Spain; Atlantic Islands: Canary Islands, Cape Verde Islands, Madeira, Salvage Islands; Caribbean Islands: Cuba, Trinidad & Tobago; Africa:

Angola, Mauritania, Namibia, Western Sahara; Pacific Islands: American Samoa (Guiry 2006)

REFERENCE SPECIMENS: WELT A027293, A027294, A027295, A027296, A027297, A027298, A027299, A027300, A027301, A027302, A027303, A027304, A027305, A027306, A027307, A027308, A027309

COMMENTS:

A total of 109 specimens were identified as this species, making *Ulva compressa* one of the most abundant and widespread entities in New Zealand. It comprises a complex of tubular forms, with at least two different distinct morphologies (much branched tubes vs. smooth tubes). Womersley (1994) distinguished Australian specimens with much branched tubes ('terete form') from compressed tubes with only a few basal branches ('compressed and ruffled form'). Likewise, New Zealand samples within this clade showed a range of variable morphologies, ranging from apparently unbranched "*Enteromorpha intestinalis*"-like tubes to tubes that were completely covered with branches, from tiny tubes to large inflated specimens. However, the branching in *Ulva compressa* is known to be highly dependent on environmental conditions, and is especially influenced by salinity: in brackish waters this species can even form unbranched tubes/sheets which are difficult to distinguish from other unbranched tubular forms, especially *Ulva intestinalis* (Blomster *et al.* 1998, Tan *et al.* 1999). Among the New Zealand samples distinct morphological groups were not separable by *rbcL* sequence comparisons. A more variable gene will have to be studied to distinguish between true environmental forms or taxa below species level in this entity.

*Ulva compressa* is known to foul ship hulls (Fletcher 1980, cited in Blomster *et al.* 1998) and thus its distribution may reflect human-mediated dispersal. New Zealand *rbcL* sequences were identical or nearly identical to sequences from overseas. However, the widespread distribution of *Ulva compressa* in New Zealand and its presence in early collections of algae from this area (Hooker & Harvey 1845; Harvey 1855; Agardh 1878) suggests that it is a native or, if not, a species that naturalised a long time ago.

NOMENCLATURE:

Chapman (1956) lists three species names for much branched tubular *Ulva* specimens in New Zealand, each comprising a number of varieties: *Enteromorpha compressa* (L.) Greville, *E. ramulosa* (J. E. Smith) Carmichael (as *E. ramulosa* Hooker) and *E. clathrata* (Roth) Greville (as *E. clathrata* (Roth) Agardh). Adams (1994) presents a drawing of a large tubular *Ulva* with many branches and identifies it as *Ulva ramulosa* but notes that "*Ulva acanthophora* Kützing may be the correct name for the New Zealand plant" (p. 29), an opinion followed by Hayden *et al.* (2003). However, *E. ramulosa* and *E. acanthophora*, together with *E. muscoides* (Clemente y Rubio) Cremades, are currently considered synonyms of *Ulva clathrata* (Roth) C. Agardh (Guiry 2006), thus reducing the names available for terete, much-branched New Zealand specimens to *U. compressa* and *U. clathrata*.

*Ulva clathrata* is distinguished from *U. compressa* mainly by its cells which are typically arranged in rows and show 2-4 (up to 6) pyrenoids, while cells in *U. compressa* are

unordered and have a single pyrenoid. Both species are originally described from Europe, however, the type specimens have been lost.

In the present study, all large, much branched *Ulva* specimens that were sequenced were identified as *Ulva compressa* suggesting that most specimens previously attributed to *U. clathrata* (including *U. ramulosa* and *U. acanthophora*) may have been misidentified. A specimen in the Auckland Museum herbarium collected by Lindauer and named *E. clathrata* var. *prostrata* did not show a cell arrangement in rows, suggesting that this specimen may be *Ulva compressa*, while cells in a second specimen also identified as *E. clathrata* var. *plumosa* were regularly arranged. However, there are other species recorded for New Zealand which also show ordered cell arrangements such as *Ulva ralfsii* or *Ulva procera*. AlgaeBase (Guiry 2006) lists some of the varieties described for *U. clathrata*, which are currently placed in these species.

**Reference:**

Linnaeus, C. (1753): *Species plantarum*. Vol. 2 pp. 561-1200 (+ 1-31). Stockholm.

Fig. 9: *Ulva compressa* Group 1



Fig. 10: *Ulva compressa* Group 1 continued



Fig. 11: *Ulva compressa* Group 2



Fig. 12: *Ulva compressa* Group 3



Fig. 13: *Ulva compressa* Group 4



Fig. 14: *Ulva compressa* Group 5



Fig. 15: *Ulva compressa*

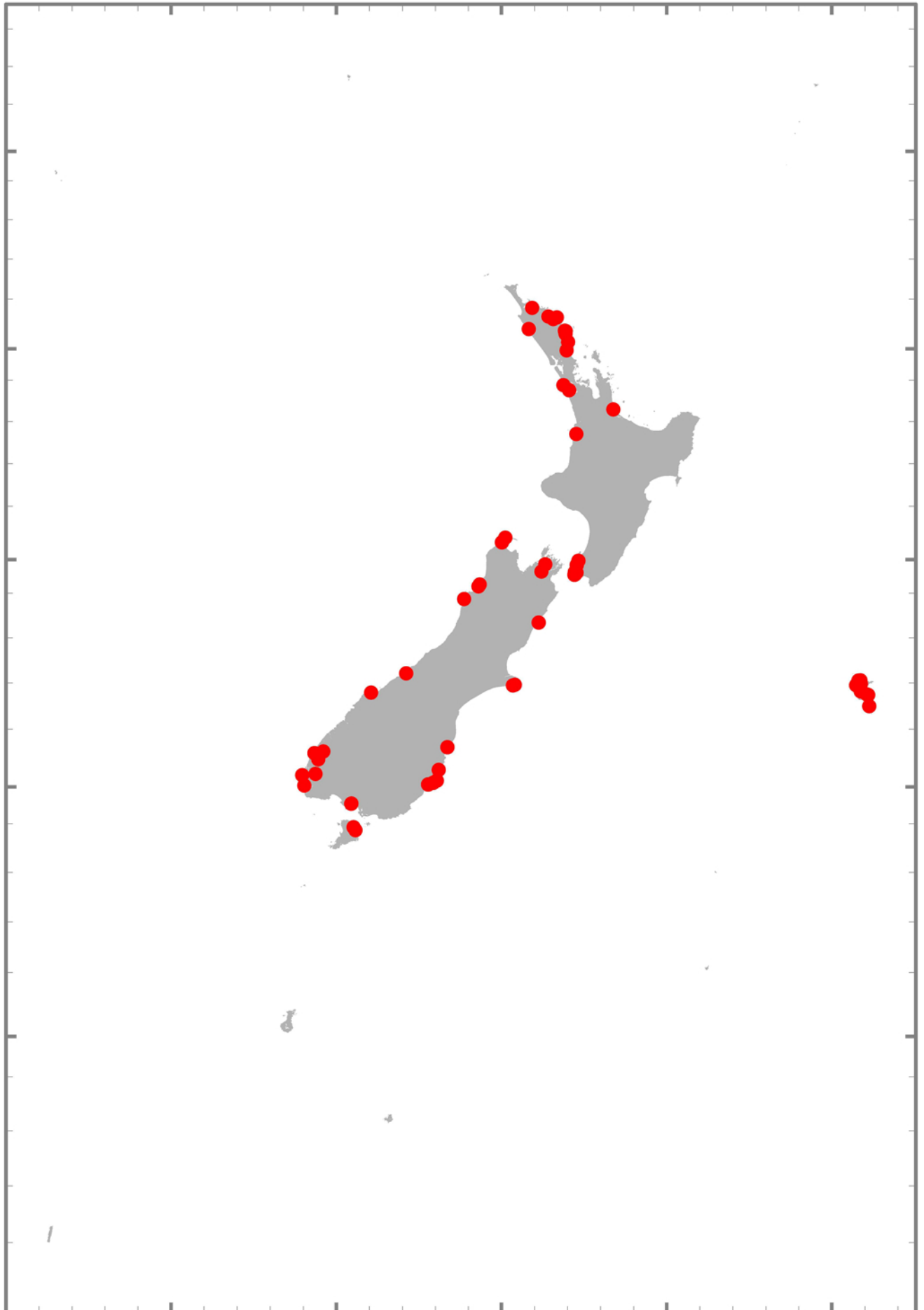
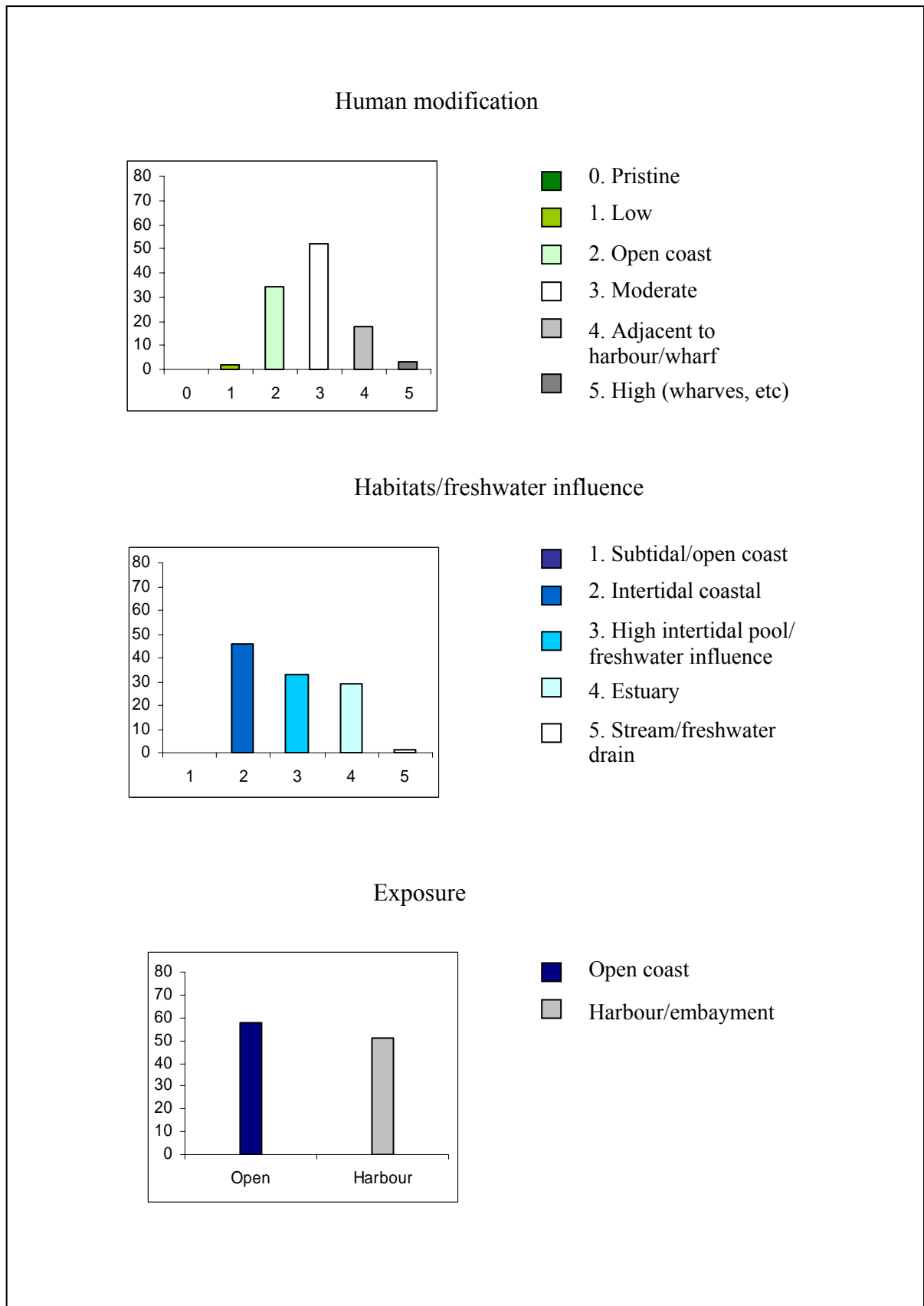


Fig. 16: *Ulva compressa*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



## ***Ulva fasciata* Delile**

Figs 17 - 19

Publication details: *Ulva fasciata* Delile 1813: 297, pl. 58: fig. 5

Type locality: Alexandria, Egypt

### SPECIES DESCRIPTION:

Thallus divided to basal region into 3 to many narrow, relatively flat laciniae; margin sometimes dentate. Cells in surface view polygonal or quadrangular in shape, arranged in no observable order. Cells in transverse section rectangular throughout the thallus. Chloroplast parietal on the outer face of the cell wall, covering half to the whole of the cell face in surface view. Pyrenoids 1-4. (after Phillips 1988)

### DESCRIPTION – NEW ZEALAND SPECIMENS:

The New Zealand specimens had small blades of grey-green colour when fresh, with a darker and comparatively stiff base. No specimens were fertile. The cells were triangular to rectangular, with round outlines, and in surface view 7-12 µm wide and 10-20 µm long.

### HABITAT:

All three samples were collected in similar habitats: subtidal (4-6 m depth) sites on open ocean coasts, subjected to little human influence. One specimen grew epiphytically on non-geniculate coralline on rock.

### DISTRIBUTION – NEW ZEALAND:

This species was found solely on the east coast of the northern North Island.

### DISTRIBUTION – OUTSIDE NEW ZEALAND:

Europe: Adriatic, France, Greece, Italy, Spain, Turkey; Atlantic Islands: Bermuda, Canary Islands, Cape Verde Islands, Madeira; North America: Florida, Georgia, North Carolina, South Carolina, Texas; Central America: Belize, Costa Rica; Caribbean Islands: Barbados, Caribbean, Cuba, Hispaniola, Jamaica, Lesser Antilles, Netherlands Antilles, Puerto Rico, Trinidad & Tobago, Virgin Islands; South America: Brazil, Colombia, Galápagos Islands, Uruguay, Venezuela; Africa: Algeria, Angola, Côte d'Ivoire, Egypt, Equatorial Guinea, Ghana, Guinea, Kenya, Liberia, Libya, Madagascar, Mauritania, Mauritius, Morocco, Namibia, São Tomé & Príncipe, Senegal, Somalia, South Africa, Tanzania, Western Sahara; Indian Ocean Islands: Andaman Islands, Laccadive Islands, Nicobar Islands, Réunion, Seychelles; South-west Asia: India, Levant states, Oman, Pakistan, Philippines, Sri Lanka, Yemen; Asia: China, Japan, Taiwan; South-east Asia: Indonesia, Singapore, Vietnam; Australia: New South Wales, Queensland, South Australia, Norfolk Island, Papua New Guinea; Pacific Islands: Hawaiian Islands (Guiry 2006)

REFERENCE SPECIMENS: WELT A027517, A027518, A027522

### COMMENTS:

Originally described from the Mediterranean, *Ulva fasciata* is a cosmopolitan species, found in the Atlantic, Indian and Pacific Oceans. In the Pacific it has been recorded from most Asian coasts. It also occurs in Australia and Mexico, where it is considered an introduced species, based on the occurrence of isolated populations close to harbours and sheltered anchorages (Phillips 1988; Aguilar-Rosas *et al.* 2005). Its status in Hawaii appears controversial, with some sources listing it as introduced (Phillips 1988; Aguilar-Rosas *et al.* 2005), while others consider it a native species (Anon. 2001). It nevertheless forms blooms fouling on ship hulls, wharf structures and shorelines, and is thus classified as invasive (Anon. 2001).

*Ulva fasciata* is known mostly from subtropical and tropical regions (Phillips 1988; Womersley 1994), throwing doubt on the attribution by Chapman (1956) of specimens from southern New Zealand (Karihana Bay, Warrington, Dusky Sound) and Chatham Island to this species. In the present study, *U. fasciata* was only encountered in subtidal sites in the northeastern North Island. Subtidal collections were limited during this study, therefore this species could be more wide-spread, however it is expected to be limited to the warm waters of the far north.

*Ulva fasciata* has a very distinct habit, with the frond being deeply divided into flat, unruffled segments. However, atypical plants with thick short fronds may be confused with *U. rigida* (Phillips 1988) as both species have similar rectangular cells in transverse sections in the basal region. The three specimens found during this study were all relatively small, without the typical divided frond, and thus could be immature or atypical possibly due to an unfavourable environment.

The *rbcL* sequences of the three New Zealand specimens were virtually identical to sequences from Japan, Australia and Hawaii. However, GenBank sequences are so far not available for material from the type locality in the Mediterranean Sea, thus a confirmation of the name *U. fasciata* for Pacific specimens is pending.

**Reference:**

Delile, A.R. (1813). Flore d'Égypte. In: *Description de l'Égypte....Histoire naturelle.* (Eds) Vol.2, pp. 145-320. Paris.

Fig. 17: *Ulva fasciata*



Fig. 18: *Ulva fasciata*

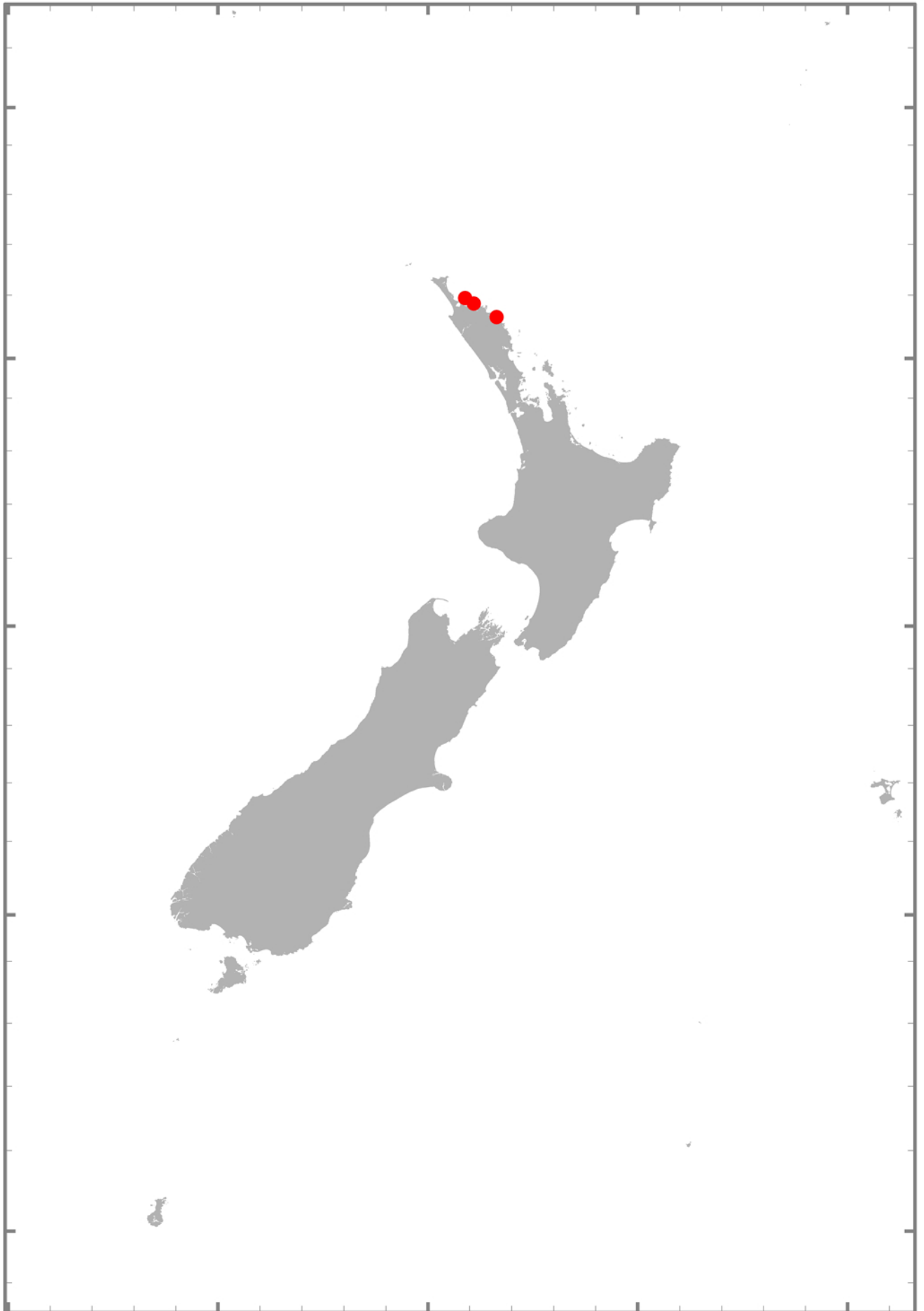
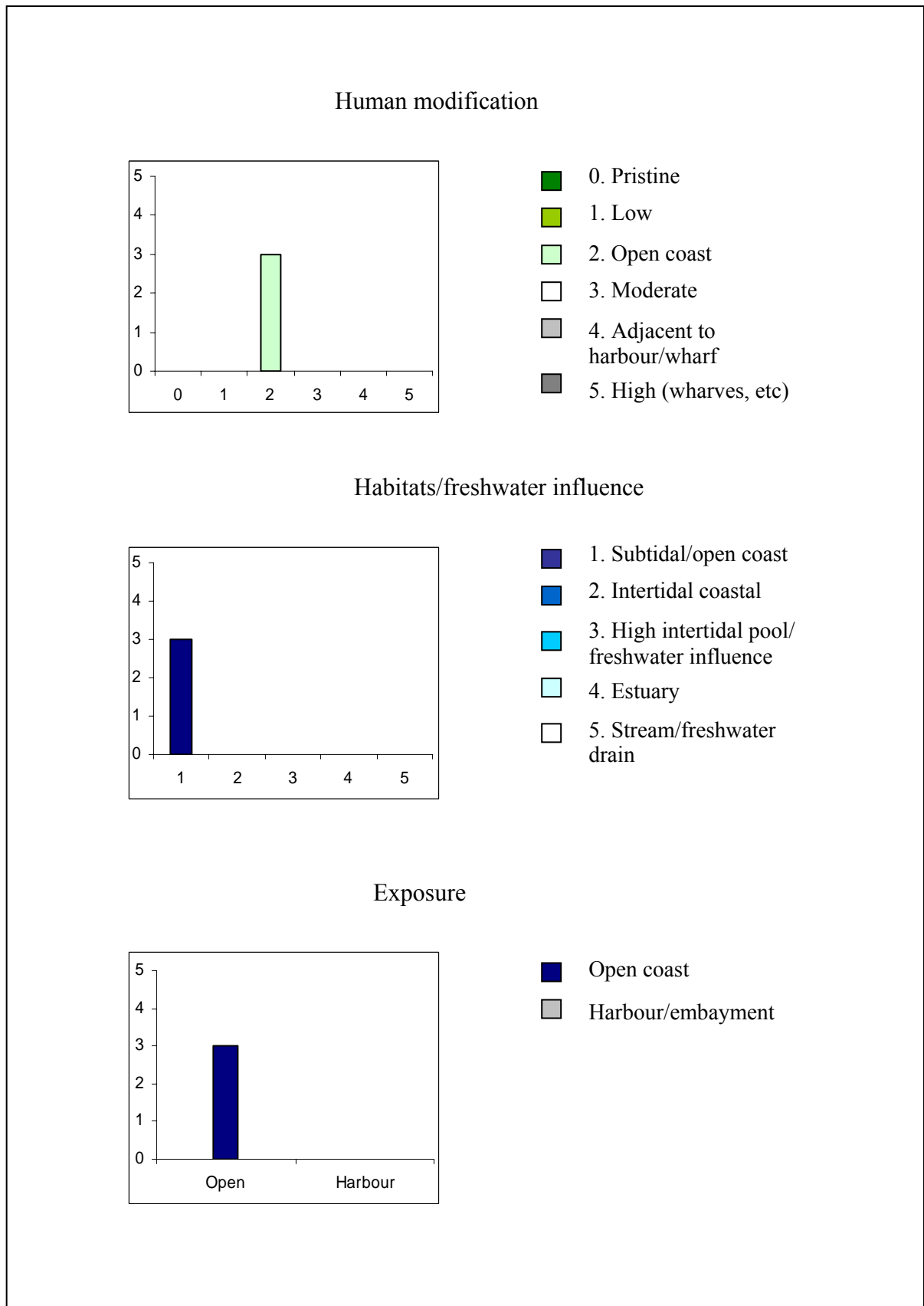


Fig. 19: *Ulva fasciata*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva flexuosa* Wulfen**

Figs 20 - 22

Publication details: *Ulva flexuosa* Wulfen 1803: 1

Type locality: Duino (near Trieste), Adriatic Sea

SPECIES DESCRIPTION:

Thallus medium green, erect but flaccid, proliferous from near the base, 3-6 cm high and 2-8 mm broad. Cells in longitudinal rows throughout most of the thallus and in many parts also in transverse rows, angular and square to rectangular, (10) 14-18 µm long and 8-12 µm broad; chloroplast parietal, usually with 2-3 pyrenoids per cell. (Womersley 1984)

DESCRIPTION – NEW ZEALAND SPECIMENS:

The thalli of this species were comprised of inflated tubes with stipes. Specimens displayed few branches, mainly from the region of the stipe. In surface view, cells were arranged in the longitudinal and transverse rows typical of this species. Cells contained more than 2 pyrenoids, and were 6-13 µm wide and 10-24 µm long. Tubes reached 28-125 mm length and 4-6 mm width.

HABITAT:

A single sample of this species was collected from a pontoon in a sheltered harbour.

DISTRIBUTION – NEW ZEALAND:

This species was only found in Waikawa Bay, Picton in the northern South Island.

DISTRIBUTION – OUTSIDE NEW ZEALAND:

Europe: Spain; Atlantic Islands: Ascension, Canary Islands, Cape Verde Islands, Madeira, Salvage Islands; Caribbean Islands: Cuba, Trinidad & Tobago; Africa: Angola, Cameroon, Côte d'Ivoire, Equatorial Guinea, Gabon, Gambia, Ghana, Liberia, Mauritania, Namibia, Nigeria, São Tomé & Príncipe, Senegal, Sierra Leone Togo; Pacific Islands: American Samoa (Guiry 2006); Asia: Japan (Yoshida et al. 2000)

REFERENCE SPECIMEN: WELT A027320

COMMENTS:

The presence of a single sample from a marina suggests this species may have been introduced to New Zealand. Whether *Enteromorpha prolifera* var. *flexuosa* Wulfen, which Chapman (1956) reported from several sites in the North and South Islands, constitutes a synonym of *U. flexuosa* Wulfen needs to be further investigated.

Adams (1994) records *Ulva flexuosa* from both the North and South Island, commenting on specimens growing in tidepools, "often epiphytic on low coralline turf" (p. 28). These records may have been confused with specimens of *Ulva* 'species 2', which were often found in tide pools as epiphytes on coralline algae, and which showed a similar pattern of cell arrangement in longitudinal and transverse rows.

**Reference:**

Wulfen, F.X. (1803). *Crytogama aquatica*. *Archiv für die Botanik* 3:1-64, pl. 1

Fig. 20: *Ulva flexuosa*



Fig. 21: *Ulva flexuosa*

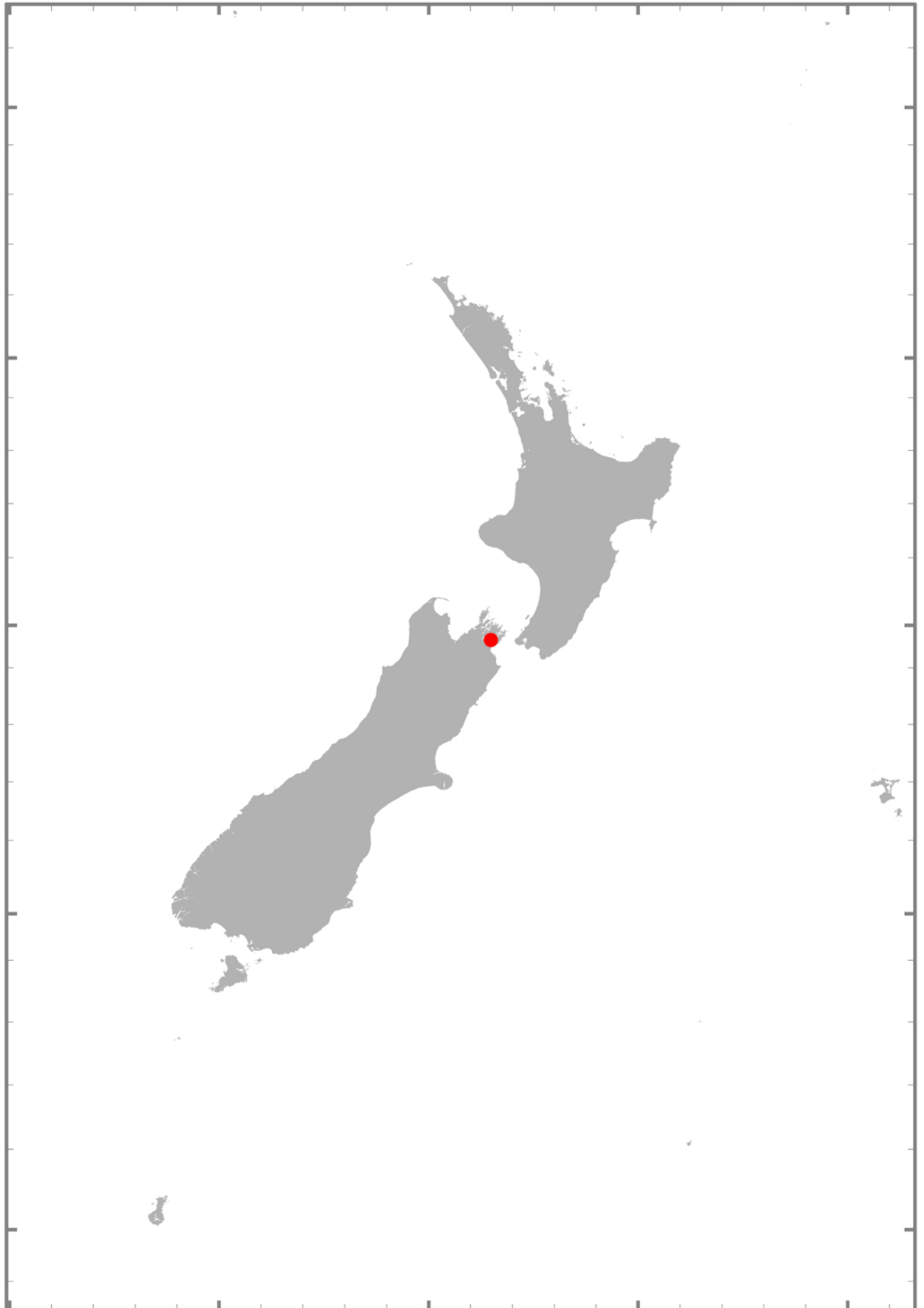
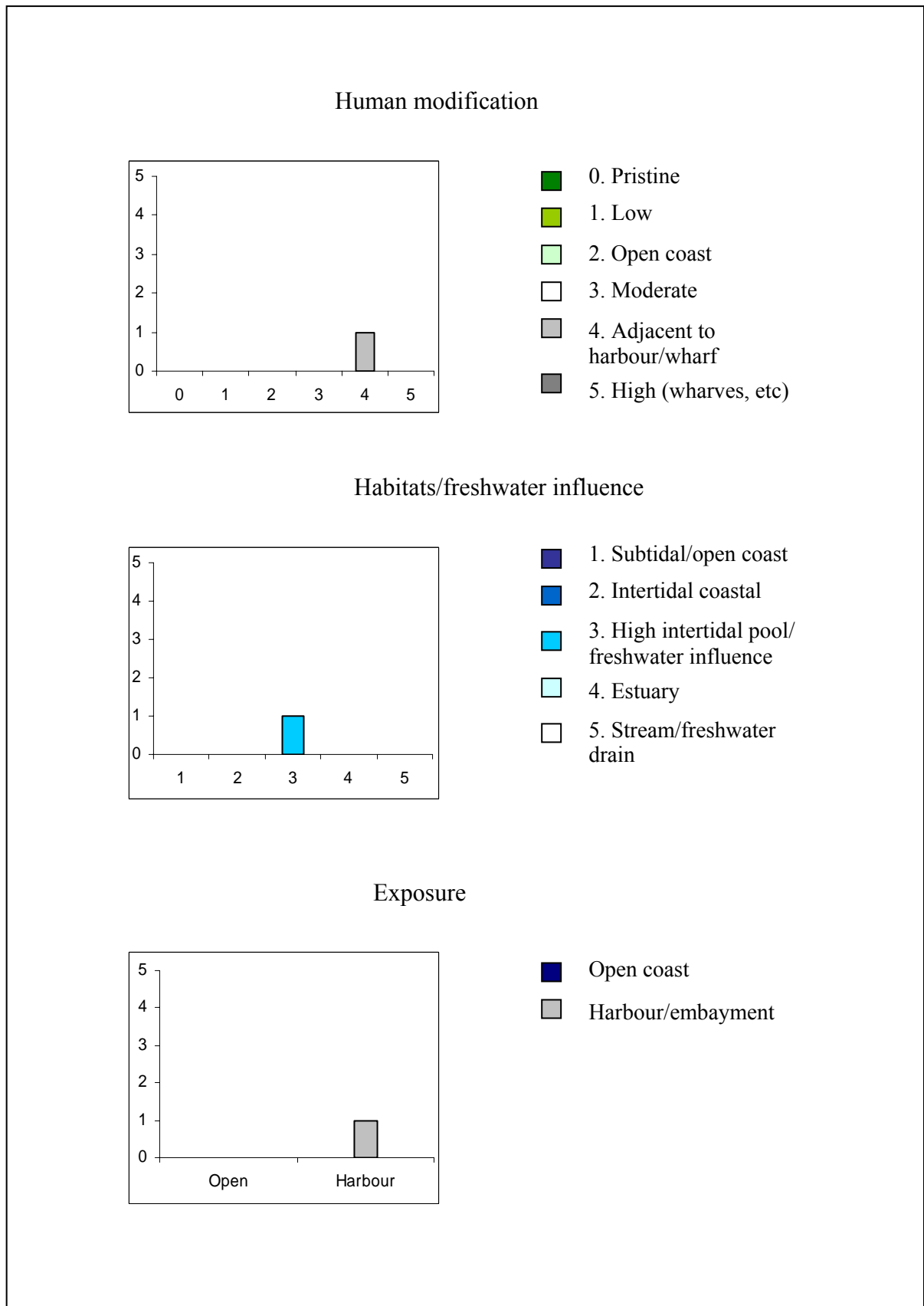


Fig. 22: *Ulva flexuosa*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva intestinalis* L.**

Figs 23 - 26

Publication details: *Ulva intestinalis* Linnaeus 1753: 1163

Type locality: "*Habitat in Mari omni*"; [probably Woolwich, England (acc. Hayden *et al.* 2003)]

SPECIES DESCRIPTION:

"*ULVA tubulosa simplex*" (Linnaeus 1753)

DESCRIPTION – NEW ZEALAND SPECIMENS:

Specimens from New Zealand formed long, unbranched, crinkled or smooth ribbons or tubes, which were sometimes convoluted or slightly inflated, varying in size up to 320 mm length and 1-10 mm width. Some tubes were comparatively wide, while others appeared thread-like, similar to *Ulva* species 5 "*U. ralfsii*". Small tubes sometimes grew in clumps forming fine carpets or turf, while others were stunted to small triangles or frilly balls with short stipes. Colours of fresh thalli ranged from yellow-green or bright green, sometimes with a darker base, to dark green. Thalli were often fertile with the upper parts of tubes becoming transparent after the release of spores. In some thin tubes, cells were arranged in rows, while wider tubes did not show any particular cell arrangement. Cells were relatively round, and reached 6-11 µm width and 7-14 µm length.

HABITAT:

*U. intestinalis* grew on hard substrates in all zones of the intertidal but was not found in the subtidal. Seventeen percent of the samples occurred in freshwater streams or run-offs and even underneath sewage outlets, indicating tolerance of this species to freshwater and highly nutrient enriched water. *U. intestinalis* was encountered in sheltered harbours and embankments as well as on open coasts. Most specimens were collected from sites with little or moderate human influence, while 10% of the samples grew in areas adjacent to harbours and wharf installations.

DISTRIBUTION – NEW ZEALAND:

*Ulva intestinalis* was found on the North Island and South Island as well as on Chatham Island. It was however, absent from the Kermadecs, Stewart Island and the subantarctic islands.

DISTRIBUTION – OUTSIDE NEW ZEALAND:

Europe: Balearic Islands, Britain, Ireland, Portugal, Spain; Atlantic Islands: Ascension, Cape Verde Islands, Madeira, Salvage Islands; Africa: Ghana, Guinea-Bissau, Namibia, South Africa; Pacific Islands: American Samoa (Guiry 2006)

REFERENCE SPECIMENS: WELT A027329, A027330, A027331, A027332, A027335, A027336, A027337, A027338, A027340, A027522

COMMENTS:

*U. intestinalis* was originally described from Europe. It is found in the eastern North and South Atlantic, but has also been recorded from the South Pacific, i.e., Samoa, Australia and New Zealand (Guiry 2006; Womersley 1984; Chapman 1956). It is an important fouling organism (Fletcher 1980, cited in Blomster *et al.* 1998), and as such may be dispersed via ships. The wide geographic distribution of *U. intestinalis* in New Zealand including its presence in areas with little human influence suggests that this species is native to New Zealand or at least was naturalised some time ago.

Chapman (1956) listed four forms of *U. intestinalis*, three of which he distinguished on environmental requirements (i.e. exposed coasts, brackish water, fresh-water influence). The 60 samples of *Ulva intestinalis* collected in the present study appeared to belong to two groups with slightly different *rbcL* sequences, which however, were not separable based on morphology - tubes in both groups displayed a range of various sizes and shapes. Likewise, there was no obvious pattern regarding the influence of exposure and salinity on the placement in phylogenetic trees. Salinity is known to influence the morphology of *U. intestinalis*, i.e., low salinity or a rapid change of salinity can induce the formation of branches resembling the morphology of *U. compressa* (Blomster *et al.* 1998). Moreover, bloom-forming specimens of *U. intestinalis* have been reported to reproduce clonally by fragmentation resulting in atypical, monostromatic sheets (Blomster *et al.* 2002). Studies on more variable genes may be able to assist in distinguishing between environmentally influenced forms and forms that are genetically distinct subspecies.

**Reference:**

Linnaeus, C. (1753): *Species plantarum*. Vol. 2 pp. 561-1200 (+ 1-31). Stockholm.

Fig. 23: *Ulva intestinalis*

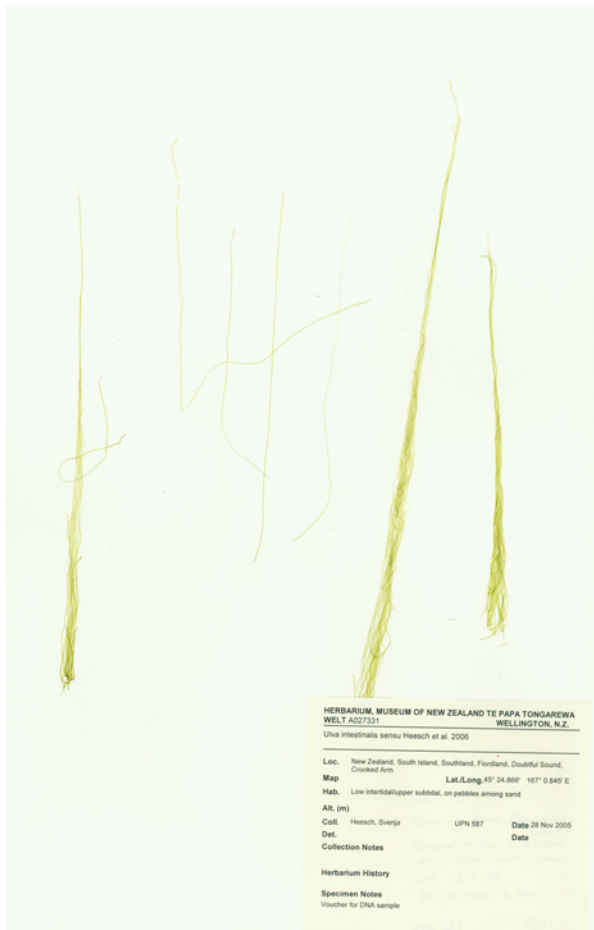


Fig. 24: *Ulva intestinalis* continued



Fig. 25: *Ulva intestinalis*

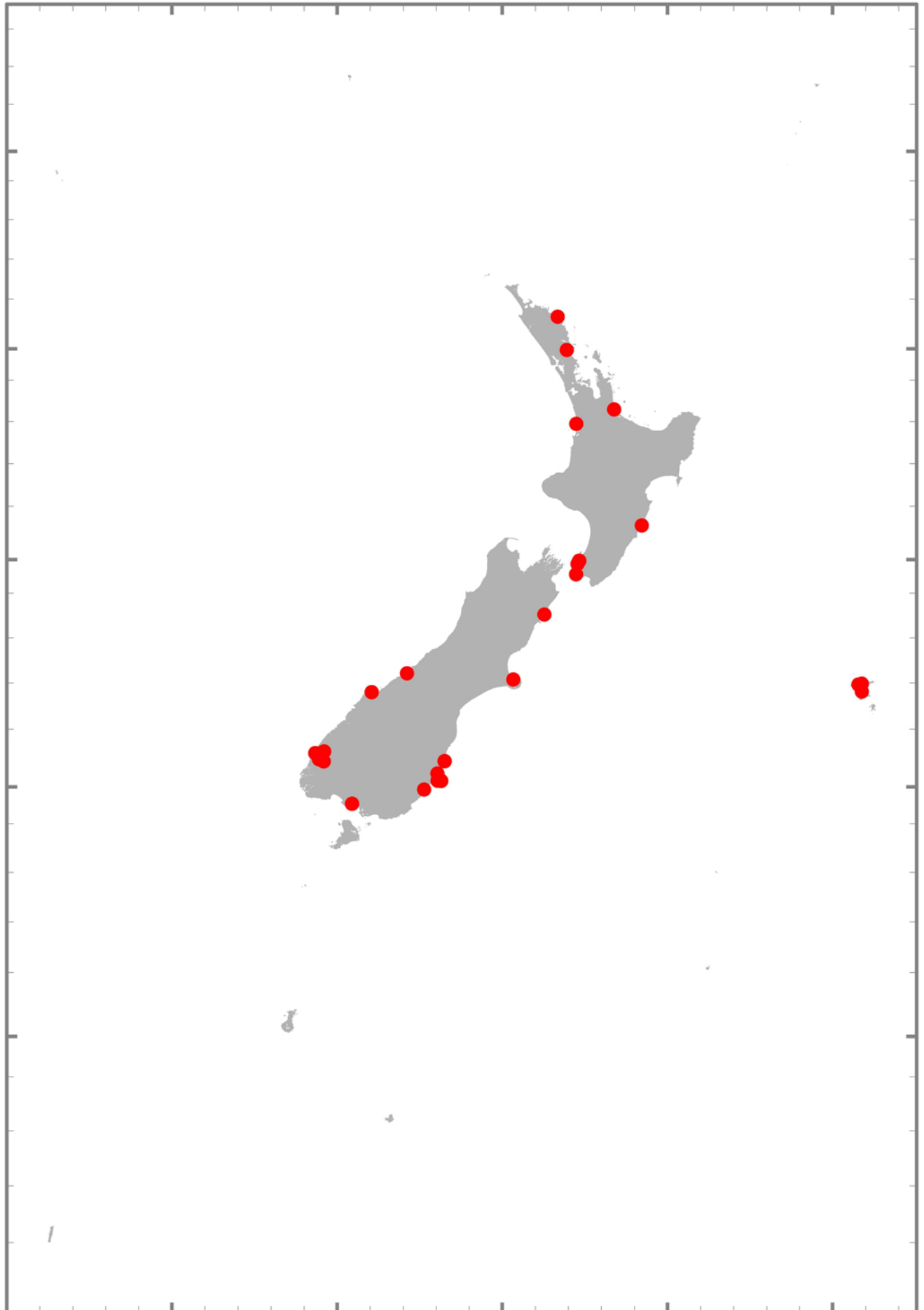
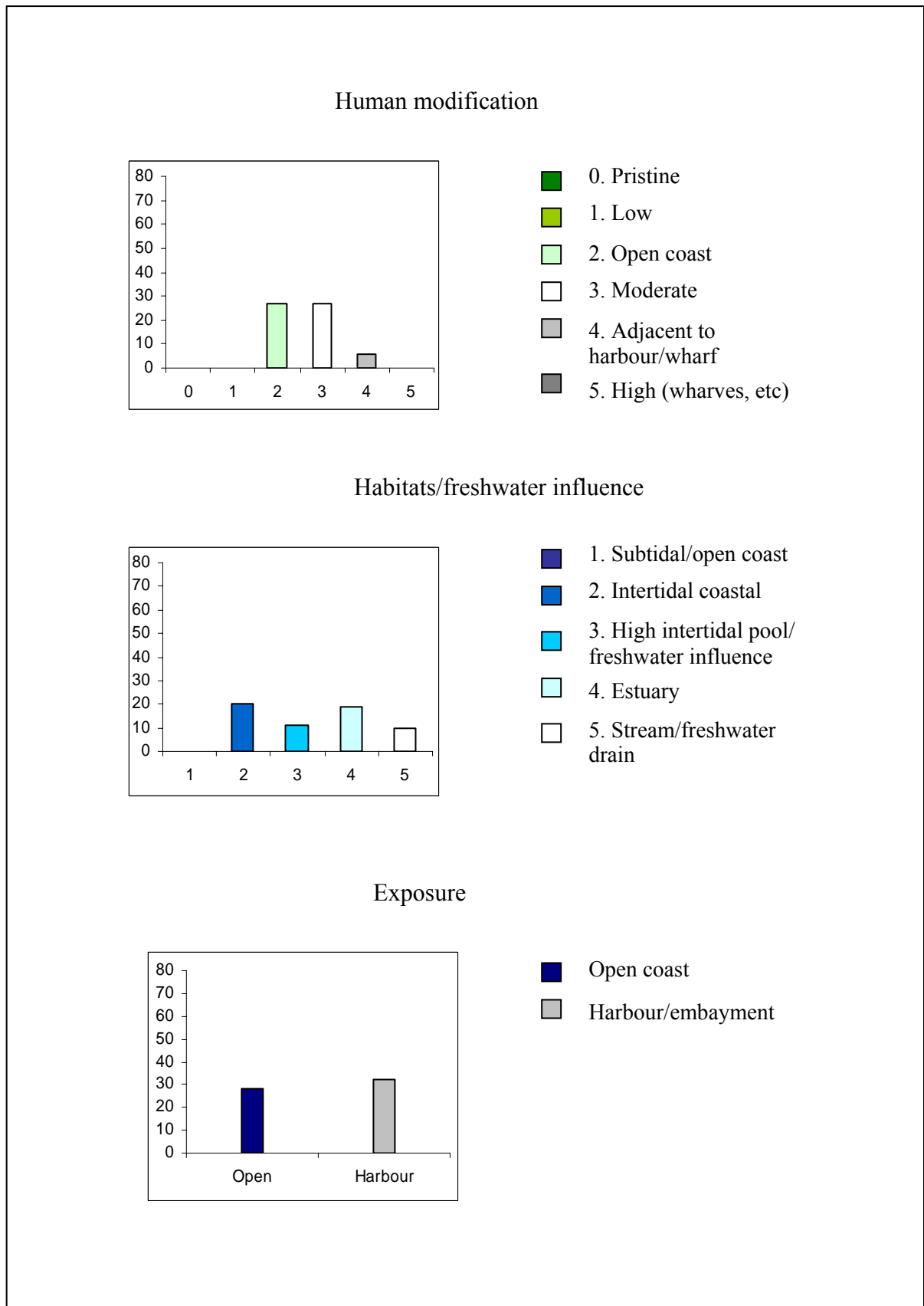


Fig. 26: *Ulva intestinalis*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva lactuca* L.**

Figs 27 - 29

Publication details: *Ulva lactuca* Linnaeus 1753: 1163.

Type locality: "*Habitat in Oceano*"; [probably west coast of Sweden (acc. Womersley 1984)]

SPECIES DESCRIPTION:

*"ULVA palmata prolifera membranacea: ramentis inserne angustatis"* (Linnaeus 1753).

DESCRIPTION – NEW ZEALAND SPECIMENS:

The thalli were composed of lobed, slightly ruffled ribbons or blades up to 280 mm long. In one specimen the blades formed a small rosette. The margin of specimen WELT A027322 was entire without teeth but was indented at the apical area. The base of this specimen was folded. Thalli were of dark or mid-to pale olive colours.

None of the samples was fertile. In basal cross sections of WELT A027322 cells were cylindrical. In surface view cells were polygonal and formed short curved rows. They contained 1-2 pyrenoids, and were 4-10 µm wide and 9-14 µm long.

HABITAT:

All three specimens were collected from high intertidal on harbour structures.

DISTRIBUTION- NEW ZEALAND:

All three specimens collected in New Zealand were from South Island - Lyttelton, Timaru and Bluff.

DISTRIBUTION – OUTSIDE NEW ZEALAND:

Arctic: Canada (Arctic); Europe: Adriatic, Baltic Sea, Britain, Corsica, Denmark, Faroes, France, Germany, Greece, Helgoland, Iceland, Ireland, Netherlands, Portugal, Spain, Spitsbergen, Sweden, Turkey; Atlantic Islands: Ascension, Azores, Bermuda, Cape Verde Islands, Gough Island, Madeira, Salvage Islands, St Helena, Tristan da Cunha; North America: Alaska, California, Florida, Gulf of California, Mississippi, Newfoundland, Quebec, Texas; Central America: Costa Rica, Islas Revillagigedo, Panama; Caribbean Islands: Alabama, Bahamas, Barbados, Caicos Islands, Caribbean, Cuba, Hispaniola, Jamaica, Lesser Antilles, Puerto Rico, Trinidad, Trinidad & Tobago; South America: Brazil, Chile, Colombia, Ecuador, Galápagos Islands, Peru, Uruguay, Venezuela; Africa: Algeria, Angola, Benin, Congo, Côte d'Ivoire, Egypt, Ethiopia, Gambia, Ghana, Guinea, Kenya, Liberia, Madagascar, Mauritania, Mauritius, Morocco, São Tomé & Príncipe, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Tunisia, Western Sahara; Indian Ocean Islands: Amsterdam Island, Andaman Islands, Christmas Island, Laccadive Islands, Maldives, Nicobar Islands, Réunion, Rodriguez Island, Seychelles; South-west Asia: Bahrain, Bangladesh, India, Iran, Iraq, Israel, Kuwait, Oman, Pakistan, Philippines, Sri Lanka, Yemen; Asia: China, Japan, Taiwan; South-east Asia: Indonesia, Malaysia, Singapore, Vietnam; Australia: Lord Howe Island, Norfolk Island, Queensland, South Australia, Victoria; Pacific Islands:

Easter Island, Federated States of Micronesia, Fiji, French Polynesia; Antarctic and the subantarctic islands: South Shetland Islands (Guiry 2006)

REFERENCE SPECIMENS: WELT A027322, A027323, A027324

COMMENTS:

Even though the name *Ulva lactuca* has been widely used in New Zealand for sheet-like thalli, only three specimens had *rbcL* sequences which were nearly identical to *U. lactuca* sequences from Ireland and from the north Pacific. Moreover, all three specimens were from harbours suggesting that this name has been incorrectly applied in New Zealand, and that "real" *Ulva lactuca* may in fact be an introduced species in New Zealand.

**Reference:**

Linnaeus, C. (1753): *Species plantarum*. Vol. 2 pp. 561-1200 (+ 1-31). Stockholm.

Fig. 27: *Ulva lactuca*



Fig. 28: *Ulva lactuca*

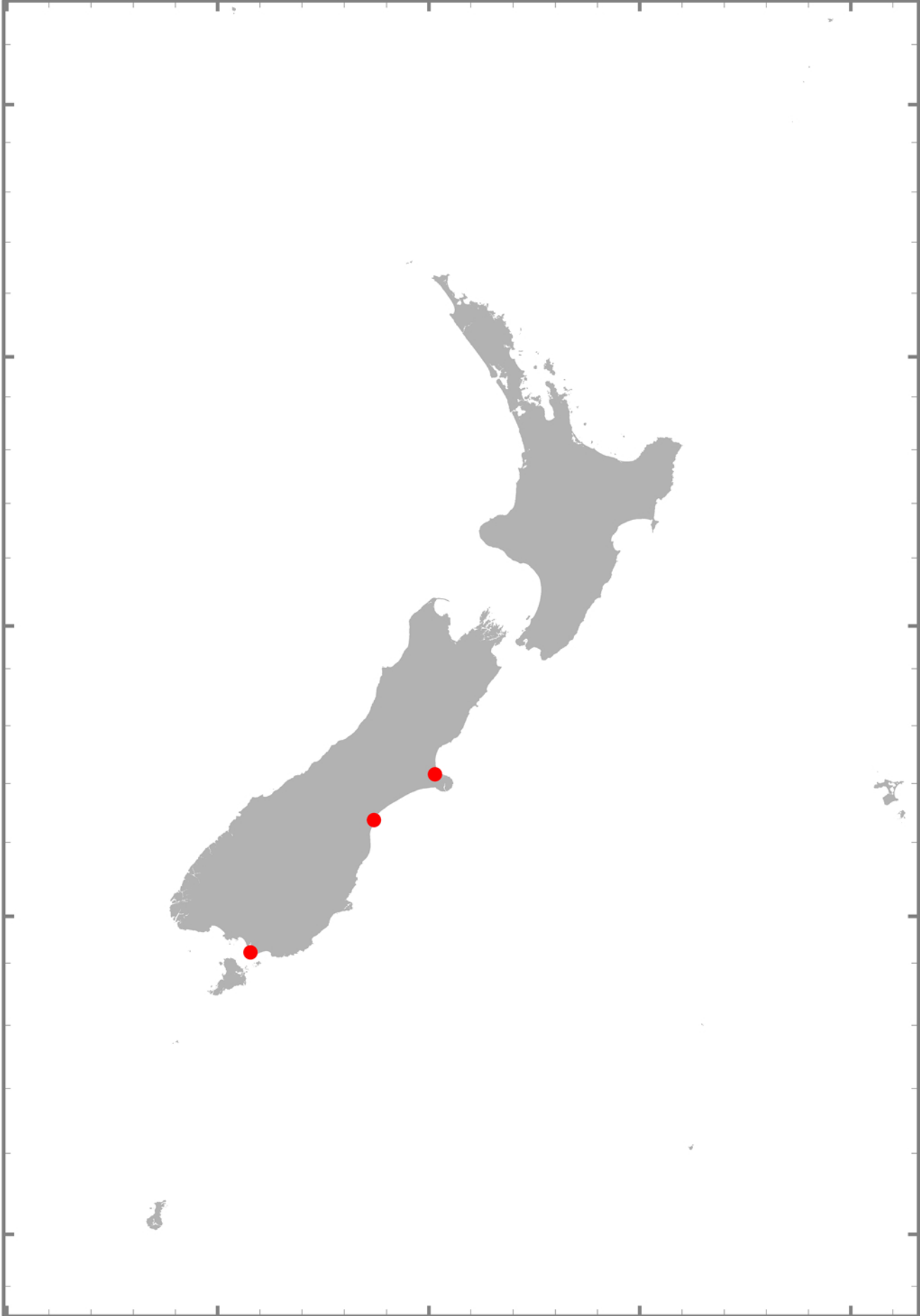
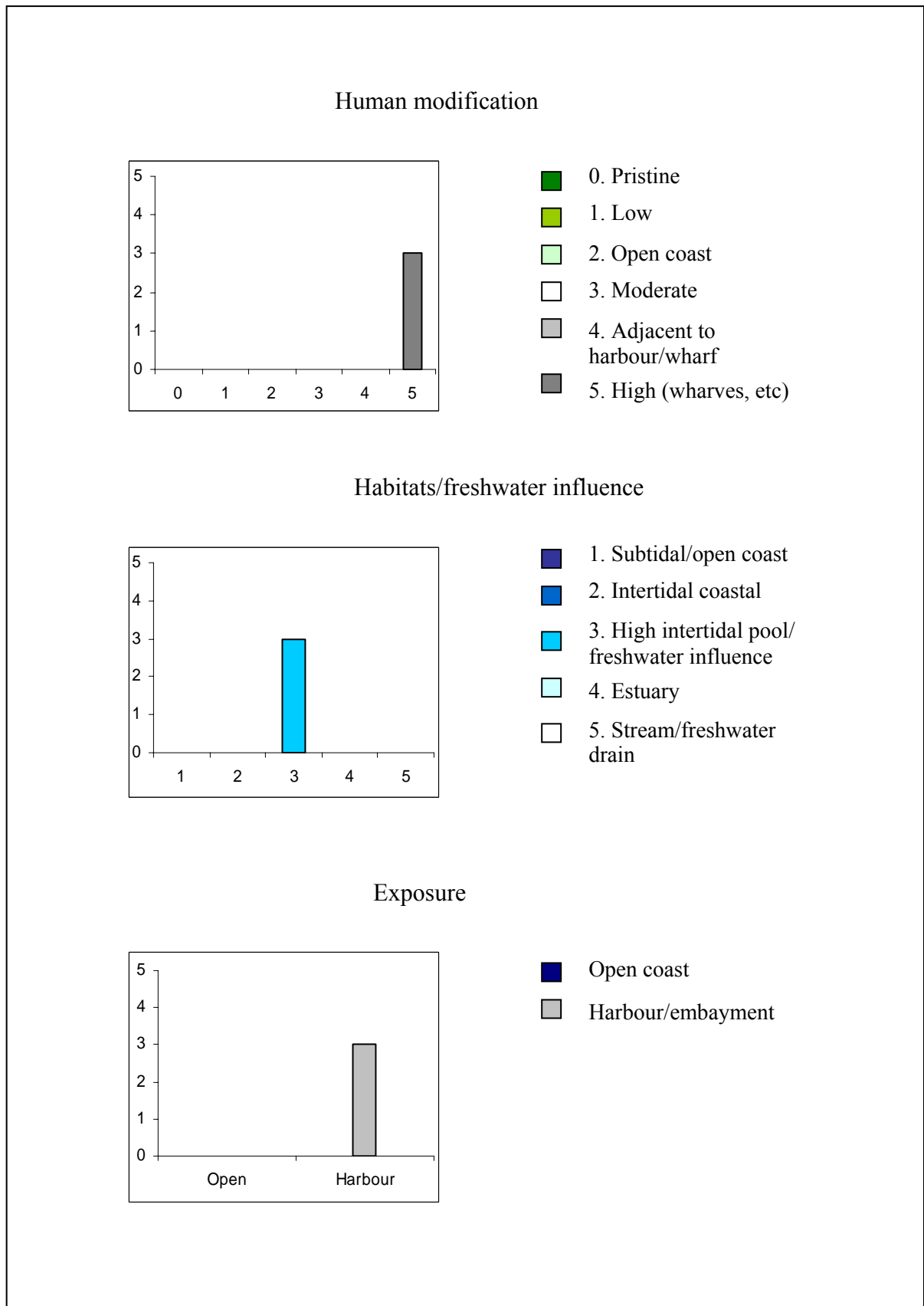


Fig. 29: *Ulva lactuca*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva linza* L.**

Figs 30 - 32

Publication details: *Ulva linza* Linnaeus 1753: 1163

Type locality: "*Habitat in oceano*"; [probably Sherness, England (acc. Hayden *et al.* 2003)]

SPECIES DESCRIPTION:

"*ULVA fronde oblonga bullata*" (Linnaeus 1753)

DESCRIPTION – NEW ZEALAND SPECIMENS:

The thalli from Chatham Island were tubular, with comparatively long stipes, which could be coiled. These specimens were hollow at the margins in cross sectional view. Cells in surface view were rectangular and comparatively large, with lengths of 20-58 µm and widths of 11-35 µm. The Stewart Island specimen had a very silky texture.

DISTRIBUTION – NEW ZEALAND:

Two samples were collected in New Zealand, one each from Owenga on Chatham Island and from Stewart Island.

DISTRIBUTION – OUTSIDE NEW ZEALAND:

Europe: Britain, Spain; Atlantic Islands: Canary Islands, Salvage Islands; Caribbean Islands: Cuba; Africa: Angola, Gabon, Ghana, Namibia; Asia: China (Guiry 2006)

HABITAT:

The samples were collected from very different habitats. The specimen from Stewart Island was growing on a bivalve shell in 7 m depth in a sheltered bay, while the thalli from Chatham Island were found as epiphytes on a drifting brown alga in an open coast site. Human influence was little to moderate at these sites.

REFERENCE SPECIMEN: WELT A027283

COMMENTS:

Originally described from Europe, *Ulva linza* is found in the Atlantic Ocean and China. In combination with its limited distribution in New Zealand this could give the impression that this species may have been introduced. However, Chapman (1956), even though he records *U. linza* from a number of places in New Zealand, comments on other entities being misidentified under this name and considers it to be uncommon in New Zealand.

The only GenBank sequence available is not based on material from the type locality or even the Atlantic but from California meaning that the New Zealand specimens are related to an entity from California which may not necessarily be *U. linza*.

One of the characters of *U. linza* distinguishing it from other sheet-like bistromatic species such as *U. lactuca* is a thallus with hollow margins, which was observed in the

New Zealand Chatham Island specimens. This feature and the comparatively large cells, distinguish *U. linza* from all other entities found in New Zealand.

**Reference:**

Linnaeus, C. (1753): *Species plantarum*. Vol. 2 pp. 561-1200 (+ 1-31). Stockholm.

Fig. 30: *Ulva linza*



Fig. 31: *Ulva linza*

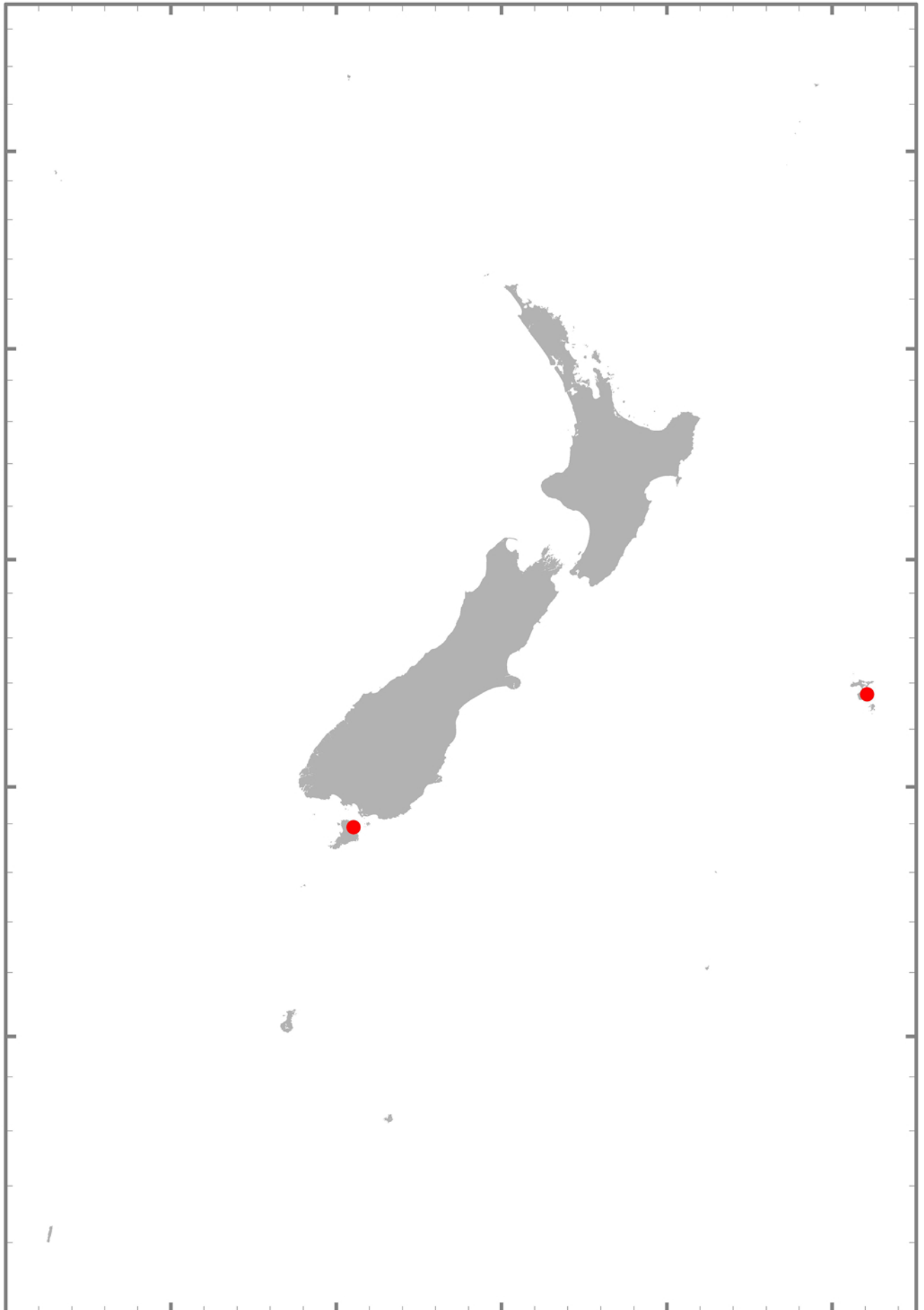
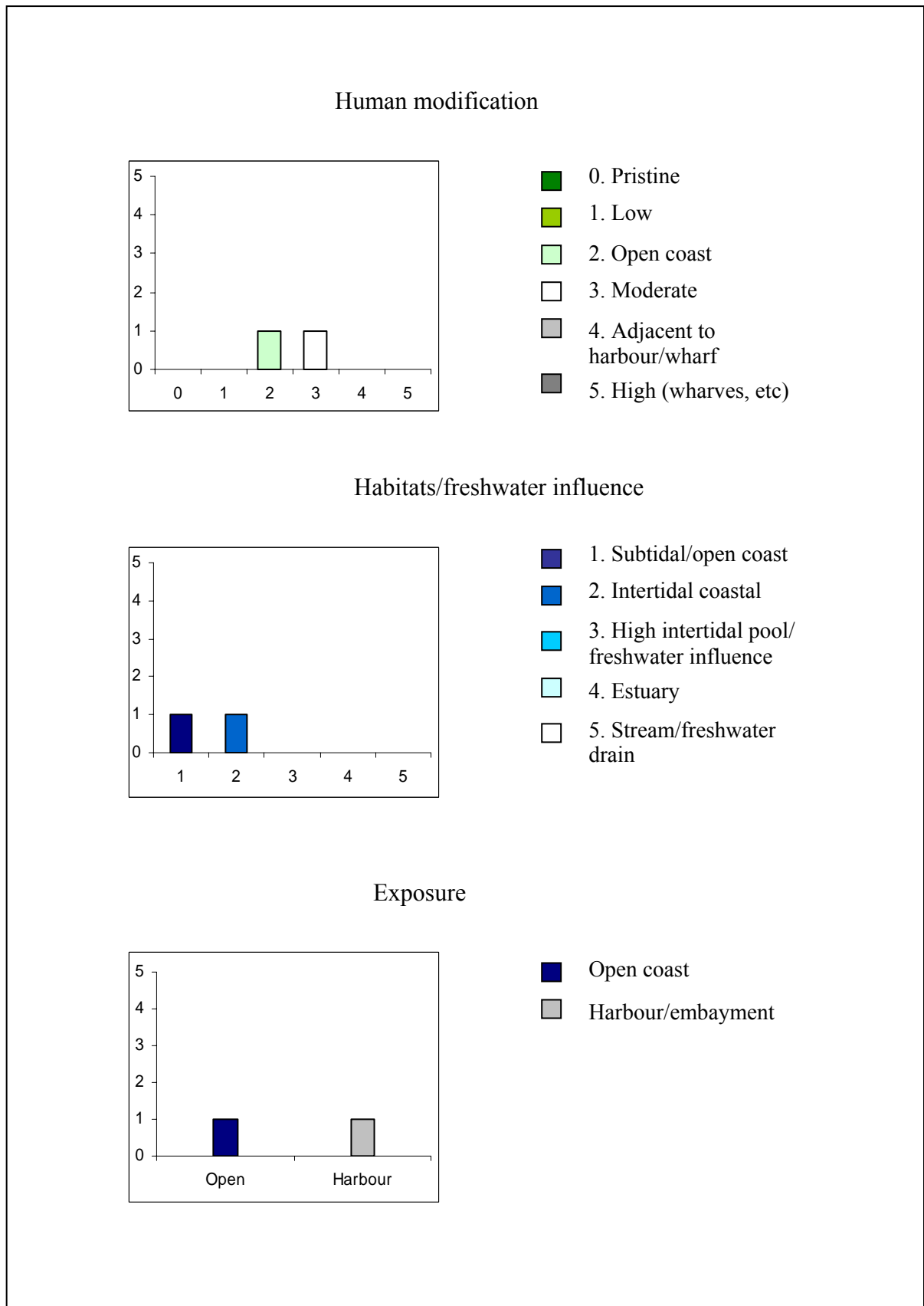


Fig. 32: *Ulva linza*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva pertusa* Kjellm.**

Figs 33 - 37

Publication details: *Ulva pertusa* Kjellman 1897: 4-7, pl. 1; pl. 3: figs. 1-8

Type locality: Japan: Hakodate, Enoshima, Yokohama (cited in description)

SPECIES DESCRIPTION:

Thalli 15-20 cm high, almost equally wide than high; usually attached but often also found drifting; holdfast comparatively thin, not very different from *U. rigida*; shoot with wide lobes of different lengths; at least 125 µm thick in the lower part and about 40 µm thick in the marginal region; perforated by many roundish or irregularly shaped holes; in detached specimens development of more holes leading to lacerate appearance. Cells in basal region regularly prismatic, 2 times as high as wide, with round corners; in the margins cells shorter, sometimes wider than high, with sharp corners. (Kjellman cited in Kamiya *et al.* 1993, Kjellman translated by A. Zadissa)

DESCRIPTION – NEW ZEALAND SPECIMENS:

New Zealand specimens formed large rounded blades or ribbons, often with round holes. The base was usually stiff, which in combination with holes, contribute to the spatulate appearance of some thalli. Small specimens often formed rosettes.

Microscopic teeth were absent from the margins of almost all specimens examined. A single specimen from Sumner, Canterbury (WELT A027524) appeared to have a dentate margin. In transverse sections cells were rectangular with rounded tips throughout the thallus or were wider than tall (brick-like) near the apex. In surface view, cells were arranged in short rows that did not show any obvious patterns. Cells were round to rectangular with sizes ranging from 6-10 µm width and 10-15 µm length. Sporophytic tissue was observed in WELT A027313. Colour varied considerably in the herbarium specimens.

HABITAT:

*Ulva pertusa* occurred in open coast sites as well as harbours and embayments. It grew on rocks, bivalve shells, barnacles, but also occasionally as an epiphyte on Rhodophyta such as *Stictosiphonia* or coralline red algae. Most samples were collected in the intertidal, particularly in the high intertidal, including rock pools (43%). Additionally, there were nearly as many samples from subtidal sites (11%) as there were from estuaries (13%). A single specimen was found in a storm water outflow.

This species grew mostly in little modified (40%) to moderately influenced (29%) sites, but 20% were encountered in highly modified environments.

DISTRIBUTION – NEW ZEALAND:

*Ulva pertusa* occurred all around New Zealand, with exception of the Kermadec Islands and the subantarctic islands.

DISTRIBUTION – OUTSIDE NEW ZEALAND:

Europe: France; Africa: Kenya, Mauritius, Tanzania; South-west Asia: Philippines, Yemen; Asia: China, Japan, Korea, Taiwan; South-east Asia: Indonesia, Singapore (Guiry 2006)

REFERENCE SPECIMENS: WELT A027310, A027311, A027312, A027313, A027314, A027315, A027316, A027317, A027318, A027524, A027525, A027526, A027527

COMMENTS:

A total of 125 specimens were identified as *Ulva pertusa*, making this species one of the most common *Ulva* entities in New Zealand. Most samples had very similar *rbcL* sequences to *U. pertusa* from Japan, where this species was originally described. Nevertheless, *U. pertusa* appears to be native in New Zealand. This widespread species has been confused previously with another bladed species which has a similar macroscopic morphology, *Ulva rigida* C.Agardh. The most noticeable difference between these two species is the presence of microscopic teeth on the margins of *U. rigida* thalli, which are absent in *U. pertusa*.

An example of the common mis-identification of *U. pertusa* were large bladed *Ulva* from Doubtful Sound, which form a distinct band in the upper subtidal/lower intertidal throughout the fiord, and are usually referred to as *Ulva rigida* (C. Cornelisen, personal communication). However, in the present study, *U. rigida* was only found in Causet Cove at the fiord entrance, while most sheet-like thalli including all specimens from sites in the inner fiord were identified as *U. pertusa*.

Specimens in New Zealand with a spathulate morphology, previously identified as *Ulva spathulata* Papenfuss, clustered with *U. pertusa* in *rbcL* sequence comparisons. Although *U. spathulata* has a distinct morphology, it has been regarded as a synonym of *Ulva rigida* based on the studies of Phillips (1988) in southern Australia, where *U. rigida* is considered the most common species. Interestingly, Phillips noted that in contrast to European *U. rigida*, "marginal teeth have never been observed" in southern Australian material (p. 448). This suggests that these specimens (including *U. spathulata*) actually belong to *Ulva pertusa*.

Three specimens (WELT A027525, A027526, A027527) had slightly different *rbcL* sequences. All three were collected in harbours (Wellington and Tauranga). Whether these comprise a variety of *U. pertusa* originating from outside of New Zealand will require further investigation.

**Reference:**

Kjellman F.T. (1897). Marina chlorophyceer från Japan. *Bihang til Kongliga Svenska Vetenskaps-Akademiens Handlingar* 23 (Afd. III, 11). 44 pp., 7 figs., 7 pls.

Fig. 33: *Ulva pertusa*



Fig. 34: *Ulva pertusa* continued

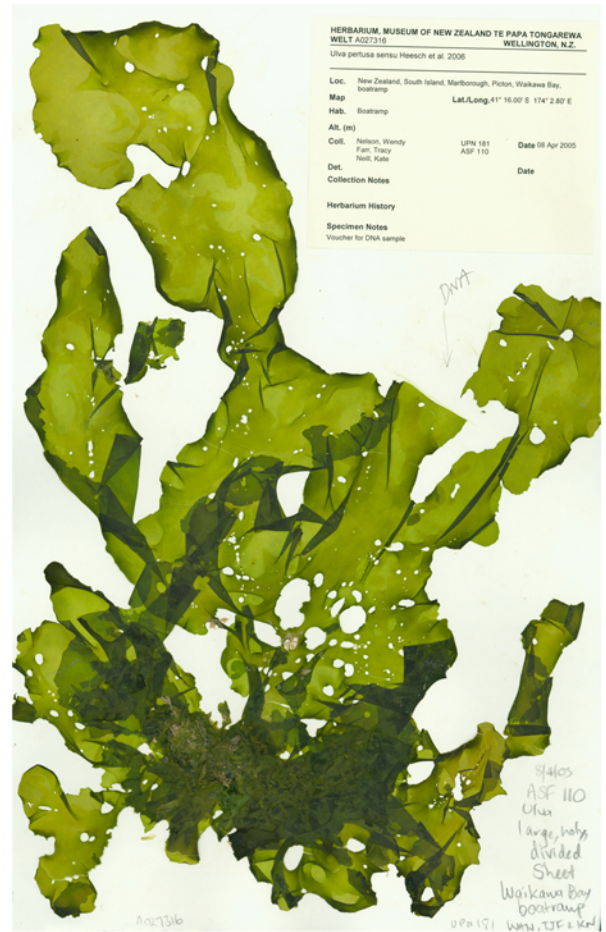


Fig. 35: *Ulva pertusa* continued

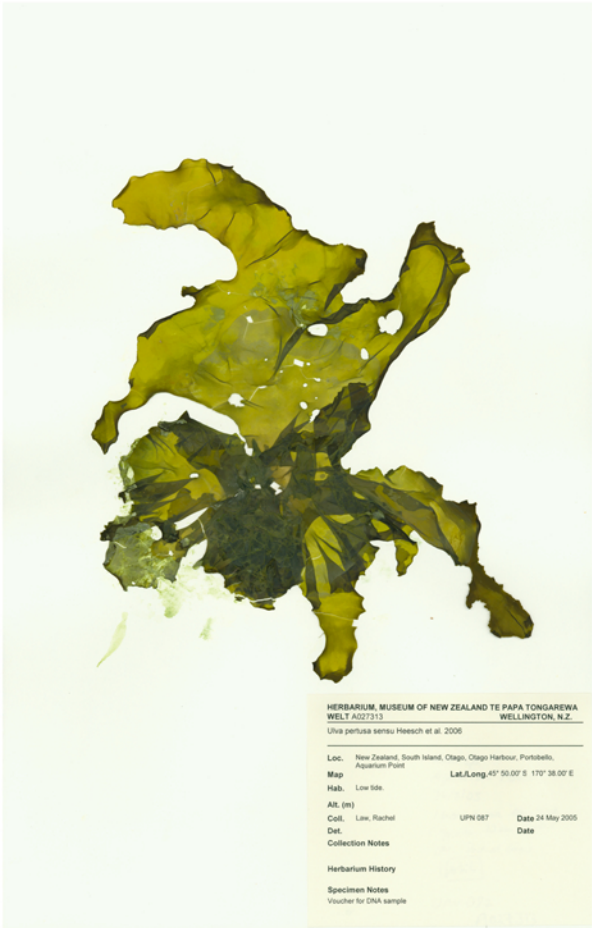


Fig. 36: *Ulva pertusa*

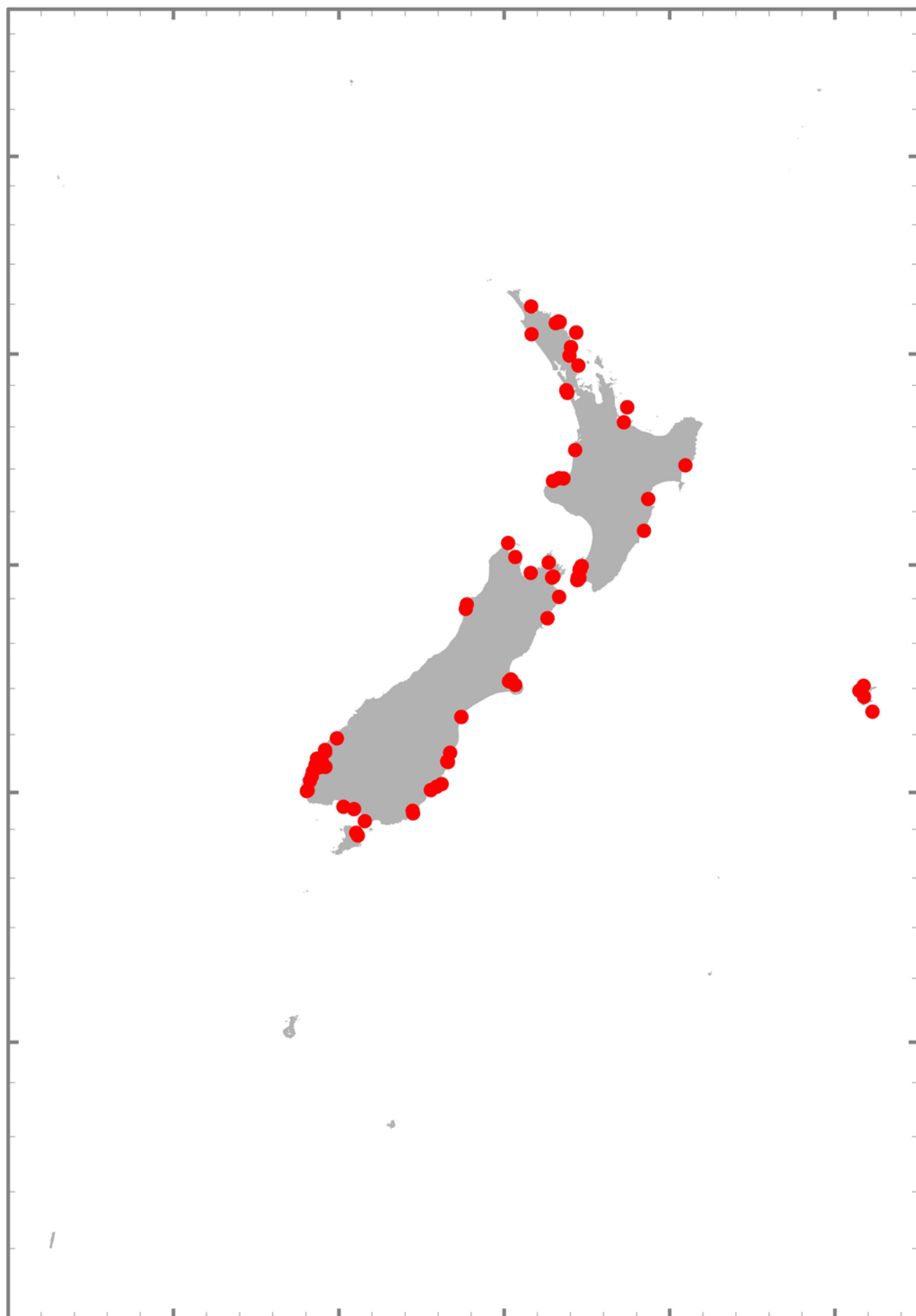
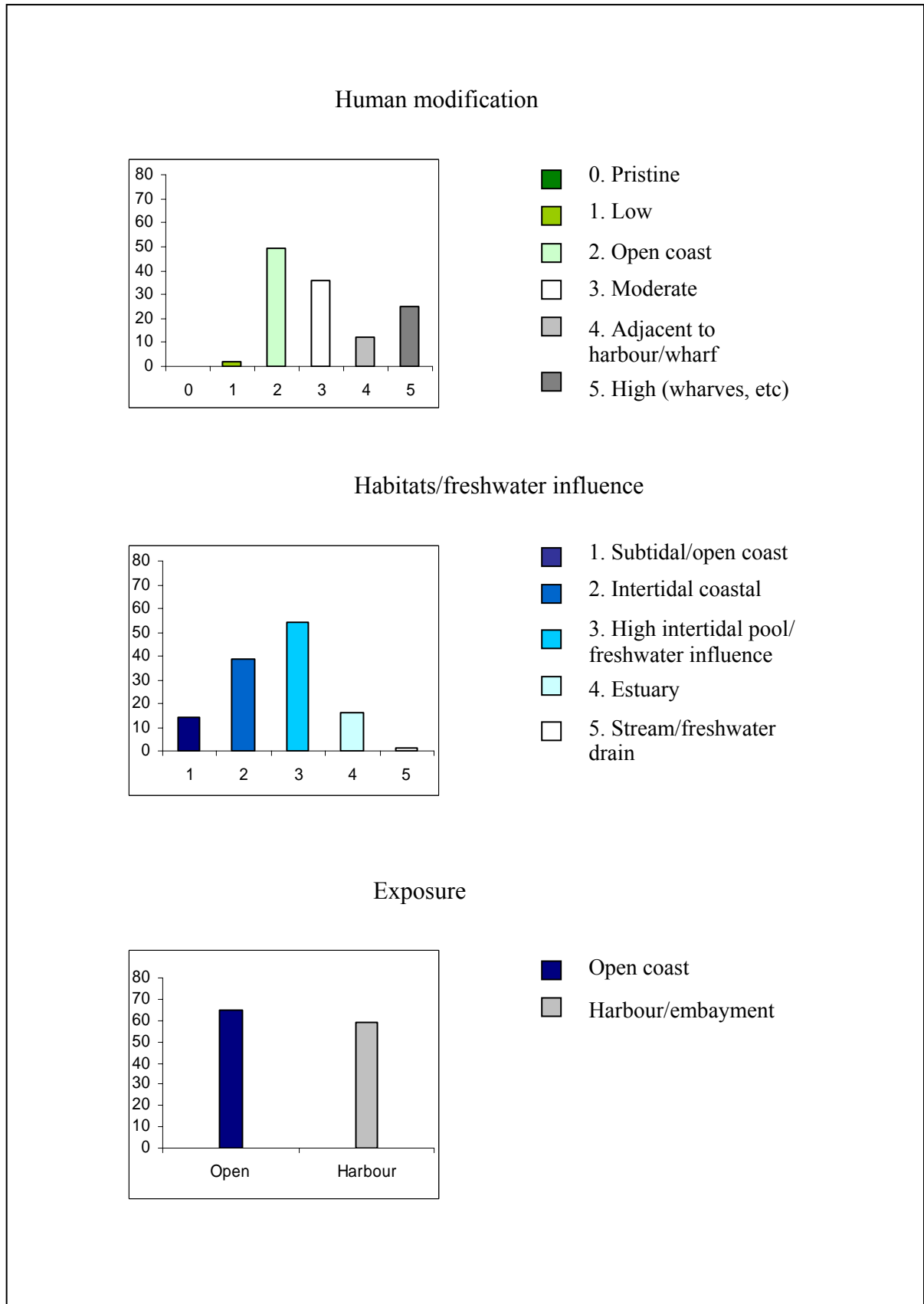


Fig. 37: *Ulva pertusa*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva procera* (K.Ahlner) H.S.Hayden, Blomster, Maggs, P.C.Silva, Stanhope & Waaland**

Figs 38 – 41

Publication details: *Ulva procera* (K.Ahlner) H.S.Hayden, Blomster, Maggs, P.C.Silva, Stanhope & Waaland 2003: 290

Basionym: *Enteromorpha procera* K.Ahlner

Type locality: Sweden

SPECIES DESCRIPTION:

Thallus up to 30 cm or longer, slim and slippery; colour in live specimens light or blue-green; often branched in mid region, branches tube or thread-like; branches many or sparse, usually simple, long and thin, equally wide, or towards the tip smaller, more or less clear tube-like; branches are either completely naked or towards the tip covered with many fine hair-like branches; cells in surface view with 4-6 corners, 16-24 µm in diameter, often without particular order; smaller branches 12-20 µm in diameter, with cells more or less in clear rows; plastids form a horizontal layer that usually covers the entire surface of the cell. (Ahlner 1877 translated by A. Zadissa)

DESCRIPTION – NEW ZEALAND SPECIMENS:

Specimens of *Ulva procera* displayed a variety of morphologies and these were separated into two groups:

1. thalli which were usually branched, very fine and *U. ralfsii*-like, up to 10-50 mm long and 1-2 mm wide
2. thalli with conspicuous tubular stipes expanding to ribbons with undulate margins. These were only occasionally branched and reached up to 225 mm length and 40 mm width but could also be stunted to small triangular shapes.

Thalli often grew in clumps and had a soft texture. Colours ranged from bright green to pale olive green. In surface view cells appeared polygonal, often quadrangular. Cells were 5-14 µm wide and 9-25 µm long. Cell arrangements were variable. Some specimens displayed cells in short rounded or transverse rows (e.g., WELT A027528, A027529), or even short vertical and longitudinal rows, giving a checkered appearance of cells in large groups (WELT A027530), while in others, cells were not arranged in an obvious pattern (WELT A027358). Fertile specimens shed spores from the upper part of the blade.

HABITAT:

*Ulva procera* occurred in sheltered harbours and embayments as well as along open ocean coasts. Half of the specimens were found in the coastal intertidal, the remaining were collected in similar proportions from high intertidal pools and estuaries. None were observed in the subtidal or in freshwater. *U. procera* grew mostly in sites which were moderately influenced by humans, and to a lesser degree in little modified sites, but also adjacent to harbours.

DISTRIBUTION – NEW ZEALAND:

This species was found on the North and the South Island, and Chatham Islands, but was absent from the subantarctic islands as well as Stewart Island.

DISTRIBUTION – OUTSIDE NEW ZEALAND:

Atlantic Islands: Madeira; Africa: Ghana (Guiry 2006)

REFERENCE SPECIMENS: WELT A027354, A027355, A027356, A027357, A027358, A027359, A027360, A027361, A027362, A027363, A027364, WELT A027528, A027529, A027530

COMMENTS:

*U. procera* thalli displayed two distinct morphologies. However, as in *U. compressa*, the morphological form was not always consistent with differences between *rbcL* sequences. The specimens clustering with a GenBank sequence of *U. procera* from Europe were almost always branched filamentous thalli, while the other group consisted mostly of unbranched tubes. Some specimens, though, displayed the stiped, ribbon-like morphology but belonged to the "in-group" of sequences most closely related to the European material.

**References:**

- Ahlner, K. (1877). Bidrag till kännedomen on de svenska formerna af algsläktet *Enteromorpha*. Akademisk afhandling, Uppsala, Sweden. 51 pp. [52 = expl. pl.], pl. [=9 figs.].
- Hayden, H.S., Blomster, J., Maggs, C.A., Silva, P.C., Stanhope, M.J., Waaland, J.R. (2003). Linnaeus was right all along: *Ulva* and *Enteromorpha* are not distinct genera. *European Journal of Phycology* 38: 277-294.

Fig. 38: *Ulva procera* Group 1



Fig. 39: *Ulva procera* Group 2

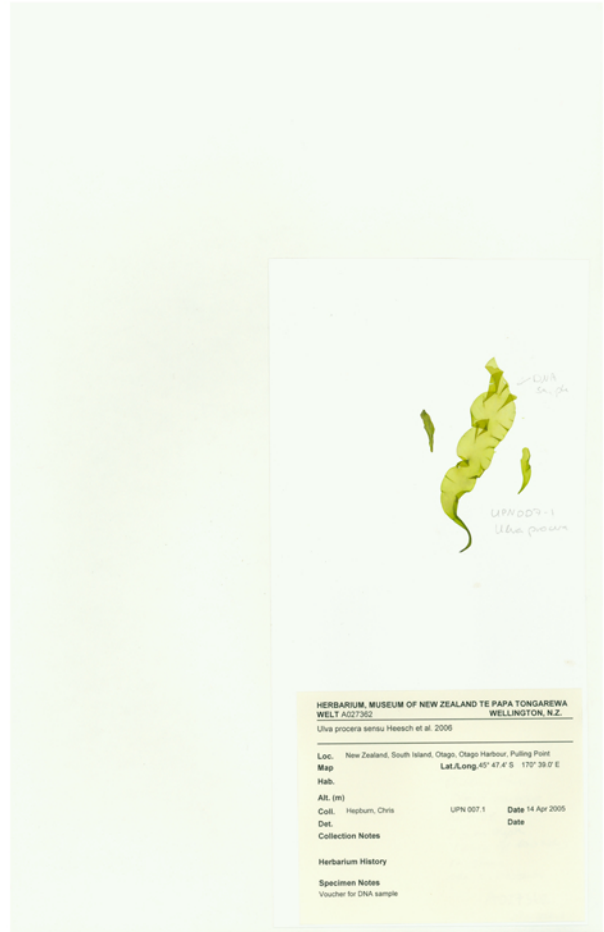


Fig. 40: *Ulva procera*

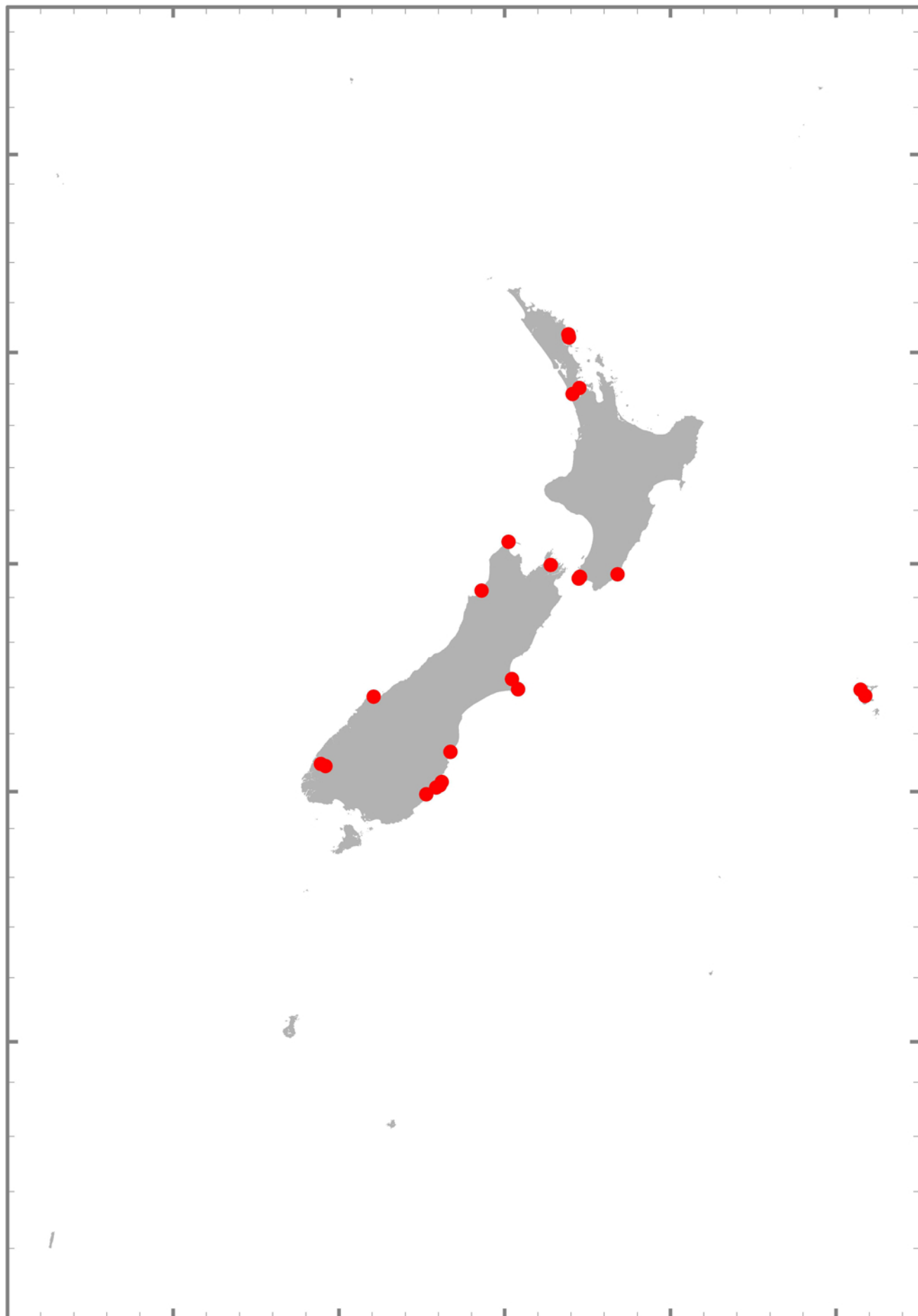
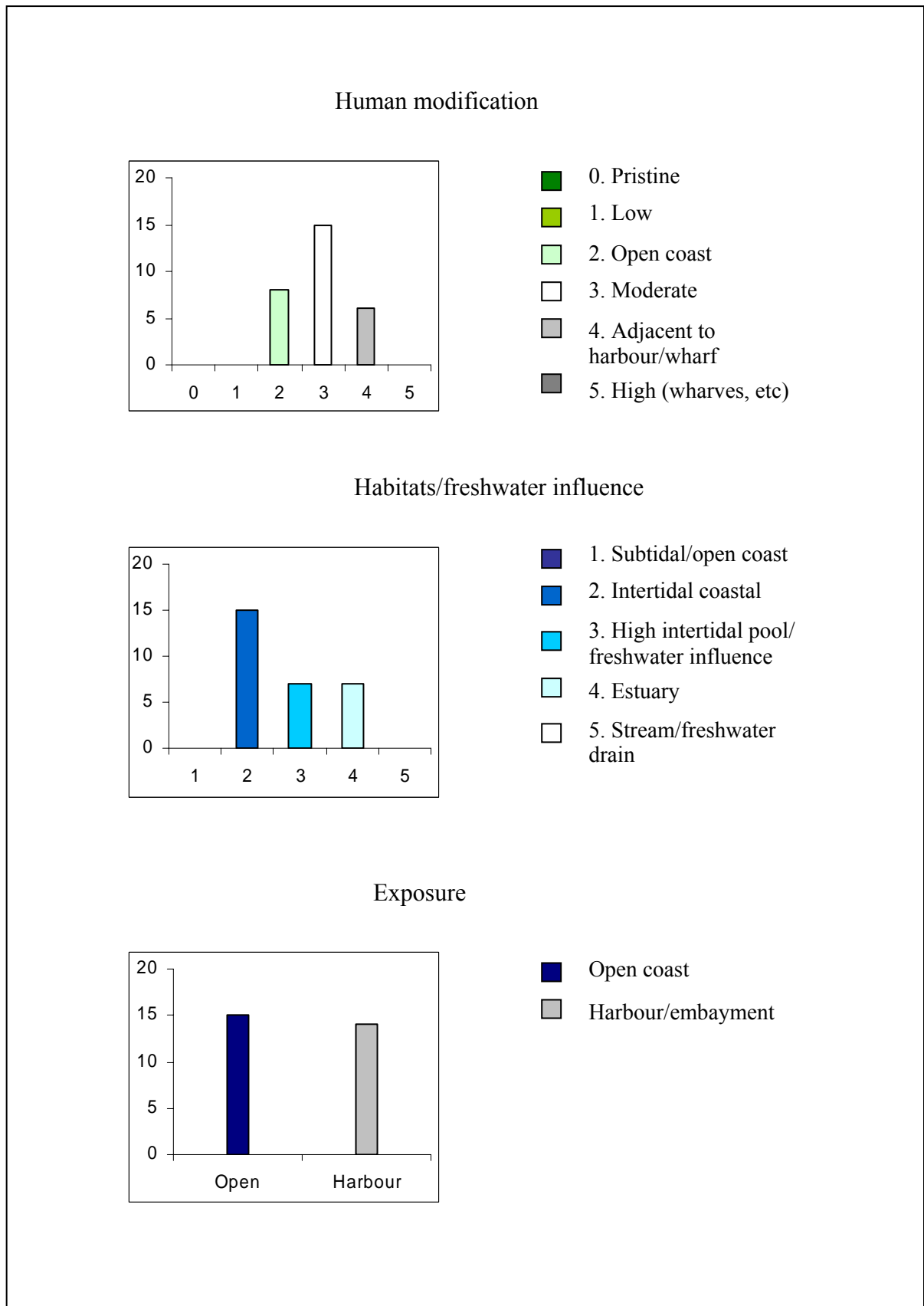


Fig. 41: *Ulva procera*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva prolifera* O.F.Müll.**

Figs 42 - 44

Publication details: *Ulva prolifera* O.F. Müller 1778: 7, pl. 763(1)

Type locality: Denmark

**SPECIES DESCRIPTION:**

Thalli either a tangled mass of threads, hollow, unbranched or sparsely branched, and more or less the same diameter throughout, diameter of cavity about 12 µm, or distinct, increasing in width from base towards middle region, from a few cm to more than 2 m long, (1)2-30 or more cm broad; thalli usually branched, often proliferous; ...cells at base in longitudinal rows, in middle region in longitudinal and also transverse rows, distal cells often disordered; cells in narrow thalli in 3-12 distinct longitudinal rows, quadrangular or rectangular, 12-28 x 11-16 µm; cells in broad thalli 9-19 x 7.5-15 µm; chloroplast a parietal plate overlapping more than one wall of cell and appearing ring-shaped in surface view with one large central pyrenoid, a few cells with 2-3 pyrenoids. (Burrows 1991: 90)

**DESCRIPTION – NEW ZEALAND SPECIMENS:**

Specimens consisted of thin, hair-like tubes or ribbons, up to 100 mm long, often richly branched but occasionally without any proliferations. Colours of fresh thalli ranged from blue-green to bright green. Cells were typically arranged in longitudinal rows, ranging in width from 6 to 11 µm and in length from 7 to 19 µm.

**HABITAT:**

*Ulva prolifera* occurred in harbours and embayments but also at open coast sites. All specimens were found in the intertidal, almost always high up on the shore, growing on stones or other hard substrate, as well as on dead wood, and sometimes fringing rockpools. Most samples were collected at sites with moderate human influence. One specimen originated from a site with little human impact while another one grew in a site adjacent to harbour structures.

**DISTRIBUTION – NEW ZEALAND:**

This species was only found on the east coast of the South Island, from Taylor's Mistake north of Banks Peninsula south to Monkey Island west of Riverton.

**DISTRIBUTION – OUTSIDE NEW ZEALAND:**

Europe: Britain, Solvenia, Spain; Atlantic Islands: Canary Islands, Madeira; Caribbean Islands: Cuba; Africa: Equatorial Guinea, Ghana, Mauritania, Namibia, Senegal, Western Sahara; Pacific Islands: American Samoa, Australia (Guiry 2006)

REFERENCE SPECIMENS: WELT A027350, A027351, A027352, A027353

**COMMENTS:**

Eleven samples from New Zealand were identified as belonging to *Ulva prolifera*. In GenBank, three *rbcL* sequences are available under the name *U. prolifera* (including

*Enteromorpha prolifera*). Only one of them is from Europe, albeit not from the type locality in Denmark, but from Scotland. The other two sequences originate from specimens collected along the Pacific coast of North America, from California and from Washington. However, in phylogenetic analyses these later two sequences group with two *U. flexuosa* samples from Japan, close to *U. californica*, while the European, presumably "true" *U. prolifera* sequence forms its own clade far away, with the closest relatives being *U. procera* from Finland and Japan. The New Zealand sequences unambiguously clustered with the European *U. prolifera*.

The samples we identified as *U. prolifera* were all from the south east of the South Island. Specimens identified by Chapman (1956) from the north of the North Island as *Enteromorpha prolifera* var. *pilifera* and var. *torta* (both varieties only occasionally branched) may have been *Ulva* species 5 "*Ulva ralfsii*".

**Reference:**

Müller, O.F. (1778). *Icones plantarum... Florae danicae. Vol. 5, fasc. 13. Vol. 5, fasc. 13* pp. 8, Plates 721-780. Copenhagen.

Fig. 42: *Ulva prolifera*

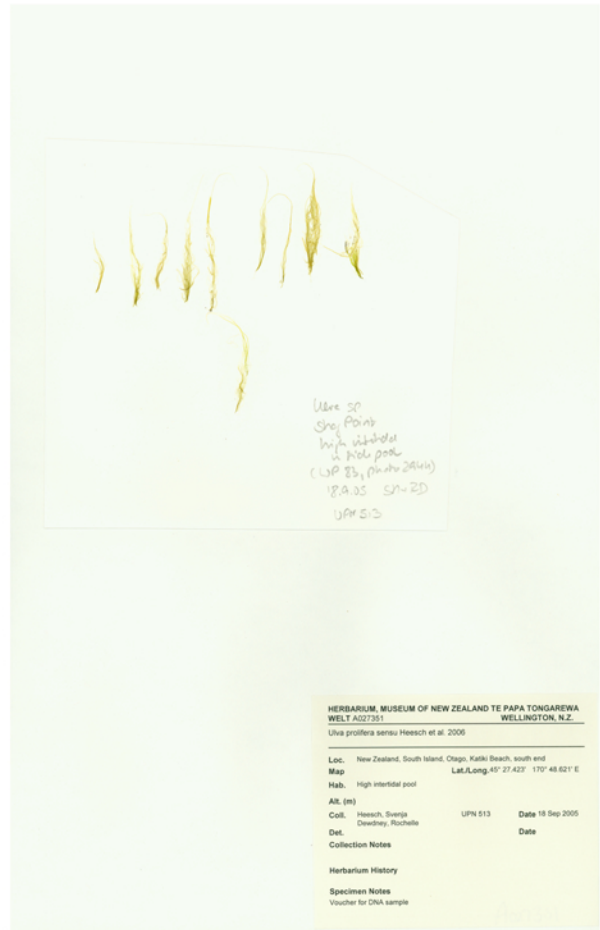


Fig. 43: *Ulva prolifera*

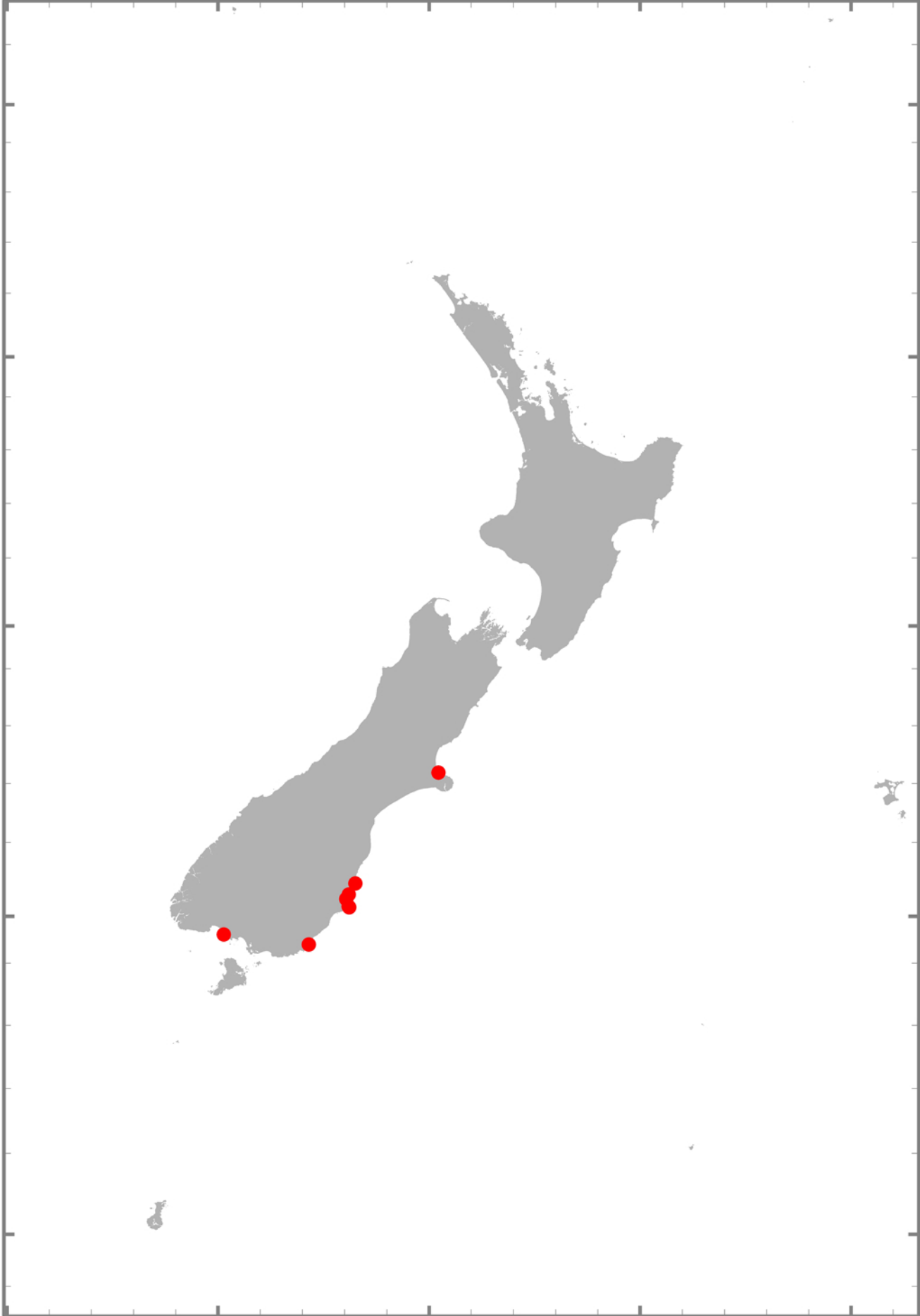
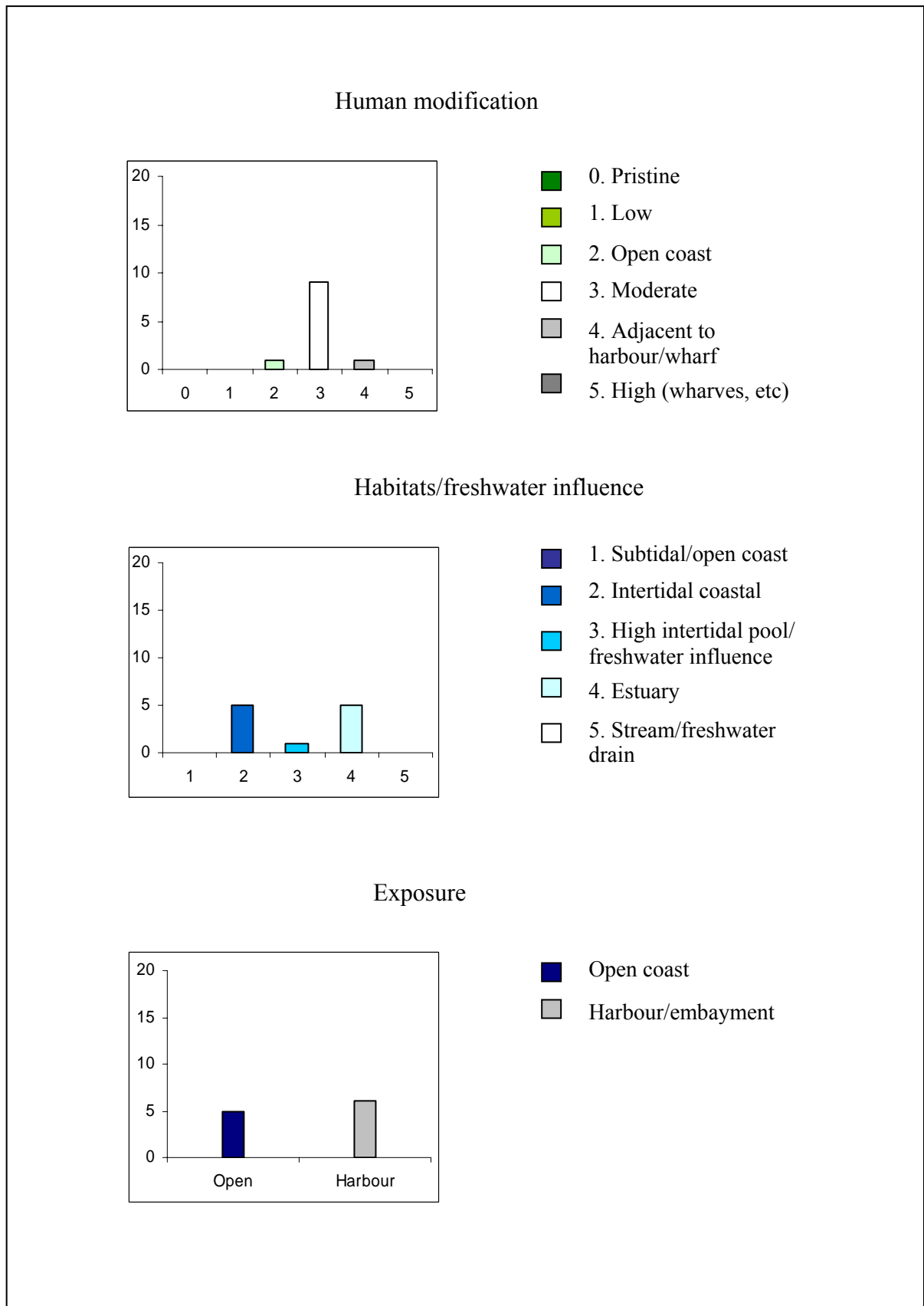


Fig. 44: *Ulva prolifera*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



## *Ulva rigida* C.Agardh

Figs 45 - 48

Publication details *Ulva rigida* C. Agardh 1823: 410-411

Type locality: Cadiz, Spain

### SPECIES DESCRIPTION:

"*ULVA RIGIDA, fronde ad basin fissa, laciniis curvato-crispis rgidis*" (Agardh 1823)

### DESCRIPTION – NEW ZEALAND SPECIMENS:

Thalli from New Zealand were lobed blades with a crisp texture and a stiff base. Holes were common. Blades were taller than wide, up to 31 cm long and 25 cm wide although on occasion very large individuals were found growing in the drift in excess of 1 m in length. Specimens were usually dark olive green, or bleached to pale khaki but with an olive tone. The margins of the blades were often ruffled and displayed microscopic teeth, but sometimes also macroscopically visible protrusions. Cells appeared highly ordered in small areas. They displayed thick cell walls, were comparatively round and 6-13 µm wide and 10-18 µm long. They contained 1-2 pyrenoids per cell.

### HABITAT:

Most samples were collected from sites with moderate human influence, in the subtidal and intertidal, with two samples originating from estuaries. Two thirds of the samples were from harbours/embayments. Thalli usually grew on hard substrate but on one occasion grew epiphytically on a brown alga.

### DISTRIBUTION – NEW ZEALAND:

In the present study *Ulva rigida* was only found on Stewart Island, South Island and the south of North Island (Wellington).

### DISTRIBUTION – OUTSIDE NEW ZEALAND:

Arctic: Canada (Arctic); Europe: Adriatic, Balearic Islands, Black Sea, Britain, Faroes, France, Greece, Iceland, Ireland, Italy, Netherlands, Portugal, Spain, Turkey; Atlantic Islands: Azores, Canary Islands, Cape Verde Islands, Madeira, Salvage Islands, Tristan da Cunha; North America: Alaska, California, Georgia, Gulf of California, North Carolina; Central America: Belize; Caribbean Islands: Caribbean; South America: Chile, Peru, Venezuela; Africa: Algeria, Angola, Côte d'Ivoire, Egypt, Ghana, Kenya, Liberia, Madagascar, Mauritius, Morocco, Mozambique, Namibia, Senegal, Sierra Leone, Somalia, South Africa, Tanzania, Tunisia, Western Sahara; Indian Ocean Islands: Aldabra Islands, Laccadive Islands, Nicobar Islands, Réunion, Seychelles; South-west Asia: India, Kuwait, Levant states, Philippines, Southeast Arabian coast, Sri Lanka, Yemen; Australia: Lord Howe Island, Papua New Guinea, Queensland, South Australia, Victoria, Western Australia; Pacific Islands: Hawaiian Islands; Antarctic and the subantarctic islands: Antarctica, Macquarie Island (Guiry 2006)

REFERENCE SPECIMENS: WELT A027369, A027370, A027371, A027373, A027374

COMMENTS:

Only 17 samples were collected in total indicating that *U. rigida* is not as widespread as previously thought. It shares a very similar macroscopic morphology with *U. pertusa*, a species which is much more common in New Zealand but until now it has not been recognized. *U. rigida* and *U. pertusa* are likely to have been confused in the past. These species can be distinguished by the microscopic teeth present on the margins of *U. rigida*, which are absent in *U. pertusa*. The apparent absence of *U. rigida* from most of the North Island is noteworthy. In Fiordland, *U. rigida* was only encountered once at the entrance to Doubtful Sound, while samples taken from the band of bladed *Ulva* that stretches along most of the fiord coasts and which is usually referred to as *U. rigida*, consisted solely of *U. pertusa*.

**Reference:**

Agardh, C.A. (1823): *Species algarum*. Vol. 1, part 2 pp. 399-531. Lund, Sweden.

Fig. 45: *Ulva rigida*

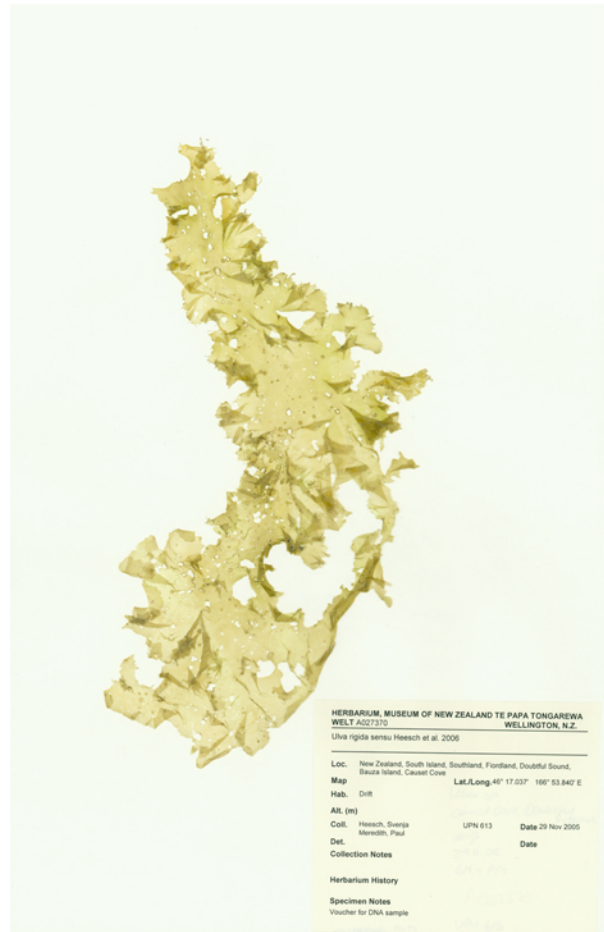
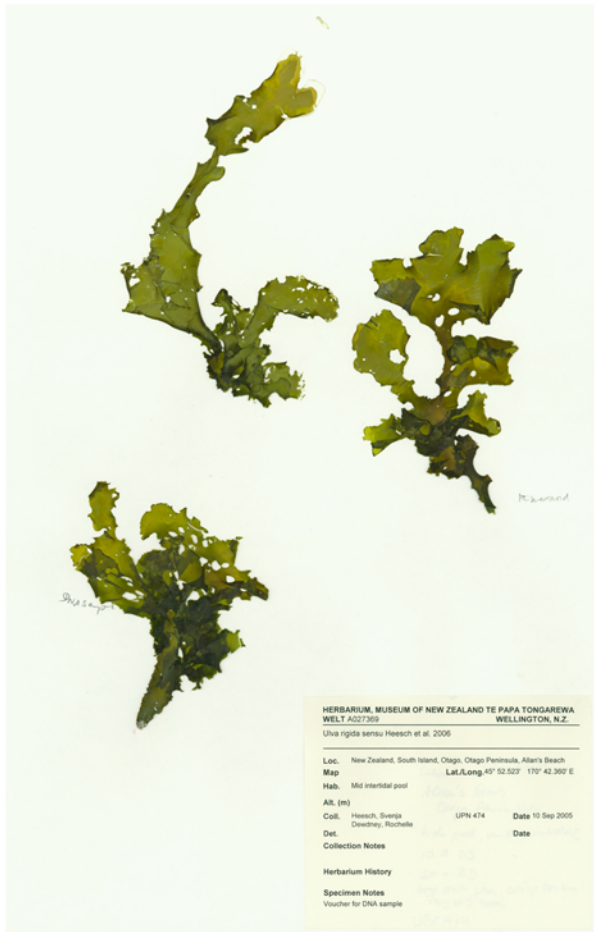


Fig. 46: *Ulva rigida* continued



Fig. 47: *Ulva rigida*

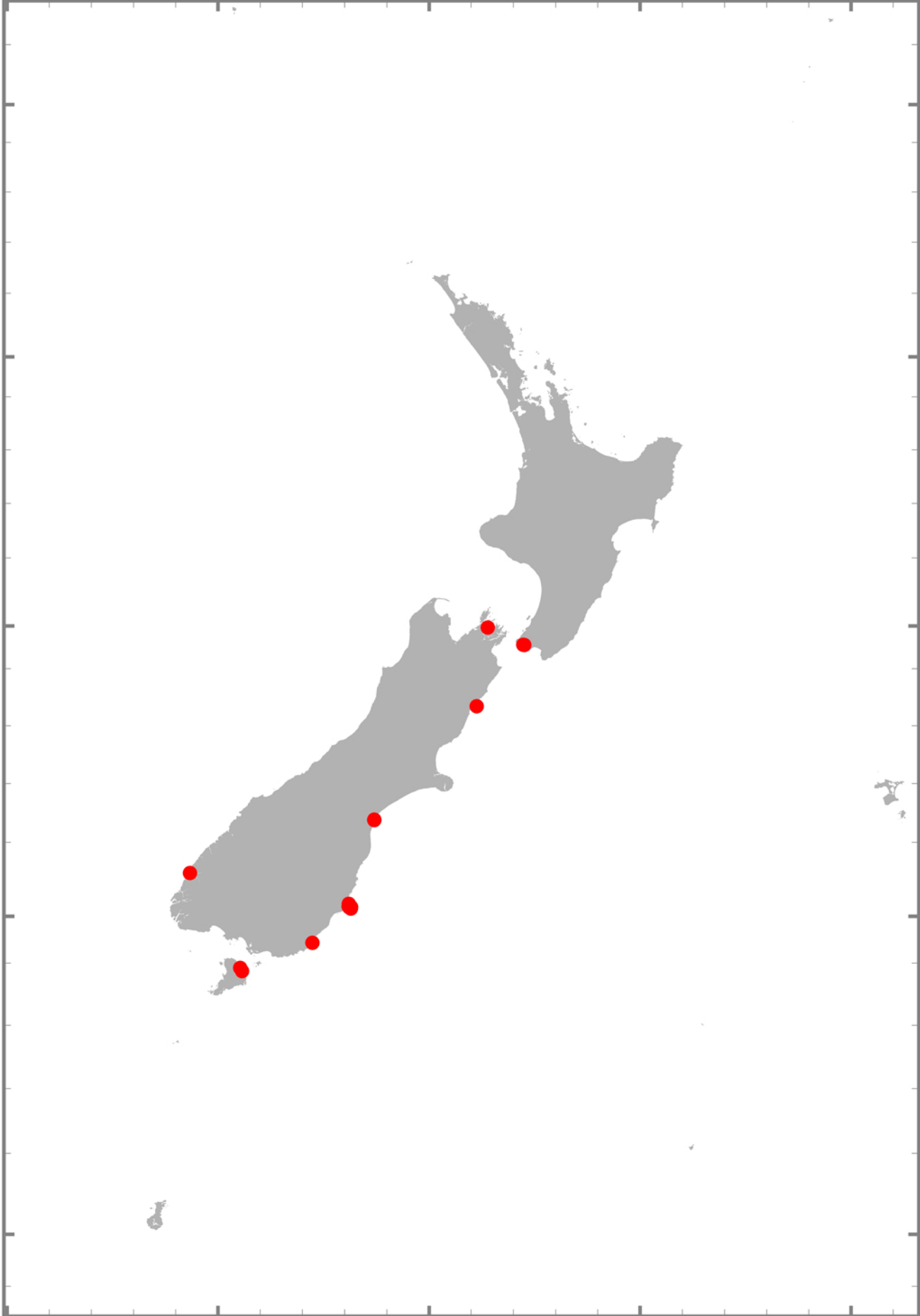
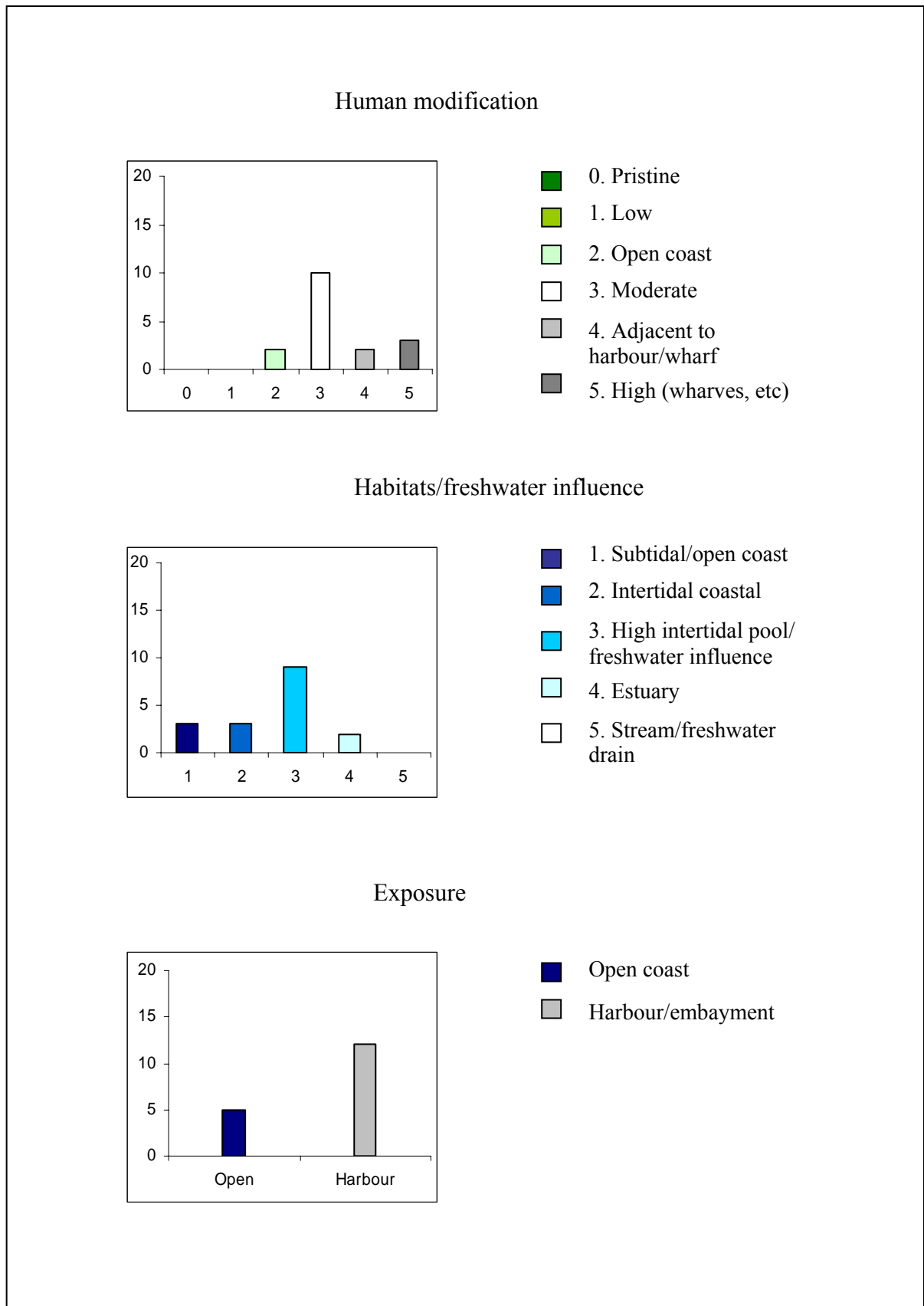


Fig. 48: *Ulva rigida*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



## ***Ulva species 1***

FIGS 49 - 53

### DESCRIPTION – NEW ZEALAND SPECIMENS:

Specimens belonging to this entity had sheet-like thalli in a range of morphologies. Specimens in wave exposed sites formed small rosettes or tufts appearing stunted and showed a stronger pigmentation, while thalli from sheltered harbours could develop into large, pale, crumpled sheets which in very sheltered habitats could reach a few meters in length. Some formed ribbons, rounded to long, which were sometimes lobed or formed a spiral or had a central flattened crisp region, with deeply ruffled silky margins. Some expanded sheets from drift collections appeared plastic-like. A stiff base was only apparent in older attached samples.

Margins usually had microscopic teeth and often also macroscopically visible outgrowths. Some specimens had fringed big holes, while very eroded thalli appeared lacey. Colours ranged from pale green bordering on olive to dark .

In surface view, cells in the base and mid-thallus were very rounded, and in the apical region more box-like. Cells, which usually displayed 1-2 pyrenoids, were 6-15  $\mu\text{m}$  long and 4-11  $\mu\text{m}$  wide. Cells at apical margin appeared to be larger. In cross sections through the base cells appeared cylindrical to rectangular without tapered ends. In the upper parts of thalli, cells were still cylindrical but became shorter and showed roundish to tapered ends. In the margins of fertile specimens, cells about to release spores had conspicuous protuberant necks.

### HABITAT:

Most samples (80%) were collected from coastal intertidal habitats, including high intertidal rock pools. Only occasionally were specimens encountered in the subtidal (up to 15 m depth), or in streams with freshwater.

*Ulva species 1* was able to grow on many hard substrates, such as rocks or mollusc shells, but also epiphytically on a variety of red and brown algae. In harbours/embayments, where 53% of the samples were collected, specimens were sometimes detached, with drifting thalli capable of forming large aggregations of biomass in sheltered bays.

Most samples (41%) originated from sites with moderate human impact, but 24% grew in high traffic areas. Two specimens came from sites with low volume of human traffic; none were found in pristine sites.

### DISTRIBUTION:

This entity was found all around New Zealand, including Chatham, Stewart and Auckland Islands.

REFERENCE SPECIMENS: WELT A027375, A027376, A027377, A027378, A027379, A027380, A027381, A027382, A027383, A027484, A027385, A027386, A027440,

A027456, A027457, A027458, A027459, A027468, A027469, A027470, A027477, A027478

COMMENTS:

*Ulva* species 1 was the most common and widespread *Ulva* entity in New Zealand, with a total of 157 samples collected. The *rbcL* sequences were identical or nearly identical to the sequence of an unnamed specimen from Chile, referred to in Hayden *et al.* (2003) as "*Ulva* species I". Even though *Ulva* species 1 has a very close relationship to the Chilean material, the fact, that it was found in all sorts of habitats, including sites with only little human traffic, suggests that this entity is native in New Zealand. However, the single specimen collected in Port Ross on Auckland Island raises the prospect that this constitutes an introduction to the subantarctic islands, probably by ship traffic.

NOMENCLATURE:

Specimens showed a large range of morphologies apparently in agreement with a number of species concepts previously applied to samples from New Zealand, such as *Ulva lactuca*, *Ulva stenophylla* Setchell & N.L.Gardner, *Ulva laetevirens* Areschoug and *Ulva laingii* V.J.Chapm. The latter is a species Chapman (1956) described from expanded sheets in sheltered habitats. Apart from *U. lactuca*, all of these species display dentate margins. Another potential name, *Ulva latissima* L. used by Chapman (1956) is invalid as it was based on a kelp species (Papenfuss 1960; Lane *et al.* 2006).

Previously most sheet-like *Ulva* species in New Zealand have been referred to as either *U. rigida* or *Ulva lactuca*. Chapman (1956) recorded a variety of *U. lactuca* for New Zealand, *Ulva lactuca* var. *lacunculata* (Kützinger) Hauck, which he distinguished from *U. lactuca* on the basis of dentate margins. Chapman's treatment of var. *lacunculata* agrees with specimens genetically identified as *Ulva* species 1, however, this entity itself is not closely related to *U. lactuca*.

A single specimen (WELT A027449) showed some characters of *U. stenophylla*, a species previously recorded from New Zealand (Adams 1994). Adams noted, in reference to *U. stenophylla*, that "long ribbon-like *Ulva* plants have also been identified as *U. dactylifera* and *U. taeniata*" (1994: 25). All three of these species were described from California. However, neither sequences of *Ulva* species 1 nor any other New Zealand specimens were closely related to the GenBank sequences of *U. stenophylla* and *U. taeniata*, both based on material originating from the west coast of the United States. No GenBank *rbcL* sequences were available for *U. dactylifera*.

*Ulva laetevirens* was described from Victoria, Australia. Womersley (1984) considered it a synonym of *Ulva australis*, which, according to AlgaeBase (Guiry 2006), itself is currently regarded as a synonym of *Ulva rigida*. However, the fact, that *U. australis* has smooth margins without microscopic teeth (Womersley 1984), makes synonymy with *Ulva pertusa* more likely (see comments on *U. pertusa*), and excludes it as a potential name for *Ulva* species 1. Apart from their distinct habits, information on the morphology for *U. laetevirens* and *U. laingii* generally agree, such as overlapping ranges for cell sizes. Unfortunately, no *rbcL* sequences are available for *U. laetevirens* to show whether

*U. laingii* and *U. laetevirens* are indeed conspecific. The name *U. laetevirens* would have priority (Areschoug 1854 vs. Chapman 1956).

Fig. 49: *Ulva* species 1



Fig. 50: *Ulva* species 1 continued

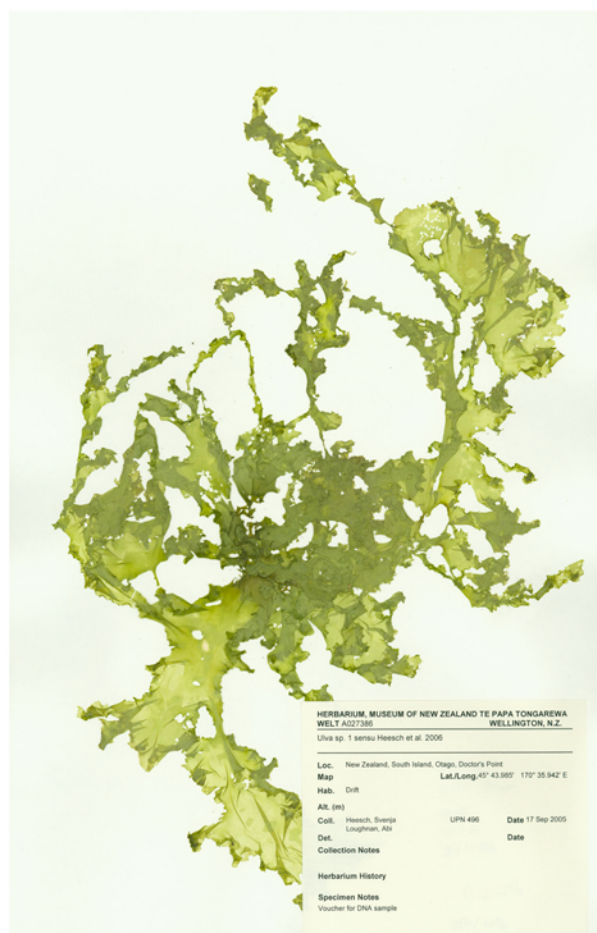


Fig. 51: *Ulva* species 1 continued

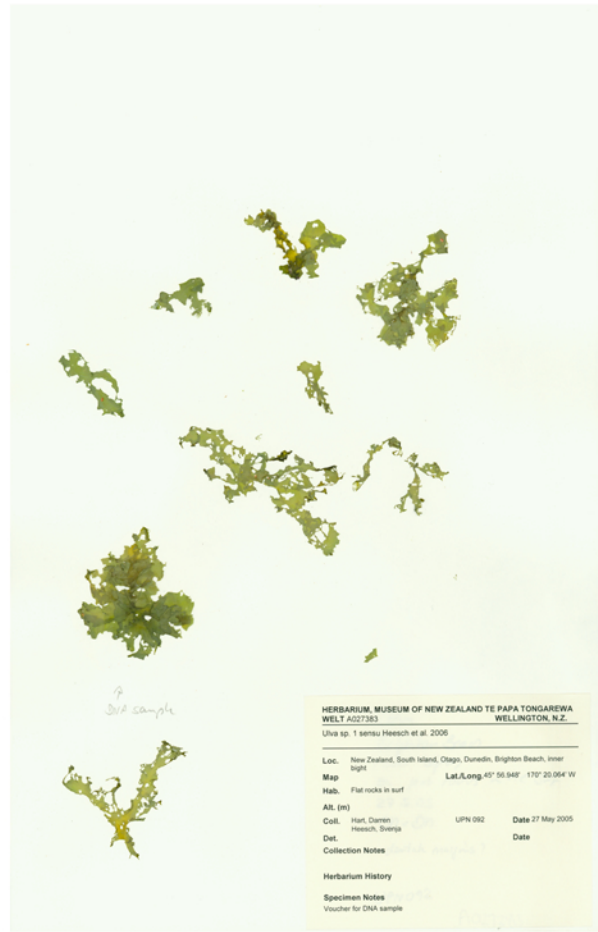


Fig. 52: *Ulva* species 1

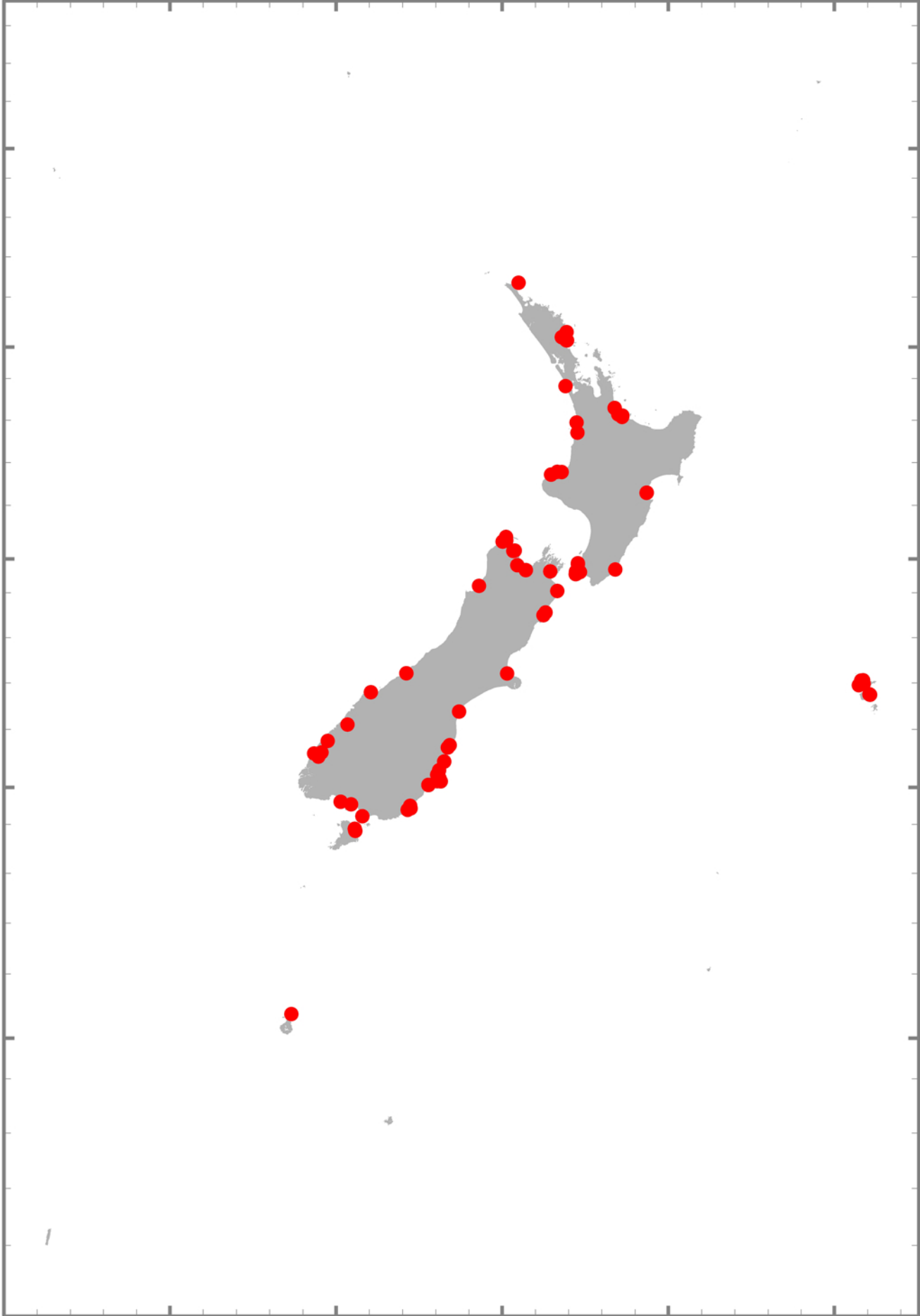
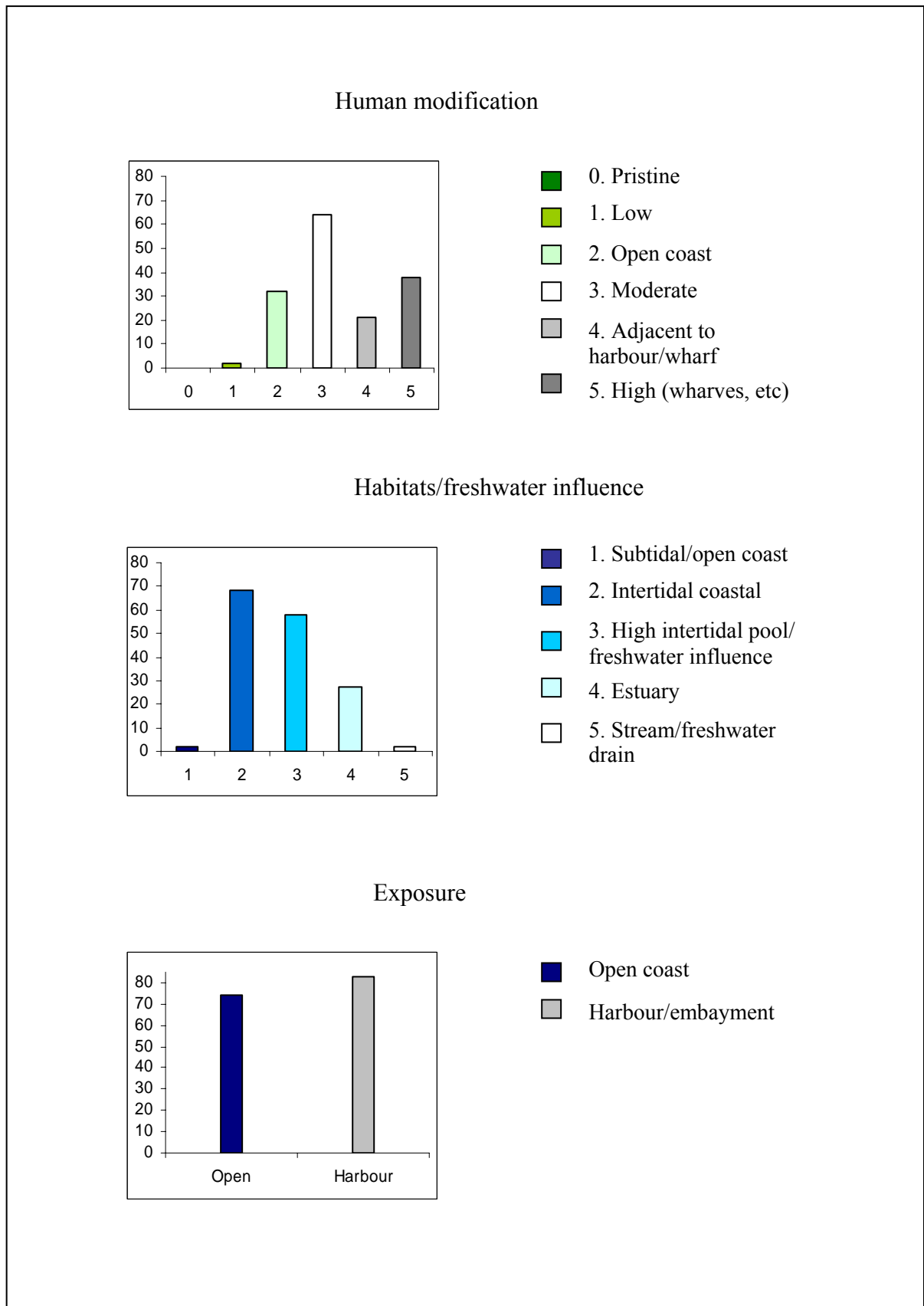


Fig. 53: *Ulva* species 1. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



## ***Ulva* species 2**

Figs 54 - 57

### DESCRIPTION – NEW ZEALAND SPECIMENS:

Specimens belonging to this entity consisted of small tubes or ribbons, up to 30 mm long and 2 mm wide, which were either unbranched or branched close to the base. Only first order branching was observed. The colour of fresh thalli was bright green. Brown tips indicated where fertile tissue had released spores/gametes. Cells in the basal area were unordered, but in the mid region were arranged in distinct longitudinal rows. Most cells contained 2-3 pyrenoids, and were quadrangular to rectangular with round corners. They were 5-13 µm in width and 11-22 µm in length (WELT A027368).

### HABITAT:

This entity was only collected in the coastal intertidal and high intertidal tide pools, growing on rocks or shells, but often also as an epiphyte on other algae, especially geniculate coralline algae (30% of all samples). Most samples (63%) originated from sites with moderate human influence. A quarter of the specimens were collected at sites with a low volume of human traffic. The remaining specimens grew in areas adjacent to or, in the case of one sample, directly on harbour and wharf structures. More than half of the samples were from harbours or embayments.

### DISTRIBUTION:

Most specimens were collected along the east coast of northern North Island, but this entity also occurred in the southern North Island and at a few sites around the South Island. It was furthermore found on Chatham Island, but not on Stewart Island or on any of the subantarctic islands.

REFERENCE SPECIMENS: WELT A027366, A027367, A027368

### COMMENTS:

Twenty seven specimens were identified as this entity. However, variations among the *rbcL* sequences indicate that probably more than one entity is included in this clade. More variable genes will have to be studied to resolve this tentative complex. Its widespread distribution and occurrence in low human modified areas suggests that this entity is a New Zealand native.

Chapman (1956) describes a new species of small bladed *Ulva* growing on *Corallina officinalis*. However, that species, *Ulva parva* V.J. Chpm., is distinguished from *Ulva* species 2 by its small membrane with flat cells and unordered cells in surface view.

Fig. 54: *Ulva* species 2

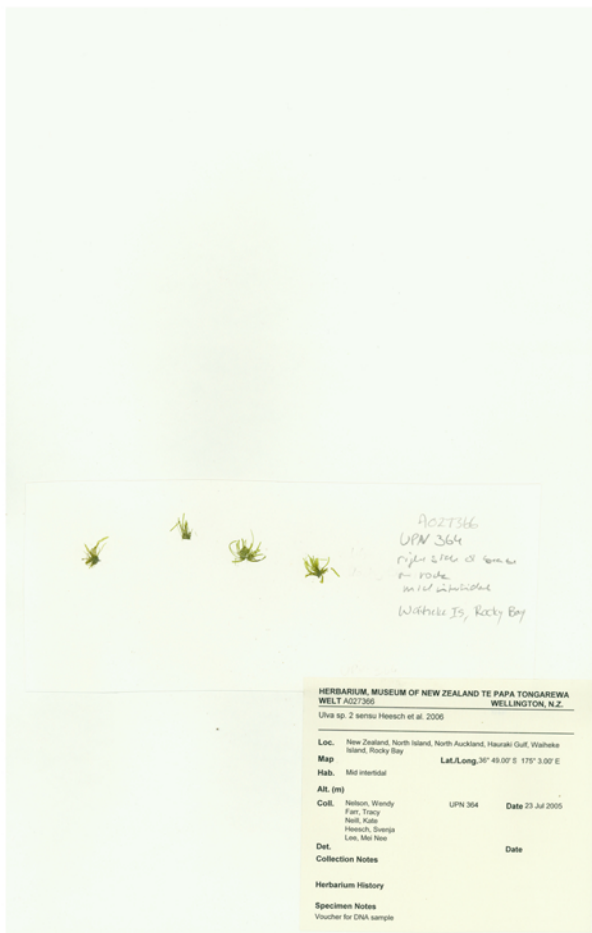


Fig. 55: *Ulva* species 2

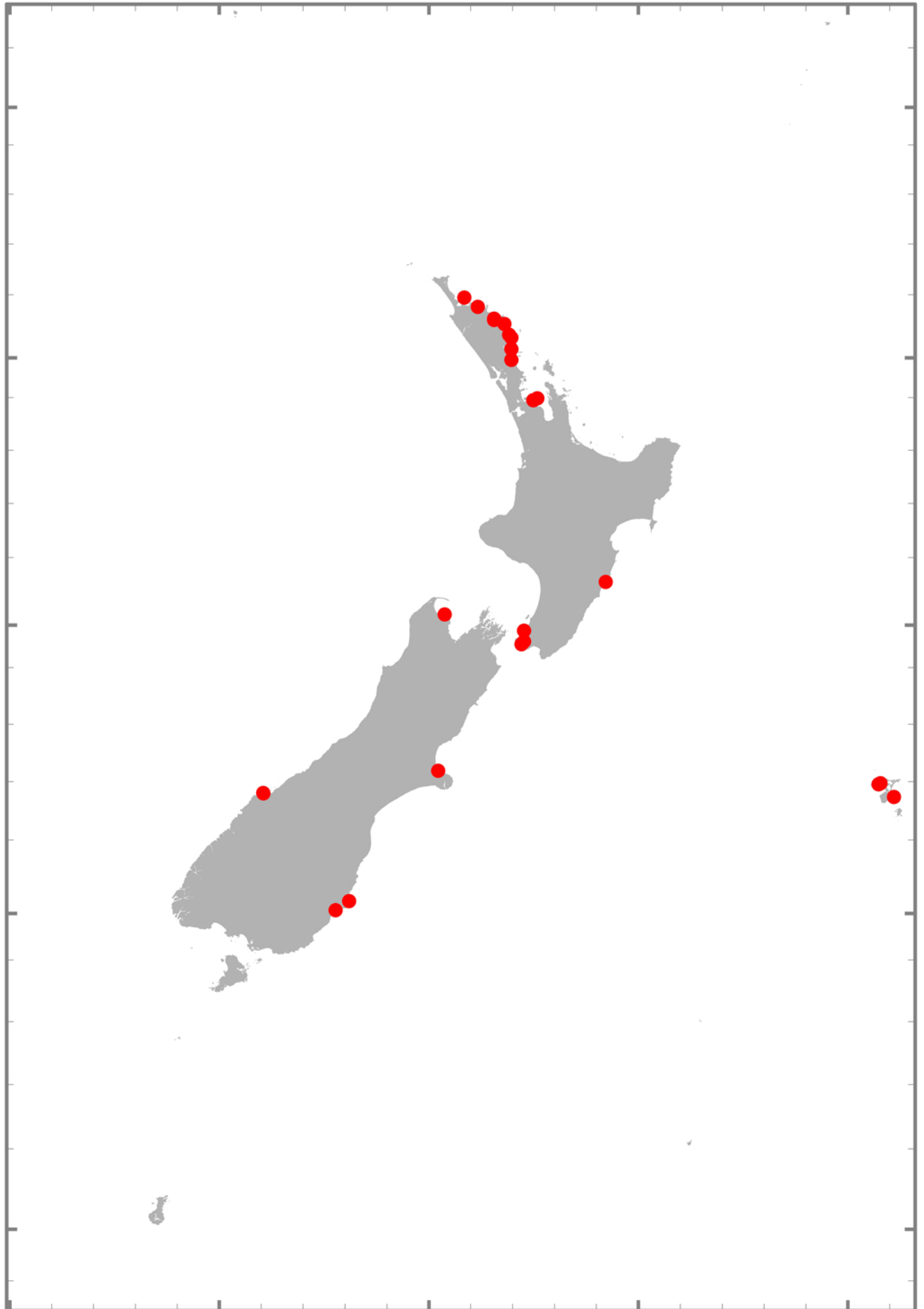
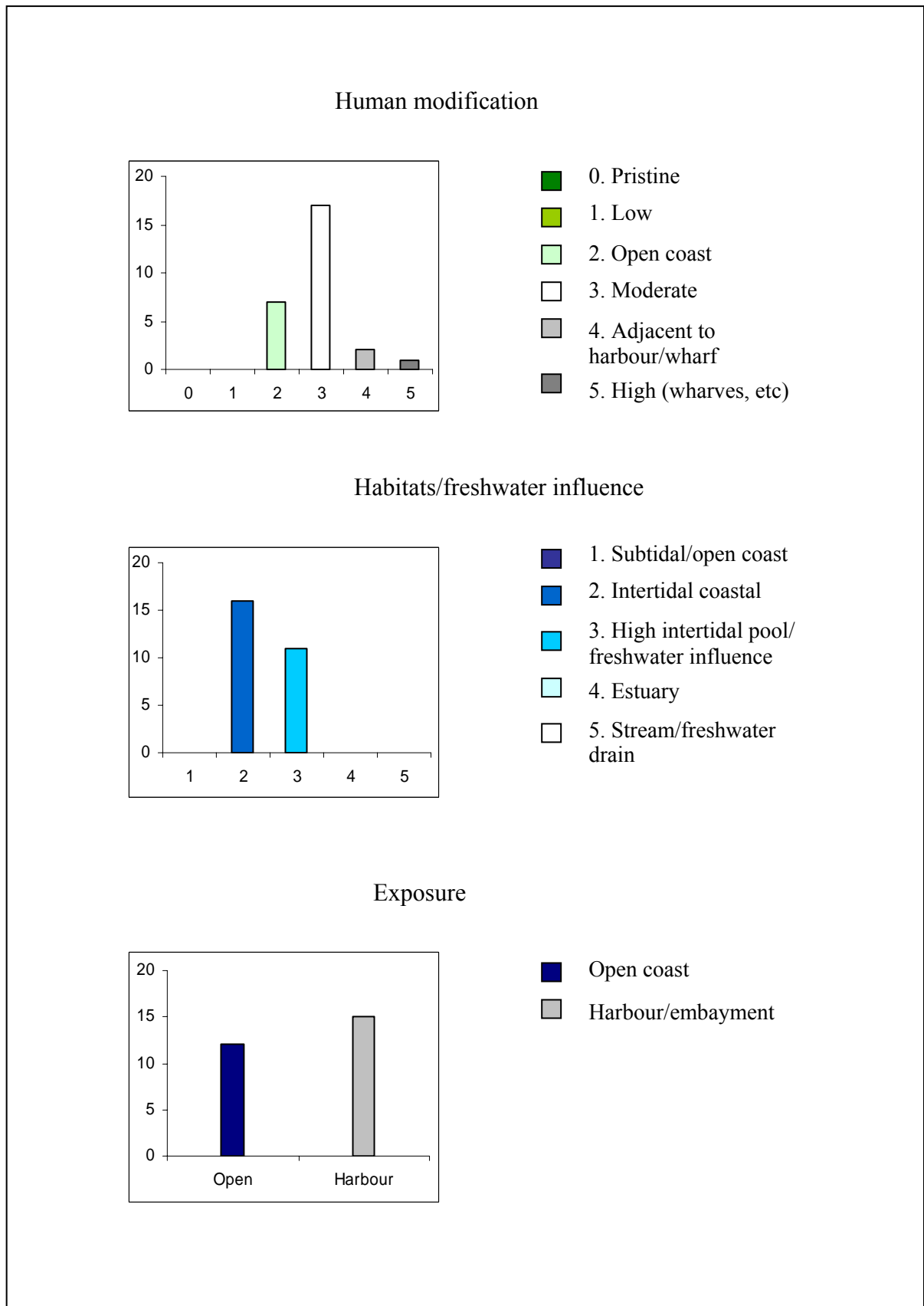


Fig. 56: *Ulva* species 2. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



#### ***Ulva species 4***

Figs 57 - 59

##### DESCRIPTION – NEW ZEALAND SPECIMENS:

Specimens formed unbranched delicate tubes of up to 50 mm length and 5 mm width. In surface view, cells were not arranged in any pattern. Cells were polygonal, and 6-11 µm wide and 8-20 µm long.

##### HABITAT:

This entity was found growing on a stone in the subtidal of a sheltered harbour, adjacent to wharf structures.

##### DISTRIBUTION:

The single sample was collected in Otago Harbour, South Island.

REFERENCE SPECIMEN: WELT A027344

##### COMMENTS:

The sample comprised six individual tubes and was collected from a stone together with specimens of two other entities (*Ulva procera* and *Ulva species 2*). This entity was unusual in regard to its basal position in the phylogenetic trees within the genus *Ulva*. It is probably introduced as it only occurred in a single sample in an area close to heavily frequented shipping lanes. However, no genetic material is available for comparative purposes so this is unable to be confirmed at present.

Fig. 57: *Ulva* species 4

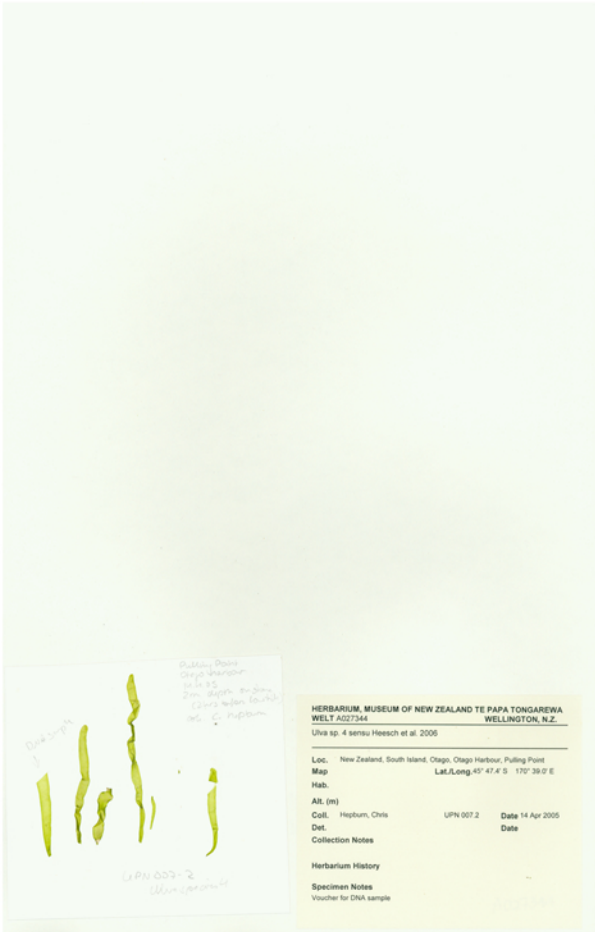


Fig. 58: *Ulva* species 4

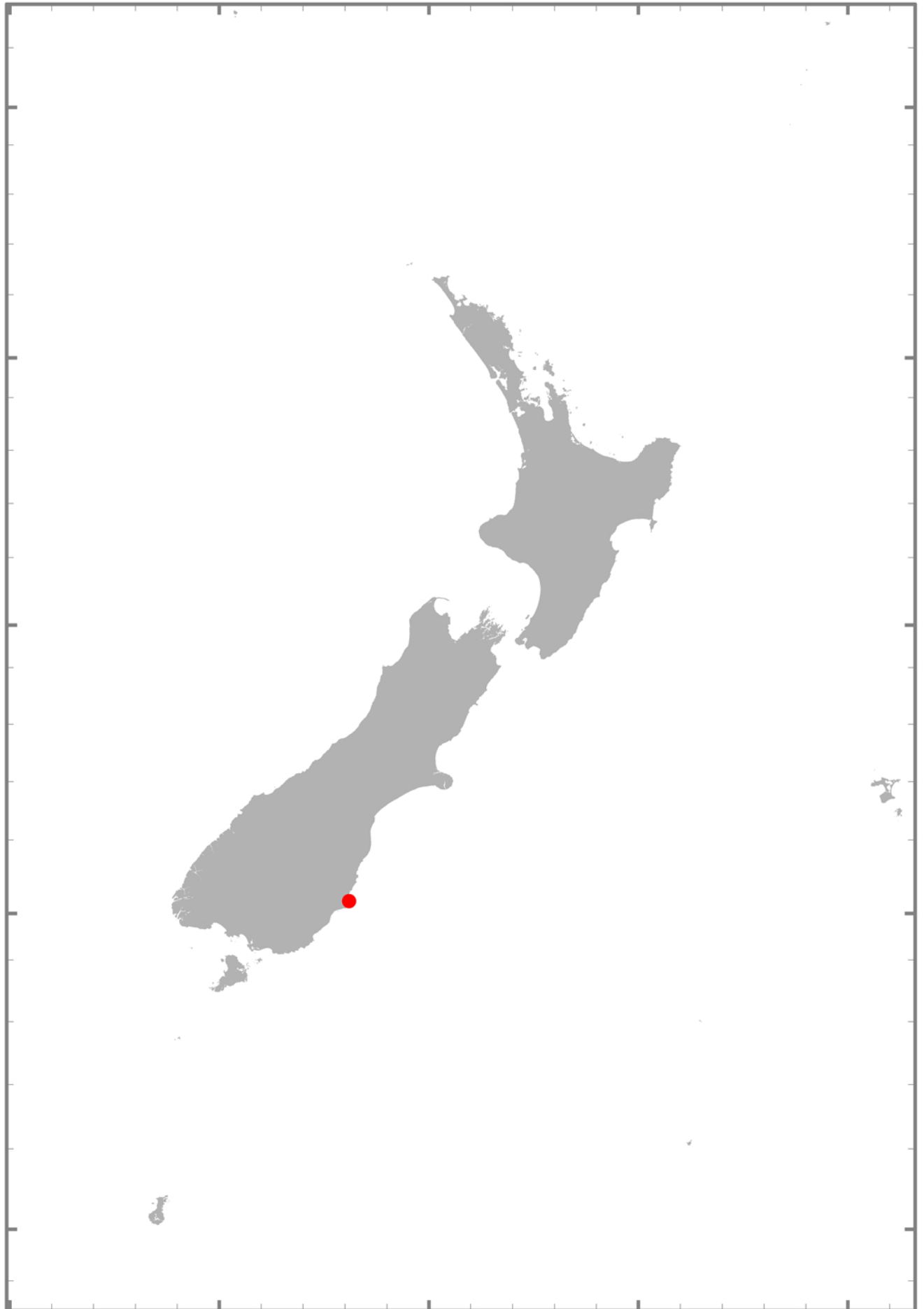
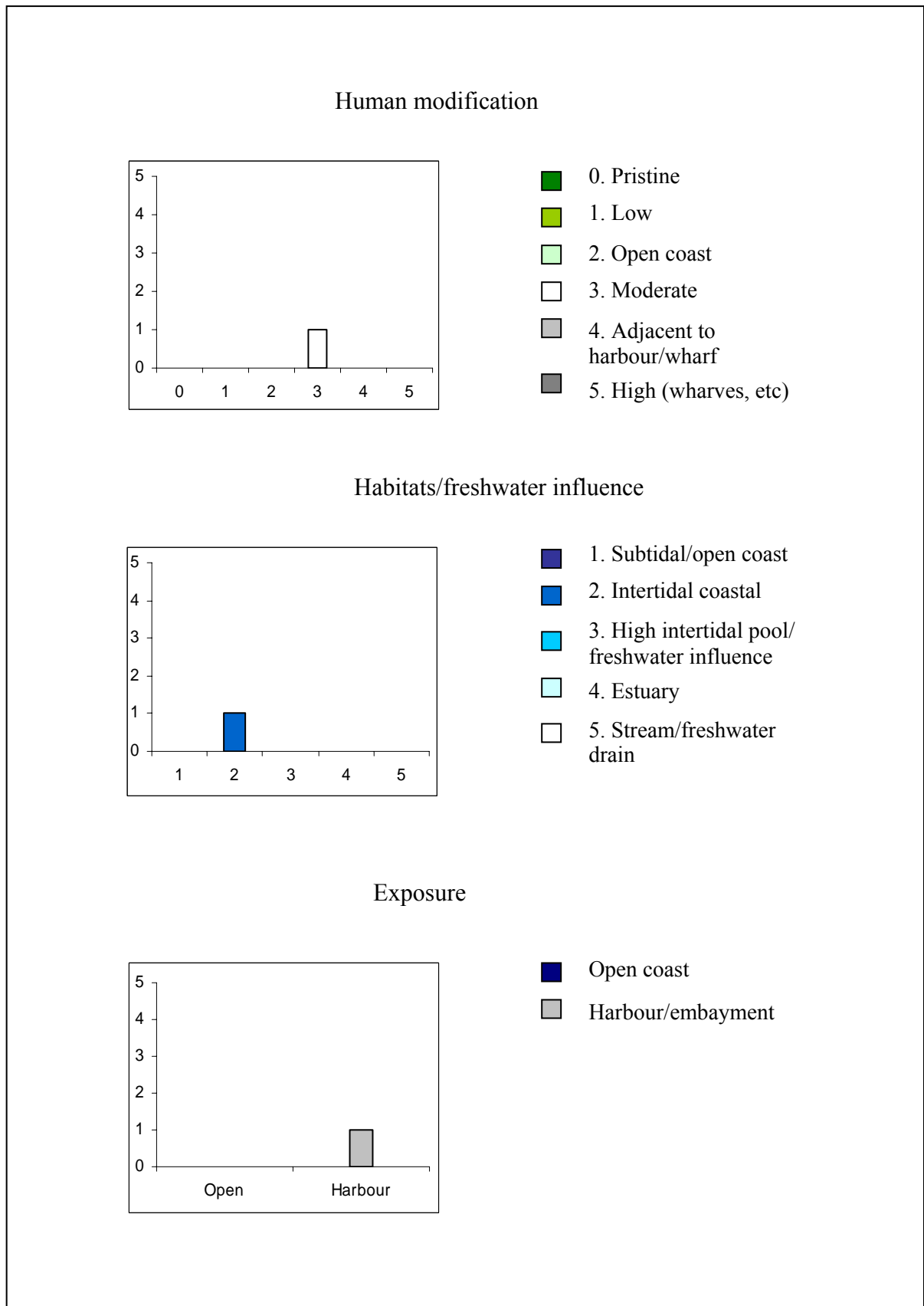


Fig. 59: *Ulva* species 4. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva* species 5 “*U. ralfsii* (Harv.) Le Jolis”**

Figs 60 - 62

Publication details: *Ulva ralfsii* (Harv.) Le Jolis 1863: 54

Type locality: Bangor, Wales, Britain (type specimen lost)

**SPECIES DESCRIPTION:**

Thallus light to dark green, unbranched (rarely with short proliferations), forming entangled, loose-lying masses on mud in the mid to upper eulittoral in mangrove or samphire communities; filaments of similar diameter throughout though differing considerably in different collections. Cells in distinct longitudinal rows (with 3-8 (15) rows in surface view), square to rectangular; chloroplast filling most of the cell, with (2) 3-5 pyrenoids per cell. (after Womersley 1984)

**DESCRIPTION – NEW ZEALAND SPECIMENS:**

Specimens consisted of long and thin stringy or hair-like tubes, which could reach a length of more than a metre and sometimes (but not obviously) displayed short branches. Fronds were often entangled and difficult to separate. One sample (WELT A027348) contained specimens sporting small stipes from which brushes of long fine filamentous tubes arose.

Cells were arranged in distinct longitudinal rows. Their number, from a few up to 22 rows, determined the width of the tubes which varied considerably among samples. In surface view, cells were rectangular, 11-24 µm long and 11-17 µm wide, and usually contained more than one pyrenoid.

**HABITAT:**

All samples were collected in the intertidal of sheltered harbours or embayments, with most specimens found in the high intertidal including tide pool and in estuaries indicating a tolerance to freshwater in this species. Most occurred in environments with moderate to little human influence, but could also be found underneath sewage outlets (WELT A027349) or in muddy ditches (WELT A027531). Specimens were growing on driftwood or other algae, or were drift themselves, often entangled in algae, saltmarsh plants or dead wood.

**DISTRIBUTION – NEW ZEALAND:**

*Ulva* species 5 was found in one site in the North Island, (Bay of Islands), and in four areas in the South Island (Golden Bay, Doubtful and Bradford Sounds, Fiordland and in Karitane Harbour, Otago). It was not observed elsewhere, including Chatham and Stewart Island.

**DISTRIBUTION – OUTSIDE NEW ZEALAND:**

Europe: Britain, Spain; Australia: South Australia (Guiry 2006; Womersley 1984)

REFERENCE SPECIMENS: WELT A027346, A027347 A027348 A027349, A027531

COMMENTS:

The name "*U. ralfsii*" for this group of samples is tentative, as no *rbcL* sequences are available from the type locality or other places in Europe to confirm its identity. Although the New Zealand specimens are very similar morphologically to the description of this species they were much wider than those of the type material.

Another potential name for this entity is *Ulva torta* (Mertens) Trevisan, a species with similar morphology of hair-like, unbranched tubes, which was described from the East Frisian Islands in Germany. *Ulva torta* has been recorded from New Zealand as *Enteromorpha prolifera* var. *torta* (Mertens) V.J.Chapm. However, this species has thinner tubes with only 3-8 rows of cells, and the cells are smaller and each contain a single pyrenoid (Chapman 1956; Womersley 1984). *U. ralfsii* fronds, in contrast, can be up to 15 cells wide and display 2-5 pyrenoids per cell (Womersley 1984).

**Reference:**

Harvey, W. H (1846-51). *Phycologia Britannica, or, a history of British sea-weeds: containing coloured figures, generic and specific characters, synonyms and descriptions of all the species of algae inhabiting the shores of the British Islands.* Reeve & Benham, London, Plate 282.

Fig. 60: *Ulva* species 5 “*U. ralfsii*”

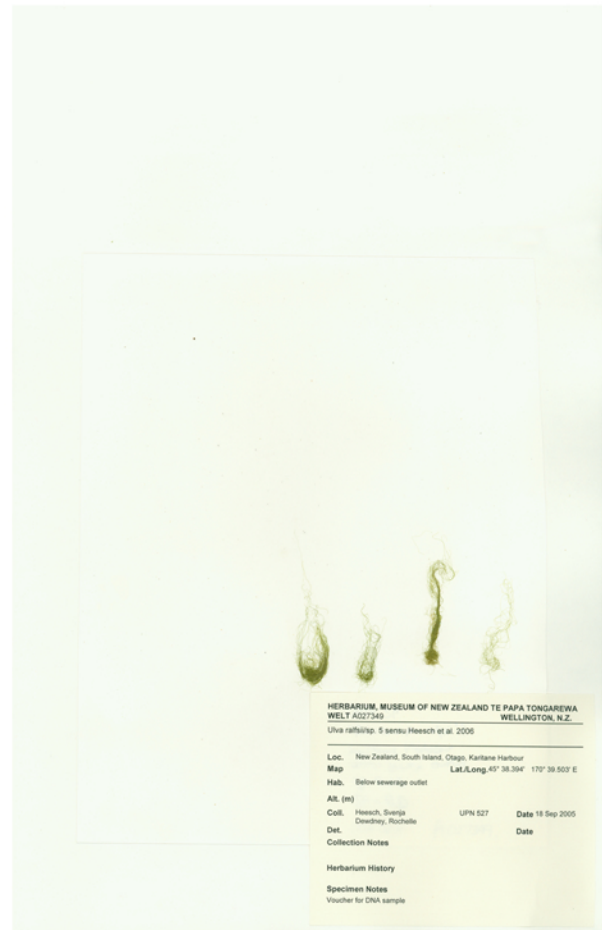


Fig. 61: *Ulva* species 5 “*U. ralfsii*”

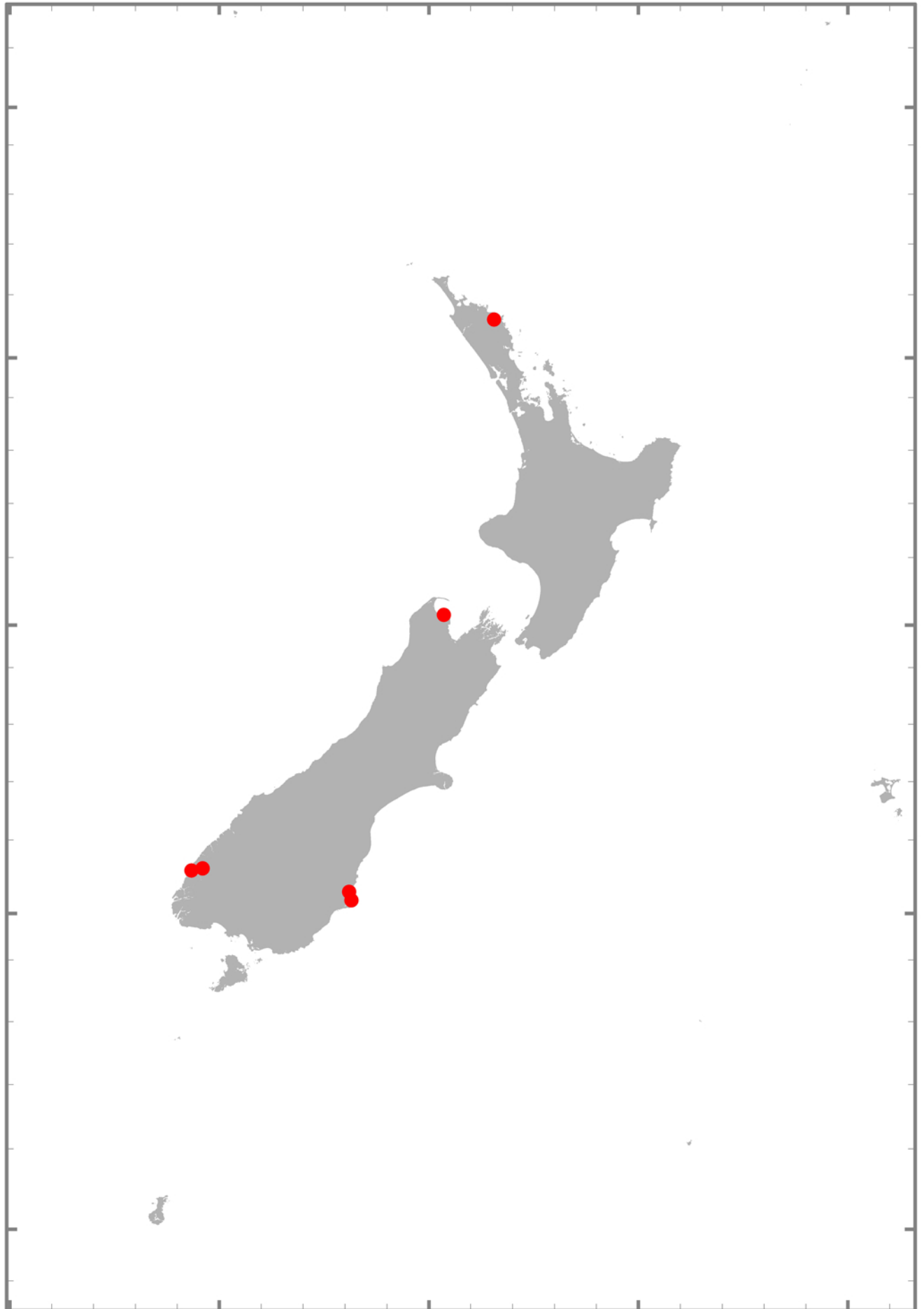
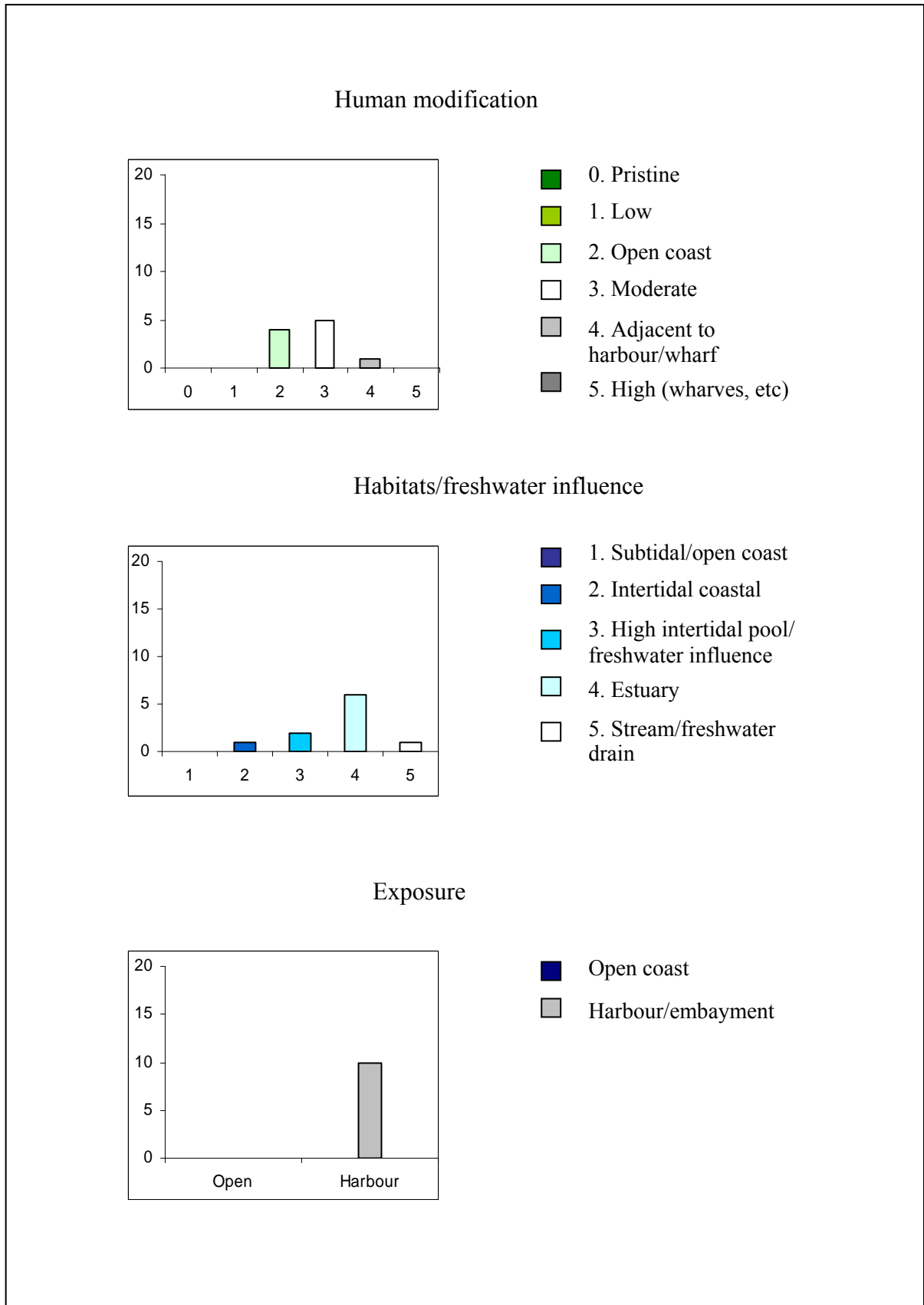


Fig. 62: *Ulva* species 5 “*U. ralfsii*”. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



## ***Ulva* species 6**

Figs 63 - 65

### DESCRIPTION – NEW ZEALAND SPECIMENS:

The specimens formed tiny tubular thalli, which were branched close to the base adjacent to the rhizoidal zone. Cells contained 1-2 pyrenoids, and were rectangular to quadrangular, 8-10  $\mu\text{m}$  long and 12-17  $\mu\text{m}$  wide (WELT A027532).

### HABITAT:

This entity grew on stones in freshwater, in a river that drained into a tidal stream. close to a marina. This site was sheltered, close to a marina and highly influenced by human activities.

### DISTRIBUTION:

This entity was only collected from Kerikeri in the Bay of Islands.

REFERENCE SPECIMENS: WELT A027520, A027532

### COMMENTS:

Only two specimens of this entity were collected from a single site. This in combination with the marina close by suggests that this species may have been introduced. Alternatively, this entity may be a species found solely in freshwater. Rivers were not included in the sites sampled in this study and thus species occupying freshwater habitats will be under-represented in the results. *Ulva* species are known to tolerate freshwater and *Ulva intestinalis* in particular has been linked to blooms in rivers and lakes. However, molecular systematic studies on material from equivalent habitats in Scotland have identified a new species that is not closely related to *U. intestinalis* (see archive of the Algae-L list in August 1998 for personal comments).

Fig. 63: *Ulva* species 6

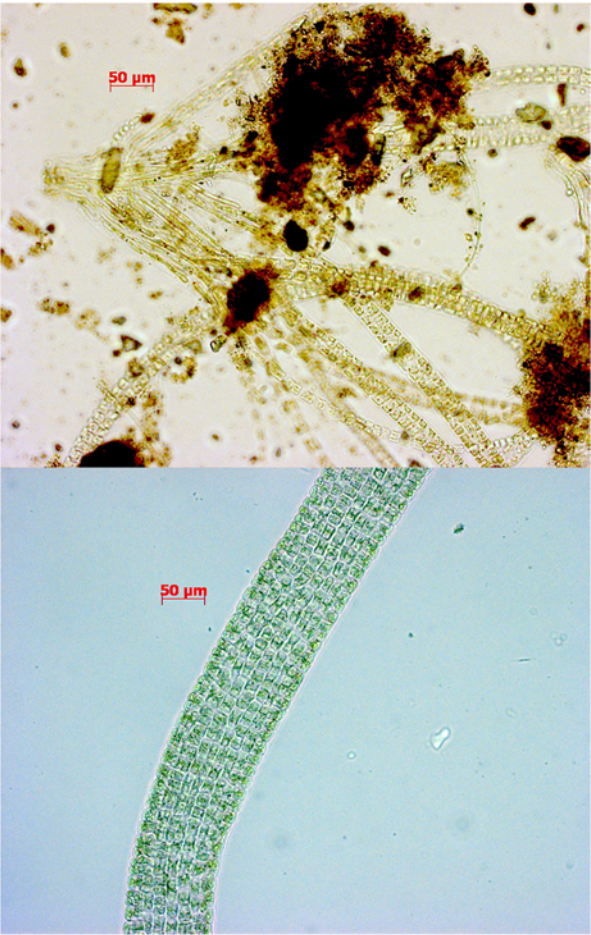


Fig. 64: *Ulva* species 6

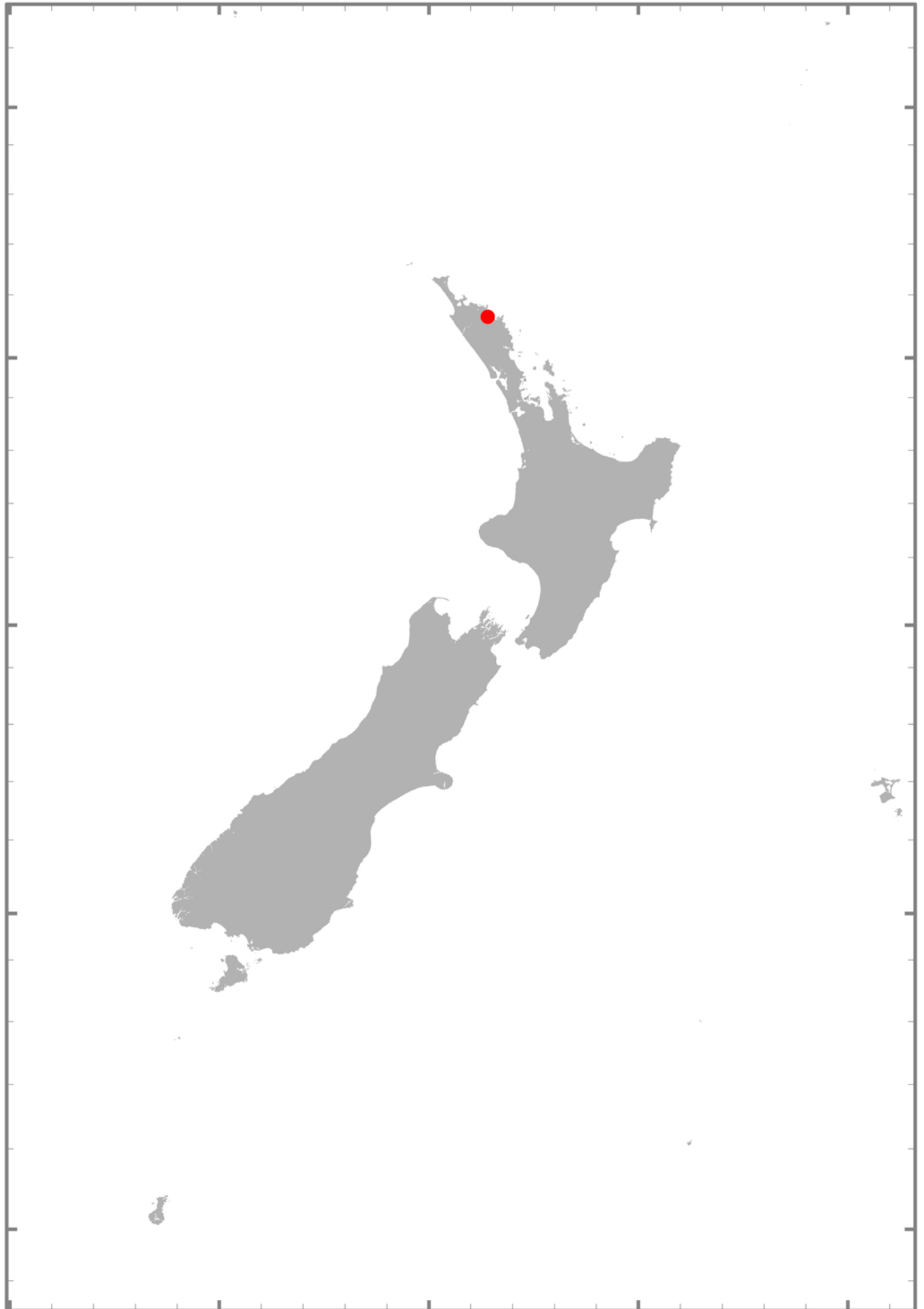
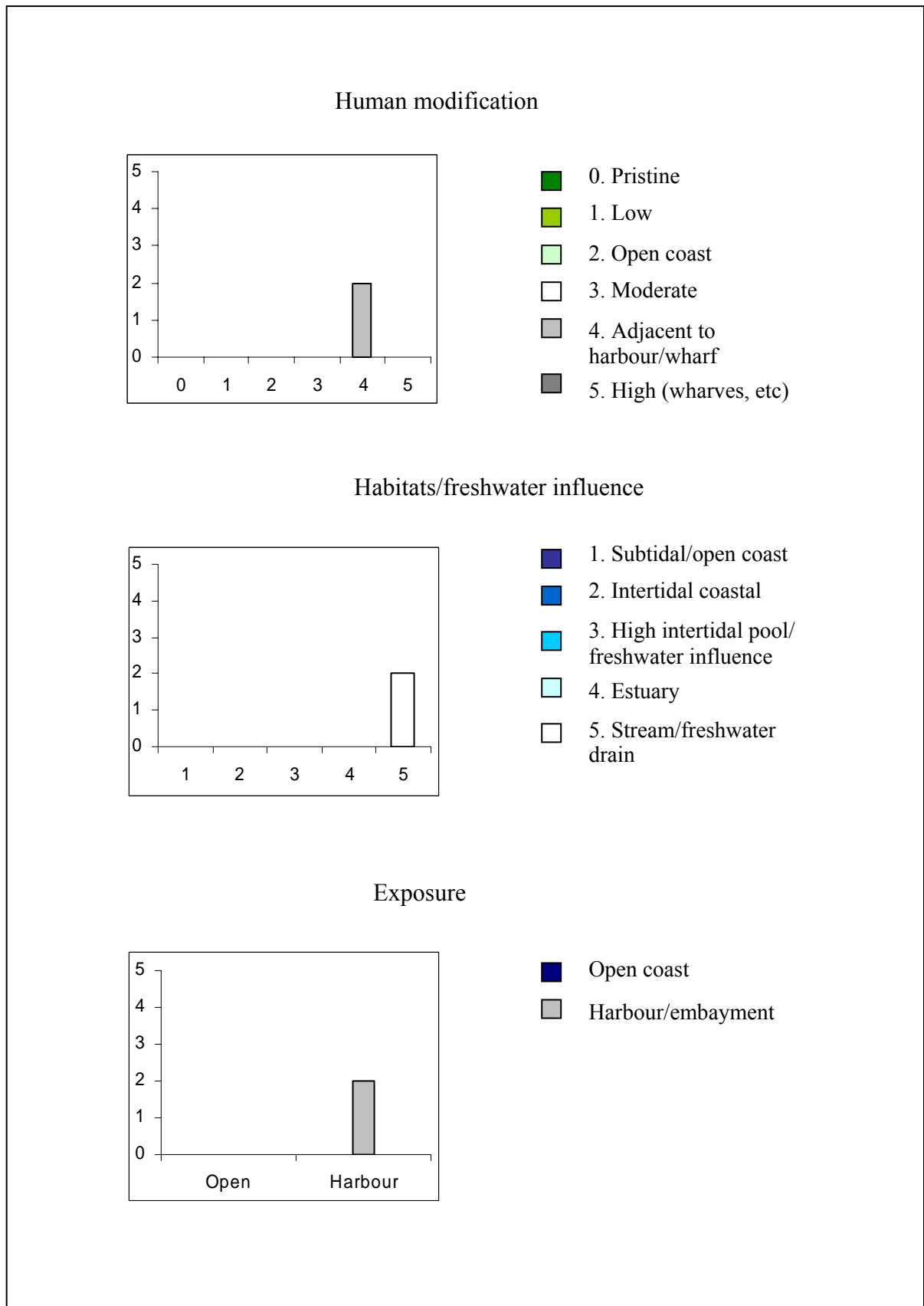


Fig. 65: *Ulva* species 6. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva species 9***

Figs 66 - 68

DESCRIPTION – NEW ZEALAND SPECIMENS:

Thalli of this entity consisted of small tubes ca 1-2 mm long. Tubes were branched throughout, with branches often arranged in opposite positions. Main axes were about six cells wide, branches only 1-3. Cells in branches were arranged in distinct rows, but less so in the main axes. Most cells were rectangular, up to 18  $\mu\text{m}$  long and up to 17  $\mu\text{m}$  wide.

HABITAT:

The collection was made from a boat ramp in a sheltered harbour. The alga was growing on geniculate coralline algae in the low intertidal.

DISTRIBUTION:

A single sample was collected from Russell, Bay of Islands.

REFERENCE SPECIMEN: WELT A027519

COMMENTS:

The occurrence of this entity on a boat ramp in a busy harbour for recreational vessels suggests that it may have been introduced. However, the identity and origin of this sample cannot be confirmed as no sequences of closely related material exist in GenBank.

Fig. 66: *Ulva* species 9

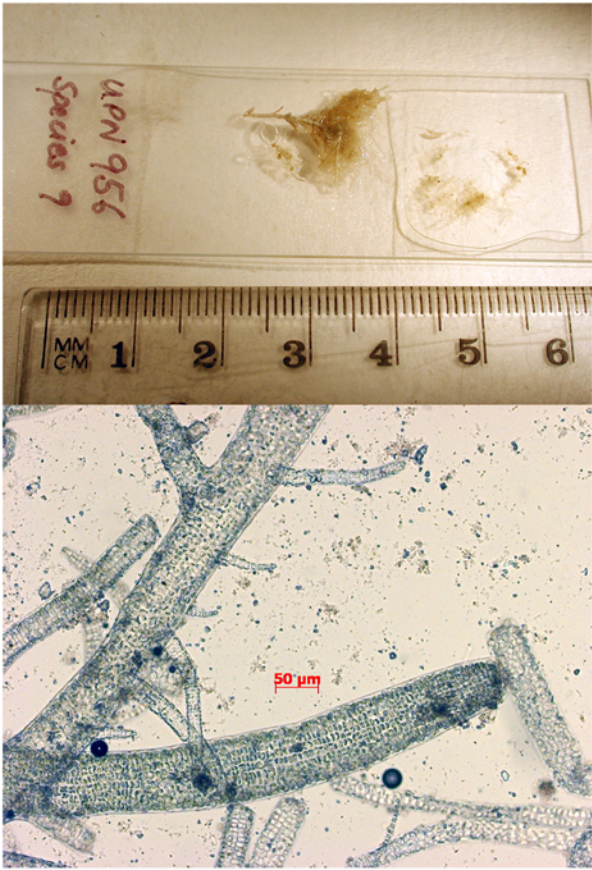


Fig. 67: *Ulva* species 9

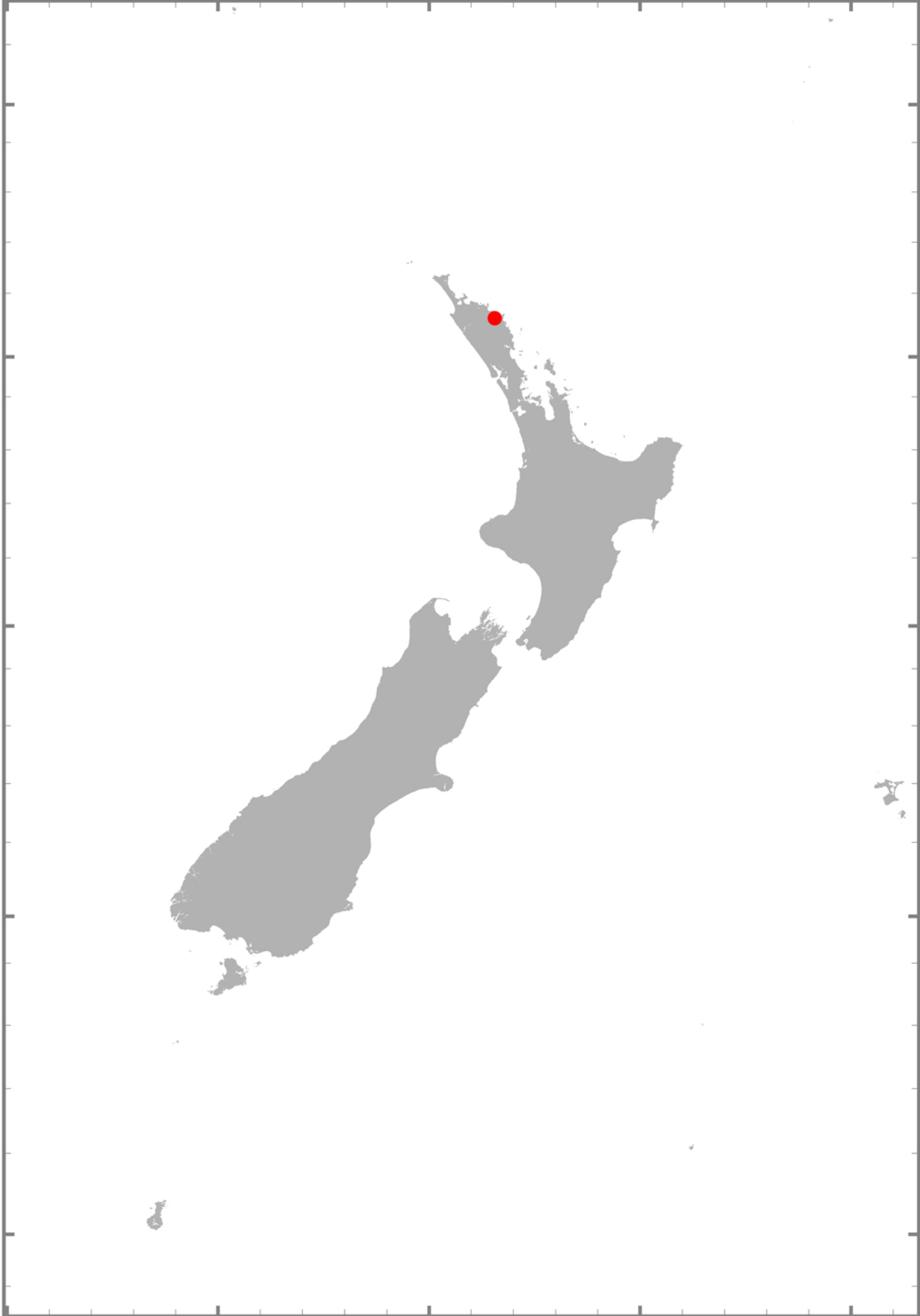
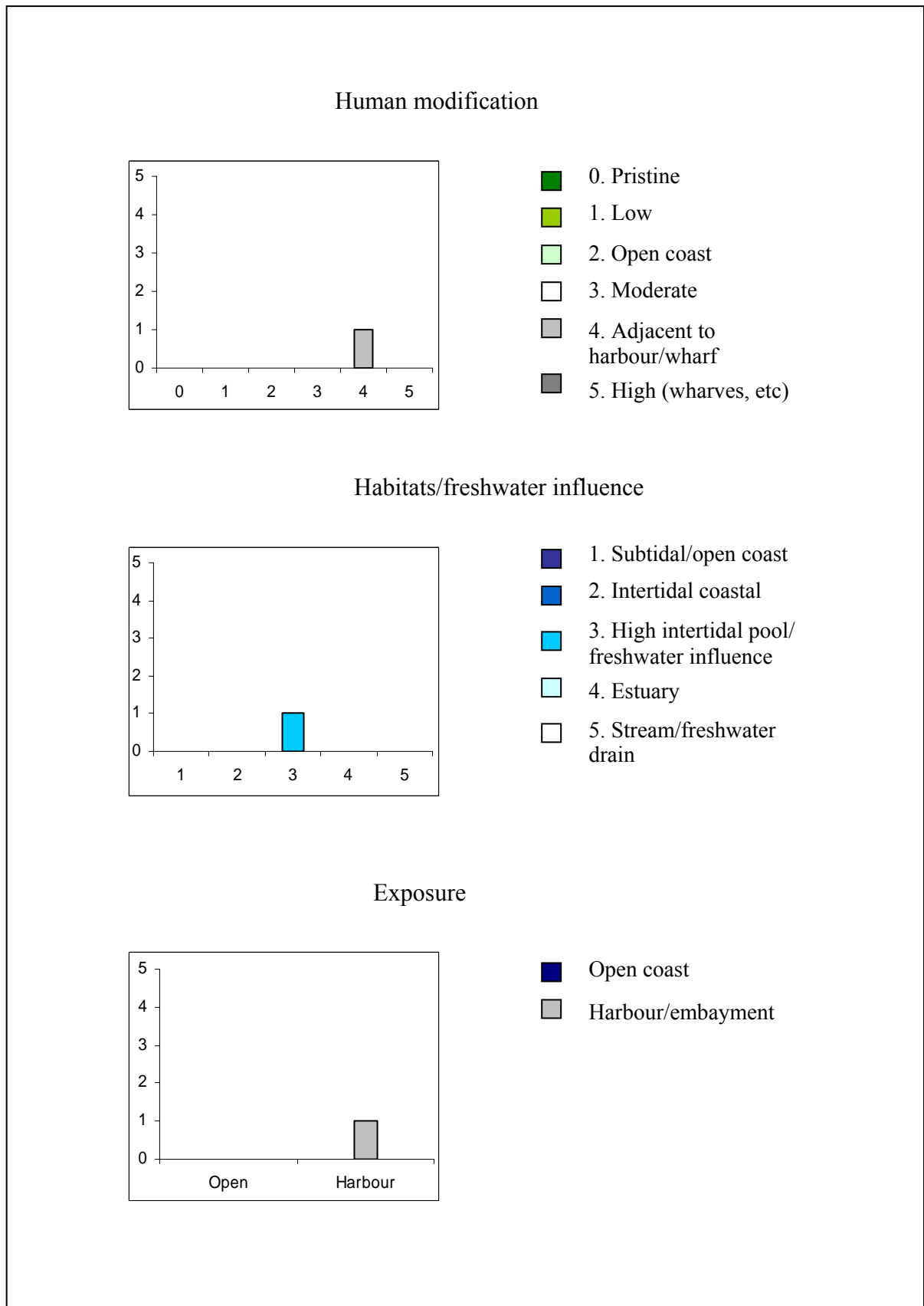


Fig. 68: *Ulva* species 9. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Ulva* species 10**

Figs 69 - 71

DESCRIPTION – NEW ZEALAND SPECIMENS:

The specimens formed a velvety turf, consisting of tiny tubes and ribbons up to 3 mm long. Thalli were rarely branched with tubes sometimes arising from ribbons split in two or three lobes. Cells in tubular and thin ribbon-like parts were arranged in distinct rows. Tubes consisted of 6-8 cell rows and were up to 0.1 mm wide, while ribbons could reach 0.6 mm width. Cells were polygonal, 6-10  $\mu\text{m}$  wide and up to 18  $\mu\text{m}$  long.

HABITAT:

This entity grew in a high intertidal pool at an exposed open coast site with moderate human influence.

DISTRIBUTION:

The sample was collected in Whale Bay, Raglan.

REFERENCE SPECIMEN: WELT A027516

COMMENTS:

This entity is probably native in New Zealand, however, additional samples are needed to assess its status.

Fig. 69: *Ulva* species 10

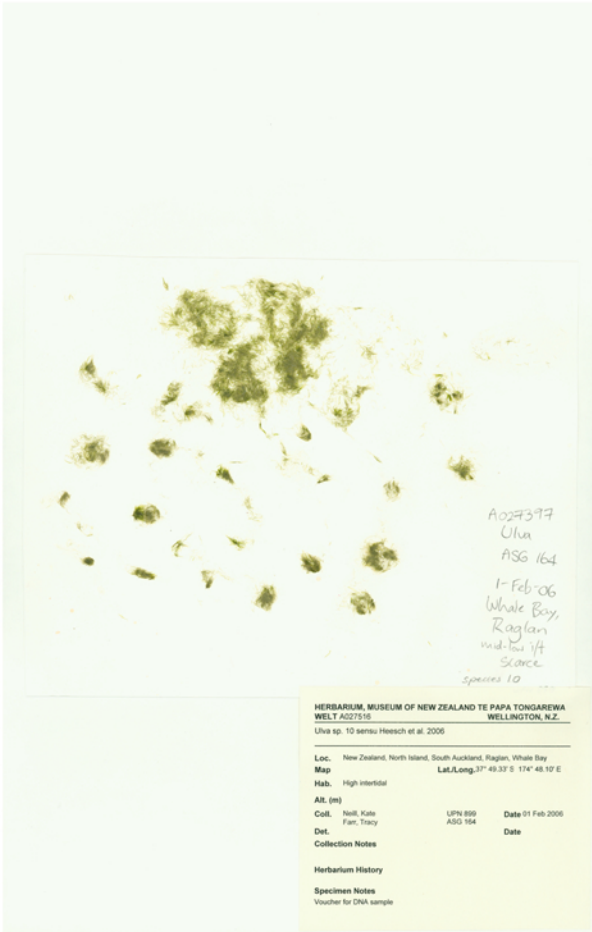


Fig. 70: *Ulva* species 10

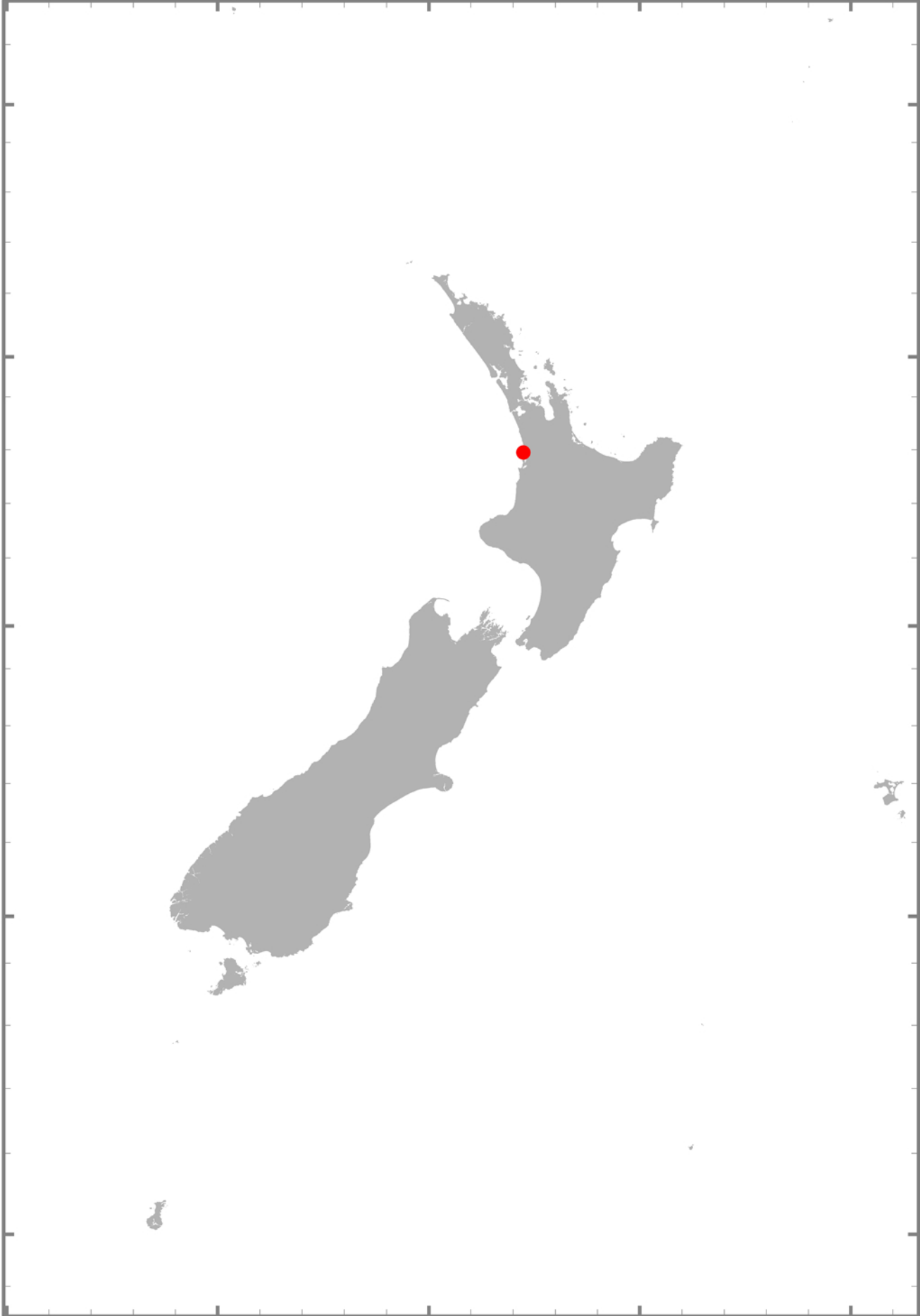
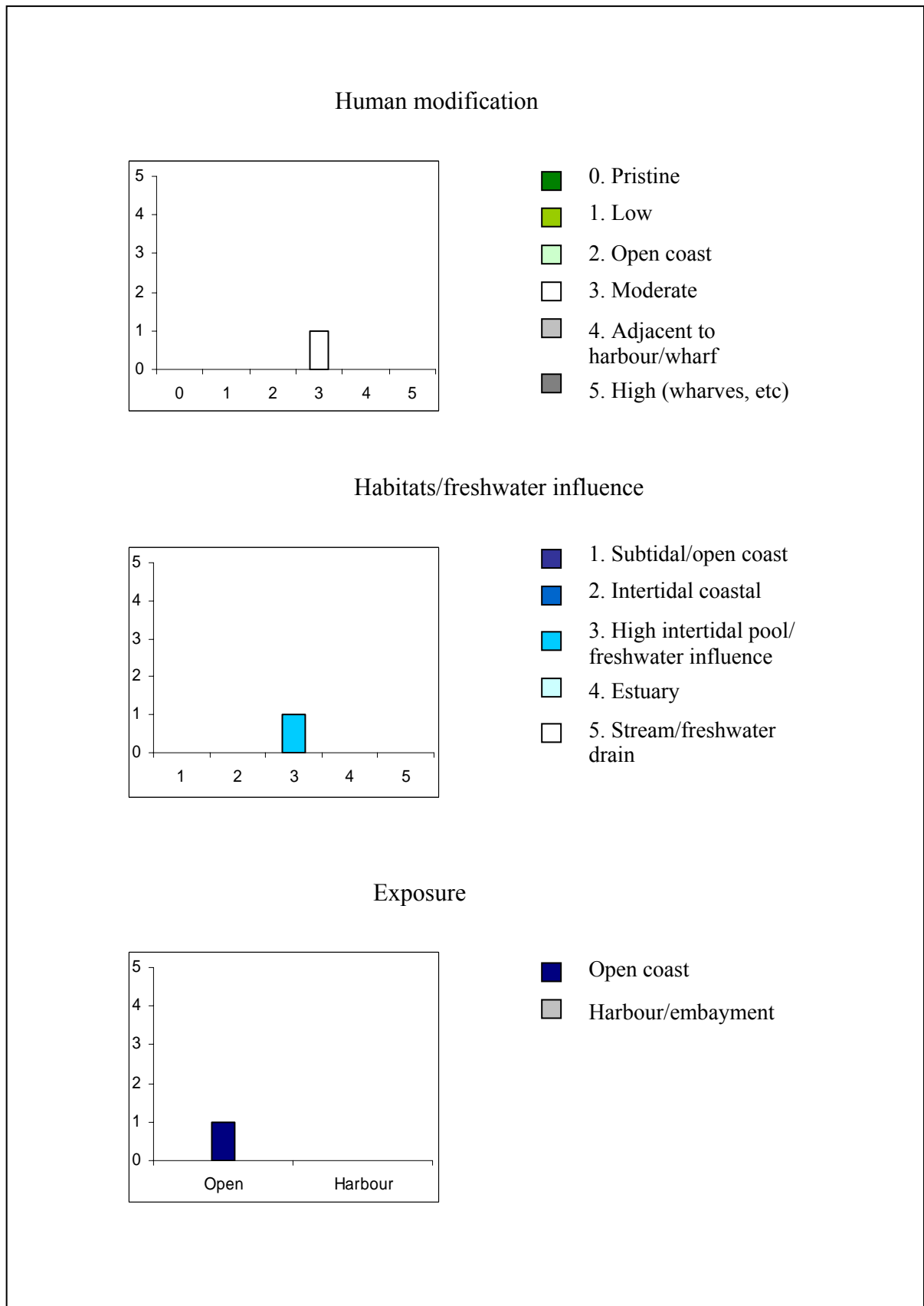


Fig. 71: *Ulva* species 10. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Gemina letterstedtioidea* V.J.Chapm.**

Figs 72 - 74

Publication details: *G. letterstedtioidea* V.J. Chapman 1952: 52-53

Type locality: Auckland Is. (CHR 44096).

SPECIES DESCRIPTION:

Thallus membranaceous, compressed, up to 8 cm long and 1 cm wide, attenuate to a stipe; plants entire or perforate, simple or branched, main thallus or branches linear or expanding into a lobe; cells 7.5-11  $\mu\text{m}$  diameter, average 8  $\mu\text{m}$ , in pairs, the pairs in short rows, 49  $\mu\text{m}$  high in transverse section; membrane 116  $\mu\text{m}$  wide, the outer wall up to 7  $\mu\text{m}$  thick.

DESCRIPTION – NEW ZEALAND SPECIMENS:

Thalli were sheet-like or lobed blades, without ruffles, and of a grey-green colour when fresh and very dark when dry. Specimens up to 1 m length have been sampled. In surface view, cells were 5-9  $\mu\text{m}$  in diameter and occurred in pairs or groups of four, surrounded by a common cell wall. In transverse sections cells were palisade-like and ca. 30  $\mu\text{m}$  high, with tapering ends of sister cells often leaning towards each other. The whole membrane reached ca. 75-80  $\mu\text{m}$  width. None of the thalli were fertile.

HABITAT:

All samples were from exposed, open coast habitats, from pristine sites or sites with only low human impact. Five of the six samples were collected in the subtidal, mostly from water depths of 4-8 m; one sample was hauled up on an anchor from 15 m depth. Another specimen was found in the lower intertidal zone.

DISTRIBUTION:

This entity was only collected from the subantarctic islands, i.e., Antipodes and Auckland Islands.

REFERENCE SPECIMENS: WELT A027235, A027326, A027327

COMMENTS:

The genus *Gemina* was described by Chapman (1952) for five species from the subantarctic islands and Stewart Island. The type species of the genus, *G. enteromorphaidea* V.J.Chapm., as well as *G. ulvoidea* V.J.Chapm. and *G. clavata* V.J.Chapm. all possess a thin membrane, while the membrane of the other two species, *G. letterstedtioidea* V.J.Chapm. and *G. linzoidea* V.J.Chapm., is thicker. *G. enteromorphaidea* is further distinguished from the other distromatic *Gemina* species by its tubular thallus. The size of cells in surface view overlap in all five species, raising the question whether the differences in habit between some of the species may be due to environmental factors or the maturity of thalli, e.g., whether *G. clavata* could be a juvenile form of the larger *G. ulvoidea*. If this is the case, only three species would be included in the genus, i.e., *G. enteromorphaidea*, *G. ulvoidea* and *G. letterstedtioidea*.

In the present study, six specimens from the subantarctic islands were identified as belonging to *Gemina*. Their morphological characters agreed well with the genus description by Chapman: They all showed the typical arrangement of cells in groups of 2-4 enveloped by the mother cell wall, and cells in transverse sections had a palisade-like shape. The *rbcL* sequences of all six specimens were identical or almost identical, indicating the presence of a single species. *Gemina letterstedtioidea* was described from material collected at the Auckland Islands, where two of the six sequenced specimens were collected, suggesting that the name *G. letterstedtioidea* should be chosen for this entity.

Chapman (1956) also recorded *Gemina* sp. from Stewart Island. An *Ulva*-like specimen collected on Stewart Island in January 2006 (R. Dewdney, pers. comm.) indeed showed the typical arrangement of cells in pairs surrounded by a common cell wall. Unfortunately this sample was preserved in formalin and thus could not be used for DNA sequence analyses.

**Reference:**

Chapman, V.J. (1952). New entities in the Chlorophyceae of New Zealand. *Transactions of the Royal Society of New Zealand* 80(1): 47-58.

Fig. 72: *Gemina letterstedtioidea*



Fig. 73: *Gemina letterstedtioidea*

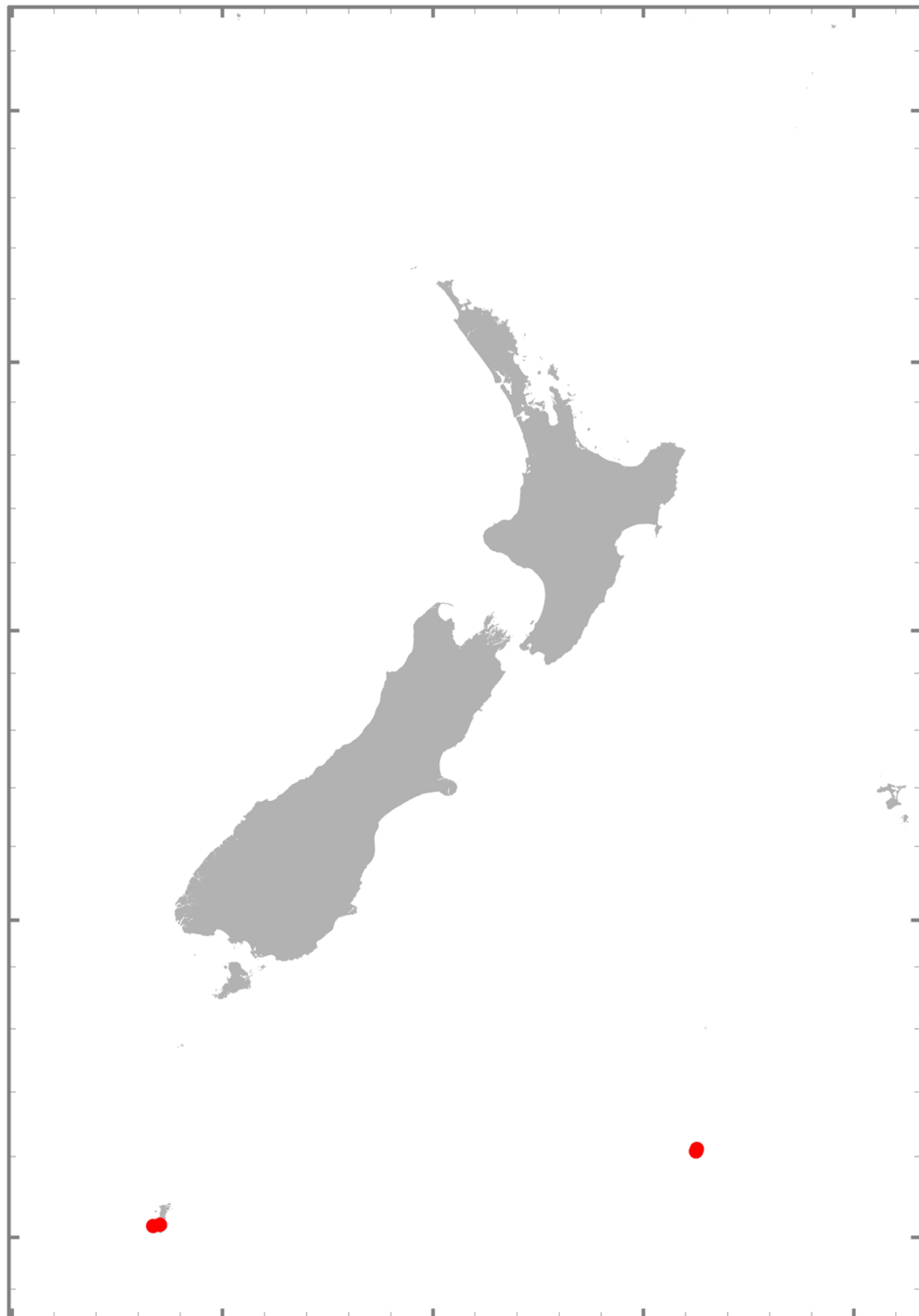
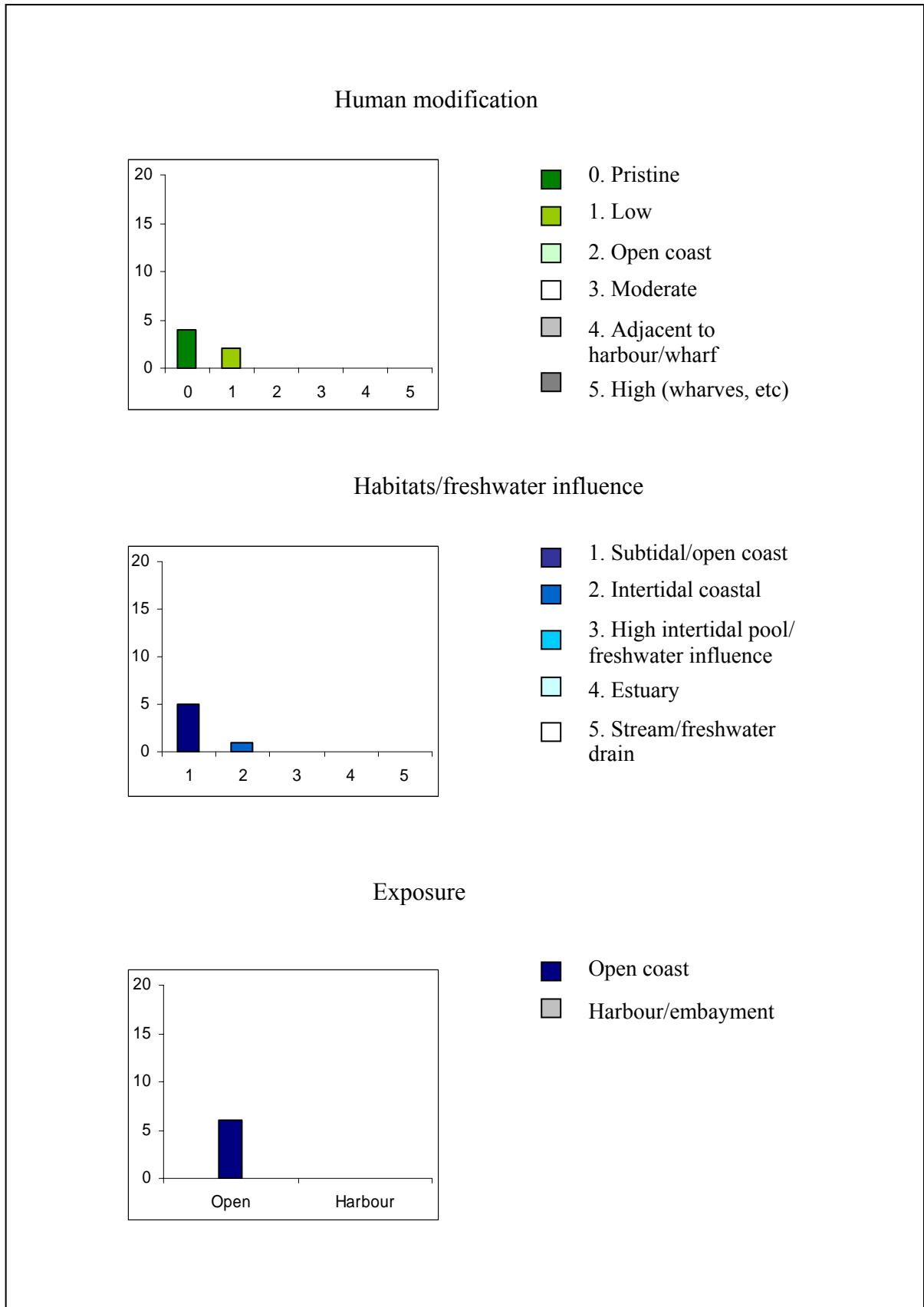


Fig. 74: *Gemina letterstedtioidea*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Umbraulva "Kermadecs"***

Figs 75 - 77

DESCRIPTION – NEW ZEALAND SPECIMENS:

Specimens had bladed thalli, which were kidney-shaped (15 x 40 mm) or formed small rosettes (30 x 40 mm). The herbarium specimens were obviously discoloured, but the DNA samples retained their colour, a pale to dark olive green. In surface view, cells were quadrangular to rectangular, 5-12 µm long and 5-8 µm wide. Cell walls appeared to be very thin.

HABITAT:

The specimens were collected in the subtidal of a pristine open coast site. They grew in 15.7 m depth on coral rubble. All material came from the same collection site.

DISTRIBUTION:

This entity was only collected in the Kermadec Islands.

REFERENCE SPECIMEN: WELT A027319

COMMENTS:

This entity is so far undescribed. Even though it was collected only once, its occurrence in a pristine area indicates that it is most likely to be a native species.

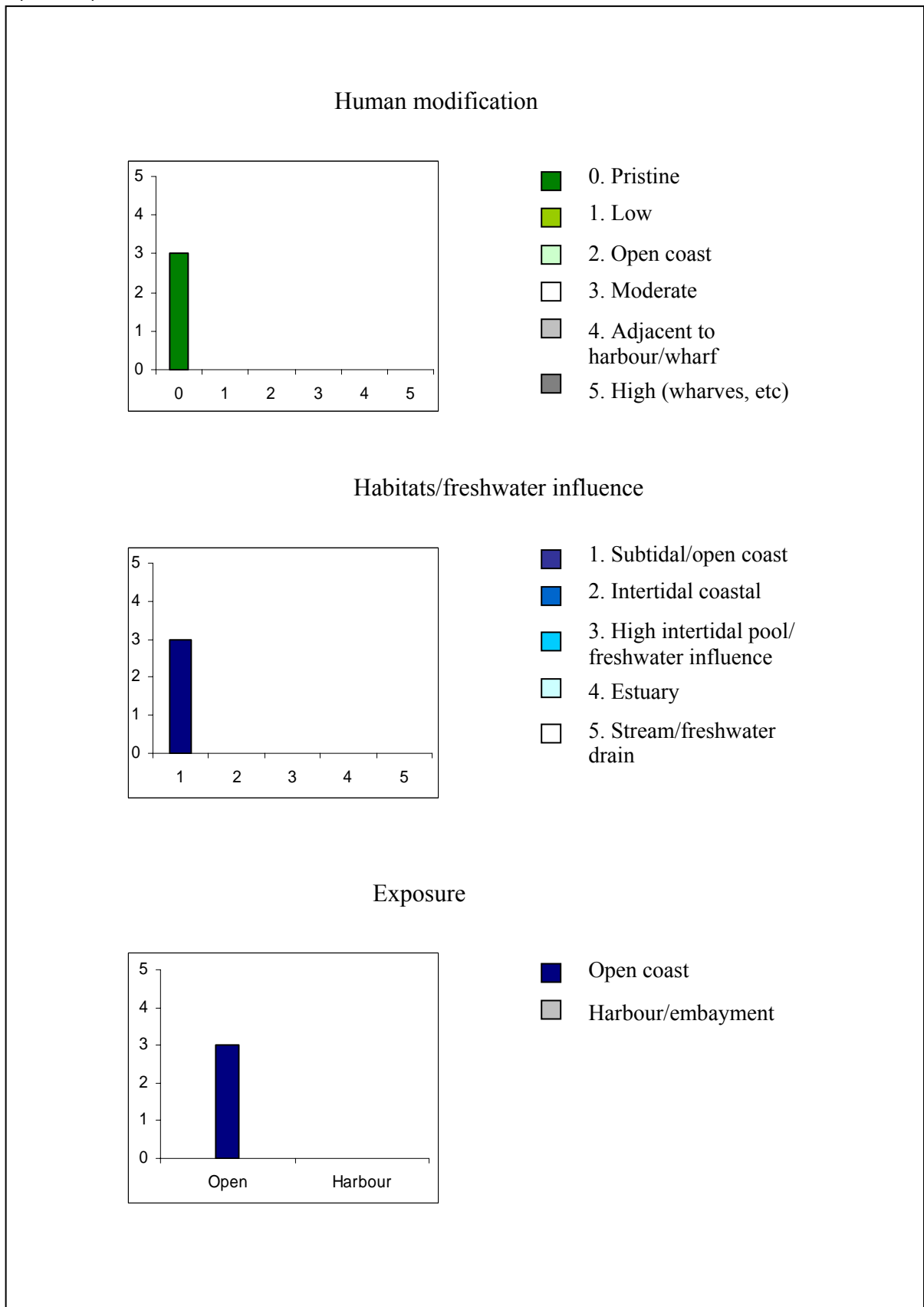
Fig. 75: *Umbraulva* “Kermadecs”



Fig. 76: *Umbraulva* “Kermadecs”



Fig. 77: *Umbraulva* “Kermadecs”. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Umbraulva olivascens* (Dangeard) Bae & I.K. Lee**

Figs 78 - 80

Publication details: *Umbraulva olivascens* (Dangeard) Bae & I.K.Lee 2001: 230

Basionym: *Ulva olivascens* P.J.L. Dangeard 1951: 27-34.

Type locality: Roscoff, Brittany, France

SPECIES DESCRIPTION:

Attached with a discoid holdfast and expanded as an orbicular to irregularly round form sometime with undulated margin. Olive to brownish green, and more or less deeper green in short basal region. Blade perforated and with or without lobes, 10-20 cm long (rarely to 1 m length), 10-15 cm broad. Young thalli with orbicular shape similar to *U. lactuca* but clearly differing in colour. Cells polygonal and large from 24 x 18 µm to 35 x 24 µm in surface view. Plastid single, parietal and with generally pyrenoid. (after Bae & Lee 2001)

DESCRIPTION – NEW ZEALAND SPECIMENS:

The New Zealand specimen consisted of a single blade with many round to oval holes throughout the thallus. The pale olive thallus was irregularly shaped, ca. 320 mm long and 160 mm wide at its widest region. The specimen was not fertile and did not have a base remaining on the thallus. Cells were polygonal, rectangular or triangular, 12-24 µm long and 8-15 µm wide, often arranged in groups of 2 to 4 but not enveloped by a common cell wall, and had 1 (-2) pyrenoids.

HABITAT:

*U. olivascens* was found in a sheltered harbour. It grew at 4-6 m depth on wharf structures in an environment with a high human impact factor.

DISTRIBUTION- NEW ZEALAND:

This species was collected once from Timaru Harbour, South Island.

DISTRIBUTION – OUTSIDE NEW ZEALAND:

Europe: Britain, Spain; Atlantic Islands: Canary Islands (Guiry 2006)

REFERENCE SPECIMEN: WELT A027321

COMMENTS:

Bae & Lee (2001) separated the genus *Umbraulva* from *Ulva* based on the presence of an additional accessory pigment, siphonaxanthin, resulting in olive coloured thalli, and on a subtidal habitat, as well as genetic differences within ITS and 18S nrDNA sequences. Currently, *Umbraulva* comprises three species, *U. olivascens*, *U. amamiensis* (Tanaka) Bae & I.K. Lee and the type species *U. japonica* (Dangeard) Bae & I.K.Lee (Bae & Lee 2001).

*U. olivascens* was described from Brittany, France. Generally it occurs along European coasts of the Atlantic Ocean and in the southern Mediterranean Sea. It is found in the

subtidal to depths of 15 m. Its olive green colour makes it easy to distinguish from other European Ulvaceae.

The New Zealand specimen had an *rbcL* sequence nearly identical to the sequence in GenBank which originated from a sample from Ireland. Its morphology agreed well with observations on specimens from Europe, e.g. the highly perforated thallus. The presence of *Umbraulva olivascens* in New Zealand with a single representative collected from a wharf suggests that it has been introduced.

**References:**

- Bae, E. H.; Lee, I. K. (2001). *Umbraulva*, a New Genus Based on *Ulva japonica* (Holmes) Papenfuss (Ulvaceae, Chlorophyta). *Algae* 16(3): 217-231.
- Dangeard, P. (1951). Sur une espèce d'*Ulva* de nos côtes atlantiques (*U. olivacea* n. sp.). *Le Botaniste* 35: 27-34.

Fig. 78: *Umbraulva olivascens*



Fig. 79: *Umbraulva olivascens*

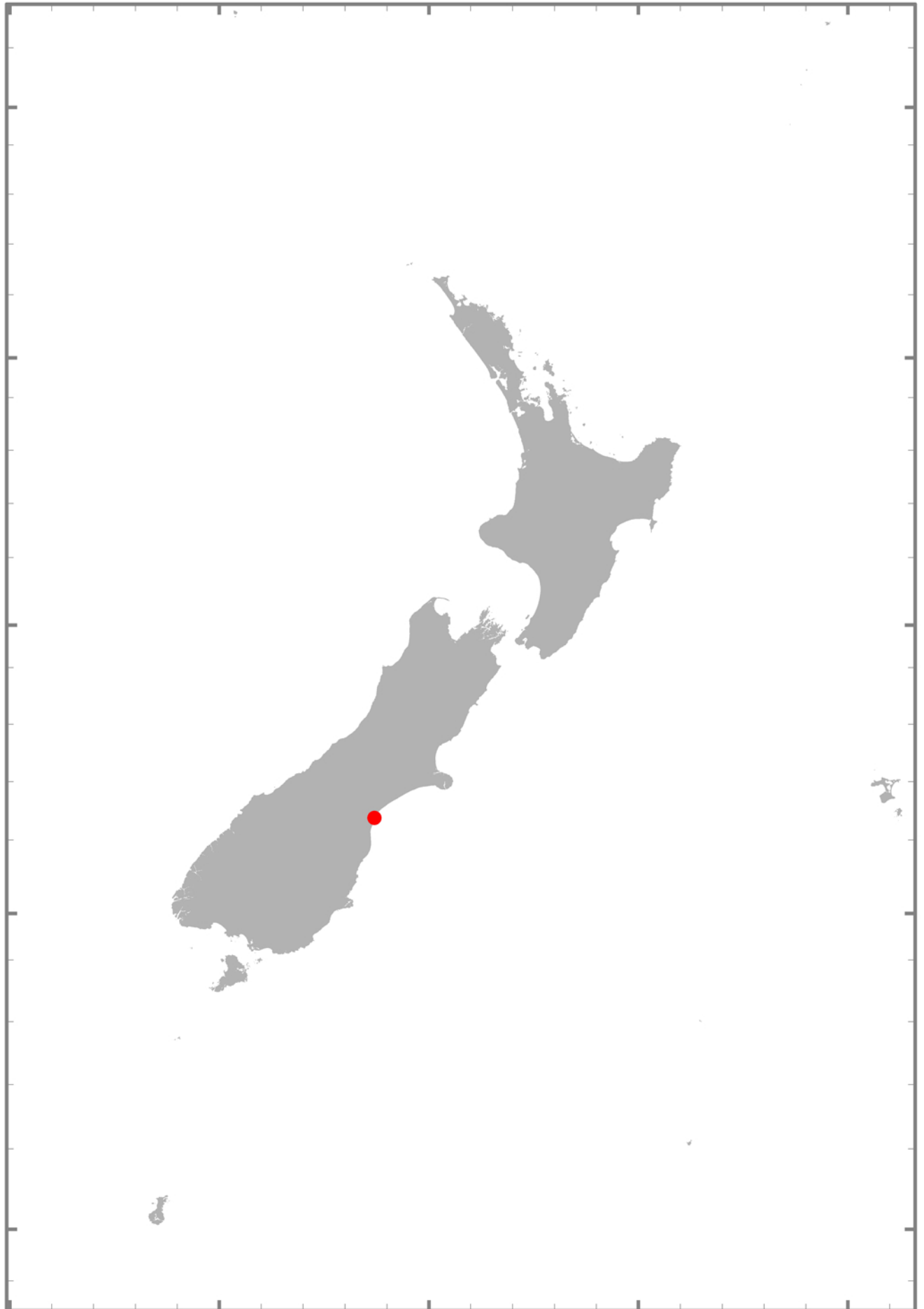
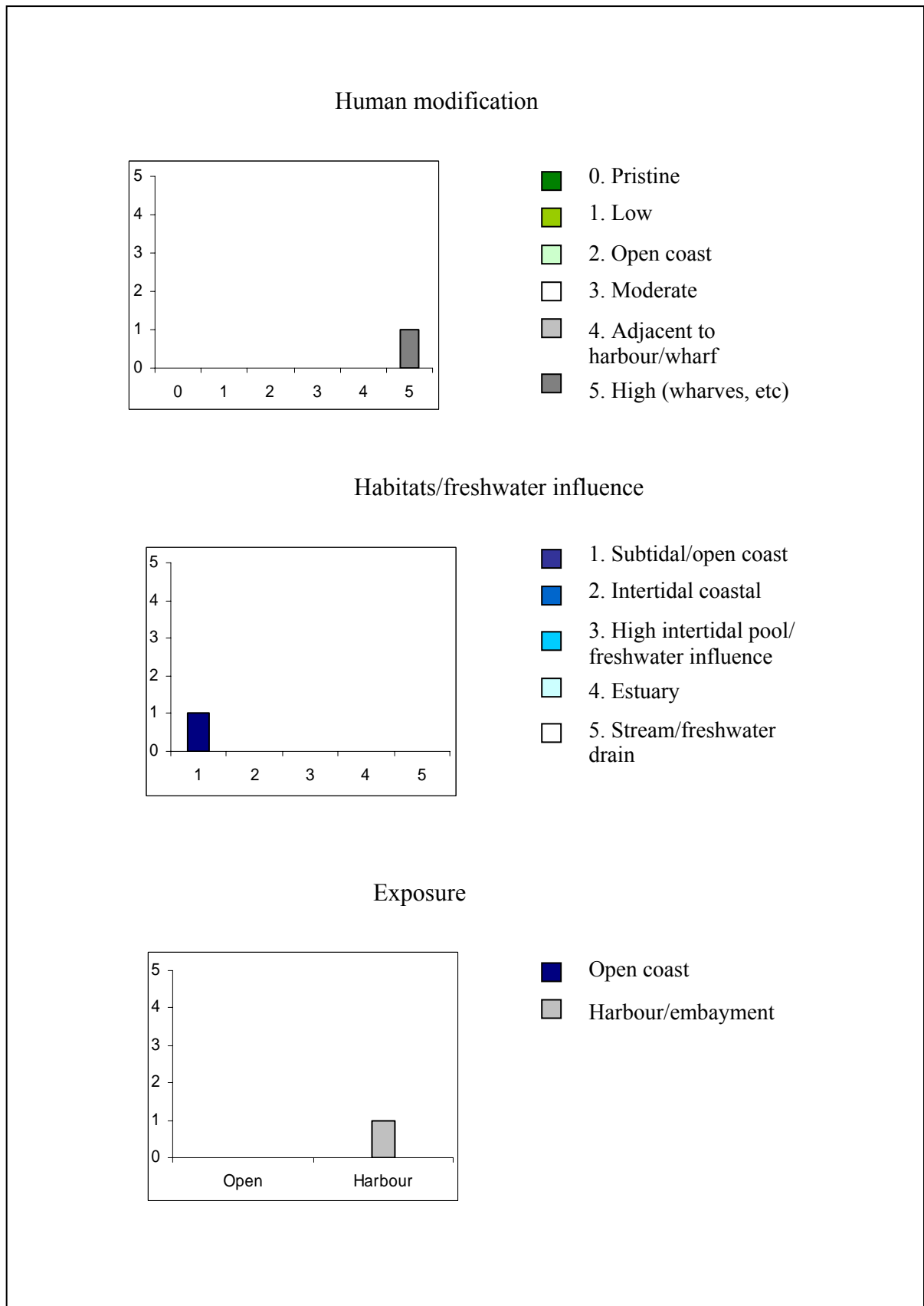


Fig. 80: *Umbraulva olivascens*. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



***Umbraulva* "Northland"**

Figs 81 - 83

DESCRIPTION – NEW ZEALAND SPECIMENS:

Specimens of this entity displayed large bladed thalli with irregular margins and a distinct olive green colour (colour of dry specimens: 153A, 152B-C). Blades reached up to 270 mm in length and 60 mm in width. The thalli were not fertile. In surface view, cells were round to rectangular, up to 23  $\mu\text{m}$  long and 10  $\mu\text{m}$  wide. Cells were not arranged in obvious patterns, but formed groups of 2 and 3. These groups were not surrounded by a common cell wall. In transverse sections, cells were rectangular without tapered ends, reaching heights of 25  $\mu\text{m}$  and widths of 20  $\mu\text{m}$ .

HABITAT:

This entity grew in 20 m water depth in the subtidal of a little modified open coast site.

DISTRIBUTION:

This entity was collected once from Karikari Bay, Northland.

REFERENCE SPECIMEN: WELT A027396

COMMENTS:

As with the other three *Umbraulva* species reported here, this entity was only represented by a single subtidal sample. This entity may have a wider geographical distribution than the single collection suggests.

Fig. 81: *Umbraulva* “Northland”



Fig. 82: *Umbraulva* “Northland”

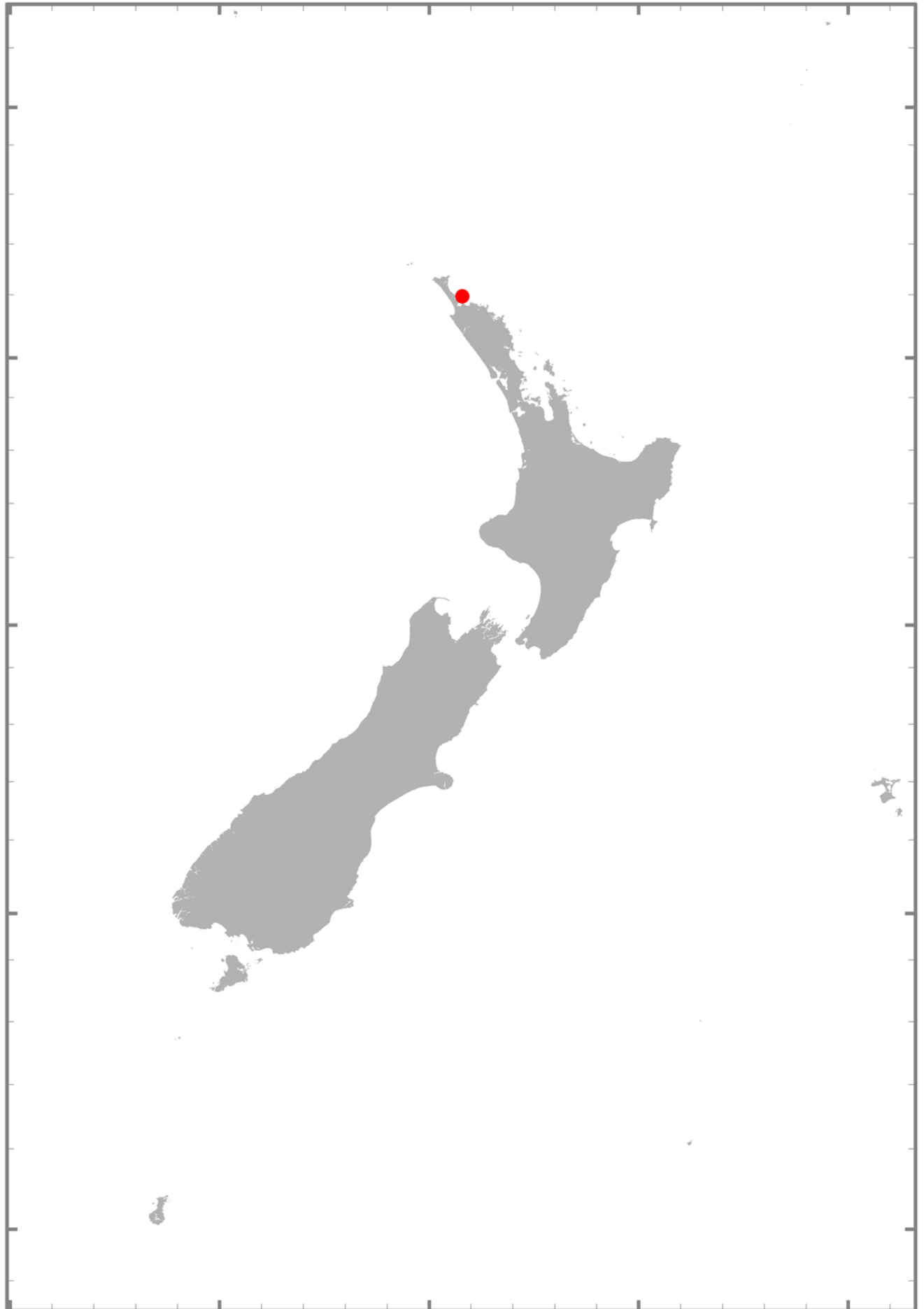
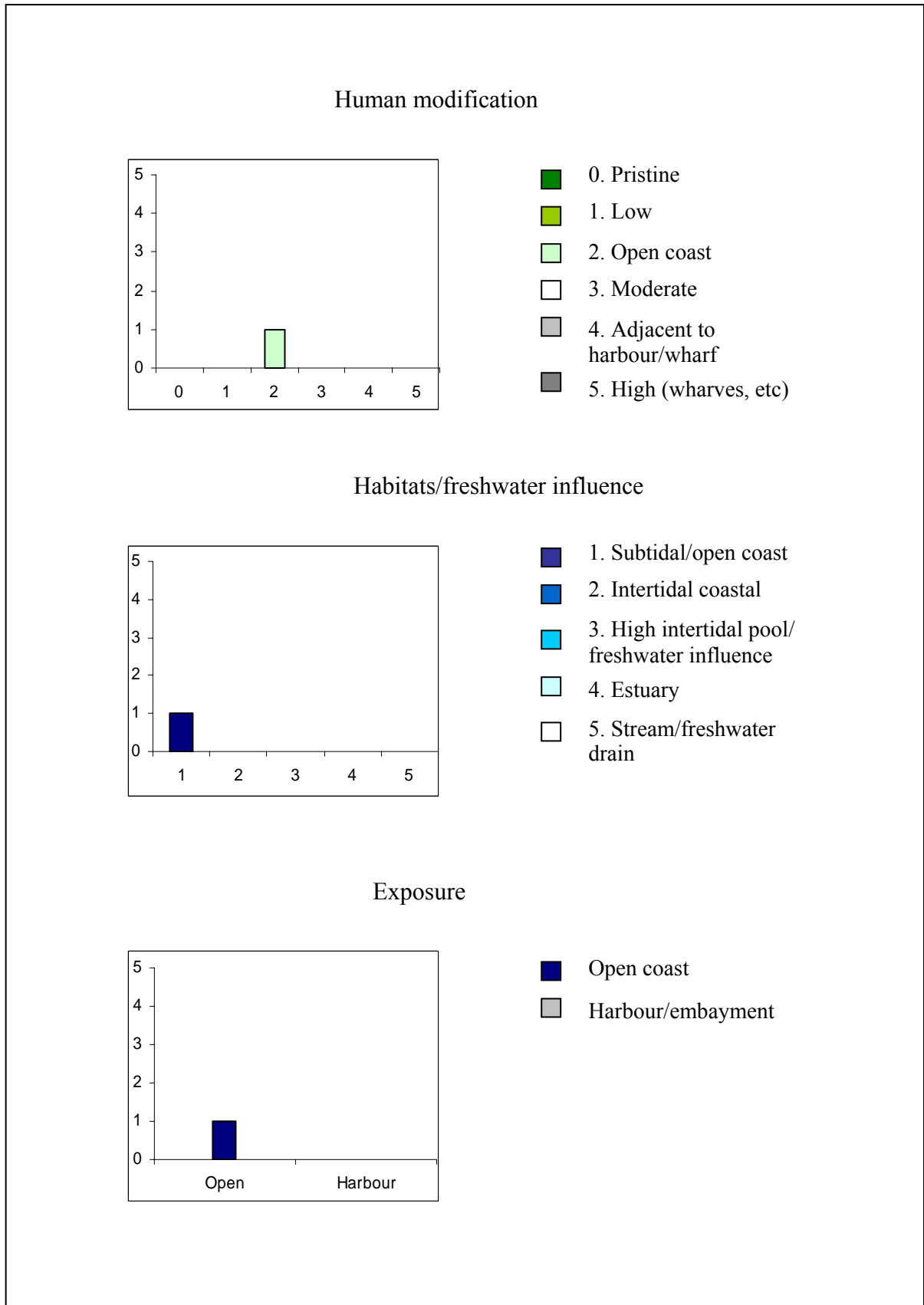


Fig. 83: *Umbraulva* “Northland”. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



## ***Umbraulva* "Auckland Islands"**

Figs 84 - 86

### DESCRIPTION – NEW ZEALAND SPECIMENS:

A single bladed specimen was collected subtidally from Shoe Island in the Auckland Islands. The sole thallus collected was dried in silica gel. The subsequent crumbling of the sample has meant that no gross morphological features have been able to be recorded, nor measurements made on the thallus.

### HABITAT:

The specimen was collected at 6 m depth from an open coast site with low human influence.

### DISTRIBUTION:

This entity is based on a single collection from Shoe Island in the Auckland Islands.

### REFERENCE SPECIMEN: WELT A027521

### COMMENTS:

A number of bladed taxa in the Ulvaceae have been described from the New Zealand subantarctic islands. From the results of this study these may be species of *Gemina*, *Ulva* or *Umbraulva*. Apart from five species included in his new genus *Gemina*, Chapman also described two species of *Ulva* from the subantarctic islands, *Ulva sorensenii* V.J.Chapm., and *Ulva geminoidea* var. *geminoidea* V.J. Chapm. In addition, in the key to the *Ulva* species of New Zealand, Chapman (1956) mentions a variety of *U. lactuca*, *U. lactuca* var. *aucklandica* (Chapman 1956, p. 386) as an olive-green plant, "restricted to Antarctic Islands". However, there is no further treatment of this entity in the text, nor are any references to this entity to be found elsewhere in the literature or in AlgaeBase, leaving this variety as a nomen nudum.

The *Umbraulva* "Auckland Islands" specimen had neither the typical arrangement of cells in pairs enveloped by a cell wall typical for the genus *Gemina* and *Ulva geminoidea* var. *geminoidea*, nor the brownish colour displayed by *Ulva sorensenii*. Adams (1994) points out, however, that the specimen, on which the description of *U. sorensenii* was based, was apparently discoloured by transport in a rusty tin.

Further collections of this entity are required before its morphology, anatomy and ecology can be thoroughly described.

Fig. 84: *Umbraulva* “Auckland Is.”

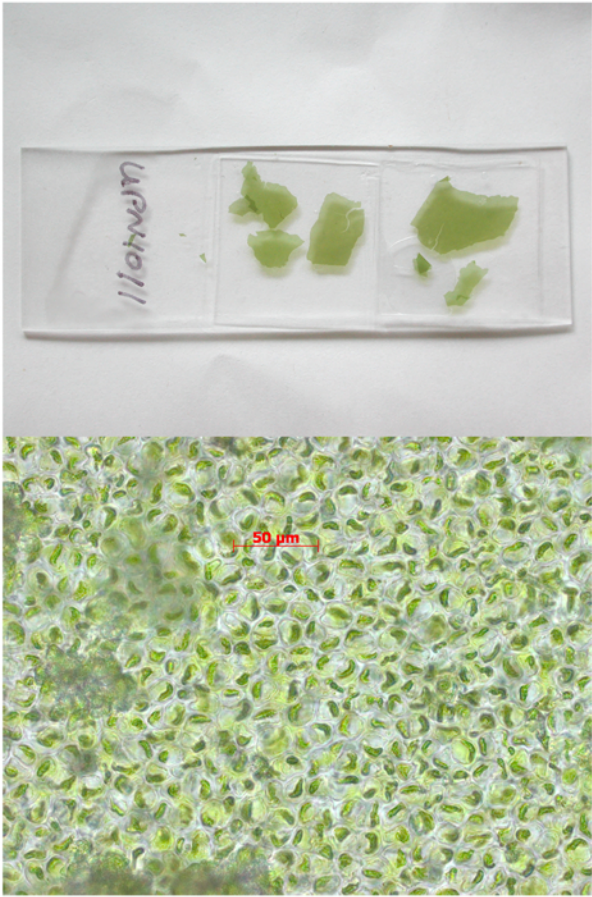
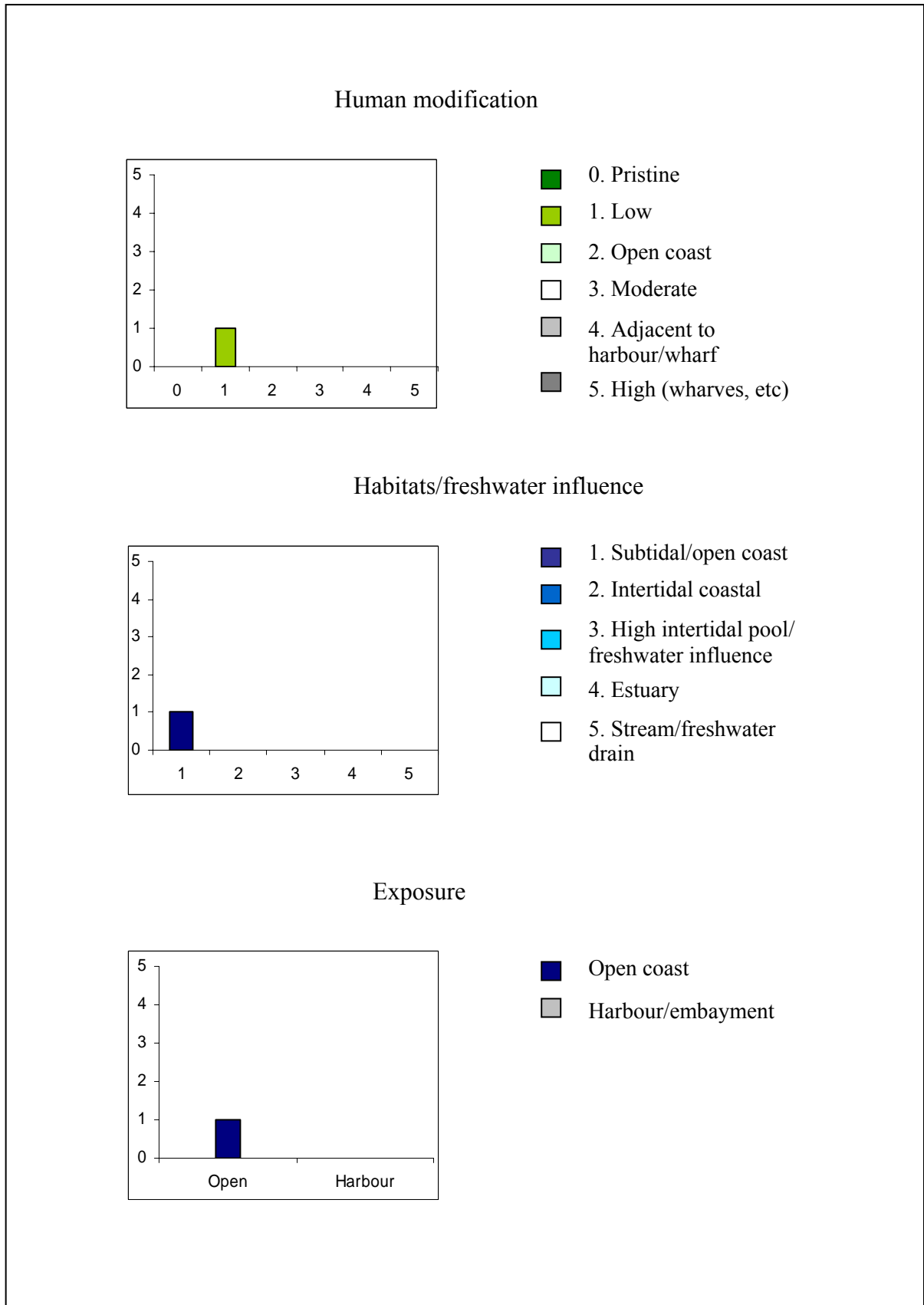


Fig. 85: *Umbraulva* “Auckland Is.”



Fig. 86: *Umbraulva* “Auckland Is.”. Number of samples (y axis) found in habitats categorised by different levels of human modification, freshwater influence and exposure (x axes).



### Species distributions:

#### Collections studied and distribution of taxa

Collections were made from throughout the New Zealand region. Figures 1 & 87 show the location of collection sites and the summaries by season of collecting effort and regions sampled. Approximately equal numbers of samples came from open coast sites (299) as from sites in harbours and embayments (282) (Table 4).

Table 4: Distribution of species in relation to exposure/shelter

	Open coast	Harbour/ embayment	Total
<i>Ulva armoricana</i>	3	5	8
<i>Ulva californica</i>	1	2	3
<i>Ulva compressa</i>	58	51	109
<i>Ulva fasciata</i>	3	0	3
<i>Ulva flexuosa</i>	0	1	1
<i>Ulva intestinalis</i>	28	32	60
<i>Ulva lactuca</i>	0	3	3
<i>Ulva linza</i>	1	1	2
<i>Ulva pertusa</i>	65	59	124
<i>Ulva procera</i>	15	14	29
<i>Ulva prolifera</i>	5	6	11
<i>Ulva rigida</i>	5	12	17
Ulva sp 1	74	83	157
Ulva sp 2	12	15	27
Ulva sp 4	1	0	1
Ulva sp 5 " <i>U. ralfsii</i> "	10	0	10
Ulva sp 6	2	0	2
Ulva sp 9	0	1	1
Ulva sp 10	1	0	1
<i>Gemina letterstedtioidea</i>	6	0	6
<i>Umbraulva</i> "Auckland Is"	1	0	1
<i>Umbraulva</i> "Northland"	1	0	1
<i>Umbraulva olivascens</i>	0	1	1
<i>Umbraulva</i> "Kermadecs"	3	0	3
	299	282	581

There were only 36 subtidal collections in which 11 species were recorded (*Gemina letterstedtioidea*, *Umbraulva olivascens*, *Umbraulva* "Kermadecs", *Umbraulva* "Auckland Islands", *Umbraulva* "Northland", *U. armoricana*, *U. fasciata*, *U. linza*, *U. pertusa*, *U. rigida*, *Ulva* species 1). Of these, the *Umbraulva* species and *U. fasciata* were found solely in subtidal habitats. Seventeen collections were made from freshwater streams or drains from which 6 taxa were identified (*U. compressa*, *U. intestinalis*, *U. pertusa*, *Ulva* species 1, *Ulva* species 5 "*U. ralfsii*", *Ulva* species 6). Of these species all but *Ulva* species 6 are known from other habitat types: *Ulva* species 6 is currently known from a single collection site.

Fig. 87: New Zealand - sampling by season

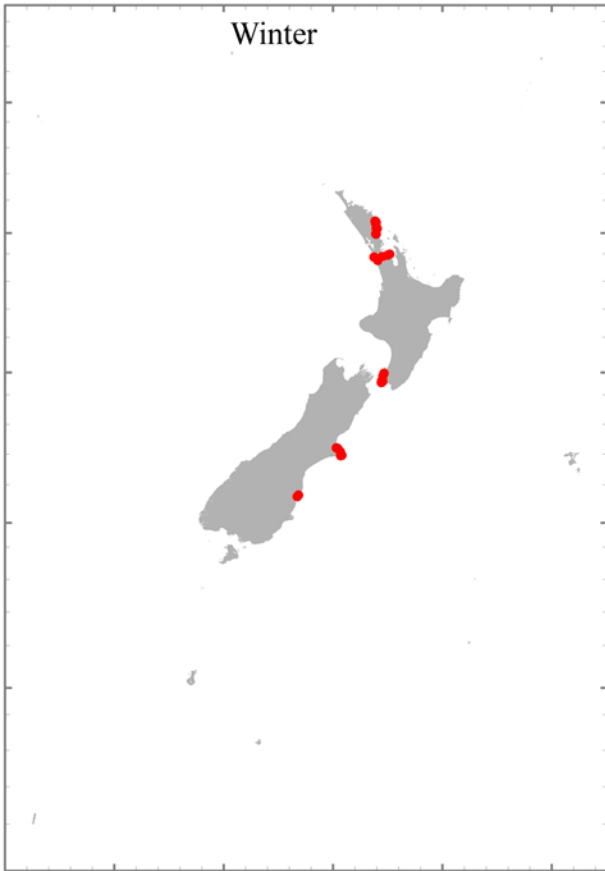
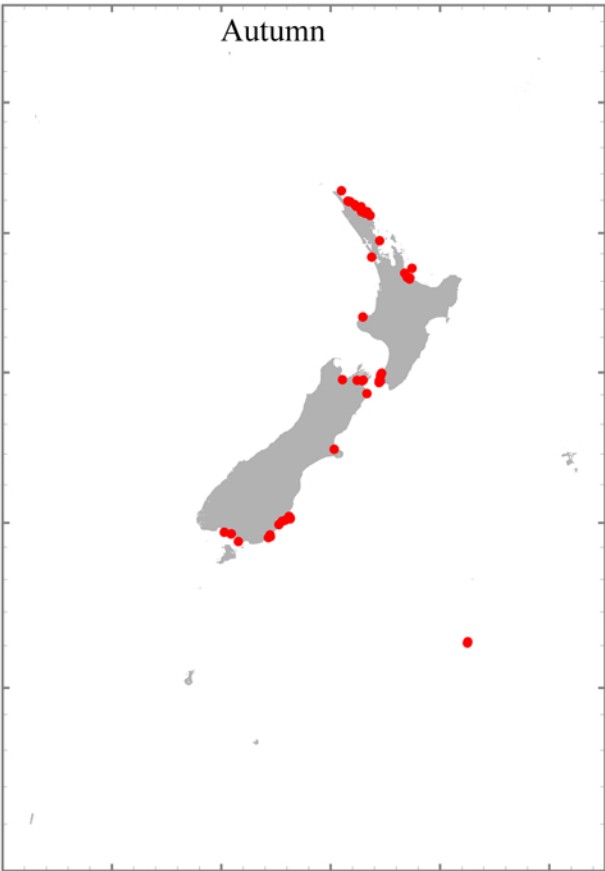
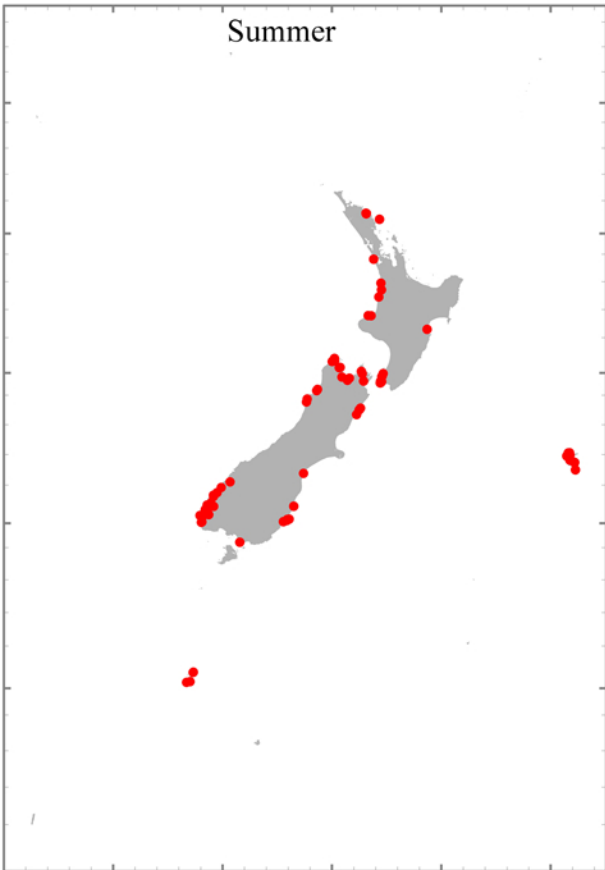
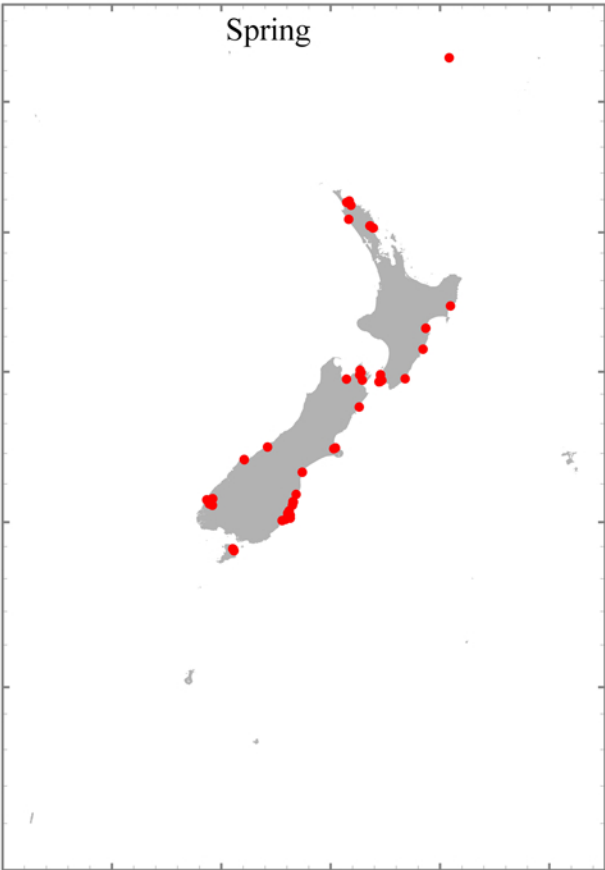


Table 5: Distribution of species in relation to habitat and freshwater influence

	Subtidal/ open coast	Intertidal coastal	High tidepool/ FW influence	Estuary	Stream/ FW drain	Total
<i>Ulva armoricana</i>	2	2	3	1	0	8
<i>Ulva californica</i>	0	0	3	0	0	3
<i>Ulva compressa</i>	0	46	33	29	1	109
<i>Ulva fasciata</i>	3	0	0	0	0	3
<i>Ulva flexuosa</i>	0	0	1	0	0	1
<i>Ulva intestinalis</i>	0	20	11	19	10	60
<i>Ulva lactuca</i>	0	0	3	0	0	3
<i>Ulva linza</i>	1	1	0	0	0	2
<i>Ulva pertusa</i>	14	39	54	16	1	124
<i>Ulva procera</i>	0	15	7	7	0	29
<i>Ulva prolifera</i>	0	5	1	5	0	11
<i>Ulva rigida</i>	3	3	9	2	0	17
<i>Ulva</i> sp 1	2	68	58	27	2	157
<i>Ulva</i> sp 2	0	16	11	0	0	27
<i>Ulva</i> sp 4	0	1	0	0	0	1
<i>Ulva</i> sp 5 " <i>U. ralfsii</i> "	0	1	2	6	1	10
<i>Ulva</i> sp 6	0	0	0	0	2	2
<i>Ulva</i> sp 9	0	0	1	0	0	1
<i>Ulva</i> sp 10	0	0	1	0	0	1
<i>Gemina letterstedtioidea</i>	5	1	0	0	0	6
<i>Umbraulva</i> "Auckland Is"	1	0	0	0	0	1
<i>Umbraulva</i> "Northland"	1	0	0	0	0	1
<i>Umbraulva olivascens</i>	1	0	0	0	0	1
<i>Umbraulva</i> "Kermadecs"	3	0	0	0	0	3
						581

An examination of the distribution of species throughout the New Zealand region selecting two 'mainland' areas known to be biogeographically distinct (Northland and Fiordland) as well as three island groups (Kermadec, Chatham, subantarctic) indicates that the flora varies across the region. In this study we found a greater diversity of taxa present in Northland than in other areas (12 taxa) although at most Northland sites *Ulva* spp. were not conspicuous in terms of population size or biomass present, in both intertidal and subtidal communities. Intertidal populations were considerably more conspicuous in both the Chatham Islands and in Fiordland, and in both of these areas 7 taxa were recorded. Some taxa are widespread (e.g. *Ulva* species 1) where others at present are known from single regions/island groups (e.g. *Umbraulva* spp.).

Table 6: Distribution of taxa at offshore island groups, Northland and Fiordland.

Species	Kermadec Is.	Northland	Chatham Is.	Fiordland	subantarctic islands
<i>Ulva armoricana</i>		✓			
<i>Ulva californica</i>					
<i>Ulva compressa</i>		✓	✓	✓	
<i>Ulva fasciata</i>		✓			
<i>Ulva flexuosa</i>					
<i>Ulva intestinalis</i>		✓	✓	✓	
<i>Ulva lactuca</i>					
<i>Ulva linza</i>			✓		
<i>Ulva pertusa</i>		✓	✓	✓	
<i>Ulva procera</i>		✓	✓	✓	
<i>Ulva prolifera</i>					
<i>Ulva rigida</i>				✓	
<i>Ulva</i> species 1		✓	✓	✓	✓
<i>Ulva</i> species 2		✓	✓		
<i>Ulva</i> species 4					
<i>Ulva</i> sp.5 " <i>U. ralfsii</i> "		✓		✓	
<i>Ulva</i> species 6		✓			
<i>Ulva</i> species 9		✓			
<i>Ulva</i> species 10					
<i>Gemina letterstedtioidea</i>					✓
<i>Umbraulva olivascens</i>					
<i>Umbraulva</i> "Kermadecs"	✓				
<i>Umbraulva</i> "Northland"		✓			
<i>Umbraulva</i> "Auckland Is"					✓

#### Seasonal distribution of taxa – Wellington, Dunedin

In Wellington a total of 9 taxa were present in the samples analysed (Figs. 88-89), and the species composition varied both at the sites visited, and seasonally (Table 7, Fig 89). In Dunedin a total of 10 taxa were present in the samples analysed (Figs 90-91) from three seasons. The species composition varied both at the sites visited, and seasonally (Table 8, Fig. 91). In both the Wellington and Dunedin samples analysed, the species *U. compressa*, *U. pertusa* and *Ulva* species 1 were present throughout the sampling period. These are also the most geographically widespread species in the New Zealand region.

Fig. 88: Wellington - all sampling

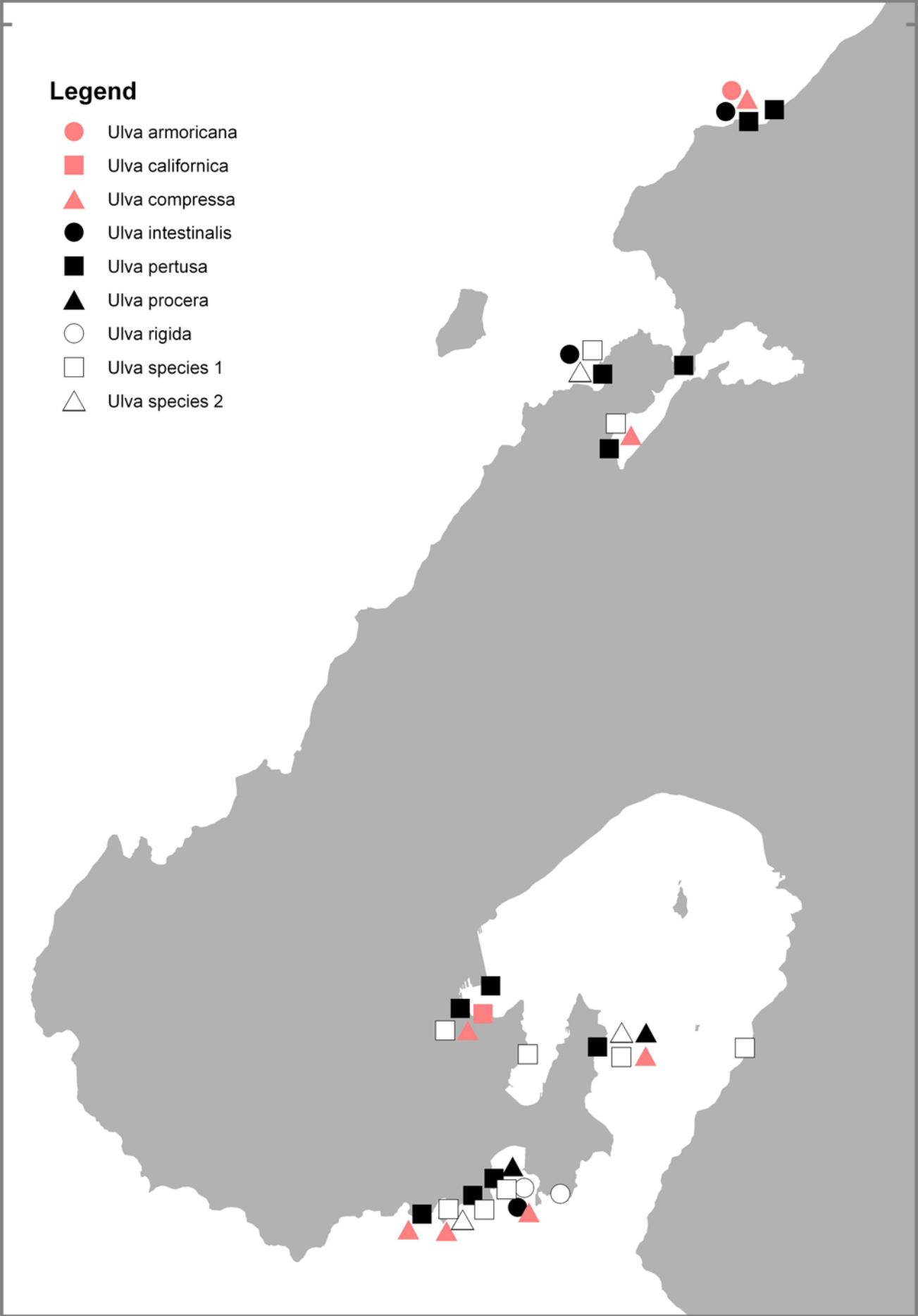


Fig. 89: Wellington - sampling by season

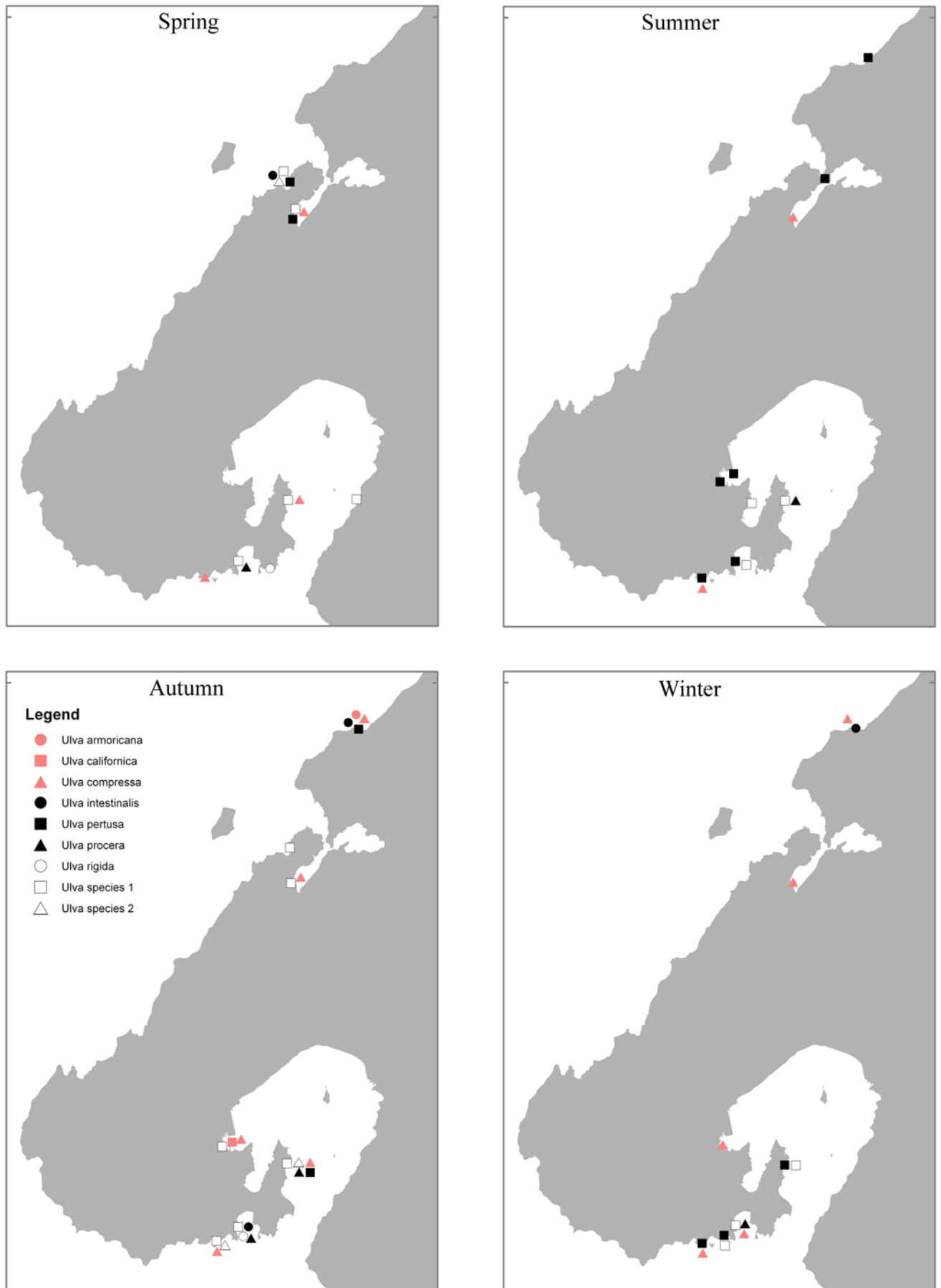


Fig. 90: Dunedin - all sampling

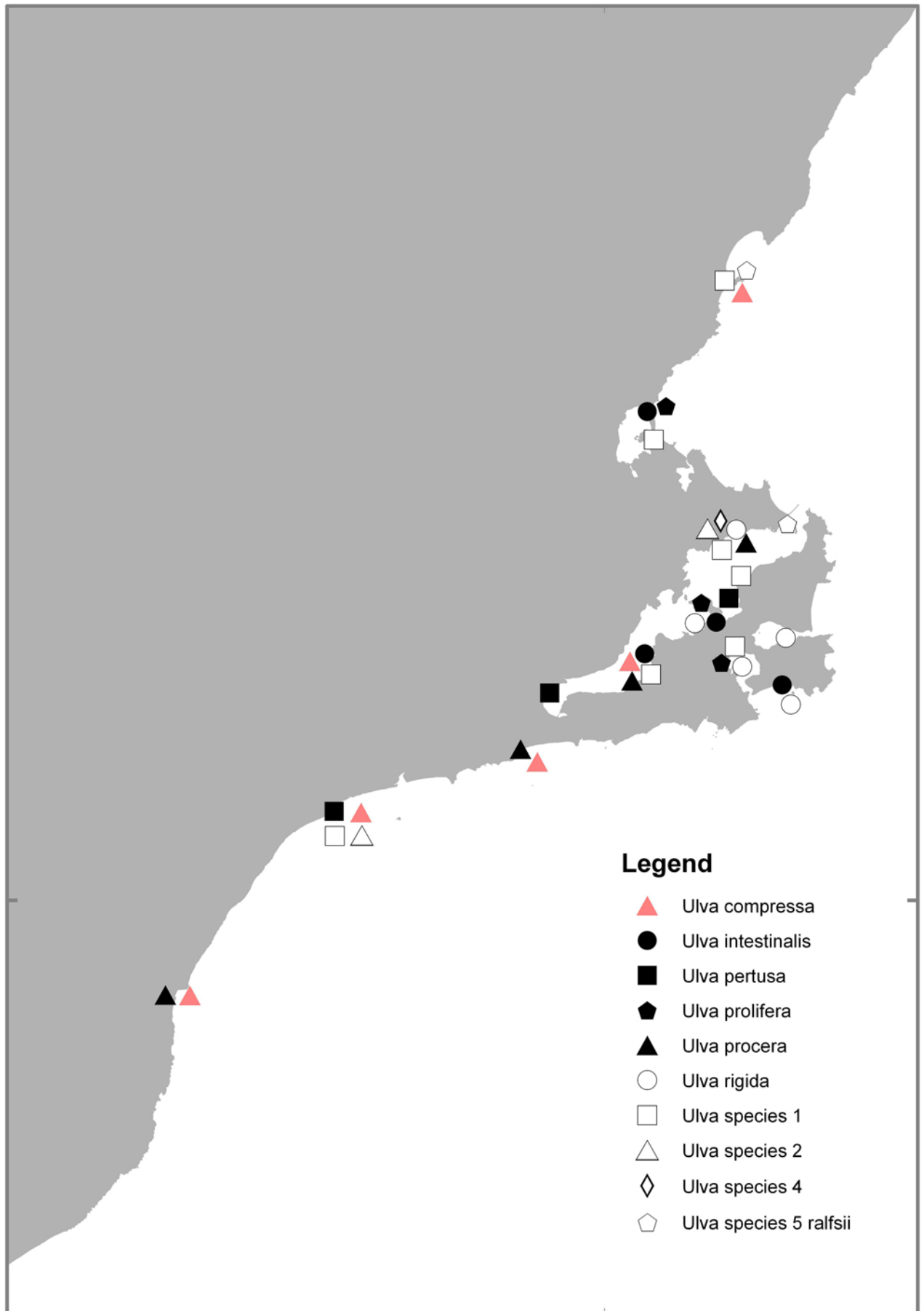


Fig. 91: Dunedin - sampling by season

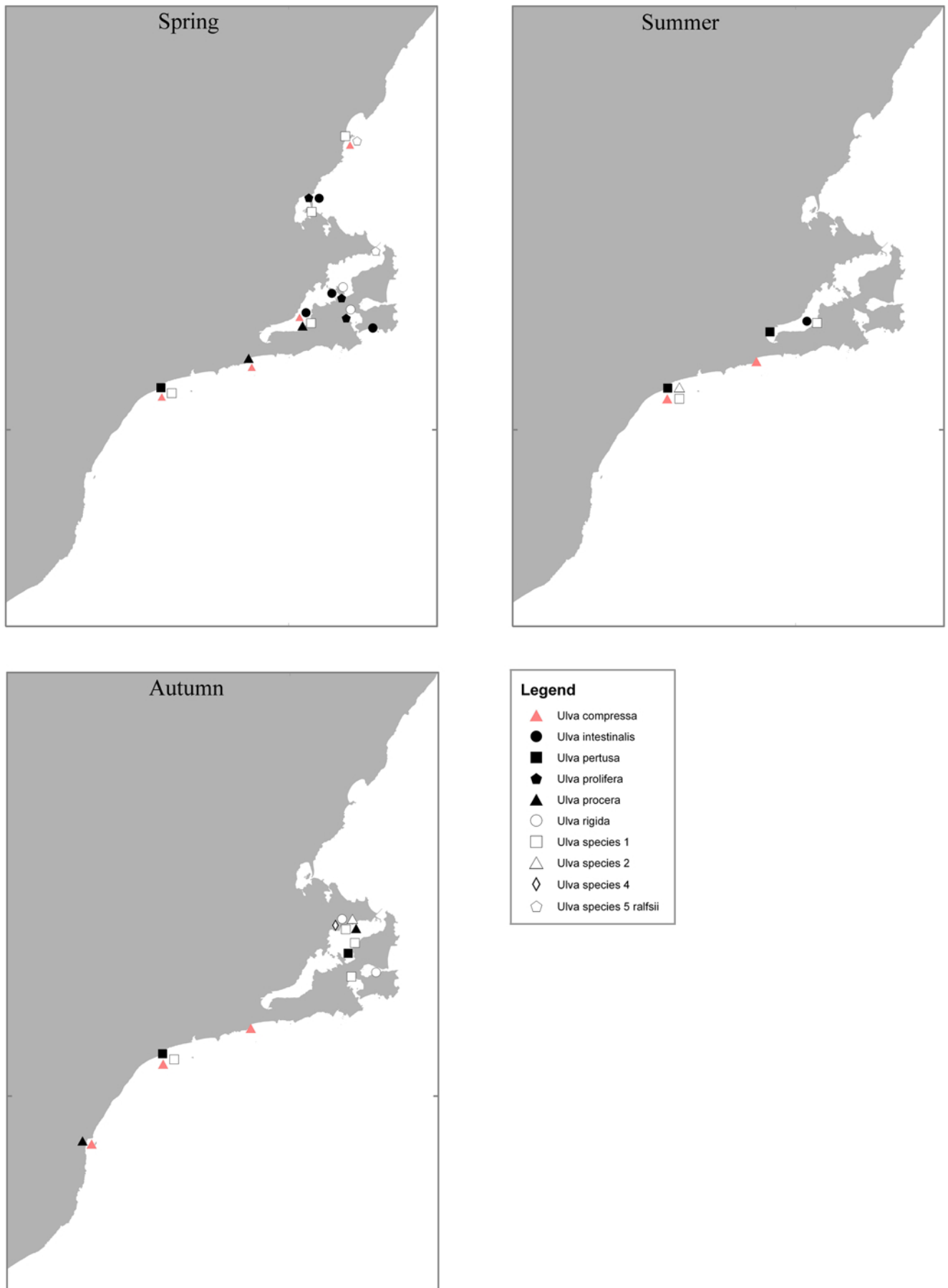


Table 7: Species composition in seasonal collections from the Wellington region

Species	Spring Sep-Nov	Summer Dec-Feb	Autumn Mar-May	Winter Jun-Aug
<i>U. armoricana</i>			✓	
<i>U. californica</i>			✓	
<i>U. compressa</i>	✓	✓	✓	✓
<i>U. intestinalis</i>	✓		✓	✓
<i>U. pertusa</i>	✓	✓	✓	✓
<i>U. procera</i>			✓	
<i>U. rigida</i>	✓		✓	
<i>Ulva</i> species 1	✓	✓	✓	✓
<i>Ulva</i> species 2			✓	

Table 8: Species composition in seasonal collections from the Dunedin region

Species	Spring Sep-Nov	Summer Dec-Feb	Autumn Mar-May
<i>U. compressa</i>	✓	✓	✓
<i>U. intestinalis</i>	✓	✓	
<i>U. pertusa</i>	✓	✓	✓
<i>U. procera</i>	✓		✓
<i>U. prolifera</i>	✓		
<i>U. rigida</i>	✓		✓
<i>Ulva</i> species 1	✓	✓	✓
<i>Ulva</i> species 2		✓	✓
<i>Ulva</i> species 4			✓
<i>Ulva</i> species 5 " <i>U. ralfsii</i> "	✓		

#### Habitats and human modification

Of the 74 sites visited in this study, 3 sites (at the Antipodes and Kermadec Islands) were scored as pristine, and a further 7 sites were recorded as having low volume of marine traffic (sites at Chatham, and Stewart and Auckland Islands). From these sites a total of 16 collections were made, belonging to 6 taxa (*Gemina letterstedtioidea*, *Umbraulva* "Kermadecs", *Umbraulva* "Auckland Islands", *Ulva compressa*, *U. pertusa*, and *Ulva* species 1). Seventy-seven collections were made from sites that were recorded as highly modified (wharf pilings, harbour installations) and 9 taxa were recorded from these sites (*Ulva armoricana*, *U. californica*, *U. compressa*, *U. lactuca*, *U. pertusa*, *U. rigida*, *Ulva*

species 1, *Ulva* species 2, *Umbraulva olivascens*). A further 95 samples were analysed from sites adjacent to ports or harbour structures and an additional 7 taxa were found at these sites (*Ulva flexuosa*, *U. intestinalis*, *U. procera*, *U. prolifera*, *Ulva* species 5 “*U. ralfsii*”, *Ulva* species 6, *Ulva* species 9).

So-called “green tides” have been reported from two areas in New Zealand – Tauranga Harbour and the Avon-Heathcote estuary, Christchurch. In the samples analysed in this study, *Ulva* species 1 formed large sheets on low intertidal soft shores in both locations. Whether this is the species that predominates in bloom conditions at these sites is not able to be confirmed.

Table 9: Distribution of species in relation to habitat modification

	Pristine	Low modification	Open coast	Moderate	Adjacent to harbour/ wharf	High modification (wharves, etc)	Total
<i>Ulva armoricana</i>	0	0	1	4	2	1	8
<i>Ulva californica</i>	0	0	0	1	0	2	3
<i>Ulva compressa</i>	0	2	34	52	18	3	109
<i>Ulva fasciata</i>	0	0	3	0	0	0	3
<i>Ulva flexuosa</i>	0	0	0	0	1	0	1
<i>Ulva intestinalis</i>	0	0	27	27	6	0	60
<i>Ulva lactuca</i>	0	0	0	0	0	3	3
<i>Ulva linza</i>	0	0	1	1	0	0	2
<i>Ulva pertusa</i>	0	2	49	36	12	25	124
<i>Ulva procera</i>	0	0	8	15	6	0	29
<i>Ulva prolifera</i>	0	0	1	9	1	0	11
<i>Ulva rigida</i>	0	0	2	10	2	3	17
<i>Ulva</i> sp 1	0	2	32	64	21	38	157
<i>Ulva</i> sp 2	0	0	7	17	2	1	27
<i>Ulva</i> sp 4	0	0	0	1	0	0	1
<i>Ulva</i> sp 5 " <i>U. ralfsii</i> "	0	0	4	5	1	0	10
<i>Ulva</i> sp 6	0	0	0	0	2	0	2
<i>Ulva</i> sp 9	0	0	0	0	1	0	1
<i>Ulva</i> sp 10	0	0	0	1	0	0	1
<i>Gemina letterstedtioidea</i>	4	2	0	0	0	0	6
<i>Umbraulva</i> "Kermadecs"	3	0	0	0	0	0	3
<i>Umbraulva olivascens</i>	0	0	0	0	0	1	1
<i>Umbraulva</i> "Northland"	0	0	1	0	0	0	1
<i>Umbraulva</i> "Auckland I"	0	1	0	0	0	0	1
							581

### Biosecurity Collections

Fifty-six of the 85 biosecurity collections were identified by their *rbcL* sequences. Table 10 lists the ports and harbours investigated, and the *Ulva* species present. Only five species of Ulvaceae were discovered among these, all of which were large and bladed: 57% were identified as *Ulva* species 1, 34% as *Ulva pertusa*, and 4% each of *U. lactuca* and *U. rigida*. A single specimen was identified as *Umbraulva olivascens*. Only 20% and 15%, respectively, of *Ulva* species 1 and *Ulva pertusa* were among the biosecurity collections, while two of three *Ulva lactuca* specimens were from the biosecurity collections, as was the only thallus of *Umbraulva olivascens* encountered in this study.

Table 10. Distribution of taxa in samples from biosecurity collections. W/M = Whangarei/Marsden, Ta = Tauranga, Na = Napier, NP = New Plymouth, We = Wellington, Ne = Nelson, Pi = Picton, Ly = Lyttelton, Ti = Timaru, Du = Dunedin and Bl = Bluff.

Species	Number of specimens	No. biosecurity collections	% of entity among all biosecurity collections	% of biosecurity collections for entity	W/M	Ta	Na	NP	We	Ne	Pi	Ly	Ti	Du	Bl
<i>Ulva armoricana</i>	8	0													
<i>Ulva californica</i>	3	0													
<i>Ulva compressa</i>	109	0													
<i>Ulva fasciata</i>	3	0													
<i>Ulva flexuosa</i>	1	0													
<i>Ulva intestinalis</i>	60	0													
<i>Ulva lactuca</i>	3	2	4	67									x		x
<i>Ulva linza</i>	2	0													
<i>Ulva pertusa</i>	124	19	34	15		x		x	x		x	x	x	x	x
<i>Ulva prolifera</i>	11	0													
<i>Ulva procera</i>	29	0													
<i>Ulva rigida</i>	17	2	4	12									x		
<i>Ulva</i> species 1	157	32	57	20	x	x	x	x		x	x		x		x
<i>Ulva</i> species 2	27	0													
<i>Ulva</i> species 4	1	0													
<i>Ulva</i> species 5 " <i>U. ralfsii</i> "	10	0													
<i>Ulva</i> species 6	2	0													
<i>Ulva</i> species 9	1	0													
<i>Ulva</i> species 10	1	0													
<i>Gemina. letterstedtioidea</i>	6	0													
<i>Umbraulva olivascens</i>	1	1	2	100									x		
<i>Umbraulva</i> "Northland"	1	0													
<i>Umbraulva</i> "Kermadecs?"	3	0													
<i>Umbraulva</i> "Auckland Is."	1	0													
	<b>581</b>	<b>56</b>													

## DISCUSSION

Prior to this study, the taxonomy of the Ulvaceae in the New Zealand region was highly problematic: previous treatments of the group have been considered unreliable and there has been difficulty in assigning names to even commonly occurring taxa. Although it is generally agreed that Chapman (1956) recognized too many taxa, particularly at sub-specific ranks, until now it has been difficult to gauge the true diversity within this family in New Zealand.

Twenty-four genetically distinct taxa were distinguished in New Zealand waters including 19 species of *Ulva* sensu lato, 4 species of *Umbraulva*, the first record of this genus for the southern hemisphere, and the confirmation of the genus *Gemina* from the subantarctic. Although this diversity may be considered high (e.g., compared to southern Australia with 14 taxa in *Ulva* sensu lato, Womersley 1984), we consider this number of taxa to be a conservative assessment, as it is based solely on *rbcL* sequence comparisons. The status of morphologically distinguishable but genetically similar groups is not yet clear, and not treated in this report. The results of this study parallel the results of equivalent studies on the diversity of the red algal family Bangiaceae in the New Zealand region (Nelson *et al.* 2006). In both the Ulvaceae and Bangiaceae the morphological simplicity of the taxa, and their apparent capacity for both phenotypic plasticity as well as cryptic speciation, create particular difficulties when distinguishing taxa, and in both instances molecular sequence data provide a valuable source of data for comparative and phylogenetic analyses.

A particularly interesting result is the rediscovery of *Gemina*. This genus was originally described from samples collected in New Zealand, from Stewart Island and the subantarctic islands (Chapman 1952). Although it is considered current in AlgaeBase (Guiry 2006), its status as a genus separate from *Ulva* has been doubted (Papenfuss 1960; Adams 1994). The present study provides the first evidence since its description in 1952 for the existence of this distinct genus. Although *Gemina* specimens were macroscopically similar to *Ulva* and *Umbraulva* specimens, they were genetically different. The presence of paired cells enveloped by a mother cell wall and their palisade-like appearance in transverse sections agree well with the description given by Chapman (1952) for the genus *Gemina*. The collection of six samples which had identical or nearly identical *rbcL* sequences from distant sites such as the Antipodes and Auckland Islands confirm the presence of a single species. Further research is required to better understand the relationships and distinguishing morphological, anatomical and ecological characteristics of the genus.

Four species of *Umbraulva* were discovered in the course of this study, of which three are undescribed (“Kermadecs”, “Northland”, “Auckland Is.”) and one, *U. olivascens*, we consider to be introduced to the New Zealand region. Prior to this study, *U. olivascens* was only known from Europe and the Canary Islands, while *U. amamiensis* and *U. japonica* have so far been reported from only South East Asia. The *rbcL* sequences of the undescribed New Zealand *Umbraulva* species were distinct from *Ulva*, and grouped with sequences of the three known species of *Umbraulva* from Japan and Ireland. Even though

these three New Zealand *Umbraulva* species were each collected only once, their occurrence in areas with low or no human influence suggests that they are native in their respective habitats, and additionally, are probably endemic species. The genus *Umbraulva* has recently been separated from *Ulva*, based on DNA sequence comparisons and the presence of an additional accessory pigment, siphonaxanthin. This pigment gives the thalli an olive-green tinge and apparently allows them to survive in deeper waters (Yokohama 1981; Bae & Lee 2001). The specimens from Northland had a distinct olive-green colour, and all *Umbraulvas* were collected subtidally. Whether they contain siphonaxanthin as an accessory pigment needs to be analysed. Further material of these taxa will be required before formal descriptions can be prepared and names assigned.

The assessment of the native/non-native status of the 19 species of *Ulva* recorded in this study was based a range of criteria: on the numbers of collections as well as types of sites where an entity was observed, and the genetic distance between sequences from New Zealand and overseas specimens. The existence of few collections in combination with a restricted distribution or close proximity to sites with high frequency of ship traffic such as harbours and marinas, was considered indicative of an introduced species, especially if the *rbcL* sequences were identical or nearly identical to sequences obtained from samples collected outside New Zealand. The collections sourced from baseline and surveillance collecting programmes only yielded 5 entities compared with the 16 entities that were collected in this study from areas of high modification or adjacent to ports or harbour structures. Only 2 of the entities assessed as non-native in this study were present in biosecurity collections. This under-representation of diversity in the biosecurity collections may result from the selection of sites being investigated, the season of collection, or because the collectors are not experienced at distinguishing algal morphologies and growth habits.

The status of an entity as native or introduced was difficult to assess for those sequences with no significant close homology to existing sequences in GenBank (e.g., species 4, 6, 9, 10). When GenBank sequences were available, they provided information about the distribution of the taxon outside New Zealand. However, the names attached to sequences in GenBank were treated with care, as identifications of material sequenced are not always reliable. It is clear that some names are mis-attributed. For example, of the three sequences available in GenBank for *Ulva prolifera*, two did not match with the third, which was derived from material collected closest to the type locality. The accuracy of the identification of material that has been sequenced and for which there are data lodged in GenBank is critical. When selecting species names for clades found in New Zealand we sought to use GenBank entries based on material from the region of the type locality of the taxon.

Ideally, type specimens or at least material collected at the type locality should provide the sequence in GenBank. However this is difficult when type specimens are very old, or lost, and/or type localities unknown, as is for example the case with most of the *Ulva* type specimens described by Linneaus (1753; Womersley 1984). No sequence data were obtained from the herbarium specimens sampled in this study. These herbarium specimens were not collected with DNA extraction in mind: specimens may have been

initially incompletely dried, may have been exposed to sunlight or excessive heat, or may have even been treated with chemicals (e.g. formaldehyde), which all affect the quality of the DNA. Amplification of genes from herbarium specimens is known to be problematic (Bruns *et al.* 1990; Mayes *et al.* 1992; Goff & Moon 1993; Brodie *et al.* 1996). In historical specimens, depending on their age and storage history, the DNA is usually broken into short fragments, which may be difficult to amplify. Additionally, contamination with recent DNA is likely, especially if related taxa are handled in the same laboratory. Sequence analyses of type material or material from type locations were outside the scope of this study but these need to be considered when monographic research on this group is carried out in the future.

Based on the criteria arrived at in this study, we have concluded that of the 19 species of *Ulva*, at least 4 are probable introductions (*Ulva armoricana*, *U. californica*, *U. flexuosa*, *U. lactuca*). Only one of these species was found in the Biosecurity collections originating from baseline and surveillance collections of New Zealand ports and harbours. A further 5 species are known from only one or two collections (*U. linza*, species 4, species 6, species 9, species 10). These species may be naturally rare, for example, either seasonally ephemeral or highly restricted in their geographic range, but they may also be introduced. Further research will be required to resolve questions about the identity of these taxa and to provide sufficient material for detailed analyses of their morphology, as well as improved understanding of their distribution and ecology.

The collecting strategy employed in this study – to sample a wide geographic range as well as obtain seasonal collections – was constrained by the fact that the field work spanned one year. There are sampling gaps in the present data set, including parts of the east coast of North Island, the Coromandel Peninsula, and the coastline from Bay of Plenty to Napier, as well as the Snares, Campbell and Bounty Islands. Access to some regions has also meant that sampling was very limited and only a small number of specimens were able to be preserved for study. Most samples were collected in the intertidal zone, and a relatively small number were from subtidal habitats. Thus the geographical range of entities which are mainly or always subtidal, such as *Umbraulva* species or *Ulva fasciata*, may be under-sampled. Moreover, seasonal collections were only carried out around Wellington and Dunedin further limiting the scope of the present study.

As a consequence of the present study, the species concepts previously applied to the genus *Ulva* in New Zealand need to be amended. This is especially evident in the case of the three most common species in New Zealand, previously thought to be *Ulva lactuca*, *Ulva rigida* and *Ulva clathrata* (including *Enteromorpha muscoides*, *E. ramulosa* and *E. acanthophora*). Adams (1994) states: "... the name, *U. lactuca*, has been widely and uncritically used in New Zealand." In this study we found that *Ulva lactuca* had a very limited distribution - at three sites all of which have a high volume of vessel traffic - , suggesting that this species is not native but has been introduced to New Zealand. The entity it is most likely to have been confused with is *Ulva* species 1, which clustered with the undescribed Chilean species in the phylogenetic analysis, and which was found to be the most abundant entity in New Zealand. *Ulva* species 1 may be synonymous with *U.*

*laetevirens* described from South Australia. If so, this confirms Adams' observations from 1994 that "the *Ulva* species on our shores have probably more in common with those found in southern Australia.". Similarly, true *U. rigida* has a limited distribution in New Zealand, while the species previously mis-identified under this name, *Ulva pertusa*, was the second most abundant *Ulva* species among the samples collected. *Ulva* species 1 and *U. pertusa* both occurred in habitats with low human influence and thus are likely to be native to New Zealand, contrary to assumptions in preliminary studies that they may have recently been introduced.

The opposite case, i.e., species that have been regarded as native but that are more likely to be introduced taxa, may be true for species such as *U. compressa* and *U. intestinalis*. Both have been recorded from New Zealand from the early period of European exploration (e.g., Hooker & Harvey 1845). Third in the list of most abundant *Ulva* species in New Zealand, *U. compressa* is much more widespread than previously thought, and also more morphologically variable, including terete, much-branched *Ulva* specimens which until now may have been identified as *U. clathrata* (including its synonyms). Both *U. intestinalis* and *U. compressa* are known hull-fouling organisms, they are tolerant to a wide range of environmental conditions, and grow and reproduce fast, which may explain their cosmopolitan distributions (Blomster *et al.* 1998; Schaffelke *et al.* 2006). However, their origins are not known and they should therefore be considered cryptogenic species. Consequently, while their wide geographical spread in New Zealand suggests that they are native, they may in fact have been naturalised some time ago.

The status of *U. fasciata* in New Zealand waters is not clear. This species is reported worldwide, in some regions considered cosmopolitan and in other regions, for example, in Mexico and Australia, regarded as an introduced taxon. Mature thalli of this species have a very distinct morphology. The samples of *U. fasciata* collected in New Zealand were small and atypical. Whether they were immature or stunted by unfavourable environmental conditions will require further investigation. As noted earlier, the *rbcL* sequences of the three New Zealand specimens were virtually identical to sequences from Japan, Australia and Hawaii, but as GenBank sequences are not available for material from the type locality in the Mediterranean, confirmation of the name *U. fasciata* for Pacific specimens is still required.

We have identified some morphological characters that can be used to distinguish New Zealand *Ulva* entities. In the large bladed species, colour and size of thalli was often variable and depended on the environment. However, the presence or absence of microscopic teeth on the margin of thalli appeared to be a good character to separate *Ulva* species which otherwise may easily be confused, such as *U. rigida* from *U. pertusa* and *Ulva* species 1 from *Ulva lactuca*. This character could not be used, though, to distinguish *U. rigida* from the putatively introduced species *U. armoricana*. These two closely related species have been separated based on cell sizes, cell shapes and the number of pyrenoids in the cells which are "mostly 1-2" in *U. armoricana* and "mostly 2-4" in European *U. rigida*. Koeman & van den Hoek (1981) note for Dutch *Ulva* species that "the ranges of cell sizes of the species overlap to a great extent" thus limiting the

usefulness of this character. Likewise, cell sizes and pyrenoid numbers overlap in European *U. rigida* and *U. armoricana*, leaving the presence of tapered cells in the base as a single character for morphological detection of *U. armoricana* in New Zealand.

The present study was designed to provide information on the genetic diversity of the genus *Ulva* in New Zealand, to better define the taxa present and to enable native and alien taxa to be distinguished. Because of New Zealand's extensive coastal area and the large numbers of samples to screen, our approach was to compare one gene in many specimens, rather than many genes in fewer specimens. The *rbcL* gene proved to be useful for this approach. This study has been focused on the identification of entities within the New Zealand region rather than on an examination in depth of phylogenetic and intrageneric relationships within *Ulva* sensu lato. The *rbcL* gene has been used in the study of *Ulva* species before, thus established methods and primers exist, and many sequences are available in GenBank for comparison. This gene provides enough variability to be useful for the identification of entities on the species level and above. Moreover, it is a coding gene region, and thus was aligned easily and rapidly.

In the present study, *rbcL* sequence comparisons allowed the allocation of 581 specimens to distinct entities. However, a number of samples could not be identified because the amplification of their *rbcL* gene failed. In most cases this was because of the low concentrations and/or poor quality of the DNA in samples which, for example, did not dry fast enough, or were exposed to excessive heat or UV radiation. All these factors can lead to break-up of DNA into pieces too small to be amplified in a PCR. However, there could also be entities hidden within samples, whose sequences did not match the primers used and which therefore did not amplify. An example of this is *Ulva rigida*, which usually fails to amplify with the general primers for green plant *rbcL* that work on other *Ulva* species (i.e., primers by Manhart 1994; L. McIvor, personal communication to N. Barr). In case of *U. rigida*, this has led in the past to identification by exclusion, i.e., if a sample did not amplify with those primers, it was putatively identified as *U. rigida* (L. McIvor, personal communication to N. Barr, C. Cornelisen). In the present study, primers were designed which readily amplified the *rbcL* of *U. rigida*, which may have failed however with other entities.

The information provided by *rbcL* sequence comparisons allows identification at the species level. However, this gene is not variable enough to separate levels below the rank of species. Distinct morphological groups were found within some taxa without any accompanying genetic distinctions observable with *rbcL* sequences (e.g., *U. procera*, *U. compressa*). Although the focus of biosecurity studies is generally at species level, sub-species of some taxa have shown potential to invade foreign environments e.g., *Codium fragile* ssp. *novae-zelandiae* is native to New Zealand (Adams 1994), whereas another sub-species, *C. fragile* ssp. *tomentosoides*, is considered invasive, not only in New Zealand, but also in other parts of the world (Adams 1994; Schaffelke *et al.* 2006).

### **Evaluation of methods – opportunities for the future**

In order to distinguish between entities at a sub-species level, sequence data from other loci which may be more variable should be examined, such as the *psbA* gene and the ITS

region of the nuclear ribosomal cistron. Trials with published primers for *psbA* and for *Ulva* ITS were generally not successful in this study: primers either did not amplify the desired region, or amplified more than one product. The resulting background noise did not allow the sequences to be read with confidence. To address these problems primers will have to be redesigned which are specific for *Ulva* species from New Zealand.

ITS sequence comparisons may assist in identifying taxonomic ranks of morphological groups, for example, in *U. compressa* and *U. procera*. Comparisons of ITS sequences of samples belonging to putatively introduced species with sequences of samples from overseas may moreover allow the identification of the origin of these entities. Additionally, carefully designed and validated species-specific primers could also serve as probes. Such primers could be used for a quick and cost-effective identification, by testing the amplification of the ITS in a single PCR reaction.

So far no *psbA* sequences for *Ulva* species are available in GenBank, and thus no information exists on the variability of this gene. However, now that New Zealand entities have been identified based on *rbcL* sequences, this information could be used as a starting point to set up a database of *psbA* sequences. If this gene proved to be more variable than *rbcL* sequences it could be used for similar purposes as the ITS.

Whichever gene is used for identifying *Ulva* species, samples could be extracted and amplified within a day, provided that the extracted DNA amplified readily with primers and produced single band PCR products. In the present study, most samples were identified based on a single sequencing reaction revealing about 800-850 bp of the 1200 bp long partial *rbcL* gene. Sequences - and thus an identification - could be available within another 3-4 working days. Costs involve mostly labour (extraction, amplification, PEG cleaning), chemicals (especially recombinant *Taq*-DNA polymerase) and automatic sequencing. However, time and costs could be considerably reduced by the development of ITS primers specific for certain entities. In the ideal case, only two PCR reactions would then be necessary to identify a sample as part of a certain clade, the first using general primers to assess whether the DNA is amplifiable at all, and the second to identify the sample with entity-specific primers, i.e., by presence/absence of PCR products.

Further molecular systematics studies could clarify the status of morphological variants observed within *rbcL* genetic entities, and extended field studies confirm the presence of species so far only encountered in single samples, thus providing information about the geographic distribution of rarely collected species. Ecological studies are needed on populations of entities considered to be introduced to provide information that may assist in the management of these species, particularly on species environmental requirements and dispersal potential.

This research has provided an excellent platform for monographic studies of the family Ulvaceae in New Zealand. This study needs to be followed by taxonomic work to confirm the identifications, name new taxa (e.g., *Umbraulva* spp.), and clarify whether the species currently not associated with GenBank entries are undescribed species, or

occur elsewhere. Given the many specific names in the Ulvaceae the work required to clarify the application of species epithets is considerable.

## CONCLUSION

Molecular sequencing of the Ulvaceae has enabled a wide geographic region to be surveyed for genetic diversity in a cost effective manner. There is no other approach available at present that could provide the amount of data obtained: many of the samples were small or immature and the classical morphological and anatomical characters that have been used in the past are known to be inconsistent and unreliable. The data obtained now provide a framework for future biosecurity and taxonomic investigations on what has been a notoriously difficult group of algae.

In conclusion, this study has greatly increased our knowledge of the New Zealand *Ulva* flora.

- Molecular sequencing tools (specifically the *rbcL* gene) have enabled species recognition and documentation of diversity in *Ulva* and closely related genera.
- Twenty-four genetically distinct entities have been distinguished in the New Zealand members of the Ulvaceae, belonging to three genera – *Ulva*, *Umbraulva*, *Gemina*.
- Five species are probable introductions to New Zealand waters – *Ulva armoricana*, *U. californica*, *U. flexuosa*, *U. lactuca*, and *Umbraulva olivascens*.
- Additional species e.g., *U. compressa*, *U. intestinalis* may be regarded as cryptogenic species in New Zealand waters. The origins of *U. fasciata* in New Zealand are also unclear.
- The presence of the genus *Umbraulva* in the southern hemisphere is reported for the first time, with four species distinguished in the study area, three of which are new, undescribed indigenous species.
- *Gemina letterstedtioidea* is reported from the New Zealand subantarctic islands.
- Of the 19 species of *Ulva* reported here, 6 currently cannot be assigned to known species groups based on close homology with sequences in GenBank. These species may include undescribed, endemic taxa, or may represent cryptogenic species of uncertain origin.

## **ACKNOWLEDGEMENTS**

We would like to thank the following people who have assisted us with aspects of this project: Rebecca Ansell (Victoria University) for assistance with database development and mapping; Roberta D'Archino (NIWA) for SCUBA collections and assistance with bibliographic databases; Darren Hart (University of Otago) for assistance in the field and for advice with sequencing and phylogenetic analyses; Mei Nee Lee and Ewen Cameron (Auckland Institute and Museum) for enabling access to the AK collections and for assistance with loans; Amonida Zadissa for translation of Swedish. We would like to thank Neill Barr for valuable advice and discussions about *Ulva*. A number of people assisted us in the field or provided collections for us, sometimes from very remote locations – the coverage we have achieved would not have been possible without their assistance: Paul Buisson, Clinton Duffy, Erin Green, Debbie Freeman, Lou Hunt, Helen Kettles, Peter de Lange, Anne McCrone (Department of Conservation); Nick Shears and Franz Smith; Sheryl Miller and Jeff Forman (NIWA); Chris Cornelisen, Rochelle Dewdney, Wilson Freshwater, Chris Hepburn, Rachel Law, Gabrielle Lockett, Abi Loughnan, Paul Meredith, Roland Pfisterer, Margaret Richards, Lisa Russell, Brett Stansfield, Mike Stuart, NIWA field staff for biosecurity collections (ZBS2000/04, ZBS2001/01, ZBS2005/18, ZBS2005/35).

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Appendix 1. A summary of the region, locality and habitat types where samples were collected.

Region	Locality	Location	Lat	Long	Site	Habitat notes (epilithic unless otherwise stated)
Kermadec Islands	Raoul Island	Denham Bay	29° 15.5 S	177° 58.5 E	Subtidal	coral rubble, 15.7 m
North Island	Auckland	Leigh, Kemps Beach	36° 17 S	174° 48 E	Subtidal	4 m
North Island	Auckland	Manukau Harbour, Cornwallis	37° 0.7 S	174° 36.3 E	Intertidal	high, rock wall mid
North Island	Auckland	Waitakere, O'Neill Bay, Kotau Point	36° 53.3 S	174° 26.15 E	Intertidal	high, tidepool on reef platform
North Island	Auckland	Waitakere, Piha	36° 57 S	174° 28 E	Intertidal	high, tidepool on reef platform mid, reef platform
North Island	Auckland	Waitemata Harbour, Orakei Basin	36° 52.017 S	174° 48.544 E	Intertidal	slipway, concrete
North Island	Auckland	West Coast, Te Henga (Bethell's Beach)	36° 53.2 S	174° 26.23 E	Intertidal	high, tidepool on reef platform, epiphytic on <i>Stictosiphonia arbuscula</i> high, tidepool high, reef platform, on shells high, reef platform
North Island	Bay of Islands	Bland Bay	35° 20.774 S	174° 21.999 E	Subtidal	epiphytic on <i>Ecklonia radiata</i>
North Island	Bay of Islands	Cavalli Islands	35° 1.2 S	173° 56.8 E	Subtidal	14 m
North Island	Bay of Islands	Kerikeri, Landing Road Bridge	35° 12.232 S	173° 58.112 E	Intertidal	high, freshwater ditch, terrace in river above tidal stream
North Island	Bay of Islands	Kerikeri, Skudders Beach	35° 12.4 S	173° 59.045 E	Intertidal	high, on mudstone underneath trees
North Island	Bay of Islands	Moturoa/Rangiatea, small island at north tip	35° 13.04 S	174° 10.83 E	Subtidal	subtidal, 8 m, on red algae
North Island	Bay of Islands	Round Island	35° 13.797 S	174° 14.138 E	Intertidal	low, epiphytic on mussels
North Island	Bay of Islands	Russell, boat ramp	35° 15.57 S	174° 7.23 E	Intertidal	low, boat ramp, epiphytic on geniculate corallines
North Island	Bay of Islands	Russell, Long Beach	35° 15.394 S	174° 7.908 E	Intertidal	mid, tidepool, epiphytic on geniculate corallines high, tidepool
North Island	Bay of Islands	Russell, Matauwhi Bay	35° 16.05 S	174° 7.58 E	Intertidal	high, on top of wharf
North Island	Bay of Islands	Russell, near beach	35° 15.57 S	174° 7.23 E	Intertidal	dirty ditch, in fresh water
North Island	Bay of Islands	Russell, south end of beach	35° 15.92 S	174° 7.26 E	Intertidal	high, tidepool, epiphytic on geniculate corallines
North Island	Bay of Islands	Russell, Tapeka Point	35° 14.55 S	174° 7.1 E	Intertidal	mid, epiphytic on <i>Hormosira banksii</i> mid, in crevice mid, tidepool, epiphytic on geniculate corallines
North Island	Bay of Islands	Urupukapuka Island	35° 12.7 S	174° 14.2 E	Intertidal	high, steep rock face
North Island	Bay of Islands	Western side of Okahu Island	35° 12.08 S	174° 12.08 E	Subtidal	1 m
North Island	Bay of Plenty	Mayor Island, Bait Pond	37° 18 S	176° 16.7 E	Subtidal	4.5 m depth outcropping rock
North Island	Bay of Plenty	Tauranga Harbour	37° 41.5 S	176° 10 E	Drift	
North Island	Bay of Plenty	Tauranga Harbour, Omokoroa Beach	37° 37.83 S	176° 3.17 E	Intertidal	mid, cobbles and shells
North Island	Bay of Plenty	Tauranga Harbour, port	37° 39.6 S	176° 10.6 E	Subtidal	1-8 m
North Island	Bay of Plenty	Tauranga Harbour, Tanner's Point	37° 28.645 S	175° 56.772 E	Intertidal	mid, cobbles in freshwater seepage by drain adjacent to sand falts
North Island	Gisborne	Kaiti Beach Reef	38° 41.016 S	178° 1.916 E	Subtidal	upper, on pontoon
North Island	Hauraki Gulf	Waiheke Island, Man O' War Bay	36° 47 S	175° 9 E	Intertidal	tidepools
North Island	Hauraki Gulf	Waiheke Island, Rocky Bay	36° 49.11 S	175° 3.206 E	Intertidal	high, reef platform, crevice mid
North Island	Kapiti Coast	Pukerua Bay	41° 1.73 S	174° 53.5 E	Intertidal	low mid high
North Island	Kapiti Coast	Pukerua Bay, Brendan Beach	41° 1.51 S	174° 54.1 E	Intertidal	mid, edge of shallow channels

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North Island	Napier	Ahuriri Beach	39° 28.64 S	176° 54.653 E	Intertidal	
North Island	Napier	Ahuriri estuary	39° 29 S	176° 54 E	Intertidal	low, on cockles
North Island	Napier	Port of Napier	39° 28.64 S	176° 54.653 E	Intertidal	mid
North Island	Northern Wairarapa	Blackhead	40° 13 S	176° 47 E	Intertidal	high, tidepools, epiphytic
North Island	Northland	Bream Bay, Langs Beach	36° 2.564 S	174° 31.902 E	Intertidal	high, reef platform, epizoic on mussels high, tidepool, epiphytic on geniculate corallines
North Island	Northland	Doubtless Bay, Cable Bay East	34° 59.406 S	173° 29.215 E	Intertidal	high, reef platform, tidepools
North Island	Northland	Hokianga, Opononi	35° 31.061 S	173° 23.254 E	Intertidal	high, reef platform mid/low
North Island	Northland	Karikari Peninsula, Karikari Bay	34° 49.6 S	173° 22.6 E	Subtidal	10 m 20m
North Island	Northland	Karikari Peninsula, Matai Bay	34° 49.68 S	173° 24.637 E	Intertidal	high, epiphytic on geniculate corallines
North Island	Northland	Karikari Peninsula, Pihakoa Point	34° 49.792 S	173° 27.097 E	Subtidal	5 m
North Island	Northland	Karikari Peninsula, Rangiputa Harbour mouth	34° 52.776 S	173° 17.313 E	Intertidal	mid, reef platform
North Island	Northland	Matapouri	35° 33.978 S	174° 30.433 E	Intertidal	under bridge, on volcanic rock
North Island	Northland	Ngunguru	35° 38.2 S	174° 30 E	Intertidal	high on buoy in sand epizoic on cockles
North Island	Northland	North Cape	34° 25.06 S	173° 3.11 E	Subtidal	15 m
North Island	Northland	Sandy Bay	35° 33.42 S	174° 28.71 E	Intertidal	high, very exposed mid, exposed semi-exposed
North Island	Northland	Tutukaka	35° 36.7 S	174° 31.92 E	Intertidal	mid, epiphytic on geniculate corallines
North Island	Northland	Waipu Cove	36° 1.83 S	174° 30.55 E	Intertidal	intertidal, on stones in riverbank (fresh water)
North Island	Northland	Wekarua Island	34° 56.1 S	173° 39.2 E	Subtidal	6 m
North Island	Northland	Whangarei Harbour, Urquhart Bay	35° 50.1 S	174° 31.95 E	Intertidal	low, epiphytic on geniculate corallines
North Island	Northland	Whangarei, Marsden Point	35° 50.2811 S	174° 29.848 E	Subtidal	
North Island	Northland	Whangarei, Ocean Beach	35° 50.1 S	174° 34.36 E	Intertidal	high, tidepool high, reef platform, tidepool high, reef platform, epiphytic on geniculate corallines low, vertical rockwall, exposed
North Island	Northland	Whangarei, port	35° 45.5202 S	174° 20.9471 E	Subtidal	
North Island	Northland	Whangaroa Harbour	35° 0.5 S	173° 44 E	Intertidal	high, on wood
North Island	Poor Knights Islands	Labrid Channel	35° 28.3 S	174° 44.3 E	Subtidal	17 m, rockwall 6 m, large boulder
North Island	Taranaki	Kawhia	38° 3.924 S	174° 49.394 E	Intertidal	
North Island	Taranaki	Kiritehere	38° 19.508 S	174° 42.175 E	Intertidal	
North Island	Taranaki	New Plymouth, Port Taranaki	39° 3.35 S	174° 2.1 E	Subtidal	
North Island	Taranaki	Onaero beach	38° 59.587 S	174° 21.007 E	Intertidal	
North Island	Taranaki	Waitara	38° 59.295 S	174° 13.13 E	Intertidal	
North Island	Waikato	Raglan, Whale Bay	37° 49.334 S	174° 48.105 E	Intertidal	mid/low, scarce
North Island	Wairarapa	Flat Point	41° 14.4 S	175° 57.9 E	Intertidal	high, very exposed
North Island	Wellington	Houghton Bay	41° 20.565 S	174° 47.051 E	Intertidal	mid-low, wave exposed
North Island	Wellington	Island Bay	41° 20.9 S	174° 45.9 E	Intertidal	high, tidepool mid in stormwater outflow

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North Island	Wellington	Island Bay, Lagoon	41° 20.8 S	174° 46.5 E	Intertidal	
North Island	Wellington	Lyllal Bay, west end of bay	41° 20.277 S	174° 47.573 E	Intertidal	high-mid mid mid-low low, epiphytic on geniculate corallines side of boat ramp
North Island	Wellington	Mana marina	41° 6.002 S	174° 51.979 E	Subtidal	Drift drift upper, on sides of yacht finger wharf
North Island	Wellington	Muritai	41° 18 S	174° 54 E	Intertidal	mid
North Island	Wellington	Porirua Harbour	41° 7.464 S	174° 50.249 E	Intertidal	Drift mid-drift/accumulation
North Island	Wellington	Porirua Harbour, opposite Whitireia College	41° 7.464 S	174° 50.249 E	Intertidal	below storm water pipe
North Island	Wellington	Tarakena Bay, boat ramp	41° 20.546 S	174° 49.112 E	Intertidal	Slipway
North Island	Wellington	Titahi Bay	41° 6.16 S	174° 50.11 E	Intertidal	low in tidepool
North Island	Wellington	Wellington Harbour, Frank Kitts Lagoon area	41° 17.315 S	174° 46.797 E	Drift Intertidal	fresh drift low high
North Island	Wellington	Wellington Harbour, Greta Point reclamation	41° 18.11 S	174° 48.36 E	Intertidal	high, concrete pool, on mussels & concrete rock wall & boat ramp
North Island	Wellington	Wellington Harbour, Scorching Bay	41° 18 S	174° 50 E	Intertidal	high mid-low on log
North Island	Wellington	Wellington Port	41° 17 S	174° 47.5 E	Intertidal	
South Island	Banks Peninsula	Akaroa Harbour, Akaroa	43° 48.2 S	172° 58 E	Intertidal	low, on stone in sand
South Island	Banks Peninsula	Akaroa Harbour, Wainui	43° 49.09 S	172° 54.24 E	Intertidal	slipway, underneath slipway in shallow ditch
South Island	Banks Peninsula	Pigeon Bay	43° 41.267 S	172° 53.763 E	Intertidal	high, on stone in mudflat
South Island	Cape Farewell	Wharariki	40° 30 S	172° 40.6 E	Drift Intertidal	on mud flat high, epizoic on mussels low
South Island	Catlins	Kaka Point	46° 23.01 S	169° 47.14 E	Intertidal	low
South Island	Catlins	Nugget Point, Pounaweia East, mudflat	46° 26 S	169° 47.5 E	Drift	drift
South Island	Catlins	Nugget Point, Pounaweia West	46° 28 S	169° 42.5 E	Intertidal	sand flat
South Island	Catlins	Tirohanga	46° 26.14 S	169° 47.83 E	Intertidal	
South Island	Christchurch	Avon/Heathcote Estuary, Mt Pleasant Yacht Club	43° 33.453 S	172° 42.586 E	Drift	drift, lying on mudflat
South Island	Christchurch	Lyttelton Marina	43° 36.669 S	172° 42.332 E	Intertidal	
South Island	Christchurch	Lyttelton Port	43° 36.4 S	172° 43.25 E	Intertidal	
South Island	Christchurch	Sumner, Cave Rock	43° 33.937 S	172° 45.519 E	Intertidal	high, tidepool
South Island	Christchurch	Taylor's Mistake	43° 35 S	172° 46.7 E	Intertidal	mid, tidepool mid-high, tidepool
South Island	Fiordland	Bligh Sound, Evening Point	44° 51 S	167° 30 E	Subtidal	3 m, steep rock wall
South Island	Fiordland	Bradshaw Sound	45° 18.169 S	167° 1.413 E	Intertidal	low
South Island	Fiordland	Bradshaw Sound, Precipice Cove	45° 15 S	167° 9.85 E	Intertidal	high, on stone in freshwater stream low, on dead tree
					Subtidal	on stone on drift wood

Appendix 1. A summary of the region, locality and habitat types where samples were collected.

South Island	Fiordland	Bradshaw Sound, Rum River Estuary	42° 15.82 S	167° 7.46 E	Drift	drift
					Subtidal	stone in riverbed
South Island	Fiordland	Breaksea Sound, First Cove	45° 33.62 S	166° 46.36 E	Drift	epizoic on cockle shell
South Island	Fiordland	Caswell Sound, inner site: "The Knob"	45° 1 S	167° 18.5 E	Subtidal	3 m
South Island	Fiordland	Charles Sound, Eleanor Island	45° 5.9 S	167° 8.5 E	Subtidal	rock wall, 1.8 m depth
South Island	Fiordland	Charles Sound, Friendship Head, Gold Arm	45° 6.18 S	167° 8.4 E	Subtidal	3.5 m
South Island	Fiordland	Charles Sound, Gold Arm, Copper pad	45° 8.539 S	167° 8.778 E	Subtidal	1.8 m, rock wall
South Island	Fiordland	Dagg Sound, Otago Point	45° 24.9 S	166° 51.2 E	Subtidal	1.5 m, gentle rock slope
South Island	Fiordland	Doubtful Sound, Blanket Bay Hotel, Malaspina Reach	45° 27.9 S	166° 58.7 E	Subtidal	0-1 m
South Island	Fiordland	Doubtful Sound, Causet Cove, Bauza Island	45° 17.05 S	166° 53.9 E	Subtidal	2 m, rocky slope
					Intertidal	high, on dead tree
						high
						high, shaded
						mid
						mid, on wood
						mid, epiphytic on Hormosira banksii
						low
					Drift	drift
South Island	Fiordland	Doubtful Sound, Crooked Arm	45° 24.866 S	167° 0.845 E	Intertidal	high, on log in freshwater stream
						low, on wood
						low, on pebbles in sand
					Subtidal	subtidal, little river stream
South Island	Fiordland	Doubtful Sound, Deep Cove, before Brassel Point	45° 27.766 S	167° 9.205 E	Drift	drift among reeds/mosses
					Intertidal	mid
						low
South Island	Fiordland	Doubtful Sound, Mid Channel	45° 21.1 S	167° 4.257 E	Intertidal	high
South Island	Fiordland	Doubtful Sound, mid channel, south side	45° 21.656 S	167° 3.476 E	Intertidal	high, under waterfall
South Island	Fiordland	Doubtful Sound, Ranson Point	45° 21.15 S	167° 1.69 E	Subtidal	0.5 m
South Island	Fiordland	Doubtful Sound, Tricky Cove	45° 21.3 S	167° 2.8 E	Subtidal	3 m
South Island	Fiordland	Dusky Sound, Anchor Island	45° 45.2 S	166° 31.6 E	Intertidal	mid
South Island	Fiordland	Dusky Sound, Bowen Channel	45° 45.05 S	166° 41.3 E	Intertidal	mid
South Island	Fiordland	Dusky Sound, Girlie Island	45° 43.585 S	166° 55.75 E	Intertidal	mid
South Island	Fiordland	Dusky Sound, Wet Jacket Arm, Acheron Passage	45° 39.8 S	166° 44.2 E	Intertidal	mid
South Island	Fiordland	Inner Edwardson Sound, Station Islet	45° 57.44 S	166° 36.9 E	Intertidal	
South Island	Fiordland	Milford Sound, inner south side of sound	44° 40 S	167° 54 E	Subtidal	2.8 m, steep rock wall
South Island	Fiordland	Stella base site	45° 58.34 S	166° 35.48 E	Intertidal	mid
					Subtidal	1 m
South Island	Golden Bay	Ligar Bay	40° 48.978 S	172° 54.835 E	Intertidal	high, on saltmarsh
South Island	Golden Bay	Pakawau Bridge	40° 35.039 S	172° 41.159 E	Intertidal	epiphytic on Gracilaria chilensis
					Subtidal	upper, on pebbles in freshwater stream
South Island	Golden Bay	Pohara Wharf	40° 49.399 S	172° 53.663 E	Subtidal	on floating pontoon
South Island	Golden Bay	Wainui	40° 48.7 S	172° 56.18 E	Intertidal	epizoic on cockles
South Island	Kaikoura	South Bay	42° 25.7 S	173° 41.4 E	Intertidal	mid
						low, on edge of boat ramp
						low/upper subtidal, epiphytic on Cystophora torulosa
South Island	Marlborough Sounds	Admiralty Bay	40° 56.7 S	173° 54.4 E	Subtidal	marine farm rope

Appendix 1. A summary of the region, locality and habitat types where samples were collected.

South Island	Marlborough Sounds	Havelock, marina/boat club	41° 16.65 S	173° 46.2 E	Intertidal	mud bank in salt marsh, mats 2-3cm thick
South Island	Marlborough Sounds	Horseshoe Bay, mussel farm ropes	41° 1.87 S	173° 57.06 E	Subtidal	marine farm rope
South Island	Marlborough Sounds	Pelorus Sound, Jacobs Bay	41° 6.7 S	173° 53.2 E	Intertidal	high
					Subtidal	on wharf piles
South Island	Marlborough Sounds	Picton	41° 17.28 S	174° 0.5 E	Subtidal	floating pontoon
South Island	Marlborough Sounds	Picton, port	41° 17.1 S	174° 0.35 E	Subtidal	
South Island	Marlborough Sounds	Picton, Waikawa Bay	41° 16 S	174° 2.78 E	Intertidal	low, on boat ramp cobbles
					Subtidal	floating pontoon
South Island	Moeraki		45° 21.415 S	170° 51.335 E	Intertidal	mid-low
South Island	Nelson		41° 15.488 S	173° 16.933 E	Subtidal	boat ramp
South Island	Nelson	Mapua, wharf	41° 15 S	173° 6 E	Subtidal	upper
South Island	Nelson	port	41° 15.5 S	173° 16.25 E	drift	drift
South Island	North of Kaikoura	Mangamaunu	42° 12.7 S	173° 52 E	Intertidal	mid, on tops of boulders
						low, moderate exposure
South Island	North of Kaikoura	Marfells Beach	41° 43.605 S	174° 13.162 E	Intertidal	mid/low
South Island	North of Kaikoura	Ohau Stream	42° 14.718 S	173° 49.889 E	Intertidal	on small boulders in stream
South Island	North of Kaikoura	Rakautara rest area (BBQ)	42° 16.2 S	173° 48 E	Intertidal	high, tidepool
South Island	Oamaru		45° 6.57 S	170° 58.75 E	Intertidal	rock wall
South Island	Otago	Allan's Beach	45° 52.523 S	170° 42.36 E	Intertidal	mid, tidepool
South Island	Otago	Aramoana salt marsh	45° 46.906 S	170° 42.624 E	Drift	drift
South Island	Otago	Doctor's Point	45° 43.985 S	170° 35.942 E	Drift	drift
South Island	Otago	Dunedin Harbour, Pulling Point	45° 47.725 S	170° 39.39 E	Subtidal	1 m
South Island	Otago	Dunedin, Brighton Beach	45° 56.948 S	170° 20.064 E	Intertidal	high
						mid
						mid, reef platform
						mid, tidepool, epiphytic on Gigartina
						mid-low
						low
						low, reef platform
						low, epiphytic on red algae
						low/upper subtidal
					Subtidal	0.3 m, epiphytic on Halopteris
South Island	Otago	Dunedin, Otago Peninsula, Hoopers Inlet	45° 51.186 S	170° 39.994 E	Intertidal	high
						low, in channel
South Island	Otago	Dunedin, Otago Peninsula, Hoopers Inlet	45° 51.186 S	170° 39.994 E	Drift	on mudflat
South Island	Otago	Dunedin, Papanui Inlet	45° 50.89 S	170° 42.56 E	drift	
South Island	Otago	Dunedin, Port of Otago	45° 52.8 S	170° 30.8 E	Intertidal	
South Island	Otago	Dunedin, Portobello, Aquarium Point	45° 49.5 S	170° 39.7 E	Intertidal	
South Island	Otago	Dunedin, St Clair	45° 54.77 S	170° 29.3 E	Intertidal	high
						mid
						mid, on concrete stairs

Appendix 1. A summary of the region, locality and habitat types where samples were collected.

South Island	Otago	Kaitiki Beach (south end), west of Shag Point township	45° 27.45 S	170° 48.65 E	Intertidal	high, on rock wall high, on rock wall below freshwater drain high, tidepool high, tidepool, epizoic on limpet mid mid, tidepool mid, on wood low low, in crevice
South Island	Otago	Kakanui Beach	45° 9.473 S	170° 55.099 E	Intertidal	high, reef platform high, on rock wall mid mid, reef platform mid, epiphytic on geniculate corallines epizoic on limpet low, reef platform
South Island	Otago	Karitane Harbour	45° 38.394 S	170° 39.503 E	Intertidal	high, on sand flat high, on pebbles mid, on stone in sandflat below sewage outlet
South Island	Otago	Moeraki Boulders	45° 20.772 S	170° 49.608 E	Intertidal	mid
South Island	Otago	Oamaru	45° 6.57 S	170° 58.75 E	Intertidal	slipway
South Island	Otago	Otago Harbour, Macandrew Bay	45° 52.14 S	170° 35.83 E	Intertidal	high, in freshwater stream on stone near freshwater stream mid drift
South Island	Otago	Otago Harbour, Portobello	45° 50.355 S	170° 39.057 E	Drift Intertidal	drift high high, below sewage outlet
South Island	Otago	Otago Peninsula, Allan's Beach	45° 52.523 S	170° 42.36 E	Drift Intertidal	drift high, on vertical rockwall mid, tide pool
South Island	Otago	Otago Peninsula, Harwood	45° 48.76 S	170° 40.32 E	Intertidal	low
South Island	Otago	Taieri Mouth	46° 3.3 S	170° 11.6 E	Intertidal	
South Island	Otago	Warrington, Blueskin Bay	45° 43.005 S	170° 35.654 E	Intertidal	high on shell
South Island	Southland	Bluff, port	46° 35.5789 S	168° 20.1259 E	Intertidal	mid, on stone
South Island	Southland	near Monkey Island	46° 18.1 S	167° 41.7 E	Intertidal	high, in lee of boulder mid epiphytic on Bostrychia
South Island	Southland	Riverton Harbour	46° 21.33 S	168° 0.6 E	Intertidal	high, on rock wall on shell on wall below outfall pipe
South Island	Southland	Riverton Rocks	46° 21 S	168° 1 E	Intertidal	high, tidepool
South Island	Tasman Bay	Motueka	41° 8.811 S	173° 0.77 E	Drift	on mud flat, sheltered
South Island	Tasman Bay	Nelson, Boulder Bank, Glenduan	41° 11 S	173° 21.8 E	Intertidal	tidepool

Appendix 1. A summary of the region, locality and habitat types where samples were collected.

South Island	Timaru	port	44° 23.5 S	171° 15.6 E	Intertidal	slipway wharf pile
South Island	Timaru	port, North Mole	44° 23.1 S	171° 15.54 E	Intertidal	on concrete breakwater
South Island	West Coast	Constant Bay	41° 54 S	171° 26 E	Intertidal	high, in freshwater flow low, epizoic on mussels
South Island	West Coast	Jackson Bay	43° 58.405 S	168° 36.858 E	Intertidal	mid, on stone epiphytic on geniculate corallines
South Island	West Coast	Jackson Bay, Ocean Beach	43° 57.914 S	168° 36.389 E	Intertidal	high high, tidepool, epiphytic on <i>Pterocladia capillacea</i> high, tidepool, epiphytic on geniculate corallines mid, in fresh water stream mid, on stone
South Island	West Coast	Kahurangi National Park, Whanganui Inlet	40° 36.4 S	172° 34.5 E	Intertidal	mid, on stone
South Island	West Coast	Makawhio Point, Hunts Beach	43° 33.25 S	169° 40.5 E	Drift	drift
South Island	West Coast				Intertidal	high, tidepool mid, on stone mid, on wood
South Island	West Coast	Ngakawau	41° 36.775 S	171° 52.083 E	Intertidal	mid, epizoic on mussels
South Island	West Coast	north of Hector	41° 34.127 S	171° 54.396 E	Intertidal	mid-low
South Island	West Coast	south of Charleston	42° 0.031 S	171° 23.725 E	Intertidal	mid-low, tidepool, epizoic on mussels
Chatham Islands	Chatham Island	Mairangi	43° 42.8 S	176° 38 W	Intertidal	high, tidepool
Chatham Islands	Chatham Island	Owenga, Manukau Reef, Tommy Solomons grave	44° 1.95 S	176° 20.25 W	Intertidal	high, tidepool
Chatham Islands	Chatham Island	Owenga, Te One Creek	44° 1.16 S	176° 22.97 W	Drift	epiphytic on <i>Sporochnus</i>
					Intertidal	low, exposed mid, tidepool mid, epiphytic on <i>Pachymenia lusoria</i>
Chatham Islands	Chatham Island	Owenga, Wharf	44° 1.5 S	176° 22.1 W	Intertidal	high, tidepool on reef platform
Chatham Islands	Chatham Island	Petre Bay, Port Hutt	43° 48.9 S	176° 42.3 W	Intertidal	high, tidepool on reef platform on stairs at stranded ship
Chatham Islands	Chatham Island	Petre Bay, Waitangi	43° 57.19 S	176° 33.461 W	Intertidal	mid, river bank above freshwater stream
Chatham Islands	Chatham Island	Petre Bay, Waitangi Wharf	43° 56.8 S	176° 33.7 W	Intertidal	mid high, under wharf on metal screw high, under wharf on wood
Chatham Islands	Chatham Island	Petre Bay, Whangatete Inlet	43° 47.88 S	176° 39.76 W	Intertidal	mid mid, tidepool, epiphytic on <i>Ulva</i> sp
Chatham Islands	Chatham Island	Te Whanga Lagoon, Blind Jim's Creek	43° 46.8 S	176° 33.333 W	Intertidal	low, on pebbles, sheltered, high nutrients
Chatham Islands	Chatham Island	Wharekauri	43° 42.4 S	176° 34.6 W	Intertidal	mid low
Chatham Islands	Mangere Island		44° 16.5 S	176° 18.5 W	Intertidal	reef platform
Stewart Island	Deep Bay		46° 54.3 S	168° 8.3 E	Intertidal	mid-low low
Stewart Island	Halfmoon Bay	Oban, wharf end of beach	46° 53.8 S	168° 7.75 E	Drift	drift
Stewart Island	Halfmoon Bay	Scollays Rocks	46° 54.02 S	168° 7.93 E	Intertidal	low/upper subtidal
Stewart Island	Lee Bay	western end	46° 51.71 S	168° 7.09 E	Intertidal	mid-low
Stewart Island	Port William	south end of beach	46° 50.7 S	168° 5 E	Intertidal	high mid-low

Appendix 1. A summary of the region, locality and habitat types where samples were collected.

Antipodes Islands	Bollons Is.		49° 39.24 S	178° 49.6 E	Subtidal	7 m, sandflats adjacent to <i>Macrocystis</i> forest
Antipodes Islands	Leeward Is.		49° 41.5 S	178° 48.5 E	Subtidal	exposed wall, 6 m
					Subtidal	exposed wall, 8 m
Auckland Islands	Auckland Island	Carnley Harbour, Western Harbour	50° 49.822 S	165° 54.867 E	Intertidal	perpendicular exposed wall, 4 m
Auckland Islands	Auckland Island	Port Ross, Erebus Cove	50° 32.603 S	166° 12.678 E	Intertidal	low
Auckland Islands	Auckland Island	Port Ross, Shoe Island	50° 32.222 S	166° 13.538 E	Intertidal	low
Auckland Islands	Auckland Island	Tagua Bay	50° 48.627 S	166° 4.486 E	Subtidal	6 m
					Subtidal	hauled up on anchor from 15 m

Appendix 2: Samples: vouchers deposited in WELT with associated GenBank accession numbers. (UPN data provided for specimens not registered in WELT)

WELT	GenBank Accession	Entity	Locality summary
A027594	EF110067	<i>Gemina letterstedtioidea</i>	Antipodes, Leeward Is.
A027235	EF110068	<i>Gemina letterstedtioidea</i>	Antipodes, Leeward Is.
A027326	EF110069	<i>Gemina letterstedtioidea</i>	Antipodes, Bollons Is.
A027327	EF110070	<i>Gemina letterstedtioidea</i>	Antipodes, Leeward Is.
A027573	EF110498	<i>Gemina letterstedtioidea</i>	Carnley Harbour, Western Harbour, Auckland Island
A027533	EF110499	<i>Gemina letterstedtioidea</i>	Tagua Bay, Auckland Island
A027285	EF110044	<i>U. armoricana</i>	Wellington, Pukerua Bay
A027290	EF110050	<i>U. armoricana</i>	Picton, Waikawa Bay
A027843	EF110294	<i>U. armoricana</i>	Rangiputa Harbour mouth, Karikari Peninsula, Northland
A027691	EF110452	<i>U. armoricana</i>	Tapeka Point, Russell, Bay of Islands, North Island
A027575	EF110462	<i>U. armoricana</i>	off Rangiatea Island, Bay of Islands, North Island
A027871	EF110495	<i>U. armoricana</i>	Mapua (wharf), South Island
A027574	EF110506	<i>U. armoricana</i>	Cavalli Islands
A027343	EF110039	<i>U. californica</i>	Frank Kitts, Wellington
A027342	EF110133	<i>U. californica</i>	Oamaru, Otago
A027515	EF110445	<i>U. californica</i>	Whale Bay, Taranaki, North Island
A027298	EF109939	<i>U. compressa</i>	Brighton Beach, Dunedin
A027308	EF109947	<i>U. compressa</i>	St Clair, Dunedin
A027307	EF109948	<i>U. compressa</i>	St Clair, Dunedin
A027773	EF109963	<i>U. compressa</i>	Riverton Harbour, Southland
A027300	EF109966	<i>U. compressa</i>	Riverton Rocks
A027737	EF109972	<i>U. compressa</i>	Riverton Harbour, Southland
A027751	EF109980	<i>U. compressa</i>	Brighton Beach, Dunedin
A027752	EF109982	<i>U. compressa</i>	Brighton Beach, Dunedin
A027752	EF109983	<i>U. compressa</i>	Brighton Beach, Dunedin
A027772	EF109984	<i>U. compressa</i>	Brighton Beach, Dunedin
A027753	EF109986	<i>U. compressa</i>	Brighton Beach, Dunedin
A027824	EF110012	<i>U. compressa</i>	Stewart Island Deep Bay
A027826	EF110014	<i>U. compressa</i>	Stewart Island, Port William
A027826	EF110015	<i>U. compressa</i>	Stewart Island, Port William
A027736	EF110023	<i>U. compressa</i>	Wellington, Scorching Bay
A027771	EF110027	<i>U. compressa</i>	Wellington, Scorching Bay
A027303, A027303/B	EF110034	<i>U. compressa</i>	Wellington, Island Bay Lagoon
A027304	EF110035	<i>U. compressa</i>	Wellington, Island Bay Lagoon
A027770	EF110040	<i>U. compressa</i>	Frank Kitts, Wellington

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A027769	EF110042	<i>U. compressa</i>	Wellington, Pukerua Bay
A027309	EF110047	<i>U. compressa</i>	Wellington, Porirua Harbour
A027768	EF110049	<i>U. compressa</i>	Havelock, Pelorus
A027761	EF110129	<i>U. compressa</i>	Akaroa, Akaroa Harbour, Banks Peninsula, Canterbury
A027754	EF110132	<i>U. compressa</i>	Wainui, Akaroa Harbour, Banks Peninsula, Canterbury
A027750	EF110135	<i>U. compressa</i>	Kakanui Beach, Otago
A027767	EF110136	<i>U. compressa</i>	Kakanui Beach, Otago
A027756	EF110137	<i>U. compressa</i>	Kakanui Beach, Otago
A027756	EF110138	<i>U. compressa</i>	Kakanui Beach, Otago
A027756	EF110139	<i>U. compressa</i>	Kakanui Beach, Otago
A027299	EF110143	<i>U. compressa</i>	Kakanui Beach, Otago
A027762	EF110144	<i>U. compressa</i>	Wellington, Pukerua Bay
A027763	EF110149	<i>U. compressa</i>	Wellington, Porirua Harbour
A027766	EF110150	<i>U. compressa</i>	Frank Kitts, Wellington
A027735	EF110151	<i>U. compressa</i>	Frank Kitts, Wellington
A027740	EF110152	<i>U. compressa</i>	Wellington, Island Bay
A027295	EF110156	<i>U. compressa</i>	Wellington, Lyall Bay west
A027738	EF110162	<i>U. compressa</i>	Cornwallis, Manukau Harbour
A027764	EF110163	<i>U. compressa</i>	Te Henga, West Coast, Auckland (Bethell's Beach)
A027302	EF110173	<i>U. compressa</i>	Langs Beach, Bream Bay, Northland
A027734	EF110177	<i>U. compressa</i>	Ngunguru, Northland
A027765	EF110180	<i>U. compressa</i>	Matapouri, Northland
A027743	EF110182	<i>U. compressa</i>	Sandy Bay, Northland
A027743	EF110183	<i>U. compressa</i>	Sandy Bay, Northland
A027741	EF110190	<i>U. compressa</i>	Ocean Beach, Whangarei, Northland
A027757	EF110195	<i>U. compressa</i>	Brighton Beach, Dunedin
A027745	EF110218	<i>U. compressa</i>	Karitane Harbour, Otago
A027858	EF110226	<i>U. compressa</i>	St Clair, Dunedin
A027859	EF110227	<i>U. compressa</i>	St Clair, Dunedin
A027852	EF110229	<i>U. compressa</i>	Macandrew Bay, Otago Harbour
A027853	EF110230	<i>U. compressa</i>	Macandrew Bay, Otago Harbour
A027733	EF110240	<i>U. compressa</i>	Jackson Bay, West Coast, South Island
A027306	EF110243	<i>U. compressa</i>	Hunts Beach, Makawhio Point, West Coast, South Island
A027732	EF110247	<i>U. compressa</i>	Hunts Beach, Makawhio Point, West Coast, South Island
A027305	EF110262	<i>U. compressa</i>	Crooked Arm, Doubtful Sound, Fiordland
A027297	EF110264	<i>U. compressa</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland

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A027775	EF110267	<i>U. compressa</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027293	EF110272	<i>U. compressa</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027731	EF110274	<i>U. compressa</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027730	EF110278	<i>U. compressa</i>	Precipice Cove, Bradshaw Sound, Fiordland
A027849	EF110291	<i>U. compressa</i>	Opononi, Hokianga, Northland, North Island
A027844	EF110295	<i>U. compressa</i>	Cable Bay East, Doubtless Bay, Northland, North Island
A027729	EF110296	<i>U. compressa</i>	Jacob's Bay
A027728	EF110297	<i>U. compressa</i>	Jacobs Bay
A027758	EF110301	<i>U. compressa</i>	Wellington, Scorching Bay
A027755	EF110305	<i>U. compressa</i>	Wellington, Island Bay
A027742	EF110306	<i>U. compressa</i>	Wellington, Island Bay
A027759	EF110317	<i>U. compressa</i>	Wellington, Porirua Harbour
A027748	EF110332	<i>U. compressa</i>	Wellington, Island Bay
A027744	EF110333	<i>U. compressa</i>	Wellington, Island Bay
A027649	EF110335	<i>U. compressa</i>	Wellington, Hutt River
A027834	EF110340	<i>U. compressa</i>	Kaikoura, South Bay
A027836	EF110342	<i>U. compressa</i>	Kaikoura, South Bay
A027837	EF110343	<i>U. compressa</i>	Kaikoura, South Bay
A027840	EF110346	<i>U. compressa</i>	Wellington, Porirua Harbour
A027796	EF110347	<i>U. compressa</i>	Brighton Beach, Dunedin
A027795	EF110352	<i>U. compressa</i>	Brighton Beach, Dunedin
A027794	EF110354	<i>U. compressa</i>	Brighton Beach, Dunedin
A027793	EF110370	<i>U. compressa</i>	St Clair, Dunedin
A027792	EF110371	<i>U. compressa</i>	St Clair, Dunedin
A027301	EF110377	<i>U. compressa</i>	Tommy Solomons grave, Manukau Reef, Owenga, Chatham
A027781	EF110380	<i>U. compressa</i>	Wharf, Waitangi, Petre Bay, Chatham
A027747	EF110381	<i>U. compressa</i>	Wharf, Waitangi, Petre Bay, Chatham
A027746	EF110383	<i>U. compressa</i>	Wharf, Waitangi, Petre Bay, Chatham
A027294	EF110385	<i>U. compressa</i>	Wharf, Owenga, Chatham
A027296	EF110389	<i>U. compressa</i>	Te One Creek, Owenga, Chatham Island
A027774	EF110391	<i>U. compressa</i>	Mairangi, Chatham Island
A027749	EF110395	<i>U. compressa</i>	Wharekauri, Chatham Island
A027760	EF110396	<i>U. compressa</i>	Wharekauri, Chatham Island
A027777	EF110399	<i>U. compressa</i>	Blind Jim's Creek, Te Whanga Lagoon, Chatham
A027780	EF110406	<i>U. compressa</i>	Port Hutt, Petre Bay, Chatham Island
A027778	EF110410	<i>U. compressa</i>	Port Hutt, Petre Bay, Chatham Island

Appendix 2: Samples: vouchers deposited in WELT with associated GenBank accession numbers. (UPN data provided for specimens not registered in WELT)

A027779	EF110411	<i>U. compressa</i>	Port Hutt, Petre Bay, Chatham Island
A027785	EF110422	<i>U. compressa</i>	Whanganui Inlet, Kahurangi National Park
A027786	EF110423	<i>U. compressa</i>	Whanganui Inlet, Kahurangi National Park
A027787	EF110426	<i>U. compressa</i>	Whanganui Inlet, Kahurangi National Park
A027776	EF110427	<i>U. compressa</i>	Wharariki, Cape Farewell, South Island
A027784	EF110431	<i>U. compressa</i>	Wharariki, Cape Farewell, South Island
A027790	EF110433	<i>U. compressa</i>	Constant Bay, Charleston, West Coast, South Island
A027783	EF110437	<i>U. compressa</i>	Ngakawau, West Coast
A027782	EF110438	<i>U. compressa</i>	north of Hector, West Coast, South Island
A027789	EF110447	<i>U. compressa</i>	Kawhia, Taranaki, North Island
A027788	EF110448	<i>U. compressa</i>	Kawhia, Taranaki, North Island
(UPN919)	EF110450	<i>U. compressa</i>	Mangere Island, Chatham Islands
(UPN933)	EF110454	<i>U. compressa</i>	Matauhi Bay, Russell, Bay of Islands, North Island
A027798	EF110459	<i>U. compressa</i>	Skudders Beach, Kerikeri, Bay of Islands, North Island
A027797	EF110465	<i>U. compressa</i>	off Round Island, Bay of Islands, North Island
(UPN964)	EF110471	<i>U. compressa</i>	Stella base site, Fiordland, South Island
(UPN968)	EF110474	<i>U. compressa</i>	Anchor Island, Dusky Sound, Fiordland, South Island
(UPN969)	EF110475	<i>U. compressa</i>	Girlie Island, Dusky Sound, Fiordland, South Island
A027791	EF110491	<i>U. compressa</i>	Tanner's Point, Tauranga Harbour
A027739	EF109990	<i>U. intestinalis</i>	Taieri Mouth, Otago
A027284	EF109992	<i>Ulva armoricana</i>	Nelson
A027517	EF110464	<i>Ulva fasciata</i>	off Red Head Island, Bay of Islands, North Island
A027518	EF110500	<i>Ulva fasciata</i>	Wekarua Island
A027522	EF110501	<i>Ulva fasciata</i>	Pihakoa Point
A027320	EF110051	<i>Ulva flexuosa</i>	Picton, Waikawa Bay
A027339	EF109969	<i>Ulva intestinalis</i>	Riverton Harbour, Southland
A027557	EF109970	<i>Ulva intestinalis</i>	Riverton Harbour, Southland
A027557	EF109971	<i>Ulva intestinalis</i>	Riverton Harbour, Southland
A027340	EF109973	<i>Ulva intestinalis</i>	Riverton Harbour, Southland
A027554	EF110031	<i>Ulva intestinalis</i>	Wellington, Lyall Bay west
A027329	EF110045	<i>Ulva intestinalis</i>	Wellington, Pukerua Bay
A027335	EF110131	<i>Ulva intestinalis</i>	Pigeon Bay, Banks Peninsula, Canterbury
A027555	EF110145	<i>Ulva intestinalis</i>	Wellington, Pukerua Bay
A027337	EF110146	<i>Ulva intestinalis</i>	Wellington, Pukerua Bay
A027338	EF110147	<i>Ulva intestinalis</i>	Wellington, Pukerua Bay
A027523	EF110148	<i>Ulva intestinalis</i>	Wellington, Pukerua Bay

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A027334	EF110172	<i>Ulva intestinalis</i>	Waipu Cove, Northland
A027333	EF110199	<i>Ulva intestinalis</i>	Allan's Beach, Otago Peninsula
A027535	EF110200	<i>Ulva intestinalis</i>	Allan's Beach, Otago Peninsula
A027536	EF110208	<i>Ulva intestinalis</i>	Blueskin Bay, Warrington, Otago
A027556	EF110214	<i>Ulva intestinalis</i>	Katiki Beach (south end), Otago
A027556	EF110215	<i>Ulva intestinalis</i>	Katiki Beach (south end), Otago
A027328	EF110216	<i>Ulva intestinalis</i>	Katiki Beach (south end), Otago
A027559	EF110217	<i>Ulva intestinalis</i>	Katiki Beach (south end), Otago
A027854	EF110231	<i>Ulva intestinalis</i>	Macandrew Bay, Otago Harbour
A027847	EF110234	<i>Ulva intestinalis</i>	Portobello, Otago Harbour
A027537	EF110237	<i>Ulva intestinalis</i>	Portobello, Otago Harbour
A027538	EF110245	<i>Ulva intestinalis</i>	Hunts Beach, Makawhio Point, West Coast, South Island
A027539	EF110250	<i>Ulva intestinalis</i>	Ocean Beach, Jackson Bay, West Coast, South Island
A027540	EF110251	<i>Ulva intestinalis</i>	Ocean Beach, Jackson Bay, West Coast, South Island
A027541	EF110253	<i>Ulva intestinalis</i>	Ocean Beach, Jackson Bay, West Coast, South Island
A027558	EF110254	<i>Ulva intestinalis</i>	Deep Cove, before Brassel Point, Doubtful Sound, Fiordland
A027542	EF110256	<i>Ulva intestinalis</i>	Mid Channel, Doubtful Sound, Fiordland
A027543	EF110257	<i>Ulva intestinalis</i>	Mid Channel, Doubtful Sound, Fiordland
A027331	EF110258	<i>Ulva intestinalis</i>	Crooked Arm, Doubtful Sound, Fiordland
A027544	EF110259	<i>Ulva intestinalis</i>	Crooked Arm, Doubtful Sound, Fiordland
A027545	EF110260	<i>Ulva intestinalis</i>	Crooked Arm, Doubtful Sound, Fiordland
A027546	EF110263	<i>Ulva intestinalis</i>	Crooked Arm, Doubtful Sound, Fiordland
A027547	EF110268	<i>Ulva intestinalis</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027548	EF110273	<i>Ulva intestinalis</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027330	EF110276	<i>Ulva intestinalis</i>	mid channel, south side, Doubtful Sound, Fiordland
A027549	EF110279	<i>Ulva intestinalis</i>	Precipice Cove, Bradshaw Sound, Fiordland, South Island
A027570	EF110281	<i>Ulva intestinalis</i>	Precipice Cove, Bradshaw Sound, Fiordland, South Island
A027332	EF110283	<i>Ulva intestinalis</i>	Precipice Cove, Bradshaw Sound, Fiordland, South Island
A027550	EF110284	<i>Ulva intestinalis</i>	Rum River Estuary, Bradshaw Sound, Fiordland, South Island
A027551	EF110286	<i>Ulva intestinalis</i>	Bradshaw Sound, Fiordland, South Island
A027552	EF110287	<i>Ulva intestinalis</i>	Deep Cove, before Brassel Point, Doubtful Sound, Fiordland
A027341	EF110309	<i>Ulva intestinalis</i>	Blackhead
A027336	EF110316	<i>Ulva intestinalis</i>	Wellington, Titahi Bay
A027553	EF110320	<i>Ulva intestinalis</i>	Deep Cove, before Brassel Point, Doubtful Sound, Fiordland
A027845	EF110336	<i>Ulva intestinalis</i>	Kaikoura, Ohau Stream
A027560	EF110363	<i>Ulva intestinalis</i>	Katiki Beach (south end), Otago

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A027561	EF110364	<i>Ulva intestinalis</i>	Katiki Beach (south end), Otago
A027562	EF110365	<i>Ulva intestinalis</i>	Katiki Beach (south end), Otago
A027563	EF110367	<i>Ulva intestinalis</i>	Katiki Beach (south end), Otago
A027564	EF110374	<i>Ulva intestinalis</i>	Macandrew Bay, Otago Harbour
A027565	EF110375	<i>Ulva intestinalis</i>	Macandrew Bay, Otago Harbour
A027569	EF110400	<i>Ulva intestinalis</i>	Blind Jim's Creek, Te Whanga Lagoon, Chatham Island
A027567	EF110401	<i>Ulva intestinalis</i>	Whangatete Inlet, Petre Bay, Chatham Island
A027567	EF110402	<i>Ulva intestinalis</i>	Whangatete Inlet, Petre Bay, Chatham Island
A027568	EF110412	<i>Ulva intestinalis</i>	Bridge, Waitangi, Petre Bay, Chatham Island
A027566	EF110446	<i>Ulva intestinalis</i>	Whale Bay, Taranaki, North Island
A027534	EF110469	<i>Ulva intestinalis</i>	The Cliff site, Bay of Islands, North Island
A027413	EF110488	<i>Ulva intestinalis</i>	Tanner's Point, Tauranga Harbour
A027322	EF110000	<i>Ulva lactuca</i>	Christchurch, Lyttelton Marina
A027323	EF110114	<i>Ulva lactuca</i>	Timaru Port
A027324	EF110122	<i>Ulva lactuca</i>	Bluff Port
A027821	EF110016	<i>Ulva linza</i>	Stewart Island, Port William
A027283	EF110386	<i>Ulva linza</i>	Te One Creek, Owenga, Chatham Island
A027622	EF109950	<i>Ulva pertusa</i>	Kaka Point
A027658	EF109954	<i>Ulva pertusa</i>	Tirohanga
A027660	EF109962	<i>Ulva pertusa</i>	Monkey Island
A027656	EF109964	<i>Ulva pertusa</i>	Monkey Island
A027621	EF109968	<i>Ulva pertusa</i>	Riverton Rocks
A027313	EF109975	<i>Ulva pertusa</i>	Aquarium Point
A027657	EF109987	<i>Ulva pertusa</i>	Brighton Beach, Dunedin
A027623	EF109993	<i>Ulva pertusa</i>	Gisborne, Kaiti Beach Reef
A027653	EF109996	<i>Ulva pertusa</i>	Kaikoura, Mangamaunu
A027310	EF109997	<i>Ulva pertusa</i>	Kaikoura, Mangamaunu
A027652	EF109998	<i>Ulva pertusa</i>	Picton floating dock
A027667	EF109999	<i>Ulva pertusa</i>	Christchurch, Lyttelton Marina
A027624	EF110001	<i>Ulva pertusa</i>	Christchurch, Taylors Mistake
A027666	EF110006	<i>Ulva pertusa</i>	Moeraki
A027651	EF110007	<i>Ulva pertusa</i>	Stewart Island, Halfmoon Bay, Scollays Rocks
A027345	EF110013	<i>Ulva pertusa</i>	Stewart Island, Port William
A027625	EF110020	<i>Ulva pertusa</i>	Marlborough Sounds, mussel farm#2
A027655	EF110026	<i>Ulva pertusa</i>	Wellington, Scorching Bay
A027315	EF110043	<i>Ulva pertusa</i>	Wellington, Pukerua Bay

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A027316	EF110052	<i>Ulva pertusa</i>	Picton, Waikawa Bay
A027654	EF110053	<i>Ulva pertusa</i>	Picton floating dock
A027620	EF110054	<i>Ulva pertusa</i>	Marfells Beach
A027650	EF110055	<i>Ulva pertusa</i>	Marfells Beach
A027584	EF110057	<i>Ulva pertusa</i>	Poor Knights, Labrid Channel
A027585	EF110058	<i>Ulva pertusa</i>	Poor Knights, Labrid Channel
A027586	EF110059	<i>Ulva pertusa</i>	Poor Knights, Labrid Channel
A027587	EF110060	<i>Ulva pertusa</i>	Poor Knights, Labrid Channel
A027588	EF110061	<i>Ulva pertusa</i>	Poor Knights, Labrid Channel
A027859	EF110062	<i>Ulva pertusa</i>	Poor Knights, Labrid Channel
A027590	EF110063	<i>Ulva pertusa</i>	Mayor Island, Bait Pond
A027591	EF110064	<i>Ulva pertusa</i>	Mayor Island, Bait Pond
A027592	EF110065	<i>Ulva pertusa</i>	Mayor Island, Bait Pond
A027593	EF110066	<i>Ulva pertusa</i>	Mayor Island, Bait Pond
A027525	EF110074	<i>Ulva pertusa</i>	Tauranga_Port
A027629	EF110079	<i>Ulva pertusa</i>	Tauranga_Port
(UPN225)	EF110088	<i>Ulva pertusa</i>	Napier_Port
(UPN227)	EF110090	<i>Ulva pertusa</i>	Napier_Port
(UPN229)	EF110092	<i>Ulva pertusa</i>	Napier_Port
A027646	EF110096	<i>Ulva pertusa</i>	Port Taranaki
A027630	EF110097	<i>Ulva pertusa</i>	Wellington_Port
A027628	EF110098	<i>Ulva pertusa</i>	Wellington_Port
A027627	EF110099	<i>Ulva pertusa</i>	Wellington_Port
A027626	EF110100	<i>Ulva pertusa</i>	Picton_Port
A027631	EF110101	<i>Ulva pertusa</i>	Picton_Port
A027647	EF110107	<i>Ulva pertusa</i>	Lyttelton Port
A027648	EF110108	<i>Ulva pertusa</i>	Lyttelton Port
A027632	EF110109	<i>Ulva pertusa</i>	Lyttelton Port
A027633	EF110110	<i>Ulva pertusa</i>	Lyttelton Port
A027634	EF110111	<i>Ulva pertusa</i>	Lyttelton Port
A027595	EF110113	<i>Ulva pertusa</i>	Timaru_Port
A027596	EF110115	<i>Ulva pertusa</i>	Timaru_Port
A027597	EF110119	<i>Ulva pertusa</i>	Timaru_Port
A027598	EF110120	<i>Ulva pertusa</i>	Timaru_Port
A027659	EF110121	<i>Ulva pertusa</i>	Port_Otago
A027599	EF110123	<i>Ulva pertusa</i>	Christchurch, Taylors Mistake

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A027524	EF110126	<i>Ulva pertusa</i>	Cave Rock, Sumner, Canterbury
A027829	EF110130	<i>Ulva pertusa</i>	Pigeon Bay, Banks Peninsula, Canterbury
A027828	EF110141	<i>Ulva pertusa</i>	Kakanui Beach, Otago
A027600	EF110153	<i>Ulva pertusa</i>	Wellington, Island Bay
A027526	EF110154	<i>Ulva pertusa</i>	Wellington, Scorching Bay
A027527	EF110159	<i>Ulva pertusa</i>	Houghton Bay, Wellington
A027601	EF110164	<i>Ulva pertusa</i>	Te Henga, West Coast, Auckland (Bethell's Beach)
A027619	EF110165	<i>Ulva pertusa</i>	Te Henga, West Coast, Auckland (Bethell's Beach)
A027602	EF110166	<i>Ulva pertusa</i>	Te Henga, West Coast, Auckland (Bethell's Beach)
(UPN385)	EF110171	<i>Ulva pertusa</i>	Kotau Point, O'Neill Bay, Waitakere, Auckland
A027603	EF110174	<i>Ulva pertusa</i>	Langs Beach, Bream Bay, Northland
A027311	EF110175	<i>Ulva pertusa</i>	Langs Beach, Bream Bay, Northland
A027312	EF110186	<i>Ulva pertusa</i>	Ocean Beach, Whangarei, Northland
A027604	EF110187	<i>Ulva pertusa</i>	Ocean Beach, Whangarei, Northland
A027605	EF110188	<i>Ulva pertusa</i>	Ocean Beach, Whangarei, Northland
A027606	EF110189	<i>Ulva pertusa</i>	Ocean Beach, Whangarei, Northland
A027607	EF110210	<i>Ulva pertusa</i>	Moeraki Boulders
A027856	EF110223	<i>Ulva pertusa</i>	Brighton Beach, Dunedin
A027608	EF110266	<i>Ulva pertusa</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027609	EF110269	<i>Ulva pertusa</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027610	EF110270	<i>Ulva pertusa</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027850	EF110292	<i>Ulva pertusa</i>	Opononi, Hokianga, Northland, North Island
A027314	EF110298	<i>Ulva pertusa</i>	Admiralty Bay
A027611	EF110307	<i>Ulva pertusa</i>	Blackhead
A027612	EF110311	<i>Ulva pertusa</i>	Napier Port
A027613	EF110318	<i>Ulva pertusa</i>	Wellington, Porirua Harbour
A027614	EF110321	<i>Ulva pertusa</i>	Deep Cove, before Brassel Point, Doubtful Sound, Fiordland
A027615	EF110322	<i>Ulva pertusa</i>	Tricky Cove, Doubtful Sound, Fiordland, South Island
A027317	EF110323	<i>Ulva pertusa</i>	Wellington, Titahi Bay
A027616	EF110326	<i>Ulva pertusa</i>	Wellington, Scorching Bay
A027617	EF110330	<i>Ulva pertusa</i>	Wellington, Lyall Bay west
A027618	EF110334	<i>Ulva pertusa</i>	Wellington, Island Bay
A027832	EF110338	<i>Ulva pertusa</i>	Kaikoura, Mangamaunu
A027838	EF110344	<i>Ulva pertusa</i>	Wellington, Pukerua Bay, Brendan Beach
A027539	EF110345	<i>Ulva pertusa</i>	Mana marina
A027635	EF110356	<i>Ulva pertusa</i>	Brighton Beach, Dunedin

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A027636	EF110357	<i>Ulva pertusa</i>	Brighton Beach, Dunedin
(UPN761)	EF110368	<i>Ulva pertusa</i>	Piha, Waitakere, Auckland, North Island
A027637	EF110376	<i>Ulva pertusa</i>	Frank Kitts, Wellington
A027665	EF110379	<i>Ulva pertusa</i>	Wharf, Waitangi, Petre Bay, Chatham
A027318	EF110394	<i>Ulva pertusa</i>	Wharekauri, Chatham Island
A027644	EF110403	<i>Ulva pertusa</i>	Whangatete Inlet, Petre Bay, Chatham Island
A027645	EF110405	<i>Ulva pertusa</i>	Port Hutt, Petre Bay, Chatham Island
A027662	EF110413	<i>Ulva pertusa</i>	Boulder Bank, Glenduan, Nelson, Tasman Bay, South Island
A027642	EF110418	<i>Ulva pertusa</i>	Pohara Wharf, Golden Bay, South Island
A027643	EF110429	<i>Ulva pertusa</i>	Wharariki, Cape Farewell, South Island
A027641	EF110432	<i>Ulva pertusa</i>	Constant Bay, Charleston, West Coast, South Island
A027638	EF110434	<i>Ulva pertusa</i>	south of Charleston, West Coast, South Island
A027410	EF110439	<i>Ulva pertusa</i>	Waitara, Taranaki, North Island
A027640	EF110441	<i>Ulva pertusa</i>	Onaero, Taranaki, North Island
(UPN898)	EF110443	<i>Ulva pertusa</i>	Kiritehere, Taranaki, North Island
(UPN921)	EF110451	<i>Ulva pertusa</i>	Mangere Island, Chatham Islands
A027673	EF110463	<i>Ulva pertusa</i>	off Red Head Island, Bay of Islands, North Island
A027664	EF110467	<i>Ulva pertusa</i>	Tapeka Point, Russell, Bay of Islands, North Island
A027663	EF110470	<i>Ulva pertusa</i>	The Cliff site, Bay of Islands, North Island
A027676	EF110472	<i>Ulva pertusa</i>	Stella base site, Fiordland, South Island
A027675	EF110473	<i>Ulva pertusa</i>	Station Islet, Inner Edwardson Sound, Fiordland, South Island
A027678	EF110476	<i>Ulva pertusa</i>	Bowen Channel, Dusky Sound, Fiordland, South Island
A027679	EF110477	<i>Ulva pertusa</i>	Wet Jacket Arm, Acheron Passage, Dusky Sound, Fiordland
A027677	EF110478	<i>Ulva pertusa</i>	First Cove, Breaksea Sound, Fiordland, South Island
(UPN973)	EF110479	<i>Ulva pertusa</i>	Otago Point, Dagg Sound, Fiordland, South Island
A027672	EF110480	<i>Ulva pertusa</i>	Blanket Bay Hotel, Malaspina Reach, Doubtful Sound, Fiordland
A027668	EF110482	<i>Ulva pertusa</i>	Eleanor Island, Charles Sound, Fiordland
A027669	EF110483	<i>Ulva pertusa</i>	Copper pad, Gold Arm, Charles Sound, Fiordland
A027670	EF110484	<i>Ulva pertusa</i>	Friendship Head, Gold Arm, Charles Sound, Fiordland
A027671	EF110486	<i>Ulva pertusa</i>	Evening Point
A027661, A027661/B	EF110503	<i>Ulva pertusa</i>	Karikari Bay 1
A027674	EF110507	<i>Ulva pertusa</i>	Kemps Beach, Leigh
A027639	EF110516	<i>Ulva pertusa</i>	Bluff Port
A027362	EF109944	<i>Ulva procera</i>	Pulling Point, Otago Harbour
A027358	EF109991	<i>Ulva procera</i>	Taieri Mouth, Otago
A027364	EF110002	<i>Ulva procera</i>	Christchurch, Taylors Mistake

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A027684	EF110021	<i>Ulva procera</i>	Wellington, Scorching Bay
A027363	EF110024	<i>Ulva procera</i>	Wellington, Scorching Bay
A027528	EF110032	<i>Ulva procera</i>	Wellington, Lyall Bay west
A027830	EF110128	<i>Ulva procera</i>	Akaroa, Akaroa Harbour, Banks Peninsula, Canterbury
A027529	EF110134	<i>Ulva procera</i>	Kakanui Beach, Otago
A027685	EF110142	<i>Ulva procera</i>	Kakanui Beach, Otago
A027530	EF110160	<i>Ulva procera</i>	Wellington, Lyall Bay west
A027360	EF110161	<i>Ulva procera</i>	Cornwallis, Manukau Harbour
A027356	EF110170	<i>Ulva procera</i>	Orakei Basin, Waitemata Harbour, Auckland
A027357	EF110179	<i>Ulva procera</i>	Ngunguru, Northland
A027688	EF110184	<i>Ulva procera</i>	Sandy Bay, Northland
A027857	EF110225	<i>Ulva procera</i>	St Clair, Dunedin
A027860	EF110228	<i>Ulva procera</i>	St Clair, Dunedin
A027846	EF110233	<i>Ulva procera</i>	Macandrew Bay, Otago Harbour
A027683	EF110239	<i>Ulva procera</i>	Marlborough Sounds, Horseshoe Bay
A027687	EF110252	<i>Ulva procera</i>	Ocean Beach, Jackson Bay, West Coast, South Island
A027354	EF110255	<i>Ulva procera</i>	Deep Cove, before Brassel Point, Doubtful Sound, Fiordland
A027355	EF110261	<i>Ulva procera</i>	Crooked Arm, Doubtful Sound, Fiordland
A027365	EF110304	<i>Ulva procera</i>	Wellington, Lyall Bay west
A027686	EF110314	<i>Ulva procera</i>	Flat Point
A027682	EF110327	<i>Ulva procera</i>	Wellington, Scorching Bay
A027361	EF110382	<i>Ulva procera</i>	Wharf, Waitangi, Petre Bay, Chatham
A027681	EF110409	<i>Ulva procera</i>	Port Hutt, Petre Bay, Chatham Island
A027689	EF110428	<i>Ulva procera</i>	Wharariki, Cape Farewell, South Island
A027690	EF110436	<i>Ulva procera</i>	Ngakawau, West Coast
A027715	EF109957	<i>Ulva prolifera</i>	Pounawea West
A027350	EF109958	<i>Ulva prolifera</i>	Pounawea West
A027718	EF109959	<i>Ulva prolifera</i>	Monkey Island
A027717	EF110124	<i>Ulva prolifera</i>	Christchurch, Taylors Mistake
A027716	EF110201	<i>Ulva prolifera</i>	Hoopers Inlet, Otago Peninsula
A027716	EF110202	<i>Ulva prolifera</i>	Hoopers Inlet, Otago Peninsula
A027719	EF110207	<i>Ulva prolifera</i>	Blueskin Bay, Warrington, Otago
A027353	EF110209	<i>Ulva prolifera</i>	Blueskin Bay, Warrington, Otago
A027351	EF110213	<i>Ulva prolifera</i>	Katiki Beach (south end), Otago
A027720	EF110220	<i>Ulva prolifera</i>	Karitane Harbour, Otago
A027352	EF110236	<i>Ulva prolifera</i>	Portobello, Otago Harbour

Appendix 2: Samples: vouchers deposited in WELT with associated GenBank accession numbers. (UPN data provided for specimens not registered in WELT)

A027374	EF109941	<i>Ulva rigida</i>	Pulling Point, Otago Harbour
A027373	EF109942	<i>Ulva rigida</i>	Pulling Point, Otago Harbour
A027721	EF109953	<i>Ulva rigida</i>	Tirohanga
A027726	EF109974	<i>Ulva rigida</i>	Papanui Inlet, Otago Peninsula
A027372	EF110004	<i>Ulva rigida</i>	Timaru, North Mole
A027820	EF110009	<i>Ulva rigida</i>	Stewart Island, Oban
A027817, A027818, A027819	EF110017	<i>Ulva rigida</i>	Stewart Island, Port William
A027727	EF110019	<i>Ulva rigida</i>	Marlborough Sounds, Horseshoe Bay
A027725	EF110029	<i>Ulva rigida</i>	Wellington, Lyall Bay west
A027723	EF110116	<i>Ulva rigida</i>	Timaru Port
A027724	EF110118	<i>Ulva rigida</i>	Timaru Port
A027369	EF110198	<i>Ulva rigida</i>	Allan's Beach, Otago Peninsula
A027722	EF110203	<i>Ulva rigida</i>	Hoopers Inlet, Otago Peninsula
A027848	EF110235	<i>Ulva rigida</i>	Portobello, Otago Harbour
A027370	EF110275	<i>Ulva rigida</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027371	EF110302	<i>Ulva rigida</i>	Wellington, Tarakena Bay
A027835	EF110341	<i>Ulva rigida</i>	Kaikoura, South Bay
A027467	EF109938	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027379	EF109940	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027511	EF109943	<i>Ulva species 1</i>	Pulling Point, Otago Harbour
A027460	EF109949	<i>Ulva species 1</i>	Kaka Point
A027394	EF109951	<i>Ulva species 1</i>	Tirohanga
A027510	EF109952	<i>Ulva species 1</i>	Tirohanga
A027468	EF109955	<i>Ulva species 1</i>	Pounawea East
A027469	EF109956	<i>Ulva species 1</i>	Pounawea West
A027459	EF109960	<i>Ulva species 1</i>	Monkey Island
A027440	EF109961	<i>Ulva species 1</i>	Monkey Island
A027458	EF109965	<i>Ulva species 1</i>	Monkey Island
A027470	EF109967	<i>Ulva species 1</i>	Riverton Harbour, Southland
A027477	EF109976	<i>Ulva species 1</i>	Hoopers Inlet, Otago Peninsula
A027457	EF109977	<i>Ulva species 1</i>	Allan's Beach, Otago Peninsula
A027478	EF109978	<i>Ulva species 1</i>	Harwood
A027383	EF109979	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027456	EF109981	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027486	EF109985	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027487	EF109988	<i>Ulva species 1</i>	Brighton Beach, Dunedin

Appendix 2: Samples: vouchers deposited in WELT with associated GenBank accession numbers. (UPN data provided for specimens not registered in WELT)

A027491	EF109989	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027441	EF109994	<i>Ulva species 1</i>	Napier_Port
A027471	EF109995	<i>Ulva species 1</i>	Napier_Port
A027389	EF110003	<i>Ulva species 1</i>	Timaru_Port
A027472	EF110005	<i>Ulva species 1</i>	Oamaru, Otago
A027473	EF110008	<i>Ulva species 1</i>	Stewart Island, Halfmoon Bay, Scollays Rocks
A027397	EF110010	<i>Ulva species 1</i>	Stewart Island, Lee Bay
A027825	EF110011	<i>Ulva species 1</i>	Stewart Island Deep Bay
A027488	EF110018	<i>Ulva species 1</i>	Greta Point, Wellington
A027378	EF110025	<i>Ulva species 1</i>	Wellington, Scorching Bay
A027390	EF110028	<i>Ulva species 1</i>	Wellington, Scorching Bay
A027442	EF110030	<i>Ulva species 1</i>	Wellington, Lyall Bay west
A027455	EF110033	<i>Ulva species 1</i>	Wellington, Lyall Bay west
A027489	EF110036	<i>Ulva species 1</i>	Wellington, Island Bay Lagoon
A027391	EF110037	<i>Ulva species 1</i>	Wellington, Island Bay Lagoon
A027388, A027388/B	EF110041	<i>Ulva species 1</i>	Frank Kitts, Wellington
A027474, A027474/B	EF110046	<i>Ulva species 1</i>	Wellington, Titahi Bay
A027376	EF110048	<i>Ulva species 1</i>	Wellington, Porirua Harbour
A027392, A027392/B	EF110056	<i>Ulva species 1</i>	Marfells Beach
A027869	EF110071	<i>Ulva species 1</i>	Tauranga_Port
A027480	EF110073	<i>Ulva species 1</i>	Tauranga_Port
A027509	EF110075	<i>Ulva species 1</i>	Tauranga_Port
A027508	EF110076	<i>Ulva species 1</i>	Tauranga_Port
A027507	EF110077	<i>Ulva species 1</i>	Tauranga_Port
A027506	EF110078	<i>Ulva species 1</i>	Tauranga_Port
A027505	EF110080	<i>Ulva species 1</i>	Tauranga_Port
A027504	EF110081	<i>Ulva species 1</i>	Tauranga_Port
A027503	EF110082	<i>Ulva species 1</i>	Tauranga_Port
A027502	EF110083	<i>Ulva species 1</i>	Tauranga_Port
A027501	EF110084	<i>Ulva species 1</i>	Tauranga_Port
A027500	EF110085	<i>Ulva species 1</i>	Tauranga_Port
A027499	EF110086	<i>Ulva species 1</i>	Tauranga_Port
A027498	EF110087	<i>Ulva species 1</i>	Tauranga_Port
(UPN226)	EF110089	<i>Ulva species 1</i>	Napier_Port
(UPN228)	EF110091	<i>Ulva species 1</i>	Napier_Port
A027497	EF110093	<i>Ulva species 1</i>	Port Taranaki

Appendix 2: Samples: vouchers deposited in WELT with associated GenBank accession numbers. (UPN data provided for specimens not registered in WELT)

A027496	EF110094	<i>Ulva species 1</i>	Port Taranaki
A027496	EF110095	<i>Ulva species 1</i>	Port Taranaki
A027495	EF110102	<i>Ulva species 1</i>	Picton_Port
A027481	EF110103	<i>Ulva species 1</i>	Nelson_Port
A027490	EF110104	<i>Ulva species 1</i>	Nelson_Port
A027482	EF110105	<i>Ulva species 1</i>	Nelson_Port
A027483	EF110106	<i>Ulva species 1</i>	Nelson_Port
A027494	EF110117	<i>Ulva species 1</i>	Timaru_Port
A027831	EF110127	<i>Ulva species 1</i>	Mt Pleasant Yacht Club, Avon/Heathcote Estuary
A027827	EF110140	<i>Ulva species 1</i>	Kakanui Beach, Otago
A027385	EF110155	<i>Ulva species 1</i>	Wellington, Scorching Bay
A027393	EF110157	<i>Ulva species 1</i>	Wellington, Lyall Bay west
A027443	EF110158	<i>Ulva species 1</i>	Houghton Bay, Wellington
A027454	EF110178	<i>Ulva species 1</i>	Ngunguru, Northland
A027453	EF110192	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027439	EF110193	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027453	EF110194	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027377	EF110196	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027484	EF110197	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027386	EF110205	<i>Ulva species 1</i>	Doctor's Point, Otago
A027382	EF110206	<i>Ulva species 1</i>	Doctor's Point, Otago
A027463	EF110211	<i>Ulva species 1</i>	Katiki Beach (south end), Otago
A027452	EF110212	<i>Ulva species 1</i>	Katiki Beach (south end), Otago
A027461	EF110219	<i>Ulva species 1</i>	Karitane Harbour, Otago
A027855	EF110224	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027851	EF110232	<i>Ulva species 1</i>	Macandrew Bay, Otago Harbour
A027444	EF110238	<i>Ulva species 1</i>	Muritai
A027445	EF110242	<i>Ulva species 1</i>	Hunts Beach, Makawhio Point, West Coast, South Island
A027462	EF110244	<i>Ulva species 1</i>	Hunts Beach, Makawhio Point, West Coast, South Island
A027464	EF110246	<i>Ulva species 1</i>	Hunts Beach, Makawhio Point, West Coast, South Island
A027512	EF110248	<i>Ulva species 1</i>	Ocean Beach, Jackson Bay, West Coast, South Island
A027446	EF110265	<i>Ulva species 1</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland, South Island
A027493	EF110285	<i>Ulva species 1</i>	Rum River Estuary, Bradshaw Sound, Fiordland, South Island
A027450	EF110299	<i>Ulva species 1</i>	Wellington, Scorching Bay
A027465	EF110300	<i>Ulva species 1</i>	Wellington, Scorching Bay
A027380	EF110303	<i>Ulva species 1</i>	Wellington, Lyall Bay west

Appendix 2: Samples: vouchers deposited in WELT with associated GenBank accession numbers. (UPN data provided for specimens not registered in WELT)

A027485	EF110310	<i>Ulva species 1</i>	Napier Port
A027387	EF110312	<i>Ulva species 1</i>	Ahuriri estuary
A027375	EF110313	<i>Ulva species 1</i>	Flat Point
A027451	EF110315	<i>Ulva species 1</i>	Wellington, Titahi Bay
A027476	EF110319	<i>Ulva species 1</i>	Wellington, Porirua Harbour
A027492	EF110325	<i>Ulva species 1</i>	Wellington, Titahi Bay
A027449	EF110328	<i>Ulva species 1</i>	Wellington, Scorching Bay
A027448	EF110329	<i>Ulva species 1</i>	Wellington, Lyall Bay west
A027475	EF110331	<i>Ulva species 1</i>	Wellington, Lyall Bay west
A027841	EF110337	<i>Ulva species 1</i>	Kaikoura, Rakautara rest area (BBQ)
A027833	EF110339	<i>Ulva species 1</i>	Kaikoura, Mangamaunu
A027438	EF110348	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027435	EF110349	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027434	EF110350	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027433	EF110351	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027432	EF110353	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027431	EF110355	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027430	EF110359	<i>Ulva species 1</i>	Brighton Beach, Dunedin
A027429	EF110360	<i>Ulva species 1</i>	Katiki Beach (south end), Otago
A027428	EF110361	<i>Ulva species 1</i>	Katiki Beach (south end), Otago
A027427	EF110362	<i>Ulva species 1</i>	Katiki Beach (south end), Otago
A027426	EF110366	<i>Ulva species 1</i>	Katiki Beach (south end), Otago
(UPN762)	EF110369	<i>Ulva species 1</i>	Piha, Waitakere, Auckland, North Island
A027425	EF110372	<i>Ulva species 1</i>	Macandrew Bay, Otago Harbour
A027424	EF110373	<i>Ulva species 1</i>	Macandrew Bay, Otago Harbour
A027381	EF110384	<i>Ulva species 1</i>	Wharf, Owenga, Chatham
A027466	EF110387	<i>Ulva species 1</i>	Te One Creek, Owenga, Chatham Island
A027447	EF110388	<i>Ulva species 1</i>	Te One Creek, Owenga, Chatham Island
(UPN811)	EF110390	<i>Ulva species 1</i>	Te One Creek, Owenga, Chatham Island
(UPN815)	EF110392	<i>Ulva species 1</i>	Mairangi, Chatham Island
A027384	EF110393	<i>Ulva species 1</i>	Wharekauri, Chatham Island
A027399	EF110397	<i>Ulva species 1</i>	Wharekauri, Chatham Island
A027395	EF110398	<i>Ulva species 1</i>	Blind Jim's Creek, Te Whanga Lagoon, Chatham Island
A027400	EF110407	<i>Ulva species 1</i>	Port Hutt, Petre Bay, Chatham Island
A027407	EF110414	<i>Ulva species 1</i>	Moutere Inlet, Motueka, Tasman Bay, South Island
A027406	EF110415	<i>Ulva species 1</i>	Wainui, Golden Bay, South Island

Appendix 2: Samples: vouchers deposited in WELT with associated GenBank accession numbers. (UPN data provided for specimens not registered in WELT)

A027642	EF110419	<i>Ulva species 1</i>	Pohara Wharf, Golden Bay, South Island
A027402	EF110420	<i>Ulva species 1</i>	Pakawau Bridge, Golden Bay, South Island
A027401	EF110421	<i>Ulva species 1</i>	Pakawau Bridge, Golden Bay, South Island
A027403	EF110424	<i>Ulva species 1</i>	Whanganui Inlet, Kahurangi National Park
A027404	EF110425	<i>Ulva species 1</i>	Whanganui Inlet, Kahurangi National Park
A027405	EF110430	<i>Ulva species 1</i>	Wharariki, Cape Farewell, South Island
A027398	EF110435	<i>Ulva species 1</i>	Ngakawau, West Coast
A027411	EF110440	<i>Ulva species 1</i>	Waitara, Taranaki, North Island
A027408	EF110442	<i>Ulva species 1</i>	Onaero, Taranaki, North Island
A027409	EF110449	<i>Ulva species 1</i>	Kawhia, Taranaki, North Island
A027513	EF110481	<i>Ulva species 1</i>	Ranson Point, Doubtful Sound, Fiordland
A027514	EF110485	<i>Ulva species 1</i>	Caswell Sound, (inner site: "The Knob"), Fiordland
A027680	EF110487	<i>Ulva species 1</i>	Milford sound (inner south side), Fiordland
A027870	EF110489	<i>Ulva species 1</i>	Tanner's Point, Tauranga Harbour
A027412	EF110490	<i>Ulva species 1</i>	Tanner's Point, Tauranga Harbour
A027415	EF110492	<i>Ulva species 1</i>	Tanner's Point, Tauranga Harbour
A027416	EF110493	<i>Ulva species 1</i>	Omokoroa, Tauranga Harbour
A027414	EF110494	<i>Ulva species 1</i>	Tauranga Harbour (near central shopping area)
A027571	EF110496	<i>Ulva species 1</i>	Erebus Cove, Port Ross, Auckland Island
A027572	EF110502	<i>Ulva species 1</i>	North Cape
A027417	EF110508	<i>Ulva species 1</i>	marsden_point
A027418	EF110509	<i>Ulva species 1</i>	marsden_point
A027419	EF110510	<i>Ulva species 1</i>	marsden_point
A027420	EF110511	<i>Ulva species 1</i>	marsden_point
A027421	EF110512	<i>Ulva species 1</i>	whangarei_port
A027422	EF110513	<i>Ulva species 1</i>	whangarei_port
A027423	EF110514	<i>Ulva species 1</i>	whangarei_port
A027437	EF110515	<i>Ulva species 1</i>	Bluff_Port
A027436	EF110517	<i>Ulva species 1</i>	Napier_Port
A027516	EF110444	<i>Ulva species 10</i>	Whale Bay, Taranaki, North Island
A027703	EF109946	<i>Ulva species 2</i>	Pulling Point, Otago Harbour
A027368	EF110022	<i>Ulva species 2</i>	Wellington, Scorching Bay
A027704	EF110038	<i>Ulva species 2</i>	Wellington, Island Bay Lagoon
A027367	EF110125	<i>Ulva species 2</i>	Christchurch, Taylors Mistake
A027711	EF110167	<i>Ulva species 2</i>	Man O' War Bay, Waiheke Island, Hauraki Gulf
A027366	EF110168	<i>Ulva species 2</i>	Rocky Bay, Waiheke Island, Hauraki Gulf

Appendix 2: Samples: vouchers deposited in WELT with associated GenBank accession numbers. (UPN data provided for specimens not registered in WELT)

A027698	EF110169	<i>Ulva species 2</i>	Rocky Bay, Waiheke Island, Hauraki Gulf
A027708	EF110176	<i>Ulva species 2</i>	Langs Beach, Bream Bay, Northland
A027709	EF110181	<i>Ulva species 2</i>	Tutukaka, Northland
A027710	EF110185	<i>Ulva species 2</i>	Sandy Bay, Northland
A027712	EF110191	<i>Ulva species 2</i>	Urquhart Bay, Whangarei Harbour, Northland
A027714	EF110241	<i>Ulva species 2</i>	Jackson Bay, West Coast, South Island
A027707	EF110249	<i>Ulva species 2</i>	Ocean Beach, Jackson Bay, West Coast, South Island
A027842	EF110293	<i>Ulva species 2</i>	Matai Bay, Karikari Peninsula, Northland, North Island
A027706	EF110308	<i>Ulva species 2</i>	Blackhead
A027705	EF110324	<i>Ulva species 2</i>	Wellington, Titahi Bay
A027702	EF110358	<i>Ulva species 2</i>	Brighton Beach, Dunedin
A027713	EF110378	<i>Ulva species 2</i>	Tommy Solomons grave, Manukau Reef, Owenga, Chatham Island
A027701	EF110404	<i>Ulva species 2</i>	Whangatete Inlet, Petre Bay, Chatham Island
A027700	EF110408	<i>Ulva species 2</i>	Port Hutt, Petre Bay, Chatham Island
A027699	EF110416	<i>Ulva species 2</i>	Wainui, Golden Bay, South Island
A027695	EF110455	<i>Ulva species 2</i>	Russell (south end of beach), Bay of Islands, North Island
(UPN936)	EF110456	<i>Ulva species 2</i>	Long Beach, Russell, Bay of Islands, North Island
A027693	EF110457	<i>Ulva species 2</i>	Long Beach, Russell, Bay of Islands, North Island
A027692	EF110458	<i>Ulva species 2</i>	Bland Bay, Bay of Islands, North Island
A027696	EF110468	<i>Ulva species 2</i>	Tapeka Point, Russell, Bay of Islands, North Island
A027694	EF110505	<i>Ulva species 2</i>	Whangaroa Harbour
A027479	EF110072	<i>Ulva species 3</i>	Tauranga Port
A027344	EF109945	<i>Ulva species 4</i>	Pulling Point, Otago Harbour
A027577		<i>Ulva species 5 "U. ralfsii"</i>	Aramoana salt marsh
A027347	EF110204	<i>Ulva species 5 "U. ralfsii"</i>	Aramoana salt marsh
A027579	EF110221	<i>Ulva species 5 "U. ralfsii"</i>	Karitane Harbour, Otago
A027349	EF110222	<i>Ulva species 5 "U. ralfsii"</i>	Karitane Harbour, Otago
A027346	EF110271	<i>Ulva species 5 "U. ralfsii"</i>	Causet Cove, Bauza Island, Doubtful Sound, Fiordland
A027348	EF110277	<i>Ulva species 5 "U. ralfsii"</i>	Precipice Cove, Bradshaw Sound, Fiordland, South Island
A027582	EF110280	<i>Ulva species 5 "U. ralfsii"</i>	Precipice Cove, Bradshaw Sound, Fiordland, South Island
A027581	EF110282	<i>Ulva species 5 "U. ralfsii"</i>	Precipice Cove, Bradshaw Sound, Fiordland, South Island
A027578	EF110417	<i>Ulva species 5 "U. ralfsii"</i>	Ligar Bay, Golden Bay, South Island
A027531	EF110453	<i>Ulva species 5 "U. ralfsii"</i>	Russell, Bay of Islands, North Island
A027520	EF110460	<i>Ulva species 6</i>	Kerikeri (Landing Road Bridge), Bay of Islands, North Island
A027532	EF110461	<i>Ulva species 6</i>	Kerikeri (Landing Road Bridge), Bay of Islands, North Island
A027519	EF110466	<i>Ulva species 9</i>	Russell, Bay of Islands, North Island

Appendix 2: Samples: vouchers deposited in WELT with associated GenBank accession numbers. (UPN data provided for specimens not registered in WELT)

A027521	EF110497	<i>Umbraulva "Auckland Is"</i>	Shoe Island, Port Ross, Auckland Island
A027319	EF110288	<i>Umbraulva "Kermadecs"</i>	Denham Bay, Raoul Island, Kermadec Islands
A027319	EF110289	<i>Umbraulva "Kermadecs"</i>	Denham Bay, Raoul Island, Kermadec Islands
A027319	EF110290	<i>Umbraulva "Kermadecs"</i>	Denham Bay, Raoul Island, Kermadec Islands
A027396	EF110504	<i>Umbraulva "Northland"</i>	Karikari Bay 2
A027321	EF110112	<i>Umbraulva olivascens</i>	Timaru Port

### Appendix 3: Names of Ulvaceae reported for New Zealand

	reference	genus	species
1	Adams, N.M. 1972: The marine algae of the Wellington area. <i>Records of the Dominion Museum Wellington</i> 8: 43-98.	<i>Monostroma</i>	<i>latissimum</i> (Kütz.) Wittr.
			<i>pacificum</i> V.J.Chapm.
		<i>Ulva</i>	<i>brevistipitata</i> V.J.Chapm.
			<i>crassa</i> V.J.Chapm.
			<i>dactylifera</i> Setch. & N.L.Gardner
			<i>fasciata</i> Delile
			<i>geminoidea</i> V.J.Chapm.
			<i>lactuca</i> L.
			<i>laetevirens</i> Areschoug
			<i>laingii</i> V.J.Chapm.
			<i>latissima</i> L.
			<i>linza</i> L.
			<i>lobata</i> (Kütz.) Setch. & N.L.Gardner
			<i>taeniata</i> (Sech.) Setch. & N.L.Gardner
		<i>Lobata</i>	<i>phyllosa</i> V.J.Chapm.
			<i>foliosa</i> V.J.Chapm.
		<i>Gemina</i>	<i>ulvoidea</i> V.J.Chapm
		<i>Enteromorpha</i>	<i>bulbosa</i> (Suhr) J.Ag.
			<i>clathrata</i> (Roth) Grev.
			<i>compressa</i> (L.) Grev.
			<i>intestinalis</i> (L.) Grev.
			<i>nana</i> (Sommerf.) Sjoestedt
			<i>procera</i> Ahlner
			<i>prolifera</i> (Muell.) J.Ag.
			<i>ramulosa</i> Hook.f. & Harv.

2	Adams, N.M. 1994: <i>Seaweeds of New Zealand. An Illustrated Guide</i> . Christchurch, New Zealand, Canterbury University Press, 360 p.	<i>Monostroma</i>	<i>latissimum</i> Wittr.
		"other recorded species"	<i>antarcticum</i> V.J.Chapm.
			<i>applanatum</i> Gain
			<i>crepidinum</i> Farlow
			<i>lindaueri</i> V.J.Chapm.
			<i>moorei</i> V.J.Chapm.
			<i>nitidum</i> Wittr. var. <i>novae-zelandiae</i> V.J.Chapm.
			<i>pacificum</i> V.J.Chapm.
			<i>parvum</i> V.J.Chapm.
		<i>Capsosiphon</i>	<i>aurea</i> V.J.Chapm.
		<i>Ulva</i>	<i>lactuca</i> L.
			<i>laetevirens</i> Areschoug
			<i>rigida</i> C.Agardh
			<i>spathulata</i> Papenf.
			<i>stenophylla</i> Setch. & N.L.Gardner
		"other recorded species"	<i>brevistipitata</i> V.J.Chapm.
			<i>crassa</i> V.J.Chapm. (non <i>U.crassa</i> Kütz.)
			<i>dactylifera</i> Setch. & N.L.Gardner
			<i>fasciata</i> Delile
			<i>geminioidea</i> V.J.Chapm.var. <i>geminioidea</i>
			<i>laingii</i> V.J.Chapm.
			<i>latissima</i> (various authors)
			<i>lobata</i> (Kütz.) Setch. & N.L.Gardner
			<i>parva</i> V.J.Chapm.
			<i>phyllosa</i> (V.J.Chapm.) Papenf.
			<i>reticulata</i> Forsskal
			<i>sorensenii</i> V.J.Chapm.
			<i>taeniata</i> (Setch.) Setch. & N.L.Gardner
		<i>Lobata</i>	<i>foliosa</i> V.J.Chapm.
		<i>Gemina</i>	<i>clavata</i> V.J.Chapm.
			<i>enteromorphaidea</i> V.J.Chapm.
			<i>letterstedtioidea</i> V.J.Chapm.
			<i>linzoidea</i> V.J.Chapm.

			<i>ulvoidea</i> V.J.Chapm.
		<i>Letterstedtia</i>	<i>ulvoidea</i> V.J.Chapm.
		<i>Enteromorpha</i>	<i>bulbosa</i> (Suhr) Mont.
			<i>clathrata</i> (Roth) Grev.
			<i>compressa</i> (L.) Nees
			<i>crassimembrana</i> V.J.Chapm.
			<i>flexuosa</i> (Wulfen ex Roth) J.Agardh
			<i>intestinalis</i> (L.) Nees
			<i>linza</i> (L.) J.Agardh
			<i>prolifera</i> (Mueller) J.Agardh
			<i>ralfsii</i> Harv.
			<i>ramulosa</i> (J.E.Smith) Carmichael
		<i>Blidingia</i>	<i>minima</i> (Naegeli) Kylin
		<i>Percusaria</i>	<i>percursa</i> (C.Agardh) Rosenvinge
3	Adams, N.M. 1997: <i>Common Seaweeds of New Zealand</i> . Christchurch, New Zealand, Canterbury University Press, 48 p. , 48 pl..	<i>Ulva</i>	<i>lactuca</i> L.
		<i>Ulva</i>	<i>stenophylla</i> Setch. & N.L.Gardner
		<i>Enteromorpha</i>	<i>intestinalis</i> (L.) Nees
		<i>Enteromorpha</i>	<i>ramulosa</i> (Mont.) Kütz.
4	Adams, N.M., Conway, E., Norris, R.E., Willa, E.A. 1974: The marine algae of Stewart Island. <i>Records of the Dominion Museum Wellington</i> 8: 185-245.	<i>Monostroma</i>	<i>antarcticum</i> V.J.Chapm.

		<i>Ulva</i>	<i>brevistipitata</i> V.J.Chapm.
			<i>crassa</i> V.J.Chapm.
			<i>dactylifera</i> Setch. & N.L.Gardner
			<i>lactuca</i> L.
			<i>lactuca</i> L. var. <i>lacinulata</i> (Kütz.) Hauck
			<i>laetevirens</i> Areschoug
			<i>latissima</i> L.
			<i>linza</i> L.
			<i>reticulata</i> Forsskal
			<i>sorensenii</i> V.J.Chapm.
		<i>Gemina</i>	<i>enteromorphaidea</i> V.J.Chapm.
			<i>linzoidea</i> V.J.Chapm.
			<i>ulvoidea</i> V.J.Chapm.
		<i>Enteromorpha</i>	<i>compressa</i> (L.) Nees
			<i>intestinalis</i> (L.) Grev.
			<i>prolifera</i> (Muell.) J.Agardh
			<i>ramulosa</i> Hook.f. & Harv.
			sp.
5	Adams, N.M., Nelson, W.A. 1985: The marine algae of the Three Kings Islands. <i>National Museum of New Zealand Miscellaneous Series</i> 13: 1-29.	<i>Ulva</i>	<i>spathulata</i> Papenf.
			sp.
		<i>Enteromorpha</i>	<i>compressa</i> (L.) Grev.
			<i>intestinalis</i> (L.) Link
6	Agardh, J.G. 1878: De Algis Novae Zelandiae marinis. In supplementum Florae Hookerianae scripsit. Lunds Univ. Arsskrift Afd. 2 14(4): 1-32. Notes: Publ.: 1878 (fide KR; Nat. Nov. Jul 1879)	<i>Ulva</i>	<i>rigida</i> Ag. ( <i>Ulva lobata</i> et <i>Ulva latissima</i> ) Harv. Fl. Nov. Zel. P. 265
		<i>Enteromorpha</i>	<i>compressa</i> (L.) Grev.
		<i>Enteromorpha</i>	<i>clathrata</i> (Roth) Grev.
7	Batham, E.J. 1956: Ecology of southern New Zealand sheltered rocky shore. <i>Transactions of the Royal Society of New Zealand</i> 84: 447-465, pl. 429-431.	<i>Ulva</i>	<i>reticulata</i>

			<i>laingii</i>
		<i>Letterstedtia</i>	sp.
		<i>Enteromorpha</i>	spp.
<b>8</b>	De Toni, G.B., Forti, A. 1922: Alghe di Australia, Tasmania e Nuova Zelanda. <i>Memorie del Reale Istituto Veneto di Scienze, Lettere ed Arti</i> 29(3): 1-183, pl. 4-13. Effective publication date: October 1922 (Stafleu & Mennega 1998: 248)	<i>Ulva</i>	<i>lactuca</i> forma <i>rigida</i> Kütz.
		<i>Ulva</i>	<i>ligula</i> Mont. in Kütz.
		<i>Enteromorpha</i>	<i>linza</i> (L.) J.Agardh
			<i>ramulosa</i> (Engl. Bot.) Hook.
<b>9</b>	Harvey, W.H. 1855: Algae. In <i>The botany of the Antarctic voyage of H.M. Discovery Ships Erebus and Terror in the years 1839-1843...</i> (Hooker, J.D.), [ <i>I. Flora Novae Zelandiae. Part II.</i> pages 211-266, pl. 107-121. Reeve: London	<i>Enteromorpha</i>	<i>compressa</i> Grev
		<i>Enteromorpha</i>	<i>intestinalis</i> Link
		<i>Enteromorpha</i>	<i>clathrata</i> var. <i>ramulosa</i> . E. <i>ramulosa</i> Hook.
		<i>Ulva</i> ( <i>Phycoseris</i> )	<i>lobata</i> Kutz.
		<i>Ulva</i>	<i>latissima</i> Linn.
		<i>Ulva</i>	<i>bullosa</i> ? Roth
		<i>Ulva</i> ( <i>Prasiola</i> )	<i>crispa</i> Lightf.
<b>10</b>	Harvey, W.H. Hooker, J.D. 1845: Algae. In <i>The botany of the Antarctic voyage of H.M. Discovery Ships Erebus and Terror in the years 1839-1843...</i> (Hooker, J.D.), [ <i>I. Flora Antarctica. Part I. Botany of the Lord Auckland's Group and Campbell's Island.</i> ], 193 pp. pls. LXIX-LXXXVIII. Reeve London.	<i>Ulva</i>	<i>latissima</i> L.

<b>11</b>	Hooker, J.D., Harvey, W.H. 1845: <i>Algae Novae Zelandiae. London Jour. Bot.</i> 4: 521-551.	<i>Enteromorpha</i>	<i>compressa</i> Ag.
		<i>Enteromorpha</i>	<i>intestinalis</i> Ag.
		<i>Ulva</i>	<i>linza</i> Ag.
		<i>Ulva</i>	<i>latissima</i> Ag.
<b>12</b>	Harvey-Gibson, R.J. 1893: On some marine algae from New Zealand. <i>The Journal of Botany, British and Foreign</i> 31: 161-167, pl. 335.	<i>Ulva</i>	<i>lactuca</i> (L.) Le Jol.
		<i>Enteromorpha</i>	<i>compressa</i> (L.) Grev.
<b>14</b>	Hay, C.H., Adams, N.M., Parsons, M.J. 1985: Marine algae of the subantarctic islands of New Zealand. <i>National Museum of new Zealand Miscellaneous Series</i> 11: 1-70.	<i>Enteromorpha</i>	<i>bulbosa</i> (Suhr) Kütz.
			<i>clathrata</i> (Roth) J.Agardh
			<i>compressa</i> (L.) Grev.
			<i>intestinalis</i> (L.) Nees
			<i>linza</i> (L.) J.Agardh
			<i>ramulosa</i> (J.E.Smith) Hook.f.
		<i>Gemina</i>	<i>clavata</i> V.J.Chapm.
			<i>enteromorphaidea</i> V.J.Chapm.
			<i>letterstedtoidea</i> V.J.Chapm.
		<i>Letterstedtia</i>	<i>stipitata</i> V.J.Chapm.
		<i>Lobata</i>	<i>foliosa</i> V.J.Chapm.
		<i>Ulva</i>	<i>geminoidea</i> V.J.Chapm.
			<i>lactuca</i> L.
			<i>lactuca</i> L. var. <i>latissima</i> auct.
			<i>rigida</i> (C.Agardh) Thuret
			<i>sorensenii</i> V.J.Chapm.
			<i>spathulata</i> Papenf.
<b>15</b>	Neale, D., Nelson, W. 1998: Marine algae of the west coast, South Island, New Zealand. <i>Tuhinga</i> 10: 87-118.	<i>Enteromorpha</i>	<i>compressa</i> (L.) Nees
		<i>Enteromorpha</i>	<i>ramulosa</i> (J.E. Smith) Carmichael
		<i>Enteromorpha</i>	spp.

		<i>Ulva</i>	<i>laetevirens</i> Aresch.
		<i>Ulva</i>	<i>spathulata</i> Papenf.
		<i>Ulva</i>	sp.
		<i>Prasiola</i>	<i>stipitata</i> Suhr
<b>16</b>	Nelson, W.A., Adams, N.M. 1984: The marine algae of the Kermadec Islands - a list of species. <i>National Museum of New Zealand Miscellaneous Series</i> 10: 1-29.	<i>Ulva</i>	<i>lactuca</i> L.
			sp.
		<i>Enteromorpha</i>	<i>compressa</i> Grev.
			<i>flexuosa</i> (Wulf. ex Roth) J.Agardh
			<i>prolifera</i> (Muell.) J.Agardh f. <i>crinita</i> (Roth) V.J.Chapm.
<b>17</b>	Nelson, W.A., Adams, N.M. 1987: Marine algae of the Bay of Islands area. <i>National Museum of New Zealand Miscellaneous Series</i> 16: 1-47.	<i>Monostroma</i>	<i>antarcticum</i> V.J.Chapm.
			<i>applanatum</i> Gain
			<i>crepidinum</i> Farlow
			<i>latissimum</i> (Kütz.) Wittr.
			<i>lindaueri</i> V.J.Chapm.
			<i>nitidum</i> Wittr.
			<i>parvum</i> V.J.Chapm.
		<i>Blidingia</i>	<i>minima</i> (Naegeli ex Kütz.) Kylin
		<i>Enteromorpha</i>	<i>bulbosa</i> (Suhr) Mont.
			<i>clathrata</i> (Roth) Grev.
			<i>compressa</i> (L.) Grev.
			<i>flexuosa</i> (Wulfen ex Roth) J.Agardh
			<i>intestinalis</i> (L.) Nees
			<i>prolifera</i> (Mueller) J.Agardh
			<i>ralfsii</i> Harv.
			<i>ramulosa</i> (J.E.Smith) Hook.f.
		<i>Ulva</i>	<i>australis</i> Aresch.
			<i>crassa</i> V.J.Chapm. non Kjellm.
			<i>geminoides</i> V.J.Chapm.
			<i>lactuca</i> L.
			<i>linza</i> L.

			<i>lobata</i> (Kütz.) Setch. & N.L.Gardner
			<i>parva</i> V.J.Chapm.
			<i>rigida</i> C.Agardh
			<i>spathulata</i> Papenf.
		<i>Capsosiphon</i>	<i>aurea</i> V.J.Chapm.
<b>18</b>	Nelson, W.A., Adams, N.M. & Fox, J.M. 1992: Marine algae of the northern South Island. <i>National Museum of New Zealand Miscellaneous Series</i> 26: 1-79 + 1 pl.	<i>Monostroma</i>	<i>moorei</i> V.J.Chapm.
		<i>Enteromorpha</i>	<i>clathrata</i> (Roth) Grev.
			<i>linza</i> (L.) J.Agardh
			<i>ralfsii</i> Harv.
			<i>ramulosa</i> (J.E.Smith) Hook.f.
		<i>Ulva</i>	<i>lactuca</i> L.
			<i>laetevirens</i> Areschoug
			<i>rigida</i> C.Agardh
			<i>spathulata</i> Papenf.
			<i>stenophylla</i> Setch. & N.L.Gardner
		<i>Ulvaria</i>	<i>oxysperma</i> (Kütz.) Bliding
		<i>Percursaria</i>	<i>percursa</i> (C.Agardh) Rosenvinge
<b>19</b>	Nelson, W.A., Adams, N.M., Hay, C.H. 1991: Marine algae of the Chatham Islands. <i>National Museum of New Zealand Miscellaneous Series</i> 23: 1-58.	<i>Enteromorpha</i>	<i>bulbosa</i> (Suhr) Mont.
			<i>clathrata</i> (Roth) Grev.
			<i>compressa</i> (L.) Grev.
			<i>flexuosa</i> (Wulfen ex Roth) J.Agardh
			<i>ramulosa</i> (J.E.Smith) Hook.f.
		<i>Ulva</i>	<i>rigida</i> C.Agardh
			<i>spathulata</i> Papenf.
			<i>stenophylla</i> Setch. & N.L.Gardner
<b>20</b>	Nelson, W.A., Phillips, L.E. 1996: The Lindauer legacy - current names for the Algae Nova Zelandicae Exsiccatae. <i>New Zealand Journal of Botany</i> 34: 553-582.	<i>Monostroma</i>	<i>nitidum</i> Wittr.
		<i>Enteromorpha</i>	<i>bulbosa</i> (Suhr) Kutz.

		<i>Enteromorpha</i>	<i>prolifera</i> (Mueller) J.Agardh
		<i>Enteromorpha</i>	<i>clathrata</i> (Roth) Grev.
		<i>Enteromorpha</i>	<i>compressa</i> (L.) Grev. <i>F. obtusa</i> V.J.Chapm.
		<i>Enteromorpha</i>	<i>procera</i> (Ahln) f. <i>opposita</i> (J.Agardh)V.J.Chapm.
		<i>Ulva</i>	<i>parva</i> V.J. Chapm.
		<i>Ulva</i>	<i>dactylifera</i> Setch.& N.L.Gardner
		<i>Enteromorpha</i>	<i>clathrata</i> (Roth) Grev.
		<i>Prasiola</i>	<i>delicatula</i> V.J.Chapm.
21	Nelson, W.A., Phillips, L.E., Adams, N.M. 1998: Algal type material and historical phycological collections in the Museum of New Zealand Te Papa Tongarewa. <i>Tuhinga</i> 10: 63-85.	<i>Ulva</i>	<i>parva</i> V.J. Chapm.
		<i>Prasiola</i>	<i>delicatula</i> V.J.Chapm.
22	Nelson, W.A., Villouta, E., Neill, K.F., Williams, G.C., Adams, N.M., Slivsgaard, R. 2002: Marine macroalgae of Fiordland, New Zealand. <i>Tuhinga</i> 13: 117-152.	<i>Enteromorpha</i>	<i>bulbosa</i> (Suhr) Kütz.
		<i>Enteromorpha</i>	<i>compressa</i> (L.) Nees
		<i>Enteromorpha</i>	<i>intestinalis</i> (L.) Nees
		<i>Enteromorpha</i>	<i>linza</i> (L.) J. Agardh
		<i>Enteromorpha</i>	<i>muscoides</i> (Clemente) Cremada
		<i>Enteromorpha</i>	spp.
		<i>Ulva</i>	<i>rigida</i> C. Agardh
		<i>Ulva</i>	sp.
		<i>Prasiola</i>	<i>crispa</i> (Lightfoot) Kütz.
23	Ricker, R.W., 1987: <i>Taxonomy and Biogeography of Macquarie Island Seaweeds</i> . London, British Museum (Natural History), viii + 344 p.	<i>Enteromorpha</i>	<i>bulbosa</i> (Suhr) Mont.
			<i>intestinalis</i> (L.) Nees
		<i>Ulva</i>	<i>rigida</i> C.Agardh
24	South, G.R., Adams, N.M. 1976: Marine algae of the Kaikoura coast. <i>National Museum of New Zealand Miscellaneous Series</i> 1: 1-67, index, map.	<i>Enteromorpha</i>	<i>compressa</i> (L.) Grev.

			<i>intestinalis</i> (L.) Grev.
			<i>nana</i> Sommerf.) Bliding var. <i>minima</i> (Bliding) V.J.Chapm.
			<i>ramulosa</i> (J.E.Smith) Hook.f. var. <i>acanthocarpa</i> (Kütz.) V.J.Chapm.
		<i>Gemina</i>	<i>clavata</i> V.J.Chapm.
		<i>Letterstedtia</i>	<i>petiolata</i> J.Agardh
		<i>Lobata</i>	<i>foliosa</i> V.J.Chapm
		<i>Ulva</i>	<i>brevistipitata</i> V.J.Chapm.
			<i>dactylifera</i> Setch. & N.L.Gardner
			<i>lactuca</i> L.
			<i>lobata</i> (Kütz.) Setch. & N.L.Gardner
25	Womersley, H.B.S. 1984: <i>The Marine Benthic Flora of Southern Australia. Part I.</i> Government Printer, South Australia	<i>Ulva</i>	<i>taeniata</i> (Setch.) Setch. & N.L.Gardner
		<i>Blidingia</i>	<i>marginata</i> (J.Agardh) Dangeard

#### Appendix 4: Summary of the treatment of Ulvaceae in Chapman (1956)

Genus	Species	Authority	Publication	Date	C=current; S=synonym + current name; E = endemic to NZ	Full reference
<b><i>Monostroma</i> Thuret</b>						
<i>Monostroma</i>	<i>antarcticum</i>	sp. nov.	p. 381		C	
<i>Monostroma</i>	<i>applanatum</i>	Gain	Fl.Alg. Antarct. et Subant. p. 22.	1912	S	
<i>Monostroma</i>	<i>crepidinum</i>	Farlow	Rep. US Fish Comm.1879 p. 42	1881	S	
<i>Monostroma</i>	<i>crepidinum</i> var. <i>pseudocrepidinum</i>	var. nov.	p. 383			
<i>Monostroma</i>	<i>latissimum</i>	(Kütz.) Wittr.	Monostr. p. 33, Tab 1, fig. 4; Kütz. Tab. Phyc. 6: Tab 14	1866; 1856	S	
<i>Monostroma</i>	<i>latissimum</i> ecad <i>australis</i>	nov. ecad	p.379			
<i>Monostroma</i>	<i>lindaueri</i>	V.J.Chapm.	J.Bot. Lond 78: 266	1940	C	
<i>Monostroma</i>	<i>moorei</i> .	sp. nov.	p. 381		C	
<i>Monostroma</i>	<i>nitidum</i> var. <i>novaezelandiae</i>	var. nov.	p. 380		var not listed	
<i>Monostroma</i>	<i>parvum</i>	sp. nov.	p. 380		C	
<b><i>Letterstedtia</i> J.Agardh</b>						
<i>Letterstedtia</i>	<i>petiolata</i>	J.Agardh	Til. Alg. Syst. 6: 176, tab. 4, figs 123-4	1882	S -This name is currently regarded as a synonym of <i>Ulva rigida</i> C. Agardh	
<i>Letterstedtia</i>	<i>stipitata</i>	V.J.Chapm.	Trans. Roy. Soc. NZ 80: 47	1952	C	
<i>Letterstedtia</i>	<i>ulvoidea</i>	V.J.Chapm.	Trans. Roy. Soc. NZ 80: 48	1952	C	
<b><i>Ulva</i> L.</b>						
<i>Ulva</i>	<i>brevistipitata</i>	sp. nov.	p. 387		C + E	

<i>Ulva</i>	<i>crassa</i>	sp. nov.	p. 391		nom. Illeg. C; E	
<i>Ulva</i>	<i>dactylifera</i>	Setch. & N.L.Gardner.	<i>Ulva dactylifera</i> Setchell & N.L. Gardner 1920: 285-286, pl. 26: fig. 1	1920	C	Setchell, W.A. & Gardner, N.L. (1920). Phycological contributions. University of California Publications in Botany 7: 279-324..
<i>Ulva</i>	<i>dactylifera</i> var. <i>rotunda</i>	var. nov.	p. 395			
<i>Ulva</i>	<i>fasciata</i>	Delile	<i>Ulva fasciata</i> Delile 1813: 297, pl. 58: fig. 5	1813	C	Delile, A.R. (1813). Flore d'Égypte. In: <i>Description de l'Égypte...Histoire naturelle</i> . (Eds) Vol.2, pp. 145-320. Paris:
<i>Ulva</i>	<i>geminoidea</i> var. <i>geminoidea</i>	sp. nov., var. nov.	p. 392		C	
<i>Ulva</i>	<i>geminoidea</i> var. <i>crispa</i>	var. nov.	p. 393			
<i>Ulva</i>	<i>geminoidea</i> var. <i>dentata</i>	var. nov.	p. 393			
<i>Ulva</i>	<i>lactuca</i>	L.	<i>Ulva lactuca</i> Linnaeus 1753: 1163		C	Linnaeus, C. (1753). <i>Species plantarum</i> . Vol. 2pp. 561-1200 (+ 1-31) Stockholm.
<i>Ulva</i>	<i>lactuca</i> va. <i>lacunculata</i>	(Kütz.) Hauck			C	
<i>Ulva</i>	<i>lactuca</i> var. <i>rigida</i>	(Agardh) Le Jol.	list of references		S of <i>U. rigida</i>	
<i>Ulva</i>	<i>laetevirens</i>	Aresch.	<i>Ulva laetevirens</i> Areschoug 1854: 370-371		C	Areschoug, J.E. (1854). Phyceae novae et minus cognitae in maribus extraeuropaeis collectae. <i>Nova Acta Regiae Societatis Scientiarum Upsaliensis</i> Ser. 3, 1: 329-372.
<i>Ulva</i>	<i>laingii</i>	sp. nov.	p. 391		C + E	

<i>Ulva</i>	<i>latissima</i>	L.			S	The name <i>Ulva latissima</i> L. has traditionally been misapplied to representative of the genus with very broad, sheet-like fronds, whereas the type is referable to <i>Laminaria saccharina</i> (L.) Lamouroux (see Papenfuss, 1960: 303).
<i>Ulva</i>	<i>linza</i>	L.	<i>Ulva linza</i> Linnaeus 1753: 1163		C	Linnaeus, C. (1753). <i>Species plantarum</i> . Vol. 2pp. 561-1200 (+ 1-31) Stockholm.
<i>Ulva</i>	<i>lobata</i>	(Kütz.) Setch. & N.L.Gardner	Mar.Alg.Pac.Coast Nth. Am. Chlorophyceae p. 268; <i>Ulva lobata</i> (Kützing) Harvey 1855: 265	1920	C	Kützing, F.T. (1849). <i>Species algarum</i> . pp. vi + 922 Lipsiae [Leipzig]: Brockhaus.
<i>Ulva</i>	<i>parva</i>	sp. nov.	p. 396		C + E	
<i>Ulva</i>	<i>reticulata</i>	Forsk.	<i>Ulva reticulata</i> Forsskål 1775: 187		C	Forsskål, P. (1775). <i>Flora Aegyptiaca-Arabica sive descriptiones plantarum, quas per Aegyptum inferiorem et Arabium delicem detexit illustravit Petrus Forsskål. Prof. Haun. Post mortem auctoris edidit Carsten Niebuhr</i> . pp.[1]-32, [1]-XXXVI, ... [1]-219, [220, err.], Map

						Hafniae [Copenhagen].
<i>Ulva</i>	<i>sorensenii</i>	sp. nov.	<i>Ulva sorensenii</i> V.J.Chapm. 1956: 390-391, fig. 34		C + E	
<i>Ulva</i>	<i>taeniata</i>	(Setch.) Setch. & N.L.Gardner	<i>Ulva taeniata</i> (Setchell) Setchell & N.L. Gardner 1920: 286, pl. 28	1920	C	Setchell, W.A. & Gardner, N.L. (1920). The marine algae of the Pacific coast of North America. Part II. Chlorophyceae. <i>University of California Publications in Botany</i> 8: 139-374, Plates 9-33.
<b><i>Lobata</i> V.J.Chapm.</b>						
<i>Lobata</i>	<i>foliosa</i>	V.J.Chapm.	Trans. Roy. Soc. NZ 80: 49	1952	C	
<i>Lobata</i>	<i>phyllosa</i>	V.J.Chapm.	Trans. Roy. Soc. NZ 80: 49	1952	C under <i>Ulva</i>	transferred to <i>Ulva</i> by Papenfuss - E ?
<b><i>Gemina</i> V.J.Chapm.</b>						
<i>Gemina</i>	<i>clavata</i>	V.J.Chapm.	Trans. Roy. Soc. NZ 80: 53	1952	C	
<i>Gemina</i>	<i>enteromorphaidea</i>	V.J.Chapm.	Trans. Roy. Soc. NZ 80: 52	1952	C	

<i>Gemina</i>	<i>letterstedtioidea</i>	V.J.Chapm.	Trans. Roy. Soc. NZ 80: 52	1952	C	
<i>Gemina</i>	<i>linzoidea</i>	V.J.Chapm.	Trans. Roy. Soc. NZ 80: 53	1952	S	This name is currently regarded as a synonym of <i>Uva laetevirens</i> Areschoug
<i>Gemina</i>	<i>ulvoidea</i>	V.J.Chapm.	Trans. Roy. Soc. NZ 80: 52	1952	C	
<b>Enteromorpha Link</b>						
<i>Enteromorpha</i>	<i>bulbosa</i>	(Suhr) Mont.	<i>Enteromorpha bulbosa</i> (Suhr) Montagne 1846: 33, pl. 39			Montagne, J.F.C. (1846). Phyceae. In: <i>Voyage autour du monde exécuté pendant les années 1836 et 1837 sur la corvette 'La Bonite' commandée par M. Vaillant. Botanique. Vol. 1. Cryptogames cellulaires et vasculaires.</i> (Gaudichaud, C. Eds), pp. 1-112. Paris:
<i>Enteromorpha</i>	<i>bulbosa</i> f. <i>cornucopiae</i>	form. nov.	p. 412			
<i>Enteromorpha</i>	<i>bulbosa</i> f. <i>foliacea</i>	V.J.Chapm.	Farlowia 3(4): 496, fig. 3	1949		
<i>Enteromorpha</i>	<i>bulbosa</i> f. <i>novae-hollandiae</i>	(Suhr) J.Agardh; (Kütz.) comb. nov.	p. 411			
<i>Enteromorpha</i>	<i>clathrata</i>					
<i>Enteromorpha</i>	<i>clathrata</i> (Roth) Ag. var. <i>angustimembrana</i>	V.J.Chapm.	p.420			
<i>Enteromorpha</i>	<i>clathrata</i> ecad. <i>prostrata</i>	Le Jol.	p. 421-2			
<i>Enteromorpha</i>	<i>clathrata</i> var. <i>plumosa</i>	Kütz.	p.420-1			
<i>Enteromorpha</i>	<i>clathrata</i> var. <i>pumila</i>	(Aresch.) comb. nov.	p. 421			
<i>Enteromorpha</i>	<i>clathrata</i> var. <i>ralfsii</i>	(Harv.) comb. nov.	p. 423			
<i>Enteromorpha</i>	<i>clathrata</i> var. <i>usneoides</i>	(Bonnem.) comb.	p. 422-3			

		nov.				
<i>Enteromorpha</i>	<i>compressa</i>	(L.) Grev.	Flor. Brit. p. 180; <i>Ulva compressa</i> Linnaeus 1753: 1163	1830	C	Linnaeus, C. (1753). <i>Species plantarum</i> . Vol. 2pp. 561-1200 (+ 1-31) Stockholm.
<i>Enteromorpha</i>	<i>compressa</i> f. <i>subsimplex</i>	Le Jol.				
<i>Enteromorpha</i>	<i>compressa</i> var. <i>australiensis</i>	(V.J.Chapm.) comb. nov.	J.Bot. Lond 78: 265; p. 406	1940		
<i>Enteromorpha</i>	<i>compressa</i> var. <i>biattenuata</i>	var. nov.	p. 406			
<i>Enteromorpha</i>	<i>compressa</i> var. <i>lingulata</i>	(J.Ag) comb. nov.	p. 408			
<i>Enteromorpha</i>	<i>crassimembrana</i>	sp. nov - V.J.Chapm.	p. 424; <i>Ulva crassimembrana</i> (V.J. Chapm.) Hayden, Blomster, Maggs, P.C. Silva, M.J. Stanhope & J.R. Waaland 2003: 289 (table 4)			Type locality: Cape Maria van Diemen, New Zealand (Hayden <i>et al.</i> 2003: 289). Holotype: AKU (Hayden <i>et al.</i> 2003: 289).
<i>Enteromorpha</i>	<i>intestinalis</i>	(L.) Grev.	Alg. Brit. p. 179; <i>Ulva intestinalis</i> L. 1753: 1163	1830	C	Linnaeus, C. (1753). <i>Species plantarum</i> . Vol. 2pp. 561-1200 (+ 1-31) Stockholm.
<i>Enteromorpha</i>	<i>intestinalis</i> f. <i>brevis</i>	Schiffn (mscr.)				
<i>Enteromorpha</i>	<i>intestinalis</i> f. <i>bullosa</i>	Hauck	Meerseealg. Deutschl. p. 427	1885		
<i>Enteromorpha</i>	<i>intestinalis</i> f. <i>cornucopiae</i>	Lyngb.	<i>Ulva intestinalis</i> var. <i>cornucopiae</i> (Lyngbye) C. Agardh		C	
<i>Enteromorpha</i>	<i>intestinalis</i> f. <i>tubulosa</i>	Kütz.				
<i>Enteromorpha</i>	<i>nana</i>	(Sommerf.) Bliding	<i>Ulva intestinalis</i> var. <i>nana</i> Sommerfelt 1826: 186		U	
<i>Enteromorpha</i>	<i>nana</i> f. <i>gunniana</i>	(J.Ag.) comb. nov.	p. 413			
<i>Enteromorpha</i>	<i>nana</i> var. <i>minima</i>	(Bliding) comb. nov.	p. 413			
<i>Enteromorpha</i>	<i>nana</i> var. <i>minima</i> ecad. <i>bullosa</i>	(Gardn.) comb. nov.	p. 416			
<i>Enteromorpha</i>	<i>nana</i> var. <i>minima</i> ecad. <i>fastigiata</i>	(V.J.Chapm.) comb. nov.	p. 415			
<i>Enteromorpha</i>	<i>nana</i> var. <i>minima</i> ecad. <i>rivularis</i>	(Collins) comb. nov.	p. 415			

<i>Enteromorpha</i>	<i>percursa</i>	(C.Ag) J.Ag	p. 429; <i>Ulva percursa</i> (C. Agardh) C. Agardh		S	
<i>Enteromorpha</i>	<i>procera</i> Ahln. f. <i>minuta</i>	V.J.Chapm.	p. 424; <i>Ulva procera</i> (K. Ahlner) Hayden, Blomster, Maggs, P.C. Silva, M.J. Stanhope & J.R. Waaland		C	
<i>Enteromorpha</i>	<i>procera</i> f. <i>chlorotica</i>	(J.Ag.) comb. nov.	p. 426			
<i>Enteromorpha</i>	<i>procera</i> f. <i>denudata</i>	(Ahl.) comb. nov.	p. 427			
<i>Enteromorpha</i>	<i>procera</i> f. <i>eramosa</i>	(Schiff. MS) comb. nov.	p. 427			
<i>Enteromorpha</i>	<i>procera</i> f. <i>novaezelandiae</i>	VJChapm.	p. 425			
<i>Enteromorpha</i>	<i>procera</i> f. <i>opposita</i>	(J.Ag. MS) comb. nov.	p. 428-9			
<i>Enteromorpha</i>	<i>procera</i> f. <i>subundulata</i>	(Schiffn.) comb. nov.	p. 428			
<i>Enteromorpha</i>	<i>procera</i> var. <i>prolifera</i>	V.J.Chapm.	p. 426	1940		
<i>Enteromorpha</i>	<i>prolifera</i>	(Muell.) J.Agardh	Till Alg. Syst. 6: 129, pl. 4 pp. 103-4; <i>Ulva prolifera</i> O.F. Müller in Oeder 1778: 7, pl. 763(1)	1882		Müller, O.F. (1778). <i>Icones plantarum... Florae danicae. Vol. 5, fasc. 13.</i> Vol. 5, fasc. 13pp. 8 , Plates 721-780. Copenhagen.
<i>Enteromorpha</i>	<i>prolifera</i> f. <i>pilifera</i>	Kütz.	Tab. Phyc. 6: tab. 30, fig 3	1856		
<i>Enteromorpha</i>	<i>prolifera</i> var. <i>crinita</i>	Roth				
<i>Enteromorpha</i>	<i>prolifera</i> var. <i>flexuosa</i>	Wulf.				
<i>Enteromorpha</i>	<i>prolifera</i> var. <i>torta</i>	(Mert.) comb. nov.	p. 410			
	<i>ramulosa</i>		<i>Ulva ramulosa</i> J.E.Smith 1810: pl. 2137		S	This name is currently regarded as a synonym of <i>Ulva clathrata</i> (Roth) C. Agardh
<i>Enteromorpha</i>	<i>ramulosa</i> f. <i>minor</i>	Kütz.	p. 418			
<i>Enteromorpha</i>	<i>ramulosa</i> f. <i>robusta</i>	Le Jol.	p. 418			
<i>Enteromorpha</i>	<i>ramulosa</i> Hook.f. f. <i>spinescens</i>	Kütz.	p. 418			

<i>Enteromorpha</i>	<i>ramulosa</i> var. <i>acanthophora</i>	(Kütz.) comb. nov.	p. 419; <i>Ulva acanthophora</i> (Kützing) H.S.Hayden, Blomster, Maggs, P.C. Silva, Stanhope & Waaland 2003: 288		C	
<i>Enteromorpha</i>	<i>ramulosa</i> var. <i>acanthophora</i> ecad. <i>comosa</i>	ecad. nov	p. 420			

**Appendix 5: Details of *rbcL* sequences obtained from GenBank used in phylogenetic analyses.**

<b>taxon</b>	<b>Origin of sequenced material and publication details</b>	<b>GenBank accession no.</b>
<i>Ulva arasakii</i> Chihara	Japan (Shimada <i>et al.</i> 2003)	AB097621
<i>Ulva armoricana</i> Dion, de Reviers & Coat	France (Shimada <i>et al.</i> 2003)	AB097630
<i>Ulva californica</i> Wille in Collins, Holden & Setchell	California (Hayden <i>et al.</i> 2003)	AY255866
<i>Ulva clathrata</i> Roth	Spain (Blomster <i>et al.</i> 1999, as <i>Enteromorpha muscoides</i> (Clemente y Rubio) Cremades)	AY255862
<i>Ulva compressa</i> L.	Ireland (Blomster <i>et al.</i> 1998, as <i>Enteromorpha compressa</i> (L.) Nees)	AY255859
<i>Ulva fasciata</i> Delile	Hawaii (Hayden & Waaland 2004)	AY422565
<i>Ulva flexuosa</i> Wulfen	Japan (Shimada <i>et al.</i> 2003)	AB097619
<i>Ulva lactuca</i> L.	Ireland (Tan <i>et al.</i> 1999)	AF499669
<i>Ulva linza</i> L.	California, USA (Hayden <i>et al.</i> 2003, as <i>Enteromorpha linza</i> (L.) J. Agardh)	AY255861
<i>Ulva intestinalis</i> L.	Great Britain (Blomster <i>et al.</i> 1998, as <i>Enteromorpha intestinalis</i> (L.) Nees)	AY255860
<i>Ulva procera</i> (Ahlner) Hayden <i>et al.</i>	Finland (Hayden <i>et al.</i> 2003, as <i>Enteromorpha procera</i> Ahlner)	AY255863
<i>Ulva prolifera</i> O.F. Müller	Scotland (Tan <i>et al.</i> 1999, as <i>Enteromorpha prolifera</i> (O.F. Müller)	AY255864

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<i>Ulva lobata</i>	J. Agardh) California (Hayden & Waaland 2004)	AY422550
(Kützing) Harvey		
<i>Ulva ohnoi</i> Hiraoka & Shimada	Japan (Hiraoka <i>et al.</i> 2004)	AB116040
<i>Ulva pertusa</i> Kjellman	Japan (Hayden & Waaland 2004)	AY422549
<i>Ulva reticulata</i> Forsskål	Philippines (Shimada <i>et al.</i> 2003)	AB097635
<i>Ulva rigida</i> C. Agardh	Chile (Hayden & Waaland 2004)	AY422564
<i>Ulva stenophylla</i> Setchell & N.L. Gardner	Washington (Hayden & Waaland 2004)	AY255874
<i>Ulva spinulosa</i> Okamura & Seqawa	Japan (Shimada <i>et al.</i> 2003)	AB097636
<i>Ulva taeniata</i> (Setchell ) Setchell & N.L. Gardner	California (Hayden & Waaland 2004)	AY422567
<i>Ulva tanneri</i> Hayden & Waaland	Japan (Hayden <i>et al.</i> 2003, as <i>Chloropelta caespitosa</i> C.E.Tanner)	AY255858
<i>Ulva</i> sp. Chile	Chile (Hayden <i>et al.</i> 2003)	AY255871
<i>Ulva</i> sp. California	California (Hayden & Waaland 2004)	AY422561
<i>Ulvaria fusca</i> Ruprecht	Japan (Shimada <i>et al.</i> 2003)	AB097611
<i>Umbraulva</i> <i>amamiensis</i> Bae & I.K. Lee	Japan (Shimada <i>et al.</i> 2003)	AB097614
<i>Umbraulva</i> <i>japonica</i> (Tanaka)	Japan (Shimada <i>et al.</i> 2003)	AB097613

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Bae & I.K. Lee		
<i>Umbraulva</i>	Ireland (Hayden <i>et al.</i> 2003)	AY255876
<i>olivascens</i>		
(Dangeard) Bae &		
I.K. Lee		

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