Fiordland (Te Moana o Atawhenua) Marine Area Monitoring 2016

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Executive summary

Fiordland Marine Area Monitoring was carried out at five Fiordland (Te Moana o Atawhenua) marine reserves from 5-16 February 2016 using visual census methods, with the primary aim of detecting positive differences resulting from Marine Reserve (MR) management. After 10 years of MR protection, there is little evidence of strong differences in fish assemblages or abundance of key species inside compared to outside of reserves. An analysis comparing fish assemblages and densities of key species for sites with long-term monitoring data was also implemented. Again, there was little evidence of significant changes over time. These findings are discussed in light of what is known about recruitment of key species in Fiordland, and the timescales at which recovery might occur. The importance of 'biological significance' at the scale of historic losses is also introduced, with the intention of developing discussion around achievable goals for FMA monitoring in future surveys.

The discovery of multiple species of sea pen (Pennatulacea) living together at shallow depths at previously unrecorded sites in George, Caswell and Charles Sounds, illustrate what little is known of communities living below diving depths in Fiordland.

1 Introduction

Following the implementation of the Fiordland (Te Moana o Atawhenua) Marine Management Act (2005), and the subsequent establishment of eight new no-take marine reserves, a long-term biological monitoring programme was initiated in 2006 (Wing & Jack 2006 and 2007). The initial monitoring surveys were conducted in 2006 and 2007 with a view to providing baseline information for future monitoring purposes.

Problems with studies examining the effects of marine reserves can include i) inadequate spatial replication, ii) inadequate temporal replication, and iii) spatial confounding associated with locating representative reference sites (Willis et al. 2003). A monitoring survey in 2009 by Willis et al. (2009b), identified issues with the design and implementation of Fiordland (Te Moana o Atawhenua) Marine Area (FMA) surveys and made a number of recommendations for future monitoring surveys to increase the utility of the results (Willis et al. 2009b). Willis et al. (2009b) criticised the survey design previously implemented by Wing (2006) and Wing and Jack (2007) as not being suitable for determining the effects (if any) of management changes in the FMA, which is the first priority in the monitoring objectives. To determine if observed differences between management and reference sites are due to protection rather than natural spatial variation among sites, the number of reference sites needs to be adequate to capture the natural spatial variation across management and reference sites. Willis et al. (2009b) implemented greater site replication to increase the power to detect or quantify any changes in density of key species at appropriate spatial scales.

Problems with inadequate replication are particularly difficult where management units or reference sites are entire fiords or island groups lacking comparable reference sites (Willis et al. 2009b, Edgar et al. 2004 and Denny et al. 2004). Most of the areas subject to small-scale spatial management within the FMA (marine reserves (MR), temporary fishing closures) occupy “unique” bodies of water, such as whole fiords or whole arms. Consequently, establishing directly comparable control (or reference) sites with which to compare managed areas is impossible at small spatial scales, because control sites are typically located in different fiords or arms, which may naturally differ in abiotic and/or biotic characteristics. The resulting spatial confounding of management and reference sites means that it is difficult to establish with any surety that observed differences between managed areas and control sites are due to MR protection, rather than merely reflecting differences among locations. Within the FMA there are three instances where entire fiords are protected: Te Hapu (Sutherland Sound) Marine Reserve; Te Moana Uta (Wet Jacket Arm); and Te Tapuwae o Hua (Long Sound) MR. In each of these cases, reference sites have to be established in nearby fiords assuming that location differences are less than those brought about by the effects of fishing. It was suggested by Willis et al. (2009b) that at Taumoana (Five-Fingers Peninsula) MR, Taipari Roa (Elizabeth Island) Doubtful Sound, Kutu Parera (Gaer Arm) MR, Kahukura (Gold Arm, Charles Sound) MR, to prevent potential biased evaluation of the effects of implementing the MR, a more robust design would be to survey a larger number of sites in each treatment location. In these cases, comparisons must be made over larger spatial scales. To add statistical power to reserve:reference site contrasts, it was recommended that site replication be doubled to six dive sites inside and six dive sites outside each MR.

A possible solution to overcoming spatial confounding and locating representative reference sites is the consistent collection of time series of data collected inside and outside managed areas for at least 5-10 years. Such data assists in establishing whether trajectories of change can be attributed to management. However, it is important to determine at what spatial scale any change may be occurring. For example, a recruitment pulse occurring at a scale smaller than the distribution of managed versus control sites could be erroneously attributed to effective management, when in fact it was a random event or due to environmental conditions particular to the managed area (Willis et al. 2009b).

Prior to fieldwork commencing, DOC recommended that three MR including Kahukura – Charles Sound, Kutu Parera – Bradshaw Sound and Taumoana – Five Fingers be included as part of this contract, and the removal of sites associated with Wetjacket MR (DOC 2015). The main focus of this monitoring was to address the following hypotheses that relate to the abundance and size structure of key species:

> H1: The abundance and size of key species will be greater in MR than reference sites
>
> H2: The rate of increased abundance and presence of legal-sized individuals of key species will differ among MRs in the FMA.
>
> H3: Species assemblages will differ:
>
> a) either irrespective of protection, or in relation to marine protection;
>
> b) depending on availability of different habitat types.

To achieve H2, NIWA were requested to incorporate historic time series data back to 2006/07, recognising “the most robust analysis will be for MRs that NIWA has surveyed previously, and those surveyed in 2016 due to replication of sites within reserves. There will be limitations associated with slight differences (and some uncertainty) in the methodology used (e.g. transect dimensions), replication etc., but so long as data are reported and interpreted with these limitations taken into consideration these issues should not prevent these valuable data from being used.” (DOC 2015).

NIWA was requested to:

1. “Wherever possible, follow the field methodology being established by DOC as part of their Ecological Integrity Program. DOC are establishing a toolbox of standard methods, and until these are confirmed we should work closely with the program leaders to align methodology” and,

2. “NIWA should be encouraged to increase the length of transects to 50 m for two reasons: 1. To keep methodology consistent with previous years, 2. To decrease the influence of small scale habitat variability on species abundance data (e.g. patchiness of suitable rock lobster habitat). Increasing the transect length will place additional demand on the dive team, so it is suggested that the proposed collection of photoquadrats be removed and diver effort reallocated accordingly.”

These proposed changes were discussed in detail by the dive team including members of DOC Ecological Integrity Program team, and it was collectively decided that the increased replication at the transect and site level used by NIWA on previous monitoring studies (Willis et al. 2009b, Handley et al. 2013) provides more statistical power and should continue to be used in this contract.

We were also requested to include Te Tapuwae o Hua (Long Sound) - Hawea -Bligh Sound, for time-series analysis, surveying MRs only at Te Tapuwae o Hua (Long Sound) including existing long term monitoring sites and new sites to increase replication. Any opportunities to establish and sample true outer coast sites were also attempted.

Surveillance to detect marine invasive species that could impact on the diversity of the FMA is very important. Historic monitoring surveys have incorporated opportunistic surveillance of permanent man-made structures in the vicinity of monitoring sites to detect fouling organisms such as *Undaria pinnatifida, Styella clava* and *Sabella spallanzanii*. The importance of such surveillance has been highlighted by the outbreak of *U. pinnatifida* in Sunday Cove, Breaksea Sound in 2010 (D'Archino et al. 2014).

Despite considerable research effort in Fiordland in recent years, there is relatively little known of the ecology or biodiversity of deep reef fauna and flora beyond safe diving depths. Surveys comparing deep reef communities using a remote operated vehicle (ROV) in Doubtful Sound versus Dusky Sound found differences in diversity in relation to depth, distance from the entrance to the fiords, and also between fiords (Handley et al. 2010). To help discover new habitats / species and increase the knowledge and understanding of lesser studied areas of the FMA, ROV surveys were again included to increase our overall knowledge of the FMA.

2 Methods: Fiordland Marine Area Monitoring

2.1 Field methods and sampling design

Transect surveys of fish habitats (including macroalgae) and large invertebrates were completed at 56 dive sites spread across nine locations including: four MRs; Caswell and George Sound; and one outer coast location not representing a MR (Figure 2-1, Table 2-1). Hawea (Bligh Sound) MR, Kahukura (Gold Arm, Charles Sound) MR, Taumoana (Five-Fingers Peninsula) MR and Kutu Parera (Gaer Arm) MR were monitored using within fiord versus reference site comparisons, although the number of reserve sites surveyed in Kahukura (Gold Arm, Charles Sound) MR was unfortunately reduced by 2 MR sites due to very heavy rainfall which reduced light levels precluding 2.5 m prescribed minimum visibility leading to a shortening of the voyage. Te Tapuwae o Hua (Long Sound) MR covers all of Long Sound, therefore it was not possible to comparable fiord reference sites when monitoring that MR (Table 2-1). Non MR locations in the survey included: three sites in George Sound and two sites in Caswell Sound. A single outer-coast site was surveyed at Cats eye Bay between Hawea (Bligh Sound) and George Sounds (Figure 2-1).

In most cases, the same dive sites were surveyed as on previous monitoring surveys (Wing & Jack 2007, Willis et al. 2009b), although in Hawea (Bligh Sound), Taumoana (Five Fingers Peninsula), George Sound, and Te Tapuwae o Hua (Long Sound), new sites were established to provide an orthogonal sampling design with respect to the null hypothesis of no difference between specific reserve and fished areas (Table 2-1).

Belt-transects 25 × 5 m, with a 5 m lead-in to avoid counting fish attracted to the diver while the measuring tape was being attached to the substratum were used. One diver swam out the tape while counting the presence of large conspicuous fish present within a 125 m^2 corridor, while the second diver followed, enumerating the percent cover of habitat types (38 variables, see Appendix B), and the number of large invertebrates (e.g., sea urchins, rock lobster (*Jasus edwardsii*)) corals (e.g., black coral, Antipatharia) and fallen trees in 5 x 5 m sections along the same transect. Minimum visibility required for a transect to be conducted was set at 2.5 m. Lengths of exploited fish species (specifically blue cod (*Parapercis colias*), blue moki (*Latridopsis ciliaris*), butterfish (*Odax pullus*), tarakihi (*Nemadactylus macropterus*), and trumpeter (*Latris lineata*)) were estimated as either sub-legal or legal size[1], whereas lobster size was visually estimated by carapace length and recorded as three categories: < 10 cm, 10-15 cm, and > 15 cm. At each site, three transects were swum at each of 5 m and 15 m depth. These transects were completed in series, 5 - 10 m apart, following the depth contour.

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[1] Blue cod >33cm, blue moki >40 cm, butterfish >35 cm, terakihi >25 cm, trumpeter >35 cm.

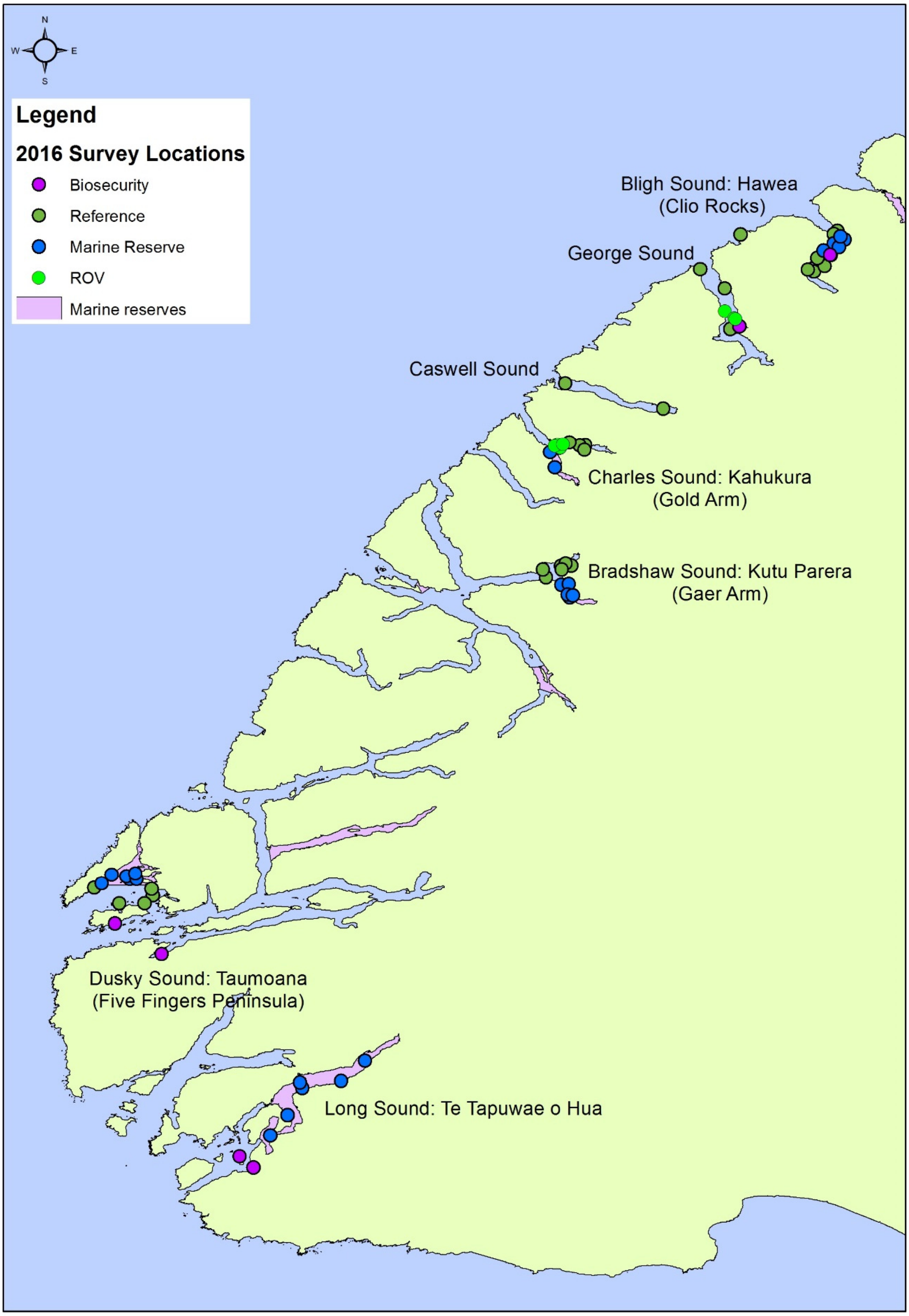

Figure 2-1: Map of the Fiordland area, showing the location of biosecurity, marine reserve, reference, and remote operated vehicle (ROV) survey site monitoring in February 2016. Close-up maps are provided in Appendix A.

Table 2-1: Summary of marine reserve (R) and reference (NR) monitoring sites within locations surveyed in 2016. Sites with a reference number (M) are those previously surveyed in Wing & Jack (2007), with the remainder new sites surveyed in 2013 (N13; Handley et al. 2013) or during the current study (N16). Position coordinates are in decimal degrees (WGS84).

Location	Reserve status	Code	Site	Date	New Site?	Long.	Latt.
Bligh Sound:	NR	M36	Evening Point	11 February 2016	Existing	167.49953	-44.85278
Hawea	NR	N16	Opp. Evening Point	11 February 2016	New	167.491683	-44.85
(Clio Rocks)	NR	N16	Opp. Smiley Face	12 February 2016	New	167.514983	-44.844967
	NR	M38	Opp. Turn Point	11 February 2016	Existing	167.53272	-44.79534
	NR	N16	Page’s Folly	11 February 2016	New	167.527883	-44.7998
	NR	M111	Smiley Face	12 February 2016	Existing	167.50483	-44.83333
	R	M39	Clio Rocks	12 February 2016	Existing	167.5239	-44.82891
	R	M112	Escape Bluff	13 February 2016	Existing	167.54353	-44.80742
	R	N16	Gordon’s Bluff	13 February 2016	New	167.528117	-44.81295
	R	N16	Kirsten’s Dilemna	13 February 2016	New	167.535233	-44.81825
	R	N16	Opp. Clio Rocks	12 February 2016	New	167.51365	-44.822817
	R	M37	Turn Point	13 February 2016	Existing	167.53737	-44.80313
Caswell Sound	NR	M33	Caswell Innner	14 February 2016	Existing	167.288389	-45.044777
	NR	M32	Hansard Point	14 February 2016	Existing	167.150808	-45.009484
Charles Sound:	NR	M29	Eleanor Is	16 February 2016	Existing	167.14067	-45.09766
Kahukura	NR	N13	East Eleanor Is	16 February 2016	Existing	167.14283	-45.10017
(Gold Arm)	NR	N13	East North Emelius	15 February 2016	Existing	167.17883	-45.09633
	NR	N13	Mid North Emelius	15 February 2016	Existing	167.1715	-45.09733
	NR	M108	South Emelius	16 February 2016	Existing	167.17805	-45.10293
	NR	M109	Waterfall Cove	15 February 2016	Existing	167.15633	-45.0925
	R	M31	Fanny Is	16 February 2016	Existing	167.13584	-45.12814
	R	N13	Opp. Friendship Head	16 February 2016	Existing	167.12933	-45.10633
Dusky Sound:	NR	M102	Earshell Cove	6 February 2016	Existing	166.57117	-45.729
Taumoana	NR		Five Fingers Outer	7 February 2016	Existing	166.4895	-45.71783
(Five Fingers	NR	N13	North Anchor Is	6 February 2016	Existing	166.55983	-45.73983
Peninsula	NR	M10	South Anchor Is	7 February 2016	Existing	166.53667	-45.76095
	NR	N13	North Earshell	6 February 2016	Existing	166.56983	-45.7195
	NR	N13	Petrel Is	6 February 2016	Existing	166.52433	-45.73983
	R	N16	Parrot Is South	7 February 2016	New	166.539033	-45.705667
	R	N13	Five Fingers Inner	7 February 2016	Existing	166.51333	-45.7
	R	M53	Five Fingers North	7 February 2016	Existing	166.5	-45.71167
	R	M8	Parrot Is	7 February 2016	Existing	166.53418	-45.70203
	R	M9	Pigeon Is	8 February 2016	Existing	166.54886	-45.70596
	R	N13	Whidby Point	8 February 2016	Existing	166.547	-45.69833
Bradshaw Sound:	NR	N13	Opp. Precipice Cove	10 February 2016	Existing	167.15917	-45.2655
Kutu Parera	NR	N13	Opp. Precipice Sill	10 February 2016	Existing	167.14467	-45.26617
(Gaer Arm)	NR	N13	Opp. Whale Rock	8 February 2016	Existing	167.12372	-45.28225
	NR	M106	Precipice Cove	10 February 2016	Existing	167.15135	-45.26263
	NR	M105	Precipice Sill	10 February 2016	Existing	167.14595	-45.27123
	NR		Whale Rock	8 February 2016	Existing	167.11967	-45.27117

Table 2-1 cont…

Location	Reserve status	Code	Site	Date	New Site?	Long	Latt
	R	M29	Greens Cave	9 February 2016	Existing	167.14539	-45.29233
	R	M24	Nicole’s Nook	9 February 2016	Existing	167.154	-45.306
	R		One Feather Face	9 February 2016	Existing	167.15683	-45.31
	R	N13	Opp. Greens Cave	9 February 2016	Existing	167.156	-45.29133
	R	N13	Opp. Nicole’s Nook	9 February 2016	Existing	167.154	-45.306
	R	N13	Opp. One Feather Face	9 February 2016	Existing	167.16141	-45.30717
George Sound	NR	M34	Anchorage Cove	14 February 2016	Existing	167.382701	-44.933235
	NR	M35	George Middle	14 February 2016	Existing	167.37503	-44.876318
	NR	N16	George Outer	13 February 2016	Existing	167.34035	-44.849317
Long Sound Te Tapuwae o Hua	R	N16	Mid-South	5 February 2016	New	166.8361167	-45.9881333
	R	M1	Only Island	5 February 2016	Existing	166.8698734	-45.9602899
	R	N16	Opposite Sandy Pt	6 February 2016	New	166.7608333	-46.03585
	R	N16	South of Trevaccoon Head	5 February 2016	New	166.7814	-45.9981333
	R	M3	The Narrows	6 February 2016	Existing	166.7361599	-46.06488
	R	M2	Trevaccoon Head	5 February 2016	Existing	166.7781419	-45.9902556
Outer Coast	NR	M45	Castseye Bay North	13 February 2016	Existing	167.39685	-44.8002

2.2 Statistical analysis

For each analysis described below, factors included Reserve (which MR was being examined: 4 levels: Bligh, Charles, Five Fingers, Gaer Arm), Depth (5 m vs 15 m: 2 levels for fish and habitat) and Status (reserve vs reference sites: 2 levels)[2]. Univariate analyses used individual transects as replicates. Multivariate analyses used either individual transects, or pooled transects (see below) as replicates. Habitat data were analysed in 5 m transect bins (5 per transect), and averaged.

2.2.1 H1: The abundance and size of key species

The influence of reserve, depth and spatial effects on the abundance of key species[3] (blue cod *Parapercis colias*, rock lobster *Jasus edwardsii*, and sea urchins *Evechinus chloroticus*) was evaluated using generalised linear models (GLM). GLM analyses used reserve and reference data from the 4 MR: n = 36 transects per depth, with the exception of Charles Sound where reserve: n=12. Because count data are bounded below by zero, not normally dispersed and have heterogeneous variances (i.e., the standard deviation tends to increase with the mean), the data were modelled using a log-linear model structure assuming a Poisson distribution. These models express the counts, Y, as

$$Y \sim \mathit{Poisson}(\lambda)$$

where $\mathit{Poisson}(\lambda)$ denotes a Poisson distribution with expected value of λ, and $\log(\lambda)$ is modelled as a linear function of the effects. For example, the count of a species in replicate l at location i, status j, and depth k is modelled by

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[2] Note: the six MR sites in Te Tapuwae o Hua (Long Sound) were excluded from these analyses because there were no reference sites for that MR.

[3] Legal plus sub-legal individuals.

$$\log(\lambda_{ijkl}) = \alpha_i + \beta_j + \delta_k$$

where α, β, and δ denote effects due to location, status, and depth, respectively. The right-hand side of this equation can be modified to include any interactions of interest. Backward model fitting was employed, where the full model (including all effects and all interactions between them) was run first, and non-significant terms progressively removed from the model. Data were tested for overdispersion (i.e. observed variance is greater than modelled variance) by examining the ratio of the residual deviance and the residual degrees of freedom. If the data were found to be overdispersed, a quasipoisson distribution was used instead of a Poisson distribution to account for likely underestimates of the standard errors and P-values.

Location effects were always important by virtue of different reserves being in different places (see Results), and sometimes formed significant interactions with Depth and/or Status because of differences in scale among sites (i.e. a species may be naturally less abundant at one location when compared to another). Where this occurred, 2-way or 1-way models examining depth and/or status effects were run separately for each reserve location. Error estimates around the ratios were given using standard errors or Wald 95% confidence limits plotted around the back-transformed mean estimates. Note that since the confidence intervals are calculated on the log scale, they become asymmetrical when expressed on the arithmetic scale.

All univariate analyses were implemented using R (R version 2.15.2, http://www.R-project.org/).

2.2.2 H2: Rate of change of assemblages and key species among MRs

To investigate the rate of increased abundance and presence of legal-sized individuals of key species that are hypothesised to differ inside and outside MRs in the FMA, analyses of trajectories over time of MRs with adequate historic data (e.g. 2006, 2007, 2009, 2010, 2013, and 2016) were carried out after the 6 datasets had been merged. The task of merging the datasets required the dropping of MR sites and years of survey that did not have adequate replication (see Appendix F). Univariate (GLM) and multivariate approaches were used, as described for H1 and H3 respectively. The Otago University transects data were standardised to 125 m^2 transect survey area (i.e. divided by 2). These multi-year comparisons were implemented for 5 m and 15 m survey depth strata under the assumptions that the different methods used by Otago University researchers (Wing & Jack 2006, 2007, 2010) using 50 m transects with no lead-time, did not differ to those used by NIWA researchers (Willis et al. 2009b, Handley et al. 2013). Tukey's pairwise comparisons were also used between years using the "multcomp" (version 1.4-1) package in R.

2.2.3 H3: Structure of species assemblages

To examine assemblages of fish species, two suites of multivariate analyses were conducted.

H3: a) Assemblages will differ either irrespective of protection, or in relation to marine protection

Exploratory analyses and relationships among variables were assessed using non-metric multidimensional scaling (MDS, Kruskal & Wish 1978). Fish transect data were square root transformed and a Bray-Curtis similarity matrix constructed. A constant (1) was added to the transformed data prior to matrix construction because some transects contained no fish (Clarke et al. 2006). MDS ordinations and all other multivariate analyses were done using the procedures in PERMANOVA+ for PRIMER (Anderson et al. 2008).

Transect data were first analysed separately and then pooled within depths at the site level (i.e. three transects at 15 m formed one replicate) because of a large degree of variability between individual transects (see Results). This pooling reduced the number of replicates per cell (Status × Depth) to six from 18, but also reduced the multivariate "noise" (between-transect variability) common in reef fish counts that tends to mask patterns, and eliminated the need to add a constant to the transformed data.

Relationships between the fish assemblage as a whole (species counted are listed in Appendix C) and the design factors (Reserve, Status and Depth) were analysed using permutational multivariate analysis of variance (PERMANOVA, Anderson 2001). Fish data were fourth-root (rather than square root) transformed prior to analysis because pooling transects had the effects of exacerbating differences in scale among the variables (e.g. schooling species such as butterfly perch *Caesioperca lepidoptera* or telescope fish *Mendosoma lineatum* can have counts of hundreds, whereas many other species counts were <10).

Differences between fiord locations were examined using canonical analysis of principal coordinates (CAP), a constrained ordination technique that finds the best means of separating *a priori* chosen groups (Anderson & Willis 2003). The procedure also generates correlations between the canonical axes and the original variables to help explain which variables (in this case, fish species) are responsible for the between-group differences. To give species equal weight, irrespective of abundance, species data were first standardised.

Further details of multivariate ordination methods are found in Willis et al. (2009a & b).

H3: b) Assemblages will differ depending on availability of different habitats

Relationships between fish assemblages, depth, and biological and physical features of the habitat were tested using multivariate regression (distance-based redundancy analysis, McArdle & Anderson 2001). Since some habitat variables covaried with each other (and with depth), initial estimates of the relative importance of 38 explanatory variables (24 biological variables) were made using conditional (sequential) tests that fitted each variable in a stepwise fashion, such that the estimated variability for each of the variables was conditional on the variables already in the model. Model fits were assessed using Akaike's Information Criterion (AIC, Akaike 1973).

2.3 Biosecurity surveys

Man-made structures (barges, moorings, and vessels) were surveyed opportunistically to determine whether invasive species were present. SCUBA was used to haphazardly survey structures for marine pests, for example the seaweed *Undaria*, the sea squirt *Styella clava*, the polychaete worm *Sabella spallanzanii*. Divers were instructed that any unusual species were to be bagged in-situ and removed for identification.

2.4 ROV surveys

Opportunistic remote operated vehicle surveys were carried out during down times between dives in George Sound, Caswell Sound and Charles Sound. Sites were chosen haphazardly by the Southern Winds' skipper, Peter Young, based on his knowledge of these fiords. Areas were primarily targeted searching for sea pens on areas of flat seabed identified on the depth sounder of the Southern Winds.

3 Results

3.1 H1: Abundance of key species responding to protection

3.1.1 Blue cod

Univariate GLM tests of main 3-way (location, status, depth) and 2-way effects (status, depth) on blue cod (*Parapercis colias*) abundance showed that fiord location and depth were highly significant (Appendix D), so further GLM analyses were carried out for each location after sub-setting the data by depth (Appendix E).

There was no significant difference in abundance of blue cod inside and outside the reserves at any of the MRs except a very low significance for Kutu Parera (Gaer Arm) MR, which had no blue cod at 5 m depth outside the reserve (Figure 3-1). As the numbers of blue cod were very low, and the differences with depth potentially biologically insignificant, a comparison of reserve status was carried out combining depths to improve power. After combining depths, the Tukey pairwise comparisons detected a low ($P<0.05$) significant difference at Kutu Parera (Gaer Arm) MR (Figure 3-2). Although the MR sites appeared to have on average more than twice as many cod, as the numbers were very low (<1 cod per 100 m^2), our confidence in the significance of these changes are low. The presence of the significant Tukey comparison, despite overlap of the confidence limits, indicates the latter is not always a good indicator of significance[4].

Plotting of blue cod by size category indicates that there is much variation between reserves and between reference and reserve sites with the greatest number of "legal" sized fish found in the Taumoana (Five Fingers) MR (Figure 3-3). Again, these comparisons were constrained by low fish densities.

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[4] In some instances, confidence limits/intervals can overlap, despite a significant difference at the $\alpha = 0.05$. E.g. http://www.tandfonline.com/doi/abs/10.1198/000313001317097960

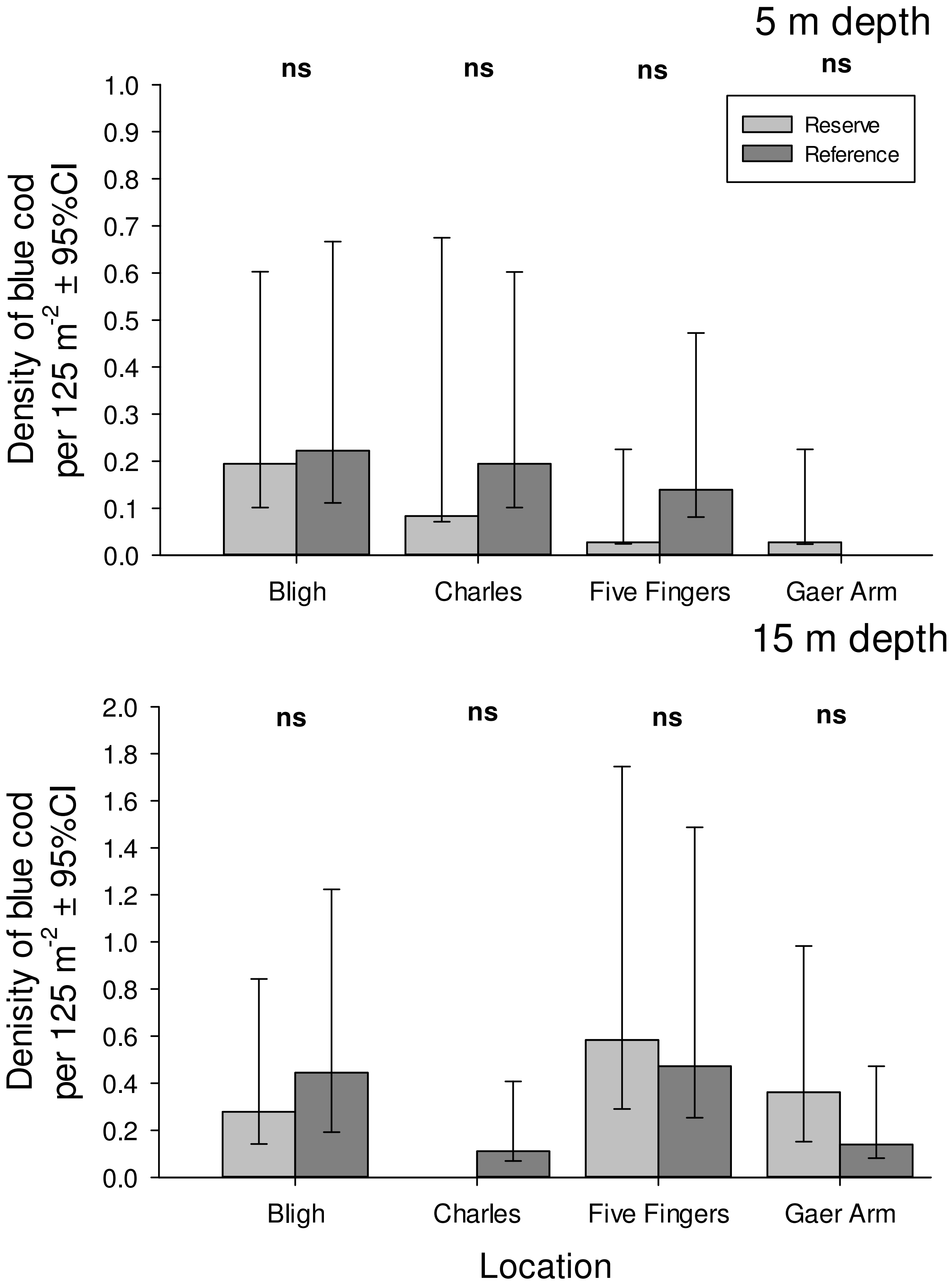


Figure 3-1: Relative density of blue cod at 5 and 15 m depth inside and outside four Fiordland marine reserves. GLM tests of significance are in Appendix E, Tukey significance levels above bars are expressed as: 'ns' not significant (P> 0.05). Number of transects: reserve and reference = 36, except Charles: n = 12 transects.

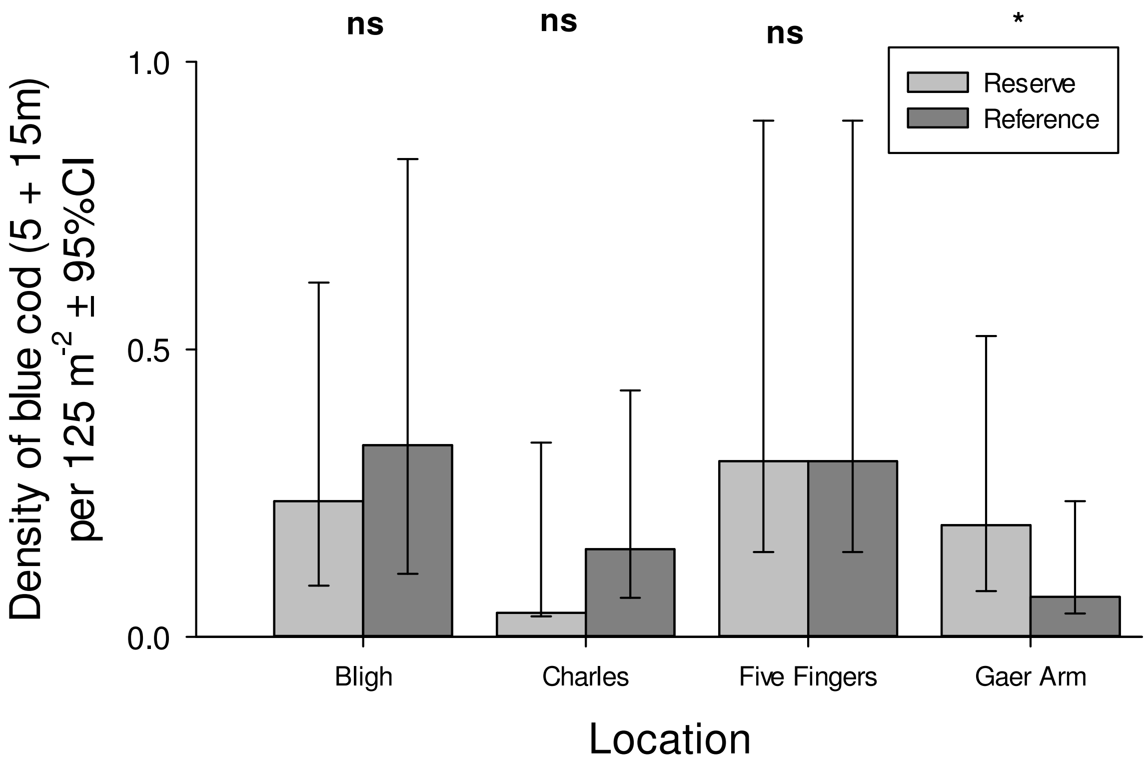


Figure 3-2: Relative density of blue cod at combined depths (5 + 15 m) inside and outside four Fiordland marine reserves. GLM tests of significance are in Appendix E, Tukey significance levels above bars are expressed as: '*' P<0.05, 'ns' not significant (P> 0.05). Number of transects: reserve and reference = 72, except Charles: n = 24 transects.

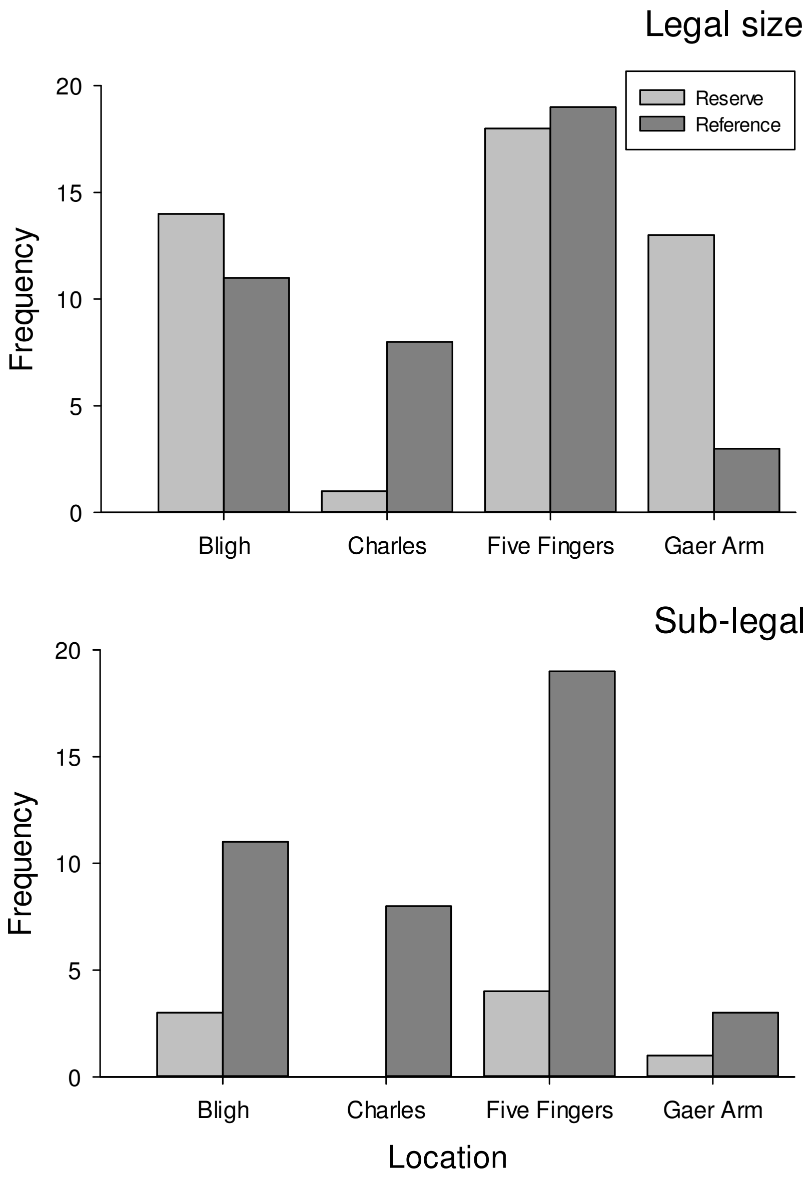


Figure 3-3: Frequency of blue cod considered by divers to be "legal" (adult) and "sub-legal" (juvenile) from inside and outside four Fiordland marine reserves. Number of transects: reserve and reference = 72, except Charles: n = 24 transects.

3.1.2 Rock lobster

Rock lobster (*Jasus edwardsii*) densities varied significantly among fiord locations (Appendix D), with the highest densities found at Taumona (Five Fingers) MR (Figure 3-4). There were no significant depth : status interactions at any of the sites, and only a marginal depth effect detected at Kutu Parera (Gaer Arm) MR (Pr(>Chi): 0.024 (Appendix E)), therefore depths were combined for MR contrasts. No significant differences were evident between rock lobster densities within and outside reserves (Figure 3-5). A further comparison of only large (>15 cm carapace length) rock lobsters at combined depths also found no significant difference between reserves, with the exception of Hawea (Bligh Sound) which contained no large lobsters outside the MR (Figure 3-5).

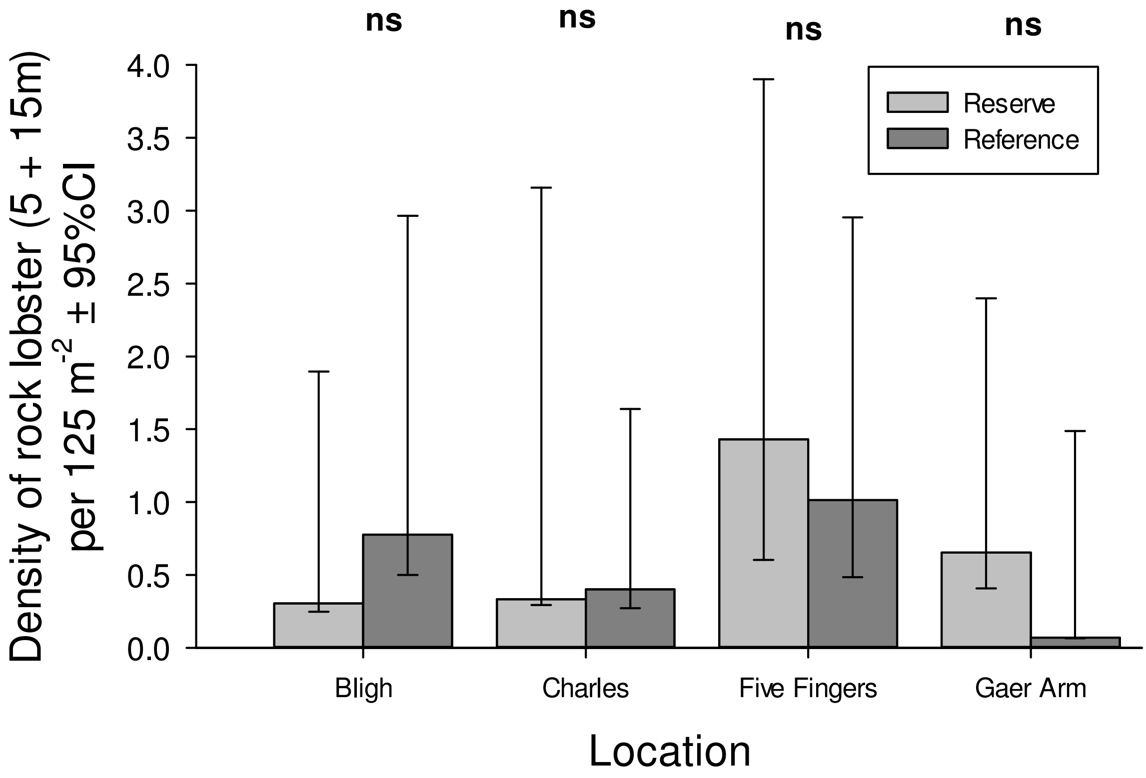


Figure 3-4: Relative density of rock lobster at combined depths (5 and 15 m) inside and outside four Fiordland marine reserves. GLM tests of significance are in Appendix E, Tukeys significance levels above bars are expressed as: 'ns' not significant ($P > 0.05$). Number of transects: reserve and reference = 72, except Charles: n = 24 transects.

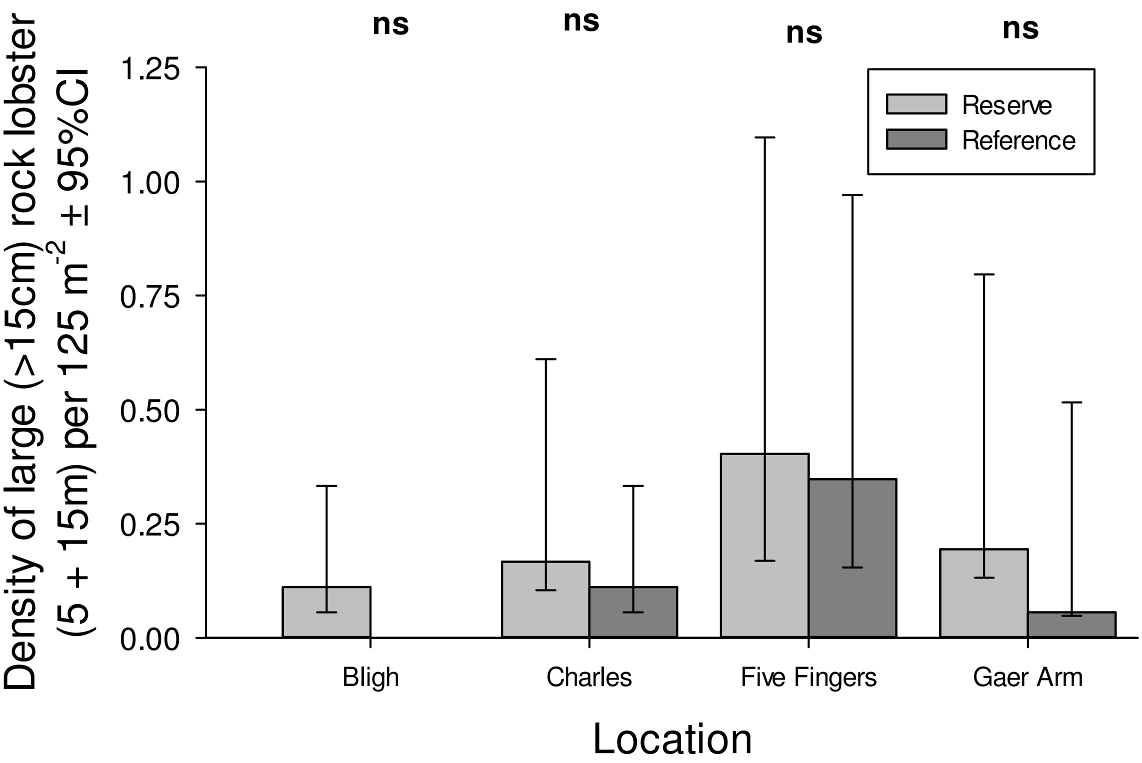


Figure 3-5: Relative density of large (>15 cm carapace length) rock lobster at combined depths (5 and 15 m) inside and outside four Fiordland marine reserves. GLM tests of significance are in Appendix E, Tukeys significance levels above bars are expressed as: 'ns' not significant (P> 0.05). Number of transects: reserve and reference = 72, except Charles: n = 24 transects.

3.1.3 Sea urchins (kina)

Differences were detected for diver surveys of kina (*Evechinus chloroticus*) densities between locations and transect depths therefore separate analyses were run for each depth and location (Appendix E). Kina were generally more abundant at 5 m than 15 m depth (Figure 3-6). Further, at Taumoana (Five Fingers Peninsula) MR, kina were significantly more abundant outside the MR at 15 m depth. While there were significantly more urchins at 5 m depth outside the Kutu Parera (Gaer Arm) MR, the densities were very low.

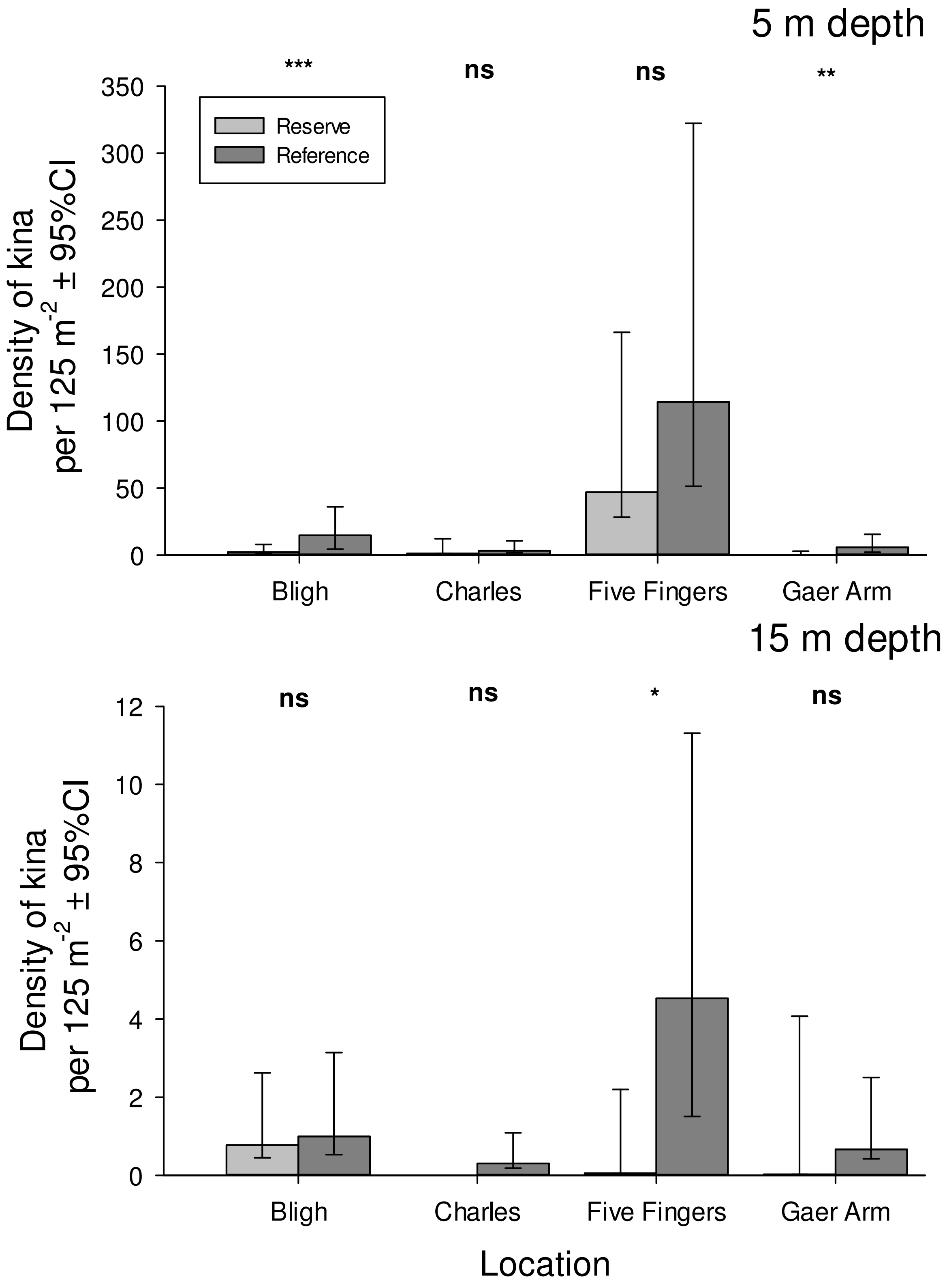


Figure 3-6: Mean density of kina *Evechinus chloroticus* inside and outside marine reserves at different fiord locations. GLM tests of significance are in Appendix E, Tukeys significance levels above bars are expressed as: '*' P<0.001 '**' P<0.01 '*' P<0.05, 'ns' not significant (P> 0.05).**

3.2 H2: Rate of change of assemblages and key species among MRs

After the 6 historic datasets had been merged, the reserve and transect data were tabulated and sorted according to frequency of surveys by site and by year (Appendix F). The results of CAP analysis of the fish data, resulted in only a 10% allocation success among years indicating little difference among years (Figure 3-7).

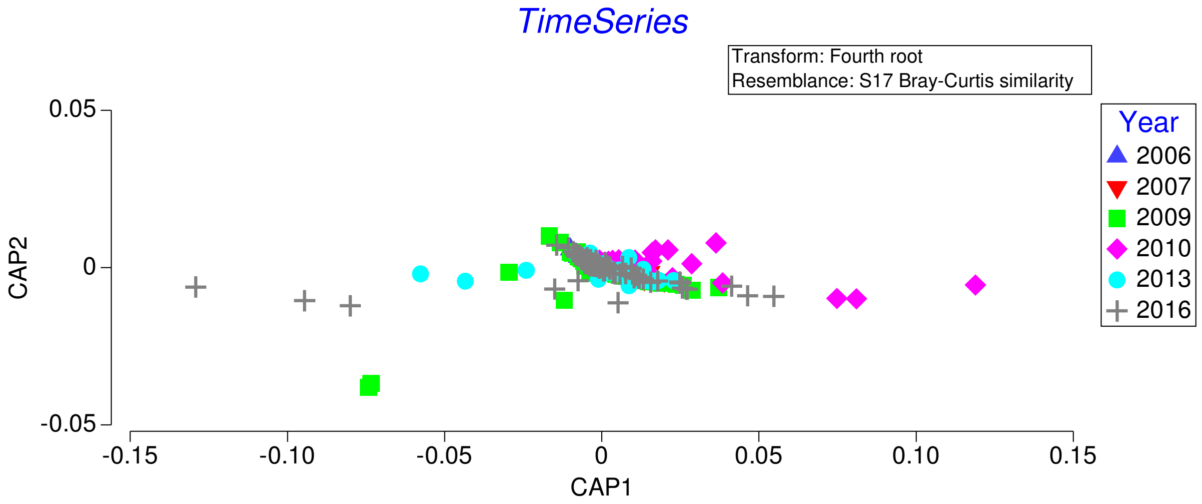


Figure 3-7: **CAP analysis of fish count data discriminating the historic survey sites (see Appendix F) by year of survey.**

Because of the low replication present in the merged dataset, further individual analyses for blue cod, rock lobster and kina were carried out using univariate GLM. Sites with the greatest replication (Appendix F) were further sorted and any sites or years with low replication eliminated before proceeding with the GLM analysis. This resulted in four reserve locations, each containing 2 sites with data from 2006, 2009, and 2016 deemed the most appropriate for analyses.

Comparisons of blue cod from 2006 until 2016 showed no significant difference among years for any the of the four MR sites, except for Kutu Parera (Gaer Arm) MR, which lacked any cod in 2006 (Figure 3-8).

Difference in rock lobster numbers between MRs showed some statistically significant differences at Hawea (Bligh Sound), Kutu Parera (Gaer Arm) MR, Kahukura (Gold Arm, Charles Sound) MR and Kutu Parera (Gaer Arm) MR, but the densities are very low, especially at Taumoana (Five-Fingers Peninsula) MR (mean = 3.8×10^{-11}) which are not visible at the scale of the plot (Figure 3-9).

Comparisons of kina density showed significant differences in Hawea (Bligh Sound) MR and Kahukura (Gold Arm, Charles Sound) MR, but at these sites the densities were very low (Figure 3-10). At sites where kina were more abundant, changes in densities over time differed. Densities of kina appeared to be increasing at Taumoana (Five-Fingers Peninsula) MR, whereas densities appear to be decreasing at Kutu Parera (Gaer Arm) MR. These latter trends however were statistically insignificant, a result that likely reflects the patchy nature of kina within transects.

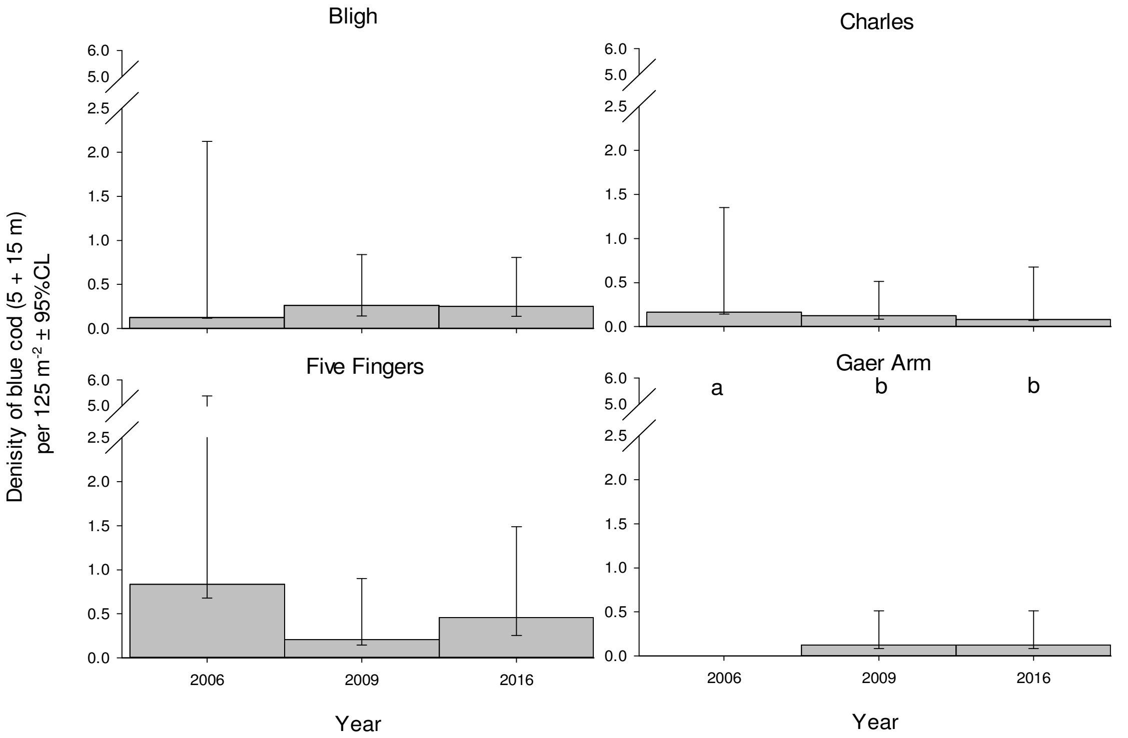


Figure 3-8: Relative density of blue cod at combined depths (5 + 15 m) for Fiordland marine reserve sites monitored for 10 years. Note: y-axes have a break from 2.5-5, to enable confidence limits to be shown at different scales. For sites with significantly different Tukey's pairwise comparisons, significant differences (p>0.05) are denoted by different letters.

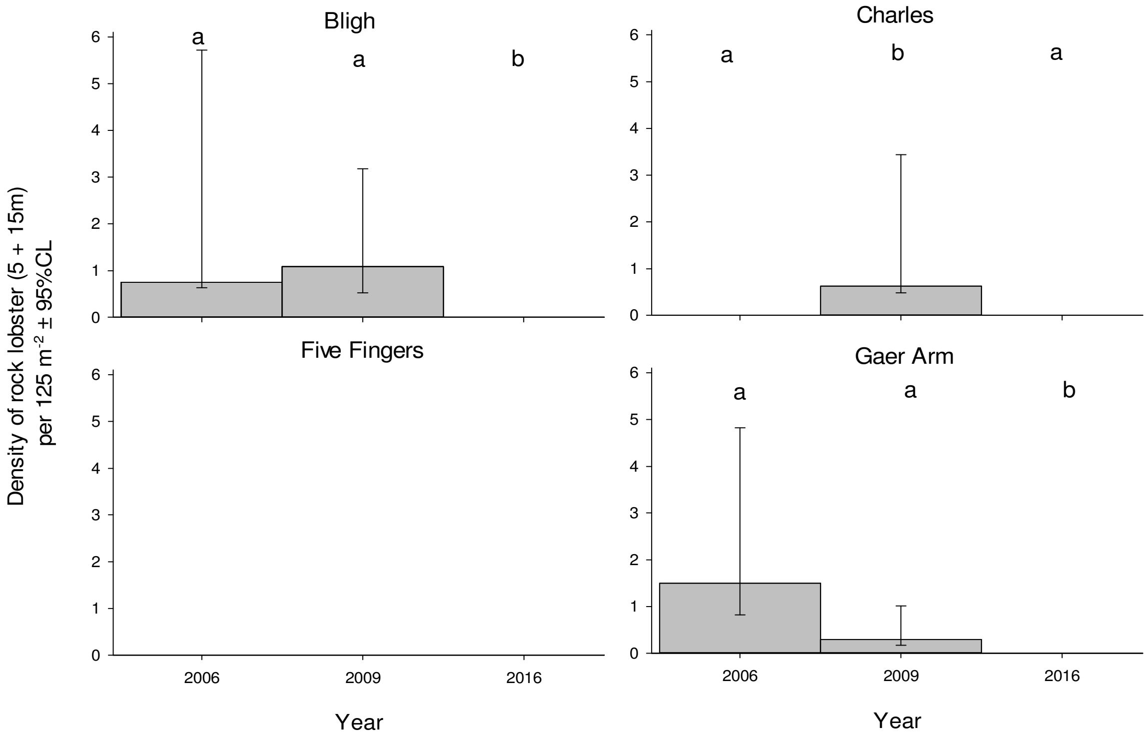


Figure 3-9: Relative density of rock lobster at combined depths (5 + 15 m) for Fiordland marine reserve sites monitored for 10 years. For sites with significantly different Tukey's pairwise comparisons, significant differences (p>0.05) are denoted by different letters. Note: data for Five Fingers are too small to be visible.

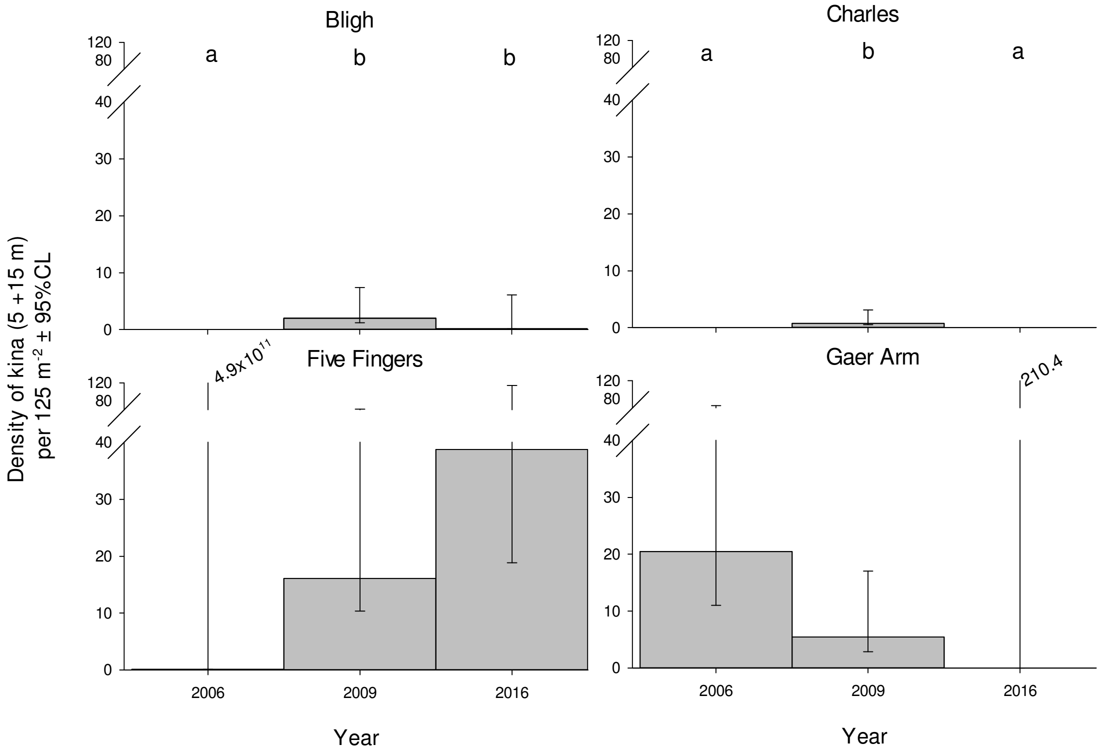


Figure 3-10: Relative density of kina at combined depths (5 + 15 m) for Fiordland marine reserve sites monitored for 10 years. Note: y-axes have a break from 70-120, to enable confidence limits to be shown at different scales. Note: very large confidence limits are as text. For sites with significantly different Tukey's pairwise comparisons, significant differences (p>0.05) are denoted by different letters.

3.3 H3: Structure of species assemblages

3.3.1 Spatial variation in fish assemblages

H3: a) Assemblages will differ either irrespective of protection, or in relation to marine protection

To examine the distribution of fish assemblages irrespective of protection status, using the individual transects (n = 288) as ordination units, large-scale differences in the fish assemblage among dive sites were examined using non-metric multidimensional scaling (nMDS). There was a large degree of overlap among the sites with Kutu Parera (Gaer Arm) appearing to be the least variable (Figure 3-11). To simplify the analysis and reduce the multivariate 'noise' brought about by using transects as replicates, the nMDS was repeated using pooled transects within each combination of site and depth (Willis et al. 2009b). As this simplified ordination provided similar patterns in the degree of overlap between sites (Figure 3-12), it was decided to conduct further multivariate analyses using the pooled data following the methods of Willis et al. (2009b). Both of these analyses had quite high stress associated with them (0.16, 0.15, respectively), indicating the results are not a particularly good solution to the data representation.

To determine between-site differences and the species responsible for them, a canonical analysis of principal coordinates (CAP) was implemented on the same data used in Figure 3-12. This analysis attempts to find the best means of discriminating monitoring sites, and the overlaid biplot shows correlations between individual species and the canonical axes (Figures 3-13 and 3-14).

The CAP analysis had an overall correct allocation success of 30.8% (see Willis et al. 2009a, Appendix 3, Section 10.6.1 for explanation), indicating that it wasn’t particularly successful in differentiating between the reserve locations (Figure 3-13), as a random allocation of points among the four locations would have returned an allocation success of 25%. Te Tapuwae o Hua (Long Sound) MR, Kutu Parera (Gaer Arm) MR and Caswell Sound were somewhat differentiated from Hawea (Bligh Sound), George Sound and Taumoana (Five-Fingers Peninsula) plus the outer coast site along the CAP1 axis. Spotty (*Notolabrus celidotus*) were more common in Kutu Parera (Gaer Arm) MR and Te Tapuwae o Hua (Long Sound) MR, Hawea (Bligh Sound) Sound was correlated with butterfly perch (*Caesioperca lepidoptera*) whereas Scarlet wrasse (*Pseudolabrus miles*), banded wrasse (*Notolabrus fucicola*) and marble fish (*Apldactylus arctidens*) were correlated with Five Finger Peninsula stations. A re-analysis of the data just selecting the 15 m transects improved the allocation success to 36.6% with similar correlations of the MR locations with fish species, with the inclusion of sea perch (*Helicolenus percoides*) correlated with Kutu Parera (Gaer Arm) MR (Figure 3-14). The increased allocation success with half the number of sample points indicates that the 5 m transect data were somehow masking differences between the reserve locations.

The variability of fish species composition differed more at some locations than others. This can be visualised in the MDS and CAP plots (Figures 3-11 to 3-14).

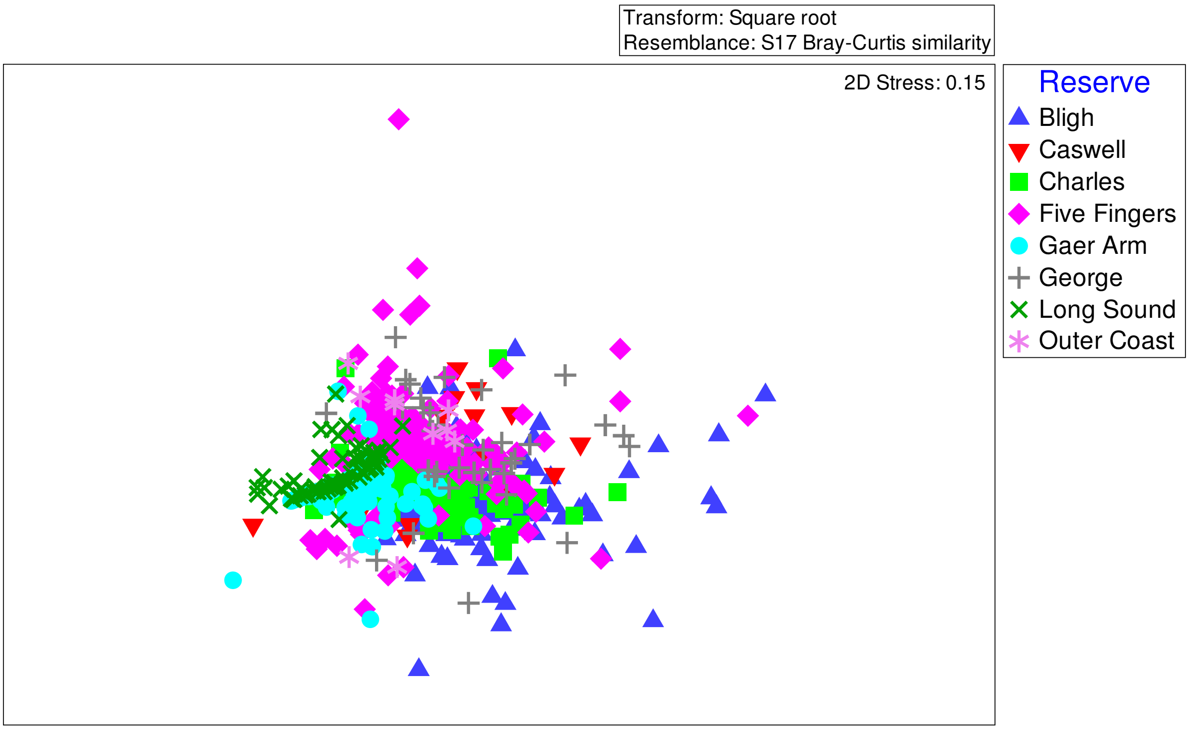


Figure 3-11: Non-metric multidimensional scaling (MDS) plot of Fiordland fish assemblages labelled by fiord location surveyed in 2016. Each point is an individual transect.

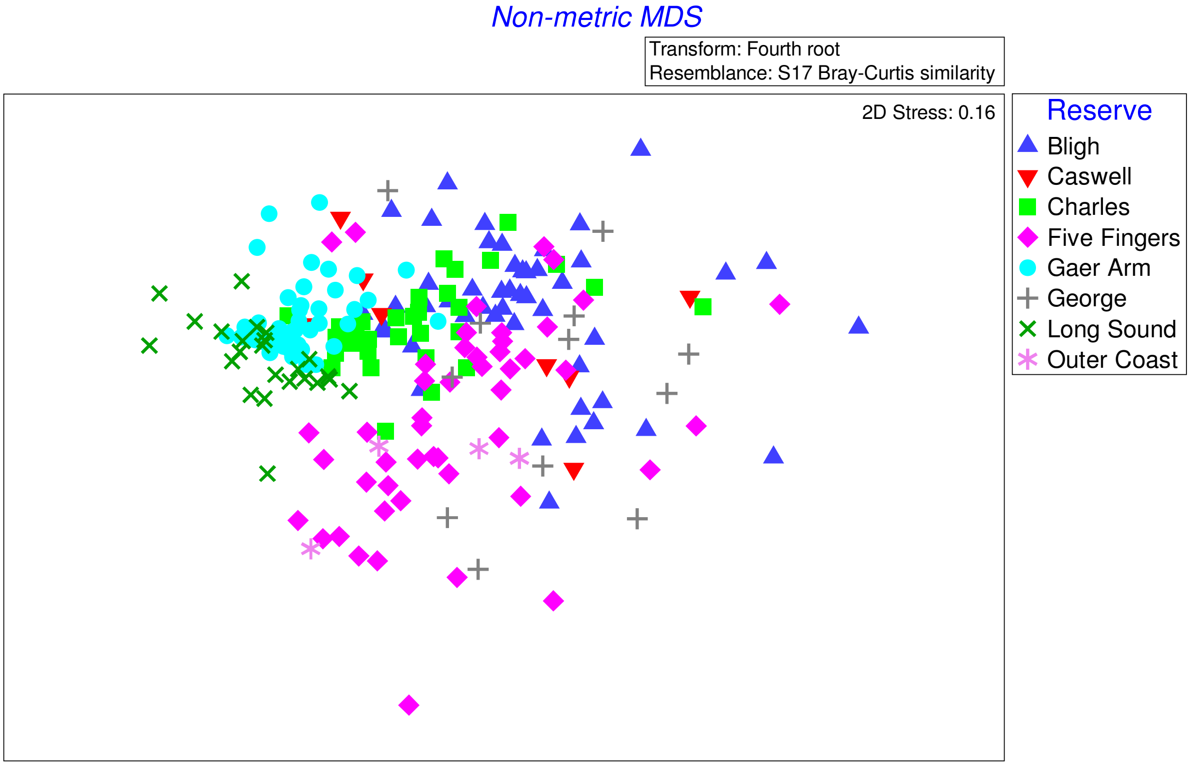


Figure 3-12: Non-metric multidimensional scaling (MDS) plot of Fiordland fish assemblages labelled by fiord location surveyed in 2016. Each point consists of pooled transects within depths at each site.

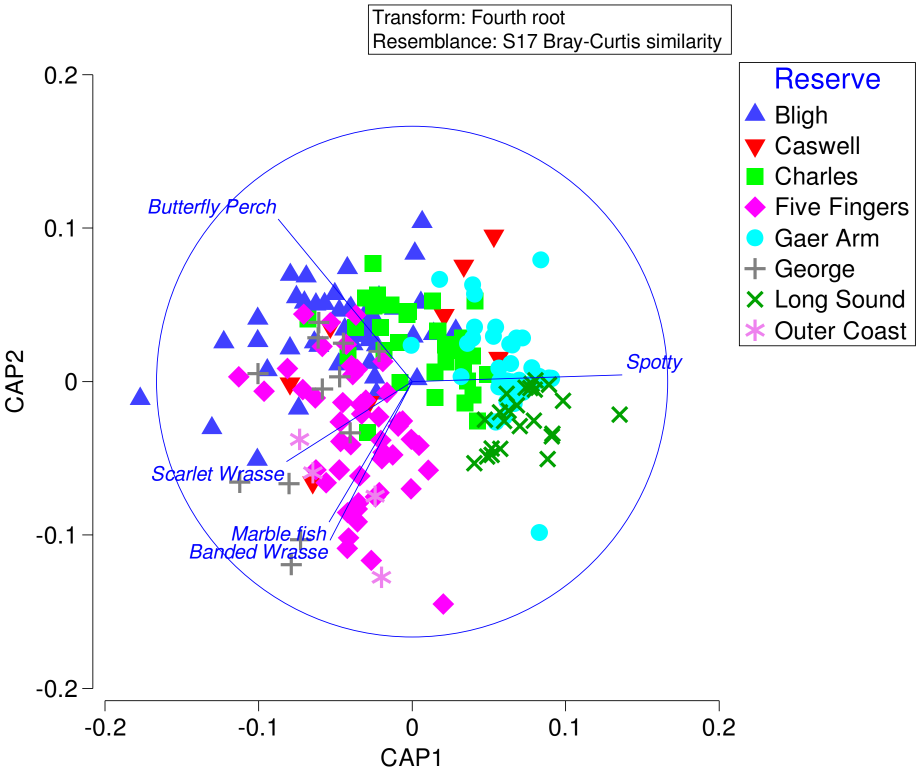


Figure 3-13: CAP analysis discriminating the four fiord locations from 5 and 15 m transect data, with a biplot showing correlations of individual standardised species with the canonical axes (for species with Pearson correlation >0.4).

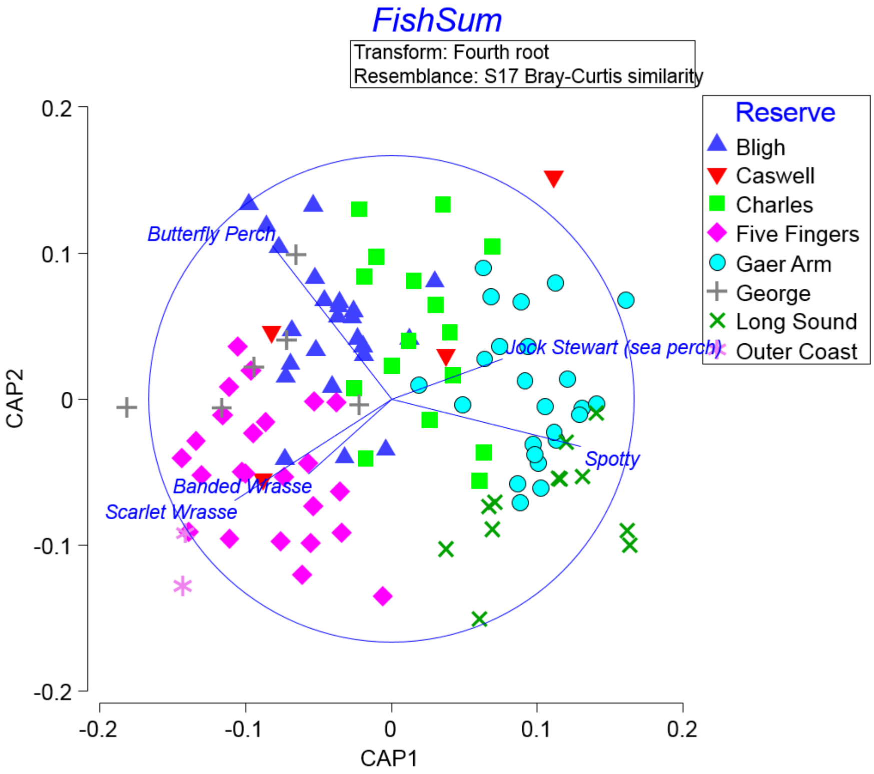


Figure 3-14: CAP analysis discriminating the four fiord locations for fish transects at 15 m depth, with a biplot showing correlations of individual standardised species with the canonical axes (for species with Pearson correlation >0.4).

H3: a) Multivariate tests for marine reserve effects

We constructed a 3-way PERMANOVA model to compare protected and unprotected fish assemblages at different fiord locations and depths, treating Location (n = 6), Status (reserve vs non-reserve) and Depth (5 m and 15 m) as fixed effects. For this analysis, the individual transects (n = 6) were pooled within each cell. This reduced the degrees of freedom with which to test the individual model terms, but also reduced the multivariate "noise" common to fish counts that is generally brought about by mobility of the individual fishes (Willis et al. 2006, McClanahan et al. 2007, Willis et al. 2009a). These analyses were also restricted to sites with MR and reference stations that were adjoining.

PERMANOVA tests for significant difference between and among locations indicated significant location, depth, and location x depth interactions (Table 3-1). Because of the significant location effect, the variability between dive sites, or multivariate dispersion evident in the MDS and CAP plots, pairwise comparisons were made between sites with MR and reference sites. The results show a significant differences between all of the MR sites (Table 3-2).

Table 3-1: Results of PERMANOVA tests of significance for fish distributions for fiord location, protection status, and depth of transects. P-values in bold are significant at the 0.05 confidence level.

Source	df	SS	MS	Pseudo-F	P(perm)	perms	P(MC)
Location	2	918.96	459.48	63.682	0.0001	9952	**0.0001**
Status	1	-1.8148	-1.8148	Negative			
Depth	1	274.33	274.33	38.021	0.0001	9950	**0.0001**
Location x Status	2	12.814	6.4068	0.88796	0.534	9936	0.5219
Location x Depth	2	115.71	57.857	8.0187	0.0001	9930	**0.0001**
Status x Depth	1	2.4777	2.4777	0.3434	0.8264	9952	0.8245
Location x Status x Depth	2	16.741	8.3706	1.1601	0.3327	9941	0.3331
Res	132	952.41	7.2152				
Total	143	2291.6					

Table 3-2: Pairwise comparisons of multivariate dispersion in fish assemblages between reserve locations with balanced replication (excluding Charles). Values in bold and * are considered to be statistically significant. (after Bonferroni correction for multiple comparisons). See Figure 3 2 to visualise dispersion patterns. Significance level: '*' P<0.001.**

Groups (locations)	t	P(perm)	P(MC)	Significance
Bligh, Five Fingers	4.575	0.0001	**0.0001**	***
Bligh, Gaer Arm	10.651	0.0001	**0.0001**	***
Five Fingers, Gaer Arm	9.0468	0.0001	**0.0001**	***

A list of all fish species counted in transects during this survey is given in Appendix C.

3.3.2 Fish assemblage and habitat relationships

H3: b) Assemblages will differ depending on availability of different habitats

To investigate the relationship between fish assemblage structure and physical habitat factors, a two-phase multivariate regression was run. First, variables were fitted individually, and then sequentially, where the other variables were taken into account (Table 3-3). Depth and large boulders explained most of the variability in the fish assemblage (Table 3-3a). After the autocorrelated variables had been removed by the forward selection model, depth, large boulders, platform rock crevices, trees, and small boulders explained 25% of the total of 29% variability explained by the model (Table 3-3b). The dbRDA plots separated site data by depth, the largest correlate, with large boulders and the presence of trees associated with the spread in the data clouds mostly along the dbRDA1 axis (Figure 3-15).

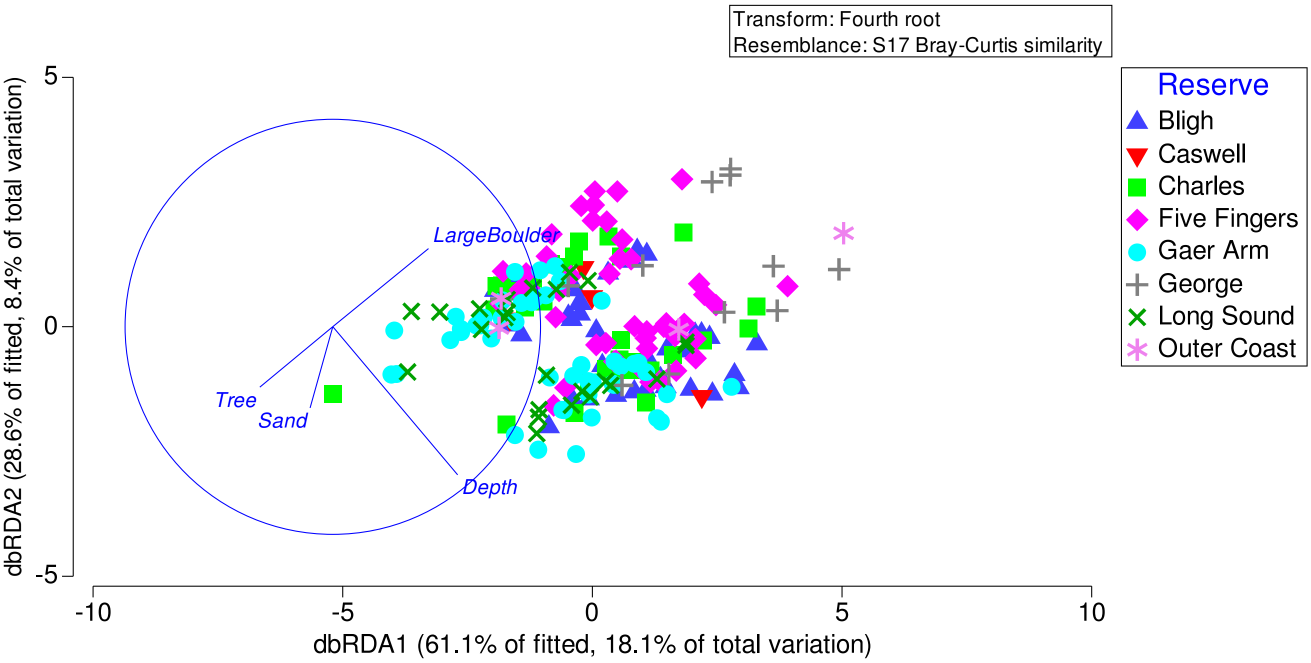
When all physical and biological habitat variables were combined together, 26 of the 37 variables were significantly correlated with fish assemblage (Figure 3-16, Table 3-4). The forward selection reduced the number of variables explaining 49% of the assemblage variability, with: depth, large brown algae, *Ecklonia*, encrusting invertebrates, large boulders, the urchin *Pseudechinus*, crustose coralline turf (CCA_Turf) contributing more than 0.5% variation each to the model (Figure 3-16). The distance based redundancy analysis using all the physical and habitat variables created greater separation between FMA sites with Taumoana (Five-Fingers Peninsula) and George Sound appearing different to Te Tapuwae o Hua (Long Sound) MR and Kutu Parera (Gaer Arm) MR. The Taumoana (Five-Fingers Peninsula) data points were correlated more with greater abundance of large brown algae, *Ecklonia* and *Evechinus*, but also large boulders (Figure 3-16). Whereas, Te Tapuwae o Hua (Long Sound) MR and Kutu Parera (Gaer Arm) MR were correlated with greater: depth (15 m), numbers of black coral juveniles, and abundance of crustose coralline turf.

Table 3-3: Results of stepwise multivariate regression of fish assemblages on depth and physical habitat features. (a) Each variable fitted individually (ignoring other variables) and (b) forward selection of variables, where each variable sequentially added to the model is conditional on the variables already in the model. P-values in bold are significant at the 0.05 confidence level.

Variable	Pseudo-F	P	Variability explained (%)
a) Variables fitted individually			
Depth	27.49	**0.001**	11.02
LargeBoulder	12.34	**0.001**	5.26
Tree	6.89	**0.001**	3.01
PlatformRockReef	4.77	**0.006**	2.11
PRLedge	4.76	**0.009**	2.10
Slope	4.67	**0.005**	2.06
SmallBoulder	4.30	**0.01**	1.90
Sand	4.24	**0.005**	1.87
PRCrevice	3.99	**0.014**	1.76
ShellHash	2.09	0.094	0.93
SandMud	2.06	0.088	0.92
TerrestrialDetritus	1.88	0.127	0.84
Cobble	0.78	0.497	0.35
MedBoulder	0.73	0.526	0.33

Variable	Pseudo-F	P	Variability explained (%)	Cumulative variability explained (%)
b) Variable fitted sequentially				
Depth	27.487	**0.001**	11.017	11.017
LargeBoulder	13.797	**0.001**	5.2287	16.246
PRCrevice	9.2149	**0.001**	3.3671	19.613
Tree	7.778	**0.001**	2.7571	22.37
SmallBoulder	6.3984	**0.002**	2.2135	24.584
PlatformRockReef	5.8164	**0.001**	1.9687	26.552
PRLedge	4.4297	**0.009**	1.476	28.028
Slope	2.4888	0.057	0.81925	29.557
Cobble	2.1387	0.085	0.70887	28.737

a) Transects labelled by site



b) Transects labelled by depth

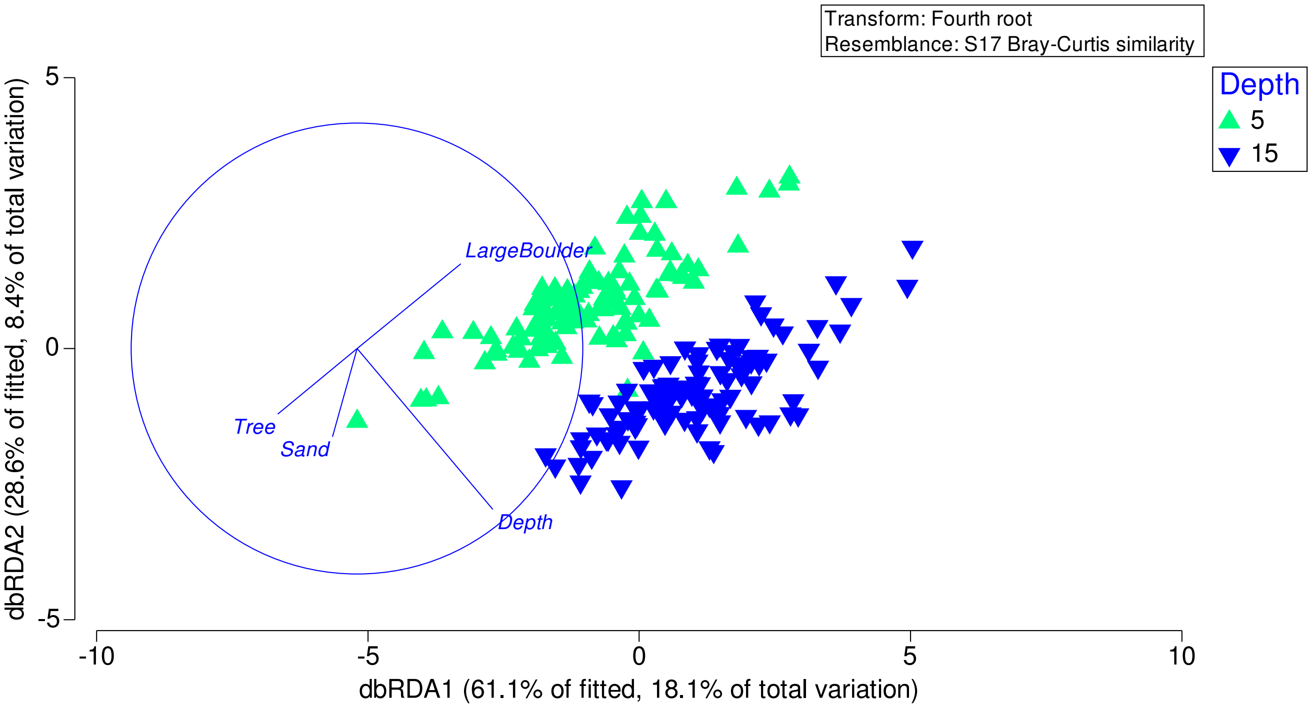


Figure 3-15: Distance-based redundancy analysis plot of relationships between physical habitat variables and fish assemblages labelled by a) site and b) depth. The overlaid biplot shows Pearson correlation vectors of those variables contributing significantly (>0.4) to fish assemblage structure.

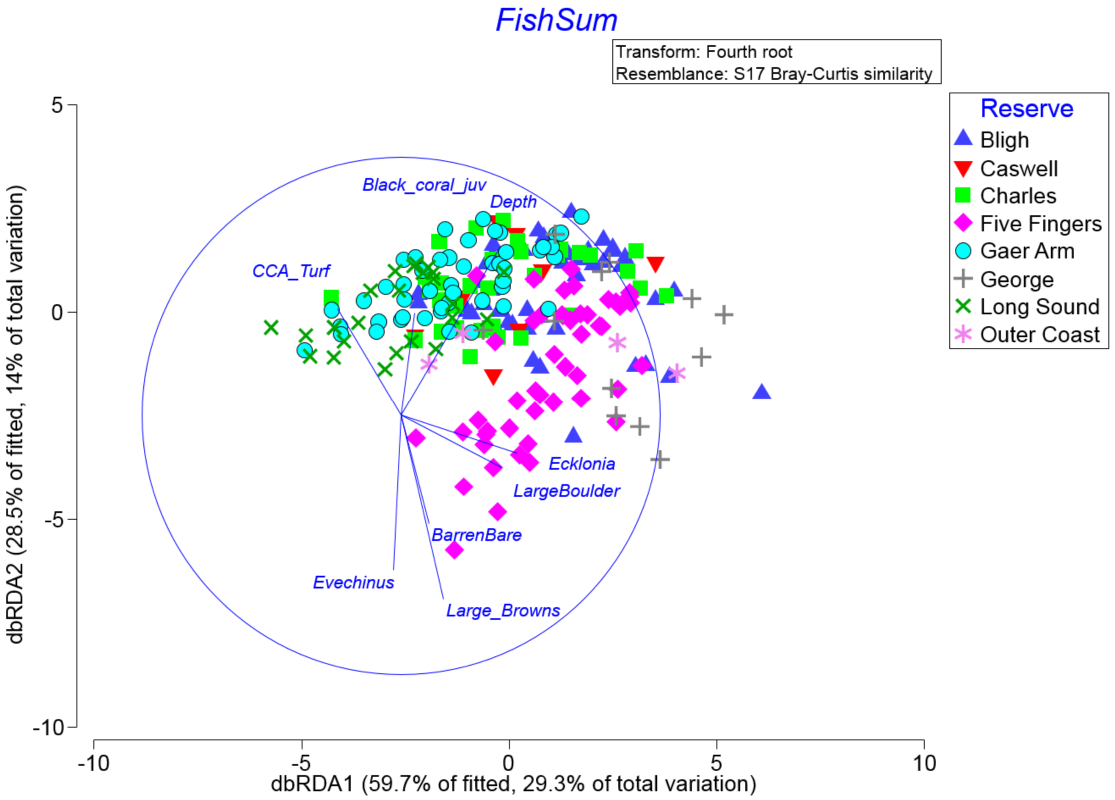
Table 3-4: Results of stepwise multivariate regression of fish assemblages on depth and physical and biological habitat features. (a) Each variable fitted individually (ignoring other variables) and (b) forward selection of variables, where each variable is added to the model is conditional on the variables already in the model. P-values in bold are significant at the 0.05 confidence level.

Variable	Pseudo-F	P	Variability explained (%)
a) Variables fitted individually			
Depth	376.85	**0.001**	11.02
Large_Browns	288.32	**0.001**	8.43
Ecklonia	219.73	**0.001**	6.42
LargeBoulder	180.08	**0.001**	5.26
CCA_Turf	173.74	**0.001**	5.08
Evechinus	170.75	**0.001**	4.99
Pseudechinus	142.86	**0.001**	4.18
Encrusting inverts	136	**0.001**	3.98
Caulerpa	128.55	**0.001**	3.76
BarrenBare	104.81	**0.001**	3.06
Tree	102.99	**0.003**	3.01
Codium	95.716	**0.003**	2.80
Black_coral_juv	77.979	**0.007**	2.28
cray10-15	75.68	**0.005**	2.21
PlatformRockReef	72.005	**0.004**	2.11
PRLedge	71.828	**0.002**	2.10
Slope	70.513	**0.006**	2.06
Tubeworms	66.218	**0.012**	1.94
cray>15	66.09	**0.011**	1.93
SmallBoulder	64.963	**0.005**	1.90
Sand	64.05	**0.01**	1.87
cray<10	62.96	**0.006**	1.84
Brachiopods	61.13	**0.018**	1.79
PRCrevice	60.349	**0.007**	1.76
FolioseRedsBrowns	51.049	**0.028**	1.49
Black_coral_ad	45.968	**0.028**	1.34
ShellHash	31.852	0.099	0.93
SandMud	31.378	0.095	0.92
TerrestrialDetritus	28.652	0.13	0.84
Coralline paint	26.426	0.12	0.77
Black_coral_dead	20.50	0.227	0.60
Ulva	19.502	0.281	0.57
Cobble	11.954	0.479	0.35
MedBoulder	11.157	0.512	0.33
Gorgonian	9.23	0.676	0.27
Errina	8.50	0.71	0.25
LowTurfRedsBrowns	5.2409	0.829	0.15
Coscinasterias	1.05	0.99	0.03

Table 3-6: Cont..

Variable	Pseudo-F	P	Variability explained (%)	Cumulative variability explained (%)
b) Variable fitted sequentially				
Depth	27.49	**0.001**	11.02	11.02
Large_Browns	20.71	**0.001**	7.63	18.64
Ecklonia	18.45	**0.001**	6.29	24.94
Encrusting inverts	15.58	**0.001**	4.73	33.85
LargeBoulder	12.94	**0.001**	4.19	29.12
Pseudechinus	8.90	**0.001**	2.61	36.46
CCA_Turf	7.62	**0.001**	2.17	38.62
Codium	6.66	**0.001**	1.84	40.47
Caulerpa	5.19	**0.003**	1.41	41.88
Tree	4.40	**0.01**	1.18	43.05
Evechinus	4.29	**0.012**	1.13	44.18
PlatformRockReef	4.29	**0.006**	1.09	47.07
PRCrevice	3.61	**0.014**	0.94	45.12
LowTurfRedsBrowns	3.36	**0.018**	0.86	45.99
BarrenBare	3.29	**0.029**	0.82	47.90
PRLedge	2.62	**0.043**	0.65	48.55
Brachiopods	1.88	0.118	0.46	49.01

a) Transects labelled by site



b) Transects labelled by depth

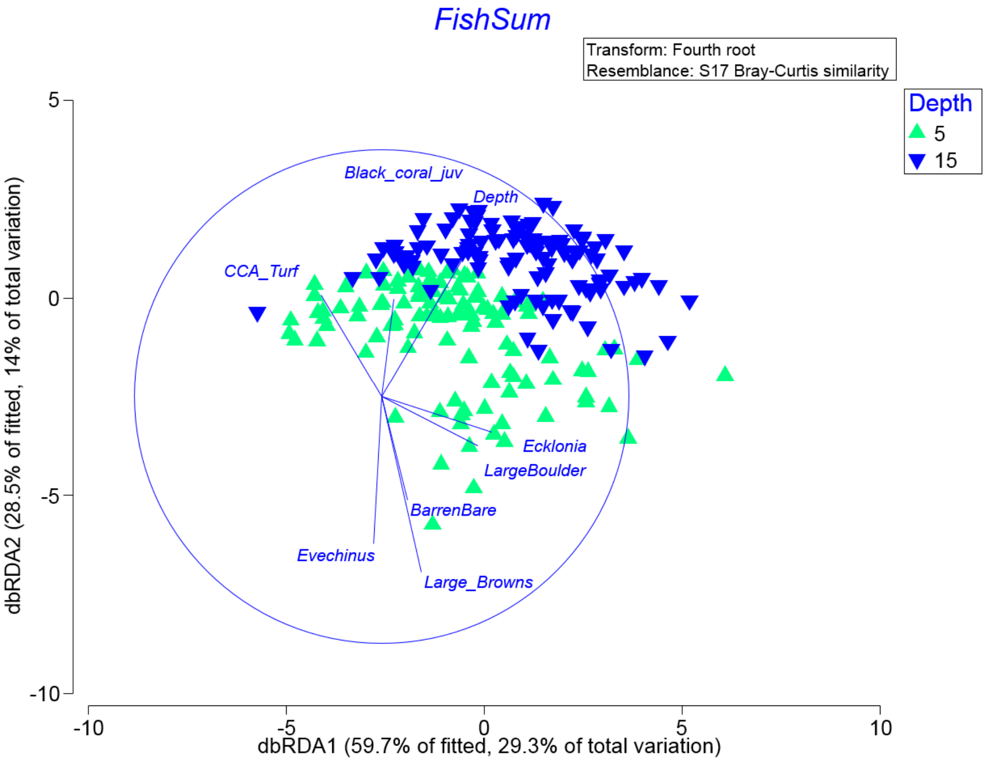


Figure 3-16: Distance-based redundancy analysis plot of relationships between physical plus biological habitat variables, and fish assemblages labelled by a) site and b) depth. The overlaid biplot shows Pearson correlation vectors (>0.4) of those variables contributing significantly to fish assemblage structure.

3.4 Biosecurity Surveys

No target invasive species (e.g. *Didemnum* sp., *Undaria pinnatifida* and *Styela clava*) were detected at the man-made structures surveyed (Table 3-5, Figure 2-1).

Table 3-5: Site, structure, longitude and latitude surveyed for invasive species.

Date	**Site**	**Substratum**	Longitude	Latitude
12/2/2016	Clio Rocks Anchor	Mooring structures	167.5229	-44.8293
14/02/2016	Anchorage Cove	Mooring structures	167.3954	-44.9292
08/02/2016	Luncheon Cove	Mooring structures	166.5184	-45.7681
05/02/2016	Weka Island	Barge + mooring lines	166.6935	-46.0937
05/02/2016	Kisbee Lodge Barge	Barge + mooring lines	166.7129	-46.1092
07/02/2016	Cascade Cove	Mooring structures	166.5839	-45.8109

3.5 ROV surveys

We found sea pens (Pennatulacea) on low relief soft sediment habitat in George, Caswell, and Charles Sounds (Table 3-6, Appendix H). In some locations, sea pens were quite dense in aggregations, and these assemblages appeared quite diverse, containing up to 6 species at depths ranging ca.80-120 m. Some of the species appeared to have overlapping habitat distributions with up to 3 species present in the video field of view at one time (Figure 3-17, Appendix H). Rocky habitat also appeared quite diverse with occasional large black coral, soft corals, red and white corals, crinoids and a seadragon seen (Appendix H).

Table 3-6: Remote operated vehicle (ROV) surveys.

Date	Long.	Lat.	Site	Notes of what was seen
13/02/2016	167.3756	-44.9079	George Sound 1	55 m depth, flat soft sediment (mud, sand), with occasional rock outcrop. Bed of armoured sea pens (*Pteroeides* sp.). (ca.5 min duration)
	167.3889	-44.9178	George Sound 2: Start	57 m depth, flat soft sediment (mud, sand). Occasional armoured sea pens (*Pteroeides* sp.) with occasional rock pens (*Anthoptilum* sp.). (ca.7 min duration)
	167.3903	-44.919	George Sound 2: End	
14/02/2016	N/A	N/A	Caswell Sound 1:	58 m depth, soft mud with occasional shells and polychaete worm tubes (*Protula* sp.). Occasional armoured sea pens (*Pteroeides* sp.) and burrowing anemone (*Cerianthus* sp.). (ca. 12 m duration).
	167.2417	-45.040	Caswell Sound 2:	82 m depth, soft mud. Occasional burrowing anemone and algae. Cobble over mud habitat between ca.65-45 m with encrusting fauna including black coral. (ca. 20 min duration).
	167.2452	-45.041	Caswell Sound 3:	Ca. 90 m depth, soft mud. Armoured sea pens (*Pteroeides* sp.) with rope like or long-leaf sea pens, and occasional rock pens (*Anthoptilum* sp.). Rock outcrops with large black coral trees, red coral, polychaete worms, and soft corals.
15/02/2016	167.1405	-45.0957	Charles Sound 1: North Eleanor	Ca.104 m depth, soft mud with occasional rock outcrop. Armoured sea pens (*Pteroeides* sp.) with rope like and/or long-leaf sea pens, and occasional club sea pen (*Kophobelemnon* sp.). (ca.20 min duration).
	167.144	-45.1	Charles Sound 2: East Eleanor	Muddy sand with occasional rock outcrops. White and red corals, soft corals, crinoids. Occasional Armoured sea pens (*Pteroeides* sp.). (ca. 6 min duration).
16/02/2016	167.1367	-45.0971	Charles Sound 3: Front Eleanor	Rock, cobble, mud habitat. Crinoids, seadragon, sponges
17/02/2016	167.1482	-45.095	Charles Sound 4: West Eleanor	Sand, mud, silt with burrows to vertical rock wall with a few sponges and encrusting invertebrates.

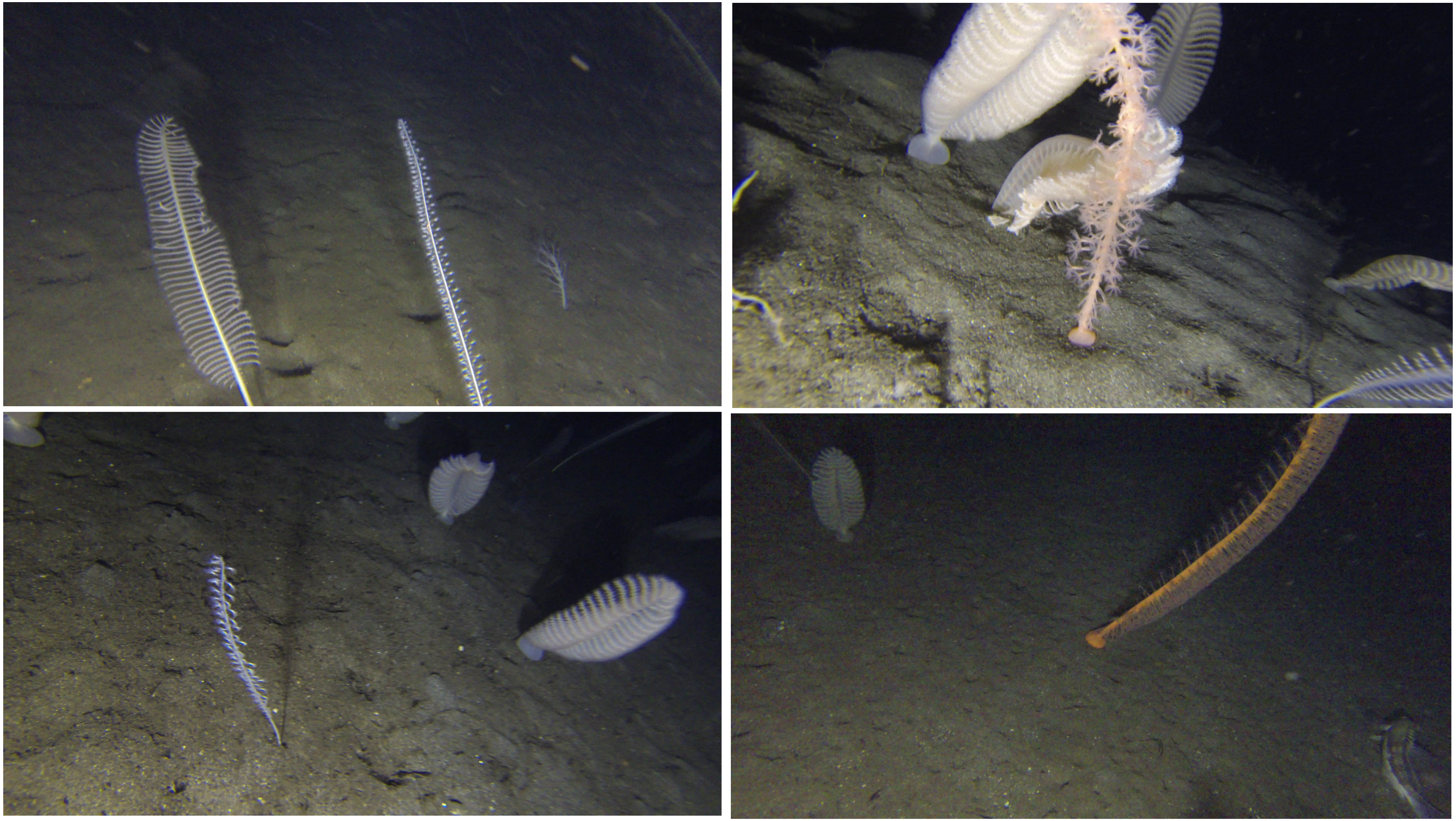


Figure 3-17: Multiple species of sea pens recorded on digital video attached to the ROV.

4 Discussion

After ten years of MR protection, there were no large statistically significant differences in contrasts between key species abundance inside and outside Fiordland Marine Area marine reserves. Significant changes in keys species abundance noted in other MRs in different geographic regions of New Zealand have been variable. Cole and Keuskamp (1998) reported increased predation of kina at Leigh Marine Reserve 19 years after it was established in 1975. Trophic shifts including increased benthic primary production inside the reserve were later reported (Babcock et al. 1999, Shears et al. 2002, Shears & Babcock 2003). Changes inside the Kokomohua (Long Island) MR in Queen Charlotte Sounds were evident after 22 years of protection from fishing, with more: predatory blue cod (3x increase); blue moki (1.4x increase); rock lobster (11.5x increase); and grazing black foot paua (1.4x increase), and reductions in the number of grazing kina (3x decrease), especially small (<45 mm) kina (Davidson et al. 2014). Despite these apparent dramatic changes at Long Island there is no evidence yet of trophic changes like changes to seaweed cover. In Nelson, the Horoirangi MR showed increased size of blue cod with more legal-sized cod after 2 years of reservation, and large rock lobster started to increase in density 5 years after reservation. Rob Davidson (pers. comm.) expects lobsters to start to really increase inside the reserve over the next 5 years (11 years after reservation).

In the absence of historic benchmarks, or adequate baseline quantification of key species densities before the establishment of FMA MR's in a BACI type design, the monitoring of changes occurring over long time periods was recommended to detect any effects from MR management (Willis et al. 2009b). In the present study, analyses of temporal changes since the establishment of Fiordland MRs showed no changes in assemblage structure or key species abundance in response to protection. This analysis was however constrained by low replication in early surveys. A potential pitfall of quantifying temporal changes is that it is blind to the presence of any 'shifting base-lines' (*sensu* Pauly 1995, Pauly et al. 2001). That is, records or memory of changes in fish populations have not kept pace with actual changes that have occurred over time, especially changes at decadal to century scales. Therefore, the lack of recovery of key species abundance in response to MR protection needs to be placed in context of historic losses, recognising that such losses were likely lower in Fiordland than experienced in other regions of New Zealand closer to towns and cities where there was greater access by recreational and commercial fishers. The issue of shifting base-lines is difficult to address especially by fisheries managers faced with fisheries management and monitoring starting long after exploitation of many species began (e.g. Sáenz–Arroyo et al. 2005).

Historic analyses indicate that significant changes to benthic habitats and fish populations have occurred, especially since Europeans colonised New Zealand largely in the late 1800's to early 1900's (e.g. Handley 2015, 2016, MacDiarmid et al. 2016a, b). Invertebrate and fish species like rock lobster, blue cod and groper were reported to be highly abundant during European colonisation around coastal New Zealand, even in remote areas like Fiordland (Appendix H, MacDiarmid 2016b). The validity of historic newspaper accounts could be criticized for falling to the allure of halcyon memories which may be confounded by only recording outstanding or rare events, thus skewing perceptions of past productivity. Historic fish biomass and harvest estimates have however been achieved using a combination of company records, government archives, newspapers, photographs, and unofficial private correspondence, and archaeological methods (Smith 2011, Paul 2014, MacDiarmid et al. 2016a, 2016b).

To illustrate the potential scale of historical change that has occurred in Fiordland, historical newspaper accounts give some insight into former abundance of New Zealand's coastal invertebrate and fish populations. Examples of loss of abundance and potential 'shifts in baselines' include (see Appendix H):

- Former abundance of rock lobster that allowed for hand-gathering from open boats in Chalky Inlet in 1909;
- abundant populations of blue cod, that supported early (1930-50's) trawl fisheries around coastal New Zealand (Rapson 1956);
- and, groper that used to feed in immense surface shoals in parts of New Zealand including Fiordland (R. Swale, pers. comm.), and were significantly more numerous around the southern coastline (Maxwell 2010, MacDiarmid et al. 2016b);

These accounts and studies indicate we may underestimate contemporary recovery levels in New Zealand MRs that may have greater scope for recovery to pristine baseline levels.

Due to the slow rate of recovery, lack of historical monitoring data, and inter-generational memory loss associated with 'shifting baselines', it is difficult to demonstrate cause and effect, and the flow on effects of changes within foodwebs. As reported elsewhere in New Zealand and overseas, removal of apex predators and engineering species like lobster can lead to "trophic-cascade effects", altering finfish species composition and benthic communities over time. It is likely that the timescales at which such trophic changes occur may vary depending on a number of factors including MR location and size, species longevity, and recruitment dynamics of predators and grazers. The magnitude of such changes will however be dependent on the scale of any historic losses to fish biomass due to harvesting or other anthropogenic disturbance, but also the ability of the species to recover from depletion at a given location. If the loss of rock lobster biomass in Chalky Inlet now precludes harvesting them by hand and that historic account was an accurate reflection of their past abundance, then there appears plenty of scope for recovery. However it may take many decades to achieve recovery to near historic population levels, but without benchmarks, we do not know the scale of the historical losses and therefore the scope of any potential recovery.

Slow recovery rates are expected in the Fiordland case, where for example it has been shown that blue cod become long-term residents inside the fiords after recruiting slowly via subsidy from the outer coast especially to inner MRs in Doubtful Sound (Carbines & McKenzie 2004, Rodgers & Wing 2008, Willis & Handley 2012). Surveys of deep reef fauna using ROV also indirectly showed that blue cod and rock lobster are uncommon beyond diver depths especially on steeply sloping walls, indicating that this habitat is potentially unsuitable for them in Doubtful and Dusky Sounds (Handley et al. 2010). This observation suggests that rates of recruitment or migration may be hindered along the corridors of shallow suitable habitat (0-40 m) between the outer coast and inner MR sites. Further, as these corridors are open to ongoing recreational fishing and potting during fisheries surveys (blue cod), translocating stocks or reducing recreational take may be the only tools available to increase rates of recovery in inner MRs. In light of the obstacles to recovery of key species like blue cod and rock lobster, we predict recovery will be slow, and expected to be in the order of several decades. This therefore raises the question, what is the optimum frequency of monitoring required to achieve the current main objective of FMA MR monitoring – "To monitor any changes in the size structure and abundance of key predatory and grazer species in response to management changes in the FMA"? And should the frequency of monitoring for this objective be reduced and resources used for other research objectives? Greater emphasis could be placed on understanding what comprises a 'biologically significant difference' (c.f. statistical significance) in key species and what are the important habitat drivers inside and outside the MR's that should be surveyed with balanced effort, to reduce confounding of analyses comparing effects from reservation.

It has been suggested that many of the FMA MR's were established for the dual purpose of protecting habitats and species from being degraded, while also contributing to restoration outcomes (K. Grange, pers. comm.). The prevention of degradation of species and habitats is a complementary goal of the main objective of the present contract. As there were very few differences in the abundance of key species inside and outside the MRs in our analyses, or between years in our time series analysis after 10 years of protection, there was no evidence for degradation of key species taking place.

As in previous NIWA surveys (Willis et al. 2009, Handley et al. 2013) reef fish assemblages from different Fiordland fiords were strongly correlated with physical habitat variables like depth, but also biological habitat components including large brown algae, especially *Ecklonia*. By separating out physical and biological variables, our analyses provides insight into fish and habitat associations in Fiordland. The spread in the fish data appeared related to site-specific differences in habitats. Fish composition at the outer coast site of Taumoana (Five-Fingers Peninsula) was more clearly correlated with the abundance of large boulders, whereas at inner fiord sites like Kutu Parera (Gaer Arm) MR and Te Tapuwae o Hua (Long Sound) MR, the presence of trees and sand appeared important to fishes. These differences are most likely due to availability of these habitats, rather than changes in habitat preference. The addition of biological habitat information further increased the explanatory power of the models. For example, large brown algae, *Ecklonia* and large boulders were correlated with fish assemblages at Taumoana (Five-Fingers Peninsula), and inner fiord sites fish assemblages were correlated with coralline turf 15 m, suggesting that low salinity levels were affecting fish at the 5 m contour inside the fiords. On this survey, the second diver in each team gathered a wide range of habitat information. It was initially anticipated that if any large differences in key species abundance were detected in MRs, we could investigate which habitat variables were correlated with key species, and test for spatial confounding of those habitat variables to ensure effects attributed to reservation were not an artefact of differences in habitat availability inside and outside reserves. However, as there were no 'biologically significant' differences inside and outside reserves (e.g. at the scales reported by Davidson et al. 2014), this exploratory analysis was not undertaken. We recommend at a later date, that a combination of univariate (GLM) and multivariate approaches (BEST, DISTLM) could be used to investigate key habitat drivers for key species (e.g. Silva and Gardner 2016). This approach could be used to identify and prioritise habitats to be monitored alongside key species in future surveys. This will allow for surveys of habitats important to key species, providing data to test for spatial confounding of habitat availability, to robustly interpret recovery or degradation of key species.

The diversity and high density of some of the sea pens found on soft sediment habitat in the northern fiords was surprising. Cold water coral and sea pen beds have been identified as biodiversity hotspots in deep water environments where they can provide habitat for fish larvae (Baillon et al. 2012). The overlapping species distributions and the relatively shallow depths of the sea pens seen on this survey appear to be unique (c.f. Williams et al. 2014) and are another example of deep-water emergent species in the FMA. Depending on habitat, topography, bottom currents, and food availability, more than one species of sea pen can be encountered in the same area (Gary Williams, pers. comm., California Academy of Sciences, U.S.A.). These observations in three out of three fiords surveyed highlight how little we know about biodiversity living below diving depths in Fiordland.

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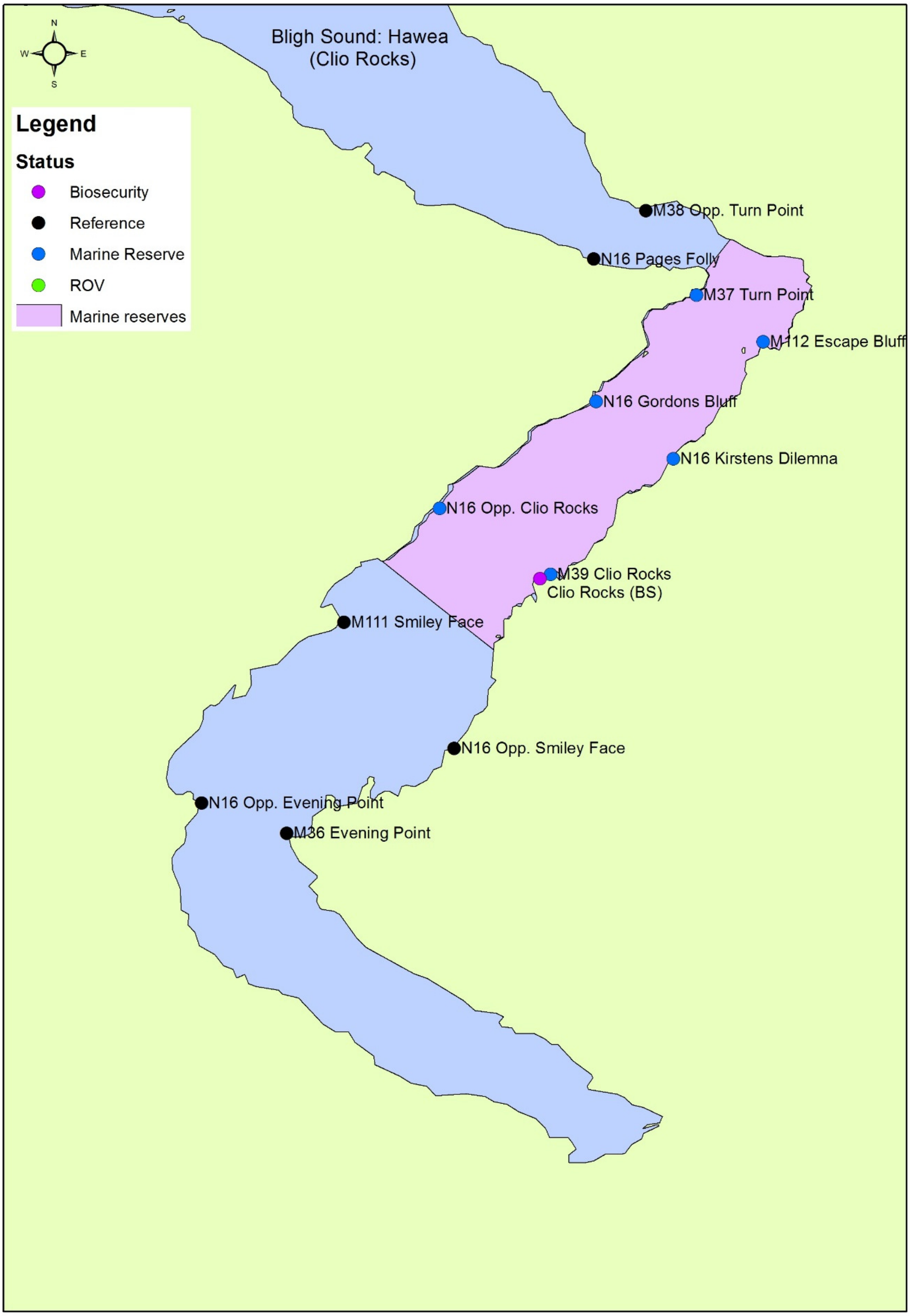
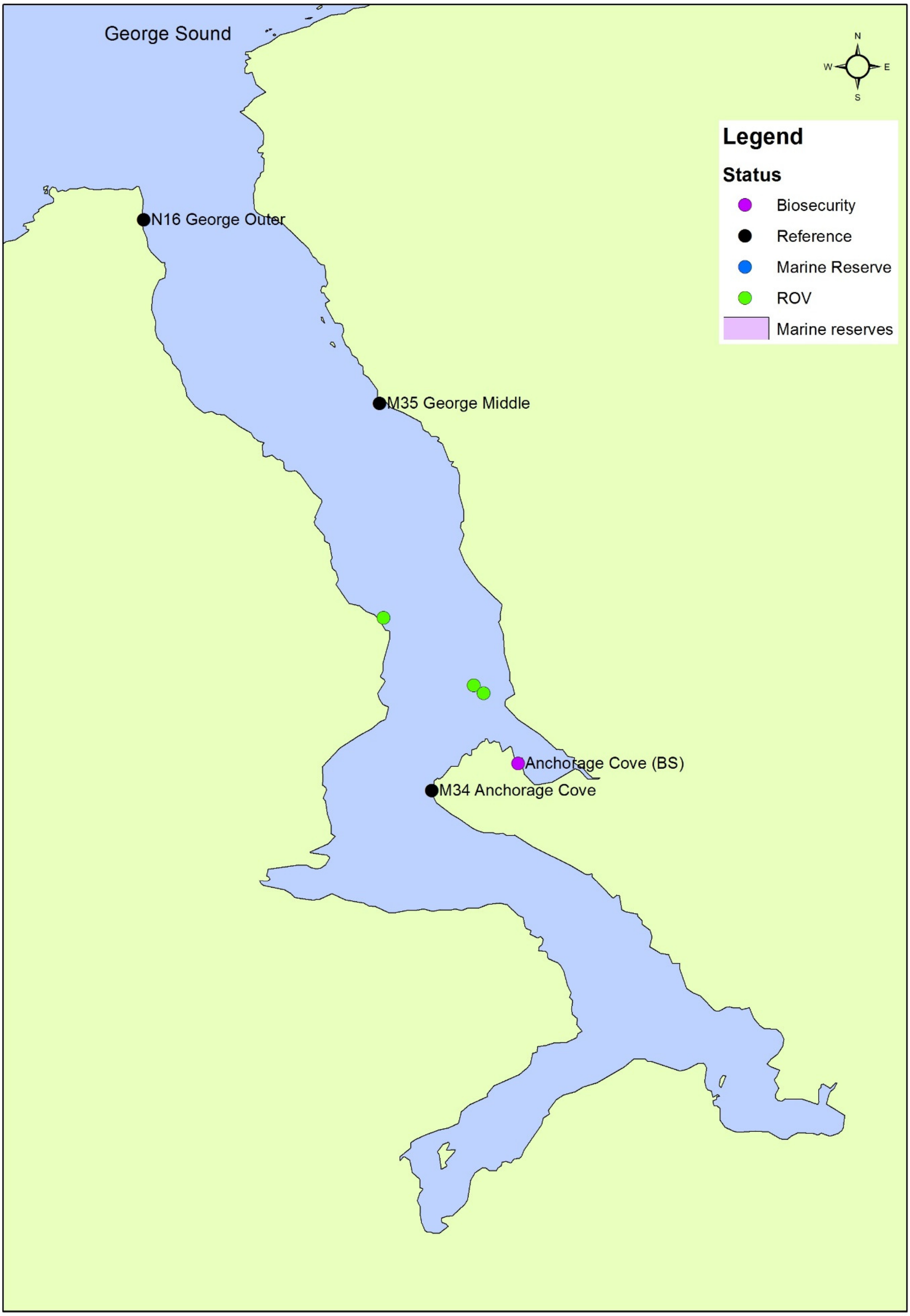
– Appendix A: Maps of dive sites within fiord locations

Bligh Sound: Hawea (Clio Rocks)



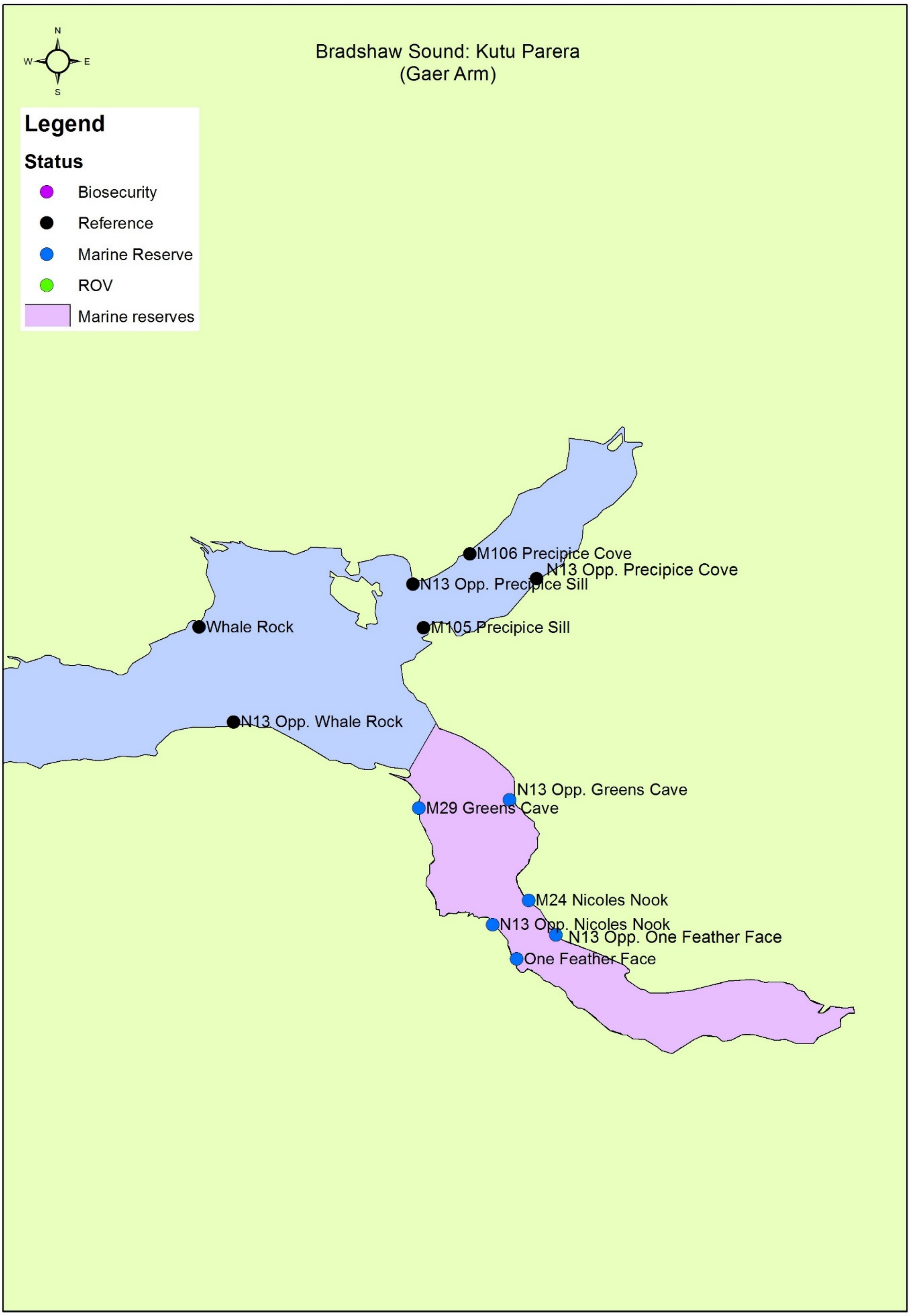
Caswell Sound

George Sound

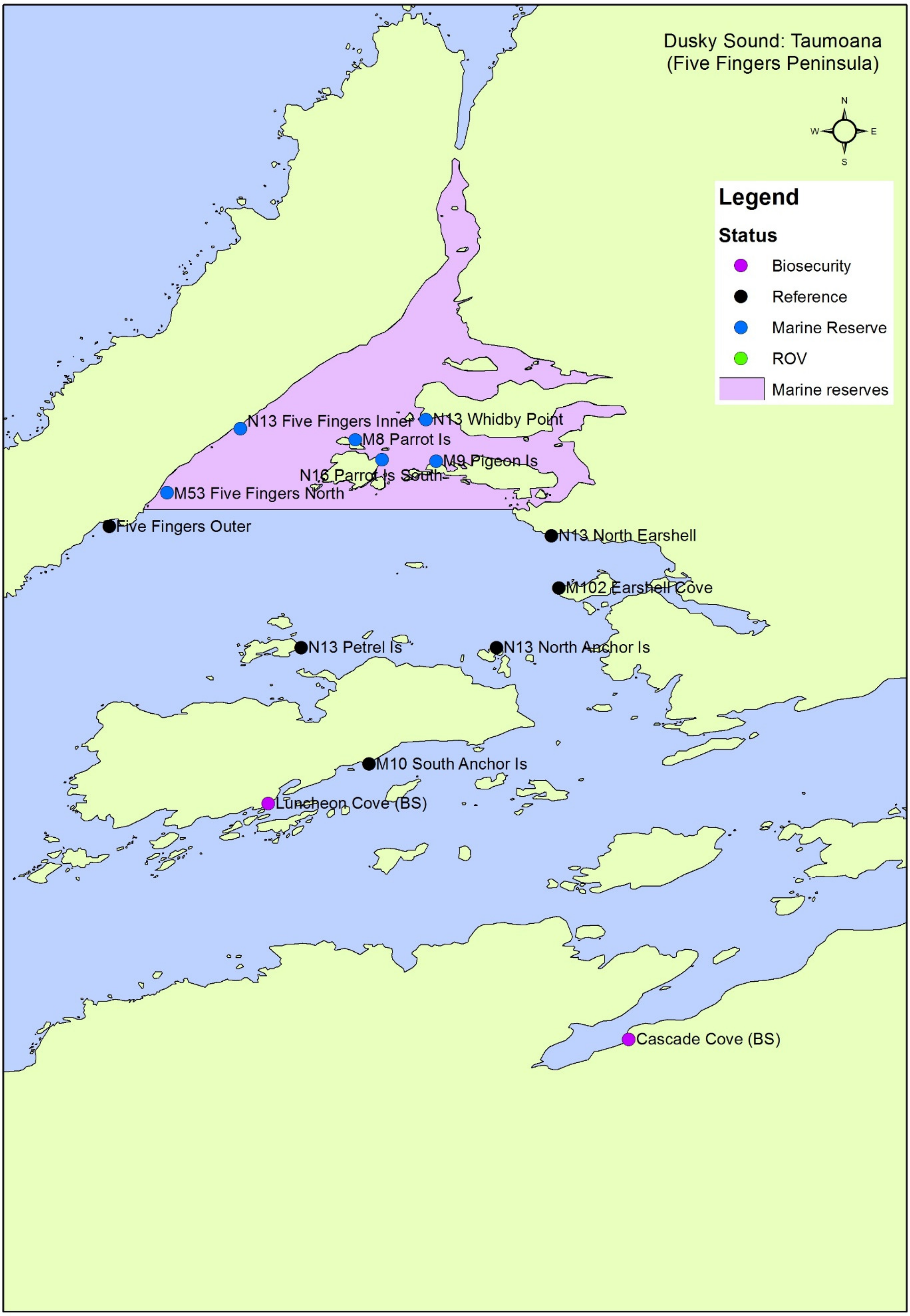


Kahukura (Gold Arm), Charles Sound

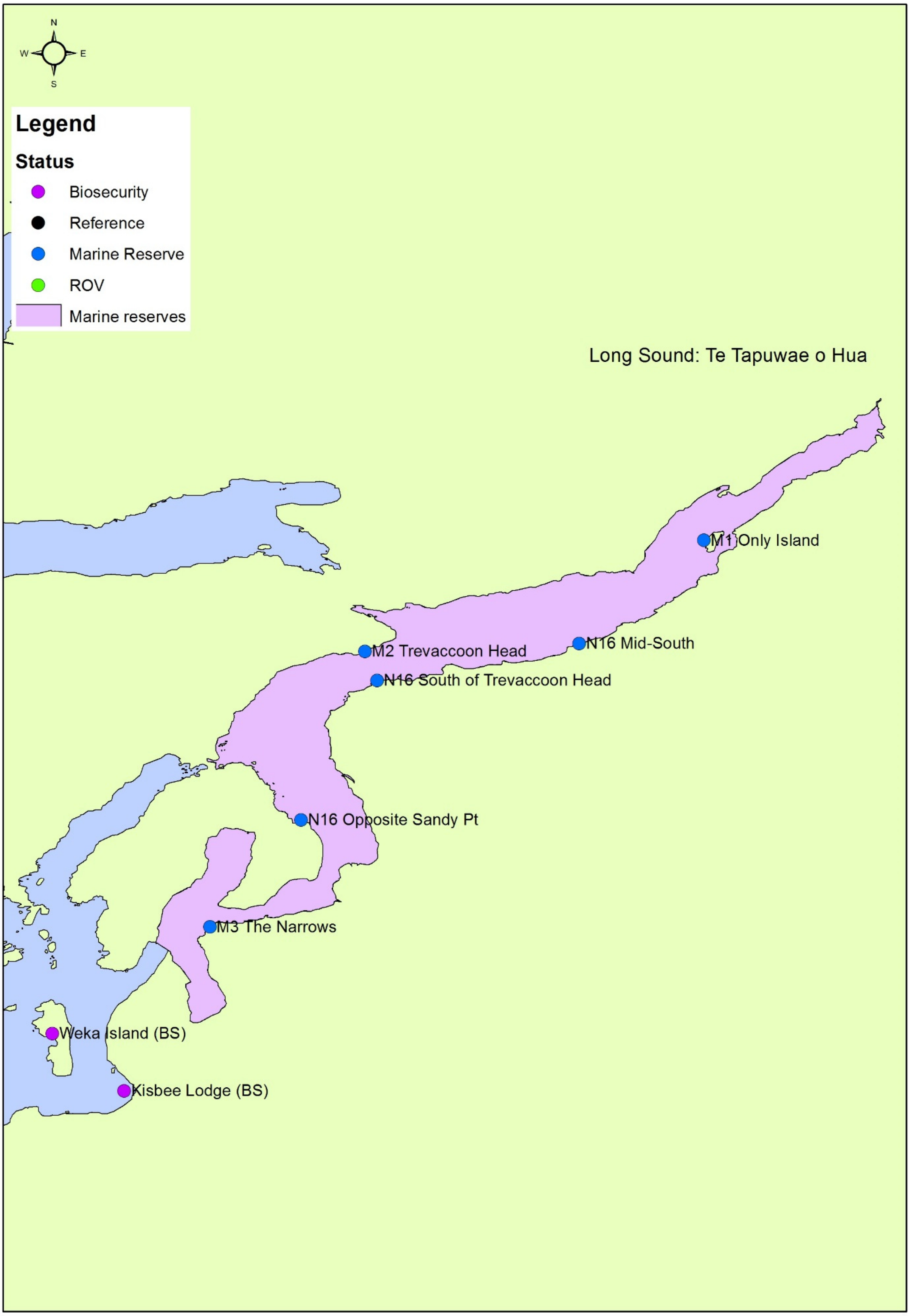
Kutu Parera (Gaer Arm), Bradshaw Sound



Taumoana, (Five Fingers Peninsula)



Te Tepuwae o Hua (Long Sound)



– Appendix B: Habitat variables recorded

Variable	Method	Notes:	Suggestions
Depth	As per transect (5, 15m)		
Slope	Degree slope from vertical	Underhangs recorded as negative	
PlatformRockReef	% rocky reef	Sum or converted to 100% with other substrata	
PRCrevice	Presence/absence	[Not all records consistent- hence converted to presence/absence]	Record as % of rock platform reef
PRLedge	Presence/absence	[Not all records consistent- hence converted to presence/absence]	Record as % of rock platform reef
Cobble	% cobble	Sum or converted to 100% with other substrata	
SmallBoulder	% small boulder	Sum or converted to 100% with other substrata	
MedBoulder	% Medium boulder	Sum or converted to 100% with other substrata	
LargeBoulder	% large boulder	Sum or converted to 100% with other substrata	
Sand	% Sand	Sum or converted to 100% with other substrata	
SandMud	% sand/mud	Sum or converted to 100% with other substrata	
ShellHash	% shell hash	Sum or converted to 100% with other substrata	
TerrestrialDetritus	% terrestrial detritus cover	Sum or converted to 100% with other substrata	Larger than silt (e.g. leaves, twigs)
CCA_Turf	% crustose coralline algal cover	Sum or converted to 100% of biological cover	
Coralline paint	% coralline paint cover	Sum or converted to 100% of biological cover	
LowTurfRedsBrowns	% low brown or red turfing algae	Sum or converted to 100% of biological cover	
FolioseRedsBrowns	% foliose reds browns (c.f. large browns)	Sum or converted to 100% of biological cover	
Brachiopods	% brachiopod cover	Sum or converted to 100% of biological cover	
Encrusting inverts	% encrusting invertebrate cover	Sum or converted to 100% of biological cover	
Tubeworms	% tubeworms	Sum or converted to 100% of biological cover	
Caulerpa %	% *Caulerpa* sp. Cover	Sum or converted to 100% of biological cover	
Codium	% *Codium* sp. cover	Sum or converted to 100% of biological cover	
Ulva	% *Ulva* sp. Cover	Sum or converted to 100% of biological cover	
Ecklonia	% *Ecklonia* cover	Sum or converted to 100% of biological cover	
LargeBrowns	% Large brown algal cover	Sum or converted to 100% of biological cover	Could record as individual species?

BarrenBare	% urchin barren grazed bare	Sum or converted to 100% of biological cover
Silt	Subjective estimate: low, medium, high	Converted to numeric e.g. low = 0.2, medium = 0.5, high = 1.
Tree	Presence/absence	
Coscinasterias	Number of *Coscinasterias*	
Atrina	Number of *Atrina*	
Scallops	Number of scallops	
Mussels	Estimated number of mussels	
Australostichopus	Number of *Austrolostichopus*	
Cerianthus	Number of *Cerianthus*	
Cymbastela	Number of *Cymbastela*	
black_coral_juv	Number of juvenile (<1m) black coral	
black_coral_ad	Number of adult (>1m) black coral	
black_coral_dead	Number of dead black coral	
Kina	Number of kina	
Pseudechinus	Number of *Pseudechinus*	
cray <10	Number of rock lobster <10cm carapace length	
cray10-15	Number of rock lobster 10-15cm carapace length	
cray>15	Number of rock lobster >15cm carapace length	
Errina sp	Number of *Errina*	
gorgonian	Number of gorgonians	

- Appendix C: List of fish species, frequency and number recorded in transects

Species	Family	Common name	Frequency (n = 288)	Sum
Spotty	*Notolabrus celidotus*	Labridae	423	5758
Butterfly Perch	*Caesioperca lepidoptera*	Serranidae	402	10629
Scarlet Wrasse	*Pseudolabrus miles*	Labridae	401	2526
Banded Wrasse	*Notolabrus fucicola*	Labridae	207	953
Girdled wrasse	*Notolabrus cinctus*	Labridae	138	426
Marble fish	*Apldactylus arctidens*	Aplodactylidae	115	197
Jock Stuart (sea perch)	*Helicolenus percoides*	Scorpaenidae	107	191
Blue Cod	*Parapercis colias*	Pinguipedidae	100	156
Telescope fish	*Mendosoma lineatum*	Latridae	67	3467
Tarakihi	*Nemadactylus macropterus*	Latridae	66	87
Butterfish	*Odax pullus*	Odacidae	42	115
Red banded perch	*Hypoplectrodes huntii*	Serranidae	41	67
Southern splendid perch	*Callanthias allporti*	Callanthiidae	40	196
Blue moki	*Latridopsis ciliaris*	Latridae	31	56
Leatherjacket	*Parika scaber*	Monacathidae	28	62
Wavey lined perch	*Lepidoperca tasmanica*	Serranidae	7	45
Common roughy	*Paratrachichthys trailli*	Trachichthydae	5	8
Scorpion fish	*Scorpaena papillosus*	Scorpaenidae	4	4
School shark	*Galeorhinus galeus*	Triakidae	3	3
Southern bastard cod	*Pseudophycis barbata*	Moridae	3	3
Trumpeter	*Latris lineata*	Latridae	2	3
Conger eal	*Conger verreauxi*	Congridae	1	1
Carpet shark	*Cephaloscyllum isabellum*	Scyliorhinidae	1	1
Eagle ray	*Myliobatis tenuicaudatus*	Myliobatidae	1	1
Sting ray	*Dasyatis brevicaudata*	Dasyatidae	1	1
Copper moki	*Latridopsis forsteri*	Latridae	1	2
Rig	*Mustelus lenticulatus*	Triakidae	1	1
Unknown rockfish	*Acanthoclinid sp.*	Acanthoclinidae	1	1
Kahawai	*Arripis trutta*	Arripidae	1	50
Porcupine fish	*Allomycterus jaculiferus*	Diodontidae	1	1

- Appendix D - Univariate results

Results of main effects tests from Generalized Linear Model (GLM). P-values in bold are significant: '***' P<0.001 '**' P<0.01 '*' P<0.05. Note: quasipoisson distribution was used for rock lobster and kina as these data were overdispersed.

	Poisson					
Blue cod	**Df**	**Deviance**	**Resid. Df**	**Resid. Dev**	**Pr(>Chi)**	
NULL			528	946.92		
Location	4	489.78	524	457.14	**< 2.2e-16**	***
Status	1	0.04	523	457.11	**8.51E-01**	**
Depth	1	28.2	522	428.91	1.10E-07	ns
Location:Status	3	7.82	519	421.09	0.049837	ns
Location:Depth	3	20.6	516	400.49	**0.000127**	*
Status:Depth	1	0.1	515	400.39	0.755155	ns
Location:Status:Depth	3	4.98	512	395.41	0.172927	ns

	Quasipoisson					
Rock lobster	**Df**	**Deviance**	**Resid. Df**	**Resid. Dev**	**Pr(>Chi)**	
NULL			528	1815.5		
Location	4	168.507	524	1647	**6.06E-05**	***
Status	1	3.772	523	1643.2	0.458074	ns
Depth	1	87.015	522	1556.2	**0.000365**	***
Location:Status	3	56.096	519	1500.1	**0.042261**	*
Location:Depth	3	102.929	516	1397.2	**0.001795**	**
Status:Depth	1	2.804	515	1394.4	0.522286	ns
Location:Status:Depth	3	11.539	512	1382.9	0.640372	ns

	Quasipoisson					
Kina	**Df**	**Deviance**	**Resid. Df**	**Resid. Dev**	**Pr(>Chi)**	
NULL			528	58255		
Location	4	33987	524	24268	**< 2.2e-16**	***
Status	1	1630	523	22637	**2.43E-07**	***
Depth	1	7524	522	15113	**< 2.2e-16**	***
Location:Status	3	122	519	14991	0.5723	ns
Location:Depth	3	84	516	14907	0.7133	ns
Status:Depth	1	22	515	14885	0.5462	ns
Location:Status:Depth	3	105	512	14781	0.6345	ns

Appendix E - Univariate results

Results of Location x depth tests for Reserve Status (Reserve vs Non-reserve) tests for Generalized Linear Model. P-values in bold are significant: '***' P<0.001 '**' P<0.01 '*' P<0.05. When the ratio of residual degrees of freedom (RD) to residual deviation (DF) exceeded 1, indicating overdispersion of the data, quasipoisson distribution was used.

Species	Depth	Location	Family	Test	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)	Significance	RD:DF
Blue cod	5 m	Bligh	Poisson	Status	2	67.008	70	55.31	**2.81E-15**	***	0.79
		Charles	Poisson	Status	2	52.104	46	30.669	**4.85E-12**	***	0.67
		Five Fingers	Poisson	Status	2	105.09	70	32.453	**< 2.2e-16**	***	0.46
		Gaer Arm	Poisson	Status	2	134.83	70	7.167	**< 2.2e-16**	***	0.10
	15 m	Bligh	Quasipoisson	Status	2	40.432	70	74.796	**2.05E-07**	***	1.07
		Charles	Poisson	Status	2	70.422	46	17.578	**5.11E-16**	***	0.38
		Five Fingers	Quasipoisson	Status	2	19.852	70	110.75	**0.0219**	*	1.58
		Gaer Arm	Poisson	Status	2	61.776	70	66.678	**3.85E-14**	***	0.95
Rock lobster		Bligh	Quasipoisson	Depth	1	5.44	143	534.17	0.412737	ns	3.74
				Status	2	128.944	141	405.23	**0.000352**	***	2.87
				Depth:Status	1	7.906	140	397.32	0.323435	ns	2.84
		Charles	Quasipoisson	Depth	1	16.515	95	250.53	0.05967	ns	2.64
				Status	2	82.457	93	168.07	**0.000143**	***	1.81
				Depth:Status	1	0	92	168.07	0.999949	ns	1.83
		Five Fingers	Quasipoisson	Depth	1	7.3296	143	556.43	0.326	ns	3.89
				Status	2	5.264	141	551.17	0.7072	ns	3.91
				Depth:Status	1	6.0245	140	545.15	0.3732	ns	3.89
		Gaer Arm	Quasipoisson	Depth	1	31.936	143	413.18	**0.02419**	*	2.89
				Status	2	140.431	141	272.75	**1.41E-05**	***	1.93
				Depth:Status	1	0.413	140	272.33	0.79775	ns	1.95
Kina	5 m	Bligh	Quasipoisson	Status	2	1918.2	70	1048.7	**2.20E-16**	***	14.98
		Charles	Quasipoisson	Status	2	129.46	46	494.21	**0.03066**	*	10.74
		Five Fingers	Quasipoisson	Status	2	40590	70	11870	**2.20E-16**	***	169.57
		Gaer Arm	Quasipoisson	Status	2	424.45	70	620.26	**1.66E-07**	***	8.86
	15 m	Bligh	Quasipoisson	Status	2	1.9264	70	204.49	0.8375	ns	2.92
		Charles	Quasipoisson	Status	2	47.916	46	51.542	**7.88E-05**	***	1.12
		Five Fingers	Quasipoisson	Status	2	294.77	70	354.38	**6.06E-10**	***	5.06
		Gaer Arm	Quasipoisson	Status	2	67.371	70	136.85	**0.005425**	**	1.96

Appendix F - Historic analysis, site replication

Number of transects surveyed for historic sites by year and depth (year, depth), with the total number of transects surveyed at each depth. Years, and sites with low transect replication were highlighted for elimination in the analyses.

Reserve	Site	2006, 5	2006, 15	2007, 5	2007, 15	2009, 5	2009, 15	2010, 5	2010, 15	2013, 5	2013, 15	2016, 5	2016, 15	Total, 5	Total, 15
Bligh	M37 Turn Point	1	1	0	4	6	6	1	2	0	0	6	6	4	5
Bligh	M39 Clio Rock	0	1	0	4	6	5	1	2	0	0	6	6	3	5
Charles	M30 Friendship Head	1	1	0	0	6	6	0	0	3	3	0	0	3	3
Charles	M31 Fanny Is	1	1	0	0	6	6	0	0	3	3	6	6	4	4
Five Fingers	M53 Five Fingers North	0	0	1	1	6	6	0	0	3	3	6	6	4	4
Five Fingers	M9 Pigeon Island	1	1	0	0	6	6	0	0	3	3	6	6	4	4
Gaer Arm	M24 Nichole's Nook	1	1	0	0	6	6	1	2	3	3	6	6	5	5
Gaer Arm	M25 Green's Cave	1	1	0	4	6	6	1	2	3	3	6	6	5	6
Long Sound	M1 Only Island	1	1	0	2	6	6	1	2	0	0	6	6	4	5
Long Sound	M2 Trevaccoon Head	1	1	0	6	6	6	1	2	0	0	6	6	4	5
Wetjacket	M13 south wall "Solanderia city"	1	1	0	0	6	6	1	2	3	3	0	0	4	4
Wetjacket	M14 The Hook	1	1	0	0	6	6	1	2	3	3	0	0	4	4

Appendix G: Screen grabs from ROV video footage

(see Table 3-6 for locations and descriptions). Note: Date, time and depth were recorded by the ROV camera, but these data were not available on the digital GoPro camera.

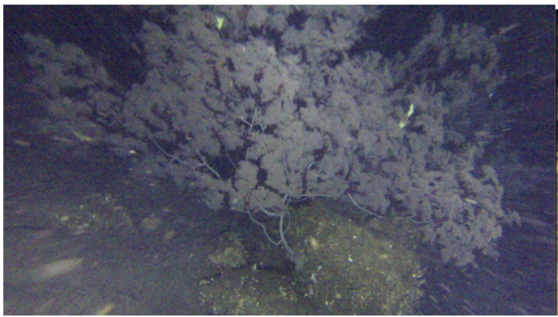
George Sound 1:

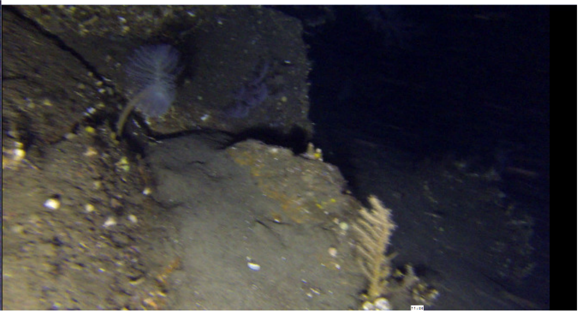
George Sound 2:

Caswell Sound 1:

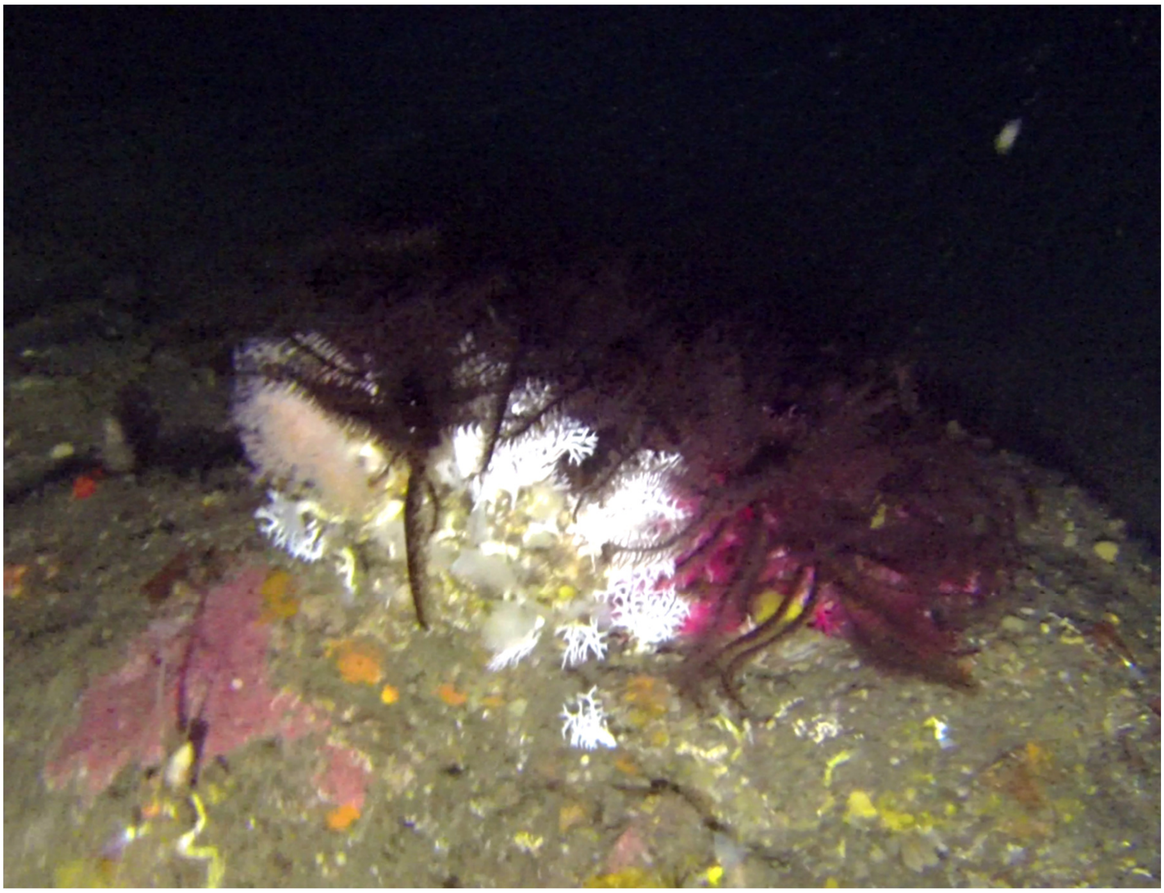
Caswell Sound 2:

Caswell Sound 3:

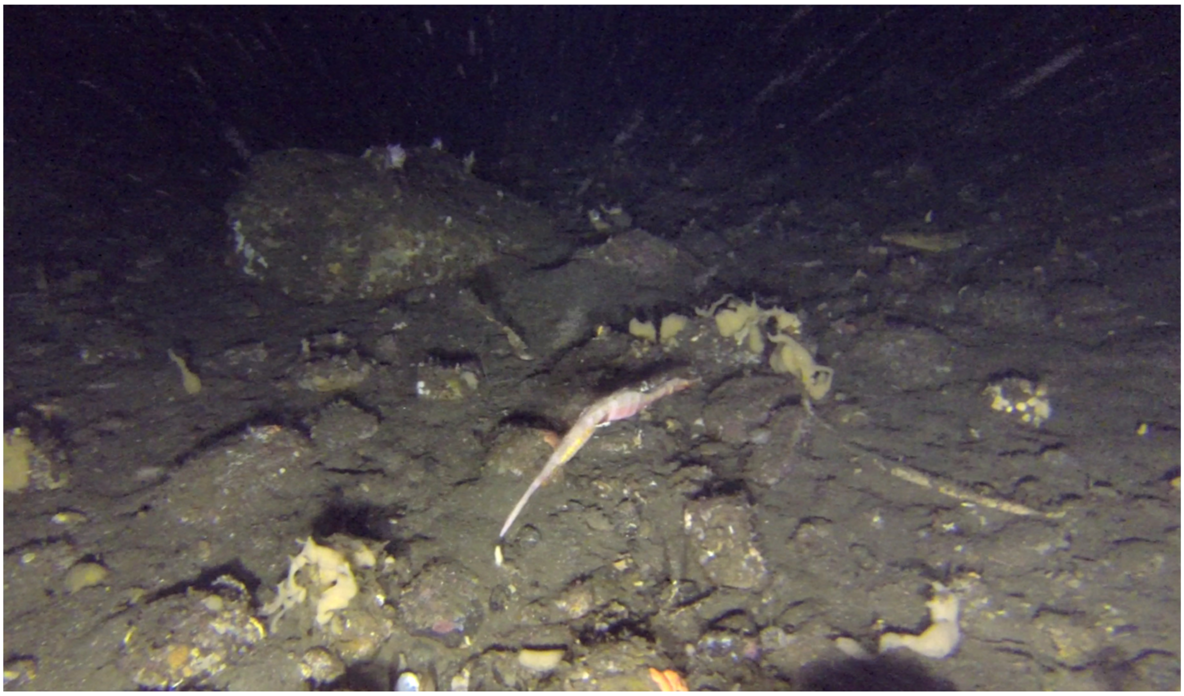




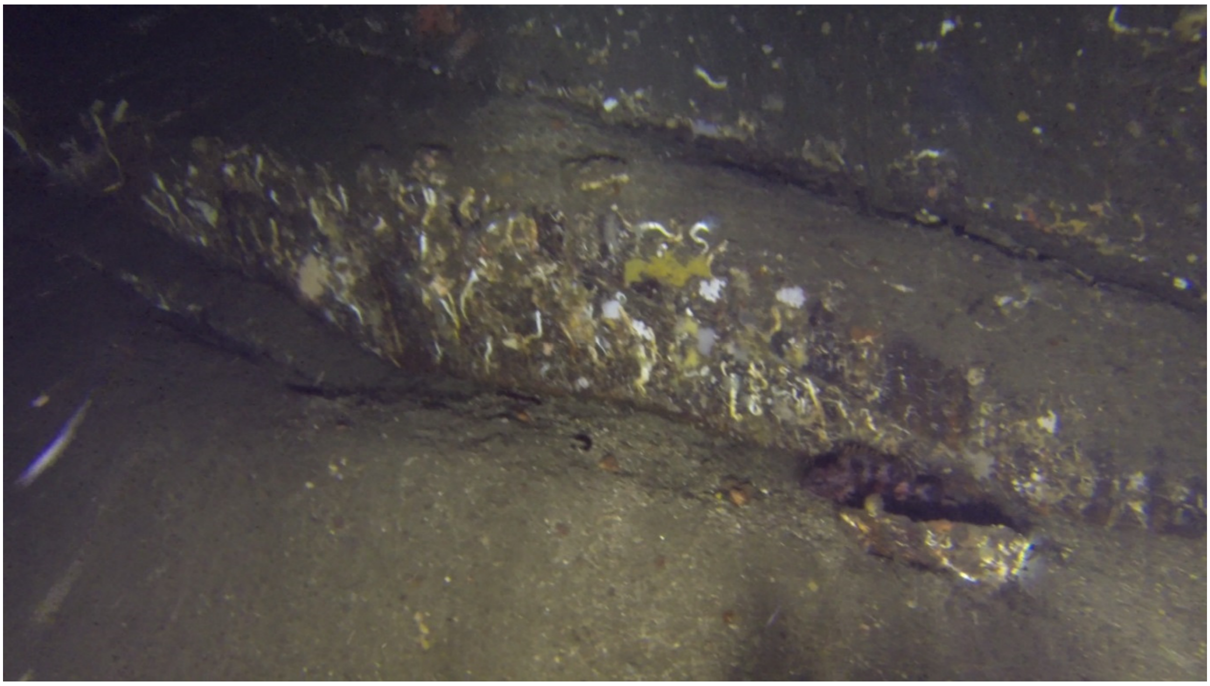
Charles Sound 1:

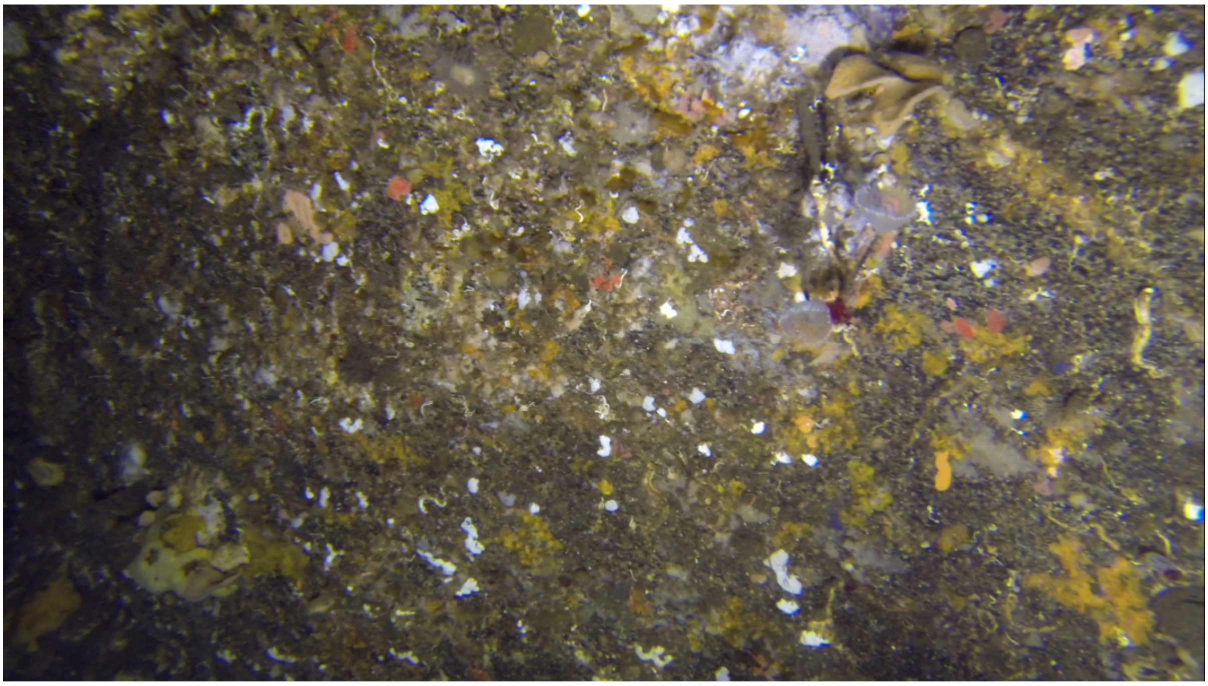


Charles Sound 3:



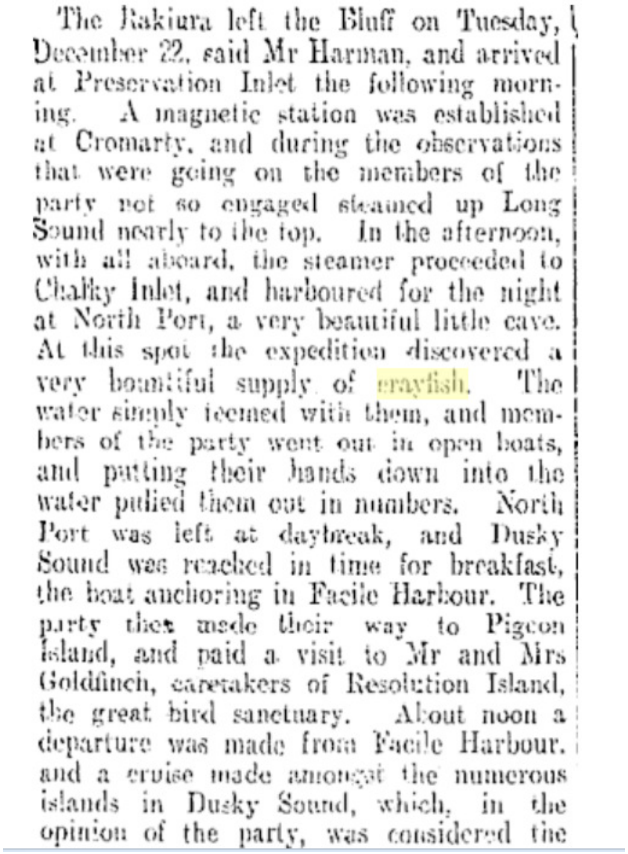
Charles Sound 4:





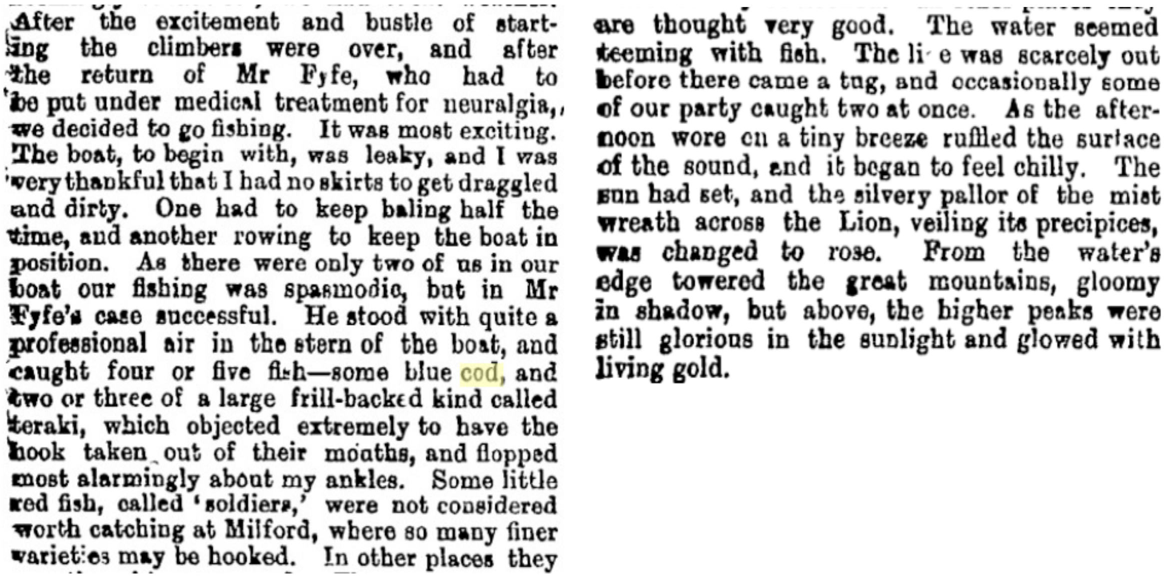
Appendix H: Historical newspaper accounts (https://paperspast.natlib.govt.nz)

A) **Rock lobster:** CRUISE OF THE RAKIURU Otago Daily Times, Issue 14415, 7 January 1909



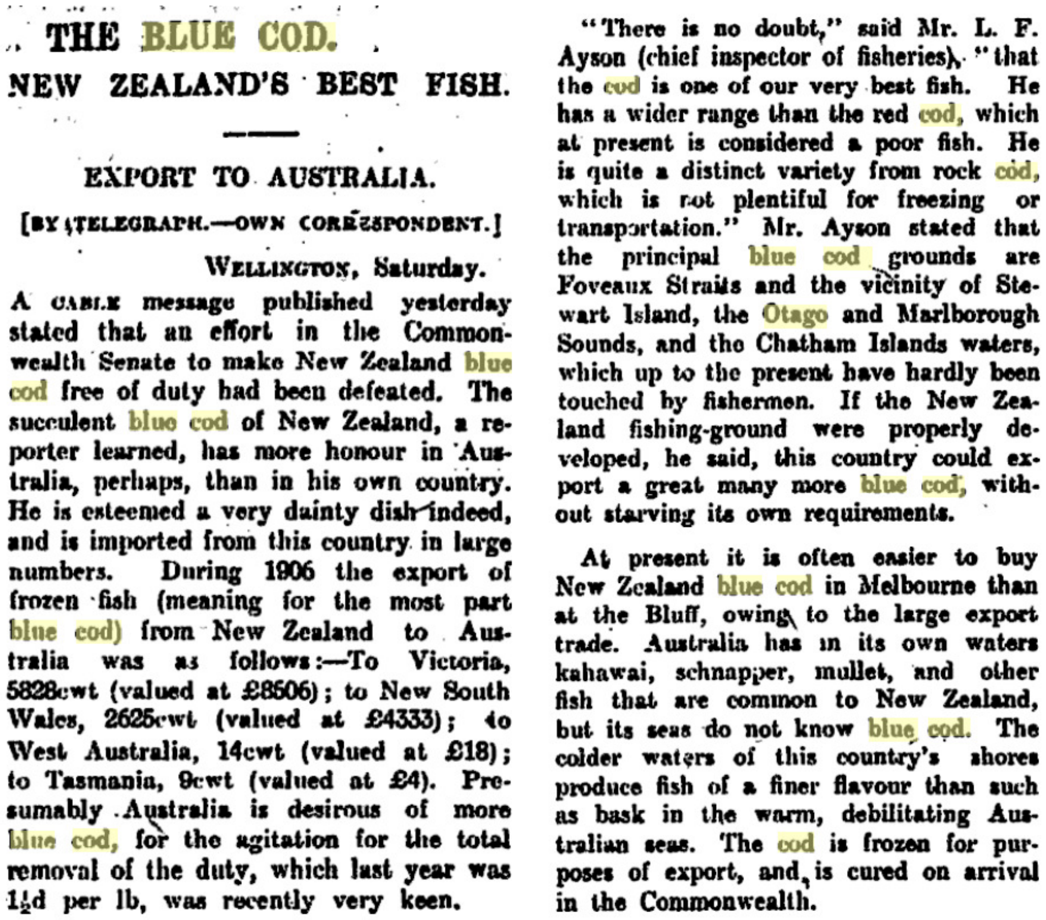
The Rakiura left the Bluff on Tuesday, December 22, said Mr Harman, and arrived at Preservation Inlet the following morning. A magnetic station was established at Cromarty, and during the observations that were going on the members of the party not so engaged steamed up Long Sound nearly to the top. In the afternoon, with all aboard, the steamer proceeded to Chalky Inlet, and harboured for the night at North Port, a very beautiful little cave. At this spot the expedition discovered a very bountiful supply of crayfish. The water simply teemed with them, and members of the party went out in open boats, and putting their hands down into the water pulled them out in numbers. North Port was left at daybreak, and Dusky Sound was reached in time for breakfast, the boat anchoring in Facile Harbour. The party then made their way to Pigeon Island, and paid a visit to Mr and Mrs Goldfinch, caretakers of Resolution Island, the great bird sanctuary. About noon a departure was made from Facile Harbour, and a cruise made amongst the numerous islands in Dusky Sound, which, in the opinion of the party, was considered the

B) **Blue cod:** THE LEADER EXPEDITION IN FIORDLAND. Otago Witness, Issue 2165, 22 August 1895



After the excitement and bustle of starting the climbers were over, and after the return of Mr Fyfe, who had to be put under medical treatment for neuralgia, we decided to go fishing. It was most exciting. The boat, to begin with, was leaky, and I was very thankful that I had no skirts to get draggled and dirty. One had to keep baling half the time, and another rowing to keep the boat in position. As there were only two of us in our boat our fishing was spasmodic, but in Mr Fyfe's case successful. He stood with quite a professional air in the stern of the boat, and caught four or five fish—some blue cod, and two or three of a large frill-backed kind called teraki, which objected extremely to have the hook taken out of their mouths, and flopped most alarmingly about my ankles. Some little red fish, called 'soldiers,' were not considered worth catching at Milford, where so many finer varieties may be hooked. In other places they are thought very good. The water seemed teeming with fish. The line was scarcely out before there came a tug, and occasionally some of our party caught two at once. As the afternoon wore on a tiny breeze ruffled the surface of the sound, and it began to feel chilly. The sun had set, and the silvery pallor of the mist wreath across the Lion, veiling its precipices, was changed to rose. From the water's edge towered the great mountains, gloomy in shadow, but above, the higher peaks were still glorious in the sunlight and glowed with living gold.

THE BLUE COD. , New Zealand Herald, Volume XLV, Issue 13669, 10 February 1908



THE BLUE COD.

NEW ZEALAND'S BEST FISH.

EXPORT TO AUSTRALIA.

[BY TELEGRAPH.—OWN CORRESPONDENT.]

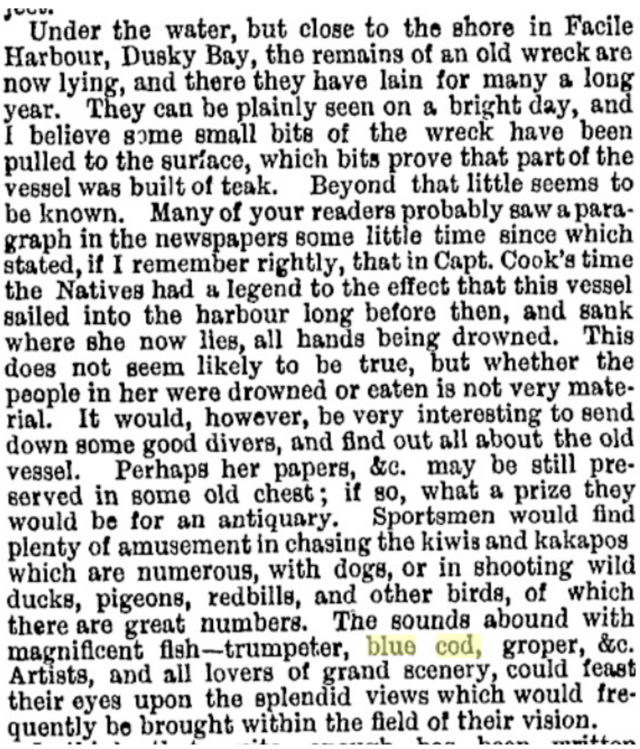
WELLINGTON, Saturday.

A CABLE message published yesterday stated that an effort in the Commonwealth Senate to make New Zealand blue cod free of duty had been defeated. The succulent blue cod of New Zealand, a reporter learned, has more honour in Australia, perhaps, than in his own country. He is esteemed a very dainty dish indeed, and is imported from this country in large numbers. During 1906 the export of frozen fish (meaning for the most part blue cod) from New Zealand to Australia was as follows:—To Victoria, 5828cwt (valued at £8506); to New South Wales, 2625cwt (valued at £4333); to West Australia, 14cwt (valued at £18); to Tasmania, 9cwt (valued at £4). Presumably Australia is desirous of more blue cod, for the agitation for the total removal of the duty, which last year was 1½d per lb, was recently very keen.

"There is no doubt," said Mr. L. F. Ayson (chief inspector of fisheries), "that the cod is one of our very best fish. He has a wider range than the red cod, which at present is considered a poor fish. He is quite a distinct variety from rock cod, which is not plentiful for freezing or transportation." Mr. Ayson stated that the principal blue cod grounds are Foveaux Straits and the vicinity of Stewart Island, the Otago and Marlborough Sounds, and the Chatham Islands waters, which up to the present have hardly been touched by fishermen. If the New Zealand fishing-ground were properly developed, he said, this country could export a great many more blue cod, without starving its own requirements.

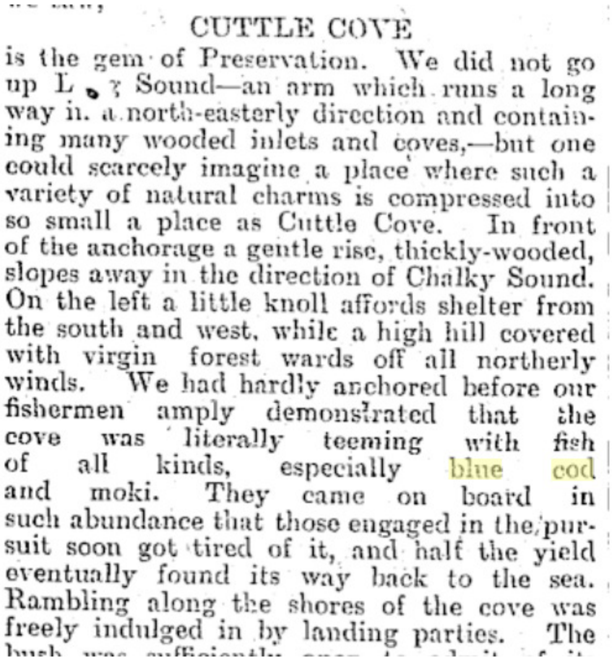
At present it is often easier to buy New Zealand blue cod in Melbourne than at the Bluff, owing to the large export trade. Australia has in its own waters kahawai, schnapper, mullet, and other fish that are common to New Zealand, but its seas do not know blue cod. The colder waters of this country's shores produce fish of a finer flavour than such as bask in the warm, debilitating Australian seas. The cod is frozen for purposes of export, and is cured on arrival in the Commonwealth.

UNEXPLORED COUNTRY. Otago Witness, Issue 1558, 17 September 1881



Under the water, but close to the shore in Facile Harbour, Dusky Bay, the remains of an old wreck are now lying, and there they have lain for many a long year. They can be plainly seen on a bright day, and I believe some small bits of the wreck have been pulled to the surface, which bits prove that part of the vessel was built of teak. Beyond that little seems to be known. Many of your readers probably saw a paragraph in the newspapers some little time since which stated, if I remember rightly, that in Capt. Cook's time the Natives had a legend to the effect that this vessel sailed into the harbour long before then, and sank where she now lies, all hands being drowned. This does not seem likely to be true, but whether the people in her were drowned or eaten is not very material. It would, however, be very interesting to send down some good divers, and find out all about the old vessel. Perhaps her papers, &c. may be still preserved in some old chest; if so, what a prize they would be for an antiquary. Sportsmen would find plenty of amusement in chasing the kiwis and kakapos which are numerous, with dogs, or in shooting wild ducks, pigeons, redbills, and other birds, of which there are great numbers. The sounds abound with magnificent fish—trumpeter, blue cod, groper, &c. Artists, and all lovers of grand scenery, could feast their eyes upon the splendid views which would frequently be brought within the field of their vision.

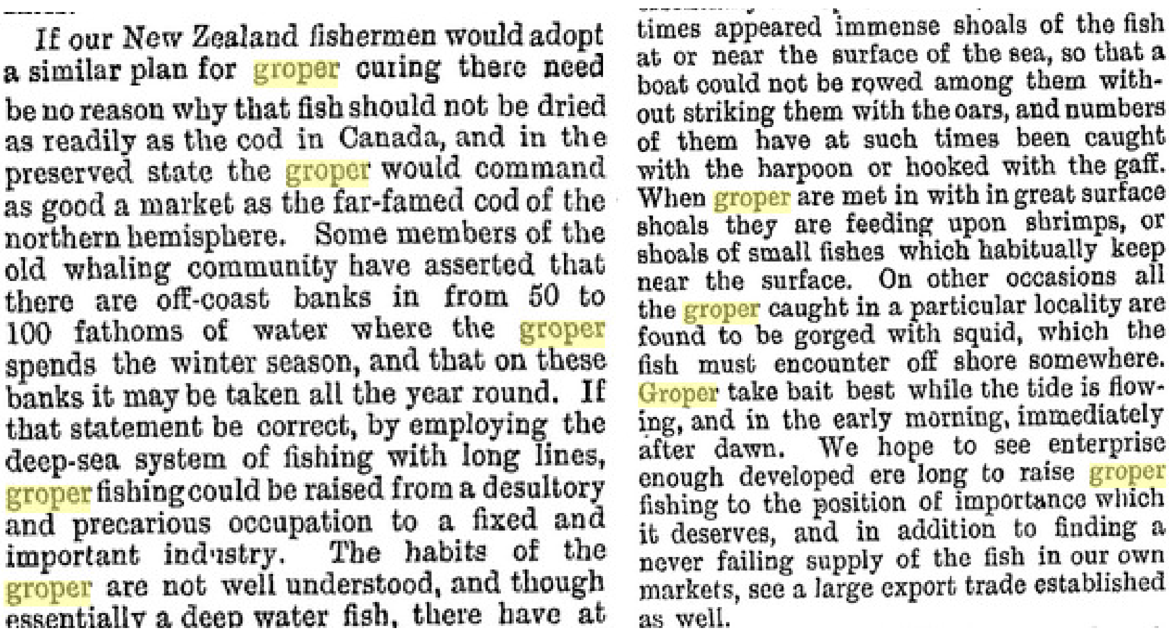
AROUND THE SOUNDS. Otago Daily Times, Issue 11696, 31 March 1900



CUTTLE COVE

is the gem of Preservation. We did not go up L[illegible] Sound—an arm which runs a long way in a north-easterly direction and containing many wooded inlets and coves,—but one could scarcely imagine a place where such a variety of natural charms is compressed into so small a place as Cuttle Cove. In front of the anchorage a gentle rise, thickly-wooded, slopes away in the direction of Chalky Sound. On the left a little knoll affords shelter from the south and west, while a high hill covered with virgin forest wards off all northerly winds. We had hardly anchored before our fishermen amply demonstrated that the cove was literally teeming with fish of all kinds, especially blue cod and moki. They came on board in such abundance that those engaged in the pursuit soon got tired of it, and half the yield eventually found its way back to the sea. Rambling along the shores of the cove was freely indulged in by landing parties. The

C) **Groper**: THE FISHERIES COURT. Otago Witness , Issue 1980, 23 January 1890, Page 17



If our New Zealand fishermen would adopt a similar plan for groper curing there need be no reason why that fish should not be dried as readily as the cod in Canada, and in the preserved state the groper would command as good a market as the far-famed cod of the northern hemisphere. Some members of the old whaling community have asserted that there are off-coast banks in from 50 to 100 fathoms of water where the groper spends the winter season, and that on these banks it may be taken all the year round. If that statement be correct, by employing the deep-sea system of fishing with long lines, groper fishing could be raised from a desultory and precarious occupation to a fixed and important industry. The habits of the groper are not well understood, and though essentially a deep water fish, there have at times appeared immense shoals of the fish at or near the surface of the sea, so that a boat could not be rowed among them without striking them with the oars, and numbers of them have at such times been caught with the harpoon or hooked with the gaff. When groper are met in with in great surface shoals they are feeding upon shrimps, or shoals of small fishes which habitually keep near the surface. On other occasions all the groper caught in a particular locality are found to be gorged with squid, which the fish must encounter off shore somewhere. Groper take bait best while the tide is flowing, and in the early morning, immediately after dawn. We hope to see enterprise enough developed ere long to raise groper fishing to the position of importance which it deserves, and in addition to finding a never failing supply of the fish in our own markets, see a large export trade established as well.