Department of Conservation
Te Papa Atawhai

DEPARTMENT OF CONSERVATION

Audit of DOC subtidal fish and invertebrate monitoring

TAPUTERANGA MARINE RESERVE

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Cover photo: Diver in typical habitat of Taputeranga Marine Reserve.
Photo V. Zintzen.

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Executive summary

This report details the main findings of an audit evaluating the biological subtidal monitoring of Taputeranga Marine Reserve by the Department of Conservation. Monitoring for the reserve began with the collection of baseline data from 1998-2000 prior to reserve establishment. Since establishment of the marine reserve in 2008, annual monitoring has been conducted in the summer for four consecutive years (2009-2013), focussing on common fish species, kina, pāua and rock lobsters. This audit identifies a number of strengths within the previous monitoring, including that the data collected to date are amenable to testing for a marine reserve effect, and an ongoing, strong, relationship between Victoria University of Wellington and the Department of Conservation since the late 90's that has guaranteed continuity in surveys, producing a unique data set in the New Zealand context.

The audit also considers the monitoring to date within the context of the National Monitoring Framework, which is under development as part of the Department Marine Ecological Integrity programme. The key deliverables for the programme are: (1) the development of marine components for the Department of Conservation's Inventory and Monitoring Toolbox, to ensure national standardisation of monitoring methodologies; (2) a reporting component, including marine reserve report cards and DOC Annual Report content; (3) the inclusion of marine reserve monitoring in business plan prescriptions; and (4) marine reserve data storage and management protocols.

Prior to the audit, a stock take of past monitoring at the reserve established the timeline of the important steps associated with the redaction of a monitoring plan, as well as compiled information on site selection, major data sources, data collection, data management, diver resources, funding, intellectual property and reporting to the public.

Specifically, the audit focussed on:

1. Scientifically reviewing the *annual* monitoring of fishes and invertebrates (yellow-foot and black-foot pāua, kina and rock lobster) prescribed by DOC. Major findings were:

    - The annual surveys carried out by DOC (2009-2013) have collected data that are comparable to the baseline data, thus, allowing robust statistical analysis of a reserve effect.
    - Strong collaboration between Victoria University of Wellington and DOC created a favourable environment to maintain ongoing monitoring of the reserve after its establishment.
    - Due to the high variability displayed in the counts of taxa using the underwater visual census method, the current design generally suffers from a relatively low statistical power to detect changes in species abundance and sizes associated with protection.
    - Improvements in sampling design are suggested for future monitoring, namely, sampling in consecutive year blocks, stratifying the sampling by depth and increasing the number of sites and transects.
    - Because the sampling depth currently used for both species of pāua does not reflect their habitat preferences, a new, shallower, sampling design is proposed for these two species.
    - Because of the uniqueness, at a national scale, of the monitoring data set collected so far, it is recommended to continue the data collection using

standardised methods until analyses show a stabilisation of the reserve effect. A timeline for collection is proposed.

2. Reviewing the monitoring objectives for the reserve. Major findings were:
   - Clear objectives for monitoring the reserve have not been defined.
   - Consistent with the National Monitoring Framework, DOC should develop a robust monitoring plan for Taputeranga Marine Reserve, involving the identification of monitoring objectives and clear statements of how survey outcomes relate to those objectives.

3. Reviewing current data quality assurance / quality control. Major findings were:
   - The technical proficiency of staff involved in the DOC monitoring was high.
   - A protocol for training divers in assessing *de visu* fish and rock lobster sizes needs to be developed as it is currently lacking.
   - A protocol for data entry and checking should be developed and implemented. Although a standard spreadsheet format is used to enter data from all surveys, there is no protocol for checking the data and, as a consequence, errors and inconsistencies have been found when reviewing the data.
   - Responsibilities in terms of data management of the Taputeranga Marine Reserve monitoring data within the Department deserve to be better defined. It is anticipated that the national scale framework for monitoring marine reserve (Marine Ecological Integrity Programme) will address this issue in the medium to longer term.

4. Reviewing intellectual property arrangements with other institutions involved with monitoring Taputeranga Marine Reserve. Major findings were:
   - Some essential baseline data collected by external parties are currently not held by DOC, preventing analyses of reserve effect using recently collected data.
   - A framework for collaboration and data exchange between DOC and Victoria University of Wellington, potentially in the form of Memorandum of Understanding, would streamline and further improve exchanges on Taputeranga Marine Reserve questions, especially regarding data ownership and sharing. Collaboration would also be improved by setting up regular meetings with external parties.

5. Reviewing the reporting procedure and reporting format for data collected during monitoring. Major findings were:
   - There is no communication or reporting plan in place to inform the public about monitoring in the reserve. The reporting has been inconsistent or deficient and nothing has been communicated since 2011.

- It is recommended to report on the status of the marine reserve at intervals related to the block design that will be implemented. The data generated by monitoring should also be integrated into the marine reserve report cards that are currently developed at a national scale under the Marine Ecological Integrity Programme.

The audit concludes with a series of short-term and medium-term recommendations for the future monitoring of the Taputeranga Marine Reserve. Further, some issues highlighted by this audit are also relevant at a national scale, and will be addressed by the continued development and implementation of the National Monitoring Framework built as part of the Marine Ecological Integrity Programme.

Taken together, the specific recommendations from this audit, combined with procedural changes associated with the implementation of the National Monitoring Framework will ensure that: (1) the monitoring design is appropriate for addressing well defined monitoring objectives; (2) ongoing monitoring of the Taputeranga Marine Reserve is incorporated into DOC’s business plan prescriptions; (3) monitoring outputs contribute to a national-scale assessment of trends and status of species and habitats within marine protected areas; (4) visibility of available monitoring data and reports are increased; and (5) data storage and management protocols for monitoring data are improved. Ultimately, this will ensure that future monitoring within the Taputeranga Marine Reserve is fit-for-purpose.

Table of Contents

EXECUTIVE SUMMARY **4**

LIST OF TABLES AND FIGURES **8**

1 INTRODUCTION **9**

1.1 CONTEXT FOR THE AUDIT 9
1.2 SCOPE OF THE AUDIT 9
1.3 INTERVIEWS 10

2 STOCK TAKE OF MONITORING AT TAPUTERANGA MARINE RESERVE **10**

2.1 THE TAPUTERANGA MARINE RESERVE 10
2.2 MAIN DOCUMENTS RELATED TO TAPUTERANGA MARINE RESERVE MONITORING 10
2.3 TAPUTERANGA MARINE RESERVE MONITORING PLAN SCOPING REPORT (WALLS, 2008B; WALLS, 2008A) 13
2.4 STATUS REPORT ON THE BIOLOGICAL AND PHYSICAL INFORMATION FOR WELLINGTON'S SOUTH COAST (VICTORIA UNIVERSITY OF WELLINGTON, EDDY ET AL., 2008) 16
2.5 TAPUTERANGA MARINE RESERVE MONITORING PLAN, WORKING DRAFT (SIMPSON, 2009) 17
2.6 TAPUTERANGA MARINE RESERVE ECOLOGICAL MONITORING PLAN, WORKING DRAFT (KETTLES, 2009) 20
2.7 VICTORIA UNIVERSITY OF WELLINGTON MEMORANDUM OF UNDERSTANDING 24
2.8 SURVEY AND ANALYSIS RECOMMENDATION FOR LONG TERM MONITORING REPORT (VICTORIA UNIVERSITY OF WELLINGTON, PANDE ET AL., 2011) 25
2.9 MAIN ACTIONS RELATED TO MONITORING OF TAPUTERANGA MARINE RESERVE 28

3 CONTEXT **38**

3.1 NATIONAL SCALE MONITORING FRAMEWORK FOR MARINE ENVIRONMENT 38
3.2 CURRENT MONITORING OBJECTIVES 38
3.3 METHODS IN PLACE TO MEET OBJECTIVES 39
3.4 ANTICIPATED OUTCOMES OF THE BIOLOGICAL MONITORING 42

4 AUDIT **42**

4.1 REVIEW OF CURRENT MONITORING OBJECTIVES 42
4.2 METHODS, STATISTICAL ANALYSIS AND INFERENCES 44
4.3 TECHNICAL PROFICIENCY OF STAFF INVOLVED IN MONITORING 62
4.4 QUALITY CONTROL PROCEDURES 63
4.5 DATA MANAGEMENT AND QUALITY 66
4.6 REPORTING 68
4.7 DATA SHARING WITH EXTERNAL PARTIES 68
4.8 LEVEL OF FUNDING 69

5 RECOMMENDATIONS **69**

6 CONCLUSIONS **71**

7 REFERENCES **74**

8 ANNEXES **80**

8.1 ANNEXE 1: MARINE ECOLOGICAL INTEGRITY PROGRAMME 81

List of tables and figures

Figures

Figure 1. Taputeranga Marine Reserve and Taputeranga Island, Wellington South Coast. 9
Figure 2. The Taputeranga Marine Reserve. Numbers indicate the current DOC monitoring sites. 12
Figure 3. Conceptual model for Taputeranga Marine Reserve as developed by Walls (2008a). 15
Figure 4. Map of the South Coast of Wellington extracted from Cole and Jackson (1989).. 33
Figure 5. Previous boundaries of Taputeranga Marine Reserve proposed in 1994, 1996 and 1999. 47
Figure 6. Depth of the DOC monitoring for fishes (A, B) and invertebrates (C, D) at Taputeranga Marine Reserve for the years 2010-2013. 59
Figure 7. Results of DOC diver calibration for measuring fish sizes underwater.. 64
Figure 8. Examples of raw datasheets collected by divers during the 2012 monitoring of fishes in Taputeranga Marine Reserve. 65

Tables

Table 1. Main documents associated with the biological monitoring of Taputeranga Marine Reserve. 10
Table 2. Design and methods presented in Taputeranga Marine Reserve Ecological Monitoring Plan draft report (Kettles, 2009). 23
Table 3. A chronological list of the references associated with research carried out in Taputeranga Marine Reserve. 26
Table 4. Timeline of decisional process for shaping a biological monitoring plan for Taputeranga Marine Reserve. 28
Table 5. Sites currently monitored within Taputeranga Marine Reserve 30
Table 6. Timeline of data collection as related to the monitoring of subtidal fish and invertebrates in Taputeranga Marine Reserve. 31
Table 7. Timeline of biological data collected in Taputeranga Marine Reserve for biological components other than subtidal fish and invertebrate data (as presented in **Table 6**). 32
Table 8. Highest qualification for divers who have participated in monitoring surveys organised by DOC in Taputeranga Marine Reserve. 34
Table 9. Timeline of data collected at Taputeranga Marine Reserve.. 35
Table 10. Number of days necessary to carry out the monitoring of fishes and invertebrates in Taputeranga Marine Reserve for the period 2010-2013. Number of diver days takes into account how many divers were present on each sampling day. Data obtained from inspecting dive logs and datasheets. Skipper time has to be added to the following figures. ... 36
Table 11. Survey costs to DOC as of 2010 for monitoring marine reserves around the country (DOCDM-670762). 37
Table 12. Timeline of discussion with Victoria University of Wellington about intellectual property of data collected for the monitoring of Taputeranga Marine Reserve. 37
Table 13. Timeline of public reporting on monitoring at Taputeranga Marine Reserve. 37
Table 14. Advantages and disadvantages of increasing the number of sites or number of replicates per site for monitoring marine reserves. 48
Table 15. Power to detect different proportional increases in abundance of fish species for different monitoring design choices in Taputeranga Marine Reserve. 52
Table 16. Power to detect different proportional increases in abundance of invertebrate species for different monitoring design choices in Taputeranga Marine Reserve. 53
Table 17. Power to detect different size increases in fish species for different monitoring design choices in Taputeranga Marine Reserve. 54
Table 18. Proposed yearly planning for future monitoring of fishes and invertebrates in three-year blocks at Taputeranga Marine Reserve. 55

1 Introduction

1.1 Context for the audit

The Taputeranga Marine Reserve (TMR, **Figure 1**) was created in August 2008. Monitoring for the reserve began with the collection of baseline data in 1998 prior to reserve establishment. Most recently, annual monitoring has been conducted in the summer for five consecutive years (2009-2013), and has primarily focussed on common fish species, kina (*Evechinus chloroticus*), pāua (*Haliotis australis* and *H. iris*) and rock lobster (*Jasus edwardsii*) at 8 sites – 3 sites within the marine reserve and 5 control sites outside the reserve. Annual monitoring was not conducted in 2014 due to logistical constraints faced by the Department. Due to this break in the continuity of the monitoring dataset and because the monitoring was to be reviewed after five years of implementation, the Wellington District Office and the Marine Ecosystems Team considers it worthwhile to complete an audit prior to continuation of the survey. The audit is primarily intended to evaluate if monitoring methodologies are fit-for-purpose and outputs are meeting monitoring objectives, in terms of the annual subtidal fish and invertebrate monitoring. The audit also reviews how data are managed and what the current reporting status is.

Figure 1. Taputeranga Marine Reserve and Taputeranga Island, Wellington South Coast.

1.2 Scope of the audit

The following elements were in the scope of this audit:

1. To scientifically review the *annual* monitoring of fishes and invertebrates prescribed by DOC at Taputeranga MR, and provide recommendations on future monitoring, taking into account budget and logistical constraints.
2. To review current data quality assurance / quality control, and provide recommendations to ensure adequate data management for future DOC and public uses.
3. To review intellectual property arrangements with other institutions involved with monitoring Taputeranga Marine Reserve (e.g., Victoria University of Wellington), including data sharing, data accessibility and ownership of monitoring data.
4. To review the reporting procedure and reporting format for data collected during monitoring and provide recommendations on future reporting.

1.3 INTERVIEWS

Key figures in the monitoring of the reserve have been selected and interviewed with specific questions related to their field of expertise:

- Prof J. Gardner (Victoria University of Wellington)
- Mr B. Tandy (Senior Ranger, DOC)
- Dr D. Freeman (Scientific Adviser, DOC)
- Dr T. Jones (ex Victoria University of Wellington)

2 Stock take of monitoring at Taputeranga Marine Reserve

The main information associated with the monitoring of TMR to date is compiled in this section. It gives a timeline of the decisional process and actions related to the monitoring. It also details the baseline data and current monitoring data that have been collected so far. Reference to reports and data are given if possible, as well as links to the internal document storage at the Department of Conservation (DOCDM, only accessible to DOC staff).

2.1 THE TAPUTERANGA MARINE RESERVE

As of 14 September 2014, there are 44 mainland marine reserves in New Zealand, of which TMR is the 25th largest. It is situated on Wellington's south coast bordering the Cook Strait and is 854.79 hectares in size. The reserve extends from Princess Bay to Quarry Bay (**Figure 2**). The formal application for the reserve was made in October 2000, and the reserve was gazetted in August 2008. In New Zealand, TMR has one of the most comprehensive bodies of data collected prior to the establishment of the reserve (i.e., baseline data *stricto sensu*) collected from sites both within the current reserve boundaries and from several control sites.

2.2 MAIN DOCUMENTS RELATED TO TAPUTERANGA MARINE RESERVE MONITORING

The main documents associated with the biological monitoring planning of TMR are presented in **Table 1**. Details of the content of those documents are given in the following sections. This content might not reflect actual monitoring as it stands now but is reported as faithfully as possible from the information available in these documents. An exhaustive list of research that has been carried out in relation to TMR can be found in **Table 3**.

Table 1. Main documents associated with the biological monitoring of Taputeranga Marine Reserve.

Reference	Description	Format and availability
Walls (2008b)	Scoping report identifying the components required for a monitoring plan of TMR	Internal report DOCDM-486336
Walls (2008a)	Conceptual model for TMR, i.e. a tool for visually depicting the marine reserve context and the major forces that are influencing its biodiversity.	Internal report DOCDM-447203 and diagram 447200
Eddy et al. (2008)	Summary of research carried out in TMR for the period 1960-2008	Public report (link) DOCDM- 1444008 with accompanying spreadsheet DOCDM- 1444009
Simpson (2009)	Based on the scoping report from Walls (2008b), development of a monitoring plan for the reserve by DOC Programme Manager Biodiversity. Report incomplete, still in draft form to date.	Internal report in draft form DOCDM-446374

Kettles (2009)	Draft plan for ecological monitoring of TMR	Internal report in draft form DOCDM-471950
DOC-VUW MoU (2011)	Memorandum of Understanding developed to assist the Department and School of Biological Sciences (Victoria University of Wellington - VUW) to work collaboratively on marine reserve research and monitoring, and to outline the roles, responsibilities and expectations of each party.	Internal document DOCDM-644906
Pande et al. (2011)	Recommendations for long-term monitoring of TMR based on power analysis of data simulated for the next 30 years	Internal report DOCDM-1444010

Figure 2. The Taputeranga Marine Reserve. Numbers indicate the current DOC monitoring sites. These have been previously sampled for fish and invertebrates by Pande (2001) (sites 2-9), Russell (2004) (sites 2-9), Eddy (2011) (sites 2-9) and Byfield (2013) (sites 1-9), according to the protocol set by Pande (2001). Note that Eddy (2011) could not sample Breaker Bay in 2008 and sampled a site at nearby Flax Bay instead.

2.3 TAPUTERANGA MARINE RESERVE MONITORING PLAN SCOPING REPORT (WALLS, 2008B; WALLS, 2008A)

Document: DOCDM-486336, with accompanying conceptual model (DOCDM-447203 and diagram 447200 – see **Figure 3**).

The scoping report identified the following essential steps in developing a monitoring plan for the reserve:

1. Define a goal and a series of general objectives for the reserve.

   The document proposes a goal statement which Walls says could be along the lines of:

   To protect and restore marine biodiversity and ecological functioning within the marine reserve to as near natural a state as possible, while allowing for the study and enjoyment of undisturbed marine life.

   The document proposes then that the monitoring plan should contain broad objectives for monitoring the marine reserve which stem from the conservation targets that will be identified in the conceptual model. It states that the general objectives could be along the lines of:

   - To detect and monitor temporal changes in the community composition and structure of the marine reserve, that may be attributed to its legal protection.
   - To measure the level of damage caused by human impacts on community composition and structure within the marine reserve
   - To contribute to the understanding of the ecology of the marine environment making up the Wellington Conservancy
   - To inform and educate the public about the benefits of marine reserves, including non-monetary and economic benefits.
2. Develop a conceptual model to define the conservation targets for the reserve. The model will indentify a number of threats to the reserve.
3. Develop a suite of monitoring programmes to address threats posed to the reserve.
4. Develop monitoring programmes for the following categories:
   - Biology
   - Water quality
   - Visitor and recreational impacts
   - Community-based monitoring
   - Environmental awareness and knowledge
   - Non-monetary benefits to society and local communities
   - Community infrastructure and business
   - Management effectiveness
   - Maori indicators
5. For each of the categories above, the monitoring plan should develop, except for Maori indicators:
   - Desired outcomes, specific monitoring objectives and indicators

- Background
- Baseline survey
- Monitoring
- Resources
- Data storage and presentation

6. Additional recommendations are given for the biological monitoring, which is the section of most interest to this audit:
   - The same sites used by Pande (2001) and Pande and Gardner (2009) should be selected for the baseline survey to enable comparisons of data collected between survey years.

     [Note from auditor: there is here a terminology confusion by the author for the concept of 'baseline monitoring'. She obviously refers to data collected right after the establishment of TMR (i.e. after 2008). However, the term 'baseline data' should be exclusively used to refer to data collected before reservation]
   - Additional sites should be included to ensure sufficient sites are well within the marine reserve. Currently only 2 of Pande's sites are sufficiently inside the reserve to avoid boundary effects (e.g. from fishing outside the reserve or boundary incursions) and this is unlikely to provide sufficient data to detect measurable changes to species populations and community structure over time. The control sites used by Pande (2001) should be used for the baseline and additional control sites should be considered.
   - The same depth zone used by Pande (2001) (6 – 15 m) should be surveyed to enable comparison of data collected over time.
   - The same species surveyed by Pande (2001) should be selected for the baseline survey using, where feasible, the same methods. However, it is noted by Eddy et al. (2008) that additional sampling effort will be required for detecting change in abundance of rock lobster, red moki and blue cod which occur in lower densities.
   - Rock lobsters should be measured for size. The method described by Freeman to estimate should be used.

     [Note from the auditor: reference to Freeman's method is not given]
   - Species size classes of fish should be recorded using the approach described by Freeman.
   - Any invasive species found in the survey transects should be identified and recorded.
   - The baseline survey should include deeper subtidal habitats, using remote census methods, such as BUV and ROV. The sites should be located over both deep rocky reef and soft sediment habitats as both habitat types occupy relatively large deeper water areas in the reserve.
7. Develop a five – ten year indicative work plan for the monitoring programmes

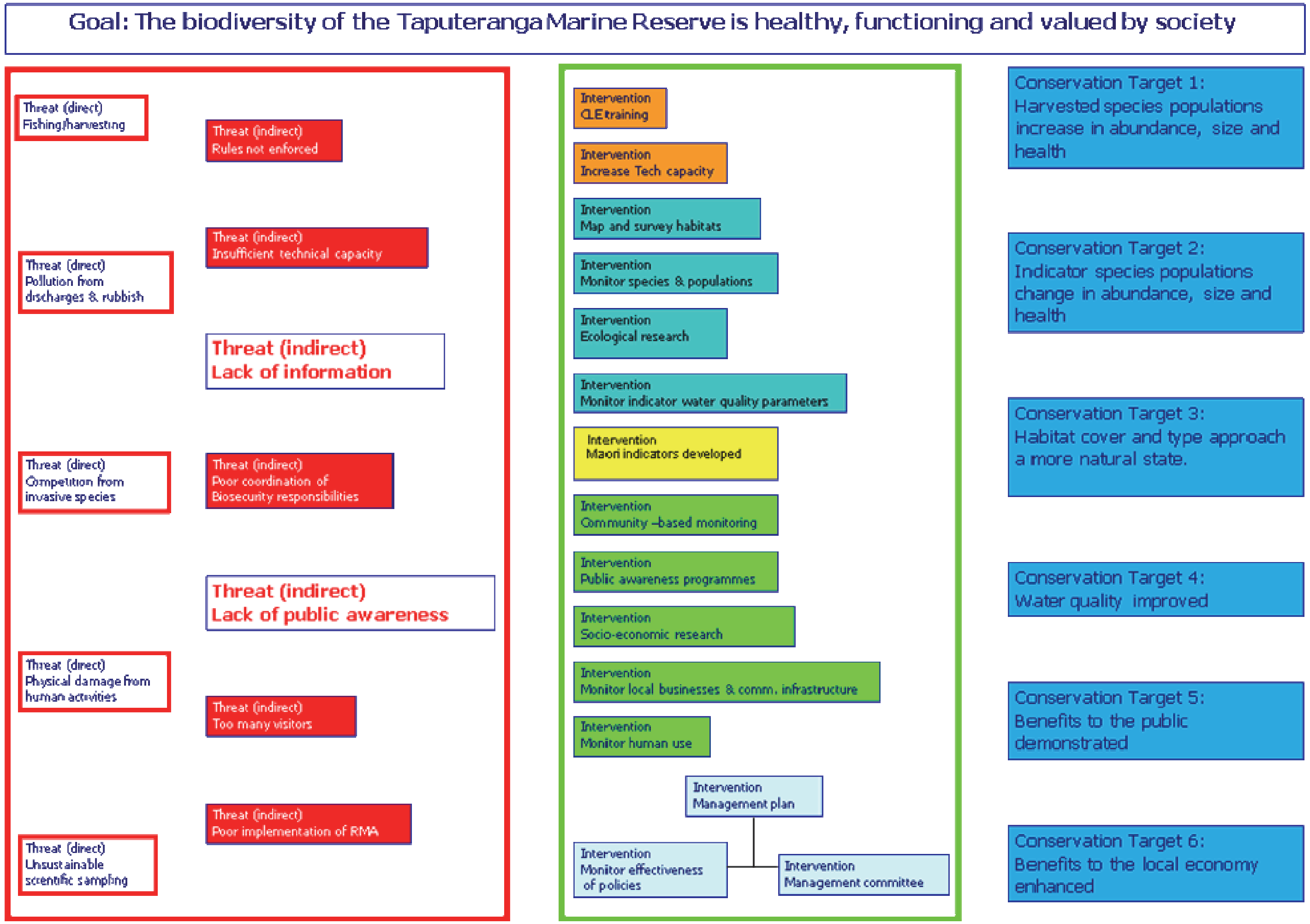

Figure 3. Conceptual model for Taputeranga Marine Reserve as developed by Walls (2008a). Reference documents: DOCDM-447203 and 447200.

2.4 Status report on the biological and physical information for Wellington's South Coast (Victoria University of Wellington, Eddy et al., 2008)

Document: DOCDM- 1444008

The aim of this report was to summarise the range of research that was relevant to the monitoring of TMR.

The report particularly highlights research from A. Pande's PhD thesis, which provides important baseline information for the new marine reserve. Consequently, most recommendations of this report for the species and sites to be surveyed, as well as suitable methodologies to be employed, follow Pande's work.

Eddy et al. (2008) mention the absence of an existing monitoring plan but propose that the following primary objectives for the marine reserve monitoring:

1. Detect any change in the size and abundance of key species of fish, macroinvertebrates, and macroalgae at marine reserve and non-marine reserve sites.
2. Detect any change in biological community structure at marine reserve and non-marine reserve sites.
3. Detect species that respond positively and negatively to marine reserve protection.

More specifically, the monitoring recommendations from Eddy et al. (2008) are:

- Survey method:
  - Use the same methods as Pande (2001) which represent the most comprehensive baseline of subtidal abundance and distribution for macroalgae, invertebrate and fishes of TMR.
  - Monitor fishes and invertebrates with Underwater Visual Census (UVC) for a given distance and width along a transect tape.
  - Regard as minimum the sampling effort carried out by Pande (2001) with respect to the number of replicates per survey.
- Species to survey:
  - Invertebrates: both species of pāua (*Haliotis iris* and *H. australis*) and rock lobster (*Jasus edwardsii*) be monitored as priority indicator species.
  - Fish: blue cod (*Parapercis colias*) and blue moki (*Latridopsis ciliaris*) be monitored as priority indicator species.
  - Secondary priority species to be monitored: kina (*Evechinus chloroticus*), spotty (*Notolabrus celidotus*) and banded wrasse (*Notolabrus fucicola*). Extend this list to the species sampled by Pande (2001) if resources allow: butterfish (*Odax pullus*), red moki (*Cheilodactylus spectabilis*), tarakihi (*Nemadactylus macropterus*), trevally (*Pseudocaranx dentex*), paddleweed (*Ecklonia radiata*), bladder kelp (*Macrocystis pyrifera*), narrow flapjack (*Carpophyllum maschalocarpum*) and *Lessonia variegata*.
  - Monitor the spread of the invasive seaweed species *Undaria pinnatifida*.
- Sampling interval:
  - Collect data every season if possible because seasonal variation in size and abundance were detected by Pande (2001).
  - If data cannot be collected at every season, focus sampling during summer months.

- Sites to sample:
  - Choose sites both inside and outside the marine reserve.
  - Use the same sites as Pande (2001), Russell (2004), Pande and Gardner (2009), Eddy (2011) and Byfield (2013) because this represents the largest baseline data set for macroalgae, invertebrate and fish species. Byfield (2013) recommends adding a ninth site (2nd Wash, see **Figure 2**) to balance the design and have three in the marine reserve, three on the east and three on the west of the marine reserve.
  - Take into account the existence of an environmental gradient running east (high in nutrients) to west (low in nutrients) of the study zone.
- Stratification by depth:
  - Conduct a review to determine if depth stratification is worth including.
  - Introducing depth stratification in the sampling design comes after community level analysis and the addition of the ninth site.

2.5 Taputeranga Marine Reserve monitoring plan, working draft (Simpson, 2009)

Document: DOCDM-446374

This working document outlines the monitoring plan for TMR. It is entirely based on Taputeranga Marine Reserve monitoring plan scoping report (Walls, 2008b). Since little information has been added compared to the Wall's document, only the differences between the two documents are highlighted here (see the section summarising the Walls' reports above for further information).

The additional information added in Simpson (2009) compared to Walls (2008b) is:

- A reserve description with map.
- A legislative context.
- A goal statement for TMR is proposed:

  The biodiversity of Taputeranga Marine Reserve is healthy, functioning and valued by society.
- Conservation targets are defined as the specific components of biodiversity at a project site that efforts to protect/manage are focussed on:
  - Harvested species populations increase in abundance, size and health.
  - Indicator species populations change in abundance, size and health.
  - Habitat cover and type approach a more natural state.
  - Water quality improves.
  - Benefits to the public are demonstrated.
  - Benefits to the local economy are enhanced.
- Threats to the reserve are identified as:
  - Direct threats:
    - ✓ Fishing/harvesting: This is a significant threat to the reserve's biodiversity. The term fishing/harvesting, as opposed to illegal fishing/harvesting, is used because the activity of fishing or harvesting in the marine reserve is prohibited (unless by permit).

- ✓ Pollution from discharges & rubbish: Water quality is affected by various discharges into the reserve from outfalls and non-point sources. Rubbish includes fishing discards and rubbish that has accumulated over the years prior to the reserve being established.
- ✓ Competition from invasive species: A significant threat to the reserve's biodiversity is the effect of competition by invasive or alien species with populations of indigenous species. The Asian kelp, *Undaria pinnatifida,* has become established already in some parts of the reserve whilst other potentially invasive species pose serious threats if they should become established there.
- ✓ Physical damage from human activities: Increasing numbers of visitors to the reserve can result in negative impacts on the biodiversity. Some activities may be more damaging than others.
- ✓ Unsustainable scientific sampling

- o Indirect threats:
  - ✓ Rules not enforced: If the rules of the reserve are not adequately enforced and illegal fishing or harvesting activities within the reserve occur unchecked, then the reserve's biodiversity will be compromised. This threat is linked to the threat "Insufficient technical capacity" below.
  - ✓ Insufficient technical capacity: This threat underpins a number of direct threats and links to several indirect threats. For example, "Rules not enforced" may lead to illegal fishing or harvesting activities in the marine reserve, because of a lack of technical capacity. This indirect threat should only be linked to other indirect threats where the link is significant.
  - ✓ Lack of information: This is a significant threat which underpins many of the direct threats to the conservation targets. DOC will not be able to measure or identify whether the conservation targets have been achieved without relevant information. Note that the interventions relating to monitoring and research will provide the information required to measure whether the conservation targets have been achieved.
  - ✓ Lack of public awareness: This is a significant threat which underpins several direct threats to the conservation targets, such as, "Fishing/harvesting", "Pollution from discharges and rubbish", "Competition from invasive species" (for example, boats visiting the reserve which have not been defouled and have invasive species on their hulls) and, "Physical damage from human activities".
  - ✓ Too many visitors: This threat underpins the direct threat of "Physical damage from human activities" and potentially underpins the direct threat of "Pollution from discharges and rubbish". There is a link to the indirect threat "Lack of public awareness".
  - ✓ Poor coordination of biosecurity responsibilities: This threat underpins the direct threat of "Competition from invasive species", with a linkage to the indirect threat "Lack of information".
  - ✓ Poor implementation of RMA: This threat underpins the direct threat "Pollution from discharges and rubbish". Any issues that might arise from infrastructure development, such as, discharges and runoff, are included in the direct threat "Pollution from discharges and rubbish".

- Fifteen ‘interventions’, or ‘actions’, are identified to reduce or mitigate threats to TMR:
    - Compliance and law enforcement training: This intervention addresses the indirect threat of “Rules not enforced” which in turn addresses the direct threat of “Fishing/harvesting” in the marine reserve. Adequate training will facilitate surveillance of the marine reserve and the necessary enforcement. Note that this intervention is linked to the interventions “Increase technical capacity” and “Lack of public awareness”.
    - Increase technical capacity: This intervention addresses the indirect threat of “Insufficient technical capacity” in the DOC, which in turn can lead to other indirect threats - “Rules not enforced, Lack of information”; and, “Lack of public awareness”.
    - Map and survey habitats: This intervention addresses the indirect threat “Lack of information”. A number of maps have been produced by NIWA that show bathymetry and seabed characteristics. These maps need to be refined and a benthic habitat map produced to assist with long term monitoring of habitat type and cover (note that work is currently underway by Victoria University of Wellington to ground truth the NIWA maps). This intervention is linked to the interventions “Monitor species and populations” and “Public awareness programmes”.
    - Monitor species and populations: Monitoring programmes will provide biological data on the state of the populations of key species in the marine reserve over time and will address the indirect threats of “Lack of information” and “Poor coordination of biosecurity responsibilities”. The programmes should include monitoring populations of previously harvested species, indicator species (e.g. species of interest, such as, sea horses) and populations of invasive species already established in the reserve. The programmes should include a baseline. Note that this intervention is linked to a number of other interventions - “Map and survey habitats, Ecological research, Community-based monitoring, Maori indicators developed, Monitor human use”; and, “Public awareness programmes”.
    - Ecological research: This intervention addresses the indirect threat of “Lack of information”. Relevant research should aim to advance understanding of the factors influencing ecosystems and community structure in this and other marine reserves. Note that this intervention is linked to a number of other interventions, including, “Monitor species and populations”; and potentially, “Maori indicators developed”.
    - Monitor indicator water quality parameters: This intervention addresses the indirect threats of “Poor Implementation of RMA, “Lack of information”, “Lack of public awareness”; and potentially, “Maori indicators developed”. Note that it is an offence under the Marine Reserve Act to pollute a marine reserve. The water quality monitoring programme should include a baseline survey.
    - Maori indicators developed: When developed, this intervention will address the indirect threat of “Lack of information”, as currently little is known about the tohu (signs or indicators) that could be used to measure the health of the marine reserve and its surrounds.
    - Community-based monitoring: This intervention addresses the indirect threat of “Lack of public awareness” and potentially, other indirect threats, depending on the monitoring that is undertaken. The monitoring programme should include a baseline survey. Note that this intervention may be linked to the intervention “Monitor species and populations” depending on the programme that is developed.

  - Public awareness programmes: This intervention addresses the indirect threat "Lack of public awareness". Note there are linkages to all the other interventions - an indication of the importance of this intervention.
  - Socio-economic research: Targeted research will assist with an in-depth understanding of the socio-economic factors relating to the marine reserve. This intervention addresses the indirect threat "Lack of information" and is linked to the interventions "Monitor local business and community infrastructure" and "Monitor human use".
  - Monitor local business and community infrastructure: This intervention addresses the indirect threat "Lack of information" and potentially, "Too many visitors". The monitoring programme should include a baseline survey. This intervention is linked to the interventions "Socio-economic research" and "Monitor human use".
  - Monitor human use: This intervention addresses the indirect threats "Lack of public awareness", "Too many visitors"; and, "Rules not enforced". The monitoring programme should include a baseline survey. There are linkages to other interventions, including the interventions "Monitor species and populations" and "Socio-economic research".
  - Management Plan: This intervention is central to effective management of Taputeranga Marine Reserve and ensuring that the objectives of the reserve are addressed. The management plan underpins many of the capacity, policy and awareness issues that have been identified as threats to the conservation targets. The plan sets out the strategic directions for the reserve's management. The presence or absence of a management plan is an important indicator of effective governance. Other interventions that are directly linked to the management plan are "Monitor effectiveness of policies" and "Management Committee".
  - Management committee: The existence of a management committee and its actions are an important indicator of the effectiveness of the reserve's governance. The committee also serves as a measure of the recognition that DOC, as manager of the marine reserve, gives to transparency of processes such as management planning and developing and enforcing rules and regulations.
  - Monitor effectiveness of policies: This intervention will assess the effectiveness of the management plan after a period of time that it has been in existence.

2.6 Taputeranga Marine Reserve ecological monitoring plan, working draft (Kettles, 2009)

Document: DOCDM-471950

This working document outlines the proposed biological monitoring for TMR and was developed by a working group. It was intended to form part of the global plan for monitoring TMR whose scope has been presented above (DOCDM-486336; Walls, 2008a,b), but was progressed little further (DOCDM-446374; Simpson, 2009).

The following was developed in this draft plan:

- Monitoring overall aim, objectives and programmes:
  - The objectives related to the monitoring of the reserve are not clearly stated. The report, however, states that "a robust monitoring programme will be implemented to determine the ecological effects of the proposed management regime. The monitoring programme will also seek to advance knowledge about interactions

between exploited species, non-harvested species, marine communities and habitats."

- The monitoring aim is expressed in the following research questions:

  (Question 1) Are the differences in human impacts inside *versus* outside the marine reserve reflected in the abundance, size, sex ratio and distribution of harvested species?

  (Question 2) Are the differences in human impacts inside *versus* outside the marine reserve reflected in the abundance, sex ratio and distribution of indicator species?

  (Question 3) Are the differences in human impacts inside *versus* outside the marine reserve reflected in the structure and composition of benthic and fish marine communities?

  (Question 4) Are the differences in human impacts inside *versus* outside the marine reserve reflected in the distribution of habitat types?

  (Question 5) What is the distribution and abundance of alien invasive species within the marine reserve?"

- Experimental design overview:
  - The proposed design and methods, described below, are based on past research in the reserve which was reviewed by Eddy et al. (2008).
  - The plan indicates that additional methods would be included to increase representativeness of sampling (e.g., extra depths) and to enable comparisons with work undertaken in neighbouring marine reserves and nationally. [Note from the auditor: it is not clear what those additional methods are compared to the review by Eddy et al. (2008). The document does not detail what they are.]
  - Underwater visual census (UVC) is the recommended method.
  - For quality assurance, divers with sufficient training and experience with UVC would be chosen.
  - Heavily harvested species are likely to be the first to show signs of recovery, therefore annual sampling is a priority for blue cod, blue moki, rock lobster and pāua, which are the most heavily-exploited taxa.
  - Monitoring will be undertaken in Feb-Apr, annually, for at least the first five years, after which the data will be reviewed and a decision made on sampling frequency. This season coincides with rock lobsters being resident in shallow waters.
  - Fish data will be initially collected seasonally to account for seasonal changes in species composition and abundance, as observed in the PhD work from Pande (2001) and Eddy (2011).
  - Given current resource constraints, this interim plan highlights the priority monitoring but also indicates monitoring that would be encouraged for other groups to take up (university or community groups).
- Monitoring sites:
  - The monitoring will be based on a treatment versus control experimental design framework (BACI). This design requires that pre- and post-gazettal monitoring is undertaken in treatment and control areas.

    - The design has the same number of sites inside and outside the marine reserve and there are control sites both east and west of the marine reserve to take into account an environmental gradient running in this direction.
    - In some cases, control or treatment sites have been placed near the reserve boundaries. The independence of the treatment and control sites will therefore not be ensured but this may allow some assessment of spill-over.
- This document proposed a series of methods (see **Table 2**) to answer the research questions 1 to 5 above. Most are based on UVC methods but a few others use video or isotopic techniques. Some of those methods also relate to other aspects of the biological monitoring of the reserve in addition to the annual surveys for fishes and invertebrates.

Table 2. Design and methods presented in Taputeranga Marine Reserve Ecological Monitoring Plan draft report (Kettles, 2009). Highlighted are methods directly related to the annual monitoring of fishes and invertebrates which are the focus of this audit.

Measure	Associated research question	Method	Frequency	Abundance	Size	Depth range	Number of sites	Number of replicates per site	Total sampling effort
1. Rock lobster density and population structure	Q1	UVC along 25 x 2 m transect	Annual, reviewed after 5 years	yes	yes	6-15 m	9	6	54
2. Black-footed and yellow footed pāua density and population structure	Q1	UVC along 25 x 2 m transect	Annual, reviewed after 5 years	yes	yes	6-15 m	9	6	54
3. Blue cod density and population structure	Q1	UVC along 25 x 2 m transect	Annual, reviewed after 5 years	yes	yes	6-15 m	9	9	81
4. Blue moki density and population structure	Q1	UVC along 25 x 2 m transect	Annual, reviewed after 5 years	yes	yes	6-15 m	9	9	81
5. Kina density and population structure	Q2	UVC along 25 x 2 m transect	Annual, reviewed after 5 years	yes	yes	6-15 m	9	6	54
6. Spotty density and population structure	Q2	UVC along 25 x 2 m transect	Annual, reviewed after 5 years	yes	Yes, in two size classes (<5cm or ≥5cm)	6-15 m	9	9	81
7. Banded wrasse density and population structure	Q2	UVC along 25 x 2 m transect	Annual, reviewed after 5 years	yes	Yes, in two size classes (<5cm or ≥5cm)	6-15 m	9	9	81
8. Kelp community (four species)	Q3 & 5	10x 0.25 m^2 quadrats every 3 m along 30 m transect	Annual, reviewed after 5 years	yes	no	Sampling not depth stratified[1]	9	3	270
9. Subtidal benthic community (macroalgae and invertebrates)	Q3 & 5	5x 1 m^2 quadrats haphazardly placed	Annual, reviewed after 5 years	yes	Yes, method unclear	4 ranges: <2 m, 4-6 m, 7-9 m, 10-12 m	6[2]	5[3]	30
10. Subtidal video transects	Q3 & 5	2x 50 m permanent video transects	Annual, reviewed after 5 years	?	?	?	9	2	18
11. Intertidal benthic community	Q3 & 5	Photographs of 5x 0.25 m^2 quadrats at three tidal heights. Sites permanently marked.	Annual, reviewed after 5 years	yes	Percent cover	3 subtidal heights	6	5	90
12. Reef fish communities	Q3 & 5	UVC along 25 x 2 m transect	Annual, reviewed after 5 years	yes	Yes, for: spotty, banded wrasse, butterfish, red moki, tarakihi and trevally	6-15 m	9	9	81
13. Food webs	Q3 & 5	Isotopes, currently under developments	Annual, reviewed after 5 years	yes	yes	?	?	?	?
14. Habitat mapping	Q4 & 5	Dropcam and aerial photography	Every 5 years	NA	NA	NA	NA	NA	NA

[1] See Shears and Babcock (2007) for rationale for not stratifying by depth for macroalgae. [2] Sites from Shears and Babcock (2007). [3] No proper replication.

2.7 VICTORIA UNIVERSITY OF WELLINGTON MEMORANDUM OF UNDERSTANDING

Document: DOCDM-644906

The purpose of this Memorandum of Understanding (MoU) was to assist the Department and the Centre for Marine Economic and Environmental Research (CMEER) within the School of Biological Sciences (SBS) at Victoria University of Wellington (VUW) to work collaboratively on marine reserve research and monitoring, as well as to outline the roles, responsibilities and expectations of each party. Although the document was finalised by both parties, it was never signed because the CMEER was disestablished and DOC restructured.

The following summarises the content of this MoU with regard to intellectual property and data sharing:

1. All intellectual property brought to the relationship by each Party will remain vested in that Party.
2. If a joint DOC/SBS project is undertaken then ownership and management of any intellectual property developed in relation to that project will be dealt with in the management agreement or other contractual arrangement relating to the project.
3. Should either Party contribute resources that are not related to a specific project the other must acknowledge their ownership and their contribution.
4. Use of logos or other corporate identification must be agreed by each Party on a case-by-case basis.
5. Standards for data management and protocols for data sharing will also be dealt with in the management agreement or other contractual arrangement relating to the project.
6. For all new monitoring data collected, a Data Agreement form will be filled out prior to the data being collected and such data will then form a part of this MOU.
7. All rights to the intellectual property in the Data and/or Information contributed by SBS that is ancillary to the monitoring programme and not under a contractual arrangement, remains its sole property or the property of a specified owner.
8. Should either Party wish to publicly present any Data and/or Information owned by the other Party (either solely or jointly) the Party wishing to present such Data and/or Information must consult with the other Party a minimum of 5 working days before presenting or publishing such information. Such consultation shall include agreement on how the data will be analysed and presented. The agreement of the other Party shall not be unreasonably withheld. For the avoidance of doubt, 'publicly present' shall include any publication, the submission of draft papers for external review, posters and oral presentation.
9. The Data cannot be sold, lent or given to any third party without prior written consent of the providing party owning the Data.
10. The user must acknowledge other Parties in any publication where their resources (time or funding) have been involved.
11. DOC and SBS will maintain their own data storage systems but will work towards having a common data standard in terms of the DOC template.

2.8 Survey and Analysis Recommendation for Long Term Monitoring Report (Victoria University of Wellington, Pande et al., 2011)

Document: DOCDM-1444010

This report aims to identify an accurate and effective means for future monitoring of TMR. It investigates different monitoring designs incorporating different levels of spatial and temporal replication. These differing monitoring designs were each modelled with data simulated over a 30-year time-period post reserve designation. It compares their effectiveness by examining the statistical power associated with each method for detecting changes in abundance of six common reef fish and four invertebrate species. In addition, the authors compare the effectiveness of these different sampling methodologies for detecting changes in the size distribution for the same fish and invertebrate species. They also compare reef fish assemblages using a Principal Components Analysis (PCA) and diversity indices (species richness, species evenness and Shannon Index), exploring site-specific or season-specific differences in fish assemblages.

The main findings of this study are:

- Power to detect biologically significant effects (doubling in abundance) is low, due to high variance in the data set in all aspects. This includes the variance in species abundance between sites and species being patchily distributed or forming aggregations.
- Greater power to detect changes in abundance was found for commonly and consistently recorded species (i.e., already abundant species), compared to those that have a lower abundance or are encountered in aggregations or display schooling behaviour.
- Power to detect changes in both size and abundance, however, was species-specific, with less abundant species benefitting most from an increase in sampling effort.
- In particular, power to detect changes in rock lobster and blue moki benefitted significantly from increased temporal replication.

If population abundances or sizes were to approach those observed at other marine reserves, as reported in the literature, the recommended sampling designs (with nine and eight transects for fish and invertebrates respectively) would achieve:

- Greater than 80% power to detect changes in abundance of banded wrasse, blue cod, blue moki, butterfish, rock lobster and kina.
- Greater than 80% power to detect changes in average size of blue moki, blue cod, butterfish and banded wrasse.
- 50% or greater power to detect changes in average size of black-foot pāua, yellow-foot pāua and kina.

From this analysis, Pande et al. (2011) make the following recommendations for monitoring the reserve:

- To maximise power to detect a change in species abundance and size due to reservation status, greater spatial and temporal replication, as well as a higher frequency of sampling periods is required than has historically been performed.
- Sample in two-year blocks with three years between blocks, or in three-year blocks with two years in between blocks if resources allow. One-year blocks give very low power and should be avoided.
- Keep the replication level for fish transects at nine.

- Increase the replication level for invertebrates from six to eight.
- Continue to collect size data as presently for all species. Size information for rock lobster should be collected during underwater visual census surveys from here onwards, using specific techniques for measuring size as described in previous studies.
- In addition to testing for changes in size distribution of observed species, compare abundances of individuals within certain size classes between pre- and post-reserve data, such as juvenile, sub-legal and legal size classes for targeted species.
- Test any future collected data using a mixed effects model with poisson/quasipoisson-based errors (GLMER). To perform a BACI test, fixed effects of Treatment, Period and Treatment:Period are required with a significant Treatment:Period effect indicating significant changes in reserve sites. Random effects of site, year and site:year should also be included to account for the variation apparent between levels of these.

Table 3. A chronological list of the references associated with research carried out in Taputeranga Marine Reserve.

Reference	Title
Wellman (1949)	Pillow lava at Red Rock Point, Wellington
Bradstock (1950)	A study of the marine spiny crayfish *Jasus lalandii* (Milne-Edwards): including accounts of autotomy and autospasy
Brodie (1953)	Stratigraphy and structure of the greywackes and argilites on the south coast of Wellington Peninsula
Beu and Climo (1960)	Marine mollusca of Wellington Harbour and approaches
Tunbridge (1961)	Special Fisheries Report - Paua Survey of Wellington Coast, September 1961
Sinclair (1963)	Studies on the Paua, *Haliotis iris* Martyn, in the Wellington District, 1945-1946
Ritchie (1970)	Notes on sea surface temperatures at the Victoria University Marine Laboratory, Island Bay, Cook Strait
Beu and Climo (1971)	Marine mollusca of Wellington Harbour and approaches
Hicks (1971a)	Check list and ecological notes on the fauna associated with some littoral corallinacean algae
Hicks (1971b)	Some littoral harpacticoid copepods, including five new species, from Wellington, New Zealand
Marshall (1973)	Lists of Mollusca collected at Island Bay
Ruck (1973)	Development of *Tripterygium capito* and *T. robustum* (Pisces: Tripterygiidae).
Anonymous (1973)	Coastal reserves investigation: Owhiro Bay-Karori Stream, Wellington
Anonymous (1974)	Notes on some shell collecting localities about Wellington
Carter and Heath (1975)	Role of mean circulation, tides, and waves in the transport of bottom sediment on the New Zealand continental shelf
Hicks (1976a)	Ecological studies on marine algal-dwelling Copepoda (Harpacticoida) from Wellington, New Zealand
Hicks (1976b)	*Neopeltopsis pectinipes*, a new genus and species of seaweed-dwelling copepod (Harpacticoida: Peltidiidae) from Wellington, New Zealand
Bowman et al. (1980)	M2 tidal effects in greater Cook Strait, New Zealand
Carter and Connell (1980)	Moa Point wastewater treatment plant and outfall study
Choat and Schiel (1982)	Patterns of distribution and abundance of large brown algae and invertebrate herbivores in subtidal regions of northern New Zealand
Dickie (1982)	Aspects of the ecology of three species of *Cellana* in the Wellington Area
Bowman et al. (1983)	Circulation and mixing in greater cook strait, new-zealand
Jones (1984)	Population ecology of the temperate reef fish *Pseudolabrus celidotus* Bloch & Schneider (Pisces: Labridae). I. Factors influencing recruitment
Quayle (1984)	Weather and sea conditions of Wellington Harbour and South Coast
Bradford et al. (1986)	Factors controlling summer phytoplankton production in greater Cook Strait, New Zealand
Livingston and Berben (1987)	East coast spawning of hoki confirmed
Cole and Jackson (1989)	Marine survey of Wellington's south coast
Hay (1990)	The distribution of *Macrocystis* (Phaeophyta: Laminariales) as a biological indicator of cool sea surface temperature, with special reference to New Zealand waters
Nunn (1991)	Some molluscs from the high littoral at Island Bay, Wellington
Burnet (1992)	Lyall Bay - yet again! A serious light-hearted look
Arron and Lewis (1993)	Wellington South Coast substrates; side scan sonographs of Southern Wellington Harbour. 1:15000.
Hay and Villouta (1993)	Seasonality of the adventive Asian kelp *Undaria pinnatifida* in New Zealand
Booth (1994)	*Jasus edwardsii* larval recruitment off the east coast of New Zealand
Willis and Roberts (1996)	Recolonisation and recruitment of fishes to intertidal rockpools at Wellington, New Zealand
Booth (1997)	Long-distance movements in *Jasus* spp. and their role in larval recruitment
Wear and Gardner (1998)	*Undaria pinnatifida* monitoring programme, Island Bay, Wellington South Coast. Final report

Reference	Title
	(September 1997 – June 1998)
Cotsilinis (1999)	Intertidal community responses following the decommissioning of a sewer outfall: Owhiro Bay, Wellington, December 1994 – March 1996
Eagar (1999)	Distribution of ostracoda around a coastal sewer outfall: a case study from Wellington, New Zealand
Wear and Gardner (1999)	*Undaria pinnatifida* monitoring programme, Island Bay, Wellington South Coast. Final report (July 1998 – June 1999).
Anonymous (2000)	South Coast Marine Reserve Coalition & Royal Forest and Bird Protection Society of New Zealand. Taputeranga Marine Reserve: Marine Reserve Application
Gardner (2000)	Where are the mussels on Cook Strait (New Zealand) shores? Low seston quality as a possible factor limiting multi-species distributions
Keith (2000)	Fish larvae of the Wellington Harbour and South Coast, 1997-1998
MacDiarmid and Stewart (2000)	Wellington South Coast Taiapure Project 1999 & 2000
Wear and Gardner (2000)	*Undaria pinnatifida* Monitoring Programme, Island Bay, Wellington South Coast. Final report (01 January 2000 – 30 June 2000).
Gardner and Thompson (2001)	Naturally low seston concentration and the net energy balance of the greenshell mussel (Perna canaliculus) at Island Bay, Cook Strait, New Zealand
Helson (2001)	An investigation into the absence of mussels (Perna canaliculus, Aulacomya maoriana & Mytilus galloprovincialis) from the south coast of Wellington, New Zealand
Pande (2001)	Evaluating biological change in New Zealand marine reserves
Gardner (2002)	Effects of seston variability on the clearance rate and absorption efficiency of the mussels Aulacomya maoriana, Mytilus galloprovincialis and Perna canaliculus from New Zealand
Christian (2003)	Growth, longevity & density of the adventive asian kelp Undaria Pinnatifida from the intertidal zone in Wellington Harbour and Cook Strait
Helson and Gardner (2004)	Contrasting patterns of mussel abundance at neighbouring sites: does recruitment limitation explain the absence of mussels on Cook Strait (New Zealand) shores?
Russell (2004)	Population biology of paua (Haliotis iris and Haliotis australis) along the Wellington South Coast, New Zealand
Stevens et al. (2004)	Broad scale habitat mapping of sandy beaches and river estuaries: Wellington Harbour and South Coast
Buchanan (2005)	The crustose brown algae of New Zealand: a taxonomic study
D'Archino and Nelson (2006)	Marine brown algae introduced to New Zealand waters: first record of Asperococcus ensiformis (Phaeophyta, Ectocarpales, Chordariaceae)
Schwarz et al. (2006)	Growth and reproductive phenology of the kelp Lessonia variegata in central New Zealand
Booth et al. (2007)	Settlement indices for 2003 for the red rock lobster (Jasus edwardsii), and investigations into correlations between settlement and subsequent stock abundance
Helson and Gardner (2007)	Variation in scope for growth: a test of food limitation among intertidal mussels
Helson et al. (2007)	Does differential particulate food supply explain the presence of mussels in Wellington Harbour (New Zealand) and their absence on neighbouring Cook Strait shores?
Shears and Babcock (2007)	Quantitative description of mainland New Zealand's shallow subtidal reef communities
Eddy et al. (2008)	A status report on the biological and physical information for Wellington's South Coast with monitoring recommendations for the Taputeranga Marine Reserve
Gardner and Bell (2008)	The Taputeranga Marine Reserve
Walls (2008b)	Taputeranga Marine Reserve monitoring plan – scoping report
Walls (2008a)	Taputeranga Marine Reserve conceptual model
Eddy and Gardner (2009)	Trophic modelling of a temperate marine ecosystem throughout marine reserve protection in New Zealand
Gordon (2009)	New bryozoan taxa from a new marine conservation area in New Zealand, with a checklist of Bryozoa from Greater Cook Strait
Harper et al. (2009)	New diatom taxa from the world's first marine Bioblitz held in New Zealand: Skeletomastus a new genus, Skeletomastus coelatus nov. comb. and Pleurosigma inscriptura a new species
Kettles (2009)	Draft report: Taputeranga Marine Reserve Ecological Monitoring Plan
Pande and Gardner (2009)	A baseline biological survey of the proposed Taputeranga Marine Reserve (Wellington, New Zealand): spatial and temporal variability along a natural environmental gradient
Smith (2009)	Environmental and life-history factors influencing juvenile demography of a temperate reef fish
Anonymous (2010)	Scientists probe the depths of Taputeranga Marine Reserve
Berman and Bell (2010)	Spatial variability of sponge assemblages on the Wellington South Coast, New Zealand
Perea-Blázquez et al. (2010)	Diet composition of two temperate calcareous sponges: Leucosolenia echinata and Leucetta sp. from the Wellington South Coast, New Zealand
Pérez-Matus (2010)	Effects of macroalgal habitats on the community and population structure of temperate reef fishes
Pérez-Matus and Shima (2010)	Disentangling the effects of macroalgae on the abundance of temperate reef fishes
Salinas de León (2010)	Patterns of connectivity and isolation in marine populations
Shears (2010)	Taputeranga Marine Reserve reef community monitoring 1999/2010 - summary report

Reference	Title
Aguirre and McNaught (2011)	Habitat modification affects recruitment of abalone in central New Zealand
Demello and Phillips (2011)	Variation in mussel and barnacle recruitment parallels a shift in intertidal community structure in the Cook Strait region of New Zealand
Eddy (2011)	Marine Reserves as Conservation and Management Tools: Implications for Coastal Resource Use
Mieszkowska and Lundquist (2011)	Biogeographical patterns in limpet abundance and assemblage composition in New Zealand
Pande et al. (2011)	Survey and analysis recommendations for a long term monitoring programme of the Taputeranga Marine Reserve
Perea-Blázquez (2011)	Interactions between sponges and the water column: nutrient utilisation and feeding by New Zealand subtidal sponges
Smith and Shima (2011)	Variation in the effects of larval history on juvenile performance of a temperate reef fish
Aguirre and McNaught (2012)	Ontogenetic variability in the habitat associations of Haliotis iris in central New Zealand
Berman (2012)	Patterns of temporal and spatial variability of sponge assemblages
Morelissen (2012)	Ecological effects of Undaria pinnatifida (Harvey) Suringar and nutrient-enrichment on intertidal assemblages in the Wellington region of New Zealand
Perea-Blazquez et al. (2012)	Estimates of particulate organic carbon flowing from the pelagic environment to the benthos through sponge assemblages
Perea-Blázquez et al. (2012)	Nutrient utilisation by shallow water temperate sponges in New Zealand
Tam (2012)	Intertidal community differences between the Cook Strait and Wellington Harbour
Aguirre and McNaught (2013)	Habitat complexity mediates predation of juvenile abalone by starfish
Byfield (2013)	Assessing ecological patterns in Wellington south coast's nearshore rocky-reef communities for resource conservation and management
Gardner (2013)	Bottom-up control of temperate rocky intertidal community structure: evidence from a transplant experiment
Perea-Blázquez et al. (2013a)	Low functional redundancy in sponges as a result of differential picoplankton use
Perea-Blázquez et al. (2013b)	Temporal variation in food utilisation by three species of temperate demosponge
Rojas Nazar (2013)	Economic, social and biological attributes of two marine reserves within New Zealand
Cárdenas et al. (2014)	Influence of environmental variation on symbiotic bacterial communities of two temperate sponges
Eddy (2014)	One hundred-fold difference between perceived and actual levels of marine protection in New Zealand
Eddy et al. (2014)	Lobsters as keystone: only in unfished ecosystems?
Jones (2014)	Designing accurate and effective means for marine ecosystem monitoring incorporating species distribution assessments
Díaz-Guisado (2014)	Effects of marine reserve protection on adjacent non-protected populations in New Zealand

2.9 Main actions related to monitoring of Taputeranga Marine Reserve

This section outlines the chronology of the main events in deciding monitoring objectives and design, data acquisition for monitoring purpose, intellectual property of collected data and reporting to the public. Only important milestones and only the data of interest to the annual monitoring of fish and invertebrates are reported here. A detailed timeline, including a full list of correspondence and documents, is available on DOCDM-1458379.

2.9.1 Development of the monitoring plan

The timeline of steps made in working on the monitoring plan for TMR, including its scope and objectives, are detailed in **Table 4**.

Table 4. Timeline of decisional process for shaping a biological monitoring plan for Taputeranga Marine Reserve.

Date	Description	Reference	DOCDM
14 Oct 2008	Hiring of Kathy Walls by the Pōneke Area Office of the Department of Conservation to develop a scoping document that identifies the components required for a monitoring plan and conceptual model of TMR.	None	DOCDM-359107

Dec 2008	Scoping report describing what the monitoring plan should contain and conceptual model for the reserve developed. Document saved in DOCDM on 24/09/2009. Actual date of final report availability unknown.	Walls (2008b); Walls (2008a)	DOCDM-486336 DOCDM-447203 DOCDM-447200
23 Oct 2008	Report finalised on past research in TMR with accompanying spreadsheet documenting research details for each reference.	Eddy et al. (2008)	DOCDM- 1444008 DOCDM- 1444009
16 Feb 2009	Memo of DOC Programme Manager (Biodiversity) to Area Manager recommending that: The Conservancy Technical Support Officer (Marine) be tasked to complete the monitoring plan developed by K. Walls or that a suitable contractor be sourced to undertake the task. The biological, visitor impacts, community infrastructure and business monitoring programmes be started on completion of the monitoring plan in point 1 above followed by the other topics as resources allow.	None	DOCDM-398927
25 May 2009	DOC Programme Manager (Biodiversity) schedules workshops to develop a comprehensive monitoring plan (incl. biological, Maori indicators, visitor, business, community monitoring). DOC Conservancy Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy appointed lead for the biological monitoring subgroup.	None	NA
18 Jun 2009	Based on the scoping report from K. Walls, development of an overarching plan for the monitoring of the reserve by the DOC Programme Manager (Biodiversity). Report incomplete, still in draft form to date.	Simpson (2009)	DOCDM-446374
Sep 2009	Release of the document 'Guidelines for monitoring reserves'	McCrone and Cooper (2009)	DOCDM-396171
Oct 2009	Working document 'ecological monitoring plan' produced by the DOC Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy, in agreement with decisions of Working Group on monitoring of the reserve (composed of Technical Support Officer (Marine), Technical Support Officer (Monitoring), Programme Manager (Biodiversity)). Report still in draft form. Monitoring objectives summarised by five research questions. Design and methods provided to answer those questions. Reviewed by Prof J. Gardner (VUW) & DOC Scientific Officer (Marine Ecology).	Kettles (2009)	DOCDM-471950
03 Nov 2009	Memo from DOC Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy to DOC Programme Manager (Biodiversity) asking for finalising the biological monitoring plan by 30 June 2011, after the power analysis of the baseline data be completed.	None	DOCDM-501117
28 Jun 2011	Report on power analysis of monitoring in TMR finalised by VUW. Report arranged by DOC Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy with support from DOC statistician.	Pande et al. (2011)	DOCDM-1444010
14 Dec 2011	Comments received on Taputeranga monitoring design from Friends of Taputeranga Marine Reserve. Review of these and plans for the 2011/12 survey by Prof J. Gardner (VUW) and DOC Scientific Officer (Marine Ecology) arranged by DOC Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy.	None	NA

After June 2011, no further action related to the elaboration of a TMR monitoring plan could be identified. The main factors responsible for this lack of progress can be attributed to the restructuring at DOC taking place April 2011-June 2012. It resulted in the reassignment of two staff, the Technical Support Officer (Marine) and Technical Support Officer (Monitoring) for Wellington Hawke's Bay Conservancy, to National Office roles on 1st July 2012.

2.9.2 Site selection for monitoring

The eight sites sampled by Pande (2001) during her PhD thesis, subsequently surveyed by Russell (2004), Eddy (2011), Byfield (2013), Rojas Nazar (2013) and Díaz-Guisado (2014), have been used by DOC during their 2010-2013 monitoring surveys of the reserve (see **Figure 2** and **Table 5** for details on the sites). The justifications for choosing those sites, as described in TMR Ecological Monitoring Plan (Kettles, 2009), relate to the importance of having a Before After Control Impact (BACI) study design for monitoring the effect of reservation. Since a BACI-type design is the most widely accepted way an effect of reservation can be proven, it is essential to monitor the reserve before it is established. The only sites that had been adequately monitored were those of Pande (2001) and colleagues.

A ninth site, 2nd Wash, located 1,160 m west of Sinclair Head, was added by Byfield (2013) to bring the number of western controls to three. This site was surveyed in 2009, 2010 and 2011 for invertebrates, but was then subsequently abandoned, as preliminary results showed this site to be very different from the others (DOCDM-853381).

Note that Eddy (2011) could not sample Breaker Bay in 2008 and sampled a site in the nearby Flax Bay instead. In 2009, he sampled both Breaker Bay and Flax Bay.

Table 5. Sites currently monitored within Taputeranga Marine Reserve

Site number	Site	Latitude	Longitude	Distance offshore (m)	Depth (m)
1*	2nd Wash	-41.35764	174.70032	128	8.5
2	Sinclair Head	-41.3623	174.71272	142	9.5
3	Red Rocks	-41.35963	174.72446	139	7.9
4	Yung Pen	-41.34995	174.75391	83	6.9
5	The Sirens	-41.34970	174.76410	95	7.3
6	Princess Bay	-41.34643	174.78822	60	6.1
7	Palmer Head	-41.34682	174.82183	174	9.2
8	Breaker Bay	-41.33289	174.83087	84	7.0
8bis†	Flax Bay	-41.33605	174.82565	121	5.8
9	Barrett Reef	-41.34059	174.83568	912	8.1

* Site only sampled for invertebrates in 2009, 2010 and 2011. † Site only sampled in 2008 and 2009 by Byfield (2013).

2.9.3 Data collection

Many research activities were conducted in the marine reserve prior to 2008. A full list was compiled by Eddy et al. (2008), which has been updated as a part of this audit for what happened after 2008 (**Table 3**). However, only a few studies are relevant as potential baselines to assess changes in subtidal fishes and invertebrates that are occurring since reservation. The list of these few studies is presented in **Table 6**. For completeness, the monitoring data relevant to other biological components of the reserve than fish and invertebrates is presented separately (**Table 7**).

Table 6. Timeline of data collection as related to the monitoring of subtidal fish and invertebrates in Taputeranga Marine Reserve.

Date	Description	Reference	DOCDM
Aug 1989	Ten sites were sampled (eight in the reserve, see **Figure 4**) qualitatively for important fish and invertebrates. The paucity of information in the document does not allow to precisely identifying the sampling site coordinates. The method used in this paper was not applied again in future studies. The document highlights low power to detect changes using this sampling technique. Raw data currently not held by DOC.	Cole and Jackson (1989)	DOCDM-1160956
Mar-Apr 1998	Jonathan Gardner & UK RAF divers surveyed Cole and Jackson (1989) sites (**Figure 4**) in Mar/Apr 1998 and then again in Mar/Apr 2001 for kina, pāua and reef fishes. Method not known. Data currently not held by DOC.	None	None
1998-2000	Eight sites (all current DOC monitoring sites, three in reserve) sampled for fish, invertebrates. Collection occurred at each season. PhD thesis. Data entered in spreadsheet but not in standard DOC format.	Pande (2001)	DOCDM-1160958 DOCDM-1246811 DOCDM-1246812 DOCDM-1246815
1999-2000	Eight sites (all current DOC monitoring sites, three in reserve) sampled for five fish species and rock lobster using standard UVC method. Data currently not held by DOC and report not found. Season of sampling unknown.	MacDiarmid and Stewart (2000)	None
Mar-Apr 2001	Prof Jonathan Gardner (VUW) & UK RAF divers surveyed Cole and Jackson (1989) sites (**Figure 4**) in Mar/Apr '98 and then again in Mar/Apr 2001 for kina, pāua and reef fishes. Method not known. Data currently not held by DOC.	None	None
2003	Eight sites sampled for *Haliotis iris* and *H. australis* along the South coast of Wellington. Counts, sizes, rates of growth, mortality, movement and recruitment studied. MSc thesis. Data currently not held by DOC.	Russell (2004)	DOCDM-1160955
2008-2010	Eight sites (all current DOC monitoring sites, three in reserve) sampled for fishes using standard UVC method. Collection occurred at each season. PhD thesis. Data currently not held by DOC.	Eddy (2011)	DOCDM-1160957
2008-2009	Nine sites (all current DOC monitoring sites, three in reserve) sampled for invertebrates using standard UVC method. Collection occurred at each season. PhD thesis partly funded by DOC. Data currently not held by DOC.	Byfield (2013)	DOCDM-1463004
25-31 Mar 2010	Invertebrate fieldwork survey, organised by Technical Support Officer (Marine) Wellington Hawke's Bay Conservancy. Fish survey not done because data acquired by T. Eddy (VUW) for his PhD. Data available to DOC in standard DOC format.	None	Sampling methods: DOCDM-518211 Invertebrate data: DOCDM-660922 Raw datasheets in NHE-07-05-22-02 WNP-1

14-16 Mar 2011	Fish and invertebrate fieldwork survey, organised by Technical Support Officer (Marine) Wellington Hawke's Bay Conservancy. Data available to DOC in standard DOC format.	None	Sampling methods: DOCDM-682679 Fish data: DOCDM-732988 Invertebrate data: DOCDM-732955 Raw datasheets in NHE-07-05-22-02 WNP-1
20 Feb – 02 Apr 2012	Fish and invertebrate fieldwork survey, organised by Area Office Marine Ranger mentored by Technical Support Officer (Marine) Wellington Hawke's Bay Conservancy. Data available to DOC in standard DOC format.	None	Sampling methods: DOCDM-853381 Fish data: DOCDM-1122927 Invertebrate data: DOCDM-1122929 Raw datasheets: DOCDM-935160 DOCDM-935143 DOCDM-935129
13 Mar - 02 Apr 2013	Fish and invertebrate fieldwork survey, organized by Area Office Marine Ranger. Incomplete fish data set, only four sites visited. Sampling method document not identified. Data available to DOC in standard DOC format.	None	Fish data: DOCDM-1188004 Invertebrate data: DOCDM-1169726 Raw datasheets scanned: DOCDM-1186546 DOCDM-1178787 DOCDM-1170316 DOCDM-1170317 DOCDM-1178818

Table 7. Timeline of biological data collected in Taputeranga Marine Reserve for biological components other than subtidal fish and invertebrate data (as presented in **Table 6**).

Date	Description	Reference	DOCDM
1995-1996	Four sites in the reserve sampled for intertidal communities following the decommission of sewer outfall at Owhiro Bay. MSc thesis. Thesis not accessible. Data currently not available to DOC.	Cotsilinis (1999)	None
Nov 1999	Six sites sampled (three inside, three outside reserve) for subtidal rocky reef communities. The study recorded habitat type, abundance of dominant species along transects, as well as abundance and cover of species in quadrats at four depths. Data currently not held by DOC.	Shears and Babcock (2007)	Report: DOCDM-1444006
2008-2009	Habitat mapping of the reserve using drop camera. Maps available in pdf form from PhD thesis, raw data currently not available to DOC. Data available to DOC in standard DOC format.	Byfield (2013)	Thesis: DOCDM-1463004

Aug 2009 - Jun 2011	Seasonal intertidal survey by T. Jones at nine sites. Data available to DOC but not in standard DOC format. Metadata not found, making interpretation of data difficult.	None	Data: DOCDM-1150021
Jan 2010	Re-sampling by Dr Nick Shears of the six sites sampled by Shears and Babcock (2007) in 1998 for subtidal rocky reef communities. The study recorded habitat type, abundance of dominant species along transects, as well as abundance and cover of species in quadrats at four depths. Data currently not held by DOC.	Shears (2010)	DOCDM-1444006

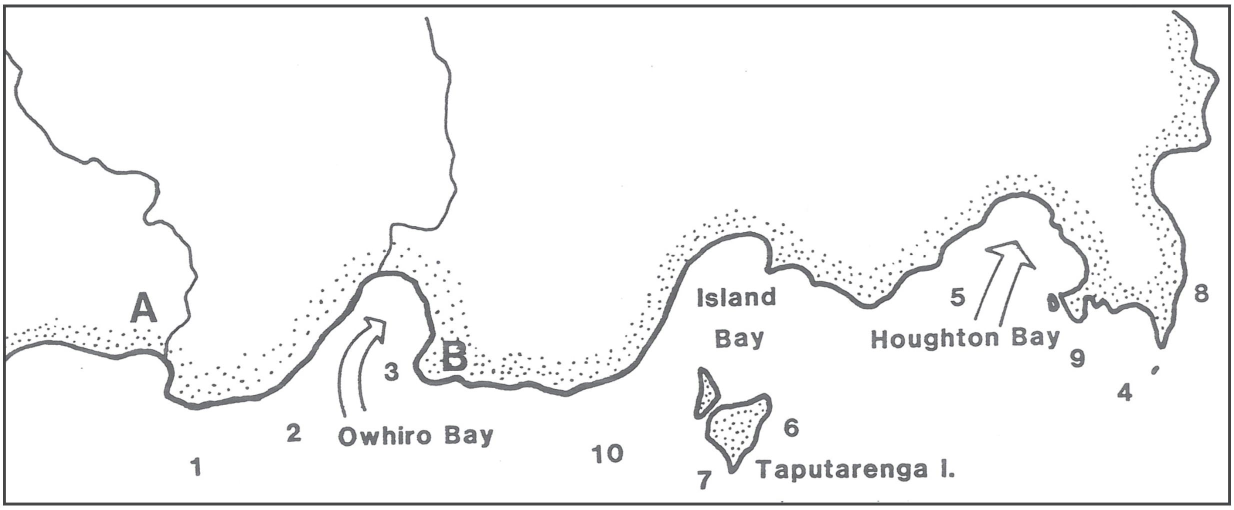

Figure 4. Map of the South Coast of Wellington extracted from Cole and Jackson (1989). Numbers indicate the sampling site locations of their survey of macroinvertebrates and fishes. The document contains no information on the GPS coordinates of the sites. Tentative comparison with current monitoring sites: Site 3 is at the Siren Rocks, Site 2 could be the Yung Pen (but this information is not stated in the document) and Site 9 could be Princess Bay (but not clearly stated in document).

2.9.4 Data management

Part of the baseline data collected pre-reservation as well as part of the monitoring data collected post-reservation is currently not available to DOC (see **Table 6** for details), mostly because those data sets have been sampled by researchers external to DOC. The reports, papers or theses resulting from those surveys do not provide a listing of raw data sets.

Dive plans, methodology and data spreadsheets have been saved in the DOC internal digital storage system (DOCDM) when DOC was in charge of the surveys. In some cases, scans of raw datasheets have been saved in DOCDM. In other cases, the original datasheets have been archived in the DOC record database as permanent records (see **Table 6**).

A standard format spreadsheet has been developed by DOC for marine protected area monitoring and research (MPAMAR, DOCDM-369096) with accompanying monitoring data storage guidelines (DOCDM-313806).

A central database (Excel spreadsheet) was used to collate the links to the files related to TMR (DOCDM-198437), including monitoring data. This file, however, lacks consistency in the recorded information. It also has not been updated with information from the 2013 survey.

2.9.5 Diver qualifications

The qualifications of divers who participated in DOC surveys in TMR are presented in **Table 8**. Divers are required to hold a current Certificate of Competency (CoC) for scientific diving that is administered by WorkSafe NZ (formerly administered by the Department of Labour). Divers who do not have a CoC are considered divers in training and required to dive under the direct supervision of a diver with a current CoC in scientific diving.

Table 8. Highest qualification for divers who have participated in monitoring surveys organised by DOC in Taputeranga Marine Reserve.

Year	**Number of divers**	**Highest qualification**		
		Certificate of Competency	PADI Dive Master or above	PADI Rescue
2010	7	5	0	2
2011	7	5	0	2
2012	6	6	0	0
2013	9	5	1	3

Table 9. Timeline of data collected at Taputeranga Marine Reserve. Data below the heavy black line were collected in addition to the annual fish and invertebrate surveys, and is presented for completeness. For fish, invertebrates and macroalgae, only the data collected during summer months using the standardised methods described in Pande (2001) are presented. Number of sites with number of replicates per site in brackets when that information is available. Fish: *Notolabrus fucicola*, *Parapercis colias*, *Latridopsis ciliaris*, *Odax pullus*, *Cheilodactylus spectabilis*, *Notolabrus celidotus*, *Nemadactylus macropterus* and *Pseudocaranx dentex*. Macroalgae: *Ecklonia radiata*, *Macrocystis pyrifera*, *Carpophyllum maschalocarpum*, *Lessonia variegata* and *Undaria pinnatifida*. Invertebrates: *Jasus edwardsii*, *Evechinus chloroticus*, *Haliotis australis* and *Haliotis iris*. Pictograms key: ⓿ Abundance of species estimated; ⇔ size of specimens measured; 🖫 data currently available to DOC.

	Baseline data														Post-reservation data					
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fish				8(9) ⓿⇔🖫	8(9) ⓿⇔🖫	8(9) ⓿⇔🖫								8(9) ⓿⇔	8(9) ⓿⇔	8(9) ⓿⇔	8(9) ⓿⇔🖫	8(6-9) ⓿⇔🖫	4?(6) ⓿⇔🖫	
Invertebrates				8(6) ⓿⇔🖫	8(6) ⓿⇔🖫	8(6) ⓿⇔🖫			8(?)[1] ⓿⇔					9(4) ⓿⇔	9(4) ⓿⇔	9(6) ⓿⇔🖫	8(6) ⓿⇔🖫	8(4-8) ⓿⇔🖫	8(8) ⓿⇔🖫	
Macroalgae				8(3) ⓿🖫	8(3) ⓿🖫	8(3) ⓿🖫								9(3) ⓿	9(3) ⓿	?	?	?	?	
Habitat mapping													Sampling period							
Intertidal communities	4 ⓿	4 ⓿													9 ⓿🖫	9 ⓿🖫	9 ⓿🖫			
Subtidal reef communities					6 ⓿											6 ⓿				

[1]*Haliotis iris* and *H. australis* only.

2.9.6 Annual surveys funding

Surveys post-reservation of TMR have not benefited from a dedicated budget to undertake annual monitoring. Although initially available, the budget for monitoring the reserve had to compete with other projects. A budget was available for operational work at the Area Office level and was divided into what was considered the year's priorities. For example, $18,000 was set aside for monitoring in 2008/09 by Area Office, but the need for this budget was finally questioned and cut. The result is that the Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy, in charge of organising the monitoring, had to secure money annually to carry out the survey.

The operational costs (lunches, dive allowance, tanks hire) associated with monitoring TMR have been $1,598 in 2010 and $2,235 in 2011, as reported by the dive organiser. Typical resource requirement leading to additional costs unaccounted for in these estimates include:

1. Salaries for DOC personnel involved in monitoring (divers and skipper). See **Table 10** for indications of the number of days necessary for monitoring surveys.
2. Dive and fieldwork allowances.
3. Depreciation of field gear (diving gear, boat, truck).
4. Boat maintenance.
5. Boat and truck fuel.
6. Boat storage on the South coast during fieldwork periods.

For the 2010-2013 period, the monitoring programme benefited from DOC diver's and skipper's time at no cost.

The number of days required to undertake annual sampling varied between 3 and 7, distributed over a period lasting from 4 to 63 days (**Table 10**).

Table 10. Number of days necessary to carry out the monitoring of fishes and invertebrates in Taputeranga Marine Reserve for the period 2010-2013. Number of diver days takes into account how many divers were present on each sampling day. Data obtained from inspecting dive logs and datasheets. Skipper time has to be added to the following figures.

Year	Survey target	Number of days at sea	Number of diver days	Sampling period
2010	Invertebrates	3	11	25-31/03 (7 days)
2011	Fish + Invertebrates	4	16	14-17/03 (4 days)
2012	Fish + Invertebrates	7	28	20/02-23/04 (63 days)
2013	Fish + Invertebrates	6	?	13/03-15/04 (41 days)

To estimate the cost of personnel, one can use the charge-out-rates for cost recovery in place at DOC (DOCDM-1095575). For tier 5 staff (most divers will belong to this tier), the cost recovery is $115+GST per hour. This would give personnel costs, including divers and skipper, equivalent to $12,888, $18,400 and $32,200 for 2010, 2011 and 2012, respectively.

The national average costs for monitoring marine reserves (as of 2010) are presented in **Table 11**.

Table 11. Survey costs to DOC as of 2010 for monitoring marine reserves around the country (DOCDM-670762).

Method	Average	Min	Max
Subtidal reef fish Underwater Visual Census (UVC)	$11,225	$3,750	$40,000
Subtidal reef rock lobster UVC	$18,050	$2,000	$50,000
Subtidal reef benthic communities and key species UVC	$11,300	$3,750	$50,000

2.9.7 Intellectual property

Because baseline data (i.e., data pre-dating the reserve establishment) were collected by VUW, and because future monitoring was envisaged to be achieved in partnership with the same institution, there has been ongoing discussion with DOC about the intellectual property of the data. The important steps of this relationship are presented in **Table 12**. The content of the proposed MoU between DOC and VUW is detailed on page 24. This agreement was never signed.

Table 12. Timeline of discussion with Victoria University of Wellington about intellectual property of data collected for the monitoring of Taputeranga Marine Reserve.

Date	Description	Reference	DOCDM
16 Oct 2009	Meeting between DOC Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy and VUW staff to develop Memorandum of Understanding (MoU) about data sharing.	None	DOCDM-498756
20 Aug 2010	Draft of MoU presented by DOC Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy to VUW staff.	None	DOCDM-629815
23 Aug 2011	VUW-DOC MoU finalised and agreed. Although the document was finalised by both parties, it was never signed because the CMEER was disestablished and DOC restructured.	None	DOCDM-644906

2.9.8 Reporting to the public

The major reporting actions to the public on TMR monitoring are presented in **Table 13**. Note that all DOC data and reports are publically available via the Official Information Act, but the following table describes the pro-active approaches to reporting.

Table 13. Timeline of public reporting on monitoring at Taputeranga Marine Reserve.

Date	Description	Reference	DOCDM
23 Oct 2008	Report on past research in TMR finalised and made publicly available.	Eddy et al. (2008) Link	DOCDM- 1444008 DOCDM- 1444009
11 Sep 2008	VUW internationally peer-reviewed paper published on baseline survey of TMR.	Pande and Gardner (2009) Link	None
11 May 2010	Area Office and DOC Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy arrange joint (DOC/VUW) press release on monitoring to date.	Link	None
June 2010	Article in Coastal News, the magazine of the New Zealand Coastal Society about monitoring at TMR	(Anonymous, 2010) Link	None
1 March 2011	Area Office and DOC Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy write joint (DOC/VUW) press release on Tyler Eddy's research (VUW).	Link	None

19 Aug 2011	DOC Technical Support Officer (Marine) for Wellington Hawke's Bay Conservancy arranges article on monitoring in "Blue Wellington" newsletter.	None	None
May 2013	Presentation to the Friends of Taputeranga Marine Reserve on the TMR monitoring and research. By J. Tam & D. Freeman	None	DOCDM-1205100

3 Context

3.1 NATIONAL SCALE MONITORING FRAMEWORK FOR MARINE ENVIRONMENT

The Department of Conservation's Marine Ecosystems Team has, since 2010/11, been developing a monitoring and reporting framework for New Zealand's marine environment, based on the concept of ecological integrity. In 2013, DOC entered a partnership with Air New Zealand to part-fund the research and development work behind the Marine Ecological Integrity Programme, as a component of PlanBlue (a programme of work within DOC's Science and Capability Group). The objective of this programme is to better understand the concept of ecological integrity in the marine environment, and then develop a suite of effective and comprehensive tools for monitoring and reporting on species and ecosystems, processes, functioning and health in the marine environment. A key area of research and development work is the identification and testing of indicators of ecological integrity for New Zealand's marine protected areas. The application of these indicators may extend well beyond these conservation areas, to include aspects such as the effects of protected species management and coastal use on ecological integrity. Further details on the Marine Ecological Integrity Programme can be found in Annexe 1.

The development of the Ecological Integrity Programme will allow DOC to fill many of the gaps identified in this audit. This monitoring will provide data, knowledge and insight to allow for national assessments of the status and trends in marine ecosystems.

3.2 CURRENT MONITORING OBJECTIVES

Robust monitoring plans involve the identification of monitoring objectives and clear statements of how survey outcomes relate to those objectives. Unfortunately, consistent clear monitoring objectives could not be identified from the stock take. Consequently, how survey outcomes relate to monitoring objectives could also not be identified.

For example, Walls (2008b), in her monitoring scoping report, defined a suite of general objectives which might be used in the monitoring plan, presented as:

1. To detect and monitor temporal changes in the community composition and structure of the marine reserve, that may be attributed to its legal protection.
2. To measure the level of damage caused by human impacts on community composition and structure within the marine reserve.
3. To contribute to the understanding of the ecology of the marine environment making up the Wellington Conservancy.
4. To inform and educate the public about the benefits of marine reserves, including non-monetary and economic benefits.

Alternatively, Eddy et al. (2008) identified the absence of an existing monitoring plan and proposed the following primary monitoring objectives:

1. Detect any change in the size and abundance of key species of fish, macro-invertebrates, and macroalgae at marine reserve and non-marine reserve sites.

2. Detect any change in biological community structure at marine reserve and non-marine reserve sites.
3. Detect species that respond positively and negatively to marine reserve protection.

Simpson (2009), in his draft Taputeranga Marine Reserve monitoring plan, stated a goal for TMR that was developed following discussions with DOC staff and reference to the draft Conservation Management Strategy (CMS) for the Wellington Conservancy:

The biodiversity of Taputeranga Marine Reserve is healthy, functioning and valued by society.

Simpson (2009) also defined conservation targets:

5. Harvested species populations increase in abundance, size and health.
6. Indicator species populations change in abundance, size and health.
7. Habitat cover and type approach a more natural state.
8. Water quality is improved.
9. Benefits to the public are demonstrated.
10. Benefits to the local economy are enhanced.

Finally, in her draft report on ecological monitoring of TMR, Kettles (2009) referred to overall monitoring aim and research questions rather than monitoring objectives. This approach was consistent with other Conservancy monitoring plans (e.g. DOCDM-438321):

> 'A robust monitoring programme will be implemented to determine the ecological effects of the proposed management regime. The monitoring programme will also seek to advance knowledge about interactions between exploited species, non-harvested species, marine communities and habitats. This aim is expressed in the following research questions:
>
> **Q1**. Are the differences in human impacts inside *versus* outside the marine reserve reflected in the abundance, size, sex ratio and distribution of harvested species?
>
> **Q2**. Are the differences in human impacts inside *versus* outside the marine reserve reflected in the abundance, sex ratio and distribution of indicator species?
>
> **Q3**. Are the differences in human impacts inside *versus* outside the marine reserve reflected in the structure and composition of benthic and fish marine communities?
>
> **Q4**. Are the differences in human impacts inside *versus* outside the marine reserve reflected in the distribution of habitat types?
>
> **Q5**. What is the distribution and abundance of alien invasive species within the marine reserve?'

The lack of clear monitoring objectives inhibits an evaluation of whether survey outcomes are meeting those objectives.

3.3 METHODS IN PLACE TO MEET OBJECTIVES

Although a series of consistent and clear monitoring objectives have not been identified by DOC for TMR monitoring, a series of sampling methods have been proposed (**Table 2**), and some have been implemented. In regard to the methods pertaining to the annual surveys for subtidal fishes and invertebrates, they follow the protocols used by Pande (2001) during her PhD thesis, with small adaptations. The rationale behind following these protocols was to be able to compare post-reserve establishment results with baseline surveys. Eddy (2011) sampled fish in the reserve in 2008, 2009 and 2010 during his PhD. Byfield (2013) sampled invertebrates in 2008 and 2009. Both followed Pande (2001)'s work. Once the two students finished the surveys associated with their PhD research, DOC started organising sampling in the reserve. Fish were surveyed in 2011, 2012 and 2013, although only four of the eight sites were sampled in 2013. Invertebrates were surveyed in 2010, 2011, 2012 and 2013. The following protocol was used, as described in the survey team briefing documents DOCDM-518211 (2010), DOCDM-682679 (2011) and DOCDM-853381 (2012). No reference to the methods used in 2013 could be found. Notes are made to highlight changes compared to Pande's (2001) protocol.

The methodologies are here reported as they are presented in those documents.

3.3.1 Fish

Focal species

1. The focus of the fish survey was on commercially important and commonly encountered demersal and pelagic species on the Wellington South Coast and around Kapiti Island (Pande, 2001). Small benthic species were not sampled. These species are:
    - *Odax pullus* (butterfish)
    - *Parapercis colias (blue cod)*
    - *Latridopsis ciliaris (blue moki)*
    - *Cheilodactylus spectabilis (red moki)*
    - *Notolabrus fucicola (banded wrasse)*
    - *Nemadactylus macropterus (tarakihi)*
    - *Pseudocaranx dentex* (trevally)
2. Other species were also encountered and their abundance/size noted:
    - *Peltorhamphus novaezeelandiae (common sole)*
    - *Arripis trutta (kahawai)*
    - *Meuschenia scaber (leatherjacket)*
    - *Aplodactylus arctidens (marblefish)*
    - *Forsterygion maryannae (oblique swimming triplefin)*
    - *Pseudolabrus miles (scarlet wrasse)*
    - *Notolabrus celidotus (spotty)*
    - *Latris lineata (trumpeter)*
    - *Scorpis lineolata (sweep)*
    - *Aldrichetta forsteri* (yellow eyed mullet)

Design

1. Nine sites: three in the Marine Reserve, three west of the western boundary, three east of the eastern boundary (see **Figure 2**). Those sites are the same as for the invertebrate survey. Note that nine sites were only sampled in 2009 and 2010. During Pande's thesis and after 2010, only eight sites were surveyed (three inside and five outside the reserve, the 2nd Wash site being excluded because it was shown to be too different from the other sites).
2. One depth stratum at each site: 6-15 m.
3. Nine transects, each 25 x 5 m =125 m^2 (2.5 m either side of the transect line).

4. The methodology mentions, without giving more information that 'Replicate transects do not need to be far apart, but must be placed along suitable rocky habitat for the species to be surveyed, i.e. not over sand'.
5. For 2011: Two transects could be run one after the other in a line but, if this is done, a 5 m buffer should be left between them.
6. For 2012: Three replicate transects could be run out in different directions from the tied tape if there is suitable reef habitat. The methodology mentions without giving more information that 'This will ensure independence'.

Method

1. A tape measure is attached to a kelp plant/rock. One diver runs the tape out to 30 m behind the diver who counts the fish (communication is by fin tugging). At the 5 m mark, the lead diver starts to count and estimates the size to the nearest 5 cm of any fish in a 25 m transect (in a 2.5 m arc both horizontally and vertically). Starting, and finishing depths are recorded. After retrieving the tape measure, the next transect starts from the same start point.
2. Three transects are normally run in a star from the same point. After completion of the three transects, it is not clear from the methodology documents what the divers do. The documents only mention that nine transects have to be collected in total. Interviews confirmed that divers could either surface or swim an undetermined distance and start sampling three transects in star from an anchor point again.
3. For 2012: A compass bearing is taken in the direction of the transect.
4. For 2012: As the tape was being wound in, species seen on the return swim were also recorded. It is not clear from the methodology documents if those fishes are part of the transect data or not. After inspecting the Excel spreadsheets with entered data, it appears that fishes observed on return are mentioned in the 'comments' field. It means that the fish recorded on return were differentiated from the transect data.
5. Prior to sampling, the divers are trained to estimate fish length using calibrated underwater fish cut-outs. The detailed protocol related to this training could not be identified. Data is presented on page 63.

3.3.2 Invertebrates: yellow-foot and black-foot pāua, kina and rock lobster

Design

1. Nine sites: three in the Marine Reserve, three west of the western boundary, three east of the eastern boundary (see **Figure 2**). Those sites are the same as for the fish survey. Note that nine sites were only sampled in 2009 and 2010. During Pande's thesis and after 2010, only eight sites were surveyed (three inside and five outside the reserve, 2nd Wash being excluded because it was shown to be too different from the other sites). In addition, Eddy (2011) could not sample Breaker Bay in 2008 and sampled a site in the nearby Flax Bay instead.
2. One depth stratum at each site: 6-15 m.
3. Six transects, each 25 x 2.0 m =50 m^2 (1 m on either side of the transect line).
4. The methodology mentions, without giving more information that 'Replicate transects do not need to be far apart, but must be placed along suitable rocky habitat for the species to be surveyed, i.e. not over sand'.

5. Two transects can also be run on from each other in a line but if this is done a 5 m buffer should be left between them.

Method

1. A tape measure is attached to a kelp plant/rock and the tape reeled out. On the return towards the start point, divers estimate the abundance and size of invertebrates on 25 x 2.0 m transect, each diver searching for taxa in 1 m each side of tape.
2. The search was intensive, looking in crevices with a torch and under boulders (but not turning boulders upside down).
3. The size of rock lobsters was visually estimated. Carapace (shell) length was estimated to the nearest 5 mm. Calibration using collected rock lobsters was undertaken at the beginning of survey.
4. The sex of rock lobsters was also recorded if possible.
5. Length of pāua at maximum shell length (using callipers) was measured to the nearest mm.
6. Test diameter of kina (excluding spines using callipers) was measured to the nearest mm.

3.4 Anticipated outcomes of the biological monitoring

Anticipated outcomes of the biological monitoring have not been identified in the monitoring plans for TMR. This is likely because: (i) there are no consistent monitoring objectives; and (ii) no clear statements have been made relating survey outcomes to monitoring objectives.

4 Audit

The following audit is based on all the documents detailed in the stock take section of this document as well as interviews with Prof J. Gardner (VUW), Dr D. Freeman (DOC), Dr T. Jones (ex-VUW), Mr B. Tandy (DOC), and discussion with Ms H. Kettles (DOC).

4.1 Review of current monitoring objectives

During the contextualisation phase (page 38), it has been highlighted that clear outcomes for monitoring TMR were not identified in the Taputeranga Marine Reserve monitoring scoping report (Walls, 2008b), the status report on the biological and physical information for Wellington's South coast (Eddy et al., 2008), the Taputeranga Marine Reserve Monitoring Plan (Simpson, 2009), or in the draft report on ecological monitoring of the Taputeranga Marine Reserve (Kettles, 2009). In these documents central to the monitoring of TMR, statements related to the concept of 'monitoring objectives' have been presented in different forms: Walls (2008b) describes general objectives, Eddy et al. (2008) primary objectives, Simpson (2009) conservation targets and Kettles (2009) research questions.

Although those propositions are not mutually exclusive and have some commonalities, none are fully satisfying in regards to formulating clear objectives for the annual monitoring for fishes and invertebrates. Further, the data collected so far do not fully address those objectives, aims or questions. Perhaps, Eddy et al. (2008) provide the best set of aims, stating that the primary objectives for the monitoring should be:

1. To detect any change in the size and abundance of key species of fish, macro-invertebrates, and macroalgae at marine reserve and non-marine reserve sites.

2. To detect any change in biological community structure at marine reserve and non-marine reserve sites.
3. To detect species that respond positively and negatively to marine reserve protection.

Objective 2 cannot be answered with the data collected because the sampling focussed on a limited number of focal species, and does not provide an overall assessment of community structure within TMR. This is especially true for invertebrates (only four species were collected). However, this statement should be tempered by the fact that, often in the scientific literature, focussing on a reduced set of species has been used as a surrogate for true community structure since it is virtually impossible to sample the entirety of a community. Other monitoring outlined in Kettles (2009) was designed to assess community composition (subtidal and intertidal rocky reefs). In addition, the objectives given by Walls (2008b) mostly focus on a community level analysis or on an assessment of the level of damage caused by human impacts. It is, however, anticipated that some of the changes observed within the reserve will not be directly due to a decrease of human impact but due to indirect factors affecting the ecology of coastal marine systems (e.g., trophic cascades). The same remark applies to the research questions presented by Kettles (2009) who focusses on comparisons between human impacts inside *versus* outside TMR. We would recommend avoiding using this terminology. The conservation targets given by Simpson (2009) also suffer from some pitfalls: (1) they exclusively focus on harvested or 'indicator' species [not defined] and (2) there is no reference to the temporal component of marine reserve establishment, i.e. this definition fails to take into consideration that, to show a reserve effect, we are to prove that the abundance of some species changes after reservation compared to site outside the reserve. It is always possible that species abundance increases both inside and outside the reserve after reservation, and that this would have nothing to do with the establishment of the reserve itself. Fish or invertebrate populations can change over time for many factors other than fishing pressure.

It is recommended that a robust monitoring plan involving the identification of monitoring objectives and clear statements of how survey outcomes relate to those objectives be developed. These objectives should be regularly reviewed as they might change over time.

It is also recommended that research questions be proposed as scientific hypotheses, focussing the monitoring task on rejecting the null hypothesis that TMR has no impact on the population of harvested or other important species.

Based on the data that has been collected so far, the following section of the audit will focus on determining if the methods in place are currently fit for purpose for the following hypotheses (proving a marine reserve effect would reject those hypotheses):

1. H_0: Relative to non-protected sites, the abundance and size of focal fish species do not increase within TMR following protection.
2. H_0: Relative to non-protected sites, the abundance and size of invertebrate species do not increase within TMR following protection.

Focal species refer here to species that are likely to respond quickly to an increase in protection, such as those that have been previously harvested.

Other hypotheses might need to be developed since it is impossible to predict how other species which have not been the focus of intense harvesting but are still potentially important for the ecology of the area (e.g., spotty or banded wrasse) will react to protection.

4.2 METHODS, STATISTICAL ANALYSIS AND INFERENCES

4.2.1 Initial remark

The methods that were selected in 1998 to start the monitoring of the future TMR were the best available at the time. They were also selected to allow standardisation with monitoring being conducted in other NZ marine reserves at the time, e.g. at the Cape Rodney to Okakari Point Marine Reserve (CROP). Standardisation was important to allow for meaningful comparison between sites at a national scale. In addition, nothing was known about how to monitor TMR at the time. To gain an understanding of the variability of the data collected in the reserve, a prerequisite for a robust monitoring programme, it was necessary to start a pilot monitoring study. This formed the PhD thesis of Pande (2001), which was co-funded by DOC and VUW. These data provided valuable information on what a potential monitoring design should look like. Due to the nature of data which is composed of many zeros (low abundance of fishes), it was realised that the power to detect changes in the reserve was low. However, adapting the monitoring design to be statistically more powerful could only be achieved by increasing the number of replicates and sites. The level of funding for monitoring was such at the time, and subsequently, that an increase in replication level could not be implemented. The consequence was that the initial monitoring design of Pande (2001) was kept in future monitoring surveys.

4.2.2 Site selection

For the monitoring of TMR, three sites have been selected inside the reserve and five outside; two to the west and three to the east (**Figure 2** and **Table 5**). A ninth site, 2nd Wash, was added to the west in 2009 and 2010. The 2nd Wash site was abandoned because it was deemed different to all the other sites, adding unnecessary variability to the resulting dataset. The original eight sites were surveyed by Pande (2001) during her PhD thesis. The same sites were also sampled repetitively by Russell (2004), Eddy (2011), Byfield (2013), Rojas Nazar (2013) and Díaz-Guisado (2014) during their PhD theses, producing a large baseline dataset. Note that Eddy (2011) could not sample Breaker Bay in 2008 and sampled a site in the nearby Flax Bay instead. He also sampled this site in 2009. Subsequent DOC surveys have not sampled Flax Bay. Note also that DOC did not survey fishes or invertebrates in 2009 and did not sample fishes in 2010, because it was done by Eddy (2011) and Byfield (2013).

The justification for the selection of sites inside and outside the marine reserve relates to the importance of having a Before-After-Control-Impact (BACI) study design for monitoring the effect of reservation (Kettles, 2009). A BACI design is the most widely accepted method for demonstrating an effect of reservation. The BACI concept examines the Before (pre-reservation baseline) and After (post-reservation) condition of the area, as well as to compare Control (non-reserve areas) and Impact sites (reserve areas). Before-After sampling determines how the restoration process changed the marine reserve through time from its historical condition. Control-Impact sampling allows effects to be discerned from natural variability, stochastic events and underlying trends in the larger area – for example, large-scale inter-annual recruitment variability may result in increased fish numbers within the reserve following establishment, and Control-Impact sampling will allow us to discern this from a reserve effect because recruitment will increase at sites both inside and outside the reserve.

It is important to understand that any change in the monitoring design which would add new sites not sampled before reservation faces the risk of being criticised for not proving a 'pure' reservation effect. For those new sites, comparisons would only be possible between the next sampling surveys to come (likely in the summer 2014/2015) and future ones, i.e. all the sampling surveys would happen after the actual establishment of TMR. It would then be possible to postulate that the effect we observe for those new sites, if any, would not be due to reservation, especially if the more noticeable changes occurred during the first years of reservation. To document this further, here is a description of the different options we have for analysis if new sites are added in 2014/15 to the current eight sites that have been sampled before and after reservation:

1. Sites could be pooled into reserve and non-reserve groups, assuming that sites are replicates of the factor 'Protection status'. In this case, increasing the number of sites could be beneficial to the power of the statistical test to detect changes occurring in the reserve, even if there is not any baseline data for them. However, this may not be reasonable in the context of TMR because of the high variability between sites both within and outside the reserve (Pande & Gardner, 2009; Pande et al., 2011). This variability originates from the environmental gradient running east to west in the area which means that the variation is particularly large between control sites in the east and the west, effectively splitting them in two groups.

2. Sites are not pooled into reserve and non-reserve groups. In this case, two different analyses should be made with the data:

    a. A BACI test using the eight sites previously sampled and for which a baseline data (i.e. data collected before 2008) is available. For this analysis, the new sites are of no use because they have no baseline data and, thus, they cannot be incorporated in the analysis. In this analysis, the Before of the BACI design represents the state of the system before TMR was established and the After the state after protection in 2008.

    b. A BACI test using the eight sites previously sampled and the new added sites. This test can only be made using data collected from the summer 2014/15 (assuming data will be collected in the coming year). The next block of sampling, which might be three years if our recommendations are adopted (2015-2017 for fishes, see **Table 18**), will represent the Before of the BACI analysis and the next blocks (2021-2023, then 2027-2029) will be the After. So, in practice, the new sites can only help detecting changes that are happening from now on.

3. Adding sites will be beneficial for having a better representation of the variability in the area and thus, results would be more general. In particular, average values for abundance and sizes inside and outside the reserve would be more meaningful. However, it can also introduce bias in the analysis if the new sites are (very) different in terms of sizes or abundance of taxa compared to previously sampled sites. For example, assume the average density for rock lobster inside and outside the reserve before preservation was 5.2 and 4.5 ind.100m^2. In 2014, the average density in the reserve has increased to 7.0 ind.100m^2. Now a new site which is particularly abundant with rock lobster is added inside the reserve. The increased abundance of rock lobster is not due to a pure reserve effect but simply because it offers more suitable habitat (and this type of habitat had not been sampled in the other reserve sites in the past). The density of lobster in the new site is 15 ind. 100m^2 and the resulting average for the reserve sites is 10.0 ind.100m^2. In this circumstance, it would not be recommended to make comparison between densities of rock lobster before and after reservation using this new site because it introduced a strong bias in the results.

It is noted that the sites currently sampled by DOC were also recommended by Eddy et al. (2008) in their status report on the biological and physical information for Wellington's South Coast.

We identified the following issues with the site selection:

1. The number of sites inside the reserve is low, especially knowing that there is a great deal of variability between sites both within and outside of TMR. Therefore, it is not recommended during the analyses to pool sites into 'control' or 'reserve' sites (Pande et al., 2011). This variability, among other factors, takes its origin from a gradient of increasing sediment concentration and nutrients running west to east (Gardner &

Thompson, 2001; Eddy et al., 2008; Pande & Gardner, 2009; Pande et al., 2011). In addition, several surveyed species exhibited significant temporal variation among years and seasons. Acknowledging that this spatial and temporal variation exists gives not only a baseline against which to compare future survey data, but also gives a measure of the variation through time that would be naturally expected and thus provides a background for separating marine reserve effects from natural variation (Jones, 2014).

The design is unbalanced; there isn't an equal number of replicates inside (3) and outside the reserve (5). Ideally, the design should be balanced and it was in 1997/98 when the first monitoring started. At the time Pande started her PhD in 1997/98, the proposed boundaries for TMR were different, extending from Palmer Head to Quarry gates (see 1996 limits in

2. **Figure 5**). It meant that the Princess Bay site would be well within the reserve, alleviating the edge effect mention above. It also meant that a fourth site, Palmer Head, was within the reserve, producing a balanced design with four sites inside the reserve and four outside. However, this site would have been located at the very edge of the reserve, with likely effects on fish abundance and sizes due to human pressure.

3. The site at Princess Bay is very close to the boundary of the reserve, which is likely to influence patterns of fish abundance and sizes due to intensive human pressure, mostly fishing, at the border of the reserve. It is possible that this site display features associated with a control site, or even a strongly impacted control site. If it was the case, this should be taken into account when doing statistical analysis related to the marine reserve effect and this site might have to be excluded from the reserve site pool if it is susceptible to strongly bias the results towards a no effect of the reserve.

   It is <u>recommended</u> that the Princess Bay site be treated cautiously when analysing the data. It will be important to carefully inspect the abundance and sizes of taxa at this site and compare them to neighbouring sites (both inside and outside the reserve) to detect if it has been strongly impacted by fishing.

4. The Yung Pen site takes its name from a shipwreck which might influence the distribution of species. Artificial structures have a well known aggregating effect on fish and other species (Bohnsack et al., 1991; Castro et al., 2001). However, from close inspection of the site selection and from interviews, it appears that the sampling is actually not conducted at the Yung Pen shipwreck itself, but in its vicinity. This should reduce the potential bias introduced by the presence of the shipwreck.

   It is <u>recommended</u> staying well off the shipwreck for future monitoring (at least 50 m).

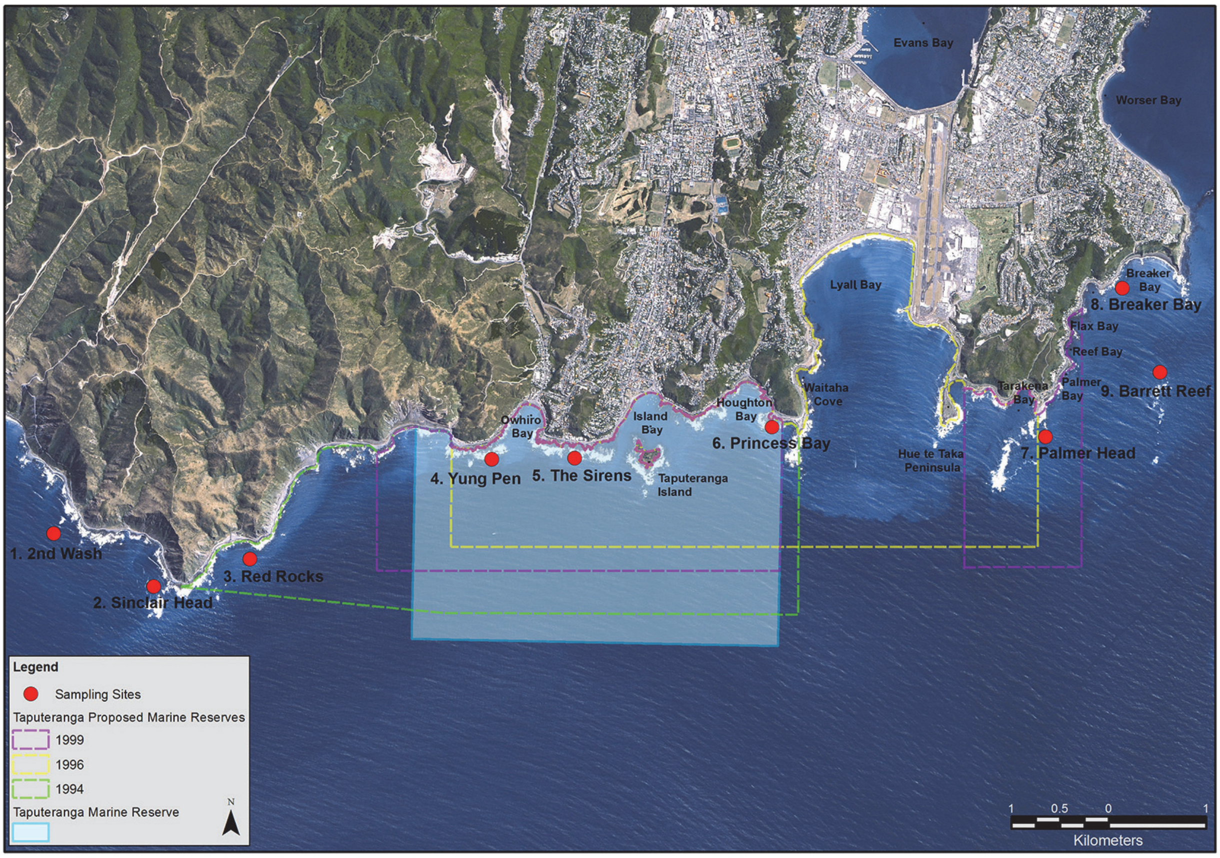

Figure 5. Previous boundaries of Taputeranga Marine Reserve proposed in 1994, 1996 and 1999.

We also acknowledge that the design of the monitoring protocol for the baseline survey was driven more by what could reasonably be achieved on a very limited budget and within a tight time frame (PhD thesis: 3 years), rather than by what was biologically desirable or statistically robust (Pande, 2008).

We think that the monitoring design would gain in power and precision if the number of sites inside the reserve was increased. Jones (2014), in his study on designing accurate and effective means for marine ecosystem monitoring, showed that a doubling of the number of sites is usually more beneficial to detect changes than a doubling of replicates within sites. Because there would not be any baseline data for those sites (i.e., no data collected before reservation), inference about changes in abundance and sizes of taxa could only be made between now and future monitoring dates for those new sites. It would mean that all the changes that have occurred during the first 6 years of preservation could not be documented for those sites. It would, of course, still be possible to use the currently monitored eight sites for comparison with baseline data, but an analysis including the eight current sites and the potential new sites could only assess if there are differences in size and abundance of taxa between the first date of sampling of the new sites and a future date. Additional sites would also mean an increased cost associated with the monitoring, which would be substantially higher than a cost increase due to sampling more transect replicates within a site. This is because adding sites inevitably increases the number of dives to achieve the monitoring plan, while adding transects could just mean adding diving bottom time. It takes more time to relocate the boat to a new site and dive it, than to stay at one site and achieve more transects.

A summary of the advantage and disadvantages of either increasing the number of sites or replicates is given in **Table 14**.

Table 14. Advantages and disadvantages of increasing the number of sites or number of replicates per site for monitoring marine reserves.

Option	Advantage	Disadvantage
Increase the number of sites, without increasing the level of replication within a site	• Increase of power to detect changes by sampling a wider fraction of the community of interest. • Increase the generality of the results, i.e. results are less likely to be biased towards the values exhibited by sites alone. • More efficient than increasing the number of transects to increase power.	• More time consuming and costly to monitor than increasing the number of transects. • Might be difficult to identify more sites with similar habitats to the already sampled sites. • If new sites fall outside the magnitude of variation observed at previous sites, this will introduce further variability in the data set. It would introduce bias in the comparisons between old and new data. • Additional cost associated with identifying the new sites (extra dives). • Comparisons incorporating new sites can only be made for future sampling dates.
Increase the number of transects per site, without increasing the number of sites	• Increase of power to detect changes. • Less time consuming and costly to monitor than increasing the number of sites, up to a point this does not require additional dives. • Continuity with the current BACI design.	• Less efficient than increasing the number of sites to increase power. • Could be difficult to sample more transects independently within a certain site.

It is recommended increasing the number of sites to monitor. Because, this comes with logistical and budget constraints, we propose selecting one or two new sites inside the reserve. If two sites were added in the reserve, it is also recommended adding a new control site to have a balanced design (five sites inside and five sites outside the reserve). Options to consider for new sites could be: South western or South eastern side of Taputeranga Island (inside TMR, but could difficult to access and relatively different to other typical sites due to their high exposure), Elsdon pipe (inside TMR) and between western side of the reserve boundary and Red Rocks, where the rocky outcrops are (outside TMR).

4.2.3 Power to detect changes

Power analysis is a statistical technique to determine the probability of detecting an effect, for example between treatments (inside *versus* outside a reserve) or times (before *versus* after preservation) (Pande et al., 2011; Jones, 2014). Power can then be used to compare competing monitoring designs in terms of their effectiveness for detecting a given effect. Pande et al. (2011) and Jones (2014) produced convincing power analyses on the baseline data of TMR, identifying which monitoring design would be most appropriate for detecting changes. See also the recent PhD work from Díaz-Guisado (2014) who is using different methods but obtaining similar results to Jones and Pande. Because these comprehensive power analyses have been undertaken and because there is consistency in the findings of these analyses, this audit uses their outputs to evaluate the power of current monitoring methodologies to detect change.

The power of a statistical test depends on four parameters:

1. The variability inherent to the dataset. The greater the variability, the lower the power to detect a change.
2. The effect size. The larger an effect (e.g., an increase in fish abundance), the more likely this effect will be apparent compared to other source of variability in the data set.

3. Type I error level (α). More relaxed α values increase the power of the analysis to detect a change.
4. The sample size. The greater the sample size, the greater the statistical power.

The studies of Pande et al. (2011) and Jones (2014) tested the power to detect change in the abundance and sizes of blue cod, blue moki, butterfish, banded wrasse, scarlet wrasse, spotty, kina, rock lobster, black-foot pāua and yellow-foot pāua for different monitoring designs. Specifically, the authors tested the effect of the following parameters:

1. The power to detect change in abundance when it increases 2, 4, 6 or 8-fold; or the power to detect an average increase in fish size of 5, 10, 15, 20, 25 or 30%. For both size and abundance analyses, the following were examined:
   - The number of transects per site (6, 9 or 12 for fish; 4, 6 or 8 for invertebrates).
   - The temporal block design. A temporal block consists of periods of years where sampling is performed in consecutive summers (1, 2, 3, 4 or 5 years in a row). The power of each of those data blocks to detect changes was compared with the baseline data. Different gaps with no sampling between years of sampling were also tested. Seven designs were tested:
     - ✓ Sample 2 years, no sampling for 2 years, Sample for 2 years,...
     - ✓ Sample 3 years, no sampling for 2 years, Sample for 3 years,...
     - ✓ Sample 2 years, no sampling for 3 years, Sample for 2 years,...
     - ✓ Sample 3 years, no sampling for 3 years, Sample for 3 years,...
     - ✓ Sample 3 years, no sampling for 5 years, Sample for 3 years,...
     - ✓ Sample 5 years, no sampling for 5 years, Sample for 5 years,...
     - ✓ Sample 1 year, no sampling for 4 years, Sample for 1 year,...
2. Unfortunately, Pande et al. (2011) and Jones (2014) could not test for change in power when varying the number of sites, which was restricted to three inside and five outside TMR. This is because no additional sites were available to include in the analysis as all the data available from the baseline surveys were used.

<u>Power analysis on TMR data revealed relatively low power, low precision and high potential bias of underwater visual census data for determining trends in reef fish abundance.</u>

Abundance

The main findings of the Pande et al. (2011) and Jones (2014) studies (see **Table 15** & **Table 16** for a synopsis of the abundance results) are:

1. Power to detect biologically significant effects (doubling in abundance) is low for most species, due to high variance within the data set. This includes the variance in species abundance between sites and species being patchily distributed or forming aggregations.
2. Greater power to detect changes in abundance was found for commonly and consistently recorded species (i.e., already abundant species), compared to those that have a lower abundance or are encountered in aggregations or display schooling behaviour.

3. Power to detect change in abundance was more increased by varying the replication over years than by increasing the number of replicates within a site. It means it is generally a better choice to collect data over 2, 3, 4 or 5 years and use this as a block, than achieving more transects over one sampling event (one year).
4. Power to detect changes in abundance (and size), however, was species-specific, with less abundant species benefitting most from an increase in sampling effort.
5. In particular, power to detect changes in rock lobster and blue moki benefitted significantly from increased temporal replication, i.e sampling over consecutive years in blocks.

If population abundances or sizes were to approach those observed at other marine reserves, as reported in the literature, a sampling design with nine transects for fishes and eight for invertebrates (as recommended in Pande et al., 2011) at each of the eight sites would achieve:

1. Greater than 80% power to detect changes in abundance of banded wrasse, blue cod, blue moki, butterfish, rock lobster and kina.
2. Greater than 80% power to detect changes in average size of blue moki, blue cod, butterfish and banded wrasse.
3. 50% or greater power to detect changes in average size of black-foot pāua, yellow-foot pāua and kina.

Size

Analyses of data for scarlet wrasse and spotty were not included because very little information on spotty sizes could be found and because scarlet wrasse baseline size data were already comparable to maximum average sizes observed at other MRs, meaning that power to detect changes in size of this magnitude would be low.

The main findings for this study are (see **Table 17** for a synopsis of the size results):

1. Power to detect significant effects is low. Sampling in three-year blocks has an average power of 56% (range: 42-89%) to detect a 20% increase in average size.
2. Higher replication designs had considerably higher power to detect changes in size than lower replication designs.
3. Power to detect changes in size was higher for the smaller fish species, i.e. banded wrasse and blue cod, than for butterfish and blue moki, which had higher variation in recorded sizes.
4. Three-year block designs had considerably higher power to detect changes in size than two-year block designs, which in turn had a higher power than the one-year block designs.

Following these power analyses, it is recommended the following adaptation to the sampling design be adopted:

1. Sample 12 transects per site for the fish survey, or 9 if logistically not feasible to do 12 transects.
2. Sample 8 transects per site for the invertebrate survey.
3. Sample in a three-year block design, with a period of three years between consecutive sampling events. In practice, this would mean that fishes would be annually surveyed for three summers, and that the following three summers would be used to survey invertebrates. The cycle would then start again with fishes. This design would allow for (1) decreasing the variability in the data set by collecting data in consecutive years and

(2) keeping a good temporal view of the changes occurring in the reserve with a data point every six years. Further, sampling either fishes or invertebrates in each three-year block would afford more time to sample additional sites and allow increased replication within sites.

Replication of transects within sites

Eddy et al. (2008) recommended that the number of replicates carried out by Pande (2001) be considered as a minimum sampling effort. Kina, pāua, spotty, banded wrasse and blue moki are present in low abundance and hence difficult to sample accurately.

Jones (2014) note that performing 12 transects for fishes was optimal in over 50% of cases (**Table 15** & **Table 17**). These analyses reveal that reducing the number of replicates below 12 would save little time and cost given that one dive would still be required per site. Thus, reducing the number of transects below 12 would have a detrimental effect on the benefits, in terms of power, precision and accuracy without a similar reduction in costs. Performing more than 12 transects would require two or more dives at each site and so would at least double the number of dives, approximately doubling the cost of performing the monitoring. As such, 16 transects were only optimal for the highest targets because this was the only monitoring design capable of reaching these goals and so was the optimal design by default. In addition, in many cases increasing the number of transects did not greatly increase precision, power or accuracy. In nearly all cases, increasing spatial replication by increasing the number of sites was more beneficial than increasing the replication within each site. The addition of extra sites will undoubtedly increase the cost of the project because adding additional sites means more dives and greater associated costs.

For invertebrates, Pande et al. (2011) recommend increasing the number of transects from six to eight due to the high spatial variability of abundance recorded for pāua, rock lobster and kina (see **Table 16**).

As already presented above, we follow Jones (2014), recommending that:

1. 12 transects be collected per site for fishes.
2. 8 transects be collected per site for invertebrates.

Table 15. Power to detect different proportional increases in abundance of fish species for different monitoring design choices in Taputeranga Marine Reserve. Data from baseline data sets are here compared to proportional increase of those baselines abundances (x2, x4, x6 and x8). The final four columns give a comparison of the difference in average power between different levels of spatial replication (differences averaged across temporal designs) and between different temporal designs (differences averaged across replication levels). Design 1: data generated from one year surveys are compared; Design 2: data are replicated over two consecutive years; Design 3: data are replicated over three consecutive years. Extracted from Jones (2014).

Species	Proportional increase in abundance	Power (α=0.05) Design 1 Transects			Design 2 Transects			Design 3 Transects			Power compared across replication		Power compared across designs	
		6	9	12	6	9	12	6	9	12	6-9	9-12	1-2	2-3
Banded wrasse	2	35	39	40	46	51	54	50	59	65	+6	+3	+12	+8
	4	88	93	94	99	99	100	100	100	100	+2	+1	+8	+1
	6	98	100	99	100	100	100	100	100	100	+1	0	+1	0
	8	100	100	100	100	100	100	100	100	100	0	0	0	0
Blue cod	2	3	3	3	5	4	4	7	4	5	-1	0	+1	+1
	4	10	11	11	25	27	26	33	39	39	+3	0	+15	+11
	6	20	22	23	44	49	54	61	66	71	+4	+4	+27	+17
	8	24	33	36	60	70	72	80	86	90	+8	+3	+36	+18
Blue moki	2	3	4	4	6	7	10	6	8	11	+1	+2	+4	+1
	4	17	18	24	42	49	55	61	68	73	+5	+6	+29	+19
	6	43	45	50	79	84	84	91	94	95	+3	+2	+36	+11
	8	62	65	67	94	96	97	99	100	100	+2	+1	+31	+4
Butterfish	2	12	11	13	13	14	16	17	18	14	0	0	+2	+2
	4	40	46	49	56	67	69	67	79	78	+10	+1	+19	+11
	6	62	67	71	84	87	91	93	97	97	+4	+3	+21	+8
	8	80	83	82	95	96	97	99	100	100	+2	0	+14	+4
Scarlet wrasse	2	10	10	8	16	18	16	21	20	21	0	-1	+7	+4
	4	40	39	40	68	73	75	84	88	90	+3	+2	+32	+15
	6	62	68	71	93	93	95	97	98	98	+2	+2	+27	+4
	8	75	81	82	98	98	99	100	100	100	+2	+1	+19	+2
Spotty	2	19	20	20	16	16	18	13	14	12	+1	0	-3	-4
	4	48	50	52	53	53	56	60	61	62	+1	+2	+4	+7
	6	64	68	68	75	78	80	84	85	87	+3	+1	+11	+8
	8	77	79	83	88	91	94	95	96	97	+2	+3	+11	+5

Table 16. Power to detect different proportional increases in abundance of invertebrate species for different monitoring design choices in Taputeranga Marine Reserve. Data from baseline data sets are here compared to proportional increase of those baselines abundances (x2, x4, x6 and x8). The final four columns give a comparison of the difference in average power between different levels of spatial replication (differences averaged across temporal designs) and between different temporal designs (differences averaged across replication levels). Design 1: data generated from one year surveys are compared; Design 2: data are replicated over two consecutive years; Design 3: data are replicated over three consecutive years. Extracted from Jones (2014).

Species	Proportional increase in abundance	Power (α=0.05)									Power compared across replication		Power compared across designs	
		Design 1 Transects			Design 2 Transects			Design 3 Transects						
		4	6	8	4	6	8	4	6	8	4-6	6-8	1-2	2-3
Black-foot pāua	2	8	8	7	9	7	6	9	6	7	-2	0	0	0
	4	22	22	23	32	32	33	37	41	42	+1	+1	+10	+8
	6	35	35	36	54	57	58	67	67	70	+1	+2	+21	+12
	8	45	46	51	71	73	76	82	87	86	+3	+2	+26	+12
Yellow-foot pāua	2	16	14	17	26	25	27	32	32	35	-1	+3	+10	+7
	4	42	44	44	73	74	74	87	88	90	+1	+1	+30	+15
	6	61	64	66	91	92	92	97	98	98	+2	+1	+28	+6
	8	76	76	78	98	98	98	100	100	100	0	+1	+21	+2
Kina	2	5	8	7	7	8	9	6	10	8	+3	-1	+1	0
	4	23	27	28	32	43	45	46	55	53	+8	0	+14	+11
	6	39	42	46	61	69	69	76	85	85	+7	+1	+24	+16
	8	57	59	62	79	82	85	92	94	96	+2	+3	+23	+12
Rock lobster	2	7	8	7	21	23	30	33	39	51	+3	+6	+17	+16
	4	30	40	41	72	82	87	90	96	97	+9	+2	+43	+14
	6	59	65	72	95	96	99	99	99	100	+2	+4	+31	+3
	8	71	84	89	98	100	100	100	100	100	+5	+2	+18	+1

Table 17. Power to detect different size increases in fish species for different monitoring design choices in Taputeranga Marine Reserve. Data from baseline data sets are here compared to percent increase of those baseline average sizes (5, 10, 15, 20, 25 and 30%). The final four columns give a comparison of the difference in average power between different levels of spatial replication (differences averaged across temporal designs) and between different temporal designs (differences averaged across replication levels). Design 1: data generated from one year surveys are compared; Design 2: data are replicated over two consecutive years; Design 3: data are replicated over three consecutive years. Adapted from Pande et al. (2011).

Species	Percent increase in size	Power (α=0.05)									Power compared across replication		Power compared across designs	
		Design 1 Transects			Design 2 Transects			Design 3 Transects						
		6	9	12	6	9	12	6	9	12	6-9	9-12	1-2	2-3
Banded wrasse	5	4	6	4	4	5	4	5	6	6	+1	-1	0	+1
	10	8	13	12	12	15	17	17	20	22	+4	+1	+4	+5
	15	18	24	27	29	36	42	38	46	52	+7	+5	+13	+10
	20	34	44	52	56	68	78	70	83	89	+12	+8	+24	+13
Blue cod	5	6	6	5	6	6	4	6	6	4	+0	-2	0	0
	10	8	10	13	12	15	15	14	19	19	+3	+1	+4	+3
	15	12	15	21	19	25	28	23	33	36	+6	+4	+8	+7
	20	17	21	29	27	37	42	34	48	53	+9	+6	+13	+10
	25	25	29	37	37	50	58	48	64	70	+11	+7	+18	+12
	30	36	42	46	52	65	75	67	79	87	+10	+7	+23	+14
Blue moki	5	3	3	3	4	3	3	3	3	3	0	0	0	0
	10	4	8	7	7	10	9	6	11	11	+4	-1	+2	+1
	15	7	12	13	12	18	19	14	22	24	+6	+1	+6	+4
	20	11	18	22	20	28	33	26	36	42	+8	+5	+10	+8
	25	18	25	33	32	40	51	43	54	63	+9	+9	+16	+12
	30	27	34	46	48	56	70	62	74	83	+9	+12	+22	+15
Butterfish	5	4	4	4	3	3	3	3	3	2	0	0	-1	0
	10	6	9	6	8	10	11	9	12	14	+3	0	+3	+2
	15	8	13	10	13	18	20	17	23	28	+5	+1	+7	+6
	20	12	18	17	20	26	31	26	34	42	+7	+4	+10	+8
	25	16	23	26	28	36	44	37	47	58	+8	+7	+14	+11
	30	22	29	38	38	48	60	51	63	75	+10	+11	+19	+14

4.2.4 Monitoring duration

In some cases, changes in marine reserves may not become apparent for 20 years or more following reserve establishment (Shears & Babcock, 2003). For example, changes in macroalgal abundance at CROP Marine Reserve were still being observed up to 25 years after reserve establishment due to the slow recovery of carnivorous species controlling grazers (Shears & Babcock, 2003). Between 1978 and 1996, benthic communities in the CROP Marine Reserve shifted from being dominated by sea urchins to being dominated by macroalgae. This was a result of a trophic cascade thought to be an indirect effect of increased predator abundance. Since 1996, densities of kina have continued to decline in shallow areas of the reserve (< 8 m), and all sites classified as urchin barrens in 1978 are now dominated by large brown algae. When interactions such as these occur, the expected time scale of monitoring is recommended to be twice the longevity of the longest lived species involved in order to truly assess that the reserve site has returned to a stable state (Cole, 2003).

It is recommended continuing the sampling of TMR so that a suitable time series of four points (composed of a block of three years of sampling) for both fishes and invertebrates be collected, after which data should be reviewed (see **Table 18** for a proposed timetable).

Table 18. Proposed yearly planning for future monitoring of fishes and invertebrates in three-year blocks at Taputeranga Marine Reserve. Block 1 for fishes and invertebrates has been already achieved.

	Summer months of																							
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Fish			**Block fish 1**					**Block fish 2**						**Block fish 3**						**Block fish 4**				
Invertebrates			**Block inv 1**								**Block inv 2**						**Block inv 3**						**Block inv 4**	

4.2.5 Best period of the year for monitoring

The DOC draft monitoring plan (Kettles, 2009) mentions that monitoring should occur seasonally (four times a year), following the protocol from Pande (2001), Eddy (2011) and Byfield (2013). However, the actual monitoring has only been conducted once a year, because of financial and logistical constraints.

DOC sampling has occurred during the summer months, specifically between 20 Feb and 15 Apr. Summer months were chosen because:

1. It is the most favourable season in terms of weather for accessing the dive sites.
2. Focussing the sampling effort in one season reduces variability in the data set. Pande (2001) collected her data seasonally and observed strong variability in abundances for some species between the different seasons.
3. Rock lobsters undertake seasonal migrations (McKoy, 1983; MacDiarmid, 1991; Kelly & MacDiarmid, 2003), and this phenomenon is well documented by commercial and recreational fishers. Note, however, that this was not observed for the South Coast by Pande and Gardner (2009). This species should be more abundant in the shallow waters surveyed during the summer months.

It is recommended continuing to sample TMR during summer months. Although it is scientifically desirable to obtain seasonal data, it would logistically not be feasible (cost and dive time) and depending on monitoring objectives, may not be as important as obtaining robust data for a single season.

4.2.6 Sampling method

Underwater visual census (UVC) is currently used to monitor both fish and invertebrates in TMR. The protocol follows Pande (2001), which is essential for consistency of data collection. From interviews and inspection of protocol documents in the DOCDM system, the surveys organised by DOC have likely followed Pande (2001)'s protocol. Only for the 2013 surveys, a written, documented, protocol is lacking.

We noted that the methods presented in Kettles (2009) (see **Table 2**) did not always match with what has been actually done during monitoring surveys. Discrepancies in depth range, number of sites and number of replicates exist between the draft monitoring plan and actual monitoring as it has been achieved.

A series of issues related to the current UVC methodology have been identified:

1. The high variability and over-dispersed nature (many zeros in data set) of the fish and invertebrate data collected with UVC lead to low power of the statistical analysis to detect effects due to reservation.

Jones (2014) mentions that UVC methodologies are used extensively in marine studies but that there have been few studies examining the effectiveness (in terms of accuracy and precision) of these studies for determining long-term trends in fish abundance. Data collected by UVC techniques are often characterised by high variability and low precision due to the often over-dispersed nature of the data (Brock, 1982; Samoilys & Carlos, 2000; Willis et al., 2003; Pande & Gardner, 2009). The data collected so far in TMR are no exception (Pande et al., 2011). Compared to *in situ* visual census methods, the use of video reduces inter-observer variability, improves definition of the sample unit area and provides a permanent record of the assemblage that can be validated where required or independently re-analysed (Langlois et al., 2010; Gardner & Struthers, 2013). Units with stereo capability increase accuracy of fish length estimates. Forward facing stereo-baited remote underwater video techniques (stereo-BRUV) generally obtain estimates of assemblage metrics with less variance, resulting in greater power to detect spatial and temporal changes in the fish assemblage metrics (Langlois et al., 2010; Zintzen et al., 2012). BRUVS also offer the possibility to sample deeper habitats that are hard to survey by divers (Zintzen et al., 2012). DOC is currently using a non-stereo downward facing system (BUV) which provides an easy and cheap alternative to more complicated stereo-BRUV.

It is <u>recommended</u> investigating the use of DOC BUV and/or stereo-BRUV for monitoring fishes in TMR, as already started by Díaz-Guisado (2014) during her PhD. DOC BUV/BRUVS could be used in deeper habitats not sampled yet in the reserve. Expertise and gear is currently locally available at Te Papa for stereo-BRUV (Zintzen et al., 2012). However, we do not think that this should be done instead of UVC, but rather to complement it. Although video could be a methodology providing increased power to detect changes in the reserve, it might come with its own issues, such as competitive exclusion around the bait, selectivity towards carnivorous species, low attraction of herbivorous species (e.g. butterfish, see Díaz-Guisado (2014) for example) and additional post-processing costs.

2. Sampling in a star pattern with three arms (the transects) and with the same start for each transect, has been used. This method introduces two potential problems:

    a. All transects achieved within a site are not truly independent from each other. This method violates the assumption of replicates being randomly allocated, with potential consequences on the sphere of inference that can be made when statistically analyzing the data. It is, however, hard to estimate if this non-independence would have a strong influence on the results. We are not convinced that moving a transect a few meters further, instead of starting from the same point, would significantly reduce the independence issue to justify the additional time (and likely cost) it would incur. Even when moving 10 or 15 m between transects, which would be possible, the independence of replicates could be compromised because of the diver's presence which can attract or deter specimens. Unfortunately, this is an intrinsic problem associated with the UVC method.

       Combining the results from the three 'star' transects into one would not solve the independence issue since to do this, all three transects would need to be also considered independent. It is not by pooling them that you resolve the issue of independence. It would simply add a level of replication at the station level. It is <u>not recommended</u> to do so because it would drastically reduce the number of replicates at the site level, hence the power of our tests to detect changes.

b. This method encourages a wider depth range to be incorporated into the data, which increases the variance in the data set due to species preferences in depth distribution. If sampling is achieved in three directions from a single point along a slope, one increases the likelihood of sampling towards the shallow and towards the deep at this station. However, it would be possible to decrease the depth range of the transects by not doing a star transects but by having divers moving at least 25 m along an isobath between each transects. It is likely that this would take significantly more time than the star transects.

It is recommended moving away from sampling in star design, and rather sampling following a more conventional sampling methodology using a buffer between consecutive transects that follow depth contours.

3. There is no documentation of a clear standardised procedure for reducing the variability of the habitats to be sampled during a dive. Different habitats, like rocky reef or cobbles, could potentially be sampled during a single transect. This would add uncontrolled variability in the data set since habitat will influence the distribution and abundance of the observed species. However, interviews with VUW staff highlighted that, during surveys, the scientists tried to keep the inter-variability between transects as constant as possible. The sampled habitat was rocky reef and transects that contain non-suitable habitat were either not swum at all (if it was obvious at the start) or discarded later. A transect was considered acceptable if less then 10% was covered with other habitat type than rocky reef. The methodology used during DOC surveys (see DOCDM-682679 for an example) mentions the following: '*Replicate transects need not be great distances apart but must be placed along suitable rocky habitat for the species to be surveyed i.e. do not place over sand.*' This means that DOC has targeted rocky habitats during their surveys, information which was confirmed during interviews. In their encoded data sets, DOC entered 'Rocky reef dominated by mixed algae' in the field 'Site habitat type' for all data (see DOCDM-1122927 for example).

   Habitat type classification could also be used as a covariate to decrease some of the variability in the data set. This would likely increase the chance of observing an effect of abundance or size increase through time. We acknowledge, however, that recording habitat type can be more difficult if swimming above different habitat types. In this case, the percentage of each habitat should be recorded.

   It is recommended that habitat type be standardised as much as possible to 'rocky reef' and that habitat type be recorded for each transect. Habitat data should be routinely recorded, including substrate type and % algal cover and composition. Macroalgal habitat has been surveyed in the past along with fish and invertebrate sampling, but not annually. In addition, with rocky reef being the main focus of the monitoring, we want to stress that any inference on a potential reserve effect can be made for this habitat only. The corollary is that one cannot make any inference about the influence of protection status on how species might respond in other habitats (soft sediments, cobble fields, ...).

4. On some occasions, fishes have also been recorded on the way back to the start point of a transect, after having performed the transect itself. These data have been kept separate from the main data, which is essential. This information is stored in the 'comments' field of the DOC standard Excel form spreadsheets. Although not lost, this information is not easily accessed and has been associated with another fish record performed on the 'way in' of the transect. During interviews, divers mentioned that taking note of these species was not taking extra time on their dive. It was done when reeling back the tape towards the start point. We stress that such data must be kept separate from the transect data. Since recording this information does not take extra time, it is recommended that it be

recorded since it can provide further information on unusual species or large schools of fishes that were not captured from the transect.

It is also recommended that a new protocol is not produced for each survey, but a single master protocol is used for all surveys to ensure consistency.

4.2.7 Sampling depth

The methodology for monitoring fishes and invertebrates set the sampling depth between 6 and 15 m, which is quite a broad depth stratum. This initial choice was made in 1998 as a compromise to have a safe, achievable (shallow enough to have multiple dives per day) and ecologically meaningful habitat (not crossing biological habitat boundaries), acknowledging that, ideally, the sampling should be stratified by depth. Resources were not available to achieve depth stratification at the time.

Some species will be commoner in shallow strata and *vice versa*. This adds over-dispersion to the data when some transects range wide across depth and others do not. This will undoubtedly add variability in the counts of several species, leading to reduced power to detect changes. Since the sampling has not been depth-stratified so far, one cannot add depth or depth bands as a covariate to decrease variance when analysing the data set. Ideally, we would like to recommend stratifying the sampling by depth, with for example three depth strata (1-5 m, 5-10 m and 10-15 m). It is not easy to estimate by how much this would increase the cost of sampling. The power analysis is conducted on data that suffers from heavy over-dispersion. So if the sampling is depth stratified, one might afford to reduce the number of replicates to get the same power because variability in the data set will be reduced. By how much is difficult to tease apart without testing it. There would undoubtedly be issues with previously sampled data which have not been depth stratified, the number of replicates available in each site x depth stratum cells being inconsistent but it would give the opportunity to remove some of the variability in the data set for analysis using data collected in the future.

We believe that the 6 to 15 m sampling depth is adequate, even if not perfect. It encompasses a meaningful habitat for most of the species that are monitored. Sampling deeper, soft sediment, habitats would be better for assessing population status of blue cod and moki, but sampling at 6-15 m can already give valuable information on those species.

The data that DOC collected so far have been sampled in the depth range 2.6-16.1 m for fishes, and 3.0-17.7 m for invertebrates. Transects have been achieved within a relatively narrow depth band. For most transects, the difference between start and finish depths of transects is small, usually under 4 m (**Figure 6**). The maximum-recorded difference between start and finish depths is 5.9 m for all transects. In terms of average depth of sampling, differences are observed between sites and also between taxa of interest (**Figure 6**). Palmer Head has been usually sampled at shallow depths for fishes (0-8 m), while Princess Bay has been usually sampled at deep depths for invertebrates (12-15 m).

The most significant issue that we can identify is for the monitoring of both species of pāua. The 6-15 m depth band is far from ideal for monitoring these two species. *Haliotis australis* is present from the intertidal to 20 m but is more abundant 1-5 m (de Cook, 2010). *Haliotis iris* ranges from the intertidal to 10 m, but is usually commoner 1-6 m.

It is recommended analysing the pāua data with caution, not drawing any firm conclusions on absolute abundances. The data might be used for relative comparisons.

It is recommended that the 6-15 m depth range be used in future monitoring of fishes in TMR, but adding stratification by depth with two levels (6-10 m and 10-15 m). Six replicates should be achieved within each depth stratum. For invertebrates, it is recommended that two depth strata be used: (1) 6-15 m for kina, rock lobster and yellow-foot/black-foot pāua with 8 replicates and (2) 1-6 m for pāua only with 4-8 replicates.

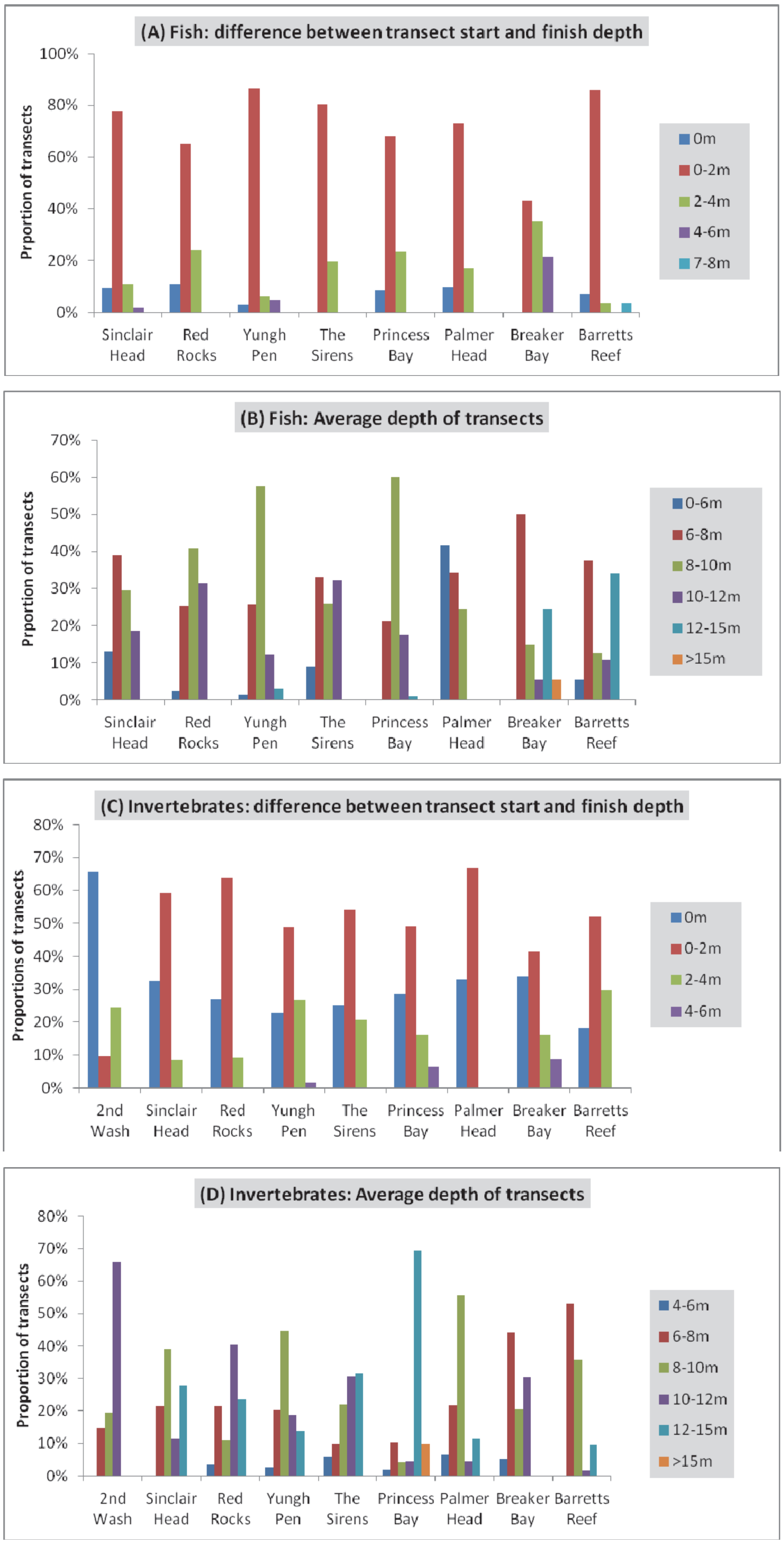

Figure 6. Depth of the DOC monitoring for fishes (A, B) and invertebrates (C, D) at Taputeranga Marine Reserve for the years 2010-2013. (A) & (C): depth difference between the start and finish of transects. (B) & (D): average depth of transects (i.e., average between the depth at the start of transect and the depth at finish of transect).

4.2.8 Species to sample

The TMR, as many other marine reserves in New Zealand, has focussed its monitoring effort on documenting the recovery of commercially or recreationally valuable species. The motivation to monitor these species is understandable in that these species experience the largest fishing pressures, both commercially and recreationally, and thus are most in need of monitoring (Jones, 2014). These species are most likely to have the strongest and most rapid response to reserve status (Battershill et al., 1993; Shears, 2007; Pande & Gardner, 2012) and so are most likely to provide a good indication that marine reserves achieve their conservation goals. Monitoring a larger set of species to assess changes at the community level would be desirable, but the level of investment to achieve this is unrealistic (McCrone & Cooper, 2009).

Eddy et al. (2008) recommended sampling the following species:

1. Invertebrates: both species of pāua (*Haliotis iris* and *H. australis*) and rock lobster (*Jasus edwardsii*) be monitored as priority indicator species.
2. Fish: blue cod (*Parapercis colias*) and blue moki (*Latridopsis ciliaris*) be monitored as priority indicator species.
3. Secondary priority species to be monitored: kina (*Evechinus chloroticus*), spotty (*Notolabrus celidotus*) and banded wrasse (*Notolabrus fucicola*). Extend this list to the species sampled by Pande (2001) if resources allow it: butterfish (*Odax pullus*), red moki (*Cheilodactylus spectabilis*), tarakihi (*Nemadactylus macropterus*) and trevally (*Pseudocaranx dentex*).

Eddy et al recommend that blue cod and blue moki be monitored as priority species. However, both species are most abundant over the cobble areas at the seaward edge of the rocky reef habitat, and would be poorly sampled by a survey design targeted at rocky reef habitats in 6-15 m. Furthermore, blue moki adults (> 40 cm long) are highly migratory and, thus, are not residents of the marine reserve; this could potentially affect the interpretation and utility of fish counts in the Marine Reserve. We support the inclusion of these two species in the revised monitoring programme over rocky reef habitat, but they are not appropriate priority species unless the survey design is modified to include sampling of cobble habitats.

A list of 17 fish species was compiled from the DOC surveys (but see issues detailed in the data quality control section): blue cod, blue moki, banded wrasse, butterfish, jack mackerel (*Trachurus novaezelandiae*), kahawai (*Arripis trutta*), leatherjacket (*Meuschenia scaber*), marblefish (*Aplodactylus arctidens*), oblique-swimming triplefin (*Forsterygion maryannae*), red moki, common sole (*Peltorhamphus novaezeelandiae*), spotty, sweep (*Scorpis lineolata*), scarlet wrasse (*Pseudolabrus miles*), tarakihi, trumpeter (*Latris lineata*), yellow-eyed mullet (*Aldrichetta forsteri*).

The four monitored invertebrate species are: black-foot and yellow-foot pāua, kina and rock lobster.

It is recommended that the same invertebrate and fish species monitored in the past by DOC surveys be monitored in the future. Investigators performing fish UVCs should also record any new species not already listed as this information could be useful for community analysis. It is also recommended that sizes be recorded for all species, as is currently achieved. Finally, it is recommended interpreting the results for both species of pāua with caution since the sampling design is not optimal to capture their abundance.

4.2.9 Statistical analysis of monitoring data

Statistical testing for differences between baseline and recent surveys of abundance and size of fishes or invertebrates has not been performed in the past by DOC. This analysis could not be performed for the audit because the baseline data, namely the studies from Eddy (2011) and Byfield (2013), is currently not available to DOC.

Univariate method: testing for changes in abundance and sizes of a specific species

If we were able to statistically analyse the data, we would recommend using the method proposed by Pande et al. (2011) and Jones (2014) to test for reservation effect on abundance and size on each species.

The analysis incorporates fixed effects of Treatment, Period and an interaction term, Treatment:Period. Random effects of Site, Year and Site:Year should also be included to account for the variation apparent between levels of these. The fixed effect of Treatment describes and accounts for the magnitude of differences between reserve and control sites, irrespective of time period, and so is not an indicator of effects due to reservation, but rather that there are differences between sites. This is something we would expect given the heterogeneity of the habitats along Wellington's south coast (Eddy et al., 2008; Pande & Gardner, 2009). The fixed effect of Period describes the magnitude of differences between the time periods, but is not specific to reserve sites because it describes changes common to all sites. The interaction term Treatment:Period tells us whether there is a significant difference between the treatments when comparing changes over time. If the Treatment:Period effect is statistically significant it tells us that there have been changes at TMR sites between the two periods that were different to those observed at control sites, and so these changes can be attributable to a marine reserve "effect" (Pande et al., 2011).

To test for statistically significant interactions between Treatment and Period for a chosen species, it is recommended to use a generalised linear mixed-effects model (GLMER). The package 'lme4' in R implement these methods. It is recommended that a specific R code be written to analyse the data directly from DOCDM spreadsheets. It is also recommended to explore new methods like Before-After Control-Impact Paired Series which could be more powerful in evidencing reserve effects (see Díaz-Guisado (2014) for an example).

Reef fish community analysis

Pande et al. (2011) recommended using Principal Component Analysis (PCA) to visualise site or treatment effects (control *versus* reserve) on fish assemblages. We do not believe, however, that this is the most appropriate method to explore and test for differences between fish assemblages because it uses Euclidean distances to calculate dissimilarity between the different samples. Euclidean distance is not an appropriate measure of dissimilarity for ecological data composed of site by species matrices (Clarke & Warwick, 2001).

A better and recommended method for data sets with many zeros like this one is to use the Bray-Curtis coefficient on raw or transformed data to calculate dissimilarities between samples. The dissimilarity matrix is then ordinated using multi-dimensional scaling (MDS) to visualise patterns of differences between sites or treatment (Kruskal & Wish, 1978; Clarke & Warwick, 2001). To test for a significant reserve effect on fish assemblages, the statistical significance of the interaction between the factors Treatment and Period can be estimated using permutational analysis of variance (PERMANOVA; Anderson, 2001).

Concluding remark from Jones (2014)

Jones (2014) notes also that identifying targets with regard to precision and bias (accuracy) are the most appropriate ways to design a monitoring program because whereas power analysis focuses on the probability of rejecting an *a priori* false hypothesis, a focus on precision and accuracy shifts the focus towards gathering more data about the true state of the system (McBride et al., 1993; Anderson et al., 2000; Nakagawa & Cuthill, 2007; Gerrodette, 2011). It also places greater emphasis on interpreting the data in terms of what it tells you about the magnitude of potential biologically important changes in abundance, and how certain are we, as researchers, of these changes. This will aid in the identification of more focussed and specific monitoring "questions", ensuring that future monitoring is more relevant and the data collected are more capable of answering questions of ecological importance.

We concur with this statement and reinforce the importance of estimating not only the effect but also the effect size.

4.3 TECHNICAL PROFICIENCY OF STAFF INVOLVED IN MONITORING

4.3.1 Staff training

A majority of divers (72% on average) involved in the DOC monitoring possessed a certificate of competency (CoC) for scientific diving (**Table 8**). This indicates a good level of general proficiency for working as a scientist underwater. Staff who were not in possession of a CoC were under the direct supervision of a diver with CoC and participated as divers in training.

The UVC methodology asks for a high level of expertise in terms of fish identification and size estimation. These are specialist skills that necessitate a high level of continuous training and standardisation across observers. It was difficult to estimate if the personnel involved in TMR surveys were adequately trained for UVC methodology. From the review of the expertise and experience of staff involved in the surveys, we can have a relatively high confidence that they were capable of obtaining data of a good quality standard. Most observers had performed UVCs in the past during other research projects. The data available regarding diver estimates of fish sizes (see page 63 and **Figure 7**) also confirm a good level of training.

In the future, it is recommended divers are used in accordance with Scientific Diver raining and operation standards. It is also recommended continuously training people in these specific methods. This could include test dives with fish taxonomists or people experienced in identifying fishes underwater to assess and improve their identification skills. It should also include test transects to become familiar with the method and to calibrate the divers' size estimations for fishes and rock lobster.

4.3.2 Project management

We feel that improvement can be made in the management of the monitoring programme, especially in regard to continuity between project leaders and data management. A restructuring occurred at DOC during April 2011-June 2012. After June 2011, no further action related to the elaboration of TMR monitoring plan could be identified. Consequences were that both the monitoring plan for TMR (Simpson, 2009; DOCDM-446374) and the biological monitoring plan (Kettles, 2009; DOCDM-471950) were not finished and are still currently in draft forms.

It is recommended that those documents be completed to frame the monitoring in TMR, be it biological or different.

A TMR Home page in the form of an Excel spreadsheet has been set up in September 2007 to centralise the information related to TMR (DOCDM-198437). It is a useful tool to access the documents related to TMR. It has a section related to the biological monitoring of the reserve. This section has most, but not all of the documents related to the monitoring attached, and has not been updated since 2012. The Home page could also be improved if the information was sorted in a logical manner. It will become hard to find information when the spreadsheet becomes larger.

It is recommended that the information and data related to the monitoring, both from past surveys and futures ones, be centralised in this dedicated spreadsheet. The design of the spreadsheet should also be improved to allow for easy search of the information. We believe that a comprehensive, well designed, portal where the information related to TMR can be easily accessed is essential to the successful management of TMR.

TMR is one reserve within a growing network of over 40 reserves. As such, data management from tier 2 monitoring for the TMR will be integrated within a nationally consistent system. This system is currently under development as part of the Marine Ecological Integrity Programme, and will be implemented in the coming years.

4.4 QUALITY CONTROL PROCEDURES

4.4.1 Observer bias

It is recommended that the same team of divers be used from year to year to minimise biases associated with observers. If the same team of divers was not available, it is essential to provide continuity by having at least some of the divers from the previous year providing guidance to the new team. Ideally, the team of divers within a year should also be relatively small so that measurements are made by the same observers.

4.4.2 Diver training

The experience of divers carrying out the monitoring was high, with most of them in possession of a certificate of competency (CoC) (**Table 8**). Divers in training (without a CoC) were always under the supervision of a diver with CoC. There was, however, no protocol in place to train the divers without CoC.

It is recommended that divers without CoC and with CoC be simultaneously recording transect data so that their results can be compared. A trainee diver should be authorised to record transect data only when the team leader is satisfied that he/she has acquired sufficient knowledge of the fauna and methodology. This is likely to involve several training dives.

It is recommended that monitoring dives be carried out by CoC divers and if divers in training are used it is in accordance with Scientific divers training and operational standards.

4.4.3 Sampling calibration

On the first test dive of a monitoring survey, divers were required to calibrate their sizing skills for both fishes and rock lobsters. For fishes, plastic fishes of known sizes were used underwater to train the diver. For lobsters, divers had to find one, estimate visually its size, catch and measure it, and then compare the estimation with its measured size. It is noted by divers that since the number of lobster that can be found is limited, it was not possible to practice on many specimens.

Although interviews confirmed that this calibration occurred, we could not find a detailed protocol for it. The only mention of this exercise was in the monitoring methodology documents for 2011 and 2012 (there was no mention in 2010 and there was no methodology document for 2013). These documents state that '*On the first dive the observer estimates of fish length will be calibrated underwater using fish cut-outs. This will also serve as a shake down dive.*' There is no mention of what is done to calibrate the rock lobster sizes.

We could only find records that indicated the sizing calibration was achieved for the fish surveys in 2011 (hard copies on file) and 2013 (DOCDM-1188004). The results of the 2013 calibration are presented for two divers and are satisfying: both divers could estimate within 5 cm of true fish size (**Figure 7**).

It is recommended having a clear protocol for methods to train people in sizing fishes and rock lobsters. This protocol should be strictly adhered to during the test dive at the beginning of a survey. Documentation of this exercise should also be kept in records for quality control purposes.

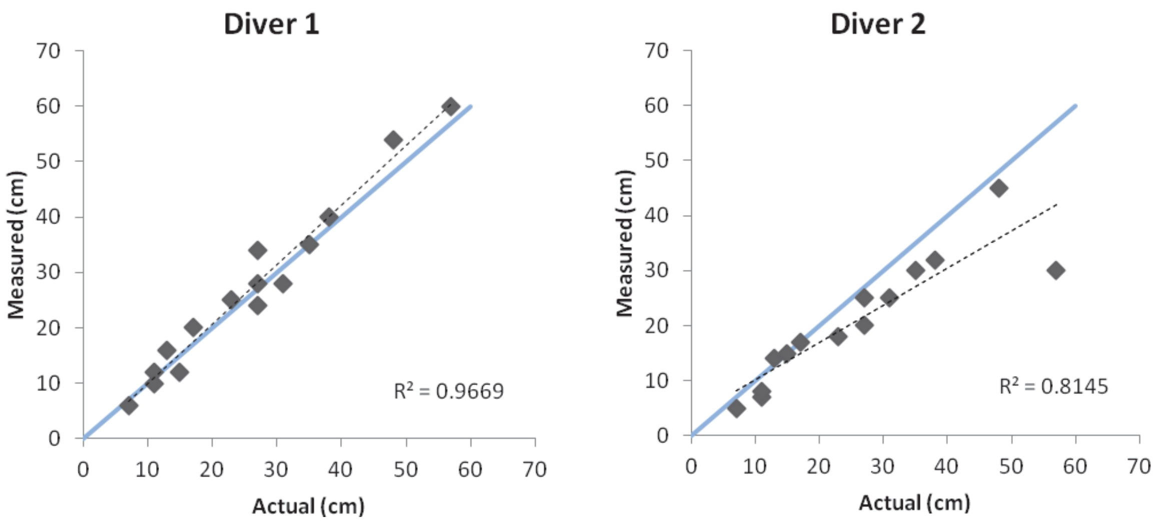

Figure 7. Results of DOC diver calibration for measuring fish sizes underwater. Data presented for 15 (diver 1) and 14 (diver 2) different tests. Plastic cut-outs mimicking fishes of different sizes were used. The average error was +1.1 cm and -4.9 cm for diver 1 and 2, respectively. Plain line: 1-1; dashed line: linear regression (coefficient of correlation also shown).

4.4.4 Data entry

Data were transferred from diver raw sheets to standard DOC format in Excel spreadsheets (DOCDM-369096). A single person was in charge of this data entry and this person varied from year to year. Interviews highlighted difficulties in reading and interpreting the diver sheets, especially for fishes (see **Figure 8** for example of data sheets). The number of inaccuracies resulting from wrong interpretations of writings in the raw data is difficult to estimate.

Interviews highlighted that there is no protocol in place to check data transfer from raw sheets and data entry in spreadsheets. It is then likely that there were no checks of this data at any stage.

Quality control of data entry needs to be improved. It is recommended to design sheets for divers that are standardised with common species names to decrease interpretation problems when transferring the data into spreadsheets. Pre-printing sheets before surveys on water resistant paper is now an easy task.

It is also recommended to put in place a protocol for checking data entry accuracy. Initial data entry should be achieved by Pōneke / Wellington Office staff with sufficient knowledge of Excel. If there is insufficient knowledge of tabular software amongst the personnel, training should be provided. Data entry is an essential task; sufficient time should be allowed to accurately enter the data as soon as possible after surveys. If difficulties are encountered in interpreting raw data sheets, the Pōneke / Wellington staff should get in touch with the diver who recorded the information as soon as possible following the survey.

Nationally, standards are currently being developed for diver sheets and protocols for data entry as part of the Ecological Integrity Programme.

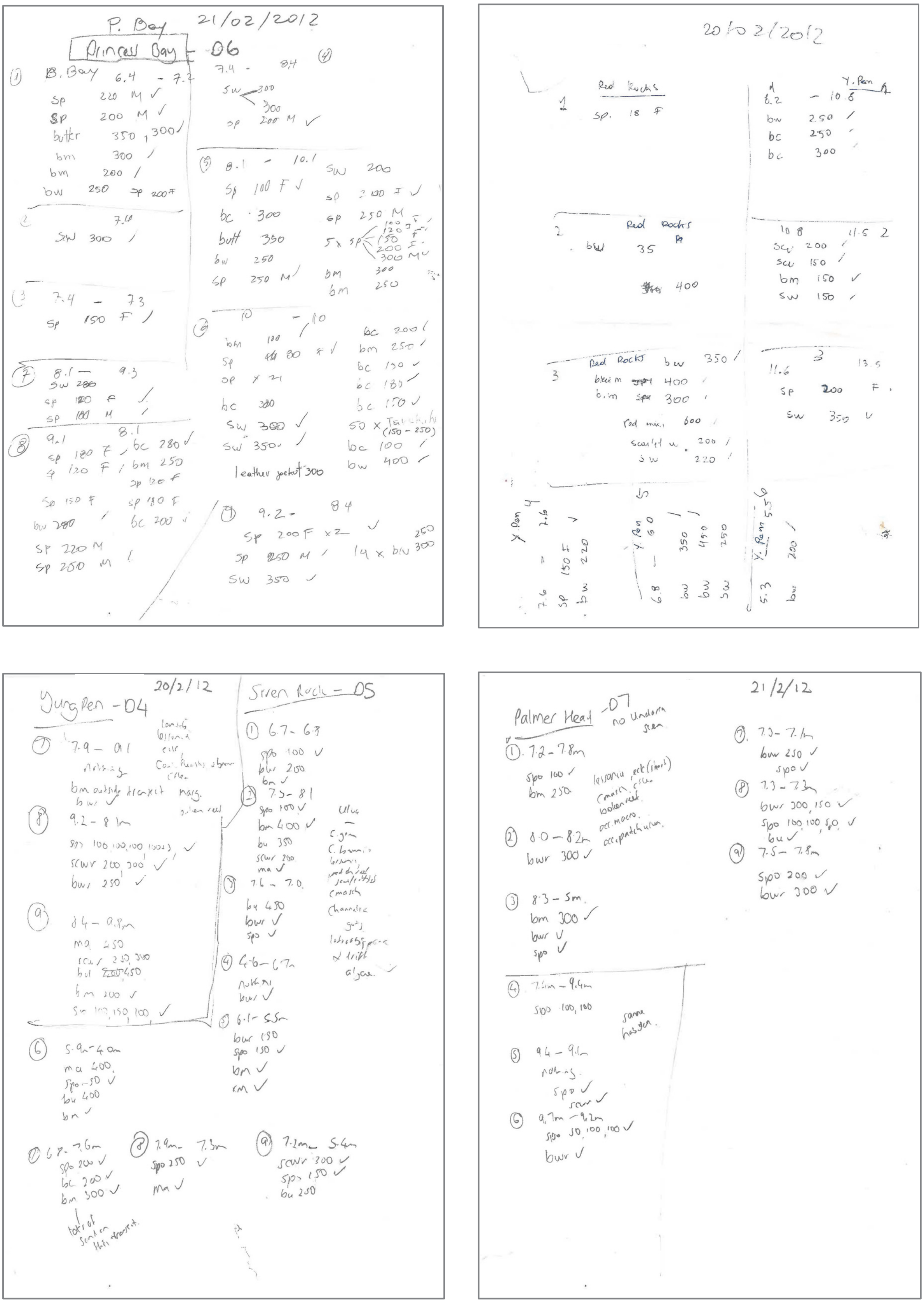

Figure 8. Examples of raw datasheets collected by divers during the 2012 monitoring of fishes in Taputeranga Marine Reserve.

4.5 DATA MANAGEMENT AND QUALITY

4.5.1 Overview

The biological data collected by DOC for the fish and invertebrate surveys include:

1. Counts of individuals per species per transect.
2. If the species was searched for but not found (i.e., like for pāua, kina and rock lobster), then a count of 0 is recorded (absence of the species).
3. Size measurement for each observed individual of each species, in mm.

The metadata includes for each record of all specimens:

1. Site.
2. Site habitat type.
3. Transect (replicate) number.
4. Date of sampling.
5. Time of start of sampling.
6. Observer name.
7. Depth of transect (this is not the depth of observation).
8. Comments, if any.

Data are recorded underwater on paper and are then archived, either as a paper archive or scanned and stored in DOCDM. Although not centralised in the home page information of TMR, we could find archived copies for 2010 and 2011, and scanned copies for 2012 and 2013.

Data are then entered into a standard form spreadsheet (MPAMAR) composed of four tabs:

1. An introduction to the spreadsheet.
2. Site meta-data.
3. Species info.
4. Sampling unit data.

Guidelines for entering the data into the standard spreadsheet are available (DOCDM-313806).

4.5.2 Data accuracy

The data entered by DOC into standard DOC format (see DOCDM-369096) were checked for inconsistencies and errors (DOCDM-1508181 and 1508184 contain a line by line summary). The following issues were identified:

1. There is potential confusion in the way the data are entered. In the spreadsheet, a line can sometimes represent more than one individual (count>1). A size is also recorded. The confusion comes from the size associated with this number of individuals. If the count is 3, does it mean that all three individuals have the same size? There would not be any possible confusion if the spreadsheet was composed of one line per organism, which is what is usually done when entering ecological data into spreadsheets.
2. 39% of the species entered in the fish Excel data sheets had some incorrect use of the standard abbreviation. We tried to extract a list of species from the data spreadsheets stored in DOCDM but faced the issue of having to interpret species codes (for example

'BCD' for 'Blue cod') which were not referenced in the species tab. A list of standard codes and associated species was provided in the Excel document, but some other codes were invented or wrongly spelled when entering the data e.g. BCOD, BRW, BSR, JM, MA, PUF, RML and SO. They likely correspond to BCOD: blue cod, BRW: banded wrasse, BSR?, JM: jack mackerel, MA: marblefish?, PUF: porcupine fish?, RML? and SO: sole.

3. 35 lines in the fish data sets (5.2%) have errors in the way species have been entered. Errors are (1) no species were entered and (2) a wrong species code was entered, with no definition in the species tab (see point above).
4. 31 lines in the invertebrate data sets (1.6%) have errors in the way species have been entered. Errors are: (1) PAUA has been entered with space at the end; (2) some records which should be PAUA2 are recorded as PAUA3, PAUA4 or PAUA5. This last error is probably due to the use of an automatic copy/paste function in Excel.
5. The field 'Time' has been inconsistently recorded. Values are sometimes present, sometimes absent.
6. The field 'Recorder' has been inconsistently recorded. An individual is recorded under different names (e.g., Jean Dupont, Jean D or Jean).
7. The field 'Depth' records both start and finish depth for each transect and observation. This information should be split into two different fields ('Depth_start' and 'Depth_finish'). In addition, the data on depth have been entered with inconsistencies. The depth range sometimes finishes by 'm' or the decimal place of the figure is changing (e.g. 8-10.0m, 8.0-10.0m, 8-10.0, 8.0-10.0 or 8-10). These inconsistencies make the extraction of the start of finish depth difficult.
8. Site codes should be recorded as D01, D02, D03, ..., D10 and not D1, D2, D3, ..., D10 for ease of ordering.
9. A field 'Year' would be useful, although it can be easily extracted from the field 'Date'.

It is recommended to use one line per organism sampled in the data spreadsheet to avoid confusion about organism sizes. Previous data should also be checked and corrected.

It is also recommended to correct all the other errors mentioned above and make the required adaption to the format of the standard form Excel spreadsheet. This could have far more reaching implications than for TMR data since this template has been and is currently used for all marine reserve data.

4.5.3 Data management

For each year of monitoring and species of focus (fish or invertebrates), data have been entered into a standard form Excel spreadsheet (MPAMAR). These data are stored on multiple servers and locations and are accessible through the DOC internal data storage system (DOCDM) to DOC staff. Permissions to edit the data are restricted.

From interviews, it was pointed that responsibilities in terms of data management were not well established. It was not clear who is responsible for entering and archiving the data after the surveys. Data entry was undertaken by different individuals depending on year. It has been done internally or subcontracted to VUW. We could not identify any protocol for independent checks of data after entry from the encoder (see Quality control procedures section). The quality of the data then solely depends on the work of the primary encoder.

It is recommended to put in place data management protocols detailing clear accountabilities and that incorporate independent checks of data entries.

There is no compilation protocol in place to collate the data from the different years. It would be useful for future analysis, once the yearly data have been entered and checked, to import these data into a main database.

It is recommended that a centralised database (i.e., a unique database where all data and metadata is stored and easily accessible) be implemented to collate data from the different sampling events.

In addition, the data from Pande (2001) have not been entered into standard DOC format. It is recommended that these data be coerced into the DOC format. If the data from Eddy (2011) and Byfield (2013) can be made available to the Department, it is recommended to also convert these data into DOC standard format.

The recommendations above are likely to be implemented in the coming years under the development of the Marine Ecological Integrity Programme.

4.6 REPORTING

Communication to the wider public about monitoring in TMR emanating from DOC consists of (1) the report from Eddy et al. (2008) that was made publicly available, (2) two media releases, (3) one article in the Blue Wellington Newsletter, (4) one article in the magazine of the New Zealand Coastal Society (**Table 13**). In addition, VUW published an important peer-reviewed paper related to the baseline data of TMR in an international journal (Pande & Gardner, 2009). The last communication dates back from Aug 2011.

Because of ongoing monitoring, there was not, however, any reporting to the public specifically on monitoring results at TMR during the period 2008-2014. Friends of Taputeranga of Marine Reserve have been occasionally updated of research and monitoring in the TMR during their regular meetings.

Reporting will largely be governed by the duration of the monitoring and data collection. If data collection is ongoing, regular reports should be submitted at 3-5 year intervals; however, if the recommendation of three-year blocks is adopted, reporting would occur at 6 year intervals, with new reports incorporating a new block of fish and invert data.

It is suggested that data from annual surveys be incorporated into the national scale 'marine reserve report cards' that are currently under development by the Department as part of the Ecological Integrity Programme.

4.7 DATA SHARING WITH EXTERNAL PARTIES

Victoria University of Wellington has been, and is likely to be in the future, an important partner associated with the monitoring of TMR. In this respect, text for a MoU on data sharing (see p24) was agreed between VUW and DOC in 2011. However, it was never signed due to internal issues at VUW and the restructuring at DOC. Interview with Prof J. Gardner made it clear that he is supportive of this MoU and data sharing in general. He noted, however, that there seems to be a lack of data management within DOC and that he had to send several times the same data set to different persons.

It is recommended to actively engage with VUW and re-activate the MoU that was agreed between parties. A circulation of the MoU between both parties should be initiated as soon as possible.

It was also identified during interviews that a focal point of contact at DOC for VUW was hard to identify after the restructuring happening at DOC 2011-2012.

It is recommended that a stable point of contact within the Pōneke / Wellington Office be given to VUW for interactions related to TMR matters.

Finally, it is recommended that DOC sees a more holistic approach in data sharing at the national level. DOC should, for example, facilitate research publication using these large data sets that are gathered from around the country. If it is important to have a good understanding of what is happening in TMR, it is even more important to see it as one conservation tool within a network of reserves. For this, DOC should take the initiative to engage with scientists who provided the data. This approach is likely to raise important intellectual questions which will need to be discussed with all parties.

4.8 Level of funding

For the period 2010-2013, there was no dedicated annual budget for the monitoring of TMR. Monitoring of the biological components of the reserve had to compete with other projects to get funded. The budget available to manage TMR was $18,000. This budget was to cover all aspects related to the management of TMR, including all monitoring, boat maintenance, boat storage, boat fuel, signage and compliance. In 2014, the sampling did not occur, not because of financial reasons, but because of the restructuring happening in DOC.

Starting in the 2014/15 financial year, an annual budget of $10,000 was set aside by the Pōneke / Wellington Office exclusively for monitoring purposes. It is envisaged that this budget be rolled out for the next 12 years. Boat maintenance costs are now covered by DOC Fleet management and the District Office (the new name of Area Offices) is not given this budget anymore.

With this budget, it is likely that the Pōneke / Wellington Office will need to find divers within DOC that will be allowed to give their time for diving. It is unlikely that this budget would be sufficient to entirely subcontract the monitoring. It could, however, help supplementing the number of DOC divers with externally subcontracted divers, if that was required.

It is anticipated that the sampling in blocks of three years, alternating between fishes or invertebrates, will free enough time and resources to adopt the proposed recommendations of this audit. Because both fishes and invertebrates are proposed not to be sampled in similar years, more time will be available to refine the sampling protocol (e.g., increased number of sites, replicates and stratification by depth).

Implementation of the National Monitoring Framework in the coming years is also likely to come with its own budget which might influence the level of funding available for monitoring TMR.

It is recommended that the Pōneke / Wellington Office makes early contact with the managers of the potential DOC divers and asks for their time availability. Once the list of available divers has been identified, the Pōneke / Wellington Office should decide if further divers need to be hired outside DOC.

5 Recommendations

Monitoring for Taputeranga Marine Reserve (TMR) began with the collection of baseline data in 1998 prior to reserve establishment. Since establishment of the reserve in 2008, annual monitoring has been conducted by DOC, in summer, for five consecutive years (2009-2013). It has primarily focussed on common fish species, kina (*Evechinus chloroticus*), pāua (*Haliotis australis* and *H. iris*) and rock lobster (*Jasus edwardsii*) at eight sites – three sites within the marine reserve and five control sites outside the reserve. Annual monitoring was not conducted in 2014 due to logistical constraints faced by the Department. The audit presented here was primarily intended to evaluate if monitoring methodologies were fit-for-purpose and outputs were meeting monitoring objectives, in terms of the annual subtidal fish and invertebrate monitoring.

Resource limitations (e.g., time, funding, availability of trained observers), but also the nature of collecting ecological data in a environment difficult to sample, meant that the chosen survey design for the reserve may not meet all the requirements for having a high statistical power to detect changes resulting from reservation.

With this in mind, the audit comes with the following recommendations to be addressed in the short term:

1. In the interim prescription, DOC should keep sampling annually, in summer, the eight sites (three inside, five outside TMR) that have been sampled in the past, based on the protocol established by Pande (2001), with some adaptations (see below).
2. The number of sites to monitor should be increased. Because this comes with logistical and budget constraints, we propose selecting one or two new sites inside the reserve. If two sites were added in the reserve, we recommend also adding a new control site to have a balanced design (five sites inside and five sites outside the reserve). Options to consider for new sites could be: South western or South eastern side of Taputeranga Island (inside TMR), Elsdon pipe (inside TMR) and between western side of reserve boundary and Red Rocks (outside TMR).
3. Twelve transects should be sampled per site for the fish surveys, or nine if logistically not feasible to do 12 transects. Eight transects per site should be surveyed for the invertebrate surveys.
4. DOC should sample TMR using a three-year block design, with a period of three years between consecutive sampling events. In practice, this would mean that fishes would be annually surveyed for three summers, and that the following three summers would be used to survey invertebrates. The cycle would then start again with fishes.
5. As much as logistical and financial resource will allow, TMR should be sampled for at least 4 blocks of 3 years for both fishes and invertebrates. This would give a meaningful number of points in time to assess the effect of preservation on fishes and invertebrates.
6. Habitat type should be standardised as much as possible to ‘rocky reef’ and habitat type be recorded for each transect.
7. Rather than following a star design, transects should be started from a new place every time and follow the reef contour, with a minimum of 25 m between consecutive transects.
8. A 6-15 m depth range should be used for monitoring of fishes, but adding stratification by depth with two levels (6-10 m and 10-15 m). Six replicates should be achieved within each depth stratum.
9. For invertebrates, one depth stratum should be added to the previously implemented protocol to take into account pāua habitat: (1) 6-15 m for kina, rock lobster and yellow-foot/black-foot pāua with 8 replicates, as previously implemented, and (2) 1-6 m for yellow-foot/black-foot pāua with 4-8 replicates.
10. The same invertebrate and fish species that have been monitored in the past should be monitored in the future. Investigators performing fish Underwater Visual Census (UVC) should also record any new species not already listed as this information could be useful for community analysis.
11. Size data should continue to be recorded for all species, as is currently done.
12. To statistically test for a reserve effect on a chosen species, the interactions between the factors Treatment (inside *vs.* Outside the reserve) and Period (before *vs.* after reservation) should be inspected (BACI design). It is recommended to use a generalised linear mixed-effects model (GLMER) for this type of analysis. Methods using paired series should also be explored. It is recommended that a specific R code be written to analyse the data directly from DOCDM spreadsheets.

13. Bray-Curtis dissimilarities should be used for analysing community structure of fishes. Ordination should be made using MDS. To test for a significant reserve effect on fish assemblages, the statistical significance of the interaction between the factors Treatment and Period can be estimated using permutational analysis of variance.
14. The Princess Bay site inside TMR should be treated cautiously when analysing the data because it is located at the border of the reserve and may be influenced by heavy fishing pressure outside the reserve. Abundance and sizes of taxa at this site should be carefully inspected and compared to neighbouring sites (both inside and outside the reserve) to detect if it has been strongly impacted by fishing.
15. DOC should analyse the pāua data with caution, refraining from drawing any firm conclusions on absolute abundances. The data might be used for relative comparisons. Pāua should be sampled separately in another depth band (1-6 m), as proposed. However, this might be difficult to achieve in terms of resources and logistics.
16. At the current level of funding for monitoring TMR, it will be necessary to use DOC diver time and volunteer divers with a CoC for the monitoring. It is recommended that the Pōneke / Wellington Office makes early contact with the managers of the potential DOC divers and asks for their time availability. Once the list of available divers has been identified, the Pōneke / Wellington Office should decide if further divers need to be hired outside DOC.

The audit also highlighted deficiencies in the current programme and recommend the following actions to be implemented in the medium term:

17. Consistent with the National Monitoring Framework, DOC should develop a robust monitoring plan for TMR, involving the identification of monitoring objectives and clear statements of how survey outcomes relate to those objectives. These objectives should be periodically reviewed because they are likely to change with time.
18. A series of errors was found in the spreadsheets collating data from monitoring surveys. Data should be checked and corrected. There was also possible confusion in the way data for size were entered which needs attention. Finally, the DOC standard form spreadsheet would need some adaptation to address for deficiencies.
19. DOC should actively engage with VUW to re-visit the MoU on data sharing that was agreed between parties in 2011.
20. DOC should identify and communicate to external parties a focal person of contact in the Pōneke / Wellington Office regarding all questions related to the monitoring of TMR.

6 Conclusions

The audit of the annual fish and invertebrate monitoring of Taputeranga Marine Reserve has found that the data collected so far by DOC is amenable to testing of a marine reserve effect for most of the species that have been surveyed. An ongoing, strong, relationship with Victoria University of Wellington since the late 90’s has guaranteed continuity in surveys, producing a unique data set in the New Zealand context.

Nationally, Taputeranga Marine Reserve is unique because it is one of the only reserves with comprehensive monitoring baseline data, i.e. data that have been collected prior to reserve establishment on multiple years, for several species and using a standardised methodology. To make best use of these baseline data, continuity in selecting similar sites, species and method is essential.

At the same time, the audit highlighted some deficiencies associated with the current monitoring approach, and includes a series of recommendations (listed above) to address those deficiencies. The main issue with the current monitoring is the generally low statistical power of the design to detect changes in size and abundance of the species surveyed. Both logistical and financial constraints associated with the monitoring design, coupled with the highly variable nature of the ecological data collected (due in part to a strong environmental gradient in the South Coast of Wellington and the unpredictable weather), have been critical factors leading to this situation. Further, the audit also identified the lack of a clear monitoring plan and objectives for the reserve, which deserve to be addressed.

Taputeranga Marine Reserve is part of a growing network of close to 50 other marine reserves within New Zealand. A National Monitoring Framework is currently being developed by DOC under the Marine Ecological Integrity Programme, which will integrate previous monitoring undertaken within New Zealand's marine reserves, including Taputeranga Marine Reserve. The key deliverables for the programme that will be implemented as part of the National Monitoring Framework over the next three years fall into a few major components, all of which are relevant to ongoing monitoring with Taputeranga Marine Reserve:

1. A marine component for the Department's Inventory and Monitoring Toolbox. Toolboxes are detailed documents developed to standardise sampling methods across New Zealand. Each sampling method implemented in marine reserves will have its own toolbox element.
2. A reporting component which will include report cards for individual marine reserves and inputs into the DOC Annual Report.
3. The inclusion of marine reserve monitoring in business plan prescriptions.
4. The development and implementation of marine reserve data storage and management protocols.

A large proportion of the issues highlighted by this audit are also relevant at a national scale, and they will be addressed as the National Monitoring Framework continues to be developed and implemented. This framework will address the following concerns that were highlighted during the audit:

- To ensure consistency in the collected data, monitoring protocols (toolboxes) are being developed that will allow the implementation of standardised methodologies across the country.
- To complement the Underwater Visual Census (UVC) data and to allow adequate sampling of species not well covered by UVC, other methodologies like Baited Underwater Video (BUV) or stereo Baited Remote Underwater Video (stereo-BRUV) for monitoring fishes are being trialled.
- To maximise data quality, standardised training protocols are being developed. Continuous training in the methods used during monitoring, including test dives with fish taxonomists or specialists to assess and improve identification skills, will be required. It will also include test transects to become familiar with methods and calibrate diver size estimations for fishes and rock lobsters.
- To minimise observer bias, the possibility of establishing a dive team with similar members from year to year is being explored. If the same team of divers is not available, the new framework will provide continuity by having at least some of the divers from the previous year providing guidance to the new team.
- To improve quality controls, clear protocols are being elaborated for training people to visually estimate the size of fishes and rock lobster during test dives at the beginning of

each survey. Data centralisation in a unique database will also allow recording documentation of this exercise for quality control purposes.

- To further improve quality controls, protocols for independent checks of data entries and accuracy are being developed.
- To decrease interpretation problems when transferring the data into databases, pre-printed sampling sheets for divers are being designed. These sheets will be scanned, archived and their path documented in the centralised file storage system of the data management system.
- To streamline project management, the information and data related to the monitoring from both past and futures surveys will be centralised in dedicated databases, giving easy and transparent access to all the information related to the monitoring of marine reserves.
- To centralise data collected during surveys, a centralised database is being built up to collate data from the different sampling events.
- To improve public reporting on the status of marine reserves, a system of individual 'report cards' for each reserve is being developed. Those report cards will provide a visual summary of the status of, and trends in, water, habitat, and living resources within the marine reserves, based on the standardised data collected at different time intervals. They will distil large amounts of complex, technical, traditional and local ecological information into concise, easily understood assessments, which can be easily displayed in printed and electronic formats (web and apps) for a wide audience.

Taken together, the specific recommendations from this audit, combined with procedural changes associated with the implementation of the National Monitoring Framework will ensure that: (1) the monitoring design is appropriate for addressing well defined monitoring objectives; (2) ongoing monitoring of the Taputeranga Marine Reserve is incorporated into business plan prescriptions; (3) monitoring outputs contribute to a national-scale assessment of trends and status of species and habitats within marine protected areas; (4) visibility of available monitoring data and reports are increased; and (5) data storage and management protocols for monitoring data are improved. Ultimately, this will ensure that DOC's future monitoring within the Taputeranga Marine Reserve is fit-for-purpose.

Finally, past monitoring has benefited immensely from a strong relationship between Victoria University of Wellington, Friends of Taputeranga Marine Reserve, NIWA and the Department of Conservation, and we recommend that these relationships continue to be fostered.

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8 Annexes

Annexe 1: The Marine Ecological Integrity Programme.

8.1 Annexe 1: Marine Ecological Integrity Programme

Context

Monitoring of marine areas managed by DOC (such as marine reserves) has in the past been undertaken largely without national oversight and coordination, resulting in inconsistencies in monitoring approaches, a range of data quality, access and ownership issues and an inability to report on outcomes at a national level. Monitoring has focussed predominantly on the recovery of previously-harvested species, presenting only one aspect of the condition of particular protected areas. High quality, long-term data sets do exist for some marine reserves, but the current lack of requirement to report on marine reserve monitoring, combined with issues around capacity, have led to many marine monitoring programmes being discontinued over recent years. It has been difficult to demonstrate how DOC's conservation management in the marine environment is contributing to achieving its intermediate outcomes and how to make improvements in our management. The Department currently has limited ability to report on conservation outcomes in the marine environment at a national level.

Overview of Ecological Integrity Programme

The Department of Conservation's Marine Ecosystems Team has, since 2010/11, been developing a monitoring and reporting framework for New Zealand's marine environment, based on the concept of ecological integrity. In 2013, DOC entered a partnership with Air New Zealand to part-fund the research and development work behind the Marine Ecological Integrity Programme, as a component of PlanBlue (a programme of work within DOC's Science and Capability Group). The objective of this programme is to better understand the concept of ecological integrity in the marine environment, and then develop a suite of effective and comprehensive tools for monitoring and reporting on species and ecosystems, processes, functioning and health in the marine environment. A key area of research and development work is the identification and testing of indicators of ecological integrity for New Zealand's marine protected areas. The application of these indicators may extend well beyond these conservation areas, to include aspects such as the effects of protected species management and coastal use on ecological integrity.

Progress to date

In 2011, NIWA was commissioned to review the concept of ecological integrity in the marine environment, and provide a draft framework (including indicators) for assessing ecological integrity in the New Zealand marine environment, with a focus on DOC-managed marine reserves. Since then, the Marine Ecosystems Team has been trialling these indicators, with a view to refining the suite of indicators, including those relating to indicator species such as seabirds and marine mammals. Alongside these field trials, the Marine Ecosystems Team has been developing components of the Department of Conservation's Inventory and Monitoring Toolbox, including developing a consistent methodological approach for using baited underwater video systems for monitoring predatory fish, and developing a monitoring approach for benthic systems based on functional trait diversity. It has also undertaken a "stocktake" of marine reserve monitoring data across New Zealand's marine reserve network, identifying data sources and collating data where possible, with a view to incorporating these data into any national DOC system for housing monitoring data. In addition, there is ongoing work on a reporting component of the programme, including the development of "report cards" for marine reserves, using the suite of ecological integrity indicators for each site.

The key deliverables for the programme are: 1) marine components of the Department of Conservation's Inventory and Monitoring Toolbox; 2) a reporting component, including marine reserve report cards and DOC Annual Report content; and 3) inclusion of marine reserve monitoring in business plan prescriptions; and 4) marine reserve data storage and management protocols.

The Ecological Integrity Programme is intended to achieve the following outcomes:

1. Marine monitoring is incorporated into DOC Statement of Intent and Annual Report.
2. Data on trends and status of marine species and habitats are collated and reported on nationally.
3. Marine monitoring guidelines are available to be implemented by DOC Operations, the community and researchers.
4. Monitoring data and reports are available, stored securely and visible to both DOC and the public.
5. Outputs from marine reserve monitoring expenditure are identified and able to be tracked.