

Marine: transects for mobile invertebrates

Version 1.0



This specification was prepared by Kate Schimanski in 2016.

Contents

| | |
|---|----|
| Synopsis | 2 |
| Assumptions | 3 |
| Advantages..... | 4 |
| Disadvantages..... | 4 |
| Suitability for inventory..... | 5 |
| Suitability for monitoring..... | 5 |
| Skills | 5 |
| Resources | 6 |
| Minimum attributes | 8 |
| Data storage..... | 10 |
| Analysis, interpretation and reporting..... | 10 |
| Case study A | 12 |
| Case study B | 18 |
| Full details of technique and best practice | 21 |
| References and further reading | 31 |
| Appendix A | 33 |

Disclaimer

This document contains supporting material for the Inventory and Monitoring Toolbox, which contains DOC's biodiversity inventory and monitoring standards. It is being made available to external groups and organisations to demonstrate current departmental best practice. DOC has used its best endeavours to ensure the accuracy of the information at the date of publication. As these standards have been prepared for the use of DOC staff, other users may require authorisation or caveats may apply. Any use by members of the public is at their own risk and DOC disclaims any liability that may arise from its use. For further information, please email biodiversitymonitoring@doc.govt.nz



Synopsis

Mobile macroinvertebrates are a well-recognised and important part of New Zealand's rocky reef fauna. This monitoring methodology focuses on surveying three common mobile macroinvertebrates: *Jasus edwardsii* (the spiny rock lobster), *Evechinus chloroticus* (kina or sea urchin) and *Haliotis* sp. (pāua or abalone). These species all have high cultural, commercial and recreational value and are subject to high fishing pressure (both legal and illegal). As a consequence, all three macroinvertebrates are responsive to no-take protection, which makes them good indicator species for determining the effectiveness of no-take marine protection in shallow rocky reef environments (Cole et al. 1990; Babcock et al. 1999; Kelly et al. 2000; Shears & Babcock 2003; Shears et al. 2006; Freeman et al. 2012).

The rock lobster is a high-level predator that consumes a range of prey species, including bivalves, molluscs and echinoderms, and this predation, in particular on *Evechinus chloroticus*, may play a significant role in the structuring of subtidal reef communities (Andrew & MacDiarmid 1999). The lobster is also an important food source for a range of species, including octopus and fish. Lobster populations have increased in abundance inside many New Zealand marine reserves (Cole et al. 1990; Kelly et al. 2000; Shears et al. 2006; Freeman et al. 2012), and recent work has indicated that spatial distribution of lobsters can be modelled using habitat data (Chang et al. 2010). In addition to transects, lobster populations have also been commonly monitored inside New Zealand marine reserves using baited pots or traps. For a description of these methodologies, see the Toolbox method 'Marine: lobster potting' (doccm-1547446).¹

Kina are dominant grazers (Andrew 1988) in shallow rocky reef habitats around New Zealand. Kina can modify habitat through the removal of macroalgae, resulting in the creation of crustose coralline algae-dominated urchin barrens typically occurring at depths between 3 and 10 m (Ayling 1981; Choat & Schiel 1982). Kina are predated on by lobsters and predatory fish such as snapper and blue cod. Kina abundance is typically lower inside a marine reserve relative to outside due to the increased abundance of kina predators inside marine reserves. Kina behaviour also differs inside and outside marine reserves; kina typically exhibit cryptic behaviour (e.g. occupying a rocky crevice) inside marine reserves, whereas exposed behaviour (e.g. occupying open substratum) is commonly observed outside reserves (Shears & Babcock 2002). Kina health can be determined through observing spine condition; all spines intact suggest a healthy individual, whereas a loss of spines indicates poor health. Kina are typically surveyed using dive transects or quadrats.

Pāua are also grazers. Adults are typically found in shallow subtidal regions to 20 m depth, whereas juveniles often occupy intertidal habitat. They are predated on by sea stars and rock lobster. There are three species of pāua in New Zealand: *Haliotis iris* (blackfoot), *Haliotis australis* (yellowfoot) and *Haliotis virginea* (whitefoot). This report focuses on *H. iris*, the largest and most commonly harvested species. *Haliotis iris* can grow up to approximately 180 mm in length and often aggregate in clusters on exposed coasts. *Haliotis iris* (hereafter referred to as pāua) is the only abalone

¹ The method specification 'Marine: lobster potting' (doccm-1547446) is currently under development.



species that is currently farmed in New Zealand, and its abundance has been shown to be higher inside marine reserves than outside.

Transect sampling by divers typically consists of two components. First, a transect is placed within a habitat of interest to define an area of known size. Second, divers swim the transect and record the number and size of macroinvertebrates. Because the habitat occupied by lobsters, kina and pāua is often structurally complex, divers may need to search under rocky outcrops, in crevices and under macroalgae, and may need a torch to aid in searching. Additional information on sex, moult, health, reproductive status, cohabitation and behaviour can also be recorded if applicable to the species or monitoring objectives (MacDiarmid 1991). To obtain the most accurate information, data should be recorded *in situ*, rather than via post-processing of photographic or video still images captured in the field.

Examples of the type of questions that macroinvertebrate dive transect surveys can be applied to include:

- What is the density of mobile macroinvertebrates within and outside a marine reserve?
- How does abundance of macroinvertebrates change over time?
- How does the size of the macroinvertebrates change over time?
- What is the sex ratio of rock lobsters within and outside a marine reserve?
- What is the health of the kina within and outside a marine reserve?
- Does behaviour of the macroinvertebrates differ within and outside a marine reserve?

Key considerations to take into account when considering applying macroinvertebrate dive transect survey methodologies:

- Suitability of conditions at the location for this survey technique (e.g. ability to deploy divers for data collection)
- Skill level required of personnel
- Equipment and other resources required
- Size and width of the transect to be used
- Time of year
- Number and placement of replicates
- Temporal replicates
- Which variable(s) to observe and record
- Any covariate information to be recorded concurrently

Assumptions

- Sampling, if annual, will take place at a similar period of the year, usually the summer months. This is because, due to their migration behaviour, the abundance of some species will vary with period of the year.



- To obtain data with the least possible biases during ongoing monitoring, divers will have received thorough training and be regularly re-calibrated for their size estimates. It is important that all divers have similar and high ability to identify and measure macroinvertebrates in the field.
- The underwater visibility is sufficient to record adequately the macroinvertebrate species on the width of the transect.
- The width and length of the transect is chosen to adequately sample the macroinvertebrate population at the designated sites. It means in practical terms that the length will be long enough to minimise null counts but short enough to be operationally manageable.
- The taxa of interest can be detected and identified with sufficient accuracy for the research or survey objectives.
- Observer effort and skills are similar across sites, locations and/or sampling occasions.
- Transects sampled represent the variability of the habitat, taxa or area of interest (if no additional information is to be collected as co-variables).
- Transects used are an appropriate size to capture the spatial variability in the taxa of interest or have sufficient replication depending on the research or survey objectives.
- Sites and transects are statistically independent.

Advantages

- A non-destructive method.
- With adequate replication and the appropriately sized transect, a precise estimate of macroinvertebrate abundance in the area sampled can be obtained.
- Abundance and size of macroinvertebrates can be acquired simultaneously.
- Other variables of interest, such as behaviour, and (for lobsters) sex, moult, reproductive status, den cohabitation, and health can be acquired simultaneously.
- The method is amenable to the collection of covariate data regarding the physical environment, allowing for more robust data interpretation.
- The presence of the transect line can be used as a continuous reference point.
- No specialised equipment is necessary (except SCUBA equipment).
- Can be used in long-term monitoring because sampling is easily repeatable over time.
- It is a universally used method.
- Reasonably quick and cost effective to gather data from a high number of sampling units.
- Sampling is easily repeatable over different sites of interest.

Disadvantages

- Suitably qualified divers are required to carry out the work, which may make sourcing appropriate personnel difficult.



- Difficult to obtain precise estimates of density when macroinvertebrates are in structurally complex habitats because individuals may be difficult to detect.
- It requires a high level of expertise of scientific divers for underwater sex identification (for lobsters) and sizing.
- Divers have a deterrent effect on lobsters, which will makes it difficult to size and sex individuals.
- Observer bias can be introduced if different observers are used among times and places.
- Underwater visibility must be greater than the width of the area being sampled.
- This method only provides data for the habitat that has been sampled, hence it is very much dependent on site selection and size of quadrat used, relative to the spatial heterogeneity of the habitat or species being sampled.

Suitability for inventory

- One transect size will generally not be suitable for sampling all types of organisms in an area, therefore making inventory across a broad range of taxa groups difficult. If feasible, a transect that is large enough for the most heterogeneous taxa can be used, with subsequent subsampling for other taxa. However, where the taxa of interest can all be sufficiently detected using one transect size, transect sampling may be appropriate for conducting an inventory survey.

Suitability for monitoring

- Transect sampling is well suited to monitoring of macroinvertebrates known to be observable by divers due to the ability to replicate the same method over time and space with a high level of consistency.
- It can provide information on the relative abundance and size class distribution of macroinvertebrates.
- Because lobsters are highly mobile, and along with pāua and kina can be inconspicuous, special attention should be given to carefully searching crevices and under macroalgae to get an accurate estimate of abundance.

Skills

Macroinvertebrate dive transects require a relatively high level of expertise.

Pre-survey:

- Survey design skills for determining the number of replicates, stratification (if any) and placement of replicates, and what variables are to be recorded
- GIS knowledge for the planning of field locations and sites



- Transfer of site coordinates to portable GPS
- Appropriate dive-planning skills (e.g. max depth and times) and knowledge of relevant standard operating procedures

In the field:

- Appropriate SCUBA diving certification
- Ability to identify, count, size and (if applicable) sex macroinvertebrates and record any other variables of interest along transects
- The skills to record and securely manage data
- Use of portable GPS
- Good fitness level

Data analysis:

- Familiarity with basic statistics
- Familiarity with statistical package (*R* recommended)
- Appropriate storage of data

Resources

In addition to the usual SCUBA diving gear and associated safety equipment, this section describes the specific gear required for mobile macroinvertebrate dive transects.

- Sunscreen, hat, insect repellent and plenty of snacks and water.
- Wet weather gear and warm items of clothing, as weather can change quickly.
- General field equipment, including pencils, slates, waterproof paper, datasheets.
- Data recording sheets, printed on waterproof paper. Figure 1 shows a generic transect sampling field data sheet; however, this may need to be adapted depending on the particular survey objectives and design.
- For sampling requiring the use of divers, all equipment and personnel necessary for the safety of divers will be required as outlined in DOC's 'Scientific diving and snorkelling technical document' (doccm-237640).²
- Where sampling requires the collection of organisms, sample jars containing 70% isopropyl alcohol for storage and preservation of animals, or ziplock bags for algae.
- Additional ziplock bags for samples of unknown species for lab identification.
- Transect tape. Its minimum size is the transect length and it should feature an attachment hook or carabiner at its end to secure it to rock or kelp at the start of the transect. The recommended method is to use a short length of steel wire to temporarily secure the tape to

² <http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-scientific-diving-and-snorkelling-technical-document.pdf>



kelp, but being able to release it by a strong tug allowing the diver not to have to swim back to the start of the transect.

- GPS unit for site location.
- Calipers, plastic ruler or other measuring device where the size of individuals is to be directly measured.
- Dive torch.
- ID guides to aid in species identification.
- A survey vessel and associated personnel if sampling is boat-based.
- Personnel time for the adequate completion of all stages of the project, including planning, field work, data management and analysis, and write-up of the survey and results.



| | | | |
|---------------------|---------------|------------------------------|-------------|
| Date: | Survey name: | Recorder: | Visibility: |
| TRANSECT # : | Site name: | Time start: | Time end: |
| | Depth strata: | Depth start: | Depth end: |
| Species | Count + sizes | Habitat general description: | |
| <i>Rock lobster</i> | | NZMHCS Biotic: | |
| <i>Kina</i> | | NZMHCS Abiotic: | |
| <i>Paua</i> | | Other notes | |
| | | | |
| TRANSECT # : | Site name: | Time start: | Time end: |
| | Depth strata: | Depth start: | Depth end: |
| Species | Count + sizes | Habitat general description: | |
| <i>Rock lobster</i> | | NZMHCS Biotic: | |
| <i>Kina</i> | | NZMHCS Abiotic: | |
| <i>Paua</i> | | Other notes | |
| | | | |
| TRANSECT # : | Site name: | Time start: | Time end: |
| | Depth strata: | Depth start: | Depth end: |
| Species | Count + sizes | Habitat general description: | |
| <i>Rock lobster</i> | | NZMHCS Biotic: | |
| <i>Kina</i> | | NZMHCS Abiotic: | |
| <i>Paua</i> | | Other notes | |
| | | | |

Figure 1. 'Mobile macroinvertebrates dive transects: field data sheet' (doccm-2784833).³

Minimum attributes

Consistent measurement and recording of the following attributes is critical for the implementation of the method. Depending on the research question(s), other attributes may be required.

DOC staff must complete a 'Standard inventory and monitoring project plan' (doccm-146272).⁴

³ <http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-mobile-macroinvertebrates-dive-transects-field-data-sheet.pdf>

Survey metadata

- Survey name
- Survey objectives
- Survey period (dates)
- Site name and coordinates
- Observer and recorder's names
- Vessel name
- Date and time
- Tide
- Underwater visibility
- Water temperature
- Weather
- Transect dimensions (length and width)
- How sampling sites were spatially arranged (e.g. random, random within stratified areas, fixed)

Transect data

- Location of transect within the site (e.g. depth)
- Transect (replicate) number
- Depth at start and end of transect
- Time at start and end of transect
- Data for the variables of interest to the survey objectives (e.g. species counts, size measurements)

Optional attributes

- Whether any images were taken and reference numbers for images for linking with the quadrat number
- Physical attributes associated with the transect (e.g. substrate type, slope, aspect), or any other covariate data such as a broader habitat characterisation
- If permanent transects are established, photographs and detailed notes to allow future researchers to relocate the transects
- Any additional notes that may be useful for future surveys or for interpretation of the results
- Details of any physical samples collected

⁴ <http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-standard-inventory-and-monitoring-project-plan.doc>



Data storage

DOC is currently developing a national database to hold and provide access to data collected from marine reserve monitoring in New Zealand. The aims of the database are to:

- Support consistent standards in national marine reserve monitoring programmes for marine environmental quality
- Coordinate and optimise marine reserve monitoring in New Zealand
- Provide a high quality monitoring dataset for New Zealand's marine reserves

Once operational, this methodology will be updated with a description of how to lodge data within the national database. In the interim, data should be recorded within the spreadsheets associated with this methodology. It is essential that all raw data sheets are completed, digitised and backed up on external hard drives. Raw data and associated metadata should be entered into databases/spreadsheets in a standardised format. This should include metadata stored in a separate sheet, and a sheet containing sampling data collected during the monitoring programme stored in one 'brick' of data that can be continually updated as more surveys in that monitoring programme are carried out.

For internal DOC monitoring, information pertaining to each survey within a marine reserve and resultant data/reports should be entered into the Marine Protected Area Monitoring and Research (MPAMAR) datasheet ('MPAMAR metadata—National'—doccm-1163829) so there is an easily accessible account of the survey.

Analysis, interpretation and reporting

Seek advice from a statistician or suitably experienced person prior to undertaking any analysis. Ideally, statistical advice should be sought prior to any data collection to ensure that the design of the data collection is robust and suitable for answering the question at hand. For quality control the data should be checked for unlikely abundances of organisms, and errors in data entry.

Data analysis

The type of analysis most applicable to the data will largely be determined by the research question, and whether additional supporting information has been collected or is available. However, the following table provides a brief description of the more common metrics derived from mobile macroinvertebrate transect data.



Table 1. Common metrics that can be calculated from transect data, a description of their data requirements and how to calculate/present them.

| Metric | Required data | Calculation/Presentation |
|--|--|---|
| Density | <ul style="list-style-type: none"> Number of individuals per transect Area of transect sampled | Convert the number of individuals observed per transect to the number per unit area, typically per m ² . For example, if 10 individuals are counted within a 500 m ² transect, the density of those individuals within that transect is 0.02 per m ² . |
| Size structure | <ul style="list-style-type: none"> Size or size class of each individual observed | Population size structure may be presented simply as a mean of the parameter measured, or the full set of data may be presented as size frequency histograms. |
| Cohabitation structure (for lobsters) | <ul style="list-style-type: none"> Number of cohabiting individuals in each den Area of the transect | Cohabitation data can be presented using frequency histograms: number of individuals within each den against frequency of the occurrence over the transect area. |
| Sex ratio (for lobsters) | <ul style="list-style-type: none"> Number of females and males along each transect | Population sex ratio may be presented simply as a proportional figure, such as a bar chart, pie graph or line graph (if comparing over time). |

Interpretation

Interpretation of results should be performed with the assistance of a statistician as well as consideration of the major driving forces operating within the system. At this stage, it should be determined whether the objectives of the original data collection have been achieved and whether the data are sufficient to answer those questions outlined prior to the initial surveys.

Reporting

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, whereas for short-term (< 2 years in duration) data collection, reports should be submitted within a year of the final data collection.



Case study A

Case study A: Cape Rodney to Ōkākari Point Marine Reserve and Tāwharanui Marine Reserve lobster (*Jasus edwardsii*) monitoring programme (Haggitt & Freeman 2014)

Synopsis

The Cape Rodney to Ōkākari Point (CROP) Marine Reserve, commonly known as the Leigh Marine Reserve, was established in 1975. A formal monitoring programme for the spiny rock lobster, *Jasus edwardsii*, was established in May 2000 by DOC to monitor the reserve lobster population. Monitoring of lobster populations found in the Tāwharanui Marine Reserve (TMR) was added into the programme in 2009.

To allow comparisons between annual surveys, seasonal effects were eliminated by surveying the lobsters between May and June, which coincides with their mating season. Three shallow (0–10 m) and 3 deep (> 10–20 m) sites were randomly selected from a suite of candidate sites. At each site, five 50 × 10 m (500 m²) haphazardly placed transects were sampled. Lobster abundance and sex ratio within each transect was recorded using visual observation. Additionally, the number of lobsters within individual dens/shelters, the habitat type lobsters associated with, and habitat with 5 m segments along the transect were recorded. This study provides an illustration of a common marine reserve monitoring approach using transects to survey lobster populations. Although size of lobsters was estimated, this case study will focus on the abundance, sex ratio, cohabitation and habitat type methodologies used.

Objectives

- To determine the current population status of *Jasus edwardsii* within CROP and TMR.
- To compare lobster abundance and sex ratio within CROP and TMR with equivalent non-reserve (NR) control sites.
- To compare trends in lobster population through time within the CROP and Tāwharanui Marine Reserves, relative to NR sites.

Sampling design and methods

Rock lobster surveys were undertaken within CROP, TMR and NR sample areas between 28 May and 30 June 2014.

Three shallow (0–10 m) and three deep (> 10–20 m) sites within the reserve and NR areas were surveyed in order to meet the objectives of the programme. Haggitt & Freeman (2014) note that this number of sites was chosen because previous surveys indicated that:

- 'The design had sufficient power to detect differences between reserve and non-reserve areas and would provide reliable estimates of lobster population parameters.
- The design was consistent with previous surveys and allowed direct comparisons to be made with a historic dataset.



- An ongoing monitoring program is more likely to be maintained if costs are minimised.'

Site selection was based on the following criteria:

- Sites within each reserve were randomly selected from five potential shallow and deep sites.
- The sites contained reefs with suitable shelters for lobsters.
- The NR sites were randomly selected from a number of possible sites in the area. Selection occurred prior to the survey with no knowledge of lobster abundance or population structure in the areas concerned.
- A maximum depth limit of 20 m was set to ensure repetitive, multi-day diving could be conducted safely.

At each selected site, five 50 × 10 m (500 m²) haphazardly placed transects were sampled. Haphazard selection maintained inter-annual sample independence allowing data to be analysed with analysis of variance (ANOVA) techniques. The transect size was chosen due to a pilot study that examined precision of three different transect sizes by MacDiarmid (1991), maximising the efficiency of dive time and limiting the number of zero counts in areas with low lobster abundance.

Four types of data were recorded along each transect.

- **Abundance data:** Lobsters within each transect were recorded. Torches were used to aid the detection of lobsters in deep dens/shelters.
- **Sex data:** Sex was also determined by using the dimorphic characteristics of female and male lobsters.
- **Cohabitation data:** The number of lobsters within individual dens/shelters was recorded.
- **Habitat type:** The rocky reef habitat occupied by a lobster was also recorded. Additionally, habitat type was recorded at 5 m intervals along each transect. Six rocky reef habitat categories were used (Table 2).

Count data were analysed using generalised linear mixed models. A quasi-Poisson distribution (with a log-link function) was used to account for over-dispersion. Fixed factors were Location and Depth. The factor Site (Location × Depth) was regarded as a random effect.

Table 2. Rocky reef classification used to assign dominant rocky reef types when *Jasus edwardsii* were encountered along individual transects and to categorise dominant rocky reef habitat types at 5 m intervals along individual transects. Taken from Haggitt & Freeman (2014).

| Rocky reef type | Description |
|---|---|
| Large boulder complex (LBC) | Boulders > 750 mm diameter. High to moderate complexity. |
| Small boulder complex (SBC) | Boulders 250–750 mm diameter. High to moderate complexity. |
| Cobbles (C) | < 250 mm diameter. Moderate to low complexity. |
| Platform reef with horizontal crevices (PRC) | Rock substrata with vertical crevices. Complexity ranging from high to moderate depending on crevice number, crevice depth, and crevice spatial extent. |
| Platform reef with horizontal ledges | Rock substrata with horizontal ledges and undercuts, commonly at |



| | |
|--------------------|--|
| (PRL) | the base of vertical reef walls. Complexity ranging from high to moderate depending on ledge depth and ledge spatial extent. |
| Platform reef (PR) | Low-lying platform reef with minimal topographic features and low complexity. |

Results

The results discussed here are a brief summary from the 2014 survey, as well as patterns emerging from all prior surveys.

- Mean lobster abundance per 500 m² (pooled across depth and sites) was higher within the two reserve locations than the NR location (CROP = 7.6 ± 1.5 standard error (SE); TMR = 10.6 ± 1.9 SE; and NR = 1.1 ± 0.3 SE; Figure 2).
- Lobster abundance within the two reserves (CROP and TMR) was lower than the previous survey in 2009 (Figure 2). The abundance in CROP increased between 2001–2004, plateaued between the 2006 and 2009 surveys and has declined from the 2009 to the 2014 surveys. The abundance of lobsters in the NR location has remained at low levels (< 2 lobsters per 500 m²; Figure 2).
- Abundance is variable between depth and sites. Shallow-water sites generally had higher abundance compared to deeper-water sites at CROP. Conversely, at TMR lobsters were typically more abundant at deep-water sites compared to shallow-water sites.

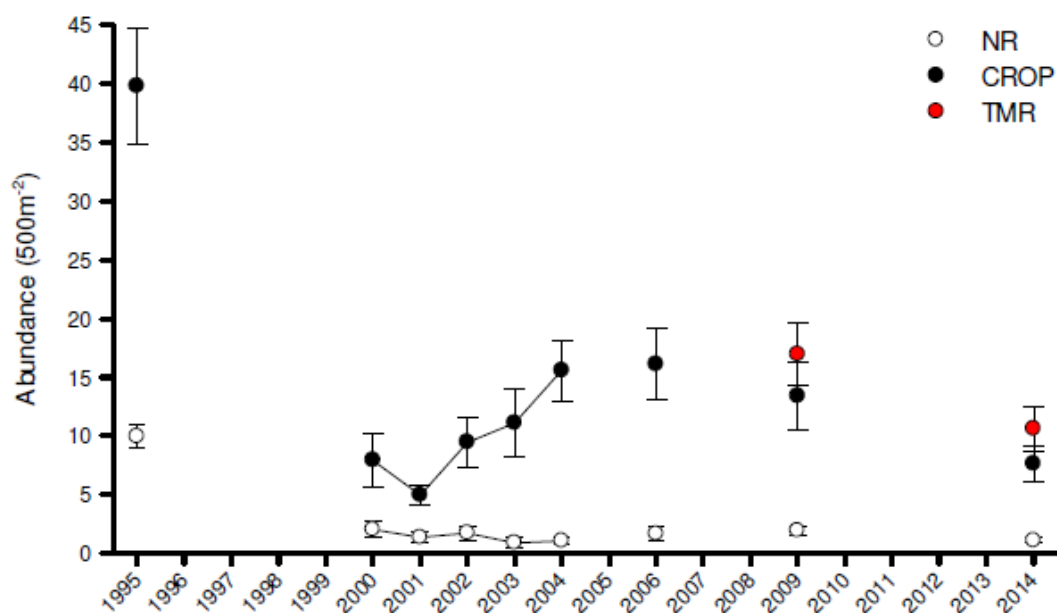


Figure 2. Abundance of *Jasus edwardsii* (\pm SE) pooled from survey sites within Cape Rodney to Ōkākari Point (CROP) Marine Reserve and non-reserve (NR) control sites between 1995 and 2014; and, for Tāwharanui Marine Reserve (TMR) between 2009 and 2014. Data are mean values \pm SE. Note: 1995 data are pooled from 4 sites within CROP and 4 sites outside the reserve, whereas subsequent data are pooled from 6 sites within each reserve and 6 sites outside. Taken from Haggitt & Freeman (2014).



- The sex ratio of lobsters in 2014 was similar across locations, with a slight bias towards males in the NR population. Between 2004 and the 2014 survey, CROP has shown to have a bias towards females, compared to the NR populations, which had a bias towards males. Before 2004, the NR population was strongly biased towards females (Figure 3).
- In the 2014 survey all six rocky reef habitat types were recorded in each location (CROP, TMR and NR). Large boulder complexes and platform reef with crevices were the dominant habitats (Figure 4). The majority of lobsters sampled in CROP, TMR and NR were associated within the large boulder complexes (85%, 71%, 83%, respectively; Figure 5). Lobsters also occurred in small boulder complexes, platform reef with vertical crevices, and platform reef with horizontal ledges, but not within low-lying platform reef or cobble habitat.

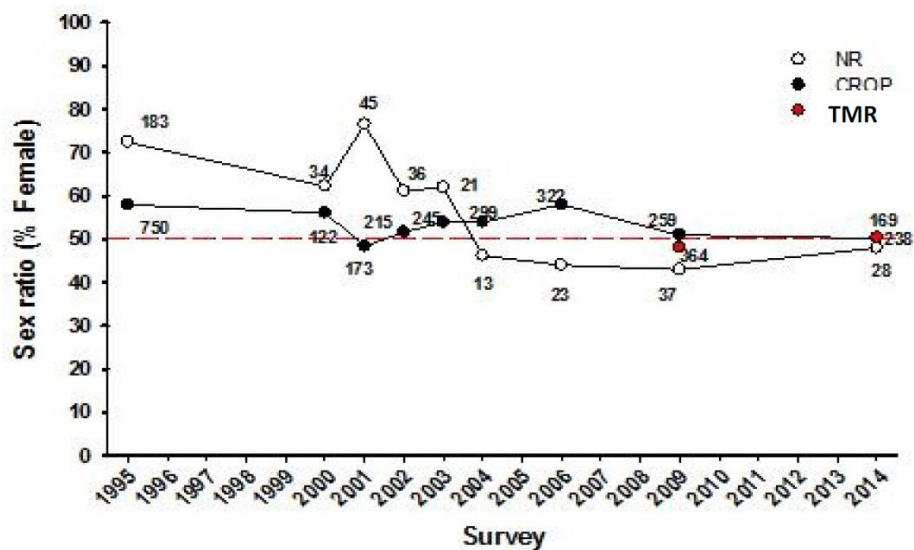


Figure 3. Sex ratios (% female) of lobsters within CROP and NR between 1995 and 2014, and TMR between 2009 and 2014. Sample sizes for estimates are given. Taken from Haggitt & Freeman (2014).



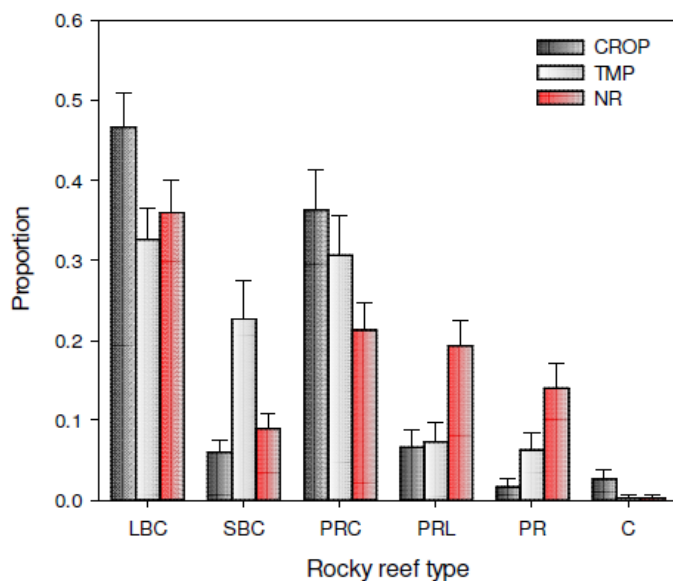


Figure 4. Proportion of rocky reef habitat types averaged across sample transects within CROP, TMR and NR. Data are mean values +SE. LBC = large boulder complex; SBC = small boulder complex; PRC = platform reef with vertical crevice; PRL = platform reef with horizontal ledges; PR = low-lying platform reef; C = cobbles. Taken from Haggitt & Freeman (2014).

- Variable cohabitation densities were recorded at all three locations (Figure 6). Solitary habitation occurred at the highest frequency, followed by small aggregations (2–4 individuals). Aggregations of more than five individuals occurred only in the two reserve locations (Figure 6). Thirty-three percent of lobsters within CROP, 38% at TMR and 32% at NR were cohabitating. Cohabiting was found most frequently in large boulder complex habitat.

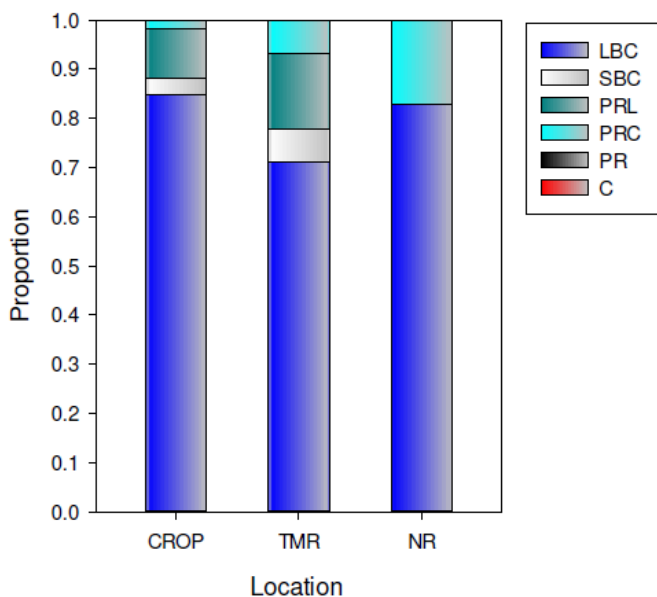


Figure 5: Proportion of *Jasus edwardsii* occurring within each rocky reef habitat type for CROP, TMR and NR in 2014. LBC = Large boulder complexes; SBC = Small boulder complexes; PRC = Platform reef with vertical crevices; PRL = Platform reef with horizontal ledges; PR = low-lying platform reef; C = cobbles. Taken from Haggitt & Freeman (2014).



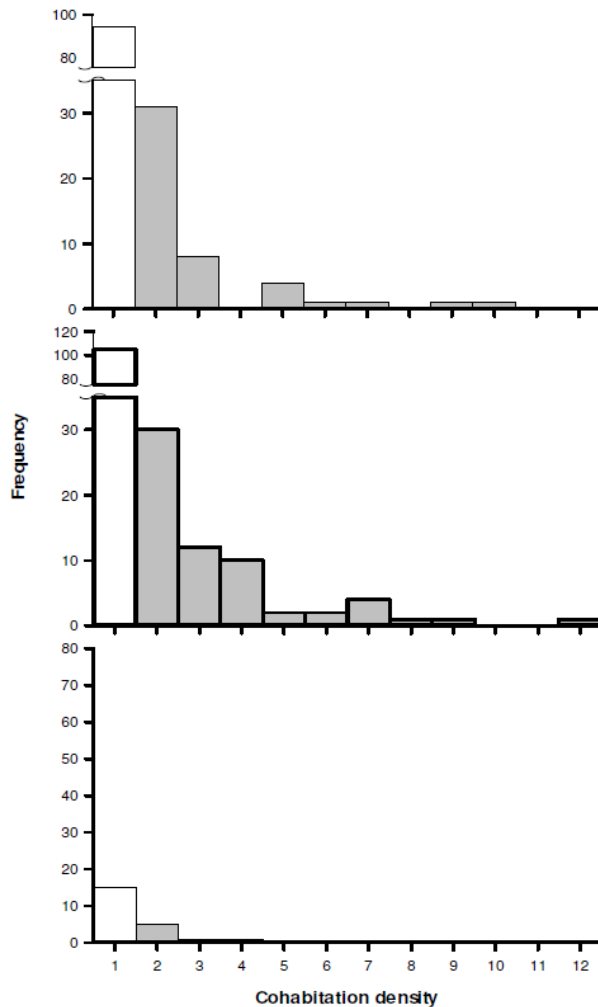


Figure 6: Frequency of *Jasus edwardsii* cohabitation within CROP (top), TMR (middle) and NR (bottom) in 2014. Data are pooled for individual transects ($n = 30$ per location). White bars denote frequency of solitary lobsters; grey bars denote frequency of cohabitating (aggregating) lobsters. Taken from Haggitt & Freeman (2014).

Limitations and points to consider

- Data quality and consistent implementation of methods over time are likely to be high as the methods have stayed the same throughout the survey period.
- This study indicates the importance of the relationship between habitat type and lobster abundance and the value in collecting habitat data to improve marine reserve design, develop robust sampling methodologies and aid the interpretation of the survey data.
- This methodology illustrates how transect sampling can be used efficiently to collect data for a number of different variables of interest regarding resident lobster populations, including shifts not due to natural fluctuations, marine reserves and their management, dynamics and frequency of recruitment events and habitat use. One transect was able to be used for all variables measured, thus making for a simpler and quicker operation by divers underwater.

Please note that this study also reported sex and size of lobsters, but those are not reported in this case study.



References for case study A

Haggitt, T.; Freeman, D. 2014: Cape Rodney to Okakari Point Marine Reserve and Tawharanui Marine Reserve lobster (*Jasus edwardsii*) monitoring programme: 2014 survey. Report by eCoast Limited to the Department of Conservation, Wellington.

<http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-protected-areas/crop-lobster-survey-2014.pdf>

MacDiarmid, A. 1991: Seasonal changes in depth distribution, sex ratio and size frequency of spiny lobster *Jasus edwardsii* on a coastal reef in northern New Zealand. *Marine Ecology Progress Series 70*: 129–141.

Case study B

Case study B: A baseline biological survey of the Taputeranga Marine Reserve: spatial and temporal variability along a natural environmental gradient (Pande & Gardner 2009), with a focus on mobile macroinvertebrates

Synopsis

Four mobile macroinvertebrate species were monitored as part of a larger survey of three areas inside and five areas outside the Taputeranga Marine Reserve over a 3-year period (January 1998 to December 2000) before the reserve was established. These data provided baseline information on the temporal and spatial variability on abundance and size of macroinvertebrates, enabling changes in these variables to be monitored after the marine reserve was established. The four mobile macroinvertebrate species were *Haliotis iris* (blackfoot pāua, abalone), *Haliotis australis* (yellowfoot pāua, abalone), *Evechinus chloroticus* (kina or sea urchin) and *Jasus edwardsii* (rock lobster). An additional four macroalgal and eight fish species were also surveyed but results are not reported here. Sites were selected based on the proposed marine reserve boundaries and to represent the wider coastline. There were 11 sampling events carried out in water depths between 5 and 15 m. The abundances of kina and blackfoot pāua, and the size of kina, varied between sites. The east-to-west environmental gradient along this section of Cook Strait is likely to have influenced observed variability in abundance and size.

Objectives

- To provide baseline information on the temporal and spatial variability of macroinvertebrate abundance and size, enabling changes in these variables to be monitored following marine reserve implementation.
- Compare differences in size and abundance with the existence of a natural east-to-west environmental gradient.
- To provide robust baseline data to quantify the ecological changes associated with a newly established marine reserve.



Sampling design and methods

- Eight rocky reef sites were sampled between January 1998 and December 2000. Sites were selected based on the proposed marine reserve boundaries and to provide a good representation of the coastline in and around the proposed marine reserve. The resulting marine reserve boundaries meant that three of the sites were inside the reserve, and five were outside. There were 11 sampling events carried out in water depths between 5 and 15 m.
- Macroinvertebrates were sampled using 25 m long belt transects. Divers swam along the transect and searched 1 m either side of it recording a count for each of the four macroinvertebrate species (blackfoot pāua, yellowfoot pāua, kina, rock lobster). Using a plastic ruler on the side of the data slates, pāua and kina size measurements were taken. The longest axis of the shell was measured for the two pāua species, and the test diameter was measured for kina. To minimise disturbance, rock lobsters were not measured. Six replicate transects (comprising a total area of 300 m²) were completed at each of the eight sites on each of the 11 sampling dates.
- Non-parametric Kruskal–Wallis analysis and parametric analysis of variance (ANOVA) were used to test for differences in species-specific abundance or size among sites. A Bonferroni sequential correction for multiple testing was applied. Analysis of covariance (ANCOVA) was used to test for seasonal effects (as indicated by sea surface temperature) on mean abundance. Multi-dimensional scaling (MDS) was used to examine the site-abundance relationships.

Results

- Mean abundance of blackfoot pāua and kina at the eight sites surveyed, throughout the period of the survey, are shown in Figure 7. Analysis showed statistically significant differences in mean abundance between sites for the blackfoot pāua *Haliotis iris*, while there were no statistically significant differences between sites for mean size estimates of any species observed.
- MDS analysis of mean abundance for all macroinvertebrates identified west-to-east site differences in the mean abundance of macroinvertebrates, with two of the three most eastern sites (Barrett Reef and Palmer Head) separated from the other sites (Figure 8).
- Statistically significant differences in abundance were observed with seasonal variation for yellowfoot pāua.



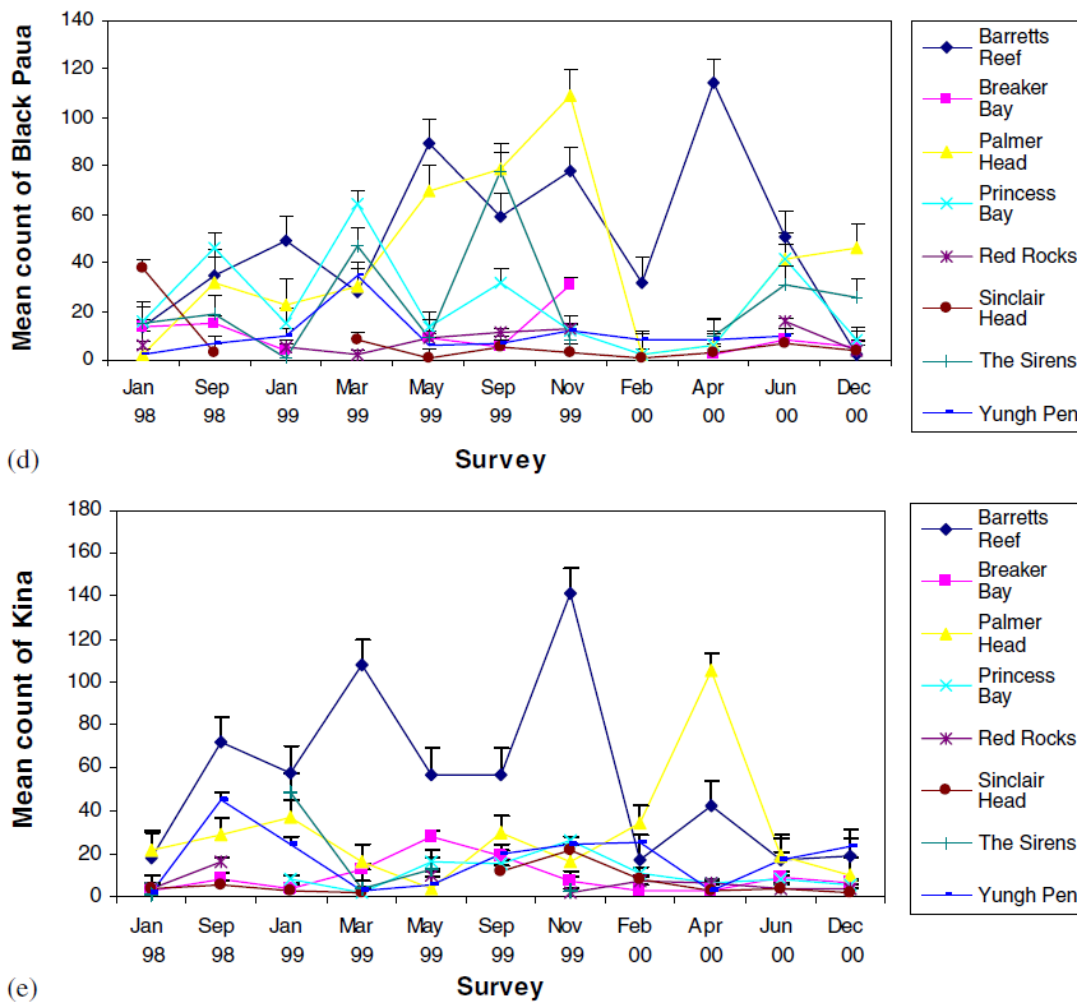


Figure 7. Mean (\pm SE) abundance of blackfoot pāua (top) and kina (bottom) at eight sites on Wellington's south coast at each survey period. Taken from Pande & Gardner (2009).

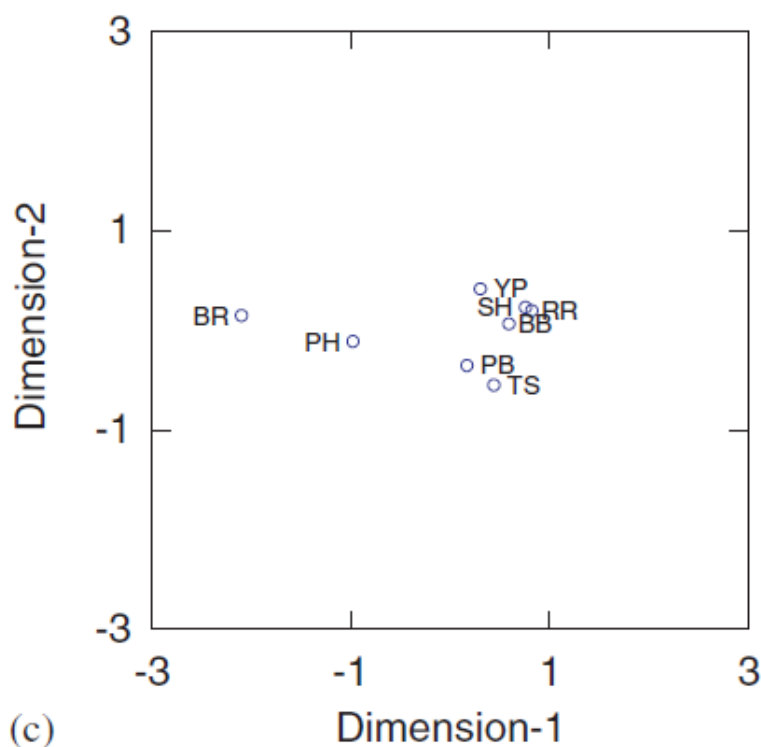


Figure 8. MDS plot of macroinvertebrate abundance survey data for all eight sites on the Wellington south coast at all time periods. The sites are located west to east in order as follows. Sinclair Head (SH), Red Rocks (RR), Yungh Pen (YP), The Sirens (TS), Princess Bay (PB), Palmer Head (PH), Breaker Bay (BB) and Barrett Reef (BR). Taken from Pande & Gardner (2009).

Limitations and points to consider

- Yellowfoot pāua showed significant seasonal variation in abundance; therefore, monitoring needs to incorporate a seasonal component to account for this variability.
- Abundance and size differences between sites were evident for some species (including a west-to-east variation). It is recommended that control sites should be close to reserve sites on an east–west scale to minimise potential confounding of results due to this gradient.
- This methodology illustrates how transect sampling can be used efficiently to collect data for a number of different variables of interest. Similarly, one transect was able to be used for all variables (abundance and size) measured, thus making for a simpler and quicker operation by divers underwater.

References for case study B

Pande, A.; Gardner, J. 2009: A baseline biological survey of the proposed Taputeranga Marine Reserve (Wellington, New Zealand): spatial and temporal variability along a natural environmental gradient. *Aquatic Conservation: Marine and Freshwater Ecosystems* 19: 237–248.

Full details of technique and best practice

The exact survey/monitoring design will be governed by the research questions, but the following text details the techniques and general survey design to be used when surveying mobile macroinvertebrate populations using the transect methodology.



Survey design

Monitoring preparation includes developing a robust survey design, including prior consultation with experts/statisticians, to ensure the design meets the requirements to answer the research question. The following aspects need to be incorporated into a robust survey design:

- Identification of monitoring objectives.
- Statement of clear outcomes of the surveys and how they relate to the original monitoring objectives.
- Determining what variables are to be measured, and how the data are to be recorded.
- Determining the number of sites to be surveyed within the survey location, and where they are to be situated. This will depend on the research question and if the survey is part of ongoing monitoring, in which case the same sites are likely to be sampled (e.g. Haggitt & Freeman 2014).
- Determining the number and attributes of transects to be sampled at each site (see Table 3).
- Determining a survey schedule to ensure that data are collected as required over the lifetime of the study. Sampling, if annual, should take place at a similar time each year. This is because abundance of lobsters, kina and pāua may vary throughout the year. For example, cohabitation (for lobsters) varies according to the time of year, sex of the individual, moult, reproductive status and due to their migration behaviour. For pāua, movement into deeper water may occur in winter.

Table 3. Recommended number and attributes of transects to be sampled at each site.

| Species | No. transects per site | Transect size | Depth stratification | Covariate data collection |
|--------------|------------------------|---------------|-------------------------------|---|
| Rock lobster | 5 | 50 × 10 m | 6–15 m or 6–10 m & 11–15 m | Abiotic habitat classification |
| Pāua | 5–8 | 25 × 2 m | 1–4 m & 5–10 m | Abiotic and biotic habitat classification |
| Kina | 5–8 | 25 × 2 m | 5–10 m or 1–4 m & 5–10 m | Abiotic and biotic habitat classification |

Sampling procedure

Following the determination of a clear and robust survey design, the following steps outline a typical process for conducting a transect survey.

To obtain data with the least possible biases during ongoing monitoring, divers will have received thorough training. It is important that all divers have similar and high ability to identify and measure the macroinvertebrates in the field and, if applicable, to determine sex, behaviour, health and other variables of interest (see [‘Quality assurance’](#) section for more information).



Collecting observations

- Navigate to the site where sampling is to begin, using either pre-determined GPS coordinates, previous site descriptions, or permanent markers. If establishing a new site, be sure to accurately record GPS coordinates and a description of the site.
- Each dive team consists of two divers. Before starting the transects at each site, the divers should establish that the water visibility is sufficient to adequately record the macroinvertebrates across the width of the transect.
- Both divers lay out the transect ensuring it is pulled taut and secure throughout its length.
- Each diver then surveys one side of the transect.
- While progressing along the transect, divers should thoroughly and systematically search the transect area, making sure to check within cracks and crevices (using a torch if necessary) and record data as per the section on '[Recording and securing data](#)' below.

General methodologies for the collection of specific data types are provided below.

- **Size estimation:** Lobster size is assessed during diver transects by estimating carapace length (the distance between the base of the antennal platform to the posterior end of the carapace at the insertion of the tail) (see Figure 9). Pāua length is measured in a straight line across the greatest overall length of the shell using calipers (Figure 10). Kina test diameter is measured across the widest portion of the test using calipers (this does not include spine length (Figure 11) Figure 12).
- **Sex:** Lobster sex can be determined by the presence or absence of paired pleopods on the underside of the tail (Figure 12). Females have paired pleopods, which supply oxygen to the eggs when the female is in berry (male pleopods are in single form). Females also have small chelae (pincers) on the rear pair of legs (fifth), whereas males do not. Males tend to be larger than females with prominent feeding appendages. Torches should be used to aid in the sexing of lobsters, and to ensure lobsters inhabiting deep holes and crevices are not missed. Some lobsters may be well tucked into crevices, making sexing difficult. In this situation, an estimation of size should still be recorded.
- **Behaviour** can also be recorded as cryptic (present in crevice or under macroalgae), or exposed (present on open substratum).
- **Cohabitation:** To record cohabitation (the occurrence of lobsters occurring together), the number of lobsters within each den/crevice should be recorded.
- **Habitat** is an important predictor of macroinvertebrate presence. Record habitat type for each 5 m segment along the transect (i.e. 0–5 m, 5–10 m etc) and also the habitat associated with each macroinvertebrate. Haggitt & Freeman (2014) used for broad dominant rocky reef types for classifying habitat type during lobster transect surveys (large boulder complex, small boulder complex, cobbles, platform reef with horizontal crevices).
- **Health:** The health of kina can rapidly be assessed during diver transect surveys. Three categories can be used to quantify kina health: 1 = healthy (all spines intact); 2 = loss of guard spine; 3 = complete loss of spines resulting in areas where the test is visible (Haggitt et al. 2013).





Figure 9. Measuring lobster carapace length. Calipers should be placed at the base of the antennal platform and at the posterior end of the carapace, at the insertion of the tail. Length is measured along the midline of the carapace.



Figure 10. Measuring pāua size. A straight line is measured along the greatest overall length of the shell as indicated by the orange line.



Figure 11. Measuring kina test. A straight line is measured across the widest portion of the test.



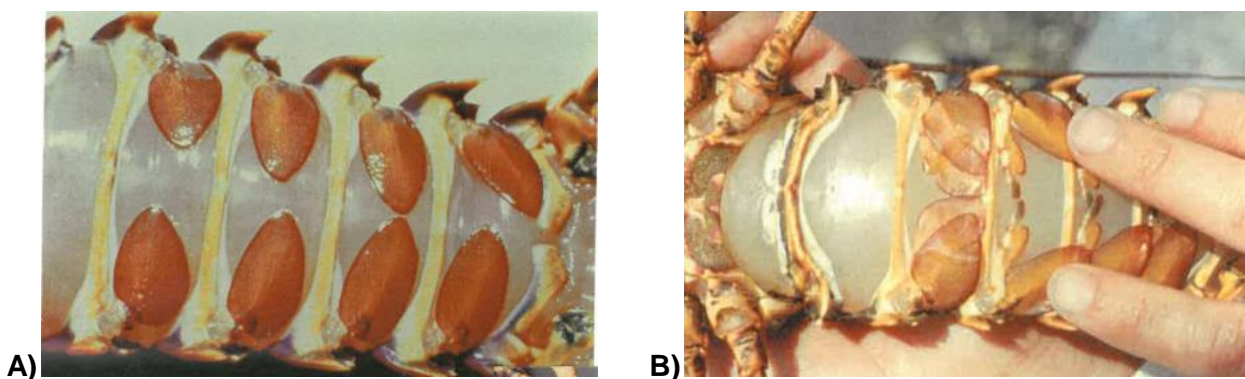


Figure 12. Sex determination using the presence or absence of paired pleopods on the underside of the tail. A) Males have a set of single pleopods. B) Females have a set of paired pleopods. Note: Although not pictured, females also have a small chelae (pincer on the rear pair of legs, and tend to be smaller than males).

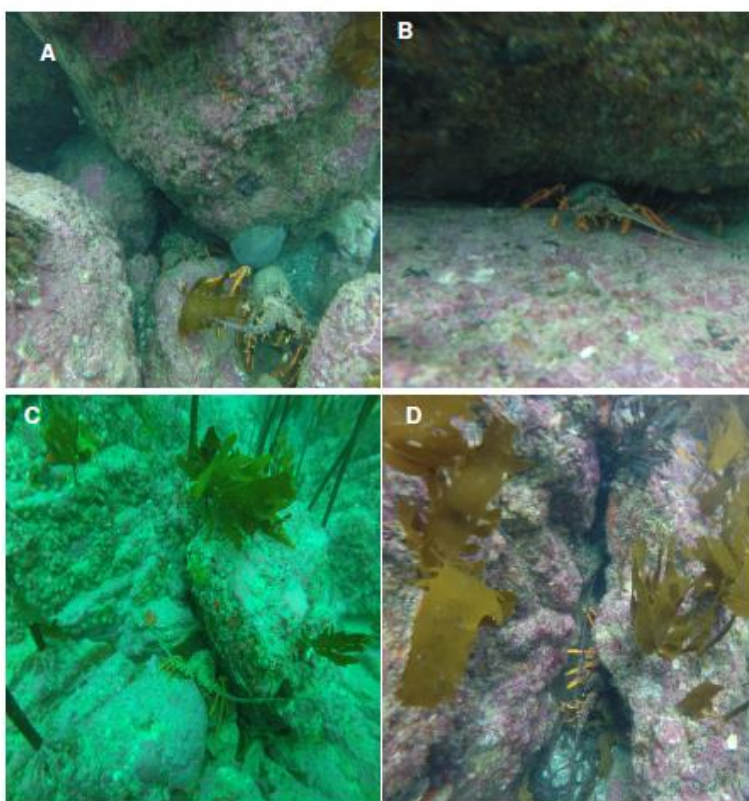


Figure 13. Examples of rocky reef habitat types where *Jasus edwardsii* were encountered. A = large boulder complexes; B = platform reef with horizontal ledges; C = small boulder complexes; D = platform reef with vertical crevices (fissures).

Recording and securing data

- Relevant metadata for the survey and site can be recorded throughout the survey while on shore or on a boat, using the 'Mobile macroinvertebrates dive transects: onboard field data sheet' (doccm-2780650)⁵ (see Table 4 for field explanations).

⁵ <http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-mobile-macroinvertebrates-dive-transects-onboard-field-data-sheet.pdf>
<http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-mobile-macroinvertebrates-dive-transects-onboard-field-data-sheet.pdf>



- Metadata and data acquired while underwater should be recorded onto the 'Mobile macroinvertebrates dive transects: field data sheet' (doccm-2784833)⁶ (see Table 4 for field explanations).
- At the end of each diving day, data sheets should be securely stored, or preferably entered into a spreadsheet. Taking a photograph of the original field datasheets is also a good solution for backing up the information.

Table 4. Minimum attributes to be recorded for mobile macroinvertebrate dive transects.

| Field | Description | Value |
|-------------------------|---|---|
| Location | General locality where the unit was deployed (e.g. Ulva Island). | Short text |
| SurveyName | A name for this survey. Allows to differentiate surveys achieved at different dates at similar location (e.g. Poor Knights Feb 2015). | Short text |
| SurveyLeaderName | Name (first name + surname) of the person in charge of this survey. | Short text |
| ContractorName | Name of person/company contracted out to carry out the survey, if applicable. | Short text |
| OfficeContact | Name (first name + surname) of the key contact in DOC office who was related to this survey. | Short text |
| SiteName | Site within <i>Location</i> where the unit was deployed. | Short text |
| ProtectionStatus | Indicates the protection status of the area sampled. | One of the six values: <ul style="list-style-type: none"> • Marine reserve (type 1 MPA) • Type 2 MPA • Mātaitai • Taiāpure • Other protection • No protection |
| Latitude | Decimal degree latitude for the deployment (WGS84) (e.g. latitude for Wellington Conservation House is -41.289904). | Number with up to 6 digits after decimal. Values are between -90 to 90, but typically negative for New Zealand. |
| Longitude | Decimal degree longitude for the deployment (WGS84) (e.g. longitude for Wellington Conservation House is 174.775043). | Number with up to 6 digits after decimal. Values are between 0 and 360. |
| TransectID | A unique identifier during this survey for this specific transect. | Unique number |

⁶ <http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-mobile-macroinvertebrates-dive-transects-field-data-sheet.pdf>



| | | |
|-----------------------------|---|---|
| TransectLength | Length of the transect in metres. | Integer |
| TransectWidth | Width of the transect in metres. | Integer |
| Strata | Depth stratum within which the transect is to be made. The investigator might not have designed different depth strata for his/her study. In this case, a general value encompassing the depth range at which the survey occurred should be entered (e.g. 5–25 m) | e.g. 5–15 m or 16–25 m |
| ReplicateWithinSite | Number of replicate within the site, starting at 1 and up to the number of deployments achieved at that particular site. Note that if only one deployment was achieved per site, then this field takes the value 1 throughout. | Integer |
| UnderwaterVisibility | Estimation of the water visibility, in metres (as assessed with a Secchi disk if available or by diver otherwise). | Integer |
| Abiotic | A description of the physical component of the benthos (silt, mud, gravel, shell hash, boulder, etc.). | Short text |
| Biotic | A description of the dominant habitat-creating organisms associated with the benthos (<i>Ecklonia</i> , red algae, CCA, Mytilidae, Pinnidae, etc.). | Short text |
| Vessel | Vessel used to deploy the diver, if appropriate. | Unlimited text |
| Recorder | Name of the person who recorded the transect data. | Unlimited text |
| EventDate | Date of sampling. | Date (dd/mm/yyyy) |
| Tide | Simplified tidal level at the time of sampling. | One of the four values: <ul style="list-style-type: none"> • Low • Medium • High • Undetermined |
| Weather | Description of the atmospheric conditions (wind, sea state, swell, etc.). | Unlimited text |
| DepthStart | Depth at the start of the transect, in metres. | Number |
| DepthEnd | Depth at the end of the transect, in metres. | Number |
| EventTimeStart | Time at which the transect started. | Time in 24 h format (hh:mm) |
| EventTimeEnd | Time at which the transect ended. | Time in 24 h format (hh:mm) |
| Notes | Any additional notes of interest in relation to this sampling event. | Unlimited text |
| ScientificName | Scientific name of the species observed. | Short text |
| Sex | Indicate the sex of the individual if the recorder could note this information. | One of the four values: |



| | | |
|--------------|--|--|
| | | <ul style="list-style-type: none"> • Male • Female • Juvenile • Undetermined |
| Count | Number of individuals of <i>ScientificName</i> observed. Note that if specimens of the same species have different sizes, a line per size group needs to be created. | Integer |
| Size | Size of the specimen(s) observed in cm. | Integer |

Timing

Consideration of timing of the surveying activity should include:

- Any diurnal, seasonal or lunar characteristics of the macroinvertebrates and how this may affect surveying (including whether previous surveys have occurred at a certain time of year/day etc).
- What are deemed 'safe' hours of operation for the surveying activity (e.g. for allowing enough time for personnel involved to return safely home/back to base within daylight hours).

Safety

Safety is paramount during any survey activity. The safety recommendations below are provided as general guidance, but it is imperative that the survey leader understands all risks associated with the activity, always uses caution, and develops a Safety Plan for the survey activity and location (DOC staff should use RiskManager, and non-Departmental staff should consult WorkSafe New Zealand's 4-step risk management⁷ or their own organisation's safety plans). Safety Plans should include resources (e.g. equipment, boats, communication, support, personal protective equipment), environmental hazards or considerations (e.g. remoteness, surf zones), personnel (experience, training, physical and mental fitness), weather and mission complexity. Following a thorough safety briefing, all team members should read and then sign the Safety Plan.

Specifically, the survey must be planned so that:

- A minimum of three people make up the dive survey team
- All personnel are operating within the limits of their training and experience
- The magnitude and complexity of the survey are relevant for the planned duration of the survey

⁷ <http://www.worksafe.govt.nz/worksafe/hswa/health-safety/how-to-manage-work-risks>
<http://www.business.govt.nz/worksafe/hswa/working-smarter/landing-page-contents/four-steps-risk-management.png>



Quality assurance

Before the survey begins, all dive members must be trained in all survey protocols, including search method and sizing macroinvertebrates. Care needs to be taken to search all habitats as macroinvertebrates can be inconspicuous. The use of torches will aid searching ability in some areas.

A calibration dive will be required as quality control for estimating abundance and individual size.

For lobsters, divers visually estimate carapace length. The lobster is then collected by hand and measured using vernier calipers. Diver size estimation must be within an average of 10 mm of the actual size. If calibration is proving difficult, divers may carry a plastic ruler or calipers to assist with estimation.

Pāua and kina size can be easily measured *in situ* using calipers; however, an assessment of the variability within or between divers should be made prior to beginning the surveying. This can be done during a pre-survey dive by each diver measuring each of 10 kina and/or pāua three times. To evaluate within-diver variability, examine error between each of the three measurements associated with each pāua and/or kina. To evaluate between-diver variation, examine error between divers associated with one measurement for each pāua and/or kina. Measurement variability should be within an average of 5 mm. This approach is illustrated in Tables 5–7 below, and indicates an acceptable level of measurement variability both within a diver's observations, and between the two divers making observations.

Table 5. Diver calibration data for kina measurements. Each of two divers measured each of 10 kina three times.

| Kina | Diver A measurements | | | Diver B measurements | | |
|------|----------------------|----|----|----------------------|----|----|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | 55 | 54 | 51 | 54 | 52 | 55 |
| 2 | 55 | 55 | 52 | 55 | 51 | 55 |
| 3 | 61 | 60 | 59 | 59 | 59 | 57 |
| 4 | 62 | 63 | 63 | 63 | 64 | 61 |
| 5 | 63 | 63 | 60 | 64 | 67 | 65 |
| 6 | 51 | 52 | 55 | 55 | 57 | 57 |
| 7 | 53 | 51 | 50 | 54 | 52 | 51 |
| 8 | 64 | 67 | 66 | 68 | 69 | 69 |
| 9 | 67 | 64 | 68 | 69 | 66 | 67 |
| 10 | 45 | 44 | 41 | 47 | 44 | 44 |



Table 6. Investigation of within-diver measurement variability for measurements from Table 5, where for each diver the mean and associated variability is calculated for each pāua. For Diver A, variability around the mean ranges between 0.65 and 2.36 mm. For Diver B, variability ranges between 0.65 and 2.61 mm.

| Kina | Diver A variability | | Diver B variability | |
|------|---------------------|--------|---------------------|--------|
| | Mean | 95% CI | Mean | 95% CI |
| 1 | 53.33 | 2.36 | 53.67 | 1.73 |
| 2 | 54.00 | 1.96 | 53.67 | 2.61 |
| 3 | 60.00 | 1.13 | 58.33 | 1.31 |
| 4 | 62.67 | 0.65 | 62.67 | 1.73 |
| 5 | 62.00 | 1.96 | 65.33 | 1.73 |
| 6 | 52.67 | 2.36 | 56.33 | 1.31 |
| 7 | 51.33 | 1.73 | 52.33 | 1.73 |
| 8 | 65.67 | 1.73 | 68.67 | 0.65 |
| 9 | 66.33 | 2.36 | 67.33 | 1.73 |
| 10 | 43.33 | 2.36 | 45.00 | 1.96 |

Table 7. Investigation of measurement variability between Diver A and Diver B for measurements from Table 5. For each pāua, the difference between each diver's mean is presented. These are then used to calculate mean measurement variability between divers.

| Kina | Between-diver variability |
|---------------|---------------------------|
| 1 | 0.33 |
| 2 | 0.33 |
| 3 | 1.67 |
| 4 | 0.00 |
| 5 | 3.33 |
| 6 | 3.67 |
| 7 | 1.00 |
| 8 | 3.00 |
| 9 | 1.00 |
| 10 | 1.67 |
| Mean | 1.60 |
| 95% CI | 0.82 |

A quality control measure for counting errors involves reassessment of a portion of the transects by an experienced observer and estimating the variability in the two sets of observations. It is recommended that 5% of transects sampled are reassessed to give a measure of the counting error or counting efficiency. Singleton (2010) provides a description of a quality control method used for a different sampling technique, but it can be applied to transect sampling. For more detail, see Singleton (2010), but in brief the identification and enumeration efficiency is calculated as:



$$\frac{\text{\# organisms in recount} - \text{number of errors}}{\text{\# organisms in recount}} \times 100$$

where the 'number of errors' is the difference between the original count and the recount.

If possible, it may be useful to carry out a quality control exercise during a pilot study, and if the counting efficiency is less than 90% (or another level as determined by the survey objectives), steps can be taken to try to improve this when the full study is undertaken (e.g. via observer training).

Although it is difficult to calculate the counting efficiency in the field and adjust the programme as necessary, it is still useful to have a measure of this error for reporting purposes.

References and further reading

- Andrew, N. 1988: Ecological aspects of the common sea urchin, *Evechinus chloroticus*, in northern New Zealand: a review. *New Zealand Journal of Marine and Freshwater Research* 22: 415–426.
- Andrew, N.; MacDiarmid, A.B. 1999: Sea urchin fisheries and potential ecological interactions with a kina fishery in Fiordland. Department of Conservation, Wellington.
- Ayling, A.M. 1981: The role of biological disturbance in temperate subtidal encrusting communities. *Ecology* 62: 830–847.
- Babcock, R.C.; Kelly, S.; Shears, N.T.; Walker, J.W.; Willis, T.J. 1999: Changes in community structure in temperate marine reserves. *Marine Ecology Progress Series* 189: 125–134.
- Chang, J.-H.; Chen, Y.; Holland, D.; Grabowski, J. 2010: Estimating spatial distribution of American lobster *Homarus americanus* using habitat variables. *Marine Ecology Progress Series* 420: 145.
- Choat, J.H.; Schiel, D.R. 1982: Patterns of distribution and abundance of large brown algae and invertebrate herbivores in subtidal regions of northern New Zealand. *Journal of Experimental Marine Biology and Ecology* 60: 129–162.
- Cole, R.G.; Ayling, T.M.; Creese, R.G. 1990: Effects of marine reserves protection at Goat Island northern New Zealand. *New Zealand Journal of Marine and Freshwater Research* 24: 197–210.
- Freeman, D.T.; MacDiarmid, A.B.; Taylor, R.B.; Davidson, R.J.; Grace, R.V.; Haggitt, T.R.; Kelly, S.; Shears, N.T. 2012: Trajectories of spiny lobster *Jasus edwardsii* recovery in New Zealand marine reserves: is settlement a driver? *Environmental Conservation* 39: 295–304.
- Haggitt, T.; Freeman, D. 2014: Cape Rodney to Okakari Point Marine Reserve and Tawharanui Marine Reserve lobster (*Jasus edwardsii*) monitoring programme: 2014 survey. Report by eCoast Limited to the Department of Conservation, Wellington.
<http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-protected-areas/crop-lobster-survey-2014.pdf>



- Haggitt, T.; Mead, S.; Smith, H.; Hillock, K. 2013: Te-Whanganui-a-Hei Marine Reserve benthic and lobster monitoring programme: 2013 survey. Report prepared for the Department of Conservation. 86 p.
- Ihde, T.F.; Frusher, S.D.; Hoenig, J.M. 2006: Do large rock lobsters inhibit smaller ones from entering traps? A field experiment. *Marine and Freshwater Research* 57: 665–674.
- Kelly, S.; Scott, D.; MacDiarmid, A.B.; Babcock, R.C. 2000: Spiny lobster, *Jasus edwardsii*, recovery in New Zealand marine reserves. *Biological Conservation* 92: 359–369.
- MacDiarmid, A. 1991: Seasonal changes in depth distribution, sex ratio and size frequency of spiny lobster *Jasus edwardsii* on a coastal reef in northern New Zealand. *Marine Ecology Progress Series* 70: 129–141.
- Pande, A.; Gardner, J. 2009: A baseline biological survey of the proposed Taputeranga Marine Reserve (Wellington, New Zealand): spatial and temporal variability along a natural environmental gradient. *Aquatic Conservation: Marine and Freshwater Ecosystems* 19: 237–248.
- Shears, N.T., Babcock, R.C. 2002: Marine reserves demonstrate top-down control of community structure on temperate reefs. *Oecologia* 132: 131–142.
- Shears, N.T.; Babcock, R.C. 2003: Continuing trophic cascade effects after 25 years of no-take marine reserve protection. *Marine Ecology Progress Series* 246: 1–16.
- Shears, N.T.; Grace, R.V.; Usmar, N.R.; Kerr, V.; Babcock, R.C. 2006: Long-term trends in lobster populations in a partially protected vs. no-take marine park. *Biological Conservation* 132: 222–231.
- Singleton, N. 2010: Regional Estuary Monitoring Programme (REMP) data report: benthic macrofauna communities and sediments—July 2008 to April 2009. Southern Firth of Thames and Whaingaroa (Raglan) Harbour. *Environment Waikato Internal Series 2010/37*. Hamilton, Waikato Regional Council (Environment Waikato).
- Ziegler, P.E.; Frusher, S.D.; Johnson, C.R. 2003: Space-time variation in catchability of southern rock lobster *Jasus edwardsii* in Tasmania explained by environmental, physiological and density-dependent processes. *Fisheries Research* 61: 107–123.
- Ziegler, P.E.; Haddon, M.; Frusher, S.D.; Johnson, C.R. 2004: Modelling seasonal catchability of the southern rock lobster *Jasus edwardsii* by water temperature, moulting, and mating. *Marine Biology* 145: 179–190.



Appendix A

The following Department of Conservation documents are referred to in this method:

| | |
|---------------|--|
| doccm-1163829 | MPAMAR metadata—National |
| doccm-1547446 | Marine: lobster potting |
| doccm-2784833 | Mobile macroinvertebrates dive transects: field data sheet |
| doccm-2780650 | Mobile macroinvertebrates dive transects: onboard field data sheet |
| doccm-237640 | Scientific diving and snorkelling technical document |
| doccm-146272 | Standard inventory and monitoring project plan |

