Marine: functional trait surveys for benthic organisms

Version 1.0

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Hewitt, J; Parkes, S. 2015. Assessing the functional trait diversity of benthic marine areas using video cameras. Prepared by the National Institute of Water and Atmospheric Research Ltd for the Department of Conservation, Wellington. doccm-2666541 http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-assessing-the-functional-trait-diversity-of-benthic-marine-areas-using-video-cameras.pdf

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Department of Conservation
Te Papa Atawhai

Synopsis

The method presented here targets a selected ecosystem component (benthic organisms), and gathers information on their functional trait diversity. Focusing on benthic organisms (flora and fauna) has several advantages:

- Their taxonomy and quantitative sampling is relatively easy.
- Most are relatively sedentary and are therefore useful for studying the local effects of disturbances.
- Some species are long lived and can reflect historical conditions and regimes of disturbance.
- There is extensive literature on their distribution in specific environments and on changes related to various stressors (e.g. Lohrer et al. 2006; Borja et al. 2008; Shears & Ross 2010).

Benthic organisms are a food source for fish and birds, and have been demonstrated to increase nutrient and sediment fluxes between the sediment and the water column (Lohrer et al. 2015; Norkko et al. in press), suggesting that they are key drivers of primary productivity and ecosystem functioning.

The method of assessment presented here is based on diversity and redundancy of functional traits of benthic components, supplemented by estimates of spatial heterogeneity (habitat transitions) and vertical habitat complexity. Functional traits are defined as the biological traits of species that relate to community or ecosystem functioning (e.g. dispersal, recovery, trophic dynamics, nutrient fluxes) (Bremner et al. 2003; de Juan et al. 2007; Villnäs & Norkko 2011).

This method focuses on visual components of the seafloor. While traditional sampling of benthic organisms is generally small-scale through coring or grabbing, video techniques offer the ability to survey large areas rapidly in a non-destructive and more cost-effective way (e.g. Hewitt et al. 2004; Lo Iacono et al. 2008; Lambert et al. 2013), which integrates well with conservation initiatives. Several studies have used video transects to evaluate the 'health' of ecosystems related to trawled areas (e.g. Thrush et al. 1998; Collie et al. 2000; Smith et al. 2001); effects of marine aggregate dredging (Cooper et al. 2008); marine protected area (MPA) effects (Lindholm et al. 2004); or for the detection of vulnerable habitats (e.g. Jones & Lockhart 2011). Eyre & Maher (2011) generated maps of benthic ecosystem processes and overall functional value that were used to identify 'hot spots' of functioning with high conservation value. While the video survey method only allows us to focus on larger (usually ≥ 4 cm) visible flora and fauna, it has the advantage of being able to concurrently identify ecologically significant features, sample over a wide depth range, and collect data over large areas (Thrush et al. 2012). Also, the recording of 'real' images of the seafloor is more likely to capture behaviours (e.g. burrowing, grazing, scavenging) of larger mobile organisms that are missed by other sampling methods (Hewitt et al. 2014).

Assumptions

- 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.
- Sites are representative of the wider environment.
- Sites and transects are statistically independent.

Advantages

- A non-destructive method.
- It is relatively easy to ascertain the types of habitats present and the functional diversity of dominant life forms from video footage.
- It is possible to survey a much greater area in one transect compared to using other survey methods (e.g. coring, grabbing or SCUBA divers collecting video footage using hand-held cameras).
- It is a time-efficient and potentially cost-effective means of surveying a large number of sites.
- Sampling is non-destructive.
- It is easier to obtain a reliable GPS position for a transect surveyed using the drop camera method than to calculate one for a transect line surveyed by divers.
- It is possible to survey sites that are too deep to be easily surveyed by divers.
- Surveying is repeatable over time, provided good GPS positioning and tracks are recorded. However, the exact same transect lines are not likely to be repeated (due to narrow field of view and the relative lack of control of vessel-towed camera systems).
- Video can be re-analysed to capture other data at a later stage.
- Camera height above the seafloor can be adjusted to acquire close-up footage or images of any special features of interest, although this is better achieved with divers using hand-held cameras.
- Recording 'real' images of the seafloor is more likely to capture the behaviours of larger mobile species that are missed by other sampling methods.

Disadvantages

- Current and wind make it difficult to maintain a slow and constant boat speed, which is needed to achieve good quality footage.
- Field of view may be relatively small due to the height of the camera off the seabed being limited by water clarity (see 'Sample collection').
- Video data alone cannot be used to complete a detailed taxonomic assessment of a location's biodiversity.

- Work is weather dependant, with waves causing problems in video focus.
- It is time-consuming to process all the video footage, as it is a less practised method than, for example, processing sediment macrofaunal cores.
- There is scope for subjective judgment.
- For best results it requires some specialised equipment (e.g. drop camera with purpose-built frame and scaling lasers, electronic 'titler' for digitally recording depth and GPS positions onto the video).
- Requires a reasonably large vessel (to accommodate a lot of bulky equipment) with a dry cabin (necessary for electronic equipment).
- Requires good taxonomic knowledge to identify organisms from video.
- Canopy-forming algae can obscure understorey organisms, and organisms in crevices and overhangs cannot be recorded.

Suitability for inventory

- This technique is highly suitable for developing inventories of the functional trait diversity of locations; however, greater uncertainty of the absolute values for locations or sites with highly heterogeneous habitats will be inevitable unless sampling is carefully planned.
- The video data can also be used for creating inventories of the diversity of epibenthic species (flora and fauna) in soft sediments, but in rocky areas many epibenthic species will not be visible (i.e. hidden by canopy plants or in rocky crevices).

Suitability for monitoring

- Changes in functional traits can be strongly associated with physical changes to the benthic environment, making this method suitable for identifying remedial management actions such as the implementation of marine reserves.
- Focusing on larger-sized organisms is generally expected to reduce seasonal variability as only larger and older juveniles will be observed.
- Physical properties of the seafloor can be assessed, although this report focuses on functional traits.

Skills

Functional trait surveys require a relatively high level of expertise.

- Survey design skills for determining the number of replicates, stratification (if any) and placement of replicates, and what variables are to be recorded
- Video enumeration skills are important for performing these surveys.
- A well-experienced skipper is needed to ensure good boat handling when surveying along transect lines, especially in moderate weather conditions.

- If using a heavy drop cam frame (as is recommended in 'Full details of technique and best practice') then a crew member trained in using the on-board davit will be required.
- Ability to process video information into major habitat types 'on the fly' (while on-board the boat) is necessary to ensure enough transects are collected to give an accurate representation of the site and/or location ('Full details of technique and best practice').

Resources

Survey work is possible with only two people. However, it is much easier to carry out the work with three people (especially if the weather conditions are not ideal): one to skipper the boat, one to handle the drop cam frame, and one to monitor the laptop, take down notes etc.

Critical field gear includes:

- Drop camera, cable and supplied software
- Chart plotter/GPS unit
- Laptop, or portable screen with direct-to-hard-drive recorder
- Invertor
- External hard drive
- 12 V batteries to power camera
- Rope to attach to frame
- Small fishing weight and string
- Wet weather gear and warm clothing
- Sturdy footwear (steel cap boots to protect toes from heavy frame)
- Notepad, pre-prepared data sheets and pencils
- Cable ties for securing any loose cable or rope
- ID guides to aid in species identification

Optional field gear to improve data collection and quality (see 'Equipment setup'):

- Sunscreen, hat, insect repellent and plenty of snacks and water.
- Wet weather gear and warm items of clothing, as weather can change quickly.
- Durable heavy frame with tail fin fitted and scaling ruler marked out on it
- Scaling lasers
- Additional lights
- Ruler for checking mounted distance of lights and lasers either side of the camera
- Dive weights (to add extra weight to frame)
- Video titler (a device that can receive an electronic signal from another device—e.g. a boat's GPS unit—and stamp the information onto recorded video footage in real-time) and supplied software.

Minimum attributes

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

DOC staff must complete a 'Standard inventory and monitoring project plan' (doccm-146272).[1]

Data collection

The minimal set of attributes that should be collected when undertaking functional trait data collection in the field are presented in Table 1. The 'Functional trait data sheet' (doccm-2794895), which is used for logging information while at sea, is available online.[2]

Table 1. Minimum set of attributes to be collected when undertaking analysis of functional trait diversity.

Field	Description	Value
SurveyName	Allows to differentiate surveys achieved at different dates at similar location.	Unlimited text in the form 'Poor Knights 2015 summer'
Location	General locality where the transects were undertaken (e.g. Ulva Island).	Short text
SiteName	Site within *Location* where transects were undertaken.	Short text
ProtectionStatus	Indicates the protection status of the area sampled.	One of the six values: • Marine reserve (type 1 MPA) • Type 2 MPA • Mātaitai • Taiāpure • Other protection • No protection
TransectID	A unique identifier in respect to this survey for the transect, in the form of an incrementing number starting at 1.	Integer
ReplicateWithinSite	Number of replicate within the site, starting at 1 and up to the number of transect achieved at that particular site. Note that if only one transect was achieved per site, then this field takes the value 1 throughout.	Integer
SurveyLeaderName	Name of the person (first name + surname) in charge of the survey.	
RecordedBy	Name of the person (first name + surname) in charge of the sampling.	Short text

[1] http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-standard-inventory-and-monitoring-project-plan.doc
[2] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-functional-trait-data-sheet.pdf

Vessel	Vessel used for sampling.	Short text
Skipper	Name of the skipper (first name + surname).	Short text
Camera	Type of camera used to record the video (make and model).	Short text
Lens	Type of wide angle lens added to the camera, if any.	Short text
LatitudeStart	Decimal degree latitude at the start of 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.
LongitudeStart	Decimal degree longitude at the start of 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.
LatitudeEnd	Decimal degree latitude at the end of the deployment (WGS84).	Number with up to 6 digits after decimal. Values are between −90 to 90, but typically negative for New Zealand.
LongitudeEnd	Decimal degree longitude at the end of the deployment (WGS84).	Number with up to 6 digits after decimal. Values are between 0 and 360.
Depth	Depth in metres recorded at every minute interval. If the information overlay unit can read from the boat's depth sounder and stamp it on the video, it will give more accurate depth information for the data processing phase.	Number
EventDate	The date of the sampling.	Date (dd/mm/yyyy)
EventTimeStart	Time the recording started.	Time in 24 h format (hh:mm)
EventTimeEnd	Time the recording ended.	Time in 24 h format (hh:mm)
UnderwaterVisibility	Estimation of the water visibility, in metres, as assessed with a Secchi disk.	Number
LaserDistance	Distance in cm between the mounted scaling lasers.	Number
HabitatTransitionTime	Times from the timecode of the video where a major habitat transitions is happening. Recorded while underway.	Time in 24 h format (hh:mm:ss)
HabitatTransitionLatitude	Decimal degree latitude of a major habitat transition (WGS84).	Number with up to 6 digits after decimal. Values are between −90 to 90, but typically negative for New Zealand.
HabitatTransitionLongitude	Decimal degree longitude of a major habitat transition (WGS84).	Number with up to 6 digits after decimal. Values are between 0 and 360.

Weather	Description of the atmospheric conditions (wind, sea state, swell, etc.).	Unlimited text
GPSTrackName	GPS boat tracks for each transect line are essential. These 'runlines' are usually stored digitally on the boat's GPS and can be exported to a PC. This can be used later to calculate average boat speed and transect length. The overlay system (titler) unit will also stamp this information onto the video footage, which is absolutely critical for analysis.	Unlimited text
DateEntry	Date of data entry in a spreadsheet.	Date (dd/mm/yyyy)
EncoderName	Name (first name + surname) of the person who encoded the data in this spreadsheet.	Short text
Notes	Any additional notes of interest in relation to this deployment.	Unlimited text

Data processing

The following minimum attributes should be recorded when processing the video images. The video data may need to be viewed multiple times in order to achieve all of the below steps. For more details, please refer to 'Full details of technique and best practice'.

1. Location, site and transect name
2. Scale used for sizing benthic organisms and habitat features
3. Area (m^2) of seafloor analysed
4. Name of analyst
5. Whether the transect was used for quality assurance, and if so, who conducted it
6. Habitat types based on dominant biological or physical component (e.g. bare sand, bioturbated mud, kelp canopy, see 'Sample collection')
7. Number of transitions (from one dominant biological component to another, e.g. bare sand to kelp canopy) between habitats used
8. Relative abundance of each visually obvious microtopographic feature and biotic group observed
9. Comment on whether relating organisms to microtopographic features and biotic groups was difficult
10. The number of new items that were added to the list of previously recorded microtopographic feature and biotic groups
11. Resultant functional trait data derived from microtopographic feature and biotic groups
12. Resultant habitat complexity based on sedentary growth-forms, sizes and abundances of the various microtopographic feature and biotic groups.

See 'Analysis, interpretation and reporting' and 'Full details of technique and best practice' for details on these measures.

Optional attributes

Sample collection:

1. GPS coordinates of any specimens collected
2. GPS coordinates of any close-ups made (frame grabs can also be taken from the video and sent to experts for checking)
3. Details (e.g. GPS coordinates, surface or bottom water sample, date, site) of any water or sediment samples taken.
4. Details of any extra information required (e.g. if the sites are arrayed along any gradient in degradation or physical environment).

Sample processing:

- Species or family level information

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.

Data storage should occur at three levels:

1. Metadata of location, site, replicate and methods.
2. In-depth result data.
3. Raw data storage of GPS track lines and video. Backups of these should be made as soon as possible after collection and stored in a separate place.

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 statistical advice from a statistician or suitably experienced person prior to undertaking any analysis. It is also essential that statistical advice is 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. Further information on analysis, interpretation and reporting can be found in 'Full details of technique and best practice'.

Three measures of functional trait diversity at a replicate (transect) level are gained from this methodology: spatial heterogeneity of habitats; vertical complexity; and a functional trait matrix. The latter can also be used to calculate the number, richness, evenness and Shannon–Wiener diversity of functional traits observed along each transect. The number of biotic groups representing each trait can also be calculated.

Site analyses

For each site, means and standard errors of spatial heterogeneity, vertical complexity, number of functional traits, richness, evenness, Shannon–Wiener diversity and number of biotic groups in each trait should be calculated and presented graphically. Differences between sites within a location in these variables may be of interest if sites have been chosen to represent either a stress gradient or inside–outside a reserve. These data can be analysed by generalised linear modelling (GzLM) to answer such questions. GzLM should be used rather than analysis of variance (ANOVA) as the spatial heterogeneity of habitats and the number of traits are unlikely to be normally distributed. Differences between sites in functional trait composition can also be analysed by analysis of similarity (ANOSIM), permutational multivariate analysis of variance (PERMANOVA) or distance-based linear modelling (DistLM; e.g. in Primer software) using Bray–Curtis similarities.

The relative occurrence of traits in each transect should be averaged for each site to produce an average functional trait matrix. Similarly, within-trait relative occurrence (as maximum of the transect values) for each site should be calculated and used to produce a total functional trait matrix, similar to the average functional trait matrix. The total number of traits (γ-diversity) at each site should be calculated (see Figure 1) and the ratio of total number of traits (γ-diversity) to the site average (α-diversity) used as β-site diversity (a representation of within-site trait heterogeneity). Note that total number of traits calculated for each transect should be standardised by the area viewed (i.e. transect length × width in metres) and similarly the total number of traits observed at a site should be standardised by the total area viewed (i.e. sum of all transect length × width in metres).

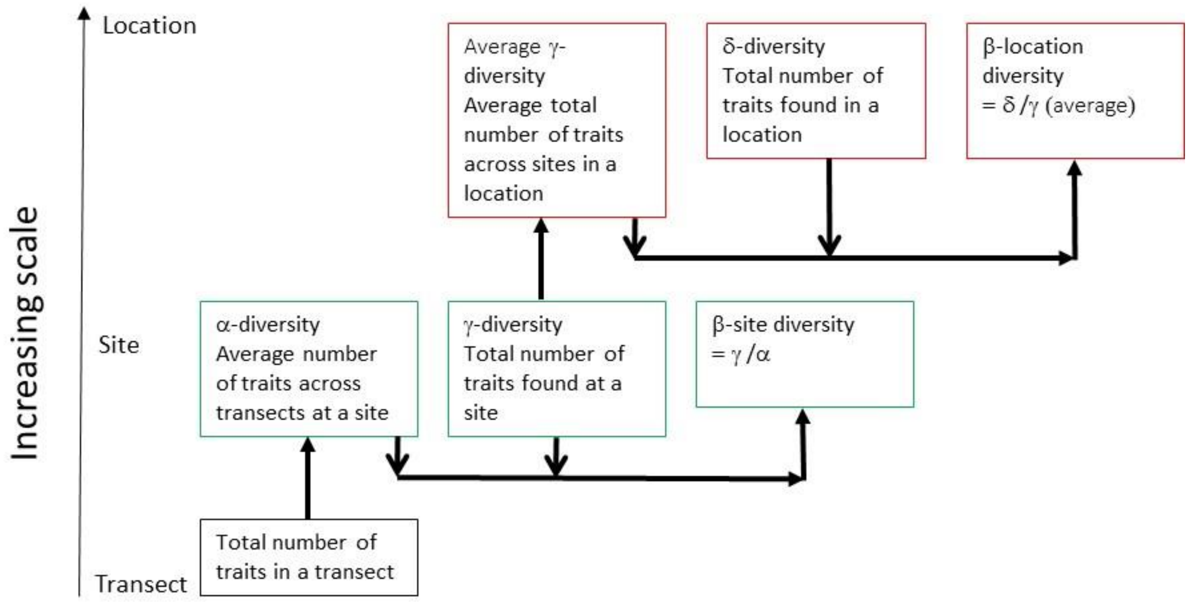

Figure 1. Diagram showing relationship of scale to aspects of trait richness.

Location analyses

For each location, means and standard errors of site estimates (see 'Site analyses') of spatial heterogeneity, vertical complexity, number of functional traits, evenness, Shannon–Wiener diversity, number of biotic groups in each trait and β-site diversity should be calculated and presented graphically (see 'Case study B' and Figure 2). Differences between locations in these variables may be of interest, and if so, data can be analysed by GzLM as per the 'Site analyses' section.

The total number of traits (δ-diversity) observed at each location should be calculated, and standardised by the total area viewed (i.e. sum of all transect length × width in metres). The difference between the average γ-diversity and the total number of traits (δ-diversity) can be used as an indication of β-location diversity (a representation of within-location trait heterogeneity).

Differences between locations in functional trait composition can also be analysed by ANOSIM, PERMANOVA or DistLM (e.g. in Primer software) using Bray–Curtis similarities on either the site-average or site-total functional trait matrix. Differences in results based on these two matrices, together with information on δ-diversity, γ-diversity and β-location diversity, give valuable information on health status (Hewitt et al. 2010).

Interpretation

Biological trait analyses are increasingly being used to assess sensitivity to, and recoverability from, human activity. For example, bottom fishing has been documented to decrease the abundance of long-lived, large, erect and fragile organisms (Thrush et al. 1998; de Juan et al. 2007). Recent work on the sensitivity of benthic organisms to bottom fishing in New Zealand focused on living position, size, mobility, feeding mode and fragility with large, sedentary, fragile epibenthic individuals having the highest sensitivity to fishing, while mobile or deep burrowing predators were identified as potentially responding positively (Hewitt et al. 2011; Baird et al. 2015). An indicator of trawling impact has recently been developed based on living position on the substrata, feeding mode, mobility, size and fragility (de Juan & Demestre 2012). Functional trait diversity should provide a useful component of ecological integrity assessment, particularly as more research is undertaken on the linkages between biological traits and specific pressures on the marine environment across multiple locations and spatial scales.

Case study A

Case study A: Port Pegasus

Synopsis

A critical step towards achieving conservation goals, such as those put in place by DOC, is developing robust methods for assessing biodiversity and ecological integrity at broad scales in marine environments. In response to this, Thrush et al. (2012) recommended the collection of video imagery from seafloor habitats, which could be used to ascertain the different types of habitats present and the functional diversity of the dominant life-forms therein. Following the development of the initial framework by Thrush et al. (2012), DOC staff collected underwater video footage from Port Pegasus, Stewart Island, which is considered one of the most pristine of New Zealand's coastal locations (DOC 2013).

Objectives

- To test the method of using video surveillance as a tool for assessing functional trait diversity at broad scales in marine environments.
- To highlight strengths and weaknesses of the approach and therefore develop ways of improving the method of video surveillance.

Sampling design and methods

- Eight sites were surveyed: Disappointment, Inside Pearl, Knob, Noble Island, North Arm, Pigeon House, South Arm and Sylvan Cove.
- Locations sampled ranged from 10–30 m deep.
- Locations were composed of a mix of soft-sediment biogenic habitats and hard substrates.
- The number of video transects collected at each location varied from 1 to 9.
- Analyses were conducted on the full length of the transects.

Results

- Habitat types were defined based on the dominant biological component (e.g. tube mat, kelp canopy, bare sand).

- Estimates of spatial heterogeneity had to be produced both as the total number of habitat transitions over the area, and also as an average of the number of video transects run, due to difficulty in estimating transect length.
- An index of habitat complexity was developed based on sedentary growth-forms, sizes and abundances of the various biotic groups (Table 6).
- Functional traits data were obtained by first assigning all organisms to one of 24 biotic groups (see 'Full details of technique and best practice'). Video footage was then viewed a second time to assess the relative abundance of these groups along the transect: 0 = absent; 1 = present at one point along the transect; 2 = common, found multiple times or for extended minutes of footage; 3 = abundant, widespread and dominant. This semi-quantitative scale was used as the field of view was generally unknown and inestimable. Following this, the biotic group information was converted into functional traits data (Table 7).

The three different measures highlight different aspects of functional trait diversity, and thus differ between the sites. The average number of habitat transitions per sample was lowest in South Arm and highest in Knob, while habitat complexity was highest in Noble Island, which was predominantly rocky reef substrate, and lowest in North Arm, a mix of soft-sediment and rocky reef substrates. No location was distinctly different from all others in terms of abundance of functional traits, but the number of traits and Shannon–Wiener diversity were higher in Disappointment and North Arm, and lower in Knob and Noble Island (Table 2).

Table 2. Metrics obtained from Port Pegasus: spatial heterogeneity (SH) as the average number of transitions; habitat complexity (HC) as the size-weighted average occurrence of complexity scores; number of traits (S); Shannon–Wiener diversity (H); and evenness (J).

Port Pegasus	SH	HC	S	H	J
Disappointment	1.3	113	30.7	3.13	0.92
Inside Pearl	1.9	101	28.1	3.01	0.9
Knob	3.3	107	25	2.95	0.92
Noble Island	2.8	149	24.8	2.93	0.91
North Arm	2.6	63.7	30.1	3.14	0.92
Pigeon House	2.3	117	27.8	3.05	0.92
South Arm	1.2	118	29	3.10	0.92
Sylvan Cove	1.8	90	28.4	3.08	0.93

Limitations and points to consider

- Lack of scaling lasers or information on the length of the drop camera transects.
- Transects were collected for a purpose other than assessment of functional traits, and therefore some areas had more transects than others.
- Conditions at the site (including wind, currents, waves, water depth, and hazardous marine life) affected the sample design.

References for case study A

DOC (Department of Conservation). 2013: Department of Conservation annual report for the year ended June 2013. Department of Conservation, Wellington, New Zealand.

Thrush, S.F.; Hewitt, J.E.; Lundquist, C.; Townsend, M.; Lohrer, A.M. 2012: A strategy to assess trends in the ecological integrity of New Zealand's marine ecosystems. Prepared by the National Institute of Water and Atmospheric Research Ltd for the Department of Conservation, Wellington.

Case study B

Case study B: Kawau Bay

Synopsis

Data had been collected in Kawau Bay in 1999 as part of an assessment of benthic mapping techniques (Hewitt et al. 2004). These data covered a range of mainly soft-sediment habitats and allowed comparison of acoustic and video data collection techniques. Higher resolution data of infaunal and epifaunal data were also collected for analysis of relationships between epibenthic diversity and infaunal diversity (Thrush et al. 2001) or snapper recruitment (Thrush et al. 2002).

Objectives

- To extend the methodology developed in Port Pegasus to cover largely soft-sediment environments.

Sampling design and methods

- Five sites were surveyed—Big Bay, Iris Shoal, Mayne, Motuora Island and Pembles Island.
- Sites sampled ranged between 10–30 m deep.
- Sites were mainly composed of a variety of soft sediment biogenic habitats.
- Three 1 km towed video transects were done per site using two high-resolution colour video cameras with independent light sources and scaling lasers.
- Analyses were conducted on randomly selected 100 m sections of video.
- Spatial heterogeneity was standardised as the average of transitions per 100 m in each site.

Results

- The average spatial heterogeneity ranged from 0.9 in Motuora Island to 0.4 in Mayne, but no significant differences were detected. Habitat complexity was highest in Iris Shoal, which was dominated by bivalve beds (*Atrina zelandica*) and sponges, and lowest in Motuora Island (a mix of bare sand/mud and *Atrina*) and Mayne (dominated by scallop beds). The locations differed in relative abundance of functional traits with all locations different from one another with the exception of Bigbay, Mayne and Motuora Island. Number of traits and Shannon–Wiener diversity were highest in Iris Shoal and lowest in Pembles Island and Motuora Island (Table 3).

- Comparisons between Port Pegasus and Kawau Bay data revealed that the overall spatial heterogeneity was highest in Port Pegasus area. The overall habitat complexity was also higher in Port Pegasus, although North Armand and Sylvan Cove values were similar to those from Kawau Bay. Evenness was higher on average in Kawau Bay, as was the average number of traits.

Table 3. Metrics obtained from Kawau Bay: spatial heterogeneity (SH) as the average of transitions; habitat complexity (HC) as the size-weighted average occurrence of complexity scores; number of traits (S); Shannon–Wiener diversity (H); and evenness (J).

Kawau Bay	SH	HC	S	H	J
Bigbay	0.8	77	32.3	3.4	0.98
Iris Shoal	0.6	90	34.2	3.5	0.99
Mayne	0.4	62	32	3.4	0.98
Motuora Island	0.9	57	30	3.3	0.98
Pembles Island	0.73	71	29.6	3.3	0.98

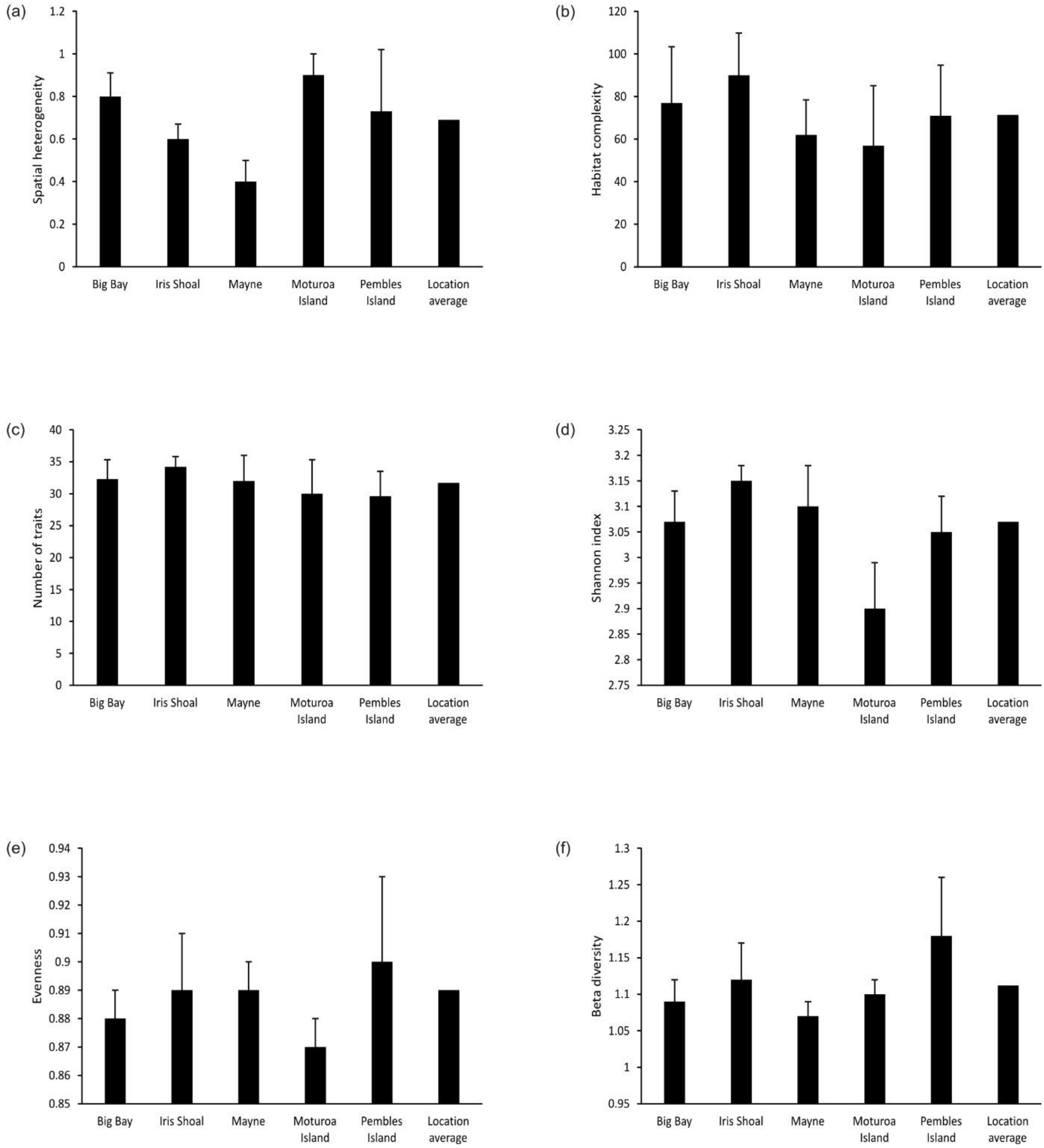

Figure 2. Site and location variables for Kawau Bay. Means and standard errors of site estimates of (a) spatial heterogeneity, (b) habitat complexity, (c) number of functional traits, (d) Shannon–Wiener diversity, (e) evenness, and (d) β-site diversity, as well as an overall location average for each variable.

Limitations and points to consider

- The assessment methodology was successfully used in another location with different physical and biological habitats, without strong differences being detected.
- The method needs to be used in a range of locations, with a strong gradient of degradation, to determine its sensitivity to human activities.

References for case study B

Hewitt, J.E.; Thrush, S.F.; Legendre, P.; Funnell, G.A.; Ellis, J.; Morrison, M. 2004: Remote mapping of marine soft-sediment communities: integrating sampling technologies for ecological interpretation. *Ecological Applications 14*: 1203–1216.

Thrush, S.F.; Hewitt, J.E.; Funnell, G.A.; Cummings, V.J.; Ellis, J.; Schultz, D.; Talley, D.; Norkko, A. 2001: Fishing disturbance and marine biodiversity: role of habitat structure in simple soft-sediment systems. *Marine Ecology Progress Series 221*: 255–264.

Thrush, S.F.; Schultz, D.; Hewitt, J.E.; Talley, D. 2002: Habitat structure in soft-sediment environments and the abundance of juvenile snapper (*Pagrus auratus* Sparidae): Developing positive links between sustainable fisheries and seafloor habitats. *Marine Ecology Progress Series 245*: 273–280.

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.

Equipment setup

The minimum equipment necessary is a GPS, a drop camera that is connected to a screen on the boat, and a weight attached to a string to provide some estimate of height above the seafloor (and thus an estimate of the field of view). Use of the fishing weight technique is most effective in environments with little variation in bottom relief.

With the GPS it is possible to simply record the start and end points of the transect, although this will only give a crude estimate of distance travelled as, due to wind, tide and sea condition, it is very rare that the boat will travel in a perfectly straight line. Recording the boat run lines on the GPS is more informative, and better still to have the camera routed through a titler, which is in turn linked to the boat's GPS. This makes it possible to view position and time information on video display screens in real time and in the recorded footage. Although there may be a short layback between the GPS antenna on the boat and the position of the camera collecting the footage, this can be minimised by maintaining a slow and constant boat speed (c. 0.5 knots = c. 0.25 m/s) and using a heavy frame to keep the camera vertical.

Best results will be achieved when the drop camera equipment is mounted in a durable heavy frame (Figure 3) fitted with a tail fin to provide directional stability. The importance of having a heavy frame is to ensure the camera is sitting vertically in a known position alongside the boat when deployed, rather than streaming out some unknown distance and angle behind it. Mounting additional lighting alongside the camera is beneficial, especially when working at depth or in poor visibility environments, as it helps to achieve much better colour and texture definition in the video footage. Image enhancement software may also be useful (instead of lighting) in low light conditions and/or where water clarity is affected by suspended sediments.

In order to be able to calculate the size of organisms or structures during the processing stage, two scaling lasers should be mounted vertically on the frame at a fixed distance (e.g. 20 cm) apart, with one on either side of the camera. Tests should be carried out to ensure the lasers are properly aligned with the central axis of the camera lens and thus fall in the centre of the field of view. As an additional measure, a scaling bar can also be marked out on the base of the drop camera frame within the camera's field of view. Camera height above the seafloor can be assessed using a third laser, positioned to cross the other lights; this laser setup can be used to calculate field of view.

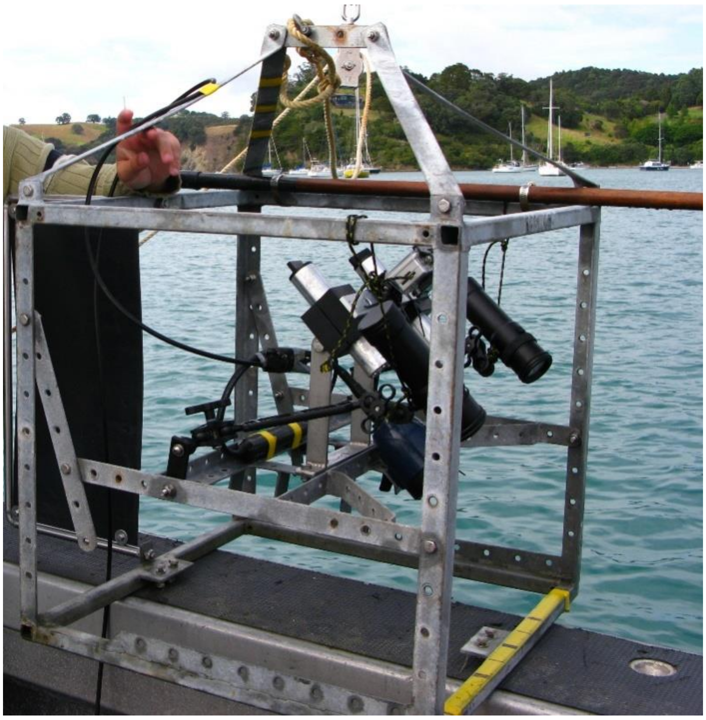

Figure 3. Setup of the drop camera and frame. Camera is centre of picture, with scaling lasers and adjustable underwater video lights mounted above on each side.

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 exact survey/monitoring designs will be governed by the project objective, i.e. monitoring recovery in a marine reserve, or a baseline assessment of functional trait diversity to allow comparisons between locations.

The following text details the techniques and general survey design to be used.

- Prior to sampling, project objectives and spatial delineation of the location should be conducted.

- Consideration of the size of the location and the physical makeup (e.g. variation in depth, sediment type, current speed, exposure, position of any major freshwater inflows), relative to project objective should be used to determine the number and approximate placement of sites. For example, is the objective best served by ensuring sites cover the full range in physical variation, or by sampling a restricted set of characteristics?
- The transect length should be longer than required for analysis. We recommend 75 or 200 m, so that either 50 or 100 m can be analysed, respectively. Longer transects should be used in more heterogeneous areas.
- The number of transects at a site is dependent on the within-site habitat heterogeneity. This will require assessment at the time of sampling. However, a minimum of 2 transects must be run in homogeneous areas. In Kawau Bay, 6 transects were sufficient even in heterogeneous sites. Location of transects within a site can be done randomly, but we recommend that the following procedure is followed:

    1. Randomly select 6 positions and spatially order them.
    2. Sample the first position.
    3. Drop the camera at the second position, and if it appears very similar to the first (see 'Sample collection' and Table 4), abort and move to the next. Otherwise, sample it.
    4. Repeat this procedure until the fourth sample position is reached. Sample the fourth position and repeat step 3 until the sixth position has been assessed.
    5. Move to a seventh position, not randomly selected but spatially separated from your previous six positions, and check with the drop camera that it does not appear markedly different from the positions already sampled. If it does, sample it as well.

Sample collection

For each transect, the visibility, which will dictate camera height above the seafloor, should be assessed prior to sampling. This can be done while the boat is stationary by slowly lowering the camera until a clear view of the seafloor is visible on the laptop/portable screen. The height of the camera may need to be reduced slightly once underway to give a clearer picture, but this will give a benchmark from which to work. The height of the camera above the seafloor can be calculated by marking the rope attached to the camera, measuring the distance once the camera is back on board and subtracting that from the depth information from the boat's depth sounder. The height of the camera off the seafloor should not be higher than a position that allows features sized 5 cm to be observed, or lower than a position that allows a width of view of less than 30 cm.

Travelling speed and stability should be checked prior to recording footage from the transects, and can be done by running a test-transect first. The crew member monitoring the screen can communicate with the skipper to achieve a speed that allows a clear picture to be viewed. In addition to this, if the boat is too unstable (due to high winds or rough seas) and is causing the camera to swing around a lot such that a clear picture cannot be obtained, work should be postponed.

While running the transect, it is useful to record types of habitats observed. Habitats in this case are defined as any dominant taxonomic group or physical feature. Examples of types of habitats previously observed are given in Table 4, although definitions could also include combinations of these, e.g. mixed mussels and sponges.

Table 4. Examples of habitats. These habitats have previously been observed in subtidal video surveys. Note that (i) only one habitat should be selected, although mixed definitions are allowed (e.g. turfing algae and sponges), (ii) physical descriptors should only be used in the absence of biological descriptors, and (iii) specifics rather than generalities (e.g. *Macrocystis* or *Ecklonia* rather than kelp) need only be used if this fits the study objectives and doing so is practical (i.e. accurate and not time consuming). For taxa that span a number of growth forms (e.g. sponges and red algae), it is more important to record the form (e.g. foliose, turfing, etc.) than the type.

Flora	Fauna	Physical
Foliose	Sponge garden	Heavy mounded
Filamentous	Mussel bed	Burrows
Turfing	Tube worm mat	Coarse sand
Kelp	Oyster reef	Shell patches
Corals	Ascidians	Sand waves
Rhodolith beds	Urchin barren	Rippled sand
Seagrass meadow	Scallop bed	Sand
Macrocystis forest	Soft-sediment gastropods	Mud
Green algal forest	Holuthurians	Reef
Ecklonia forest	Pāua	Boulders
Coralline paint	Encrusting invertebrates	Cobbles
Bull kelp (*Durvillaea*) forest	Bryozoan bed	
Red algal meadow	Seapen bed	
Mixed algae	Cerianthid bed	
	Brachiopod bed	
	Heart urchin plain	
	Surf clam bed	

If required (and if the weather allows) it may be possible to obtain close-up footage of any features of interest or collect live specimens. The person monitoring the live feed from the camera must be able to clearly communicate with the boat skipper in order to mark the GPS coordinates of any features they want more information on. Then, once the transect has been completed, the boat can return to these points and either collect close-up footage by remaining stationary and using the drop camera, or SCUBA divers can be used to collect additional footage using hand-held cameras or to bring back live specimens. Any live specimens can then be photographed on the boat and, if necessary, kept and preserved in 70% isopropyl alcohol (IPA).

Sample processing

Figure 4 shows the steps to be taken to gain the spatial heterogeneity and habitat complexity indices and the functional trait matrix.

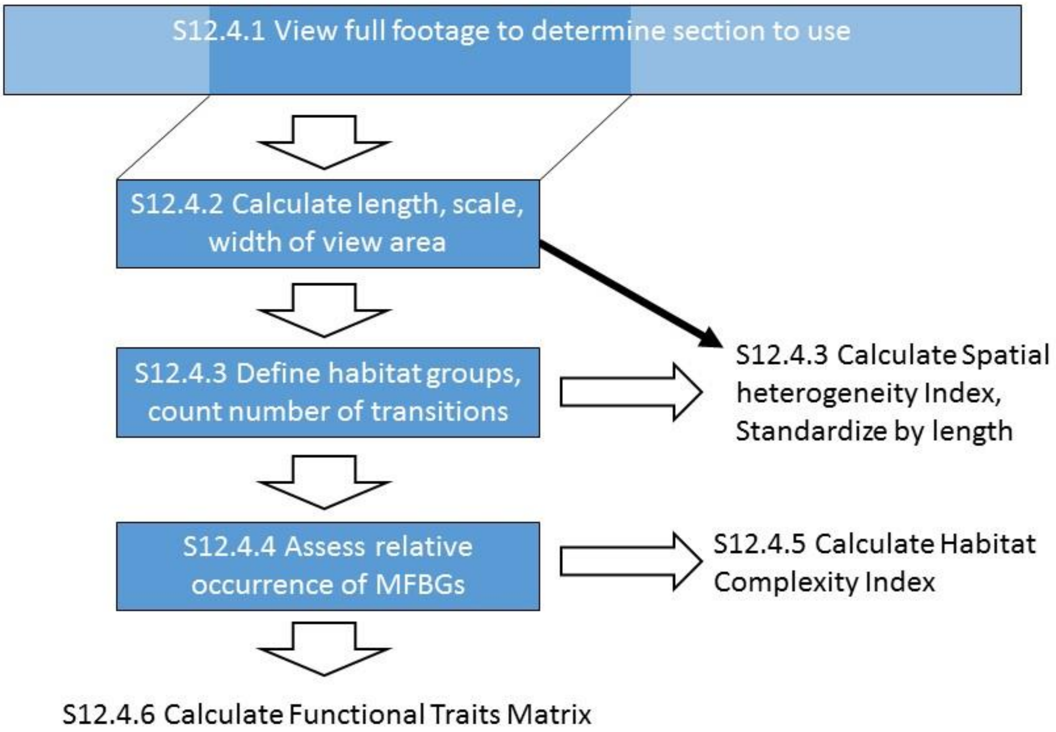

Figure 4. Flow diagram of sample processing. MFBGs = visually obvious microtopographic features and biotic groups.

Determine section of footage to use

Generally, not all footage of a transect is suitable for processing, e.g. the height of the camera varies greatly, boat speed is too fast for good viewing. After viewing the full video footage, determine the part of the footage that will be analysed (henceforth called 'video section').

Calculate length, scale, width of view and area

If filming along a tape measure, the length of footage is easily calculated. The scaling coefficient can be calculated by dividing the actual tape width by the width observed on the screen (although it is best if a ruler is videoed at the start of the transect). The width of view can then be determined by multiplying the screen width by the scaling coefficient. If the height of the camera above the seafloor varies along the footage, a separate scaling coefficient should be calculated for different camera heights. The video section area can then be calculated as width of view multiplied by length.

If not filming along a tape measure, the length of video section is calculated from the GPS coordinates recorded on the footage. The scaling coefficient can be calculated by first measuring the distance between the two lasers mounted on the frame. Once this distance is known you can use a ruler to measure the distance between the lasers' beams on the screen displaying the footage and therefore work out your coefficient. For example, if the lasers are mounted 20 cm apart but the distance between them on the video footage is only 5 cm, then your scale will be 1:4.

Determine habitat types and spatial heterogeneity index

View the video section to determine the habitat types. Habitats are defined by the dominant physical and/or biological characteristic covering ≥ 1 m^2. The use of a 1 m^2 lower limit for defining a habitat is a practical technique to ensure that time is not wasted assessing small spatial scale habitat transitions, but it means that the definition of a habitat has to include patchiness. For example, patchy seagrass, patchy mussel bed, patchy cobble-sand—all would be used to imply patchiness in the dominant habitats type at the scale below 1 m^2.

Once the habitats have been defined and recorded, the video section can be reviewed and the number of transitions from one habitat type to another can be recorded. The spatial heterogeneity index is calculated as the number of transitions standardised (divided by the transect length in metres multiplied by 50) to a 50 m standard transect.

Assess relative occurrences

View the video section to assess the relative occurrence of visually obvious microtopographic features and biotic groups (MFBGs). The term 'MFBGs' is used, rather than taxonomic groups or operational taxonomic units (OTUs), as the groups used may not necessarily be taxonomically related. Table 5 lists MFBGs observed in the Port Pegasus and Kawau Bay locations. This list is not exhaustive but gives guidance on the level of detail that can be used. Relative occurrence is used to allow integration between colonial and individual organisms and is defined as 0 (not observed), 1 (observed occasionally), 2 (common, found multiple times or for extended minutes of footage) and 3 (abundant, widespread and dominant) (de Juan et al. 2015). Examples of classifications and image grabs from video footage are given in Figures 5 to 9.

Table 5. Examples of MFBGs observed in Port Pegasus and Kawau Bays.

Port Pegasus	**Kawau Bay**
Foliose	Horse mussels
Filamentous	Sponge tall and branching
Turfing algae	Turfing algae
Ulva	Scallops
Crustose Coralline (algal paint)	Tube worms
Kelp	Sponge small no branches
Caulerpa	Mounds
Ophiuroidea	Burrows

Cerianthus	Sand waves
Holothurian	Sand ripples
Asteroidea	Shell mounds
Scallops	Starfish
Sponges-A	Asteroidea
Sponges-F	Holothurian
Ascidians tall	Ascidians short
Ascidians shorter	Nudibranchs
Mounds	Tāwera
Holes	Mixed bivalves
Black corals	Mixed gastropods
Nested mussel	*Echinocardium*
Horse mussels	Mussels
Kina	Dog cockles (*Dosinia*)
Fish	Filamentous green algae
	Holes

Figure 5. Example of horse mussel and sand habitat. An example of footage collected via drop camera from the Northwest sector of Great Barrier Island (42 m depth): moderate density of *Atrina zelandica* (distance between lasers = 22 cm). The functional traits associated with this site would be as follows: Position: epibenthic. Growth form: erect. Flexibility: calcified. Mobility: sedentary. Size: medium. Feeding: suspension feeder. Sediment stabilisation: stabiliser. If footage such as this was observed multiple times during the video section, you would say that the relative occurrence of *Atrina zelandica* was 3. However, if this footage was only glimpsed once or twice during the video section, then you would score the relative occurrence a 2.

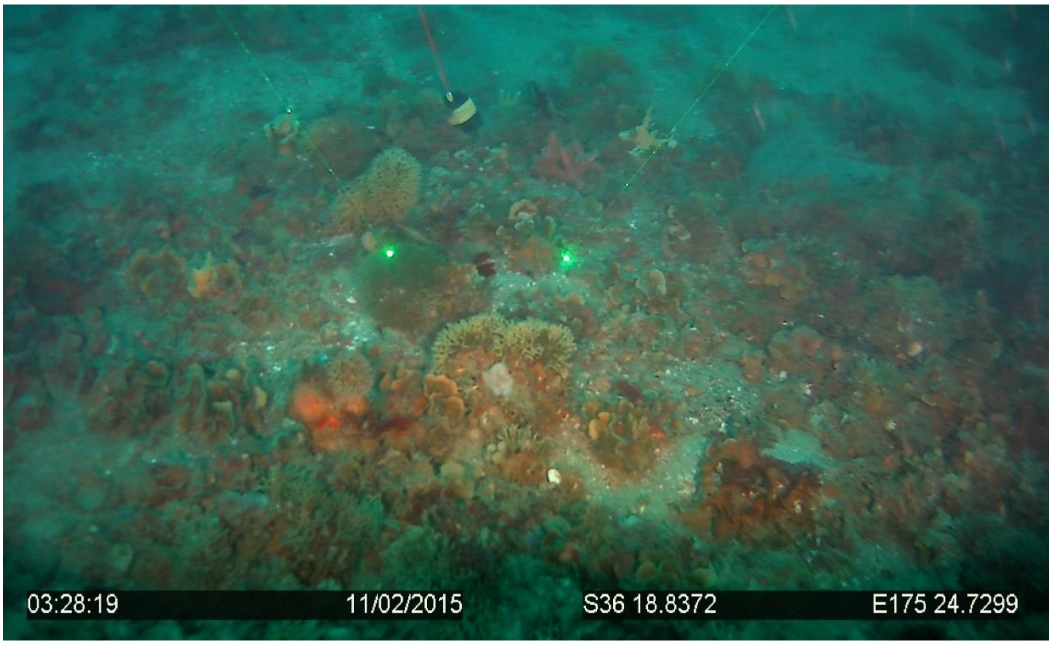

Figure 6. Example of bryozoan habitat. An example of footage collected via drop camera from the Southwest sector of Great Barrier Island (38 m depth) (distance between scaling lasers = 22 cm). The functional traits associated with this site would be as follows: Position: epibenthic and attached. Growth form: erect and crustose/encrusting. Flexibility: calcified. Mobility: sedentary. Size: small. Feeding: suspension feeder. Sediment stabilisation: stabiliser. If footage such as this was typical of the whole video section, you would say that the relative occurrence of these bryozoans was 3.

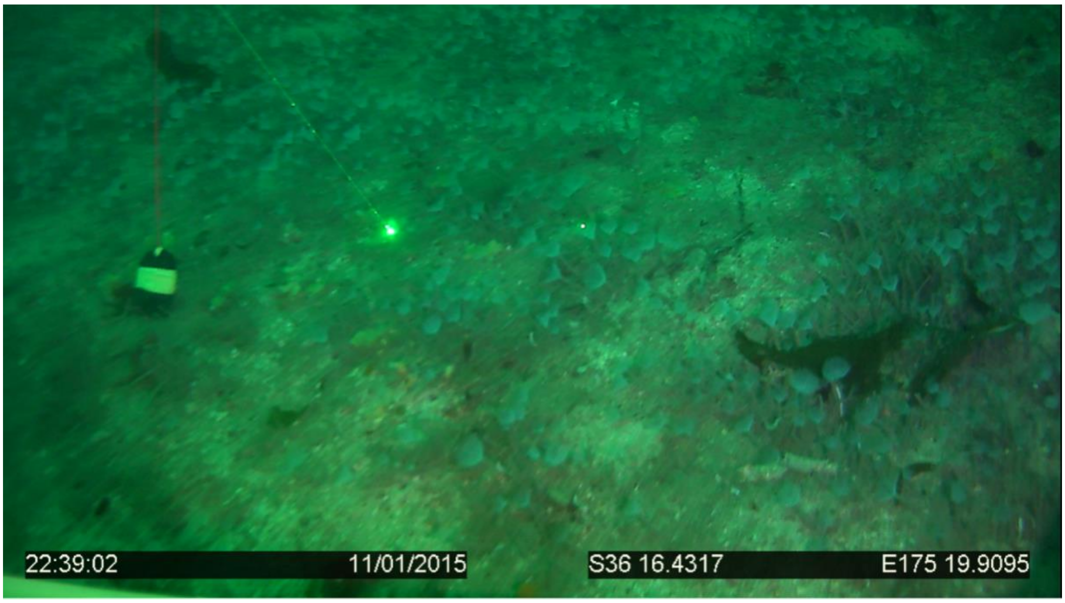

Figure 7. Example of sabellid tube worm habitat. An example of footage collected via drop camera from the Southwest sector of Great Barrier Island (35 m depth) (distance between scaling lasers = 22 cm). The functional traits associated with this site would be as follows: Position: epibenthic. Growth form: tubiculous. Flexibility: soft. Mobility: sedentary. Size: small. Feeding: suspension feeder. Sediment stabilisation: stabiliser. If footage such as this was typical of the whole video section, you would say that the relative occurrence of these sabellids was 3.

Figure 8. Example of branching sponge and shelly habitat. An example of footage collected via drop camera from the Northeast sector of Great Barrier Island (42 m depth) (distance between scaling lasers = 22 cm). The functional traits associated with this site would be as follows: Position: epibenthic. Growth form: erect. Flexibility: semi-rigid. Mobility: sedentary. Size: small and medium. Feeding: suspension feeder. Sediment stabilisation: stabiliser. If footage such as this was typical of the whole video section, you would say that the relative occurrence of these sponges was 2.

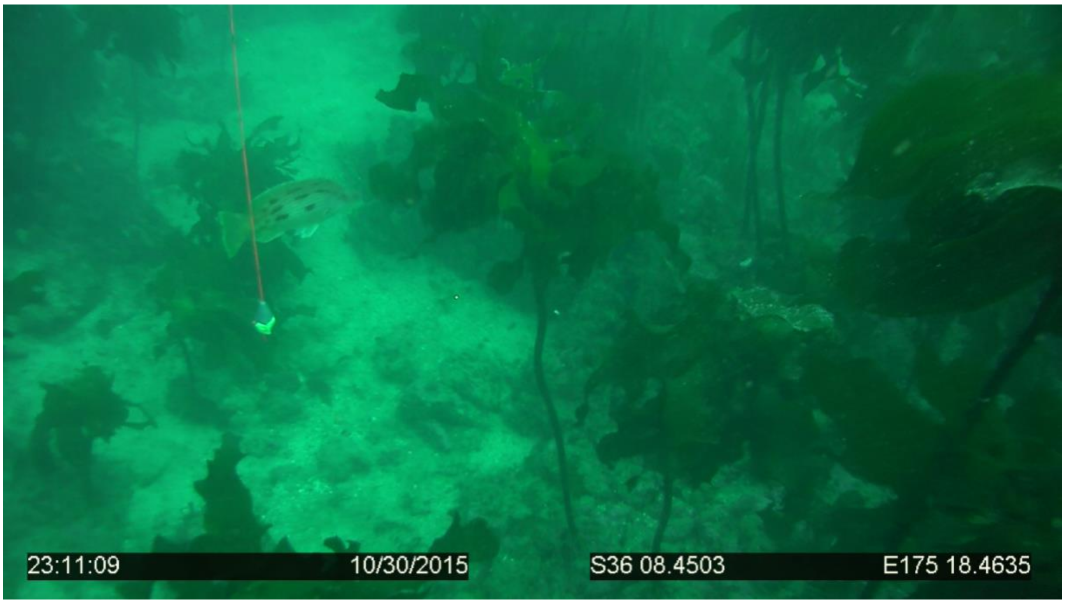

Figure 9. Example of kelp habitat. An example of footage collected via drop camera from the Northwest sector of Great Barrier Island (10–15 m depth) (distance between scaling lasers = 22 cm). The functional traits associated with this site would be as follows: Position: attached. Growth form: arborescent. Flexibility: soft. Mobility: sedentary. Size: medium and large. Feeding: primary producer. Sediment stabilisation: stabiliser. If footage such as this was typical of the whole video section, you would say that the relative occurrence of this kelp was 3.

The following procedure is suggested when viewing the first transect at the first site in a location:

- Open an Excel spreadsheet, use rows for MFBGs, and use columns for site-transect results (see Appendix B for example).
- When an MFBG is first observed, enter its name and code a 1 in the second column.
- Continue viewing the section adding new MFBGs.
- Rewind and quickly scan through the section to decide on which MFBGs are abundant, widespread and dominant. Change their code to 3.
- Rewind and quickly scan section to decide on which MFBGs are found multiple times or for extended minutes of footage. Change their code to 2.

When viewing subsequent transects at the same or other sites from the same location, use the same Excel spreadsheet and add columns. This gives you at least some predefined MFBGs.

Preferably, all transects from a site should be assessed at once so that the assessment of relative occurrence is similar. If this is not possible, at least one of the transects previously done should be reassessed when processing begins again.

Habitat complexity index

The vertical habitat complexity index is calculated from size, growth forms and sediment micro-topography that increases the vertical relief of the basal substrate (form complexity; see Table 6). A ranking system is used, depending on how intricately these forms are branched, their likely spatial extent (2-dimensional extent of a single unit) and their rigidity, based on expert's judgement. This rank is then weighted by the average vertical size of the MFBG (small = < 15 cm, medium = 15–50 cm and large = > 50 cm, multiplied by 1, 2 and 3 respectively) within the growth form and relative occurrence of the growth form.

The relative occurrence of each growth form in the video section is calculated by the following method:

- If one of the MFBGs assigned to the growth form has a relative occurrence of 3, then the relative occurrence of the growth form is 3.
- If more than one of the MFGBs assigned to the growth form has a relative occurrence of 2, then the relative occurrence of the growth form is 3 (see Appendix C for an example).
- If only one of the MFGBs assigned to the growth form has a relative occurrence of 2, then the relative occurrence of the growth form is 2 (see Appendix C for an example).
- If more than two of the MFGBs assigned to the growth form has a relative occurrence of 1, then the relative occurrence of the growth form is 2.
- If only one of the MFGBs assigned to the growth form has a relative occurrence of 1, then the relative occurrence of the growth form is 1.
- Otherwise, the relative occurrence of the growth form is 0.

Habitat complexity (HC) for each growth form is then calculated as form complexity multiplied by average vertical structure (ave VS) multiplied by growth form relative occurence (GFRO) (see Appendix C for an example).

Table 6. Growth form and microtopographic categories (left-hand column) assigned during the analysis of Port Pegasus and Kawau Bay data. Scores were assigned to these categories depending on the degree of branching, spatial extent and rigidity, which summed together give the 'form complexity' score.

Growth form and sediment microtopographic features	Branching	Spatial extent	Rigidity	Form complexity
Arborescent	3	1	1	5
Foliose	3	1	-	4
Erect colonial or bed-forming	1	2	1	4
Single tubes	1	-	1	2
Erect other	1	1	1	3
Crustose	1	-	-	1
Mounds	1	2	-	3
Burrows	1	1	-	2

Functional traits

Similarly, each MFBG can be assigned a probability of exhibiting a trait from each trait category (see Table 7). Generally an MFBG will either exhibit a trait or not. For example, flora will either be classed as soft or rigid in the flexibility category. However, in some cases an MFBG can exhibit more than one trait, e.g. being a suspension and a deposit feeder, or being able to swim and crawl. When this occurs the trait is given a probability of occurrence ranging from 0 to 1. The sum of the probabilities across the traits in the category should be 1 (see Table 8 for example).

Table 7. List of functional traits and trait categories that can be recorded in video surveys.

Trait category	Megafauna	Flora
Position/living habitat	Epibenthic, attached, infauna (endobenthic)	Epibenthic, attached
Growth form	Crustose/encrusting, globose/cushion, arborescent, tubiculous, bed forming, erect, vermiform, turbinate, stellate, bivalvia, articulate, pisciform, burrow-dweller	Foliose, laminar, arborescent
Flexibility	Soft, rigid, calcified	Soft, rigid
Mobility	Swimming, crawling, burrow, sedentary	Sedentary
Size	Small, medium, large	Small, medium, large
Feeding	Suspension feeder, deposit feeder, predator, scavenger, opportunistic, grazer	Primary producer
Sediment stabilisation	Stabiliser, destabiliser, no effect	Stabiliser, no effect

Table 8. Example of assigning traits.

Category	Trait	MFBG		
		Flatfish	Horsemussel	Brittlestar
Mobility	Swimming	0.6	-	-
	Crawling	-	-	0.4
	Burrowing	0.4	-	0.6
	Sedentary	-	1	-
	Sum	**1**	**1**	**1**
Feeding	Suspension	-	1	-
	Deposit	-	-	0.3
	Predator	1	-	0.3
	Scavenger	-	-	0.4
	Opportunistic	-	-	-
	Grazer	-	-	-
	Sum	**-**	**1**	**1**

Once the MFBGs have been assigned to traits, relative trait occurrence can be assessed as follows. For each MFBG, for each trait, calculate trait probability relative occurrence (TPRO) as the MFBG relative occurrence multiplied by the trait probability (see Appendix D for an example).

For each trait:

- If the TPRO of one of the MFBGs is 3, then the relative occurrence of the trait is 3.
- If more than one of the MFGBs have a TPRO > 2, then the relative occurrence of the trait is 3.
- If only one of the MFGBs has a TPRO > 2, then the relative occurrence of the trait is 2.
- If more than two of the MFGBs have a TPRO > 1, then the relative occurrence of the trait is 2.
- If only one of the MFGBs has a TPRO > 0, then the relative occurrence of the trait is 1.
- Otherwise, the relative occurrence of the trait is 0.

These data should be entered in the form of a matrix of relative occurrence (trait × transect, see Appendix E for an example).

Timing

Consideration of timing of the surveying activity should include:

- Any diurnal, seasonal or lunar characteristics that 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 management[3] 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 two people make up the 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

Quality control

Quality control measures should be used to ensure that data quality is consistent across surveys and with previous surveys.

- Identification of any organisms and/or structures should be carried out by somebody with expert knowledge.
- If there is any uncertainty in the identification process, then a second opinion should be sought from another experienced individual.
- Where possible, a consistent height above the seafloor should be decided upon and maintained to provide a consistent field of view.

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Appendix A

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

doccm-1163829	MPAMAR metadata—National
doccm-2666541	Assessing the functional trait diversity of benthic marine areas using video cameras
doccm-2794895	Functional trait data sheet
doccm-2795216	Functional traits: definition of data fields
doccm-2795138	Functional traits: encoding sheets and form
doccm-146272	Standard inventory and monitoring project plan

Appendix B

Raw data template

MFBG = microtopographic features and biotic group RO = relative occurrence VS = vertical size	Location =			
	Site =			
	Transect 1		**Transect 2**	
MFBG	**RO**	**VS**	**RO**	**VS**
Scallops	2	1	-	1
Atrina	2	2	2	2
Hydroids	1	1	-	1
Erect finger sponge	3	1	3	1
Large chaetopterid tubes	2	1	-	1
Foliose weed	1	2	-	2
Small tube worms	3	1	-	1
Sand	2	-	3	-
Mud	3	-	-	-
Small ascidians	1	1	-	1
Bioturbation	2	-	2	1
Gastropods	-	-	1	-
Crabs	-	-	1	-
Ripples	-	-	2	-
Turfing algae	-	-	1	1
Starfish	-	-	2	-
Hermit crabs	-	-	1	-
Mounds	-	-	2	1
Shell hash patches	-	-	2	1

Appendix C

Example of calculation of habitat complexity

Blue boxes illustrate an example of the calculation of the relative occurrence of each growth form (GFRO) as described in the 'Habitat complexity index' section. Habitat complexity (HC) for each growth form is calculated as form complexity multiplied by average vertical structure (ave VS) multiplied by GFRO (example in red boxes).

MFBG = microtopographic features and biotic group GF = growth form RO = relative occurrence VS = vertical size GFRO = growth form relative occurrence HC = habitat complexity		Location =										
		Site =										
		Transect 1						Transect 2				
MFBG	**GF**	**Form complexity**	**Transect 1**	**VS**	**ave VS**	**GFRO**	**HC**	**Transect 2**	**VS**	**ave VS**	**GFRO**	**HC**
Erect finger sponge	Arborescent	5	3	1	1	3	15	3	1	1	3	15
Bioturbation	Burrows	2	2	1	1	2	4	2	1	1	2	4
Crabs	Burrows	2	-	-	-	-	-	1	1	-	-	-
Scallops	Erect colonial or bed-forming	4	2	1	1.2	3	14.4	-	-	2	2	16
Atrina	Erect colonial or bed-forming	4	2	2	-	-	-	2	2	-	-	-
Hydroids	Erect colonial or bed-forming	4	1	1	-	-	-	-	-	-	-	-
Large chaetopterid tubes	Erect colonial or bed-forming	4	2	1	-	-	-	-	-	-	-	-
Small ascidians	Erect colonial or bed-forming	4	1	1	-	-	-	-	-	-	-	-
Turfing algae	Erect colonial or bed-forming	4	-	-	-	-	-	1	1	-	-	-
Foliose weed	Foliose	4	1	2	2	1	8	-	-	-	-	0

Mounds	Mounds	3	-	-	-	0	0	2	1	1	3	9
Shell hash patches	Mounds	3	-	-	-	-	-	2	1	-	-	-
Small tube worms	Single tubes	2	3	1	1	3	6	-	-	-	0	0
	Total habitat complexity						**47.4**					**44**

Appendix D

Example of calculation of functional traits

MFBG = microtopographic features and biotic group FT = functional trait RO = relative occurrence TPRO = trait probability relative occurrence FTRO = functional trait relative occurrence		Location =					
		Site =					
		Transect 1			**Transect 2**		
MFBG	**FT**	**RO**	**TPRO**	**FTRO**	**RO**	**TPRO**	**FTRO**
	Sedentary			**3**			**3**
Small tube worms	0.5	3	1.5		0	0	
Atrina	1	2	2		2	2	
Hydroids	1	1	1		0	0	
Erect finger sponge	1	3	3		3	3	
Large chaetopterid tubes	1	2	2		0	0	
Small ascidians	1	1	1		0	0	
Turfing algae	1	0	0		1	1	
	Burrowing			**2**			**2**
Scallops	0.5	2	1		0	0	
Small tube worms	0.5	3	1.5		0	0	
Bioturbation	1	2	2		2	2	
Crabs	1	0	0		1	1	
Turfing algae	1	0	0		1	1	

Appendix E

Example of functional trait matrix

	Location =		
	Site =		
Functional trait	**Transect 1**	**Transect 2**	***etc.***
Sedentary	3	3	
Burrowing	2	2	
Crawling			
Swimming			
etc.			