Marine: baited underwater video surveys for fish

Version 1.0

This specification was prepared by Vincent Zintzen in 2016. Based on the document:

Haggitt, T.; Freeman, D.; Lilley, C. 2014: Baited remote underwater video guidelines. Prepared by eCoast for the Department of Conservation, Wellington. 82 p. (doccm-1395189) http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-baited-remote-underwater-video-guidelines.pdf

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Inventory and monitoring toolbox: marine

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Department of Conservation
Te Papa Atawhai

Synopsis

Collecting data on reef fish abundance, diversity, and demographic attributes is an important directive of environmental monitoring programmes, both within and outside New Zealand's marine protected areas (MPAs). Baited underwater video (BUV) is an unobtrusive sampling method which is effective in providing size and abundance estimates of scavenger and carnivorous reef-fish species that can be difficult to survey using divers (Willis & Babcock 2000; Harvey et al. 2004; Shortis et al. 2009).

Within New Zealand, this technique was initially adopted by researchers at the University of Auckland (Willis & Babcock 2000) to undertake snapper (*Chrysophrys auratus*) and blue cod (*Parapercis colias*) size and abundance assessments as part of MPA surveys. This method was primarily used as a response to counteract diver-positive and diver-negative biases for snapper observed during earlier visual census surveys (Cole 1990, 1994).

Prior to conducting a BUV study, consideration should be given to identifying monitoring objectives and the motives for these:

- What species is the survey going to be primarily targeting?
- What are the central hypotheses to be tested and do these satisfy the management/survey objectives?
- Statement of clear outcomes of the surveys relative to the original monitoring objectives.

A range of BUV systems are available and used in New Zealand (Willis et al. 2000; Willis & Babcock 2000; Willis et al. 2003; Roux de Buisson 2009; Morrison & Gregor 2012; Zintzen et al. 2012; Díaz-Guisado 2014; Richardson 2015). Two main setups are available: (1) downward-facing, which look down at the seabed (Figure 1) and (2) forward-facing, which look horizontally while lying on the seabed (Figure 2). The downward-facing BUV system is relatively simple and inexpensive compared to other available gear (for reviews see Cappo et al. 2006; Mallet & Pelletier 2014). It consists of a triangular metal frame which serves as support for gear and has a calibrated field of view, a container with bait to attract fishes, and one downward-facing high-resolution camcorder which is sometimes linked to a monitor on the surface (Figure 1).

BUV units are normally positioned on soft sediment within 20–30 m from rocky reef habitat for 30 minutes (Denny et al. 2004; Langlois et al. 2010). This approach allows for unobstructed placement on the seabed and consistency in the type of habitat sampled across different areas, e.g. reserve and non-reserve sites. However, the final decision on the positioning of the unit will ultimately depend on the objectives of the study, the particular configuration of the area being sampled or on the methodology used in any previous sampling. Careful steps have to be taken when selecting sites to obtain data that are statistically robust. In particular, if the objective is to follow the trend of fish densities and size after protection, it is important to adequately sample within and outside the protected area. Those steps are detailed in 'Full details of technique and best practice'.

Typically, sampling is repeated annually, at a fixed time of the year (which varies with the species of interest), and can be used in long-term monitoring to capture the trend of the fish population demographic. In order to obtain usable time-series, methodology must be consistent across the different sampling periods.

Assumptions

- Water visibility is good enough to sample the fish species of interest. A general rule is that BUV should not be conducted unless there is at least 2–3 m of underwater visibility. Visibility should be sufficient to identify the fishes when reviewing the videos.
- Oceanographic and geomorphological conditions at the different sites are similar. If not, the bait plume dispersion could be significantly different between sites, which will confound abundance estimates.
- Bait type, quality and quantity are standardised. The same bait species should be used for all deployments. Pre-frozen pilchards *Sardinops sagax* (Jenyns 1842) are recommended.
- BUV units are consistently deployed on similar habitat type (e.g. on soft sediment at 20–30 m of the reef edges) since this will have an influence on the type and abundance of observed species. Species display habitat preferences.
- Behaviour of species towards BUV units is not density-dependent. Density of species in a sampling area can be, for example, influenced by the protection status or management regime. This hypothesis has been recently challenged for snapper and needs further research. This species might have larger home ranges in non-reserve sites and utilise more than one main area, whereas reserve snapper had higher site fidelity with only one main area of use (Parsons et al. 2010).
- BUV deployments are independent from each other (i.e. are true replicates). To avoid attraction of the same fish specimen to different deployments, consideration needs to be given to factors such as current speed, length of deployment and distance between deployments. For example, a minimum distance of 360 m between deployments is recommended for deployments of 45-minute duration (assuming current speed of 0.2 $m.s^{-1}$ and fish swimming speed of 0.6 $m.s^{-1}$; this comprises 30 minutes of advection of the bait plume down-current and 15 minutes of fish swimming time up-current to reach the field of view in time to be recorded on the BUV; from Cappo et al. 2004, see details of calculation in 'Full details of technique and best practice').
- Size frequency of individuals during highest observed abundance (MAX*count*) is representative of the size frequencies across the entire duration of the deployment. This may not be the case, e.g. if smaller individuals are displaced by larger ones as abundance increases at the bait.

Advantages

- Gives estimates of **relative** abundance of species and allows specimen sizes to be measured.

- Non-destructive method.
- Can be deployed on a wide range of habitats.
- Data beyond diver-accessible depths can be acquired.
- Results are not affected by varying levels of water visibility, pending that visibility is sufficient to view the seabed and identify the species.
- High level of repeatability.
- Few personnel needed on boat to operate.
- Scientific divers not required, lowering the survey cost and need for expertise. Note, however, costs associated with the processing of imagery, which can be significant.
- Several self-contained units can be used at the same time.
- Provides a permanent record that can be re-analysed in the future.

Disadvantages

- Biased toward sampling carnivorous fishes. Although other fishes can also be attracted to the bait (Harvey et al. 2007), they will more likely be seen using a forward-facing system.
- Counts are likely to be underestimated, as not all individuals will be seen at any one time on a video frame grab. For relative comparisons between sites, this problem only matters if the degree of underestimation is density-dependent.
- Size frequencies are based on measuring specimens during highest observed abundance (MAX*count*) but could potentially be density-dependent.
- The bait plume will change according to current and geomorphology of the area, affecting how many fish will be attracted to the video unit.
- Post analysis is time-consuming and requires software knowledge and ability to identify species on video.
- Identification of small species (e.g. triplefins) can be difficult or impossible with downward-facing BUV systems and current video resolution. However, most species commonly studied with this system are usually easily identified with dorsal shots at current image resolution.
- Inter- and intra-specific interactions may prevent some individuals, size classes or species reaching the bait.
- Noise generated from vessels (particularly diesel powered) can either attract or deter reef fishes during BUV deployment and retrieval, therefore potentially biasing fish surveys (De Robertis & Handegard 2012).
- Potential limitations occur around the accuracy of size estimates for specimens measured at the periphery of the field of view, where wide-angle lens distortion is likely to be greatest, and for those occurring at heights well above the bait container. This disadvantage can be alleviated by the use of stereo BUV systems or single-camera forward-facing systems for species where a relationship between relative eye size and body length for the considered species exists (Richardson 2015).

- Saturation, although rare, can occur in the field of view when too many individuals are present around the bait, preventing them from being all visible at any one time.

Suitability for inventory

- Inventories of large scavenger and carnivorous species may be possible.
- The technique is strongly biased towards large scavenger and carnivorous species which are attracted to the bait; consequently, it is unsuitable for inventories of herbivorous species or for assessing the fish richness of an area.
- Inventories of small species (e.g. triplefins) are limited by both the resolution of the video and potentially by the configuration of the video system. Downward-facing systems only offer a dorsal view of individuals while forward-facing systems offer lateral views that are more useful for fish identification.
- Incidental data on aspects such as benthic habitats can be collected.

Suitability for monitoring

- This method is suited for monitoring scavenger and carnivore fish species (Willis & Babcock 2000; Harvey et al. 2004; Shortis et al. 2009). It can provide information on the relative abundance and size class distribution of these species.
- Consideration of the timing of BUV surveys is crucial in designing monitoring studies because some species undergo seasonal migrations or dietary shifts depending on ontogenetic stage and season. For example, Willis et al. (2003) observed seasonal peaks in abundance of snapper, which they attributed to seasonal migrations (although facets of diet and feeding may have also been important in explaining the observed patterns).

Skills

BUV systems require a moderate level of expertise to both assemble and use in the field. More extended expertise is required for processing and analysing the video data post-fieldwork.

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 positioning of sampling sites
- Transfer of sites coordinates to portable GPS

In the field:

- Knowledge of video equipment and its use at sea
- Familiarity with deploying gear at sea

- Use of portable GPS
- Good fitness and upper body strength is required for deploying and retrieving BUV systems

Processing of imagery:

- Fish identification skills
- Familiarity with MS Excel and image analysis software

Data analysis:

- Familiarity with basic statistics
- Familiarity with statistical package (R recommended)

Resources

BUV setup and associated equipment

This section outlines the equipment required for a typical BUV survey, but more details are given in '[Full details of technique and best practice]'. A scaled drawing with specific dimensions of a standard downward-facing BUV unit is given in Figure 1A. Other, more stable systems are also in use in New Zealand (Willis & Babcock 2000). They have the advantage of moving less once deployed on the seabed, avoiding scaring fishes (especially snapper, T. Willis pers. comm.), but at the cost of heavier weight and more difficult manipulation in the field. Recent tests at the Poor Knights Islands comparing the L Frame used by DOC and the sturdier frame used by Willis and Auckland University did not show significant effect on the number or sizes of snapper observed at the bait (V. Zintzen, pers. comm.). Effect size was very small (0.25 for counts and 0.10 for size expressed in mm). With these results, a sample size of n = 492 and n = 4738 would be required to produce a significant difference at α = 0.05 and power = 0.80. The number of deployments was, however, relatively low (n = 24) and should be expanded to confirm these findings.

The main components of BUV which may change over time with technology advancements are the camera and housing. Increased video resolution might improve identification of small or difficult-to-identify fish species. A checklist of equipment and consumables required for fieldwork is provided in Table 1.

The BUV unit is constructed of three main parts (Figure 1):

1. Camera housing that contains a removable digital video recorder.
2. A base scale bar that sits on the seabed when deployed.
3. A movable angled bar that links the scale bar and the camera housing.

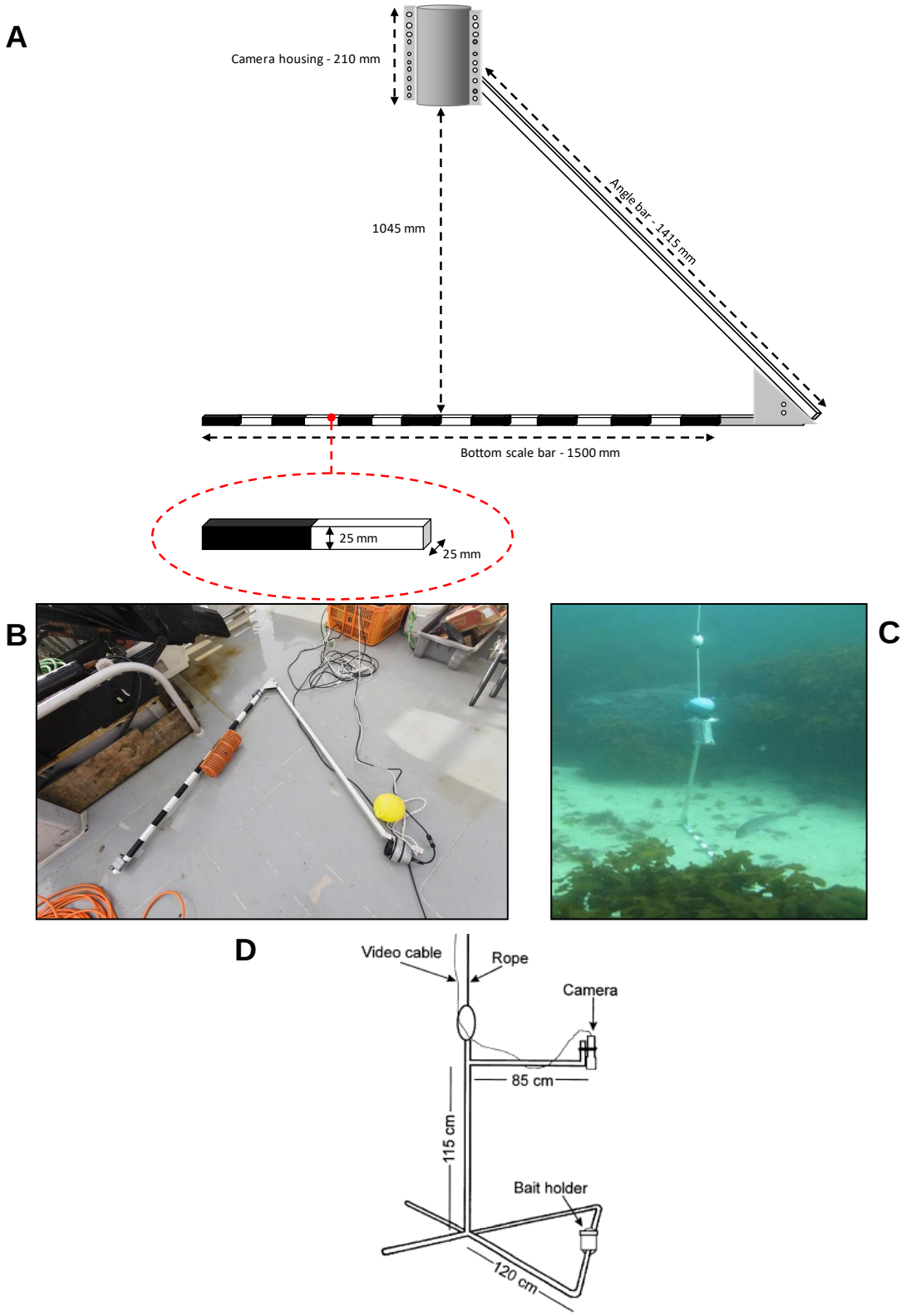

Figure 1. BUV unit used by DOC: (A) drawing with accompanying measurements (mm) for camera housing, angle bar, and bottom scale bar; (B) photo of unit ready to be deployed; (C) BUV placed on soft sediment substratum within 20 m of rocky reef habitat; and (D) a more complex and stable frame used by Willis & Babcock (2000) and Auckland University.

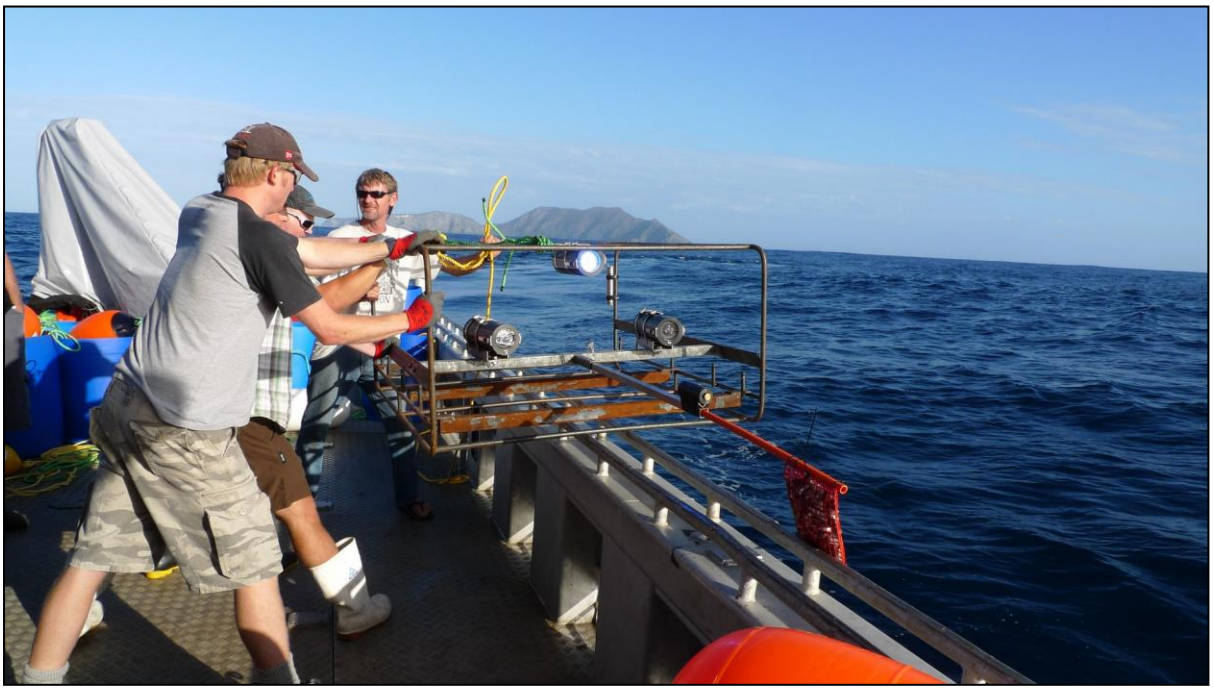

Figure 2. Forward-facing BUV system deployed by Te Papa scientists off the Three Kings Islands. Note the heavyweight bars at the base of the unit, the two video housings for the stereo system, which allows for measurement in three dimensions, and the lighting system. This unit is set up to be sent to 1200 m. Similar but lighter units are used at shallower depths.

Human resources

Survey work will require a minimum of two people (a boat skipper and crew to deploy and retrieve the BUV), although three people are recommended.

Table 1. BUV checklist—main hardware, tools and consumables.

Last updated: **By:**

Item	Checked ✓	Working ✓	Replacement date	Notes
HARDWARE				
Camera stand and accompanying screws				
Camera housing and o-ring				
Lens and accompanying screws				
Video camera and spare batteries				
Drop camera including surface screen, RCA video cables and 12 V battery				
Bait pot				
GPS (spare batteries if stand-alone)				
Depth finder				
Clock				
White board, marker pen and data folder				
Pressure buoy including spare				
Surface float and rope				
Rope (general)				
TOOLS				
Flat head screwdriver				
Phillips screwdriver				
Square-drive screwdriver				
Pliers				
CONSUMABLES				
Hose clamps				
Carabiners				
D-shackles				
Electrical tape (black and white)				
Bait				
O-ring				
DV tapes, DVDs or memory cards				
Paper towels				
Hand towel				
Anti-fog solution				
Rubber bands (assorted)				
Cable ties (assorted)				
Spare screws (assorted)				
Silicone grease				
Silica gel				
Fuses (10–20 amp) for drop camera				
Polypropylene rope—spare (10 mm dia.)				
SCUBA gear				
Fish bins for storing ropes				

Minimum attributes

Consistent recording and measurement 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).[1]

Data collection

The minimum set of attributes to be collected when deploying BUV units is presented in A data sheet for logging information while at sea is available online: 'BUV deployment data sheet' (doccm-2618429).

Table 2.

A data sheet for logging information while at sea is available online: 'BUV deployment data sheet' (doccm-2618429)[2].

Table 2. Minimum set of attributes to be collected when deploying BUV units.

Field	Description	Value
Location	General location where the survey took place (e.g. Ulva Island).	Short text
SiteName	The name of a site located within *Location* where the unit was deployed.	Short text
DeploymentID	A unique identifier during this survey for this video deployment.	Unique number
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
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
RecordedBy	First and last name of the person who recorded the	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-buv-deployment-data-sheet.pdf

	metadata during the survey (onboard the vessel).	
Vessel	Name of the vessel used for the survey.	Short text
BUV_type	Describes the type of BUV used for the survey, e.g. L-frame, Willis frame.	Short text
CameraModel	Describes the type of camera used for the deployment (make and model).	Short text
LensModel	Describes the type of wide angle lens used for the deployment, if any.	Short text
BaitSpecies	Name of the bait species used.	Short text
BaitAmount	Amount of bait used for deployment (g).	Number
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.
Depth	Depth in metres of the deployment as recorded by the sonar of the boat.	Number
EventDate	Date at which the deployment was made.	Date (dd/mm/yyyy)
EventTimeStart	Time the unit entered the water.	Time in 24 h format (hh:mm)
EventTimeEnd	Time the unit was retrieved from the seabed.	Time in 24 h format (hh:mm)
UnderwaterVisibility	Estimation of the water visibility, in metres, as assessed with a Secchi disk or description of the water visibility as seen from the video deployment, with three categories: good, fair, poor.	Integer or one of three values ‘Good’, ‘Fair’, ‘Bad’
Habitat	Brief description of the nature of the seabed (mud, sand, gravel, cobbles…)	Unlimited text
ReefDistance	Distance in metres from the reef at which the unit has been deployed, as estimated from the boat	Integer
Weather	Description of the atmospheric conditions (wind, sea state, swell…)	Unlimited text
NotesDeployment	Any additional notes of interest in relation to this deployment.	Unlimited text

Linking video footage to metadata

It is essential to be able to link the footage of a deployment to its metadata (lat, long, depth, etc.) once back from the survey. To this effect, the first seconds of a deployment should record information such as *Location*, *SiteName*, *EventDate* and *DeploymentID* that the experimenter has written on a whiteboard.

Video processing

The following minimum attributes should be recorded when processing the video images:

- **MAX*count*** for each species of interest
- **Total Length**, which should be estimated for each individual belonging to a species of interest in the MAXcount frame

See 'Analysis, interpretation and reporting' for details on those measures.

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.

Management and storage of raw data

It is essential that all raw (unprocessed) video data are labelled and stored in a suitable manner. Depending on the storage medium (e.g. hard drive, DVD, digital tape, memory cards, etc.) ensure that, as a minimum, the survey date and sites surveyed accompany each format (e.g. Figure 3). Other supporting notation (e.g. surveyors, boat, etc.) may also be of value. Generally, adhesive writeable labels are supplied with DV tapes, and DVDs and memory cards can be written on with permanent marker.

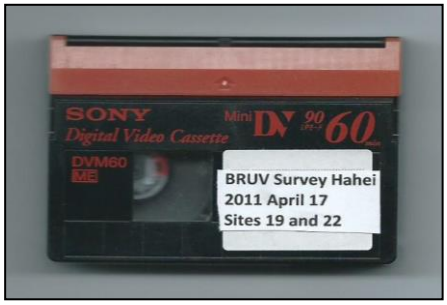

Figure 3. Example of labelling for raw BUV data stored on digital video tape.

Following field sampling, raw (unprocessed) video data should be digitised and backed up to a computer hard drive. Paper forms should also be digitised and backed up along with the video data. Appropriately labelled folders and subfolders should be created and used to archive the data. To ensure multiple copies are in existence, the downloaded data should be backed up further to external hard drives.

Editing can be done in programs such as Windows Movie Maker; however, when rendering edited data, ensure that the highest video quality settings are used (i.e. do not sacrifice video quality for storage space). It is preferable to capture and edit data for each site and place them into a separate video folder with corresponding date and site name, thus ensuring copies of both raw and edited data are archived. When editing video, be sure to retain the frames that contain the site details and entire descent of the BUV unit from vessel to the seabed.

Management and storage of edited data

Due to continuous filming over consecutive video drops, raw video will contain a range of unnecessary material that may require editing (removal) before formal analysis and archiving.

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’.

Data acquisition phase

To acquire usable data metrics, the video footage will have to be reviewed using specialised software. Procedures to obtain such data are given in ‘Full details of technique and best practice’.

Data metrics

The key abundance metric is **MAX*count*** (Willis et al. 2000) for each species of interest, i.e. the maximum number of specimens for each species of interest found during the length of the deployment. To find MAX*count* for each species, the maximum number of individuals of each species can be measured at every 30- or 60-second interval. This means that the reviewer will analyse the maximum number of individuals that are present over a period of 30 or 60 seconds, take note of this, and repeat the process for the next 30 or 60 seconds. MAX*count* will be the highest value recorded for the intended length of deployment from all values. This metric has the advantage of avoiding multiple counts of the separate visits of the same individual fish to the field of view, and as such, are conservative estimates of abundance. Refer to Willis et al. (2000) for background information pertaining to MAX*count*. Specimens that compose the MAX*count* are then used for size analysis.

The key size metric is **Total Length** (often abbreviated TL), which should be estimated for each specimen in the video frame where MAX*count* was identified. This procedure should be repeated for each species of interest. Size analysis is done with image measurement software. It is sometimes recommended to record the size of small fishes appearing early in a deployment and having been scared off by larger specimens when MAX*count* was recorded, as was observed for snapper by Willis et al. (2003). Additional data may be useful to collect, depending on the objective of the survey. For example, when the objective is to assess the effects of protection (or conversely, effects of fishing) it may be useful to divide the size data into legal and sub-legal size classes based on commercial and recreational minimum size limits. This will ultimately depend on the fisheries management area and, in some instances, timing of the survey.

If the MAX*count* occurs in multiple 30- or 60-second windows, then length measurements should be made for specimens of the first window where MAX*count* was observed in order to minimise potential effect of bullying on size frequencies analysis.

Recommended approach

As a general approach to presenting and analysing count and size data, the following steps should be undertaken:

- Undertake exploratory data analysis and graphically present data using central tendency measures (e.g. arithmetic mean and measures of error).
- Test data for violation of assumptions of normality, homogeneity of variance and independence via residual analysis if the data is to be tested using a normal model, like an ANOVA (see Zuur et al. 2007 and Zuur et al. 2009 for summary and worked examples).
- Undertake formal statistical analysis to test main hypotheses—preferably generalised linear modelling (GLM) using a Poisson distribution framework for count data (see Zuur et al. 2009 for summary and worked examples). Size data may be amenable to analysis of variance (ANOVA) or *t*-test analysis.

Data exploration and analysis

Following the data acquisition phase, there should be two sets of data generated for each BUV drop. The first set corresponds to MAX*counts* for the various species enumerated, and the second dataset corresponding to sizes for each specimen constituting the MAX*count* (Figure 4).

Once raw count and size data have been collected and collated, and data quality checks run, formal data analysis can be undertaken. The data analysis techniques presented in this section are not exhaustive and the theory underpinning some of the techniques is well beyond the scope of this document. As a prerequisite, the analyst should be familiar with linear and non-linear regression. The statistical references of Zuur et al. (2007) and Zuur et al. (2009) provide an excellent background and foundation regarding statistical inference and analysis of the type required to examine count and size data.

	A	B	D	E	F	G	H	I	J	K	L	M	N	O
1	**BRUV VIDEO ANALYSIS - 30s**				MAX	Time	MAX	Time	MAX	Time	MAX	Time	MAX	Time
2	**Deployment info** Upload pictures		Time interval	Replicate	Thyrsites atun	Barracouta	Pseudolabrus miles	Scarlet Wrasse	Parapercis colias	Blue Cod	Notolabrus celidotus	Spotty	Dasyatis brevicaudata	Shortail stingray
3	Encoder of this data (First and last name)	*Emma Brown*	0:02:42	0										
4	Tape analyst (First and last name)	*Emma Brown*	0:03:12	1										
5	Date of data entry (dd/mm/yyyy)	*6/11/2015*	0:03:42	2										
6	DocCM link to field sheets	V sites - Tapuae Marine Reserve	0:04:12	3										
7	DOC Region	*Central North Island*	0:04:42	4										
8	DOC Office	*Ngāmotu / New Plymouth Office*	0:05:12	5										
9	Contractor	*Contractor*	0:05:42	6	1	5:59								
10	Contract number	*Contract_num*	0:06:12	7	1	6:34								
11	BRUV type	*L Frame*	0:06:42	8			1	6:45						
12	Camera model	*HDR-XR350VE*	0:07:12	9										
13	Lens model	*Raynox QC-303*	0:07:42	10										
14	Survey leader (First and last name)	*Callum Lilley*	0:08:12	11			1	8:15						
15	Recorder (First and last name)	*Callum Lilley/Bryan Williams*	0:08:42	12							1	8:56		
16	Date of deployment (dd/mm/yyyy)	*13/04/2011*	0:09:12	13	1	9:17								
17	Vessel used to deploy unit	*Orca*	0:09:42	14			1	10:11						
18	Bait species	*Pilchard*	0:10:12	15					1	10:39				
19	Amount of bait (g)	*100*	0:10:42	16					1	10:54				
20	Deployment number (unique #)	*Deployment_ID*	0:11:12	17	1	11:22								
21	Location	*Tapuae Marine Reserve*	0:11:42	18	1	12:08	1	11:58						
22	Site name	*BB2*	0:12:12	19										
23	Replicate number within site	*1*	0:12:42	20	1	12:51	1	12:57						
24	Protection status	*No protection*	0:13:12	21			2	13:40	2	13:33				
25	Latitude south degree (°)	*39*	0:13:42	22	1	13:49	3	13:45	2	13:45				
26	Latitude south minute (mm.mmm)	*5.609*	0:14:12	23			1	14:23	2	14:17				
27	Longitude east degree (°)	*173*	0:14:42	24	1	15:06	2	14:46	2	14:46				
28	Longitude east minute (mm.mmm)	*58.147*	0:15:12	25			2	15:19	2	15:14				
29	Depth (m)	*14.4*	0:15:42	26			1	15:46	1	16:11				
30	Time unit in (hh:mm)	*08:17*	0:16:12	27			1	16:36	2	16:26				
31	Time unit out (hh:mm)	*08:52*	0:16:42	28			2	16:48						
32	Underwater visibility (m)	*UW_visibility*	0:17:12	29			4	17:22	1	17:18				
33	Habitat description	*Rocks, algae*	0:17:42	30			3	17:59	1	17.42				
34	Distance to reef of deployment (m)	*0*	0:18:12	31			2	18:40						
35	Weather	*Fine*	0:18:42	32			2	18:55	1	18:59				
36	Notes	*Notes_deployment*	0:19:12	33	1	19:39	1	19:24						
37	Path to pictures	*Path_picture*	0:19:42	34			2	19:55						
38			0:20:12	35			1	20:34						
39	Save data for this deployment	Recall last deployment info	0:20:42	36			1	20:45	3	21:07				
40			0:21:12	37			2	21:17	2	21:13				
41			0:21:42	38			1	21:52	2	21:45				
42			0:22:12	39			1	22:21	2	22:34				
43			0:22:42	40			2	23:09	2	22:48				

Transfer to database | video data 30sec interval | video data 60sec interval | All counts compiled | MaxCount compiled | Lengt

Figure 4. Example data sheet displaying MAX*counts* for several species of BUV deployment at Tapuae Marine Reserve (Taranaki), using a 30-second interval.

Exploratory data analysis

Following data collation, exploratory data analysis is a convenient way to examine the structure of the data, identify potential outliers, and get a general feel for the data prior to formal analysis. This may include summary statistics for a particular variable, such as measures of central tendency (i.e. mean, median and mode) or the data spread (e.g. range, quartiles, interquartile range, variance and standard deviation).

Graphical presentation of data

Presentation of data in graphical format is essential for ecological studies, primarily as a means to convey patterns (often changes) to the reader in specific metrics (size and counts) through space and time. For protected-area surveys, data are divided into protection regime (e.g. reserve and non-reserve components) and compared in this manner. Plotting can be done adequately in R statistical software (R Development Core Team 2011).

Box plots

Constructing box plots is a useful way to display data to examine differences between sampled populations. It depicts groups of numerical data based on quartiles, with the bottom and top of the box representing the first (Q1) and third (Q3) quartiles, and the band inside the box corresponding to the second quartile (median). The mean is often highlighted by a dashed line. The spaces between the various quartiles are helpful in evaluating the spread (dispersion) and skewness (tendency to lean to one side of the mean) of the data, as well as highlighting outliers. Further, this data representation does not assume it belongs to a specific distribution, i.e. it is non-parametric.

Ends of the whiskers can denote a range of measures. Common representations are: minimum and maximum of all data, highest value still within 1.5 × IQR (inter-quartile range) of the upper quartile and lowest value still within 1.5 × IQR of the lower quartile, and the 10th and 90th percentile. Outliers are values that fall outside the upper and lower whiskers, and by convention are denoted by round symbols.

Box plots can be constructed in R (using the ‘boxplot( )’ function). Due to the differing values that the end whiskers can represent, the method of whisker formulation will need to be stated in the caption accompanying the plot.

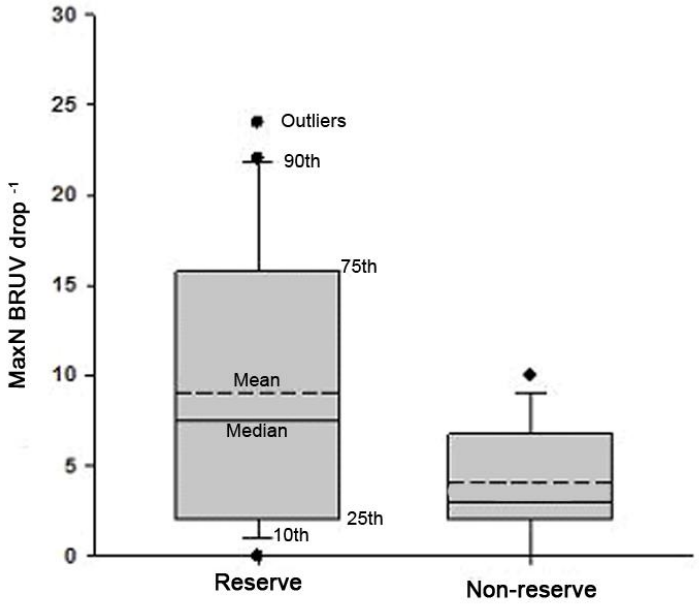

Figure 5. Example box plots generated for snapper MAX abundance within and outside Te Whanganui-A-Hei Marine Reserve in 2012. Percentiles are depicted accordingly. Whiskers denote 10th and 90th percentiles and outliers are represented by round black symbols. From Haggitt et al. 2014 (BRUV = baited remote underwater video).

Count data

Count data for MAX*count*, LEG*count* (legal size specimens), and JUV*count* (juvenile specimens) are typically presented as an average of the sample population (sample mean) (Figure 6). This is computed across reserve and non-reserve sampling stations, if this is the factor being tested, as well as for individual blocks (Figure 7 and see 'Case study B' for an explanation of the term 'block'). A measure of the error around the sample mean should always be given. The standard error (SE), which represents an estimate of the standard deviation of the distribution of a given sample mean (taken from a population), is a commonly used statistic.

Size data

Size data can be effectively presented as frequency distributions or in box plot format (Figures 6, 7, & 8). Both allow the reader to visualise the spread of sizes within the sample population and assess skewness (defined as the asymmetry from the normal distribution in a set of statistical data). Computing the frequency of the data is simply a matter of counting the number of times a score appears in the set of data. It is necessary to include scores with zero frequency in order to draw the frequency histograms correctly. Size class divisions can affect interpretation, so here we suggest using 20 mm size increments (or bins) when constructing frequency histograms (Figure 8). Species-specific size data can also be converted to biomass using length–weight relationships (see Taylor & Willis 1998; Roux de Buisson 2009).

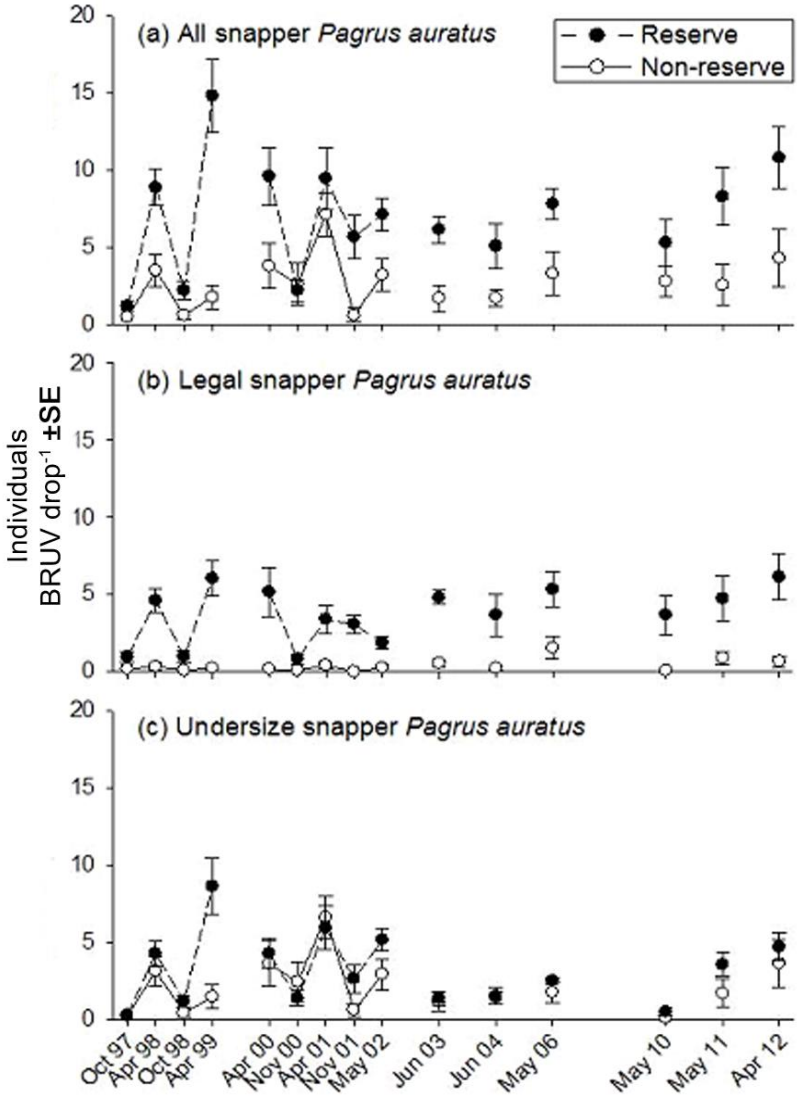

Figure 6. Long-term trends in the relative density of snapper *Chrysophrys auratus* inside and outside Te Whanganui-A-Hei Marine Reserve, as measured using BUV from October 1997 to April 2012. (A) All snapper (MAX*count*); (B) legal snapper (LEG*count*, > 270 mm fork length); and (C) undersize snapper (JUV*count*, < 270 mm fork length). From Haggitt et al. 2014.

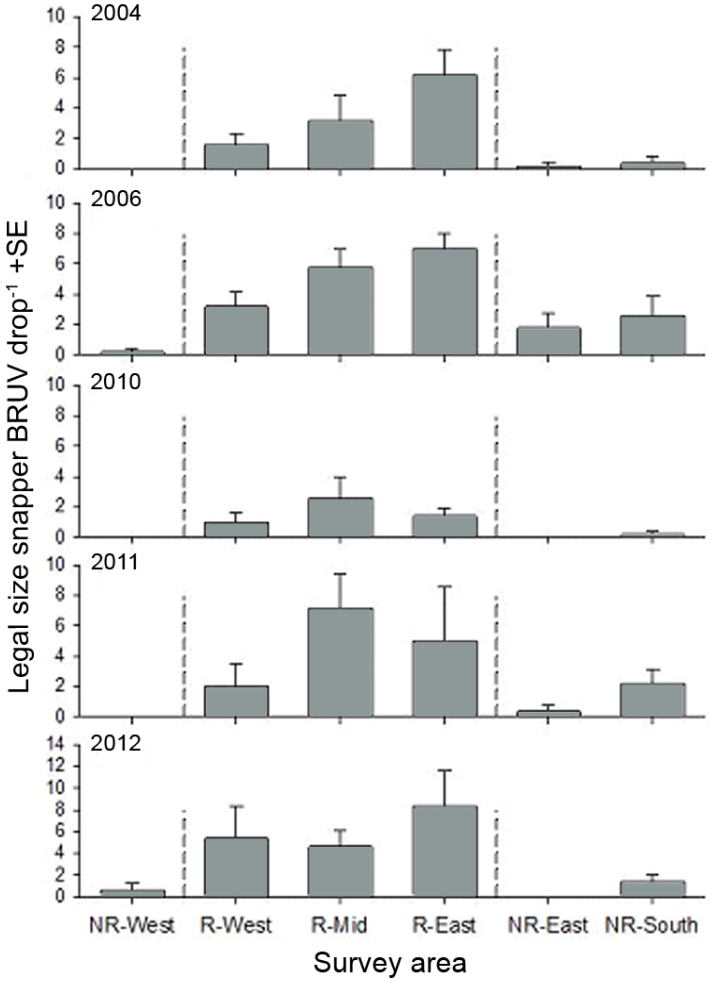

Figure 7. Average number of legal-sized snapper *Chrysophrys auratus* recorded in the six areas (blocks) surveyed within and adjacent to Te Whanganui-A-Hei Marine Reserve from 2004 to 2012, as measured using BUV. Dashed vertical lines indicate the reserve boundaries. R: reserve, NR: non-reserve. From Haggitt et al. 2014.

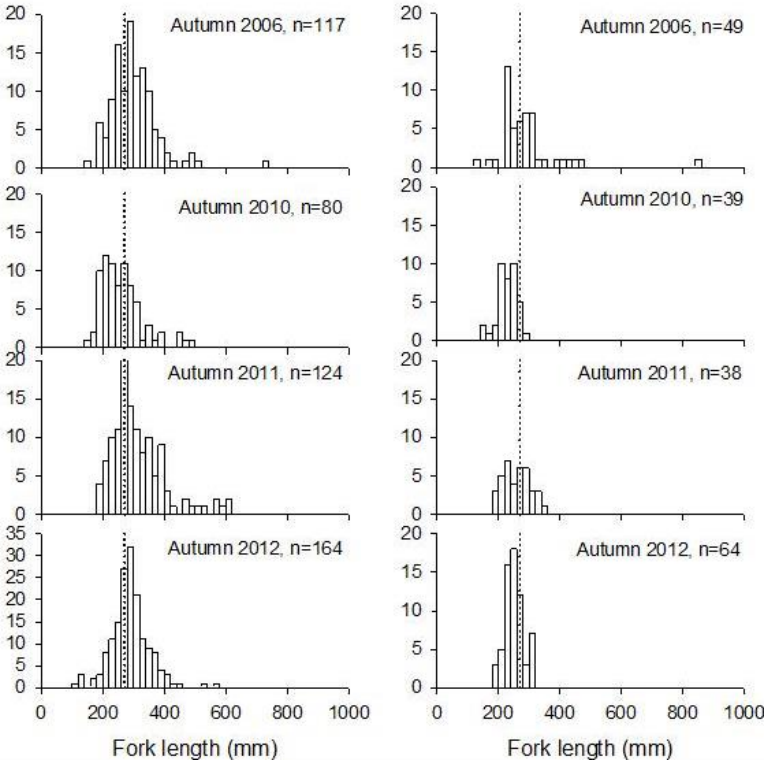

Figure 8. Size frequency distributions of snapper *Chrysophrys auratus* inside (left) and outside (right) Te Whanganui-A-Hei Marine Reserve from 2006 to 2012, as measured using BUV. Dotted line indicates recreational legal size limit (270 mm). Note: *y*-axis differs among plots. From Haggitt et al. 2014.

Formal data analysis

All sampling programmes should be directed by clear monitoring objectives supported by a central hypothesis or range of hypotheses. For a statistical hypothesis test, two hypotheses are appraised: the null (H_o) and the alternative (H_a). The null hypothesis is assumed true until proven otherwise. For example, the fundamental null hypothesis pertaining to many monitoring surveys is:

H_o There is no statistically significant difference in the abundance and size of fishes (e.g. snapper, blue cod, tarakihi, etc.) inside and outside a marine reserve.

The corresponding alternative hypothesis is:

H_a There is a statistically significant difference in the abundance and size of fishes inside and outside a marine reserve.

However, in addition to presenting statistical significance (or not), effect size and its associated error should be reported so that the relative size of an effect can be assessed (e.g. is the significant difference we observe between those two groups marginal or large/important?)

Because BUV **count data** routinely fail the assumptions underpinning ANOVA (i.e. normality of errors, homogeneity of variances and independence) even following commonly prescribed transformation procedures (e.g. LOG(x+1) transformations), we recommend that count data are analysed using GLMs with a Poisson error distribution (see McCullagh & Nelder 1989; Willis et al. 2003; Zuur et al. 2009). It should be noted that it is increasingly recommended not to log-transform data prior to analysis because transformations affect the results of the model applied to these data (McArdle & Anderson 2004; O'Hara & Kotze 2010). In some specific cases, subsets of the data (such as legal-sized counts in the case of protected *versus* fished comparisons) may also be zero-inflated—i.e. the response variable (in this case, counts) contains more zeros than expected based on the relevant distribution (e.g. Poisson, negative binomial etc.)—which can be better managed using GLMs. Further, GLMs have been applied to the majority of BUV surveys conducted in New Zealand over the last decade.

For **size data**, which are continuous (can take any value within a range), analysis by ANOVA or *t*-test may be appropriate, providing the assumptions of normality, homogeneity of variances and independence are satisfied, which may require transformation (e.g. LOG transformation). However, transforming the data prior to an ANOVA is not recommended if the experimenter is interested in effect size. Data failing to meet ANOVA assumptions should be tested using non-parametric techniques such as the Kruskal–Wallis test (non-parametric analogue of ANOVA) and Wilcoxon rank-sum test (analogue to student's *t*-test). Comparisons of size frequencies can be done using a Kolmogorov–Smirnov test or Kernel density estimates (Langlois et al. 2012, and see function 'clus.lf' from package 'fishmethods' in R).

Data 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 goals of the original data collection have been achieved and whether the data is sufficient to answer those questions identified prior to the initial surveys.

Data 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: High density and biomass of snapper *Pagrus auratus* (Sparidae) in northern New Zealand marine reserves (Willis et al. 2003)

Synopsis

BUV data was used to show that snapper (*Pagrus auratus*, now renamed *Chrysophrys auratus*, Sparidae) density and biomass are much higher inside compared to outside marine protected areas (MPAs) in northern New Zealand. This effect was mostly due to the increase in number and size of legal-size snapper within the MPAs. Video units were deployed at several times and locations, allowing for a compelling dataset to be compiled. Biomass of snappers was estimated from weight–length relationship, after measuring fish lengths on the videos.

Objectives

The aim of the study was to assess the general effects of MPAs by using spatially and temporally replicated surveys. Specifically, the authors wished to:

- Determine the magnitude of differences in snapper density and size between MPAs and adjacent fished areas, taking into account that undersize (unexploited) fish should not be affected by the protection status
- Quantify seasonal and inter-annual variability in snapper density and size.

Sampling design and methods

- The relative density and size structure of snapper were measured using BUV, inside and outside three northern New Zealand no-take MPAs (Cape Rodney to Ōkakari Point Marine Reserve, Te Whanganui-A-Hei Marine Reserve and Tawharanui Marine Park).
- Each MPA was divided into blocks and 4–5 sampling sites were selected within each block.
- Each sampling site was visited in October 1997, April 1998, October 1998 and April 1999.
- BUV was used because it avoided attraction or avoidance problems of snapper towards divers.
- BUV units were deployed within 50 m of reefs, on soft sediments.

- The density of snapper was described using MAXsna, LEGsna (legal size fish) and JUVsna (illegal or juvenile fish size). Biomass was also estimated using a weight–length relationship derived from the literature.
- The data were analysed using GLM under the assumption of a Poisson distribution. Factors were ‘location’, ‘protection status’ and ‘survey’.

Results

General effects on density:

- Biomass per BUV deployment and density of legal-size snapper (LEGsna) were higher in the MPA than adjacent non-MPA areas at all three locations and for all four surveys (Figures 9 & 10).
- There was a 14.3-fold higher density in LEGsna inside MPA areas compared with the adjacent non-MPA areas (95% confidence limits of 10.0 and 20.5).
- At the three locations, MAXsna, LEGsna and biomass were all significantly higher (i.e. 95% confidence intervals lying entirely above unity) in the MPA than in the adjacent non-MPA region.
- The relative density of undersize fish (JUVsna) varied between locations, with higher reserve densities at Te Whanganui-A-Hei, lower reserve densities at Cape Rodney to Ōkakari Point, and no difference in densities within and outside Tawharanui.

Seasonal effects on density:

- The estimated additive effect of season within the three MPAs was a spring-to-autumn mean increase.
- For undersize snapper (JUVsna) and all snapper (MAXsna) there was considerable among-location variability that was partly attributable to patchiness in the distribution of undersize fish, leading to a significant interaction between location and season. If different MPAs are surveyed at different times of year, the results will not be comparable, and will give misleading impressions of the relative effectiveness of the different MPAs.
- Individual season estimates are also given for each location.

Effects on size:

- The mean length of snapper was greater within MPAs than in fished areas at all three locations.
- Kolmogorov–Smirnov tests run on fish ≥ 270 mm fork length found a significant difference between the reserve and non-reserve size structure at Cape Rodney to Ōkakari Point (D = 0.55, $P < 0.01$) where almost all non-reserve fish were < 400 mm fork length. The comparison was not significant at either Te Whanganui-A-Hei or Tawharanui.

Limitations and points to consider

- A true Before–After–Control–Impact (BACI) design (Hurlbert 1984; Underwood 1993) could not be implemented because of the absence of comparable data prior to MPA establishment. However, the design of the study reduced the risk of location-specific biases that may have been present due to the lack of 'before' data, which in MPA studies are often unobtainable.
- Behaviour of species towards BUV units could be influenced by protection status. It is possible that the response to bait of resident fish could be stronger in marine reserves due to density-dependence. However, this hypothesis has never been tested.
- A study showed that snapper might have larger home ranges in non-reserve areas and utilise more than one main area, whereas reserve snapper might have higher site fidelity with only one main area of use (Parsons et al. 2010). If this behaviour was confirmed, it could potentially influence the conclusions of any study comparing snapper inside and outside reserves. It should be noted that Parsons inference could be merely an artefact of the short survival time of any fish trying to be resident on a heavily fished reef (Willis, pers. comm.).

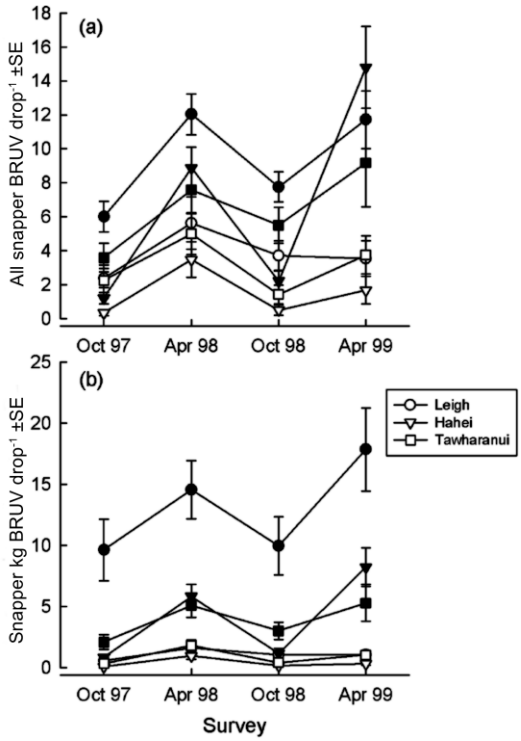

Figure 9. Mean density for (a) all size classes and (b) biomass of snapper *Chrysophrys auratus* at reserve (filled symbols) and non-reserve (open symbols) at Leigh (Cape Rodney to Ōkakari Point), Hahei (Te Whanganui-A-Hei) and Tawharanui from November 1997 to April 1999.

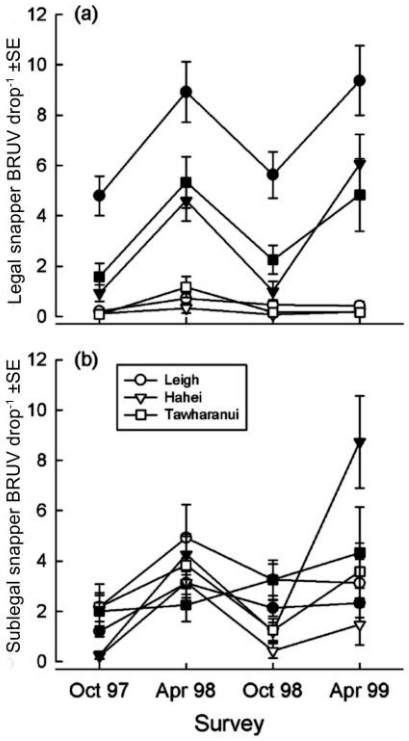

Figure 10. Mean density for (a) fish larger than minimum legal size and (b) for fish smaller than minimum legal size of snapper *Chrysophrys auratus* at reserve (filled symbols) and non-reserve (open symbols) at Leigh (Cape Rodney to Ōkakari Point), Hahei (Te Whanganui-A-Hei) and Tawharanui from November 1997 to April 1999.

References for case study A

Hurlbert, S.H. 1984: Pseudoreplication and the design of ecological field experiments. *Ecological Monographs 54*: 187–211.

Parsons, D.M.; Morrison, M.A.; Slater, M.J. 2010: Responses to marine reserves: Decreased dispersion of the sparid *Pagrus auratus* (snapper). *Biological Conservation 143*: 2039–2048.

Underwood, A. 1993: The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world. *Australian Journal of Ecology 18*: 99–116.

Willis, T.J.; Millar, R.B.; Babcock, R.C. 2003: Protection of exploited fish in temperate regions: high density and biomass of snapper *Pagrus auratus* (Sparidae) in northern New Zealand marine reserves. *Journal of Applied Ecology 40*: 214–227.

Case study B

Case study B: random site selection for BUV deployments using hypothetical example

This section provides a method for obtaining random sites within and outside a hypothetical reserve. The example assumes basic knowledge of ArcGIS and also uses add-ons like Hawth's Tools available from SpatialEcology.com for ArcView 9.x (http://www.spatialecology.com/htools/index.php) or Geospatial Modelling Environment for ArcView 10.x (http://www.spatialecology.com/gme/gmedownload.htm). For open-source solutions, the software QGIS also offers random selection tools (Vector menu > Research Tools > Random point).

The distribution of rocky reef and soft sediment areas within and outside the reserve were known prior to site selection. The latter is a necessary requirement before undertaking a survey of this nature.

The underlying hypothesis is:

H_o There is no statistically significant difference in snapper and blue cod abundance and size between reserve and non-reserve sampling areas.

The sampling design will be a randomised block design and all BUV drops are required to be done within 20 m of rocky reef habitat on soft sediment substratum. There is a fairly even spread of rocky reef and soft sediment habitat types across the survey area (Figure 11).

Key steps to obtain random sites are:

1. Create a spatial map of the reserve and non-reserve sample areas in ArcGIS based on relevant shapefiles and associated metadata, e.g. bathymetric data and spatial habitat maps. A map of rocky reef and soft sediment habitats has been created based on pre-existing data (Figures 11 & 12).

2. Designate blocks within reserve and non-reserve sample areas based on available habitat information, ensuring that blocks are broadly spatially equivalent (Figure 13).
3. For this survey, the sampling requirements are:
    a. A total of 5 replicate BUV drops per block.
    b. Individual BUV drops will be done within 20 m of rocky reef habitat on sand.
    c. Individual BUV drops will be of 30-minute duration once the BUV unit has settled on the seabed.
    d. Individual BUV drops will be a minimum of 360 m apart to avoid sampling the same fish due to overlapping area of attraction. A distance of 450 m or greater between replicate BUV deployments of 60-minute duration is recommended by Cappo et al. (2004) to achieve independence between replicates. We have reduced this to 360 m based on the reasoning that: (1) BUV deployments are shorter (30 minutes); and (2) so sufficient replication can be achieved within blocks, particularly in the case of smaller marine reserves or those that may have limited reef habitat.
4. Construct a grid composed of 200 × 200 m cells that covers reserve and non-reserve survey areas. The grid will be used to facilitate site selection within selected cells (Figure 14).
5. Select cells from running a specific ‘Attributes Selection’ query that picks those grid cells which together contain rocky reef habitat and sand habitat, i.e. where boundaries of rocky reef and soft sediment habitat intersect and create a new shapefile based on this selection (Figure 15).
6. From these available cells, generate a total of 6 random points per block (using either Hawth’s Tools or Geospatial Modelling Environment). In this instance we have chosen 6 sites (we only need 5) to build some redundancy into the programme should a particular site prove to be unsuitable in the field (Figure 16).
7. A point-based shapefile is now created and latitude/longitude coordinates generated (Figures 17 & 18 and Table 3).
8. Generated latitude/longitude coordinates can then to be loaded into a suitable GPS unit and will serve as the initial site waypoints. Note: The initial site mark may need to be adjusted in the field to satisfy placement of the BUV system within 20 m of reef habitat.

Table 3. Randomly generated sites for BUV drops within and outside the marine reserve.

Block	Status	Site	Rep	Latitude	Longitude
R1	Reserve	1	1	2011276	5813964
		2	2	2013263	5814392
		3	3	2014756	5817389
		4	4	2013786	5818749
		5	5	2012562	5818794
		6	6	2013182	5819450

R2	Reserve	7	1	2015227	5819347
		8	2	2016648	5820260
		9	3	2015332	5816839
		10	4	2015246	5818773
		11	5	2015058	5817456
		12	6	2014296	5818838
R3	Reserve	13	1	2020565	5820033
		14	2	2019951	5820379
		15	3	2023577	5820786
		16	4	2025700	5821529
		17	5	2023007	5820121
		18	6	2021150	5820387
NR1	Non-reserve	19	1	2011308	5812268
		20	2	2009714	5813648
		21	3	2010450	5812681
		22	4	2009311	5813659
		23	5	2012182	5811529
		24	6	2010416	5809104
NR2	Non-reserve	25	1	2029429	5828153
		26	2	2030578	5825233
		27	3	2026223	5821068
		28	4	2029443	5827567
		29	5	2030752	5824217
		30	6	2029650	5822635
NR3	Non-reserve	31	1	2037127	5827411
		32	2	2033705	5826213
		33	3	2035914	5825409
		34	4	2036758	5825254
		35	5	2035084	5825140
		36	6	2030368	5827899

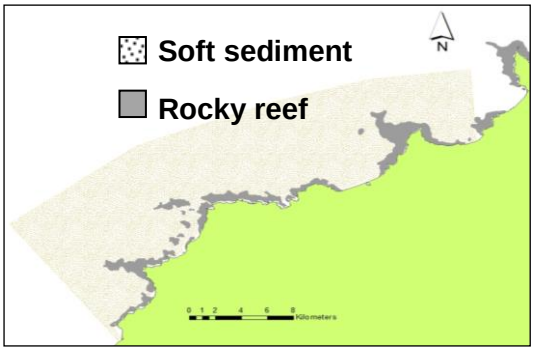

Figure 11. Distribution of soft sediment and rocky reef habitats at a hypothetical study site.

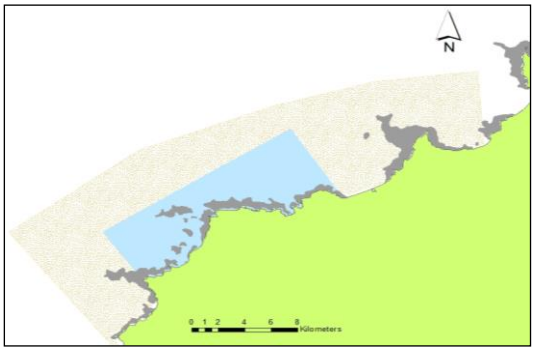

Figure 12. Localisation of the marine reserve area within the study site (blue).

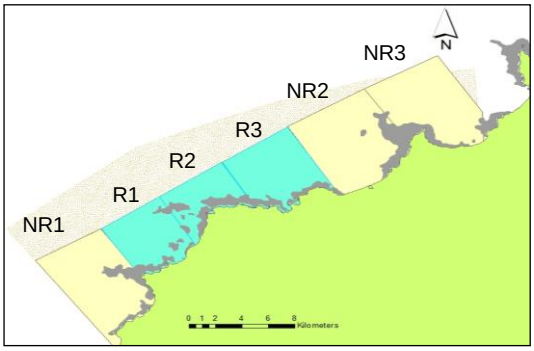

Figure 13. Reserve (R1–R3) and non-reserve (NR1–NR3) block designation across the reserve and non-reserve areas.

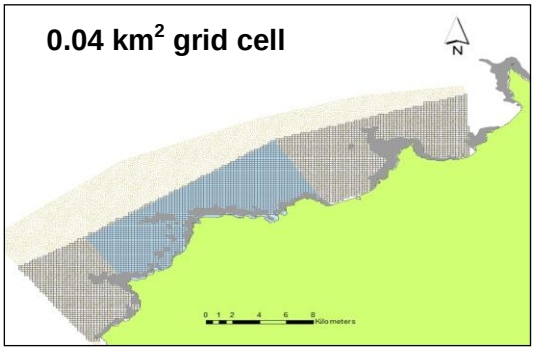

Figure 14. Reserve and non-reserve blocks gridded into 200 m x 200 m cells.

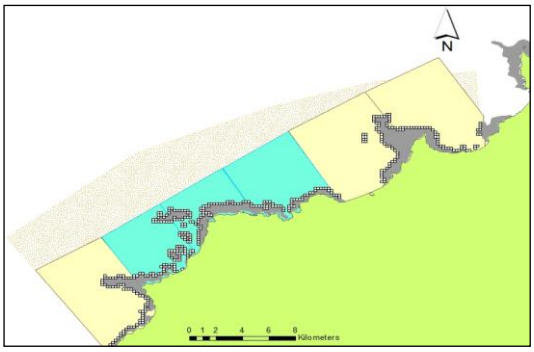

Figure 15. Identification of cells which have both rocky reef and soft sediment habitats. They show the locations of the boundaries of rocky reefs.

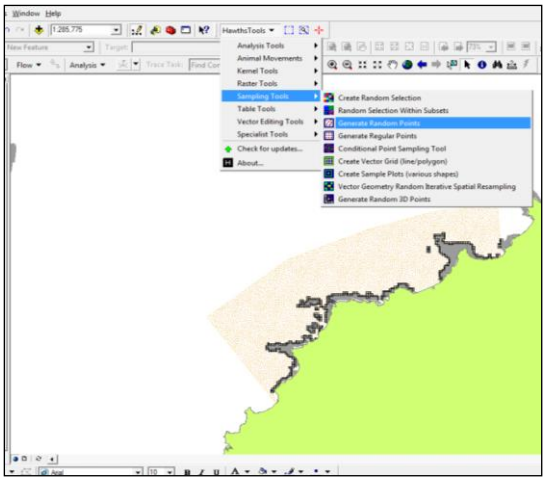

Figure 16. Random site selection using Hawth's Tools for ArcView 9.x.

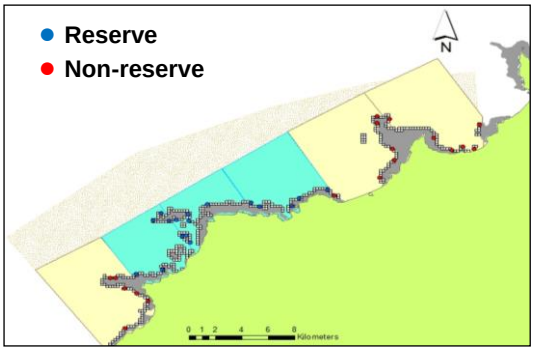

Figure 17. Random site designation (n = 6) within each block.

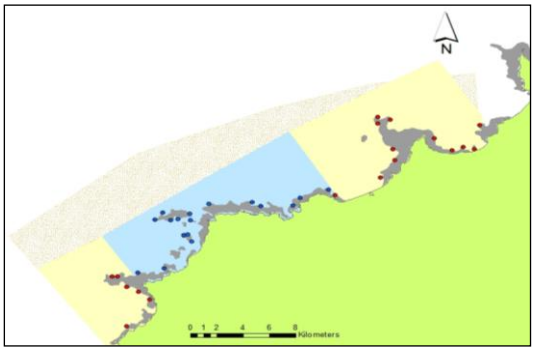

Figure 18. Final random site designation.

Full details of technique and best practice

The exact survey/monitoring design will be governed by the research question, but the following text details the techniques and general survey design to be used when conducting BUV surveys.

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.
- 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.

BUV setup and associated equipment

The range of equipment needed for a typical BUV survey is as follows.

A. Camera and camera housing

A range of cameras and underwater housings are on the market and are continually being improved and upgraded. Cheap units like those made by GoPro are also becomingly increasingly easy to obtain and attach to frames. The experimenter should seek advice on what to buy from other people active in this field.

B. Frame

This frame, in use at DOC, has proven to be easy to assemble, robust and easily transportable. There is currently little information about how fish behave around differing frames and so ensuring consistency within and among surveys is imperative.

Material: Aluminium square bar 25 × 25 mm for both the bottom scale bar and angled bar.

Length: *Bottom scale bar*: 1700 mm, with 1500 mm (outer to inner) divided into black and white segments each 100 mm in length (*n* = 15). The 100 mm segments can be delineated with black and white electrical tape.

Side angle bar: Approximately 1415 mm from the base scale bar with a 150 mm vertical bar for attachment of the housing.

The bottom scale bar and side bar are fixed at the desired angle via a removable top screw as part of a fixed bracket. When the screw is removed the angled bar folds down so that the unit can be stored efficiently. A fixed bottom screw ensures the two arms are permanently held together (Figure 19). Note: All screws and fasteners should be stainless steel marine grade 316 and should be checked regularly for corrosion and replaced if necessary.

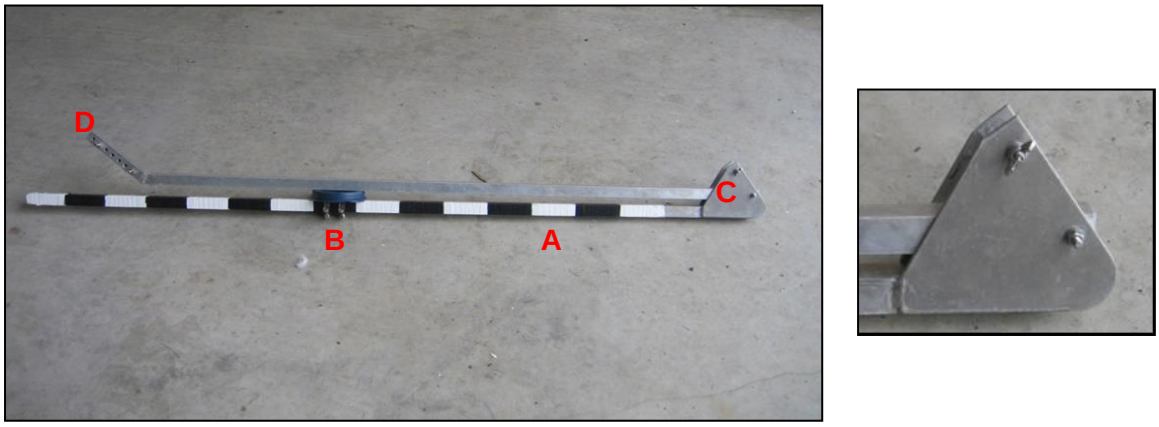

Figure 19. BUV frame in folded position with housing removed: (A) bottom scale bar; (B) base of bait pot; (C) moveable angle bar; and (D) housing attachment section and associated drill holes used to attach to the housing.

C. Bait container

A bait container (Figure 20) is required to enclose bait during a deployment. It also provides a point of reference when measuring fish during post-survey analysis. The cylindrical burley container in Figure 20A should be preferred as it produces superior odour plume characteristics and is readily available. It is 100 mm in height and 130 mm in length and can be attached to the bottom frame using cable ties and screws. The bait container in Figure 20C–E is an inverted burley pot with the base (top) attached to the middle of the scale bar with hose clamps. The base of the bait container is 130 mm in diameter and 150 mm in height. Bait containers can become damaged from fish attack

during sampling. Therefore, it is advisable to carry spares on the vessel so that repairs can be promptly made.

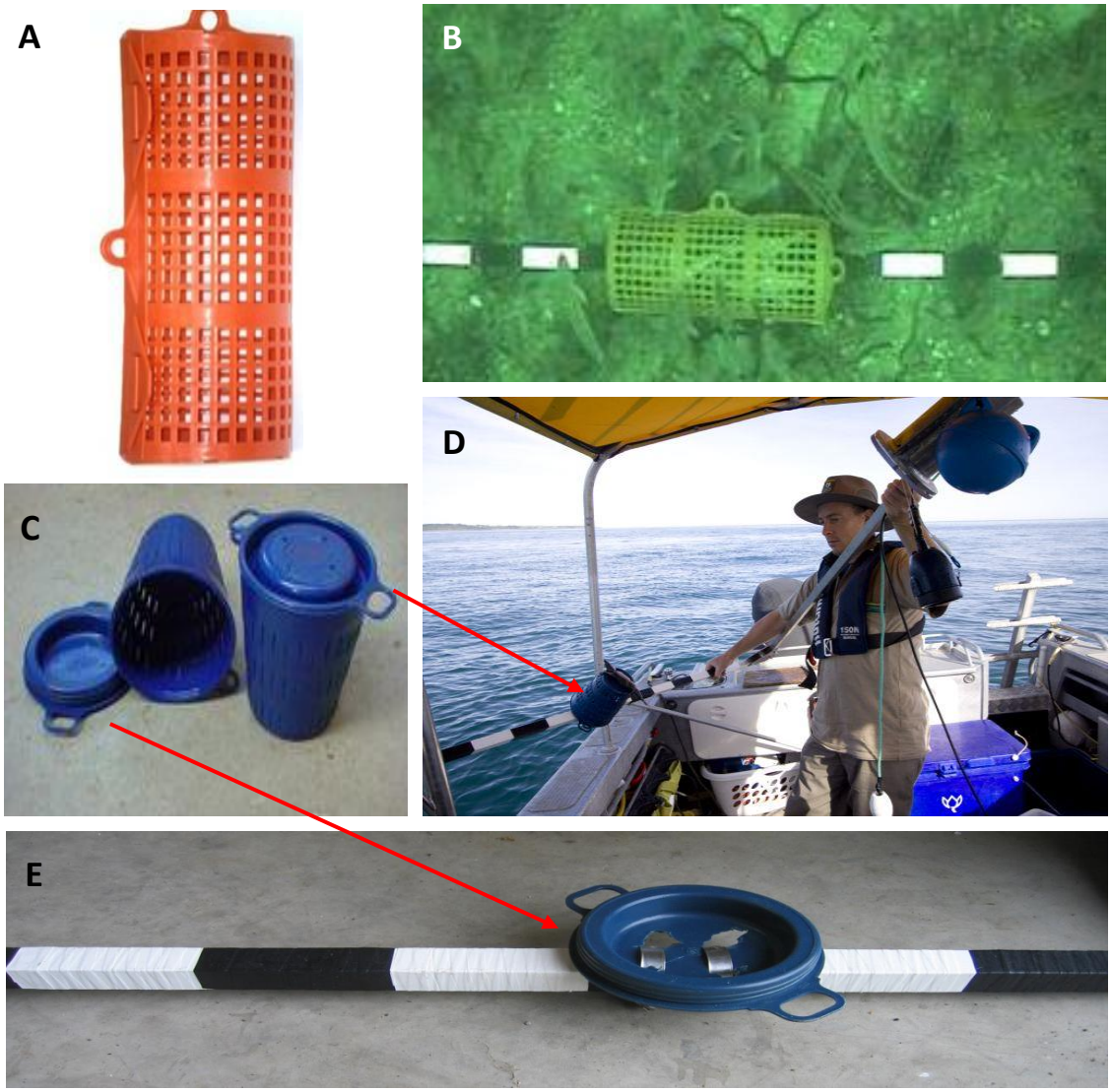

Figure 20. Typical bait containers used for BUV surveys: (A) cylindrical bait container on BUV frame (preferred container); (B) preferred container on BUV unit; (C–E) bucket style bait container—for construction purposes, the top is removed, inverted, and attached to the frame with hose clamps or screws.

D. Digital video camera

There is a range of digital video cameras available on the market. Purchase a reputable brand such as Sony Handycam or Canon camcorder. GoPro cameras also offer a cheap way to record high quality footage in a compact form. Newer video camera models offer high definition recording onto a drive or memory card, which preserves battery consumption considerably. The best option is a camera which records on a memory card so that the number of samples one can achieve in the field is not limited by the size of the hard drive. Simply have several memory cards and swap for a new one when necessary.

A semi-fisheye lens attachment (e.g. Raynox QC-303 or equivalent) will be required to ensure the majority of the scale bar is visible in the field of view. It is important that the horizontal length of the field of view at seabed level be of about 1500 mm so that the sample size is consistent (i.e. that fishes are always counted over a similar surface around the bait). Ensure the lens is compatible with the video camera. Distortion may need to be taken into account when processing the video (see 'Managing biases when measuring fish lengths', page 44). Ideas on how to deal with distortion are presented at page 44. If feasible in practice (e.g. if the video camera has a wide field of view or if the system used and visibility conditions allow it), it is recommended not to use a fish-eye lens to avoid distortion issues which can impact on fish length measurements.

When choosing a camera, specifically check:

- Record modes relative to maximum continuous record time.
- Battery life. The recording and playback time will be shorter when you use your camcorder in low temperatures (i.e. underwater). Larger batteries can remain in continuous recording mode for > 10 h and are the preferred option for fieldwork.
- Storage medium types (hard drive, memory card, flash stick, tape, etc.). Make sure that storage size will be sufficient to undertake the required level of sampling for a given day.
- Lens specifications and level of distortion.

E. Drop camera

A drop camera (Figures 21 & 22) is often used as an alternative or in conjunction with the digital video camera of the BUV unit proper. This system provides real time visuals so that substratum/habitat suitability can be evaluated immediately once the BUV unit settles on the seafloor. An assessment of this nature can save time, ensuring that kelp is not obscuring the field of view and that the unit is in a suitable habitat and position on the seafloor.

The drop camera, if providing good image quality, can replace the housing/camera setup, and be directly used to record the video data. In this case, the drop camera is directly attached to the BUV unit. It will record video to a tape or hard drive it is connected to on the boat.

The drop camera attaches to the BUV unit with rubber bands, hose clamps or duct tape and is linked (via coaxial cable) to a surface LCD monitor (or secondary video recorder that serves as a monitor) and ancillary 12 V battery which powers the unit. Drop cameras can be custom built specifically for this purpose in New Zealand by companies such as Marine Design Engineering Ltd (http://www.mdel.co.nz/) and Ocean Data Systems (http://www.oceandata.co.nz), or can be ordered online from a range of international suppliers. Allow for approximately 60 m of coaxial cable.

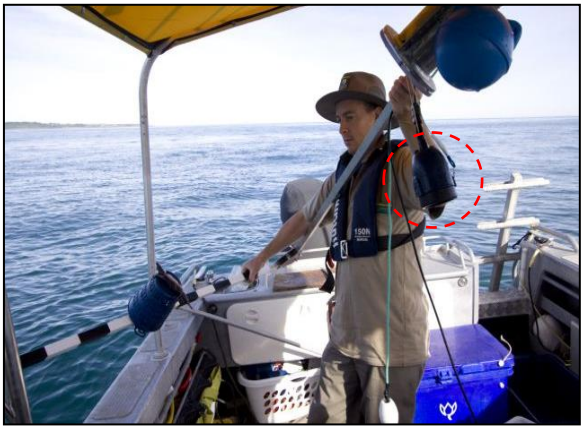

Figure 21. BUV setup prior to deployment. Red circle denotes Splashcam® drop camera. The drop camera is in this case used to assess habitat suitability at the start of the deployment. If providing good image quality, the drop camera can also be directly used to record the video data, effectively replacing the video camera in its housing.

Figure 22. Drop camera equipment: (A) MDEL drop camera and 70 m coaxial cable; (B) 12 V rechargeable battery pack used to power the drop camera unit; and (C) digital video recorder with movable screen. This setup is used for real time substratum and habitat assessment. All components are linked together in a customised waterproof case (not shown). Note: The video recorder is powered by a long-life (8 h) 7.4 V battery pack specific to the video recorder.

F. Consumables

Alongside BUV hardware, a range of consumables are required to undertake field sampling (Figure 23). These range from fasteners such as cable ties and shackles to spare fuses and data sheets. A full equipment checklist (hardware and consumables) is provided in Table 1.

Figure 23. Typical hardware and consumables required for undertaking a BUV survey.

A. Fasteners (shackles, carabiners and hose clamps)
B. Rubber bands, cable ties and spare screws
C. Digital video camera
D. Bait pots (other style preferred)
E. Rechargeable video camera batteries
F. Screwdrivers
G. Paper towels
H. Cable ties
I. Permanent marker pen
J. Electrical tape
K. Silicone grease
L. Drop camera
M. Pressure buoy
N. Cloth

Video data management and storage

It is essential that all raw (unprocessed) video data are labelled and stored in a suitable manner. Ensure that the survey date and sites surveyed accompany the storage medium (hard drive, DVD, DV tape, memory card, etc.; Figure 3). Other supporting notation (surveyors, boat, etc.) are also important. Generally, adhesive writeable labels are supplied with DV tapes, and DVDs and memory cards can be written on with permanent marker.

Following field sampling, raw (unprocessed) video data should be immediately backed up or captured to a computer hard drive. Appropriately labelled folders and subfolders should be created and used to archive the raw video data (Figure 24). To ensure multiple copies are in existence, copies of the downloaded data should be backed up further to external hard drives.

Paper forms should be photocopied or scanned so that multiple copies are in existence. If possible, physical and electronic copies of the data should be stored at separate physical locations.

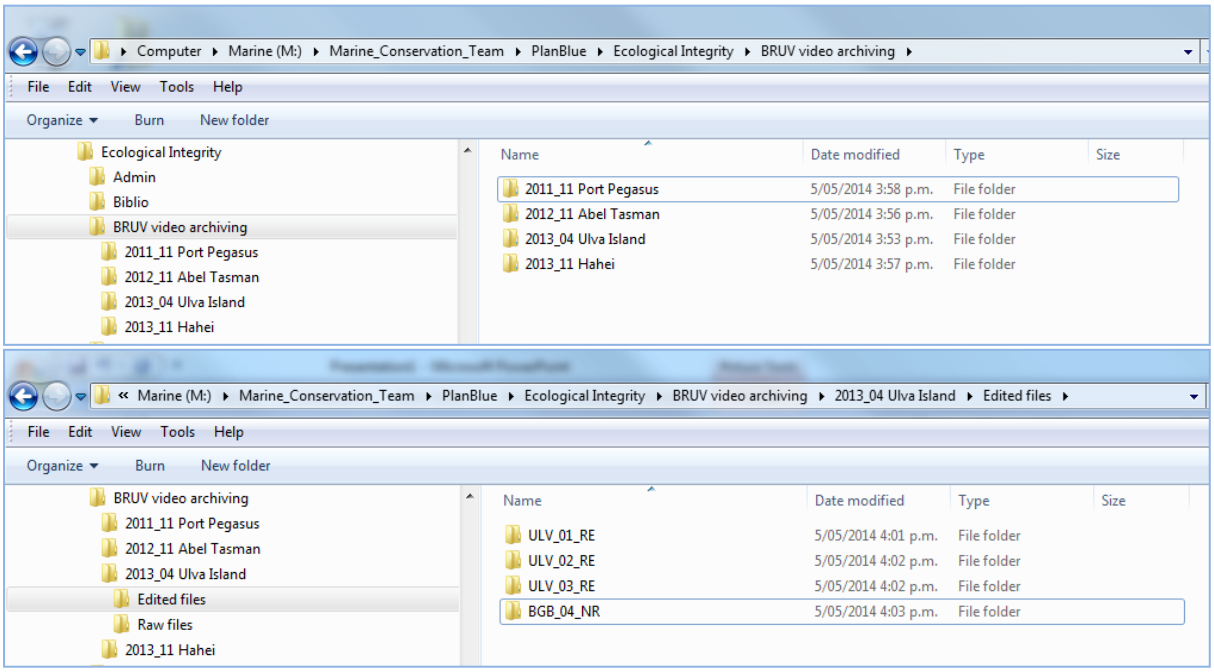

Figure 24. Example of folder specification for BUV video data. Folders should start with year and month of collecting for easy sorting. The final folders of the hierarchy should correspond to the sites of each location.

Video capturing

If transferring data from DV tape to computer, an IEEE 1394 (FireWire) cable will be required to bridge the two devices. Video will need to be captured directly from the camera using specialised software (like WinDV (http://windv.mourek.cz/), or AVS Video Recorder (http://www.avs4you.com/index.aspx and http://www.reviewstown.com/how-to-convert-vhs-tapes-to-dvd.html)).

Digital video recorders with built-in hard drives or with memory cards have the option of transferring data directly from the camera (via USB connection) to an external hard drive or DVD writer device, which can then be transferred to the computer. Memory cards can be directly read using an adequate reader and backed up to a hard drive.

Video editing

Due to continuous filming over consecutive video drops, raw video will contain a range of unnecessary material that will require editing (removal) before formal analysis and archiving. Editing can be done in programs such as Windows Movie Maker or Freemake Video Converter (http://www.freemake.com/free_video_converter/), but ensure that, when rendering edited data, the highest video quality settings are used, i.e. do not sacrifice video quality for storage space. For each site-specific video, be sure to include the frames that contain the site details and entire descent of the BUV unit from the vessel to the seabed.

Sampling design

Prior to conducting a BUV study, consideration should be given to developing a robust survey design. This should include prior consultation with experts/statisticians to ensure the sampling design meets the requirements to answer the research question. The following should be considered:

- What is the spatial extent of broad habitat types (rocky reef and soft sediment) and exposure levels within and between areas to be sampled (e.g. reserve *versus* non-reserve areas)?
- What are the habitat extents within and among blocks for the different areas? Will it be important to stratify the sampling based on these?
- How many blocks are to be assigned for the different areas? Remember, it is always better to create a balanced sampling design.
- How many replicates (sites) per block are required? At this stage it will be important to gauge statistical power and build some redundancy into the sampling design. Willis et al. (2003) provide a detailed summary of this.
- Ensure that individual sites are randomly assigned within the blocks.

The primary ethos of undertaking BUV surveys is to estimate the size and abundance of species not amenable to sampling by techniques such as visual underwater census techniques.

For example, if the main objective is to compare abundance and size of certain species within and outside MPAs, one would ideally undertake ecological surveys several times prior to the commencement of MPA designation in order to obtain information on natural variation of target species prior to protection. For the majority of early studies that developed the BUV technique within New Zealand's MPAs, there was a distinct paucity of pre-protection data. As a result, BACI designs (Hurlbert 1984; Underwood 1993) could not be applied. In the advent of new MPA designations, undertaking pre-protection surveys should be a requisite.

Hypothesis testing

For the most part, all sampling programmes should be directed by clear monitoring objectives supported by a central hypothesis or range of hypotheses. For a statistical hypothesis test, two hypotheses are appraised: the null (H_o) and the alternative (H_a). The null hypothesis is assumed true until proven otherwise. For example, the fundamental *null* hypothesis pertaining to many BUV surveys is:

H_o There is no statistically significant difference in the abundance and size of fishes (e.g. snapper, blue cod, tarakihi) between area A and area B (e.g. between a marine reserve and non-reserve adjacent area).

The corresponding alternative hypothesis is:

H_a There is a statistically significant difference in the abundance and size of fishes between areas area A and B.

Randomised block designs (see 'Case study B')

Randomised block designs are useful for MPA surveys (or other spatial protection or management), primarily as the design allows for comparisons to be made among blocks within a particular spatial area. Blocks are created by dividing the area to be sampled into units (=blocks) to account for any variation in some factor. There is no concrete rule for block allocation within and outside MPAs. In fact, the exact delineation of block boundaries often occurs subjectively among MPA and non-MPA areas. For instance, Cape Rodney-Ōkakari Point Marine Reserve (CROP) and Te Whanganui-A-Hei Marine Reserve are similar in spatial extent, yet Willis et al. (2000) delineated a different number of blocks across CROP (6 inside and 6 outside) compared to Te Whanganui-A-Hei (3 inside and 3 outside). This was due to funding and logistical constrains (Willis, pers. comm.). For offshore locations, or reserves with disparate boundaries (e.g. Kapiti Island), block assignment may be less intuitive. In such instances completely randomised designs may be more suitable, although the experimenter would only be able to compare reserve and non-reserve data with no further information on trends within blocks.

In the case of new MPAs or for those awaiting survey we suggest the researcher relates the position and number of blocks and subsequent replicates (see below) back to the underlying hypothesis and objectives of the programme. We advocate that sampling designs are balanced in terms of both the number of blocks and replication within blocks between MPA and non-MPA areas.

Additional considerations include:

- Are there distinct environmental gradients (depth, turbidity, wave exposure, reef contiguity) that need to be accounted for in the demarcation of blocks within and outside the MPA? If testing for an MPA effect, the investigator will want to control for those gradients.
- Are there obvious habitat differences across sampled areas, e.g. is one half predominantly soft-sediment and the other predominantly rocky reef and does this need to be accounted for by way of habitat stratification?

Replication

Replication is an essential component of marine ecological studies, and as a general rule every level within the sampling programme should be replicated. Kingsford & Battershill (2000) provide a useful overview on the subject. In past studies conducted in New Zealand, site replication within blocks typically ranges from 4–5 per block, i.e. 4–5 BUV samples will be made in each block. This level of replication is generally sufficient to satisfy statistical power requirements for a GLM approach (see Willis et al. 2003 for a detailed explanation). Statistical power in this sense refers to the probability that the specified test will reject the null hypothesis when the alternative hypothesis is likely to be true, i.e. the probability of not committing a Type II error (Sokal & Rohlf 1995).

It is essential for subsequent statistical analysis that replicate samples within blocks are independent of each other. Replicates therefore must be assigned randomly (or haphazardly if true spatial randomisation cannot be achieved). If replicates are not independent of each other, the assumptions underpinning many statistical tests will be violated. A method of selecting random sites is given in ‘Case study B’.

Habitats

Because species and assemblages of reef fish exhibit distinct associations with both large-and small-scale habitat features (Cole et al. 2012), it is important to consider habitat distribution when selecting sites.

As varying taxa and reef fish assemblages exhibit habitat-related preferences (Anderson & Millar 2004; Parsons et al. 2010; Cole et al. 2012), prior understanding of coarse habitat distributions across the areas to be sampled will facilitate sampling site allocation. It is important that at least the broad extents of rocky reef and soft sediment habitat across the sampled areas are known.

The standard method is to deploy BUV units within 20–30 m of rocky reef habitat. However, this approach may not be appropriate for all areas, as camera drops may by necessity be constrained to rocky reef habitat.

Sometimes, habitat stratification may be required when habitat coverage is not broadly equivalent between surveyed areas. An example of this is Tapuae Marine Reserve in New Plymouth, where the majority of the reserve habitat is rocky reef.

Distance between deployments

To avoid pseudoreplication by re-counting the same fish specimens during different deployments, a minimal distance between deployments should be chosen. For a soaking time of the unit (S_t) of 45 minutes on the seabed (taking some margin from the 30 minutes of video normally required) and assuming a current speed (V_c) of 0.2 $m.s^{-1}$ and a fish speed (V_f) of 0.6 $m.s^{-1}$ (3 body lengths per second for fishes of about 200 mm total length), a safe distance (Dist) is c. 360 m. If there are good reasons to believe current or fish speeds to be different, the following formula can be used for calculating this safe distance (Cappo et al. 2004):

$$\text{Dist} = \frac{60 \times S_t \times \left(\left(V_f \times V_c \right) - V_c^2 \right)}{V_f}$$

Field sampling protocol and deployment procedure guidelines

General comments

The deployment procedure should be discussed at length and a 'dry run' undertaken prior to field sampling proper. The equipment checklist (Table 1) should also be consulted well in advance of sampling. A minimum of two personnel are required to undertake a BUV survey, but three are recommended.

As a general rule, sampling sites should be uploaded to a GPS navigation system (fixed or handheld) prior to sampling. To avoid biases, ensure those sites adjacent to one another are not going to be surveyed consecutively (for the most part), nor that all sites from one area are to be surveyed first followed by all sites at another area. It is usually a good idea to randomise the order in which sampling occurs so the experimenter does not work through an area linearly. If for some reason, for example a storm, the sampling had to stop, data collected randomly would still be useful for analysis.

Deployment process (hypothetical example)

To avoid any biases associated with diurnal feeding behaviour, all sampling should be undertaken in daylight, 1 hour each side of dusk and dawn.

The standard method of BUV deployment is to place the unit within 20 m of rocky reef habitat. This may not be appropriate for all areas, e.g. Tapuae Marine Reserve (New Plymouth) where the majority of BUV deployments will require the unit to be placed directly on rocky reef habitat or if the experimenter has specific objectives. The exact placement protocol should be established in the sampling design phase.

Considering the hypothetical example presented in 'Case study B', there are 15 reserve sites (5 per block) and 15 non-reserve sites (5 per block) that require sampling by BUV. It is anticipated that the survey will require approximately 3.5 days to be completed. For the first day of sampling, reserve sites 3, 8, 12 and 17 and non-reserve sites 19, 23, 29 and 32 will be sampled. These locations will be uploaded to a GPS unit on the vessel prior to embarking (Figure 25).

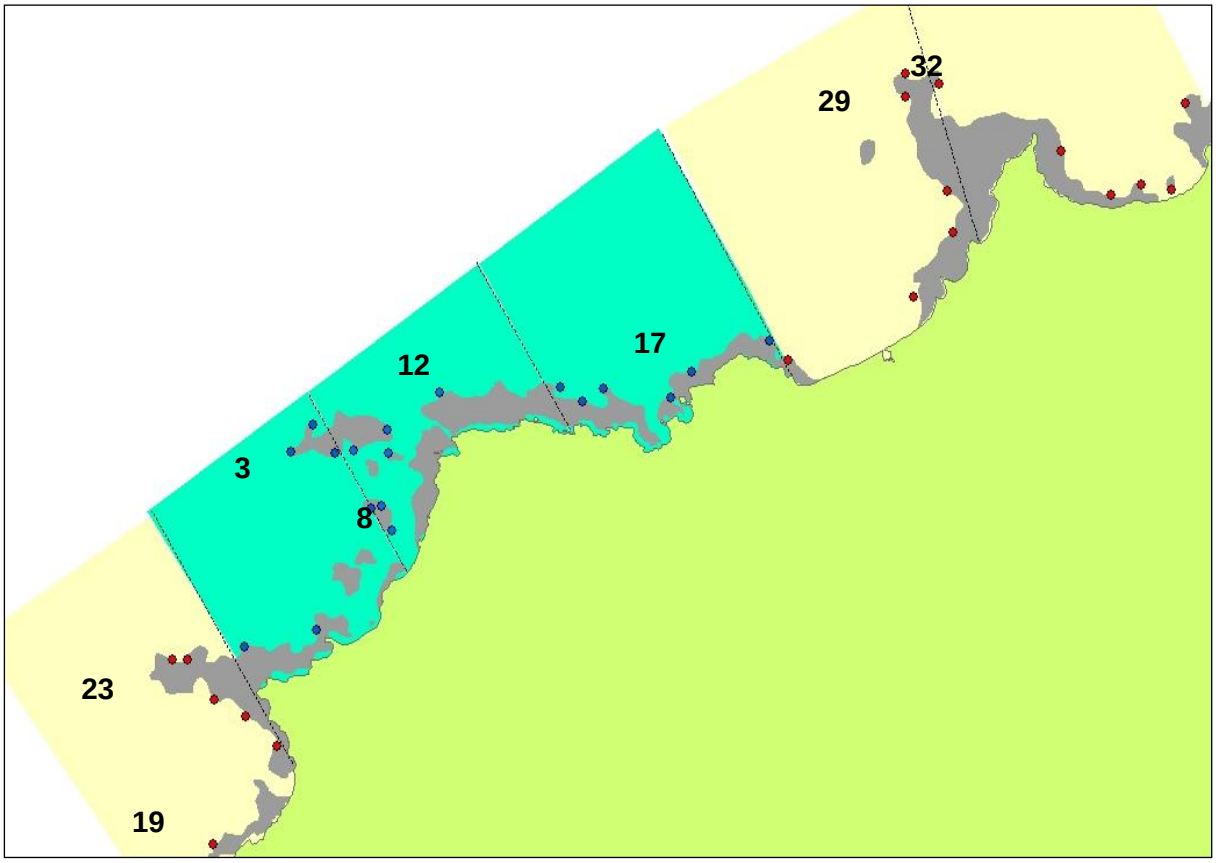

Figure 25. Hypothetical example of reserve (3, 8, 12 and 17) and non-reserve sites (19, 23, 29 and 32) to be sampled within a given day.

Once near the sampling area, locate the survey site with navigational equipment (GPS) and verify, via depth sounder, the bottom topography. It may be necessary to move the vessel in and around the original GPS waypoints to locate the reef/soft sediment transition zone.

Guidelines for the first BUV deployment are:

1. Discuss the plan of action and identify hazards (if any).
2. Locate the site using the depth sounder and, if necessary, anchor the vessel.
3. Check all frame fastenings and re-tighten if required.
4. Turn on the digital video recorder and check record mode.
5. If the camera unit has not been used for an extended period, check the battery life is sufficient to complete at least 8 hours of continuous recording. Try to decrease as much as possible opening and closing of housing to avoid leaks.
6. Ensure the digital video camera has sufficient storage capacity to satisfactorily complete the drop. Note: It is better to ensure recordings are of higher quality rather than sacrificing quality for greater storage capacity.
7. (where relevant) Place DV camera into housing and use the viewfinder to adjust the focus to ensure the scale frame is in complete view.

8. (where relevant) Place a silica pack in the camera housing.
9. Turn on the record function and ensure the camera is recording properly.
10. Place chopped bait within bait container (approximately 200 g or 6 pilchards), fasten to the container bottom on the BUV frame.
11. (where relevant) Attach drop camera to the housing with lanyard and rubber bands.
12. Attach a pressure buoy to the top hole on the flange of the BUV housing.

The BUV unit will now be ready for deployment.

Follow these steps next:

1. Write the **Date+Time**, **Location**, **SiteName** and **DeploymentID** on a whiteboard or pad and place in front of the camera before deployment (Figure 26).
2. Fill in the information about this deployment on the 'BUV deployment data sheet' (doccm-2618429)[3]
3. Deploy the BUV unit (Figure 27).
4. Steadily lower the BUV unit to the substratum. Once on the substratum, tie the surface buoy to the line using a shark clip, ensuring there is enough slack to account for vessel movement and tide—1.5 times the depth of rope is recommended.
5. If applicable, check, via the drop camera, whether the BUV has landed on suitable substratum and that macroalgae is not obscuring the field of view. If the BUV unit did not land on suitable substratum or there are problems with macroalgae blocking the field of view, gently lift the BUV unit away from the substratum, allow for some vessel and camera drift, check the depth sounder and LCD monitor for sea-bottom topography and lower to the substratum again.
6. Once a suitable site has been located, write the GPS coordinates (adjusted) in the 'BUV deployment data sheet' (doccm-2618429), release the drop camera (if relevant) from the BUV unit with a hard jerk and haul to surface.
7. Untie the surface float and accompanying rope from the vessel bollard and pitch away from the vessel.
8. Move the vessel away slowly from the site.
9. Over the ensuing 30–35-minute sampling period, additional BUV deployments can be made if a second system is available.

The BUV unit should always be deployed on the leeward side of the vessel and/or with the prevailing current to ensure the camera, rope, lanyard, and surface float do not trail under the

[3] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-buv-deployment-data-sheet.pdfhttp://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-buv-deployment-data-sheet.pdf

vessel where they may be prone to snagging or damage. It is important to avoid any hard knocks to the unit during deployment, as this may distort the pre-set focus.

Deployment duration

For general New Zealand conditions, the standard duration of a sample is 30 minutes once the unit has settled on the seabed. Shorter deployments are likely to not be long enough to attract the species of interest in the vicinity while longer deployments are not likely to bring additional information and will increase the distance required between adjacent deployments. Increased distance between stations might not always be feasible depending on the configuration of the area sampled.

Retrieval

1. Approach the surface buoy considering sea state and prevailing currents. It is best to approach the surface buoy from downwind and/or against the current so that the vessel will always move away from the BUV unit as opposed to over the top, reducing the chance of entanglement or damage to the vessel, BUV unit, or both.
2. Retrieve the rope warp with a blunted gaff, and disengage the vessel engine. Haul the BUV unit to surface taking in slack quickly.
3. Verify that the camera is still recording and fill out the remainder of the ‘BUV deployment data sheet’ (doccm-2618429) for that particular site.
4. Ensure the BUV unit is securely fastened on the vessel when traveling between sampling sites.
5. Move onto the next site repeating the above procedures.
6. If the BUV unit requires opening in the field, completely dry the unit with towels before removing the lens.
7. At the end of the day’s sampling, ensure the BUV unit is washed down with fresh water and dried.
8. All video data will require immediate backup and storage to computer hard drives.

Figure 26. Filming site-specific details (on pad) relating to the BUV drop.

Figure 27. Immediately prior to deployment. Note: The BUV coaxial cord (black) plus surface rope (green) and buoy (not in field of view) are held together by the surveyor to reduce the chance of entanglement.

Reviewing video to collect abundance data

A good open-source software for viewing videos is VLC (http://www.videolan.org/.

Edited video data for each site should be of > 30 minutes duration by default. Begin the 30-minute start point once the BUV unit has settled on the bottom.

Use the MS Excel template to enter your data when starting to review the video (e.g. Figure 28).

The example spreadsheet in Figure 28 starts at 00:02:42 (00 hours, 02 minutes and 42 seconds). Abundance data are to be collected at 30-second intervals, therefore the first count point is at 00:03:12, second count point is 00:03:42, third count point is 00:04:12 and so on.

Watch the video for each 30-second sequence noting movement of fish in and out of the field of view, intra- and inter-specific interactions, predator occurrence and any movement (drift) of the BUV setup.

Count the total number of each fish species in the frame at each count point replicate (n = 60 per 30-min drop for 30-second counts, n = 30 per 30-min drop for 60-second counts). At times fish will obscure one another. To obtain accurate counts it may be necessary to rewind or fast-forward the video footage frame by frame to ensure all fish are counted (VLC offers this option: View > Advanced Controls).

The template spreadsheet automatically gives you MAX*count* values for all species. This MAX*count* will be used for subsequent size analysis.

	A	B	D	E	F	G	H	I	J	K	L	M	N	O
1	**BRUV VIDEO ANALYSIS - 30s**				MAX	Time	MAX	Time	MAX	Time	MAX	Time	MAX	Time
2	**Deployment info**	Upload pictures	Time interval	Replicate	Thyrsites atun	Barracouta	Pseudolabrus miles	Scarlet Wrasse	Parapercis colias	Blue Cod	Notolabrus celidotus	Spotty	Dasyatis brevicaudata	Shorttail stingray
3	Encoder of this data (First and last name)	*Emma Brown*	0:02:42	0										
4	Tape analyst (First and last name)	*Emma Brown*	0:03:12	1										
5	Date of data entry (dd/mm/yyyy)	*6/11/2015*	0:03:42	2										
6	DocCM link to field sheets	V sites - Tapuae Marine Reserve	0:04:12	3										
7	DOC Region	*Central North Island*	0:04:42	4										
8	DOC Office	*Ngāmotu / New Plymouth Office*	0:05:12	5										
9	Contractor	*Contractor*	0:05:42	6	1	5:59								
10	Contract number	*Contract_num*	0:06:12	7	1	6:34								
11	BRUV type	*L Frame*	0:06:42	8			1	6:45						
12	Camera model	*HDR-XR350VE*	0:07:12	9										
13	Lens model	*Raynox QC-303*	0:07:42	10										
14	Survey leader (First and last name)	*Callum Lilley*	0:08:12	11			1	8:15						
15	Recorder (First and last name)	*Callum Lilley/Bryan Williams*	0:08:42	12							1	8:56		
16	Date of deployment (dd/mm/yyyy)	*13/04/2011*	0:09:12	13	1	9:17								
17	Vessel used to deploy unit	*Orca*	0:09:42	14			1	10:11						
18	Bait species	*Pilchard*	0:10:12	15					1	10:39				
19	Amount of bait (g)	*100*	0:10:42	16					1	10:54				
20	Deployment number (unique #)	*Deployment_ID*	0:11:12	17	1	11:22								
21	Location	*Tapuae Marine Reserve*	0:11:42	18	1	12:08	1	11:58						
22	Site name	*BB2*	0:12:12	19										
23	Replicate number within site	*1*	0:12:42	20	1	12:51	1	12:57						
24	Protection status	*No protection*	0:13:12	21			2	13:40	2	13:33				
25	Latitude south degree (°)	*39*	0:13:42	22	1	13:49	3	13:45	2	13:45				
26	Latitude south minute (mm.mmm)	*5.609*	0:14:12	23			1	14:23	2	14:17				
27	Longitude east degree (°)	*173*	0:14:42	24	1	15:06	2	14:46	2	14:46				
28	Longitude east minute (mm.mmm)	*58.147*	0:15:12	25			2	15:19	2	15:14				
29	Depth (m)	*14.4*	0:15:42	26			1	15:46	1	16:11				
30	Time unit in (hh:mm)	*08:17*	0:16:12	27			1	16:36	2	16:26				
31	Time unit out (hh:mm)	*08:52*	0:16:42	28			2	16:48						
32	Underwater visibility (m)	*UW_visibility*	0:17:12	29			4	17:22	1	17:18				
33	Habitat description	*Rocks, algae*	0:17:42	30			3	17:59	1	17.42				
34	Distance to reef of deployment (m)	*0*	0:18:12	31			2	18:40						
35	Weather	*Fine*	0:18:42	32			2	18:55	1	18:59				
36	Notes	*Notes_deployment*	0:19:12	33	1	19:39	1	19:24						
37	Path to pictures	*Path_picture*	0:19:42	34			2	19:55						
38			0:20:12	35			1	20:34						
39	Save data for this deployment	Recall last deployment info	0:20:42	36			1	20:45	3	21:07				
40			0:21:12	37			2	21:17	2	21:13				
41			0:21:42	38			1	21:52	2	21:45				
42			0:22:12	39			1	22:21	2	22:34				
43			0:22:42	40			2	23:09	2	22:48				

Transfer to database | video data 30sec interval | video data 60sec interval | All counts compiled | MaxCount compiled | Lengt

Figure 28. Spreadsheet depicting analysis of MAX*Count* for barracuda, scarlet wrasse, blue cod, spotty and short-tail stingray.

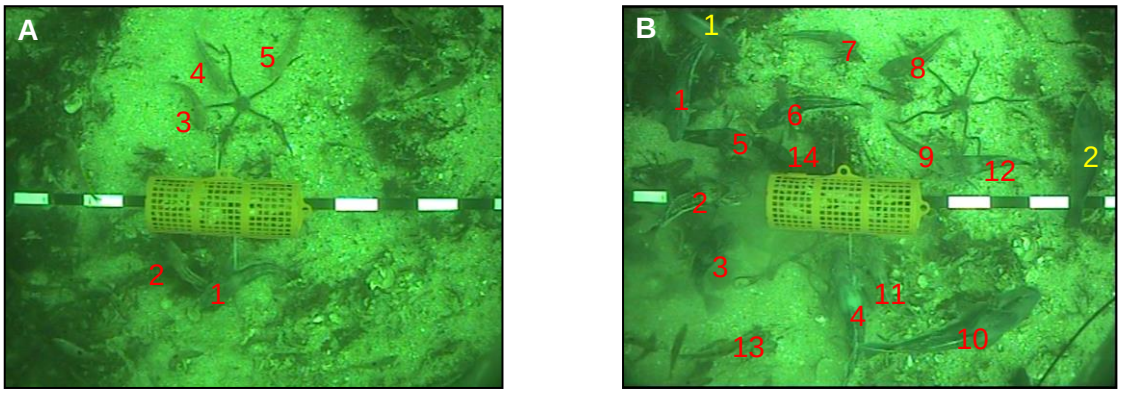

Figure 29. Counts of blue cod (red numbers) and girdled wrasse (yellow numbers) at two different times following BUV deployment.

Managing biases associated with counts

It is likely that any given BUV survey will encounter issues that are out of the control of the researcher, some of which may bias the data acquisition phase. Biases such as BUV drift and predator-related effects may impinge on abundance analysis. If camera drift is subtle or not lasting long (a few seconds) then it is likely to be inconsequential. On the other hand, if BUV drift is prolonged, then a new deployment is required. The movement of BUV units has been shown to have a deterrent effect on some species, e.g. snapper (Willis, pers. comm.). To decrease drifting issues, the BUV system could be weighted down further, but consideration should be given to factors such as potential impacts on the seabed if the unit continued to drift, the strength of the unit itself, and also the logistical difficulties associated with handling heavier equipment on a vessel.

Biases associated with predator incursions need to be dealt with on a case-by-case basis. In the instance of large predators such as seals, sea lions or sharks, there is generally a rapid scatter of fishes away from the BUV unit. In our experience this is often followed by a fairly rapid (a few minutes) return of target species to pre-incursion levels. Data acquisition should cease until pre-incursion levels have stabilised. In the instance of multiple incursions for a given deployment, it may be prudent to deploy the unit again at a later stage.

If octopus or lobsters are attracted to the bait, there is very little the researcher can immediately do to eliminate the bias other than redeploying the unit or resuming counts when the bias abates.

Irrespective of the bias, its nature and duration should be noted in detail and attached to the accompanying data spreadsheet for the corresponding deployment. Reference to any biases that have occurred should be included in data presentation and reporting sections.

Reviewing video to collect size data

Before beginning size analysis, the investigator should revisit the 30- or 60-second sequence that corresponds to the MAX*count* for each species of interest. The objective is to identify which fish can be easily sized and which will be more difficult, i.e. those present at the periphery.

Good freeware applications for obtaining length measurements are ImageTool (http://compdent.uthscsa.edu/dig/itdesc.html) and Fiji/ImageJ (http://fiji.sc/Fiji). Fiji is the same software as ImageJ but comes with additional add-ons. Other programs are available, with additional features including a three-point calibration, but are reasonably expensive. Examples of how to use Fiji are given in Appendix B.

For size analysis using Fiji, a capture program will be required to convert video data (e.g. in AVI format) into a picture file format (e.g. JPEG). To convert the entire video into frames (single pictures), several freeware options are available, such as Free Video Converter (http://www.iwisoft.com/videoconverter/video-converter-features.php), Format Factory (http://www.formatoz.com/index.html) or VLC http://www.pcfreetime.com/. However, only one or a few frames are usually necessary per video for each species and hence it is much more convenient to extract these frames of interest rather than converting the whole video into pictures. This can be done using VLC (see Appendix B).

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Managing biases when measuring fish lengths

Biases associated with size estimation are typically artefacts of the camera and BUV unit itself. They relate to lens distortion and length measurements of target fishes that occur at different heights within the field of view. At the time of writing, we do not have a clear understanding of the degree of lens distortion (minor, moderate or major) stemming from the use of the semi-fisheye lens (termed barrel distortion), but this warrants examination so that correction methods can be developed (Weng et al. 1992). The open-source software Fiji has a plugin to correct for distortion, developed by Kaynig et al. (2010). It creates a calibration file, specific to any combination of camera and semi-fisheye lens, from a series of test images. This calibration file can then be applied to all the images where fishes have to be measured. This method still has to be trialled but offers a promising solution to measurements using distorted images.

Another option to deal with lens distortion is to undertake calibration deployments using model fish of known size at different points within the field of view. Obtaining data on fish heights can be done by placing a secondary camera (e.g. GoPro or equivalent) adjacent to the hinge that links the bottom scale bar and angled side bar and adding a vertical scale bar at the outer end of the bottom scale bar. The stereo capability of BUV systems like the one shown in Figure 2 also eliminate the problem of not being able to do some measurements but at the cost of a much more complex setup.

In addition, we do not have a clear protocol for estimating the length of fishes that occur at different heights in the field of view, other than calibrating the measurement tool from the top of the bait container that sits 100 mm higher than the calibrated base and obtaining measurements when the fish are either close to the bait container or calibrated scale bar (Willis & Babcock 2000). The issue of variable heights is generally not a problem for blue cod, which typically sit on the bottom within the calibrated field of view, but can be an issue for species such as snapper and tarakihi. When it is difficult to obtain an accurate length estimate, it is recommended to exclude the measurement from the dataset.

Timing

Consideration of timing of the surveying activity should include:

- Any diurnal, seasonal or lunar characteristics 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 management[4] 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.

- Species identification 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.

References and further reading

Anderson, M.J.; Millar, R.B. 2004: Spatial variation and effects of habitat on temperate reef fish assemblages in northeastern New Zealand. *Journal of Experimental Marine Biology and Ecology 305:* 191–221.

Cappo, M.; Harvey, E.S.; Shortis, M. 2006: Counting and measuring fish with baited video techniques—an overview. Pp. 101–114 in Furlani, D.; Beumer, J.P. (Eds.): Proceedings of the Australian Society for Fish Biology Workshop, Hobart, Australia, August 2007. Australian Society for Fish Biology.

Cappo, M.; Speare, P.; De'ath, G. 2004: Comparison of baited remote underwater video stations (BUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. *Journal of Experimental Marine Biology and Ecology 302:* 123–152.

[4] http://www.worksafe.govt.nz/worksafe/hswa/health-safety/how-to-manage-work-risks

Cole, R.G. 1990: Effects of marine reserve protection at Goat Island, northern New Zealand. *New Zealand Journal of Marine and Freshwater Research 24:* 197–210.

Cole, R.G. 1994: Abundance, size structure, and diver-oriented behaviour of three large benthic carnivorous fishes in a marine reserve in northeastern New Zealand. *Biological Conservation 70:* 93–99.

Cole, R.G.; Davey, N.K.; Carbines, G.D.; Stewart, R. 2012: Fish-habitat associations in New Zealand: geographical contrasts. *Marine Ecology Progress Series 450:* 131–145.

Denny, C.M.; Willis, T.J.; Babcock, R.C. 2004: Rapid recolonisation of snapper *Pagrus auratus*: Sparidae within an offshore island marine reserve after implementation of no-take status. *Marine Ecology Progress Series 272:* 183–190.

De Robertis, A.; Handegard, N.O. 2012: Fish avoidance of research vessels and the efficacy of noise-reduced vessels: a review. *ICES Journal of Marine Science 70:* 34–45.

Díaz-Guisado, D. 2014: Effects of marine reserve protection on adjacent non-protected populations in New Zealand. PhD thesis, Victoria University of Wellington. 268 p.

Haggitt, T.; Freeman, D.; Lily, C. 2014: Baited remote underwater video guidelines. Prepared by eCoast for the Department of Conservation, Wellington. 82 p. (doccm-1395189) http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-baited-remote-underwater-video-guidelines.pdf

Harvey, E.S.; Cappo, M.; Butler, J.J.; Hall, N.; Kendrick, G.A. 2007: Bait attraction affects the performance of remote underwater video stations in assessment of demersal fish community structure. *Marine Ecology Progress Series 350:* 245–254.

Harvey, E.S.; Fletcher, D.; Shortis, M.R.; Kendrick, G.A. 2004: A comparison of underwater visual distance estimates made by scuba divers and a stereo-video system: implications for underwater visual census of reef fish abundance. *Marine and Freshwater Research 55:* 573–580.

Hurlbert, S.H. 1984: Pseudoreplication and the design of ecological field experiments. *Ecological Monographs 54:* 187–211.

Kaynig, V.; Fischer, B.; Müller, E.; Buhmann, J.M. 2010: Fully automatic stitching and distortion correction of transmission electron microscope images. *Journal of Structural Biology 171*: 163–173.

Kingsford, M.; Battershill, C. 2000: *Studying temperate marine environments—A handbook for ecologists*. Canterbury University Press, Christchurch.

Langlois, T.J.; Fitzpatrick, B.R.; Fairclough, D.V.; Wakefield, C.B.; Hesp, S.A.; McLean, D.L.; Harvey, E.S.; Meeuwig, J.J. 2012: Similarities between line fishing and baited stereo-video estimations of length-frequency: novel application of kernel density estimates. *PLoS One 7*(11): e45973.

Langlois, T.; Harvey, E.; Fitzpatrick, B.; Meeuwig, J.; Shedrawi, G.; Watson, D. 2010: Cost-efficient sampling of fish assemblages: comparison of baited video stations and diver video transects. *Aquatic Biology 9:* 155–168.

Mallet, D.; Pelletier, D. 2014: Underwater video techniques for observing coastal marine biodiversity: A review of sixty years of publications (1952–2012). *Fisheries Research 154:* 44–62.

McArdle, B.H; Anderson, M.J. 2004: Variance heterogeneity, transformations, and models of species abundance: a cautionary tale. *Canadian Journal of Fisheries and Aquatic Sciences 61*: 1294–1302.

McCullagh, P.; Nelder, J.A. 1989: *Generalized linear models*. Chapman & Hall, London.

Morrison, A.E.; Gregor, K.E. 2012: Snapper (*Pagrus auratus*) abundance and size at Tūhua Marine Reserve as determined by baited underwater video (BUV) survey. *Technical Report Series 6*. Rotorua, New Zealand: East Coast Bay of Plenty Conservancy, Department of Conservation.

O'Hara, R.B.; Kotze, D.J. 2010: Do not log-transform count data. *Methods in Ecology and Evolution 1*: 118–122.

Parsons, D.M.; Morrison, M.A.; Slater, M.J. 2010: Responses to marine reserves: decreased dispersion of the sparid *Pagrus auratus* (snapper). *Biological Conservation 143:* 2039–2048.

R Development Core Team. 2011: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Richardson J. 2015: Using unbaited remote video cameras to assess the effect of marine reserves on fish populations. Master's thesis, The University of Auckland, Auckland. 59 p.

Roux de Buisson, P. 2009: Poor Knights Islands Marine Reserve and Mimiwhangata Marine Park fish monitoring 2009: Department of Conservation, Whangarei. 43 p.

Shortis, M.; Harvey, E.; Abdo, D. 2009: A review of underwater stereo-image measurement for marine biology and ecology applications. *Oceanography and Marine Biology: An Annual Review 47:* 257–292.

Sokal, R.; Rohlf, F. 1995: Biometry: the principles and practice of statistics in biological research. 3rd edition: WH Freeman, New York, USA. 887 p.

Taylor, R.B.; Willis, T.J. 1998: Relationships amongst length, weight and growth of north-eastern New Zealand reef fishes. *Marine and Freshwater Research 49:* 255–260.

Underwood, A. 1993: The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world. *Australian Journal of Ecology 18:* 99–116.

Weng, J.; Cohen, P.; Herniou, M. 1992: Camera calibration with distortion models and accuracy evaluation. *IEEE Transactions on Pattern Analysis and Machine Intelligence 14:* 965–980.

Willis, T.J.; Babcock, R.C. 2000: A baited underwater video system for the determination of relative density of carnivorous reef fish. *Marine and Freshwater Research 51:* 755–763.

Willis, T.; Millar, R.; Babcock, R. 2000: Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. *Marine Ecology Progress Series 198:* 249–260.

Willis, T.J.; Millar, R.B.; Babcock R.C. 2003: Protection of exploited fish in temperate regions: high density and biomass of snapper *Pagrus auratus* (Sparidae) in northern New Zealand marine reserves. *Journal of Applied Ecology 40:* 214–227.

Zintzen, V.; Anderson, M.J.; Roberts, C.D.; Harvey, E.S.; Stewart, A.L.; Struthers, C.D. 2012: Diversity and composition of demersal fishes along a depth gradient assessed by baited remote underwater stereo-video. *PLoS ONE 7*(10): 1–14.

Zuur, A.F.; Ieno, E.N.; Smith, G.M. 2007: *Analysing ecological data*. Springer, New York.

Zuur, A.; Ieno, E.N.; Walker, N.; Saveliev, A.A.; Smith, G.M. 2009: *Mixed effects models and extensions in ecology with R*. Springer, New York.

Appendix A

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

doccm-1163829	MPAMAR metadata—National
doccm-1395189	Baited remote underwater video guidelines
doccm-2638313	Baited underwater video: definition of data fields
doccm-2618429	BUV deployment data sheet
doccm-146272	Standard inventory and monitoring project plan

Appendix B

Size analysis with Fiji/ImageTool and VLC software

- The Fiji software (http://fiji.sc/) can be used for size analysis (Figure 30). It is a standalone program which does not need to be installed; it can run directly from its own folder.
- The image(s) that correspond to the MAX*count* will need to be imported into the program. This can be achieved using VLC (http://www.videolan.org/vlc/index.html or http://www.pcfreetime.com/).

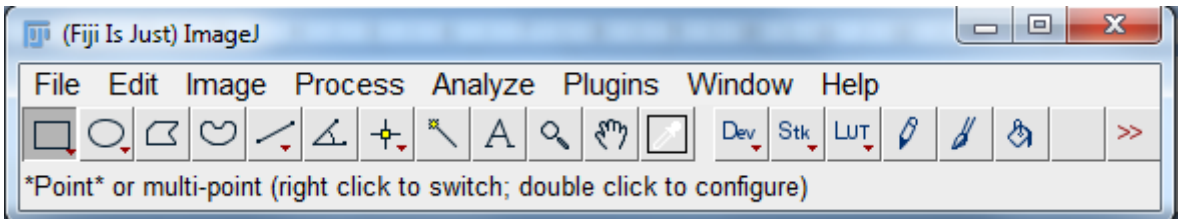

Figure 30. Fiji main menu.

Exporting frames from VLC (version 2.2.2)

- If you do not have VLC on your PC, download and install it.
- Open the video file of interest.
- Check that Advanced Controls are available: View > Advanced Controls.
- Go to the time code of your Max*count*, as based on the results of the analysis you did.
- Isolate the frame(s) you are interested in. You can use the tools provided by the Advanced Control menu to advance frame by frame 
- Press Snapshot  to save the desired frame (shortcut: SHIFT+S).
- Note that the folder where the images are saved can be changed, as well as the filename convention. Go to Tools > Preferences > Video. It makes sense to change the prefix to reflect the time stamp of the video. To do this, add '$T' (Figure 31).

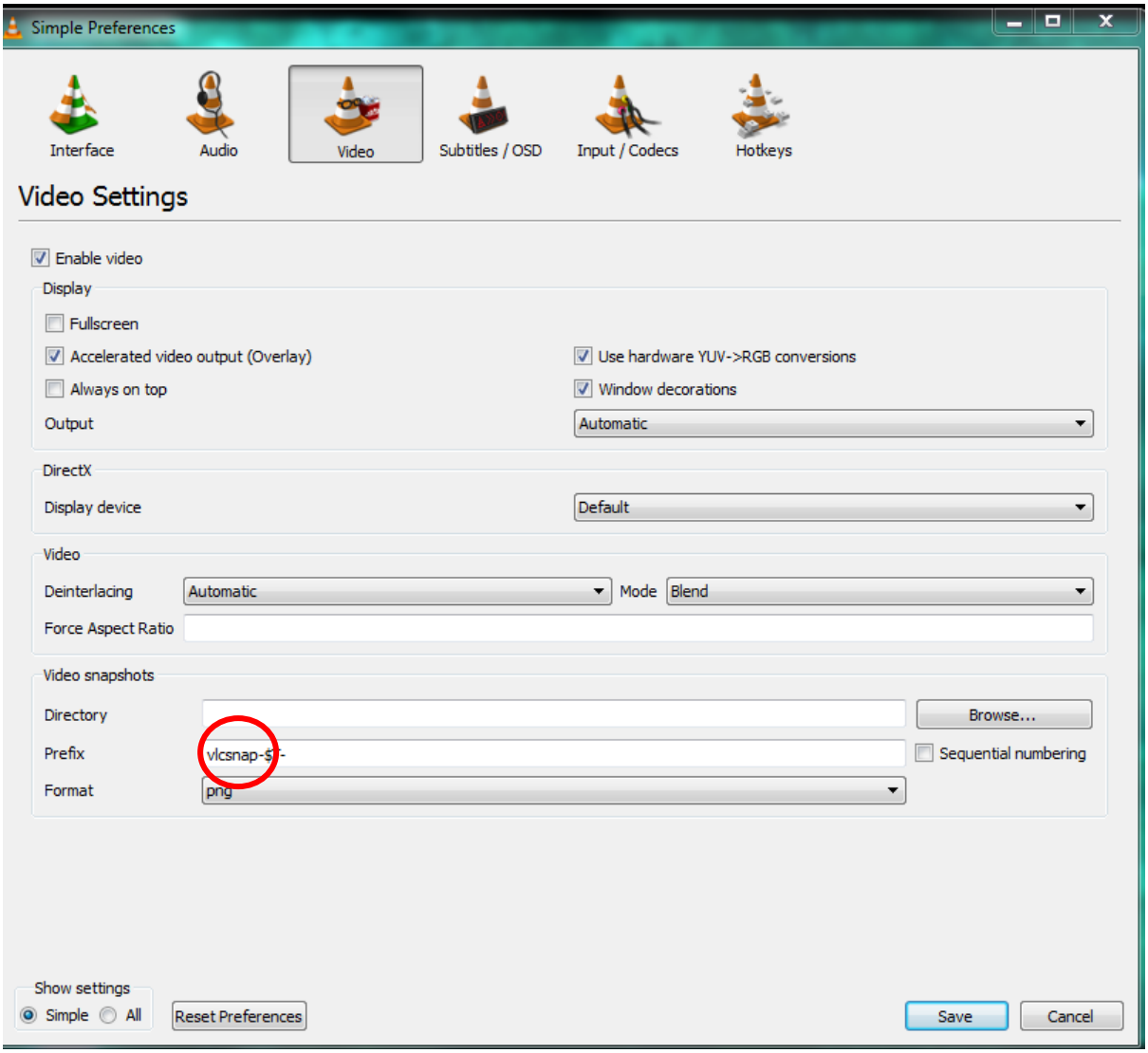

Figure 31. Changing output folder and prefix of snapshots in VLC

Image import

- To import image: File > Open.
- Check that the displayed image is correct and corresponds to the MAX*counts* (Figure 32). Note: Counts can be re-checked in Fiji using the 'Point Picker' plugin.

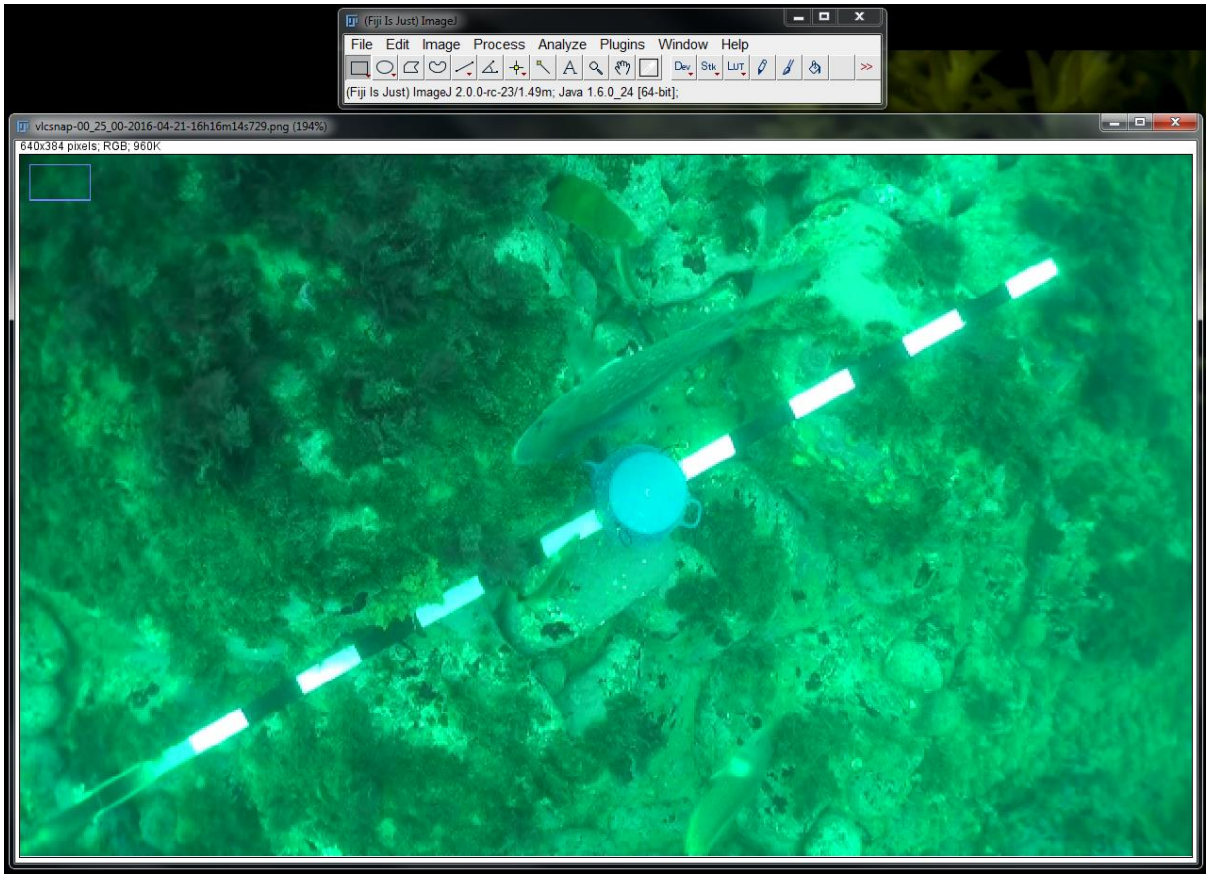

Figure 32. Imported image corresponding to the MAX*count* for snapper (a single specimen in this case).

Calibration

- Calibration only needs to be done once at the beginning of a Fiji session if the same camera system is used. Calibration should be re-done for every separate day of sampling event or any time it is suspected that the field of view changed because the camera was moved.
- Use the line tool  and draw a line over the length of one black or white mark of the frame (Figure 33). Alternatively, draw the line across the diameter of the top section of the bait holder. It can be advantageous to use the bait holder instead of the base bar for scaling the image because it is slightly higher than the seabed and more likely to be at the same height than where fishes will be measured. It might sometimes be necessary to use both scales for calibrations if fishes are seen to be at different heights.

Figure 33. Calibrating the image.

- Go to Analyze > Set Scale and enter the correct values. In this case, both the scale bar marks and the bait holder have a dimension of 100 mm. Tick the option *Global* if you want this scale to be used for the following image you will open during this Fiji session (Figure 34).

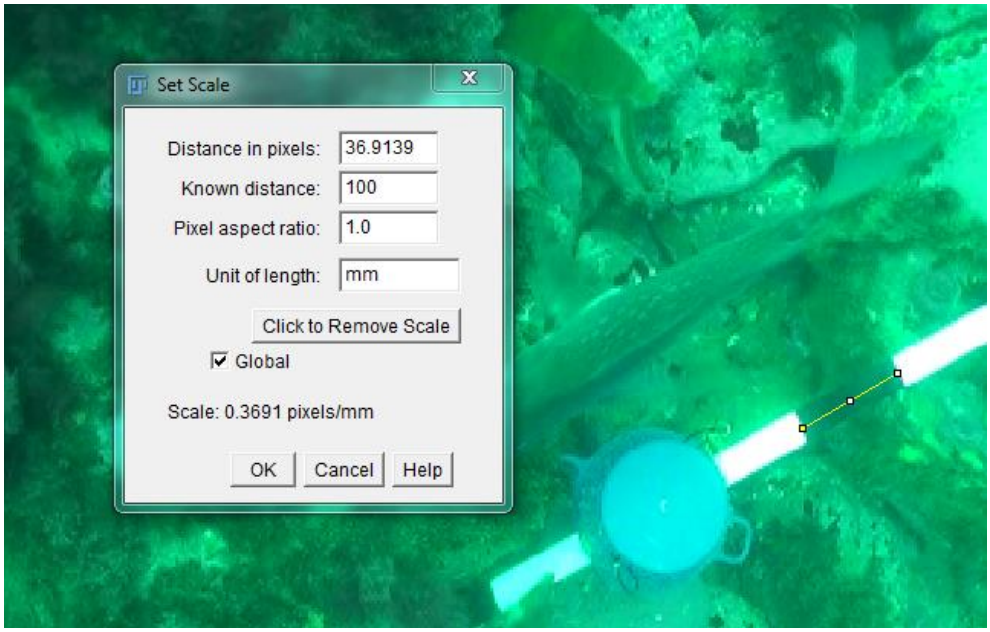

Figure 34. Setting the scale. Here the black marking is 100 mm in length. Note that the option *Global* is ticked to use this scale for all following images.

- Check that your scale is right by making a measurement of another black or white marking, or top of bait pot if its dimensions are known (see below for procedure).

Size measurement

- Use the line tool  and draw a line over the length of the first fish. Go to Analyze > Measure or Press CONTROL+M. The results of your measurements will be displayed under the *Length* field (Figure 35).

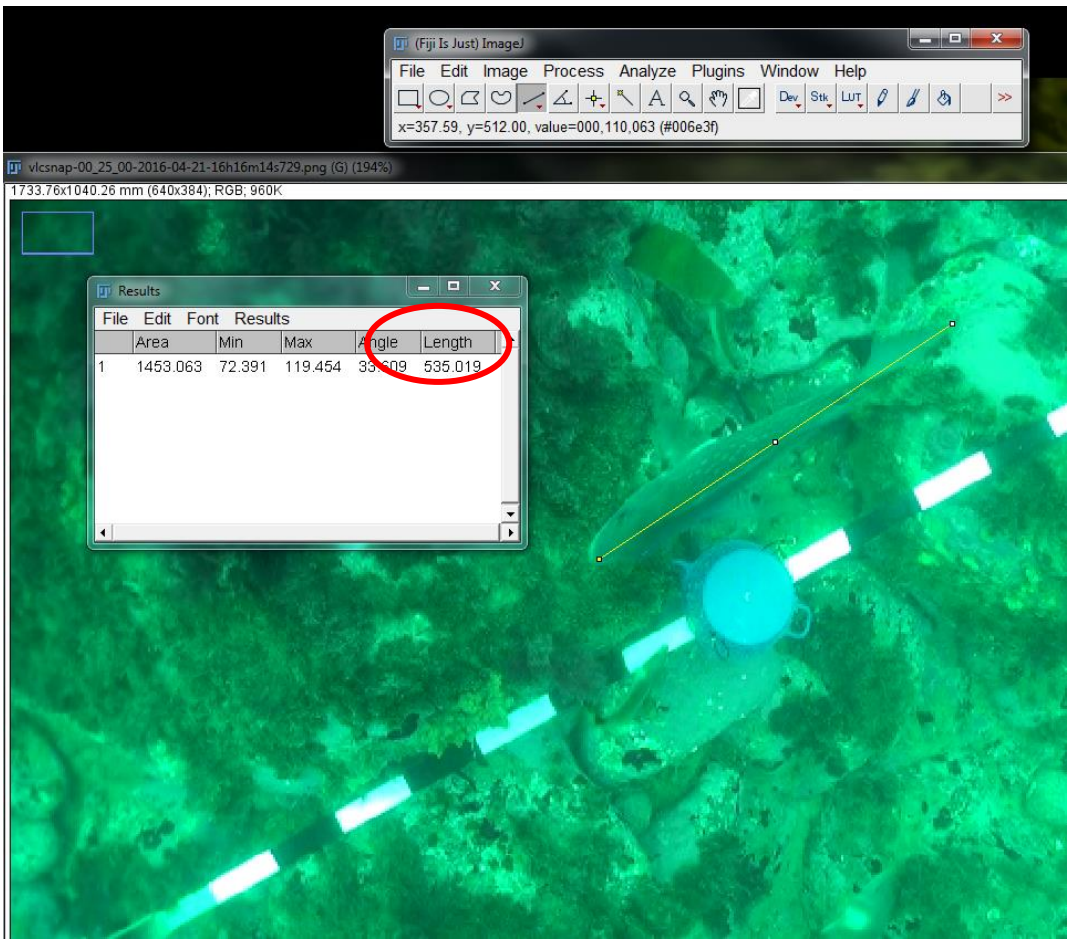

Figure 35. Measuring the length of a snapper. This specimen is 535 mm in total length.

- Transfer the length values to your master spreadsheet and then move to the next specimen (or next image if this was the last specimen to measure on this image).
- Sometimes fish specimens might not be straight and it may be necessary to use multiple lines to produce an acceptable length measurement. Note, however, that this procedure is likely to produce length results with lower values than for straight fishes.

  To do a multiline measurement, right click on  and select Segmented lines  . You can then do a multiline measurement. Always finish by pressing CONTROL+M to display your result (Figure 36).

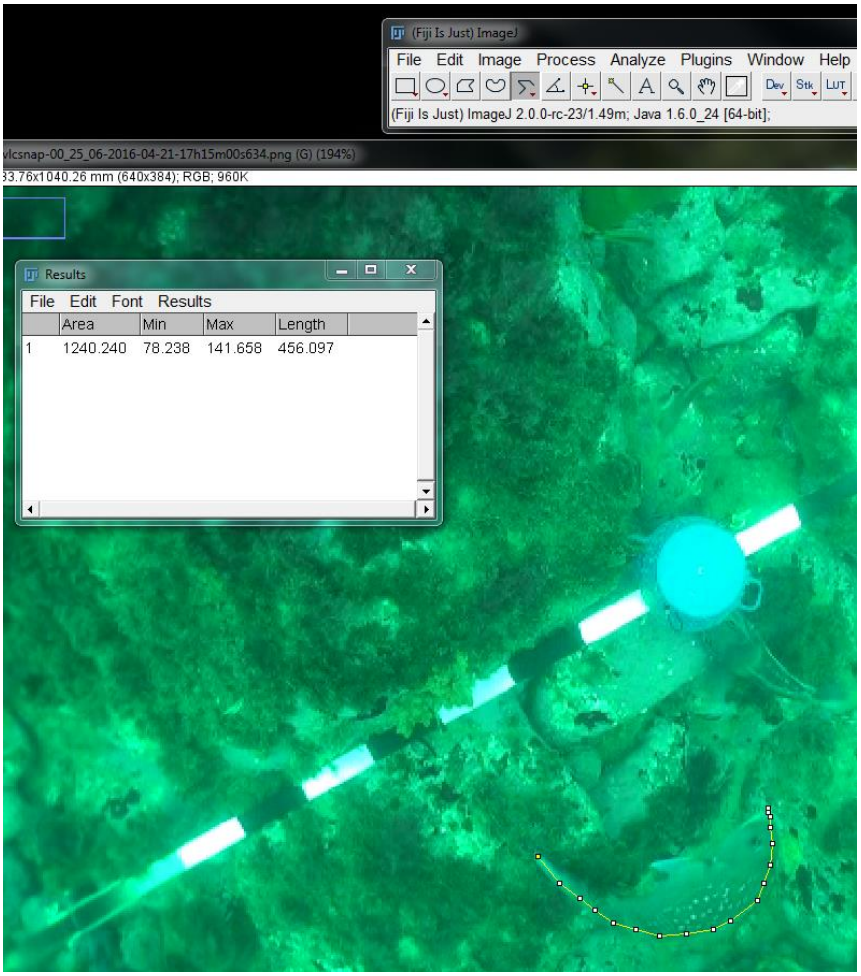

Figure 36. Multiline measurement of a non-straight specimen.