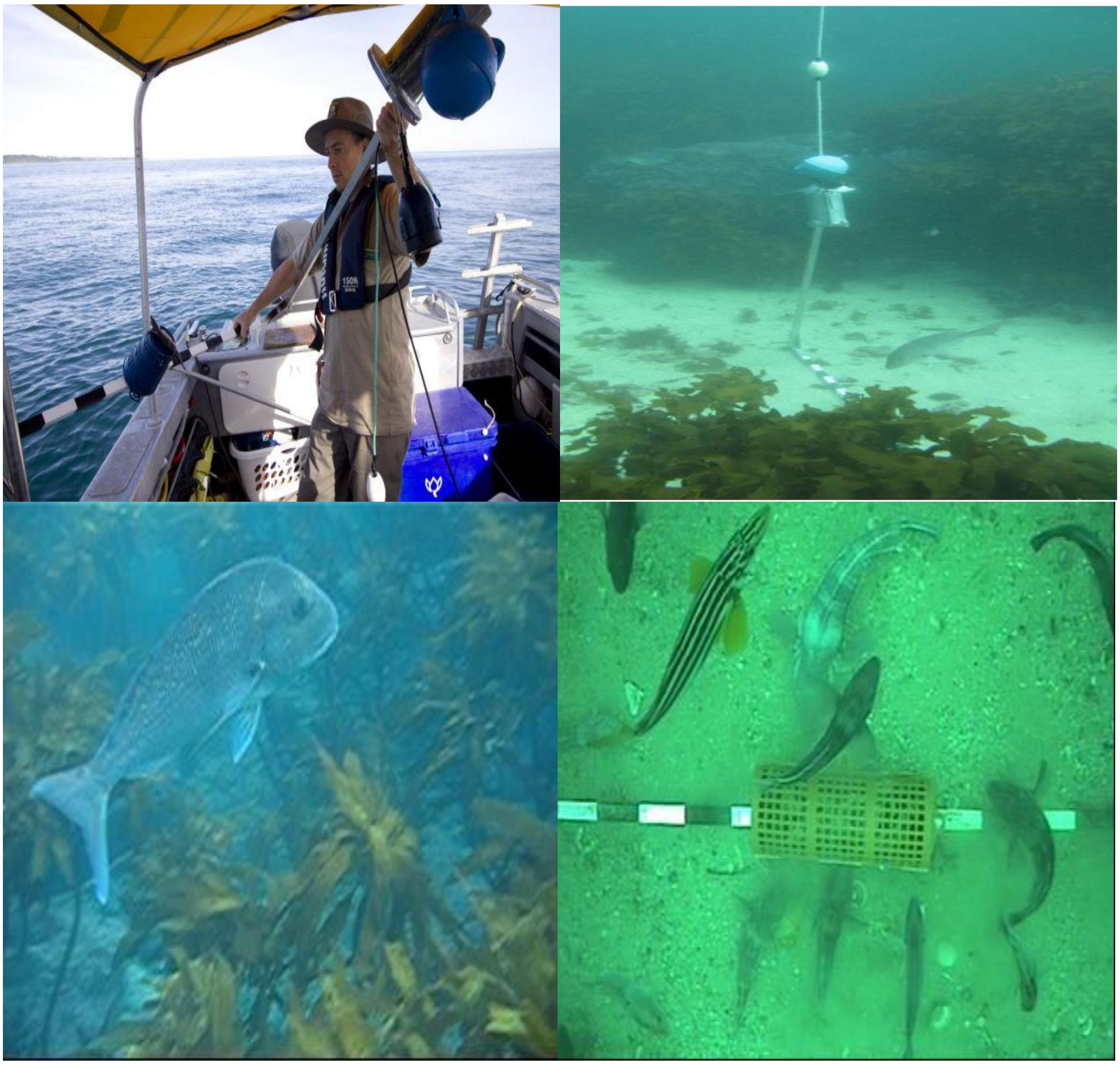
Baited Remote Underwater Video Guidelines



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V 1	November 2013	Draft
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Executive summary

- As part of a programme to improve monitoring and reporting of marine reserve fish populations the Department of Conservation required development of guidelines specific to baited remote underwater video (BRUV). The BRUV technique is considered an unobtrusive sampling technique and is effective in providing size and abundance estimates of carnivorous fish species that are otherwise difficult to survey using diver-mediated techniques.

- These guidelines were based on the premise that the BRUV methodology could be standardized and implemented consistency across a wide range of marine reserves that typify the New Zealand coastline.

- Key sections of the guidelines include:

    - Biases associated with the technique
    - Sampling design
    - Equipment
    - Field deployment
    - Data management
    - Obtaining abundance and size estimates
    - Data analysis

- At the time of writing we recommend continued use of the downward-facing (vertical) BRUV system due to its ease of application, cheap construction costs, and both historic and sustained (widespread) utilization across multiple marine reserves in New Zealand.

- There are several aspects of the system that would profit from an assessment that is focused at deriving error or correction estimates that can be placed around size measurements. Specifically this would be in relation to: 1) potential lens distortion across the field of view; and, 2) to obtain more accurate size estimates for fishes that occur at different heights within the field of view.

- A comparison of size and abundance estimates derived from the downward-facing BRUV to those derived from a stereo BRUV unit and unbaited systems would also be of value.

- Research on aspects such as the area of attraction of various bait types and volume used for BRUV surveys would help determine the sample area for BRUV deployments, establish whether different fish species are variably attracted to bait and help with standardization of the system.

Contents

1.0 Introduction

1.1 Preamble

Baited remote underwater video [commonly abbreviated to BRUV or BUV], is a technique primarily used to unobtrusively sample carnivorous fishes. It is favoured by researchers worldwide where traditional diver surveys are impractical and as a means to eliminate diver-positive or diver-negative behavioural responses that generate unwanted sampling biases (e.g., Cole 1994; Shortis and Harvey 1998; Willis *et al*. 2000; Cappo *et al*. 2007; Gardner and Struthers 2013).

The utility of the technique is vast. It is commonly employed over a range of marine environments (tropical and temperate; estuarine, coastal, and offshore; benthic and pelagic) and to fulfill myriad objectives. These include, but are not limited to, gauging ecosystem health and biodiversity (Harvey *et al.* 2012), fisheries assessments (Willis and Handley 2011), evaluating single-species and community-level depth distributions (Priede *et al*. 1990), estimating the effectiveness of complete marine reserve protection (Willis *et al.* 2000; Langlois *et al*. 2010), partial protection (Denny and Babcock 2004; Denny *et al*. 2004; Roux De Buisson 2009) and inadvertent fishing exclusion zones such as cable ways (e.g., Shears and Usmar 2006). Further, recorded images provide a visual platform to inform and engage the general public on the marine reserve functioning and conservation, and provide a valuable visual archive for future assessment of fish communities.

The array of camera systems (and associated analytical tools) are equally varied, ranging from tethered, towed, diver-operated, vertically facing, horizontal-facing, single lens, stereo, blue light, baited, and unbaited, including various combinations of the aforementioned. Variants have arisen through time for four main reasons: cost reductions; bias reduction/elimination; technological advancement; and, sampling necessity.

Surveying reef fish abundance, size, and, biodiversity is an important part of ecosystem understanding and management. The Department of Conservation (DOC) has the responsibility of conserving New Zealand's natural and historic heritage for all to enjoy for the present and in the future. The Department of Conservation's primary purpose is conservation leadership for a prosperous New Zealand, where New Zealanders gain environmental, social, and economic benefits from healthy functioning ecosystems, recreation opportunities and our history. The Department of Conservation protects marine biodiversity using a number of tools including a national network of protected marine areas representing a variety of New Zealand marine ecosystems and habitats.

Over the last 25 years, the Department of Conservation has been responsible for the collection of large datasets on exploited marine species and functionally important benthic habitats within and outside many of the marine reserve it manages. These datasets contain extensive biological and often physical data that help evaluate reserve performance, influences reserve management and informs public perception.

At a statutory level, the Department of Conservation administers the Marine Reserves Act 1971 and is responsible for the conservation of marine mammals through the Marine Mammals Protection Act 1978, and for the conservation of other species protected under the Wildlife Act 1953. The Conservation Act 1987 gives the Department a broad mandate for advocacy on marine conservation issues, as well as responsibilities for public awareness (Department of Conservation 2012). Monitoring community structure, species diversity, and the distribution and abundance of both dominant and exploited species through space and time is therefore an important component of ecosystem and conservation management.

1.2 Purpose of Investigation

As part of a programme to improve monitoring and reporting of marine reserves, the Department of Conservation wishes to develop guidelines for the use of baited underwater video for the purposes of monitoring fish populations. This report is primarily directed at providing a platform for maintaining a consistent approach to undertaking BRUVs surveys used in marine reserve research. The guidelines are to be made available both within the Department of Conservation and also be available via the Department of Conservation website (www.doc.govt.nz) primarily to provide guidance to others who may wish to undertake baited underwater video surveys.

1.3 Report Structure

The report is divided into discrete sections; these are:

- Broad literature review of methodologies employed to evaluate reef-fish abundance and biodiversity including baited remote underwater video surveys;
- Common biases central to the BRUV technique;
- Sampling design;
- BRUV setup and preparation;
- Field sampling and deployment;
- Data management;
- Abundance and size analysis;
- Data analysis.

2.0 Fish sampling methodologies and baited remote underwater video

2.1 Methodologies

Collecting data on fish abundance, diversity, and demographic attributes has been an important directive of environmental monitoring programmes. This has lead to a better understanding of coastal ecosystem functioning and management. Consequently, fish surveys are routinely undertaken worldwide over a range of habitats.

Methodological approaches used to obtain abundance, size, and demographic metrics for individual fish species and communities (multi-species) generally fall into two broad categories – capture-methods, which are typically destructive; and, observational methods, which are non-destructive (see below). Their subsequent efficacy depends ultimately on the objectives of the study/monitoring programme and nature of environments being sampled.

Destructive capture techniques such as spear-fishing, netting, dynamite and icthyocides (e.g., rotenone - Robertson and Smith-Vaniz (2008)) can yield information on whole fish assemblages, but as a rule preclude repeat sampling in the same area and may not be viable within protected areas. Unobtrusive techniques such as visual census using SCUBA and remote video (baited and unbaited) allow for repeat sampling, however, are prone to biases that may under- or over-inflate abundance and biodiversity levels for some sections of the reef-fish community. Acoustic tagging studies (e.g., Parsons *et al*. 2010) are typically directed at discerning patterns in fish movement and habitat utilization. Various attributes and drawbacks of commonly utilised fish sampling techniques are presented in Table 1.

All sampling techniques have various biases and constraints. As such, sampling approaches must be aligned and evaluated within the context of demographic attributes of the target species and communities being surveyed. Accordingly, it is often prudent to utilize several sampling techniques to completely fulfill the objects of a study (Lincoln Smith 1989; Willis *et al*. 2003). Establishing the optimal technique(s) for sampling dominant species and reef-fish communities has been the focus of many studies (see Willis *et al*. 2000; Watson *et al*. 2005; Watson and Harvey 2007; Langlois *et al*. 2010; Pelletier *et al*. 2011; Langlois *et al*. 2012; Gardner and Struthers 2013). As a general rule, BRUV and angling techniques are considered paramount for sampling carnivorous species, whereas visual census techniques are more-appropriate for non-destructively assessing assemblage structure and diversity. The following section provides a brief overview of common fish sampling methodologies including the extent of use and advances associated with BRUV. We also direct the reader to the paper of Cappo *et al*. (2007) for an excellent overview and historical milestones of BRUV.

Visual census techniques fall into two broad categories: 1) diver mediated (typically utilising SCUBA) and; 2) remote underwater video. Remote video sampling methods have distinct advantages over SCUBA-mediated visual estimate techniques, some of which include: operation in poorer visibility and at significantly greater depths (sometimes > 200 m); fewer personnel are required; bias caused by spatial variability in fish behaviour is reduced; the technique is less likely to return low (or zero) abundance estimates for large carnivorous species, meaning that the statistical power of comparisons is likely to be greater; and there is often lower field costs than diving operations (Willis and Babcock 2000; Willis *et al*. 2003; Cappo *et al*. 2007).

2.2 Remote Underwater Video

Initially the employment of baited and unbaited remote video techniques was to visually count fish and evaluate assemblage structure in habitats or at depths not accessible to SCUBA divers (e.g. Priede *et al*. 1994; Ellis and DeMartini 1995). Within New Zealand, the utility of baited remote video was adopted to undertake snapper (*Pagrus auratus*) and blue cod (*Parapercis colias*) size and abundance assessments as part of marine reserve surveys, primarily as a response to counteract diver-positive and diver-negative biases for snapper evident from earlier visual census surveys (see Cole *et al*. 1990; Cole 1994).

2.2.1 Vertical (down-ward facing) BRUV system

The first BRUV apparatus applied to survey marine reserves in New Zealand was a vertical downward facing system developed by Dr. Trevor Willis and co-workers (University of Auckland) in the late 1990's (Figure 1). As the system was chiefly developed for snapper and blue cod, it consisted of a triangular base which served as a calibrated field of view, a container that contained bait to attract fishes, and one downward facing high resolution TV camera linked to a recorder on the surface. Thus the system was permanently tethered to a vessel on the surface. Its development had an immediate positive influence on marine reserve research at both a national and international level which, albeit with several modifications, continues today.

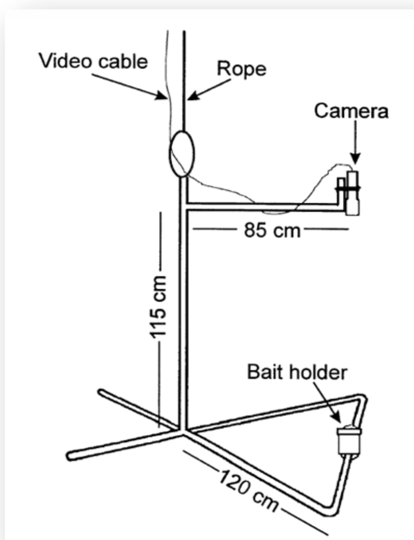


Figure 1. Schematic of the vertical facing baited underwater video unit presented in Willis and Babcock (2000).

During its inception, the BRUV system of Willis and Babcock (2000) was evaluated for abundance and size estimate accuracy (Willis *et al*. 2000). BRUV abundance estimates were based on a maximum count index (MAX*count*). The index was assessed in relation to deployment duration and compared to counts made from concurrently sampled visual transects. Measurement accuracy assessments for snapper were done using model plastic fish of known size, with the error being an overestimate of 16.9 ± 2.4 (S.E.) mm. In practise, this error was taken into account by measuring the diameter of the bait container, and scaling down the measured fish length by the observed container error (usually by 10–20%). For blue cod, size measurements were deemed to be of greater accuracy, as blue cod commonly rest on the bottom, i.e., within the calibrated field. It was suggested a mean measurement error of <20 mm was considered acceptable; see Willis and Babcock (2000) for justification and further discussion.

For the assessment of the most suitable deployment time, it was deemed that: 1) numbers of visible snapper increased with BRUV deployment time; 2) varying the length of BRUV deployment had little effect on the ability of the method to detect statistically significant differences in abundance between reserve and non-reserve – statistically significant differences between reserve and non-reserve sample means for snapper were detected within 5 min of the deployment; 3) an average of 70% of snapper detected after 60 min of deployment were identified after the first 30 min of deployment; and, 4) the maximum number (MAX*count*) of snapper observed on a 30 min video sequence was established as the best BRUV index of relative abundance, denoted as MAXsna (maximum snapper) and for blue cod – MAXcod.

The BRUV unit was further evaluated against two other commonly used sampling techniques – line angling and visual census (UVC) (Willis *et al*. 2000). Briefly, BRUV and line angling provided the best measures of adult *Pagrus auratus* density whereas UVC was less reliable. Relative density estimates were, however, broadly similar across techniques. In terms of species-specific size (mm), BRUV and angling generated similar estimates, whereas UVC tended to underestimate size.

Following on from its inception, the downward facing BUV technique has been utilised to estimate snapper, blue cod, and many other carnivorous fish species size and abundances across multiple marine reserves (e.g., Poor Knights Islands (PKI), Te Whanganui-a-Hei (Hahei), Tuhua (Willis *et al*. 2011), Kapiti (Gardner and Struthers 2013), fisheries exclusion zones (Willis and Handley 2012), cable ways that afford protection indirectly (Shears and Usmar 2006) and unprotected locations that warrant examination (Haggitt and Freeman 2013).

While the general BRUV configuration of Willis and Babcock (2000) has been maintained over the last decade, a comparable unit developed by Dr. Tim Langlois (formally University of Auckland) and Paul Roux de Buisson (formally Department of Conservation) has gained traction within the Department of Conservation over the last 5 years (Fig. 2). This unit forms the basis of the guideline sections 2 and 3.

2.2.2 Horizontal facing BRUV systems

The genesis of horizontally facing baited and unbaited remote video systems (Fig. 3) arose in Australia in the mid-to-late 1990's and have been touted to sample tropical reef fish assemblages more effectively than downward-facing remote video techniques (Harvey and Shortis 1996; 1998; Francour *et al*. 1999; Harvey *et al*. 2001a,b; Cappo *et al*. 2004; Langlois *et al*. 2010).

A large body of work has been undertaken addressing the accuracy and precision of size estimates derived from visual census, diver operated stereo video, horizontal single video and horizontal stereo video techniques for tropical and temperate reef fish systems (Harvey *et al*. 2002; Shortis *et al*. 2009; Langlois *et al.* 2012). Of all iterations examined, stereo video techniques have been championed for their general superiority in providing accurate and precise size estimates relative to the majority of other BRUV configurations (Shortis *et al.* 2009). In addition, advanced calibration and analytical software has been developed for this technique (www.SeaGIS.com). While sharing some, but not all of the biases and limitations of vertical facing BRUVs, the major drawback to the horizontal facing stereo BRUV systems is initial start-up costs (including analytical software).

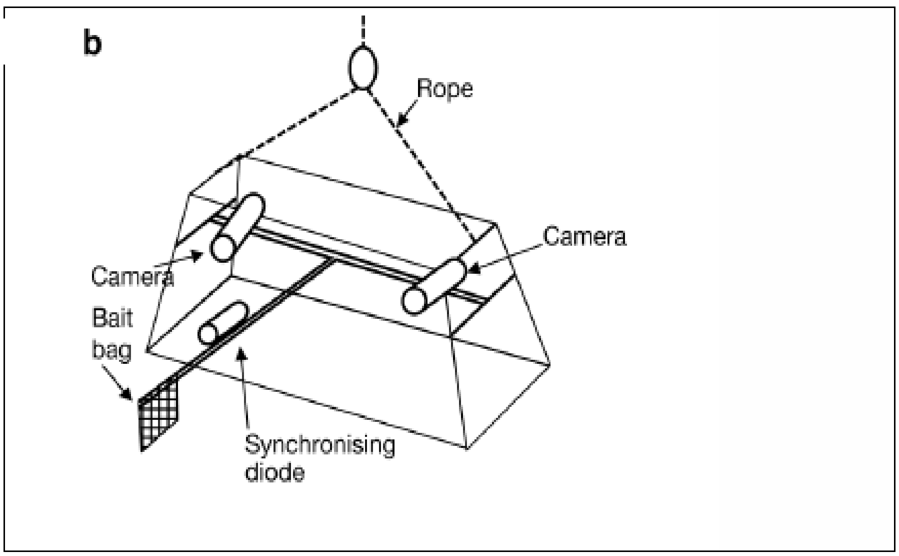


Figure 2. Baited remote underwater stereo-video (stereo-BRUV) unit courtesy Dr. Tim Langlois.

Table 1. Techniques associated with fish monitoring studies

Technique	Type	Main Advantages	Main Disadvantages
Capture	Angling	Sampling can be done on the surface Sample fish well beyond the limits of SCUBA Relatively inexpensive Provides for involvement of the community	Gear (e.g., hook) selectivity Mortality or injury associated with fishing gear High variability in CPUE among anglers Intra and interspecific competition for bait may influence catchability May not be feasible within protected areas
Capture	Netting	Sampling can be done on the surface with no time restrictions Deployment at all depths Provide specimens for study of age and reproduction	May cause damage to the seafloor Capture of non-targeted organisms may be large High variability in the area sampled May not be feasible within protected areas
Capture	Trapping	Provide specimens for study of age and reproduction and for tagging and release Traps may be left unattended and deployed to depths beyond the limits of SCUBA Can sample small and aggregated fish communities on topographically complex seabeds Tends to be non destructive	Catch rates vary for different species depending on soak time and mesh size, i.e. size bias with larger fish less likely to escape than smaller fish Difficult to convert catches to number of fish per unit area Difficult to target all species due to differences in arrival times and predator/prey relationships
Capture	Explosives/Icthyocides	Whole communities sampled, including cryptic fish that are unlikely to be able to be surveyed using other methods	Impedes repeat sampling in the same area May cause damage to the reef and seafloor Eliminates non-target species Potential health and safety risks to personnel May not be feasible within protected areas
Observational	Visual census using SCUBA	Non destructive Relatively inexpensive A large section of the reef-fish community can be sampled efficiently	Limited by depth Limited by low visibility Fish behavioural responses to diver altered Variability in diver speed Variability in size estimation and species identification among divers Cryptic individuals not sampled Not feasible for monitoring large areas Requires occupational certification
Observational	Video Surveys	Non destructive Sampling can be done on the surface Sample fish abundance well beyond the limits of SCUBA Precise and accurate counts and size of fish species Provides for community involvement Provides permanent record of the survey	Samples only selected species Variable bait plume dynamics among locations Influenced by bait preferences and fish swimming speeds Inter- and Intraspecific competitive interactions around the bait holder Inhibited by low visibility Post-analysis may be time-consuming Counts and sizes are likely to be underestimated

3.0 Biases

As for the majority of methodologies used to sample fish species and communities (Table 1) there are a range of selectivity biases associated with the general BRUV technique. For the most part, these can be addressed or eliminated through maintaining consistent procedures through space and time, whereas other biases are less straightforward to control for.

In this section some of the main sources of bias are highlighted along with mitigation methods - where appropriate. For several biases such as variation in vessel type and vessel noise we have no empirical evidence to underpin their inclusion in this review. Rather they are included more out of awareness for their potential to contribute to biases derived from published literature.

3.1 Underwater visibility

As for all observational methodologies a high degree of underwater visibility is required for BRUV. Underwater visibility will vary across locations and seasons being strongly influenced by rainfall and subsequent runoff, oceanographic processes such as storm events and tidal state, and the occurrence of phytoplankton blooms (particularly in spring and late autumn).

As a general rule, BRUV surveys should not be conducted unless there is at least 3 m of underwater visibility. If this is the upper-limit of underwater visibility at the time of sampling then some sites within the sampling regime may not be able to be sampled. Consequently, it is often prudent to build some redundancy into the sampling design, particularly if parts of the sampling area are frequently turbid.

Image enhancement technology such as LYYN Real Time Video Enhancement (www.lyyn.com) may be useful for improving image quality where there is low visibility. Recently, blue lighting has been utilised to allow BRUV surveys in deep water beyond natural light penetration (Te Papa Tongarewa / Museum of New Zealand). Traditional white lighting can attract additional "non-target" species to a baited or unbaited video system and may also cause damage to the visual sensory systems of species unaccustomed to bright light.

3.2 Odour plume and bait characteristics

The principle foundation of the baited underwater video system is derived from odour propagation (from bait) attracting carnivorous fish that are otherwise problematic to survey. Variable propagation of the bait plume may however inherently cause biases if different oceanographic situations (water velocity, sea states) exist between reserve and non-reserve sampling areas (Sainte-Marie and Hargrave 1987). Variables of this nature create an unknown sampling area that is induced by the bait plume itself and are described as a "Far Field" biases (e.g., Martinez *et al*. 2011). Consequently such biases are difficult to control for.

If several sampling sites have naturally high water velocity that could greatly augment odour plume propagation relative to other sampling sites, sampling of those sites at slack tide where currents are likely to be substantially reduced may lessen such biases. A downside to such an approach is that underwater visibility can also be reduced at slack tide.

Reef fish species exhibit different responses to bait relating from behavioural (swimming speeds) and foraging (narrow versus wide distances) characteristics and due to chemical attributes of the bait itself (Martinez *et al*. 2011). Accounting for behavioural traits is difficult in the current context; conversely, ensuring bait integrity is straightforward. For much of the BRUV work in New Zealand, ~ *200g* pre-frozen pilchards (*Sardinops neopilchardus)* has been the bait of choice due to its high oil content and should be maintained.

In addition to bait being placed within a bait container, typically a whole pilchard is cable tied to the top of the bait container, i.e., externally. During deployments this is often consumed or prone to breaking up at inconsistent rates across sites. Some researchers have used alternative baits that are less prone to disintegrating e.g., arrow squid *Notodarus sloanii* (Garner and Struthers 2013).

When considering multiple BRUV drops (replicate sites) within the same general area, there is the potential for biases to occur from sampling the same fish if the field of attraction between sites overlap (lack of independence). Biases of this nature have been examined for crabs (Aedo and Arancibia 2003), lobster (Smith and Tremblay 2003), and deep-water fish (Ellis and DeMartini 1995), whereas studies of this nature are limited for shallow-water reef fish guilds (reviewed in Cappo *et al*. 2007). In their study, Ellis and DeMartini (1995) advocated a separation distance of > 100m between replicate 10 minute duration BRUV deployments in order to achieve independence. This was based on a maximum attraction distance of 40-90m for a 200mm length fish with a current velocity of 0.1- 0.2 ms^{-1}. Cappo *et al*. (2007) calculated that a 60 minute duration BRUV drop with a corresponding current velocity of approximately 0.2 ms^{-1} would have an attraction range of around 480 m for fish of around 200-300 mm in length. A method for determining fish attraction ranges (*AR*) for BRUV deployments is presented in Cappo *et al*. (2004), but requires knowledge of current speeds and maximum swimming speeds of various fish species. Cappo *et al*. (2004) suggest that for fish biodiversity surveys, a distance of 450m or greater between replicates is required for BRUV deployments of 60 minutes duration.

3.3 Intra- and inter-specific interactions and influence of non-target species

Both intra- and inter-specific interactions in and around the BRUV system are universal characteristics of the methodology, evident by bait guarding and often aggressive displays from larger individuals towards smaller individuals irrespective of species (e.g., Stoner *et al*. 2008) and from larger predators (see below Fig. 3). Resultantly, the technique has been suggested to represent a biased estimate of population abundance because these interactions may inflate of reduced abundances of a particular species or size class (Cappo *et al*. 2007).

Where fish densities are particularly high, it is possible that "saturation" may occur, where a maximum number of individuals can be observed within the BRUV frame, but additional fish remain outside the frame due to lack of space around the bait. In these instances BRUV would underestimate fish abundance, potentially significantly. In the case of Poor Knights Island marine reserve fish monitoring (Roux De Buisson 2010), BRUV (vertical facing) saturation was observed in both summer and winter surveys leading to an underestimate of snapper abundance and size. Roux De Buisson (2010) subsequently recommended using stereo-BRUV to monitor snapper size and abundance within Poor Knights marine reserve due to its wider field of view relative to vertical BRUV systems.

A range of predators and non-target carnivores/scavengers can be attracted to both the bait and in response to the assortment of fishes surrounding the bait. Their specific activities can bias results via partially or completely excluding fishes that would otherwise be present in the field of view, directly consuming bait, and/or, defending and smothering the bait container subsequently influencing odour plumes.

In a recent non-reserve BRUV survey of Port Pegasus, Stewart Island (Haggitt and Freeman 2013), 10 out of a total of 21 BUV surveys (i.e., 48%) were interrupted by sea lion presence and 1 by octopus presence (Fig 3A and 3C). Seal incursions were characterised by a rapid scatter of fishes away from the BRUV system (Fig. 3C). Interestingly, MAX*counts* prior to and following sea lion interactions for the majority of sites were equivalent or higher than pre-MAX*counts* within 2 minutes. As such, a 2 minute buffer was deemed to be a sufficient time lag between predator disruption and recommencing BUV counts. There is no fixed rule regarding when counts should be resumed following the disruptions of this nature and buffer extents should be gauged on a case by case basis.

Some of the major non-target predators and scavengers for BRUV studies undertaken in New Zealand include: Octopus; Sharks; Sea lions; Sea stars; and Lobster.

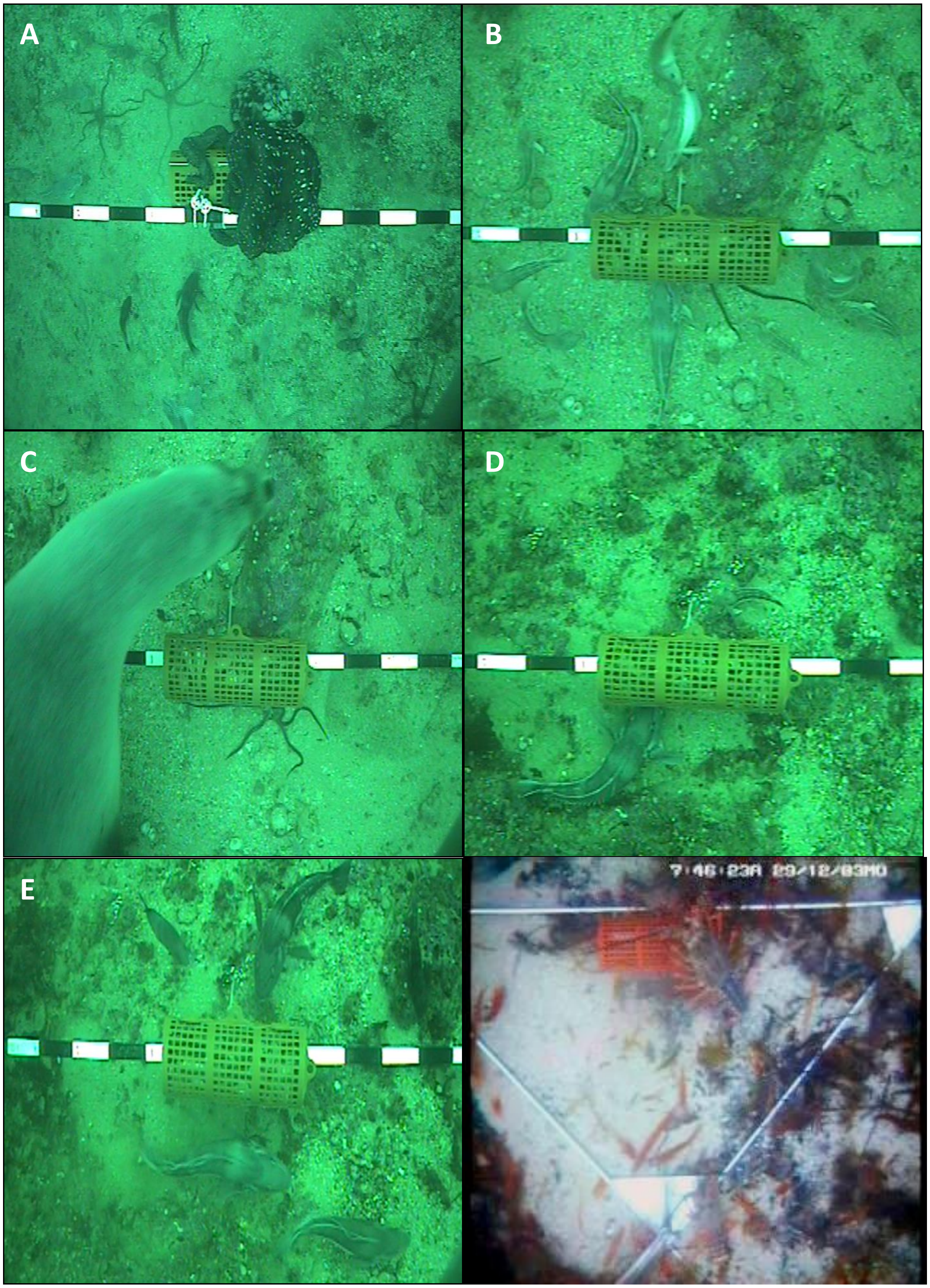


Figure 3. Frame grabs from video sequences of interest: A) Octopus encompassing bait container; B) Scarlet wrasse attacking blue cod – intra-specific competition (centre top); C) seal moving through field of view; D) blue cod attacking bait container; E) blue cod intra-specific competition (chasing and bait guarding); and F) Lobster defending bait.

3.4 Habitat type

The majority of open coast marine reserves in New Zealand are comprised of a matrix of rocky reef and soft sediment habitat types. There are obvious exceptions to this such as Tapuae marine reserve (New Plymouth), typified by extensive rocky reef habitat. As both single species and reef fish assemblages exhibit distinct associations with both large and small-scale habitat features (Jones & McCormick 2002), which appears consistent across geographic regions (Cole *et al.* 2012), consideration of habitat distribution for survey site selection is therefore important. For example, Cole *et al*. (2012) demonstrated that goatfish (*Upeneichthys lineatus*), blue cod (*Parapercis colias*), butterfly perch (*Caesioperca lepidoptera*) and snapper (*Pagrus auratus*) were associated with sand habitat near rocky reef, whereas green wrasse (*Notolabrus inscriptus*), Tarakihi (*Nemadactylus macropterus*), pigfish (*Bodianus unimaculatus)*, sandager's wrasse (*Coris sandageri*), and scarlet wrasse (*Pseudolabrus miles)* were positively associated with bottom depth and rocky reef boulder habitat.

For many BRUV studies, individual units are positioned on soft sediment within a set distance from rocky reef habitat (e.g., 20-30m) (Denny *et al*. 2004; Langlois *et al*. 2010); an approach that allows for unobstructed placement of the unit on the seabed, consistency across reserve and non-reserve sample sites and reduced likelihood of the BRUV system falling over or become snagged on the reef. Maintaining such an approach may be difficult for marine reserves such as Tapuae where sampling is, by necessity, constrained to being done directly on rocky reef habitat (Oliver 2011).

To eliminate potential habitat-related biases an understanding of coarse habitat distributions, i.e., rocky reef versus soft sediment is an important component of the sampling design Habitat stratification (see Kingsford and Battershill 1998) may be necessary if there is a paucity of a particular habitat either within or outside the study area, or to satisfy a particular requirement of a sampling design (see Section 3.0).

3.5 Camera drift

Over the course of individual BRUV deployments, BRUV drift can often occur due to rapid changes in water velocity or weather conditions. If major drift (e.g., >5 m) has occurred it will invalidate abundance estimates by effectively sampling a much greater area compared to sampling sites where drift is negligible.

The extent of camera drift can be ascertained in the field by comparing GPS waypoints taken at the time of deployment with those made at retrieval (see Section 7; Table 6). If large discrepancies exist, then it is advisable to redeploy the BRUV preferably when oceanographic conditions are more amenable for that particular site. If subtle or short-lived camera drift has occurred, the actual extent will be difficult to establish until the video is edited.

In our experience, camera drift is often subtle or short lived. When it occurs during count and size estimates, we recommend ceasing count assessments until the BRUV stabilises on the substratum. Comparison of pre- and post-drift counts will be required, although, again from our experience fish abundances generally return to pre-drift levels within several minutes.

3.6 Vessels

Several studies over the last decade have established that noise generated from vessels (particularly diesel powered) can either attract or deter reef fishes and therefore can bias fishery surveys (Rostad *et al*. 2006; De Robertis and Handegard 2013). We raise this point with respect to both historical and more-recent BUV sampling events. Primarily due to technological constraints early BUV studies (e.g., Willis *et al*. 2000) required the BUV unit to be tethered to an anchored vessel which brought into play both vessel presence and associated noise as possible sources of bias that may have either inflated or reduced fish numbers in the area (see Rostad *et al*. 2006).

The advent of a self-contained BUV camera in the mid 2000s (Taylor *et al*. 2006; Langlois *et al*. 2008) first used to survey Te Whanganui-a-Hei marine reserve simultaneously with the tethered unit of Willis and Babcock (2000) enabled increased sampling effort and eliminated the presence of a vessel for much of the deployment phase (Taylor *et al*. 2006). In that survey, the use of two different BRUV units (tethered versus self contained), raised potential biases stemming from vessel presence versus absence, although partialling out such variation is difficult. Fortunately, BUV sampling of Te Whanganui-a-Hei marine reserve over the last 6 years has used identical self contained BUV systems deployed from a 5m vessel, thus the technique has remained consistent across recent surveys.

During BRUV retrieval, noise may also be an issue if the research vessel approaches the unit before the completion of the 30 min deployment. We advocate remaining at least 100m away from the unit until the recording has fully completed. Perhaps the most important directive is to ensure consistency with respect to vessel type across surveys.

3.7 BRUV unit

In a similar vein to vessel presence, the occurrence of the BRUV unit itself may cause biases (Willis and Babcock 2000). Researchers have suggested that survey frequency may influence and bias fish counts as they become familiar with the BRUV unit itself (Cappo *et al*. 2007). This may be more pronounced in established reserves such as CROP where there have been historical issues associated with the public feeding fish, as opposed to marine reserves with less public interaction and that are surveyed with BRUV sporadically or on a biennial basis (e.g., PKI, Hahei, Tuhua, Tapuae *etc*).

In order to investigate the effects of video unit presence on fish behaviour, we are aware (at the time of writing) of planned studies in 2014 that will compare abundance estimates from baited and unbaited self contained BRUV and UVC methodologies relative to a camouflaged unbaited camera unit (Drs Shears and. Taylor- University of Auckland personal communication 2013).

3.8 Timing of surveys

Consideration of the timing of BRUV surveys is crucial, as species such as snapper undergo seasonal migrations and have different diets depending on ontogenetic stage and season. The study of Willis *et al*. (2003) demonstrated seasonal peaks in abundance of snapper attributing these to seasonal migrations, although facets of diet and feeding may have also been important in explaining the observed patterns. With regard to existing BRUV monitoring studies, it is advisable to continue monitoring in the same sampling period as previously undertaken, e.g., surveys for CROP and Hahei are typically undertaken in autumn (April-May), whereas surveys undertaken in Taranaki are undertaken in summer (January-March).

To avoid any biases associated with diurnal feeding behaviour, all sampling should be undertaken in daylight between 08:00- 16:00 hours.

3.9 Reserve versus non-reserve estimates

Recently, unreserved questions pertaining to the fundamental precept of vertical and horizontal BRUV systems are being asked. Central to these discussions are, how effectively does the BRUV technique estimate fish populations (predominantly snapper) within reserves relative to outside, i.e., are estimates for the reserve sample population over-inflated compared to non-reserve due to behavioural aspects of the target species, particularly snapper? (D. Parsons - NIWA). Doubt has largely been derived from tagging studies and anecdotal observations that have demonstrated clear differences between the behavior and habitat utilization of reserve and non-reserve snapper sample populations and from anecdotal studies that have lengthened the recording time for the non-reserve sample population. In an advanced study, Parsons *et al*. (2010) examined concurrent movement behaviour of snapper inside and adjacent to CROP marine reserve indicating that non-reserve snapper had larger home ranges and utilised more than one main area (bi-modal home ranges), whereas reserve snapper had higher site fidelity with only one main area of use (uni-modal home range). Explanations given for these differences included increased shelter offered by higher abundance of the kelp *Ecklonia radiata* inside CROP reserve, and that fish inside CROP reserve may be subject to different rates of fishery induced selection due to their different movement behaviour (see Parsons *et al*. 2010).

Focused studies have been recommended to evaluate and accommodate behavioural biases, particularly for snapper, but are largely outside of the scope of this review. These include altering the sample time between replicates (> 1 h); evaluating size and abundance estimates with horizontal stereo baited cameras; and, utilization of unbaited camouflaged cameras (Richard Taylor University of Auckland, personal communication). We are sympathetic to these concerns and supportive of such comparative studies, however adding increased sampling time to replicates is unlikely to be feasible for marine reserves that are already difficult to survey. Further, we recommend that any issues are dealt with in a constructive and useful manner particularly so that existing data sets are not invalidated.

4.0 Sampling design

4.1 Preamble

The primary ethos of undertaking baited remote underwater video surveys within marine reserves is to estimate the size and abundance of species not amenable to sampling by techniques such visual under water census techniques.

In an ideal world, ecological surveys would be undertaken several times prior to the commencement of marine reserve designation in order to obtain information on natural variation of target species prior to protection. For the majority of early studies that developed and appraised the BRUV technique within New Zealand's marine reserves, there was a distinct paucity of pre-protection data. Resultantly, before and after effect/impact (BACI) designs (Hurlbert 1984; Underwood 1993) could not be applied. In the advent of new marine reserve designations undertaking pre-protection surveys should be viewed as an important requisite.

Based on the range of BRUV surveys either undertaken directly or commissioned by the Department of Conservation over the last decade or so, it is apparent that sampling designs have not been consistent across studies. Inconsistencies may have arisen due to varying objectives, difficulties associated with surveying unique environments, and challenging locations (offshore islands versus mainland coast, sheltered versus high-exposure), variations in sampling design and BRUV apparatus or a combination of factors.

Of those studies undertaken, many have employed randomized block designs, achieved by dividing reserve and non-reserve locales into discrete areas (blocks) and sub-sampling within those (see Fig. 4). Other surveys have randomly selected sampling sites across reserve and non-reserve locations (complete randomized sampling designs, e.g., Denny *et al*. 2004), or used a combination of complete randomized and randomized block designs (Roux De Buisson 2009). Several long-term studies have been altered across surveys by way of replication and/or inadvertently sampled very different habitats inside and outside the reserve between surveys which may have invoked misleading conclusions. For some surveys there is a failure to clearly state the objectives of the monitoring and underlying hypothesis or hypotheses. A summary of select vertical BRUV studies and their sampling design are presented in Table 2.

4.2 Hypothesis testing

For the most part, all sampling programs 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 BRUV surveys is: H_o - There is no statistically significant difference in the abundance and size of fishes (e.g., snapper, blue cod, tarakihi *etc*) between reserve and non-reserve sample areas. The corresponding alternative hypothesis H_a – There is a statistically significant difference in the abundance and size of fishes between reserve and non-reserve sample areas.

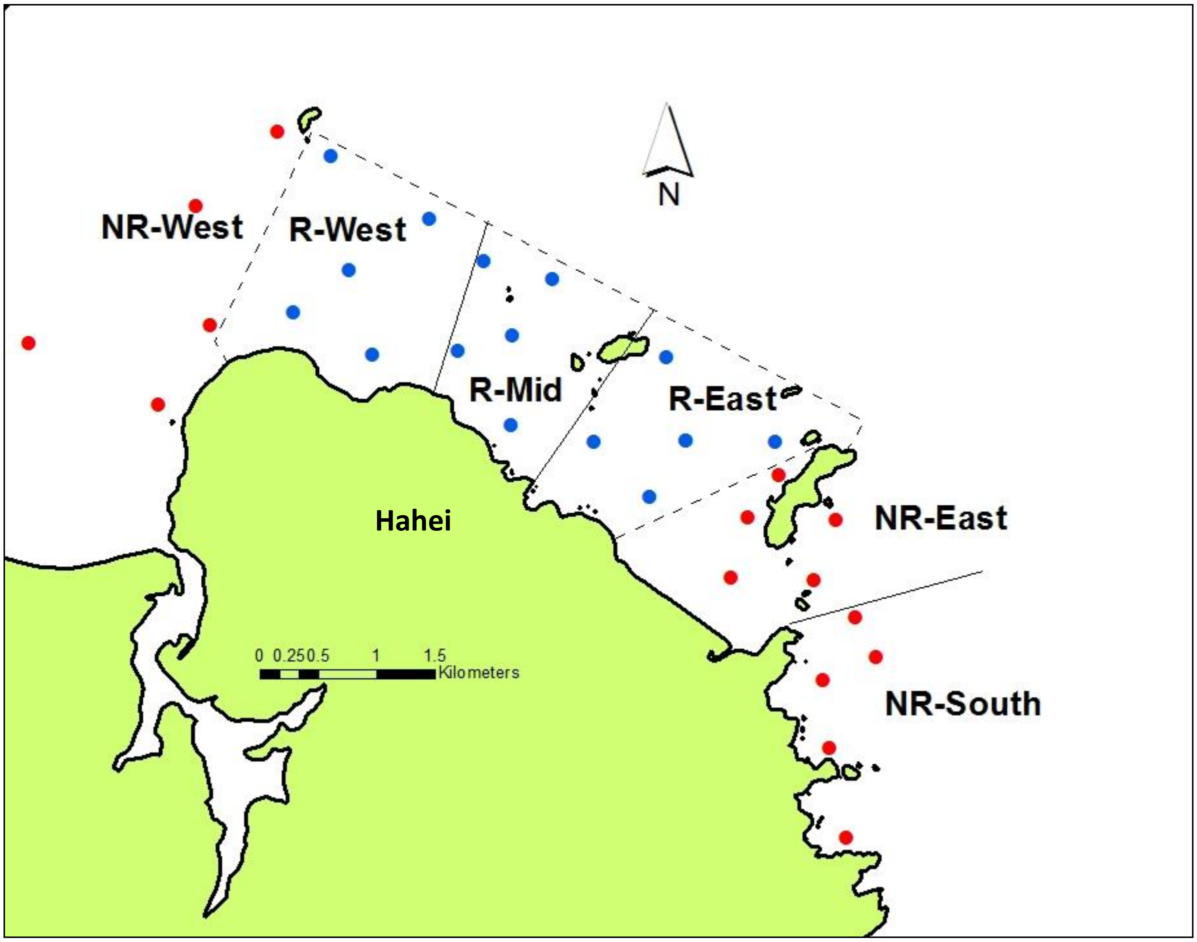


Figure 4. Example of a randomized block design Map of the six sampling areas (blocks) in and around the Te Whanganui-a-Hei Marine Reserve and location of reserve (●) and non-reserve (●) BRUV stations within blocks. The dashed line shows the reserve boundary. NR = non-reserve, R = reserve.

Table 2. Summary of BRUV sampling components for 7 North Island marine reserves. Note: * = complete randomised design; ** randomised block design. For Poor Knights Island Non-Reserve CB = Cape Brett and MI= Mokohinau Islands**.**

Location	Size	BRUV Method	Reserve block (replication)	Non-Reserve block (replication)	Total # drops	Survey Years
Poor Knights	1890 ha	R*	0(28-32)	CB (25-35); MI(29-31)	28-32	2000-2007
CROP	547 ha	RB**	6(4)	6(4)	48	2000-2007
Tawharanui	400 ha	RB	3(4)	5 (4)	32	2007
Hahei	550ha	RB	3(5)	3(5)	30	2000-2012
Tuhua	1060ha	RB	4(5-6)	5(3-4)	32-36	2004, 2011
Parininihi	1800ha	R	0(30)	0(30)	60	2012
Tapuae	1404ha	R	0(30)	0(30)	60	2011

4.3 Randomized block designs

Randomized block designs are useful for marine reserve surveys, primarily as the design allows for comparisons to be made among blocks within a respective reserve - useful for examining edge-effects. There is no concrete rule for block allocation within and outside reserves, in fact for studies that have employed such an approach, the exact delineation of block boundaries appears to occur subjectively among reserve and non-reserve areas. For instance CROP and Hahei are similar in spatial extent (Table 2) yet Willis *et al*. (2000) delineated a different number of blocks across CROP (6 inside and 6 outside) compared to Hahei (3 inside and 3 outside) and sub-sampled within these. For offshore locations, or reserve with disparate boundaries (e.g., Kapiti Island), block assignment may be less intuitive. In such instances completely randomized designs may be more suitable.

For new marine reserves, or for those awaiting survey we suggest the researcher relate 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 (see below) within blocks between reserve and non-reserve sample 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 reserve?

- Are there obvious habitat differences across reserve and non-reserve sample areas, e.g., is one half predominantly soft-sediment and the other predominantly rocky reef (see below) and does this need to be accounted for by way of habitat stratification?

4.4 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 and Battershill (1998) provide a useful overview on the subject. Of the example studies in Table 2, site replication within blocks typically ranges from 4-5 per block. Previous studies have indicated that this level of replication is generally sufficient to satisfy statistical power requirements for a generalized linear modeling approach (see Willis *et al.* 2003 for 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 and 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 randomization 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 Section 2.6 using a hypothetical example.

Exact methodological processes of sample site (spatial replication) selection within blocks for BRUV studies are often not specified for many published works or technical reports. For the early work done at CROP, TMP and Hahei, Willis *et al*. (2003) state that "true spatial randomization of sampling stations could not be obtained because of constraints caused by oceanographic currents, weather conditions or bottom topography". Equally, the study of Denny *et al*. (2004) at PKI provides negligible information on the method of replicate site selection.

4.5 Habitats

As individual taxon and reef fish assemblages exhibit habitat-related preferences (Anderson and Millar 2008; Parsons *et al,* 2008, 2010; Cole *et al*. 2012), prior understanding of coarse habitat distributions across reserve and non-reserve sample areas will help facilitate sampling site allocation. It is important that at least the broad extents of rocky reef and soft sediment habitat across reserve and non-reserve sample areas are known. With the exception of Shears and Usmar (2009) previous BRUV surveys gave little consideration to incorporating habitat information into the sampling design.

The standard method of BRUV deployment has, for the most part, been required to be placed within 20m of rocky reef habitat. We are satisfied that this directive remains but acknowledge that such an approach may not be appropriate for all marine reserves, as camera drops may by necessity be required constrained to rocky reef habitat.

In rare instances habitat stratification may be required when habitat coverage is not broadly equivalent between reserve and non-reserve survey areas. An example of this is

Tapuae Marine Reserve in New Plymouth, where the majority of the reserve is rocky reef habitat.

4.6 Random site selection using hypothetical example

The following section provides a method for obtaining random sites within and outside a hypothetical reserve. The example assumes basic knowledge of ArcGIS and also uses Hawths tool, which is an ArcGIS add-on available at www.spatialecology.com. The distribution of rocky reef and soft sediment areas within and outside the reserve were known prior to site selection. We advocate 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 randomized block design and all BRUV drops are required to be done within 20m 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 (Fig. 5).

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 (Fig. 6)

2. Designate blocks within reserve and non-reserve sample areas based on available habitat information, but ensure blocks are broadly spatially equivalent (Fig. 7).

3. For this survey, the sampling requirements are:

    - A total of 5 replicate BRUV drops per block (3 blocks in total) within and outside the reserve;
    - Individual BRUV drops will be done within 20m of rocky reef habitat on sand;
    - Individual BRUV drops will be of 30 min duration once the BRUV unit has settled on the seabed.
    - Individual BRUV drops will be a minimum of 300m apart[1] to avoid sampling the same fish due to overlapping area of attraction (defined as range of attraction (AR) in Cappo *et al.* 2004). Refer to section 3.2;

[1] A distance of 450m or greater between replicate BRUV deployments of 60 minute duration is recommended by Cappo et al (2004) to achieve independence between replicates. We have reduced this to 300m based on: 1) shorter BRUV deployments (30 min); and, 2) so that 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 (vector grid) comprised of 200m ×200m cells that covers reserve and non-reserve survey areas. The grid will be used to facilitate site selection within selected cells (Fig. 8).

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 (Fig. 9).

6. From these available cells use HawthsTools "Generate Random Points" from the Sampling Tools dropdown (Fig. 10) and generate a total of 6 random points (sites) per block. 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.

7. A point-based shapefile will be automatically created and latitude/longitude coordinates generated (Figs 11 and 12; Table 3).

8. Generated latitude/longitude coordinates are then able 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 BRUV system within 20m of reef habitat (refer to Section 7).

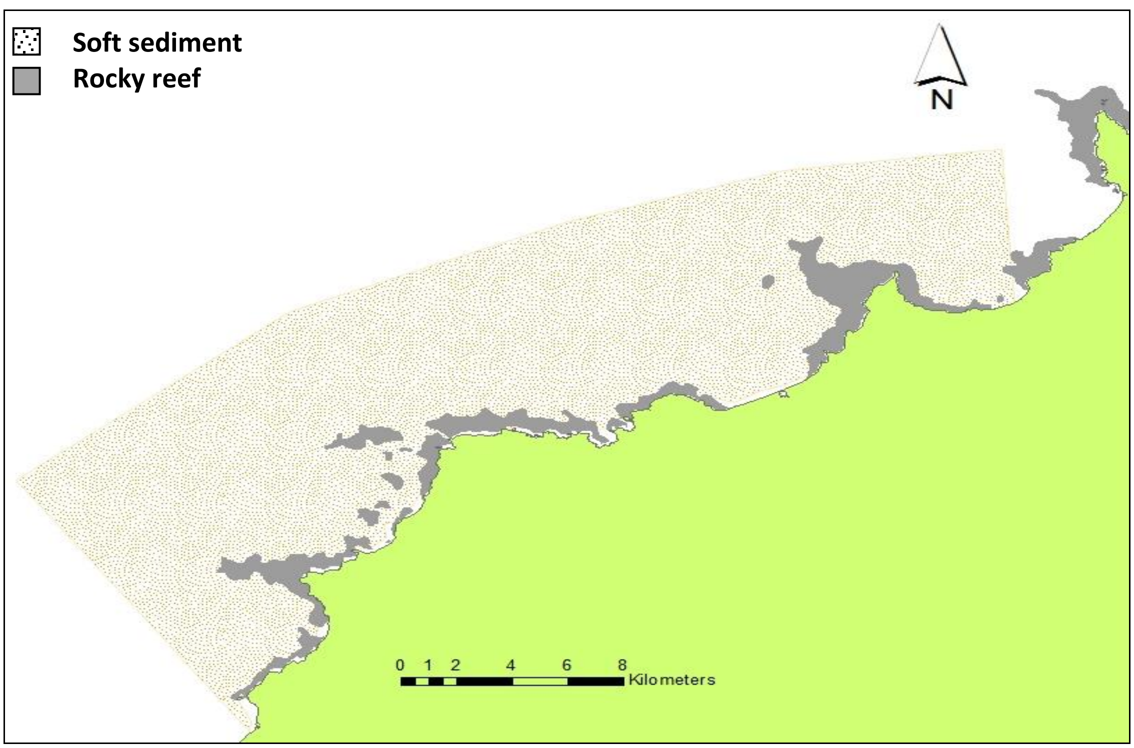


Figure 5. Soft sediment and rocky reef habitats.

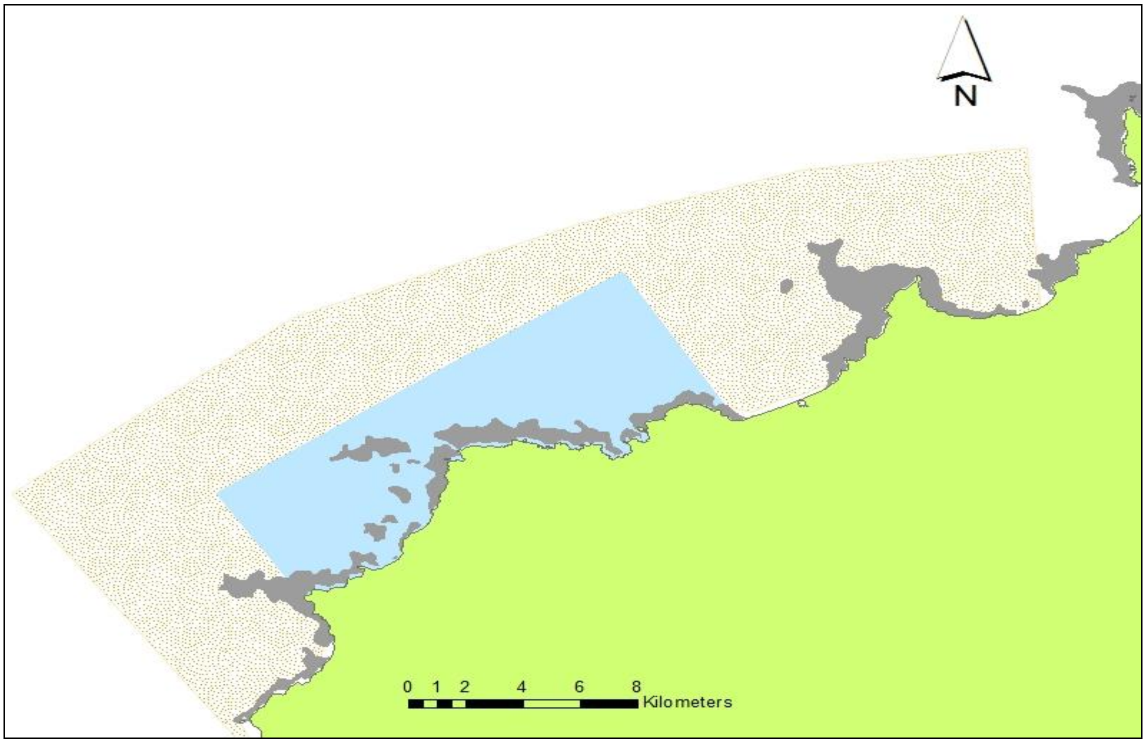


Figure 6. Reserve area.

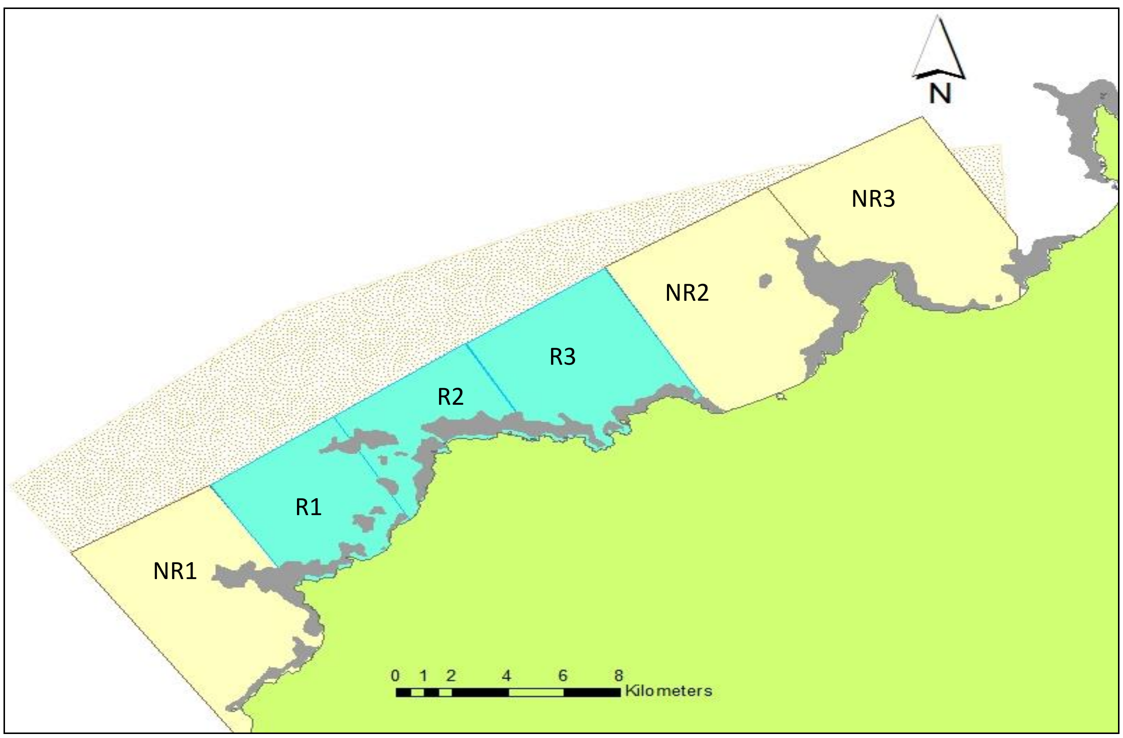


Figure 7. Reserve (R1-R3) and non-reserve (NR1-NR3) block designation.

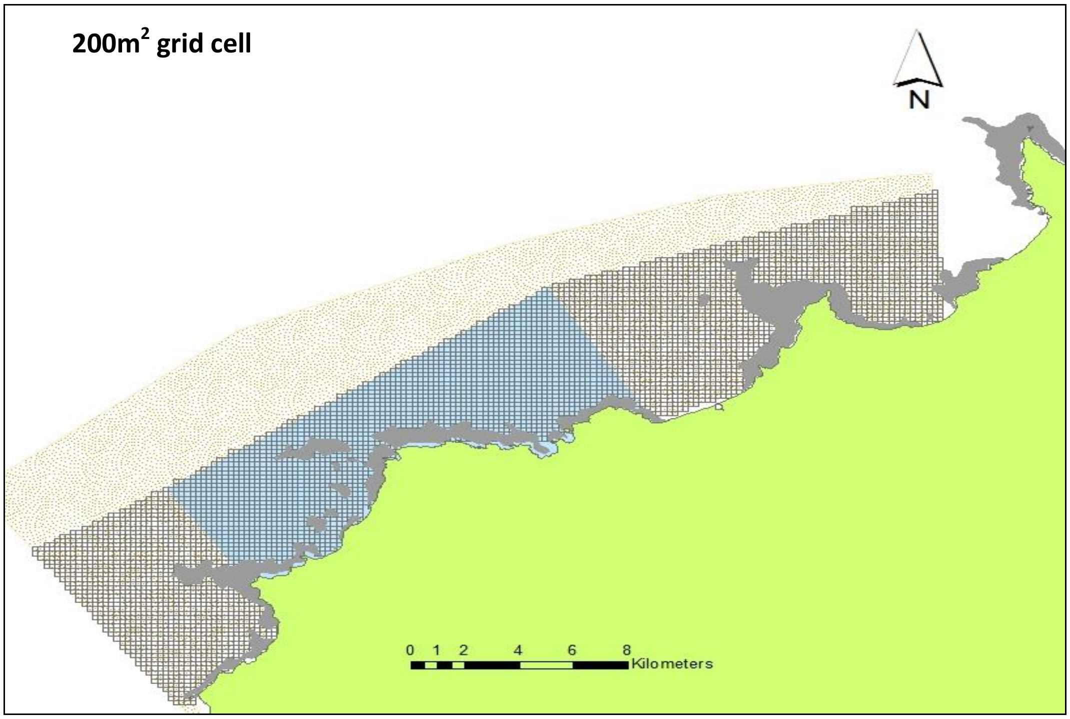


Figure 8. Rocky reef and soft sediment habitat boundary gridded into 200m × 200m cells

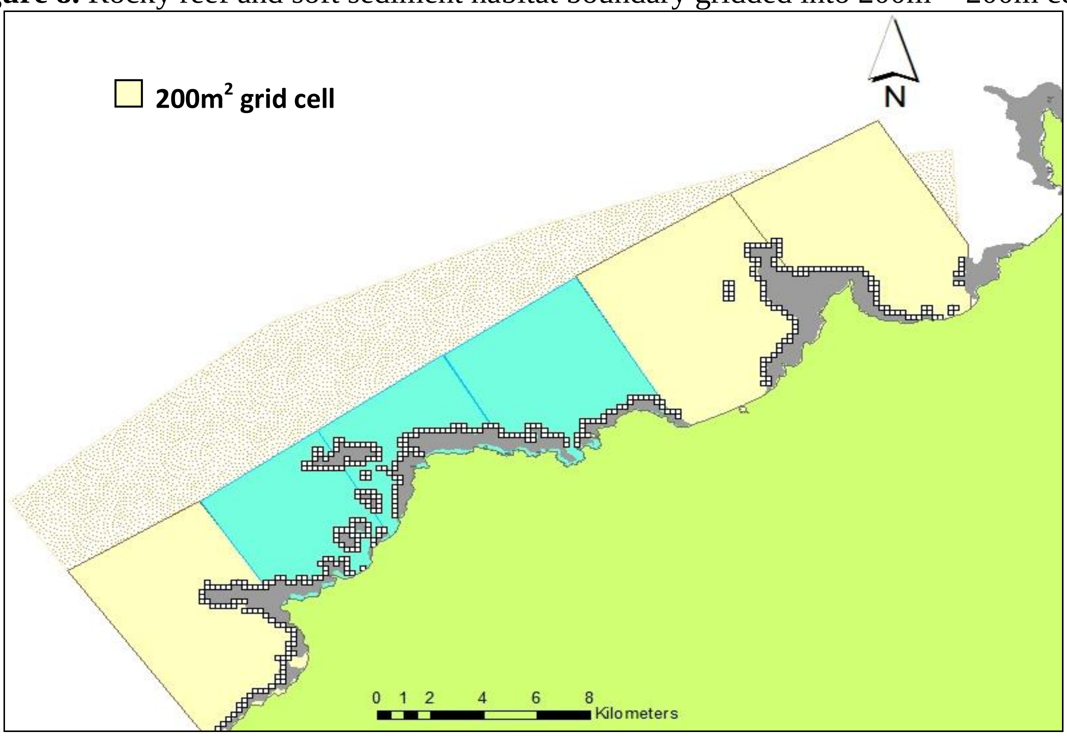


Figure 9. Rocky reef and soft sediment habitat boundary grids where the two habitat classes overlap.

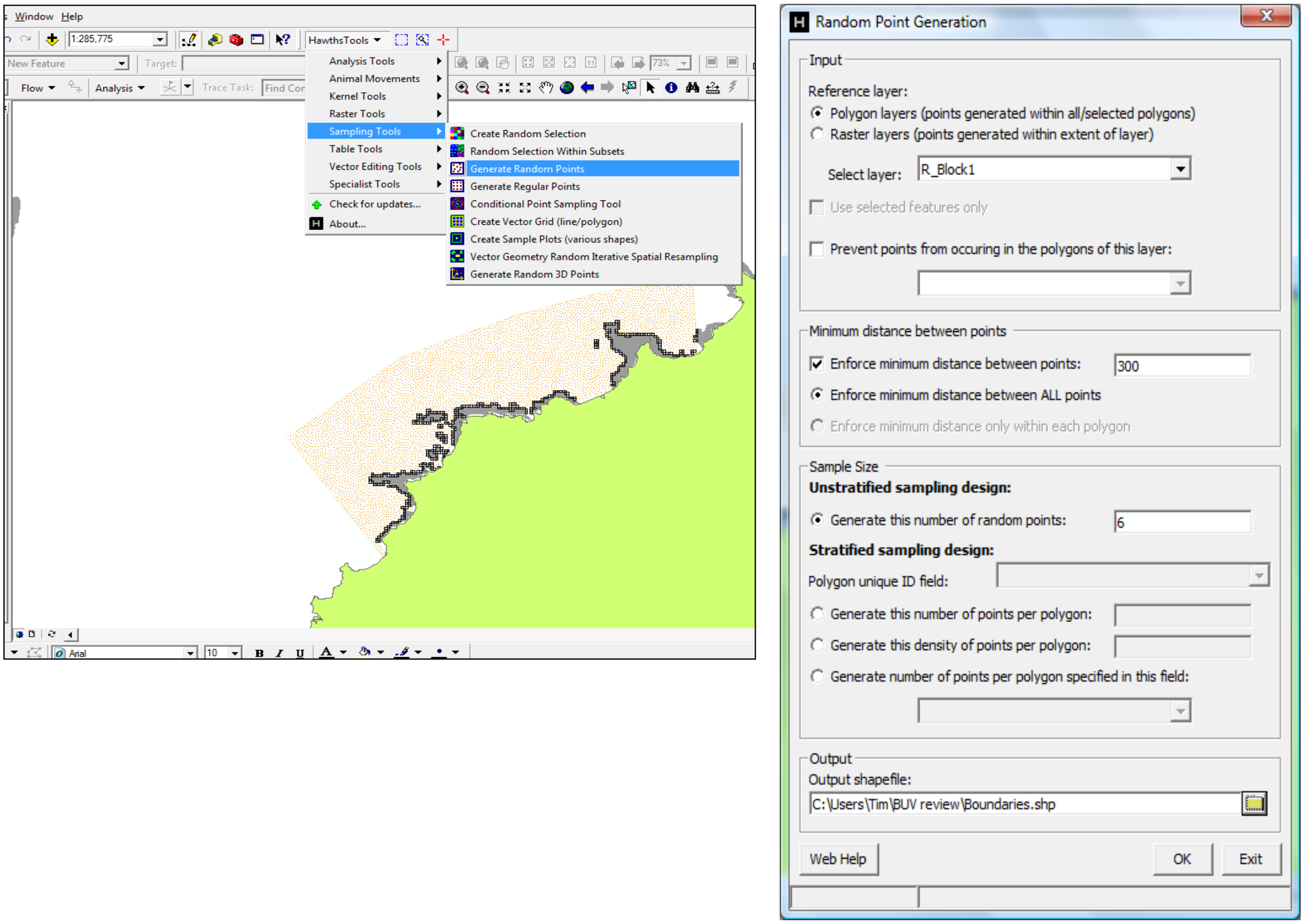


Figure 10. Random site selection using Hawths Tools

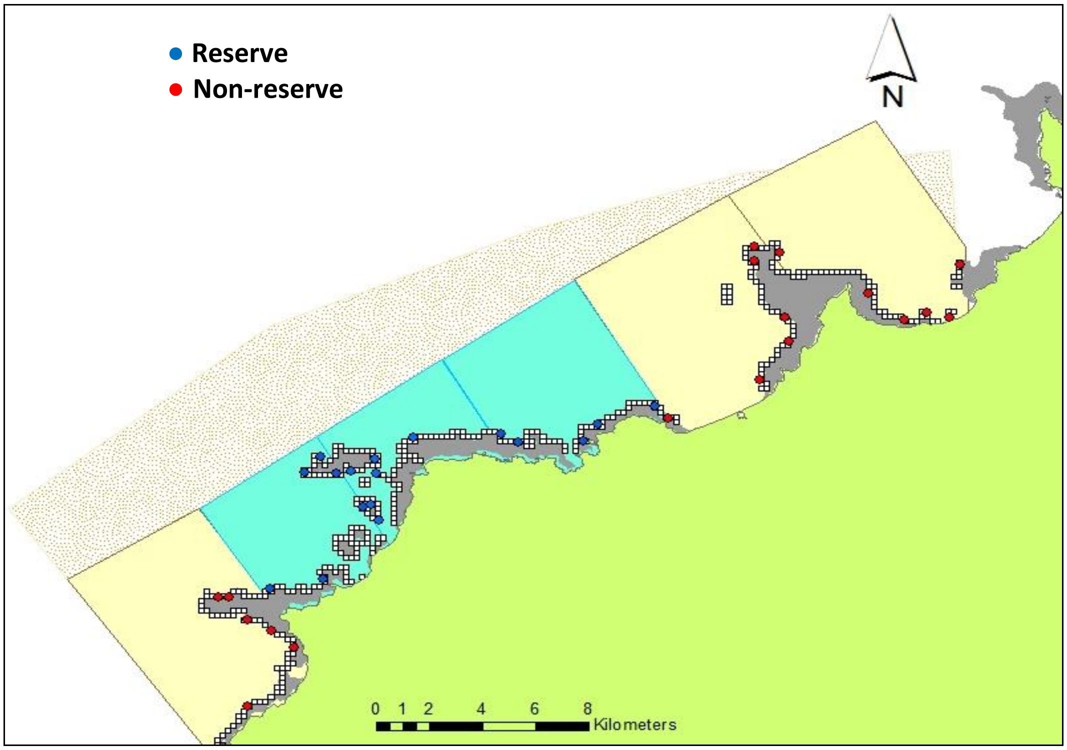


Figure 11. Random site designation *n*=6 within each block.

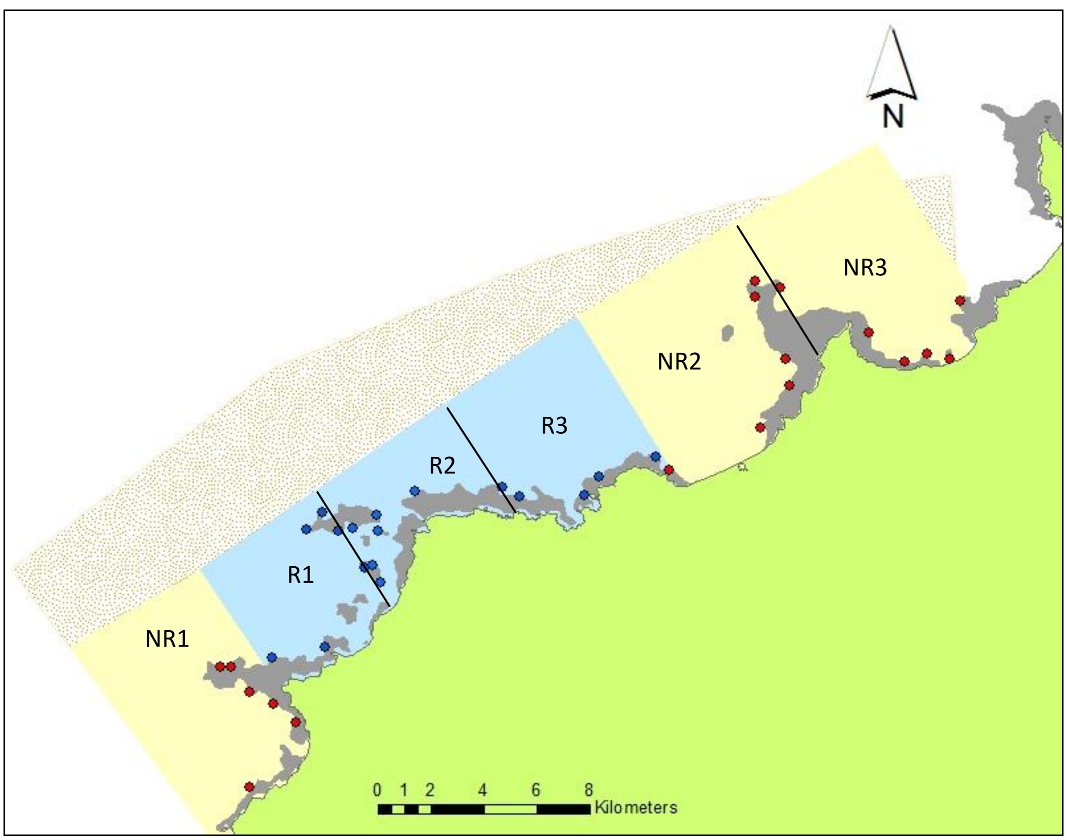


Figure 12. Final random site designation.

Table 3. Randomly generated sites for BRUV 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

4.7 Summary

In summary, prior to designing a BRUV study consideration should be given to the following:

- 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?
- What is the spatial extent of broad habitat types (rocky reef and soft sediment) and exposure levels within and between reserve and non-reserve sample areas?
- What are the habitat extents within and among blocks for reserve and non-reserve sample areas? Will it be important to stratify the sampling based on these?
- How many blocks are to be assigned within and outside the reserve? 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.

5.0 BRUV setup and associated equipment

5.1 General comments

The downward facing (vertical) baited underwater video technique requires a moderate level of expertise to both construct and use satisfactorily in the field. The following section outlines the range of equipment required for a "typical" BRUV survey. A scaled drawing with specific dimensions of a standard BRUV unit is provided (Fig. 13) as is a general checklist of equipment and consumables (Table 6). The dimensions provided *herein* should be used as a general guide. The main component that may change over time (for example, as technology changes) is the camera and housing, but such a change is unlikely to influence the resulting data.

5.2 BRUV unit

The BRUV unit is constructed of three main parts:

1) Camera housing that contains a removable digital video recorder and associated polycarbonate lens;
2) A base scale bar that sits on the substratum; and,
3) A movable angled bar that links the scale bar and the camera housing.

The downward facing BRUV system has the following general specifications:

5.2.1 Camera housing

A range of cameras and underwater housings are on the market and are continually being improved and upgraded. The below is an example of a system currently in use within DOC and one that could be replicated.The specifications for this camera housing are compatible with a Sony Handycam® CX350 model or equivalent, although there is surplus space within the housing to suit many other video recorder models on the market. It is advisable to purchase the video camera prior to housing construction. This will ensure that the housing can be manufactured around the specifics of the camera.

Material: Body – Decommissioned stainless steel fire extinguisher modified with side flanges, and a base for o-ring seat and lens attachment (Fig.14).
Height: 210mm.
Width: Internal diameter**:** 110 mm; Outer diameter including o-ring base**:** 120mm.
O-Ring: Thickness - 6mm; Diameter – 135mm.

The housing attaches to the frame at the third hole on the housing flange (Fig. 15). Additional flange holes are for adjusting the housing height relative to the bottom scale bar in order to facilitate different video cameras specifics and the attachment of subsurface and surface buoys. The center of the housing should align with the center of the bottom scale bar.

5.2.2 Lens

Material: Polycarbonate
Diameter: 175 mm
Thickness: 10 mm

A total of 5 screws (15 mm) fasten the lens to the camera housing proper (Fig. 14). Corresponding inscriptions on the side of the housing and lens, ensure proper lens:housing alignment prior to fastening (see Section 2.3).

5.2.3 Frame

This example of a frame is 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: Aluminum square bar 25mm × 25mm for both the bottom scale bar and angled bar.
Length: *Bottom scale bar* – 1700mm, with 1500mm (outer to inner) divided into black and white segments each 100mm in length (n=15). The 100mm segments can be delineated with black and white electrical tape.
Side angle bar – Approximately 1415 mm from the base scale bar with a 150mm 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 (Fig. 16). *Note:* All screws and fasteners should be stainless steel marine grade 316. All screws and fasteners should be checked regularly for corrosion and replaced if corrosion is evident.

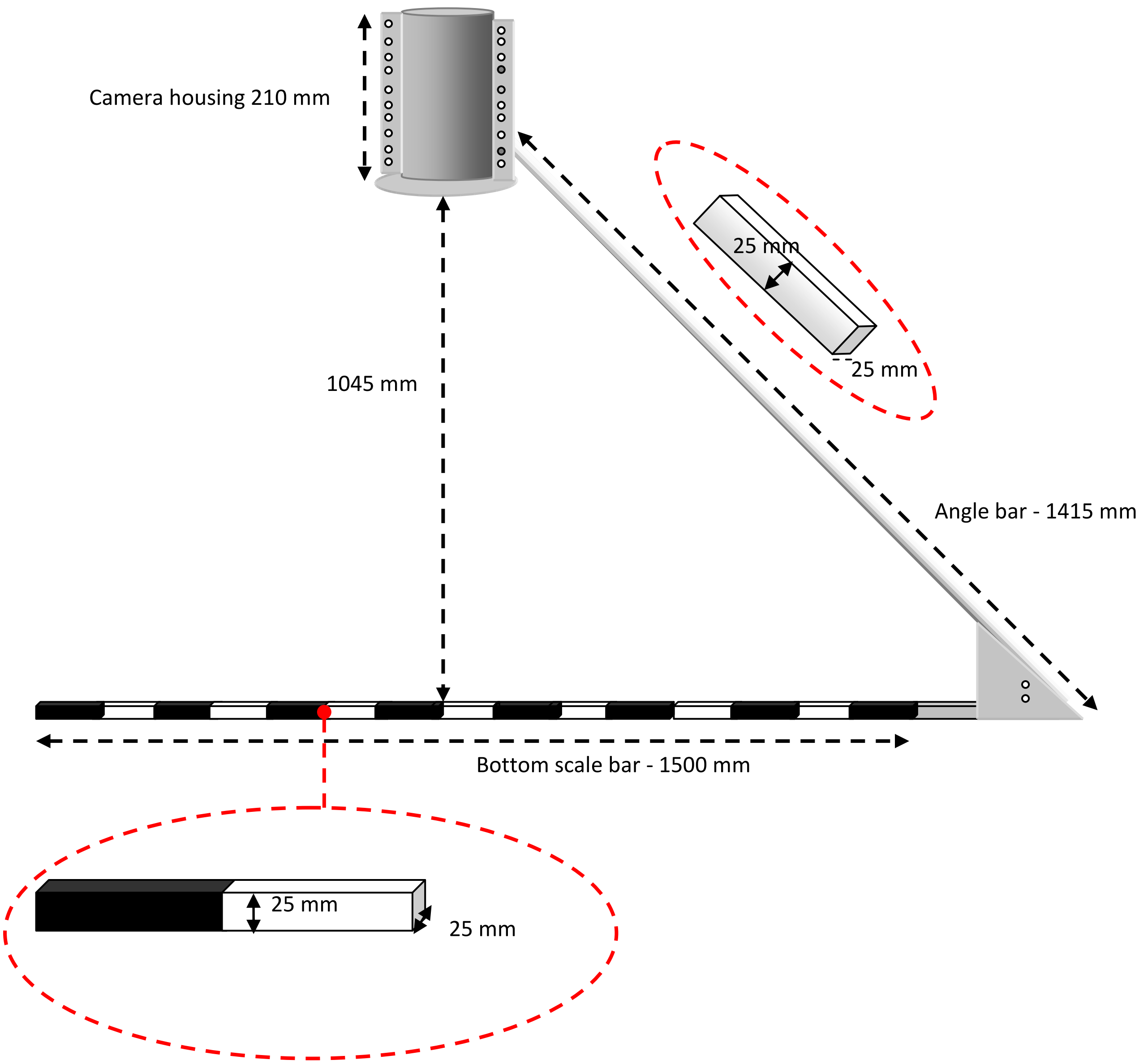


Figure 13. BRUV unit with accompanying measurements (mm) for camera housing; angle bar; and, bottom scale bar.

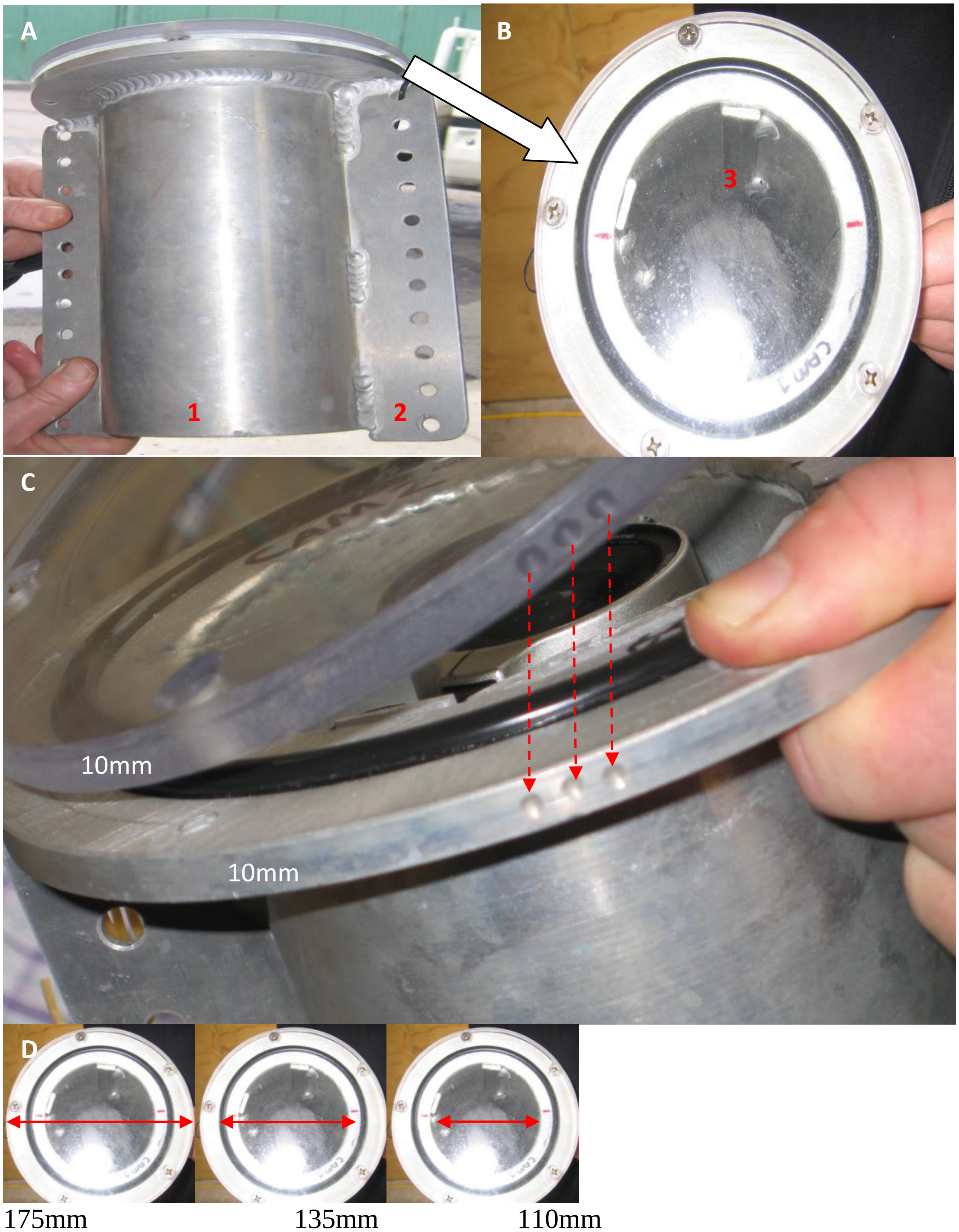


Figure 14. BRUV housing - A: 1-main body; 2- side flanges and associated drill holes used to attach the housing to the angled arm of the frame proper and for the attachment of pressure buoy and surface buoy rope and; B: 3- 10mm polycarbonate lens. C: inscriptions used for lens housing alignment D: dimensions of housing face.

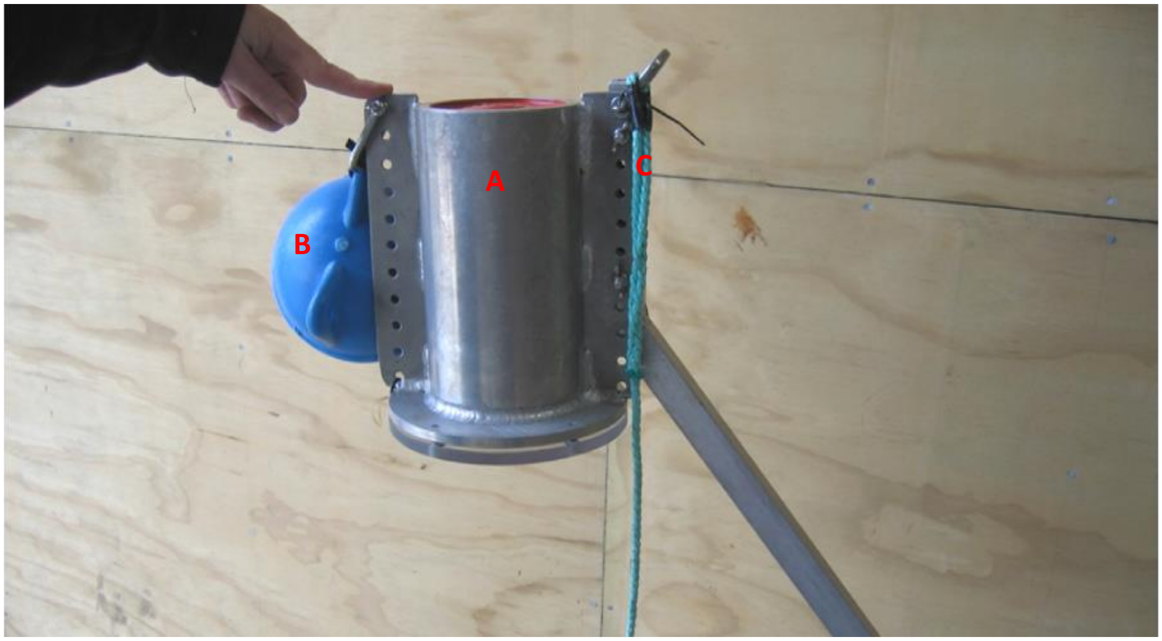


Figure 15. Housing attached to angle arm A: Housing; B: Pressure buoy; C: Rope attaching BRUV unit to surface float (not shown); Marine grade D-shackles connect the pressure buoy and rope to the housing

Figure 16. BRUV frame in folded position with housing removed. A: Bottom scale bar B: base of bait pot; C: moveable angle bar; D: housing attachment section and associated drill holes used to attach to the housing; E: 10mm thick polycarbonate lens.

5.2.4 Bait container

A bait container (Fig. 17) is required to enclose bait throughout sampling. It also provides a point of reference when measuring fish during post-survey analysis (see Section 9). The cylindrical burley container in Fig. 17A is preferred by the authors as it producers superior odour plume characteristics and readily available. It is 100mm in height and

130mm in length and can be attached to the bottom frame using cable ties and screws. The bait container in Fig. 17B-D is an inverted burley pot with the base (top) attached to the middle of the scale bar with hose clamps (Fig. 8). The base of the bait container is 130mm in diameter and 150mm in height. Bait containers can become damaged from fish attack during sampling; therefore, it is advisable to carry spare pots on the vessel so that repairs can be promptly made.

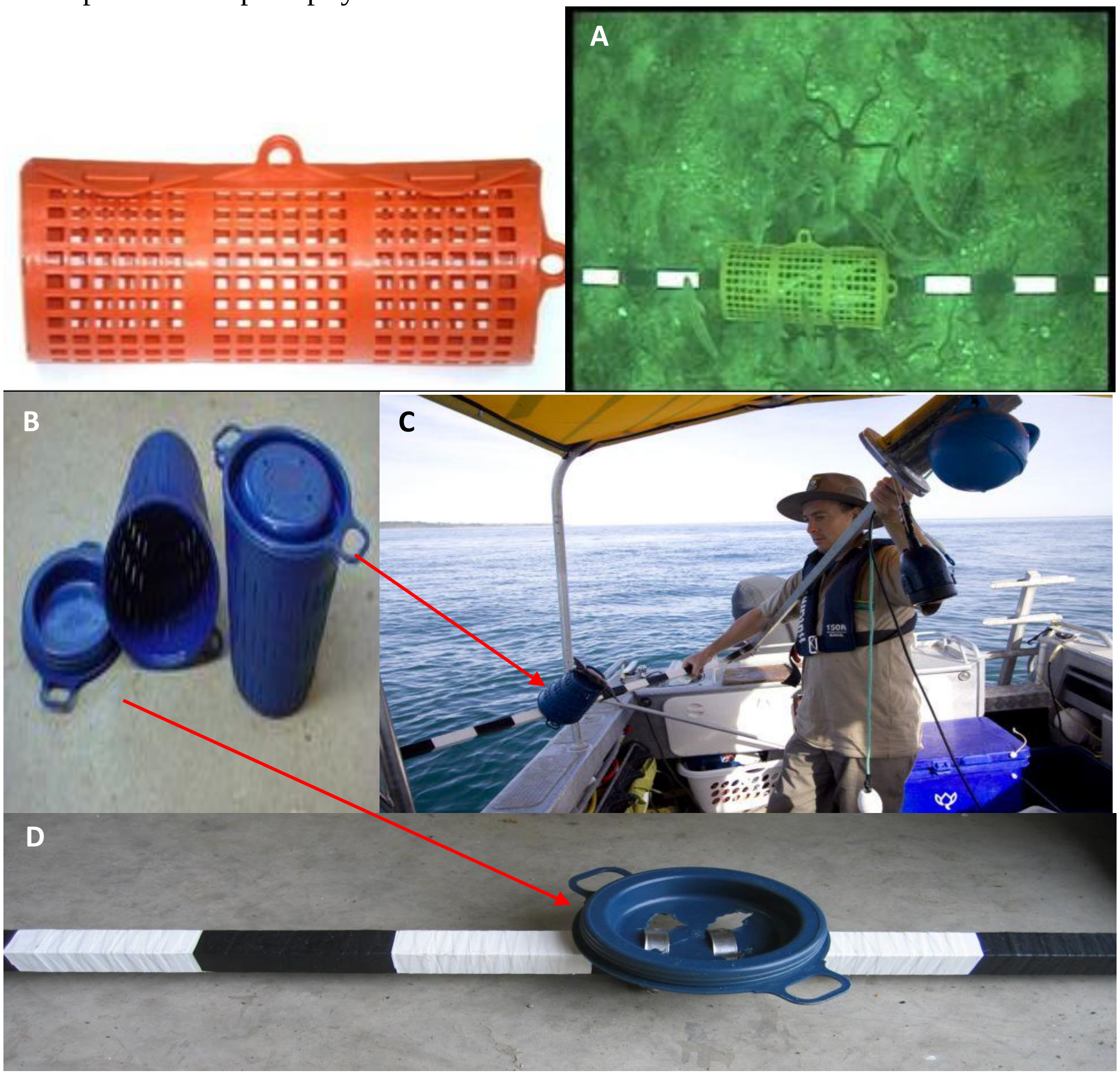


Figure 17. Typical bait containers used for BRUV surveys. A: Cylindrical bait container on BRUV frame (preferred) B: bucket style bait container - for construction purposes, the top is removed, inverted, and attached to the frame with hose clamps or screws. B: Inverted bait container with bait (pilchards) attached to the top of the pot and contained within the pot - immediately prior to deployment.

5.2.5 Digital Video Camera

There are a range of digital video cameras available on the market. Purchase a reputable brand such as Sony Handycam® or Canon camcorder. Newer models offer high definition recording onto an internal hard drive, which preserves battery consumption considerably (recommended). 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. Ensure the lens is compatible with the video camera. Distortion may need to be taken into account when processing the video.

When choosing a camera specifically check:

- Record modes relative to maximum continuous record time. Popular Sony Handycam® models and their respective recording times for different record modes to hard drive are included in Table 4A.B;
- Battery life. The recording and playback time will be shorter when you use your camcorder in low temperatures (i.e., underwater). Note: larger batteries can remain in continuous recording mode for > 10 h. These are expensive, but will reduced having to change battery packs in the field;
- Storage medium types (hard drive, memory card, flash stick, tape etc) and that these will be sufficient for undertaking the required level of sampling for a given day.
- Lens specifications and level of distortion.

Table 4A Sony Handycam® recording times in minutes and (hours) for HDR-CX350/CX350V models. *Note*: recording times are for recording to internal hard disk.

	Recording Mode	HDR-CX350 min(hr:mm)	HDR-CX350V min(hr:mm)
	[HD FX]	180 (3:00)	175 (2:55)
	[HD FH]	235 (3.55)	225 (3:45)
	[HD HQ]	470 (7:55)	455 (7:35)
	[HD LP]	800 (13:20)	780 (13:00)

Table 4B Sony Handycam® recording times in minutes and (hours) for DCR-SR68/SR88 models. HQ–high quality; SP–slow play; and, LP–Long Play. *Note*: recording times are for recording to internal hard disk.

	Recording Mode	Model DCR-SR68 min(hr:mm)	Model DCR-SR88 min (hr:mm)
	[HQ]	1220 (20:20)	1830 (30.30)
	[SP]	1750 (29:10)	2630 (43:40)
	[LP]	3660 (61:00)	5510 (91:50)

5.2.6 Drop camera

In addition to the BRUV unit proper, a drop camera (Figures 18 and 19) is also useful. This is to provide real time visuals so that substratum/habitat suitability can be evaluated immediately once the BRUV unit settles on the seafloor. An assessment of this nature is required to ensure kelp is not obscuring the field of view and the unit is in a suitable habitat and position on the seafloor. .

The drop camera attaches to the BRUV unit with rubber bands 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 from companies such as Marine Design Engineering Ltd (MDEL) 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 60m of coaxial cable.

At each deployment, the drop camera requires direct placement in front of the BRUV housing to ensure it provides a realistic representation of what the BRUV unit will be recording.

Figure 18. BRUV setup prior to deployment. Red circle denotes Splashcam® drop camera. The drop camera is used to assess substratum suitability at the start of the deployment.

Figure 19. Drop camera equipment: A) MDEL drop camera and 70m 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 customized waterproof case (not shown). Note: the video recorder is powered by a long-life (8h) 7.4v battery pack specific to the video recorder.

5.2.7 Consumables

Alongside BRUV hardware, a range of consumables are required to undertake field sampling (Fig. 20). These range from fasteners such as cable ties, and shackles to spare fuses and datasheets. A full equipment checklist (hardware and consumables) is provided in Table 5.

Figure 20. Typical hardware and consumables required for undertaking a BRUV survey. A – Fasteners (shackles, carabinas and hose clamps); B – Rubber bands, cable ties and spare screws; C – Digital video camera; D – Bait pots; E – Rechargable video camera batteries; F– screwdrivers; G – Paper Towels; H – Cable ties; I – Permanent marker pen; J – Electrical tape; K –Silicon grease; L – Drop camera; M – Pressure Buoy; N– Cloth; O – Silica gel; P – Fuses. Hardware aside, include a spare of every item.

5.2.8 Price list

An indicative price list for a BRUV unit, digital video recorder, and drop camera is provided in Table 5.

Table 5. Indicative costings for the BRUV unit, digital video recorder, drop camera and general consumables. Costs are in NZD and include GST. *Note*: If several BRUV units were being constructed then in general only 1 drop camera would be required for use with multiple BRUV units.

Item	**Price**
BRUV frame, housing and bait pot	$1,500:00
Digital video recorder - Sony HDR CX350VE; Long-life NP-FV100 battery pack; Wide angle lens – Raynox lens QC 303 or equivalent	$1,400:00 $ 230:00 $ 50:00
Subtotal for BRUV	***$ 3,180:00***
Drop camera including 60m coaxial cable Battery pack rechargeable 12 v	$ 2,000:00 $ 85:00
LCD Monitor	$ 100:00
Subtotal for drop camera	***$2,185:00***
Consumables	$ 750:00
Grand Total	***$6,115:00***

Table 6. Baited Remote Underwater Video 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 12V 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				
Carabinas				
D-shackles				
Electrical tape (black and white)				
Bait				
O-ring				
DV video tapes or DVDs etc				
Paper towels				
Hand towel				
Anti-fog solution				
Rubber bands (assorted)				
Cable ties (assorted)				
Spare screws (assorted)				
Silicon grease				
Silica gel				
Fuses (10 -20 amp) for drop camera				
Polypropylene rope - spare (10mm dia.)				
SCUBA gear				
Fish bins for storing ropes				

6.0 Preparation guidelines

It is advisable to check all BRUV sampling gear well in advance of field sampling. The following section provides general preparation guidelines that are useful to employ prior to deployment.

6.1 Housing and lens attachment procedure

6.1.1 O-ring

- The housing o-ring is one of the most important components of the camera housing. To avoid leaks when the unit is under pressure it is imperative that the o-ring is free of dust, stray hairs, and general grime (usually old silicone grease);
- Prior to use, inspect the o-ring for any cuts, abrasions and dust, especially if the unit has been in storage for a lengthy period;
- To ensure a good seal use silicone grease or petroleum jelly to lubricate the o-ring (Fig. 12);
- To avoid damage to the o-ring surface never use tools when removing the o-ring from its seat.

6.1.2 Polycarbonate lens attachment

- The polycarbonate lens must be handled with maximum care at all times;
- It is advisable to store the lens in a padded case when not in use;
- Generally the lens will be attached to the housing in the field;
- The lens attachment procedure should be undertaken on a flat surface;
- Prior to attaching the lens to the housing, the lens should be examined for scratches or defects.

Prior to lens attachment in the field ensure video camera is placed in the housing, switched on, and recording!

1. Following o-ring lubrication, line up lens inscriptions (located on the side of the lens) with equivalent inscriptions on the side of the camera housing (see Fig. 21);
2. Place all screws in their respective pilot holes;
3. Starting with screw #1 half tighten, stop, then move to screw #3 and half tighten repeating the procedure with screws #5, #2, and #4 (Fig. 22). *Note: this alternating sequence ensures that a) undue pressure is not placed on any one section of the lens, which may lead to lens fracture; and, b) an even and adequate lens:hosuing seal is achieved.*
4. Again, starting with screw #1, tighten a further quarter repeating the procedure with screws #3, #5, #2, and #4 respectively. Intermittently check the o-ring to ensure an equivalent degree of compression is occurring across the lens surface;

5. Finally, tighten all screws an additional quarter using the above sequence (i.e., screws #1, #3, #5, #2, and #4. Check the o-ring and ensure full depression has been achieved. *Note: it's important not to over-tighten the screws;*
6. As a rule of thumb, all screws should now sit directly below the lens surface (i.e., from a planar view, screws should not be overly depressed nor protruding from their respective pilot holes.
7. All screw fastening/loosening should be done manually with a suitable screwdriver for greater control. Avoid using battery-powered drivers.

Figure 21. Video camera placement and lens attachment procedure. A and B: Placement of video recorder into the housing; C: Application of silicon lubricant around housing O-ring; D: Polycarbonate lens and attachment screws; E: Aligning inscriptions on lens and housing to ensure proper lens:housing configuration: F: Fastening screws.

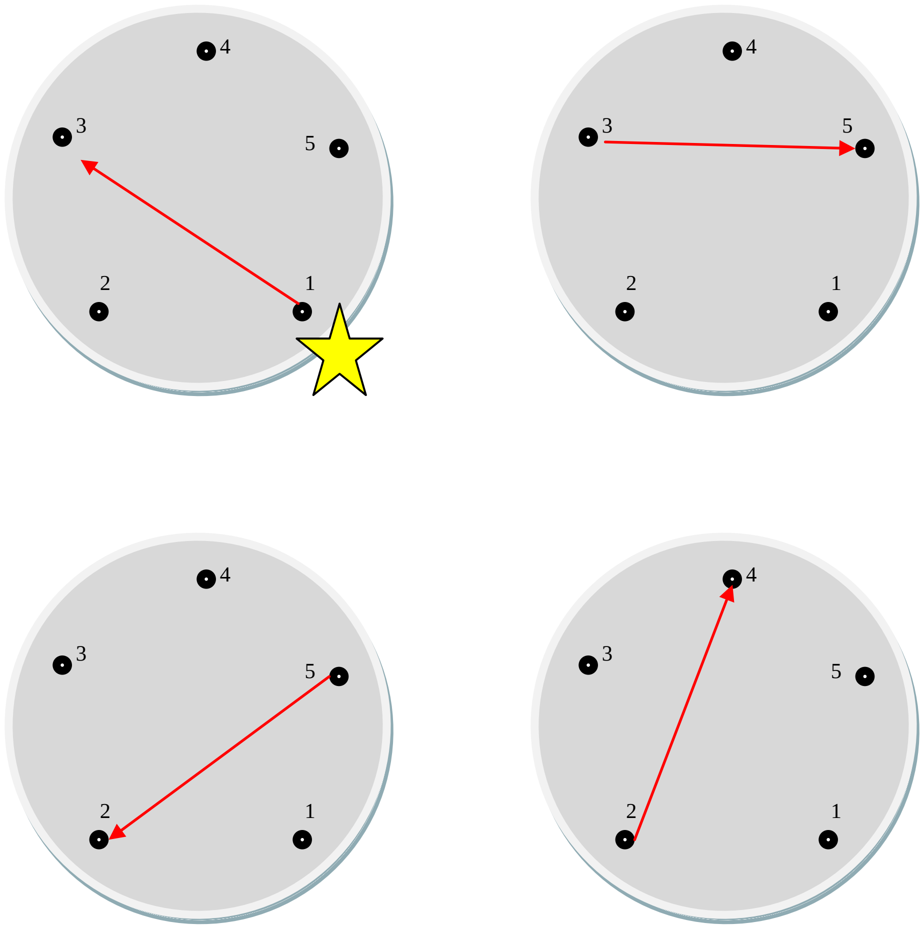


Figure 22. Fastening sequence of screws across polycarbonate lens. Starting at screw 1 (Star), the sequence is #1⇨#3⇨#5⇨#2 and # 4. A similar alternating sequence should be undertaken when removing the lens.

7.0 Field sampling protocol and deployment procedure guidelines

7.1 General comments

As best-practice the deployment procedure should be discussed at length and a "dry run" undertaken prior to field sampling proper. Further, the equipment checklist (Table 6) should be consulted well in advance of sampling. We recommend a minimum of 2 personal are required to undertake a BRUV survey.

Prior to disembarking, ensure that an up-to-date weather forecast is consulted and a land-based contact has been notified of the planned survey location and estimated time of arrival (ETA) following sampling. Notify the local coastguard operator relative to your specific area, of the following: vessel name; number of persons on board; nature and location of business; estimated check-in time and/or ETA.

A list of NZ coastguard VHF channels for North and South Island regions can be found at www.coastgaurd.co.nz and is available in pdf format.

As a general rule, sampling sites should be uploaded to a GPS navigation system (fixed or hand held) prior to sampling. To avoid biases, ensure those sites adjacent one another are not going to be surveyed consecutively (for the most part), nor that all reserve sites are to be surveyed first followed by all non-reserve sites.

7.2 Deployment process (hypothetical example)

The standard method of BRUV deployment is to place the unit within 20m of rocky reef habitat. This may not be appropriate for all marine reserves e.g., Tapuae Marine Reserve (New Plymouth) whereby the majority of BRUV deployments will require the unit to be placed directly on rocky reef habitat. The exact placement protocol should be established in the sampling design phase (Section 4), i.e., prior to any field work taking place.

Considering the hypothetical example presented in Section 4 there are 15 reserve sites (5 per block) and 15 non-reserve sites (5 per block) that require sampling by BRUV. It is anticipated that the survey will require approximately 3.5 days to complete and for the first day of sampling reserve sites 3, 9, and 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 disembarking.

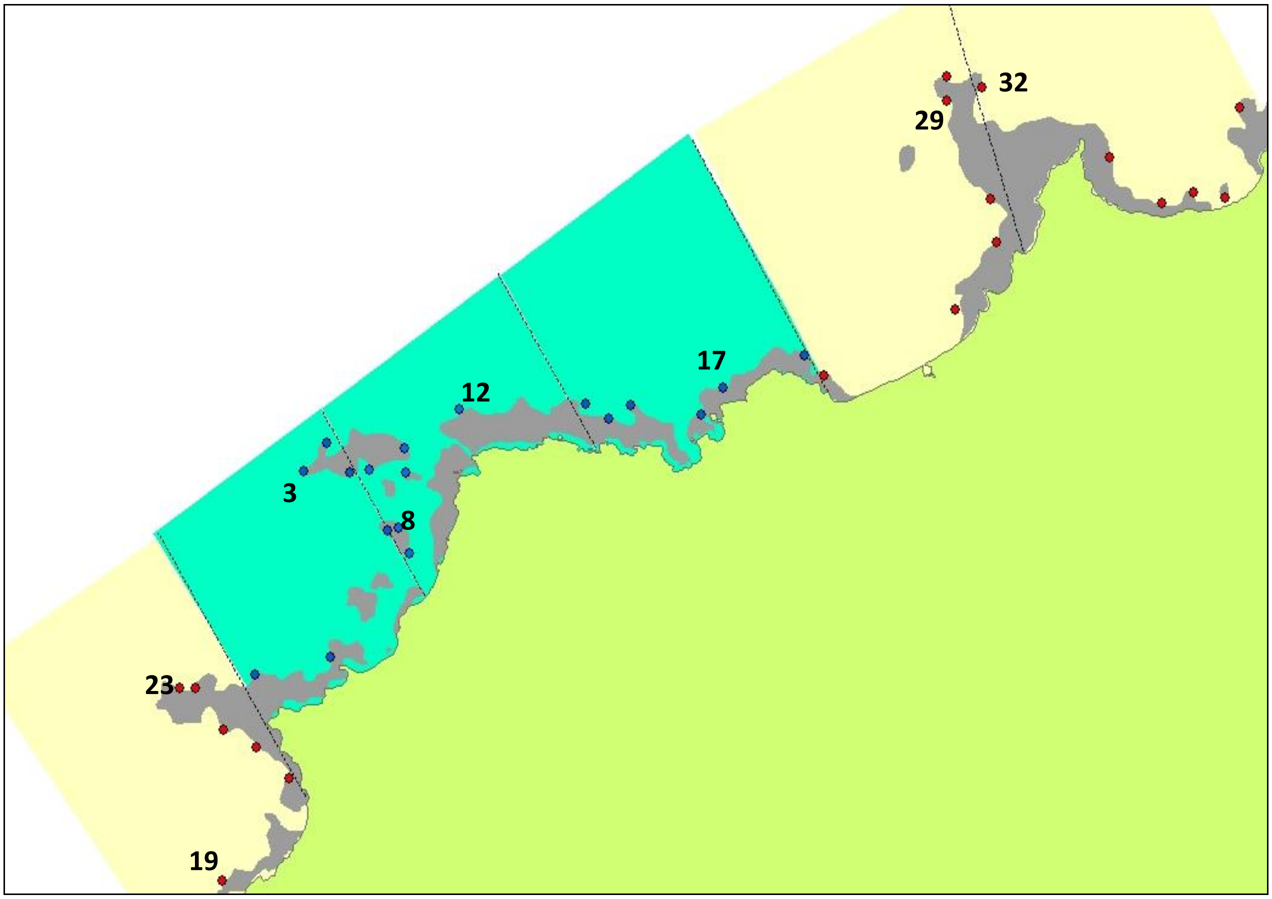


Figure 23. Hypothetical example of Reserve (3, 8, 12 and 17) and Non-reserve sites (19, 23, 29 and 32) to be sampled within a given day.

Once in the vicinity of 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. Main guidelines for the first BRUV deployment are:

1. Discuss plan of action and identify hazards (if any);
2. Locate site using depth sounder and, if necessary anchor 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. Note: the less handling (opening and closing of housing) during sampling the better;
6. Ensure the digital video camera has sufficient battery life and 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 using the viewfinder 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. Fasten lens to camera housing as described in section (above);
11. Place bait within bait container (approximately 100g or 3 pilchards), fasten to the container bottom on the BRUV frame and cable-tie pilchard to the top of the bait container;
12. Attach drop camera to the housing with lanyard and rubber bands (Fig. 24);
13. Attach pressure buoy to the top hole on the flange of the BRUV housing;

The BRUV unit will now be ready for deployment

14. Write the **Date**, **Location #**, and corresponding **GPS Waypoint** #, on a white board or pad and place in front of the camera before deployment (Fig. 14);
15. Write the **Location #** (predetermined); **GPS waypoint #** (predetermined); **Depth** (m); and **Time In** in the BRUV log folder;
16. Deploy BRUV (Fig. 25).

Note: the person(s) deploying the BRUV unit must be wearing appropriate safety gear. The BRUV 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 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;

17. Steadily lower BRUV to substratum. (Fig. 26). Once on the substratum, tie the surface buoy and accompanying rope onto a bollard (ensuring there is enough slack to account for vessel movement) until the site has been deemed suitable;
18. Check, via the drop camera, whether the BRUV has landed on suitable substratum and that macroalgae is not obscuring the field of view. If the BRUV unit does not land on suitable substratum or there are problems with macroalgae blocking the field

of view, gently lift the BRUV 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;

19. Once a suitable site has been located, take a GPS mark (adjusted), release the drop camera from the BRUV unit with a hard jerk and haul to surface.;
20. Untie surface float and accompanying rope from the vessel bollard and pitch away from the vessel;
21. Move vessel away slowly away from the site;
22. Over the ensuing 30-35 min sampling period, additional BRUV deployments can be made if a secondary system is available.

7.3 Retrieval

1. Approach the surface buoy once sea state and prevailing currents have been considered. 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 BRUV unit as opposed to over the top, thus reducing the change of entanglement or damage to the vessel, BRUV unit, or both;
2. Retrieve rope warp with a blunted gaff, disengage vessel engine and take a GPS mark (final) just before the BRUV unit releases from the substratum. Haul BRUV unit to surface taking in slack quickly;
3. Verify that the camera is still recording and fill out the remainder of the BRUV log for that particular site;
4. Ensure the BRUV unit is securely fastened within the vessel when traveling between sampling sites;
5. Move onto the next site repeating the above procedures;
6. If the BRUV unit requires opening in the field, completely dry the unit with towels before removing the lens;
7. At the end of the days sampling, ensure the BRUV unit is washed down with fresh water and dried;
8. All video data will require immediate backup and storage to computer hard drive.

Figure 24. Filming site-specific details (on pad) relating to the BRUV drop.

Figure 25. Immediately prior to deployment. *Note:* the BRUV 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.

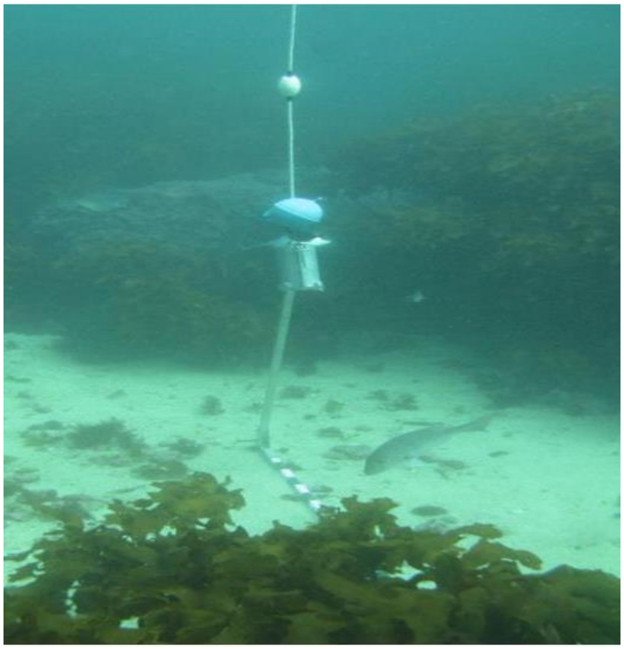
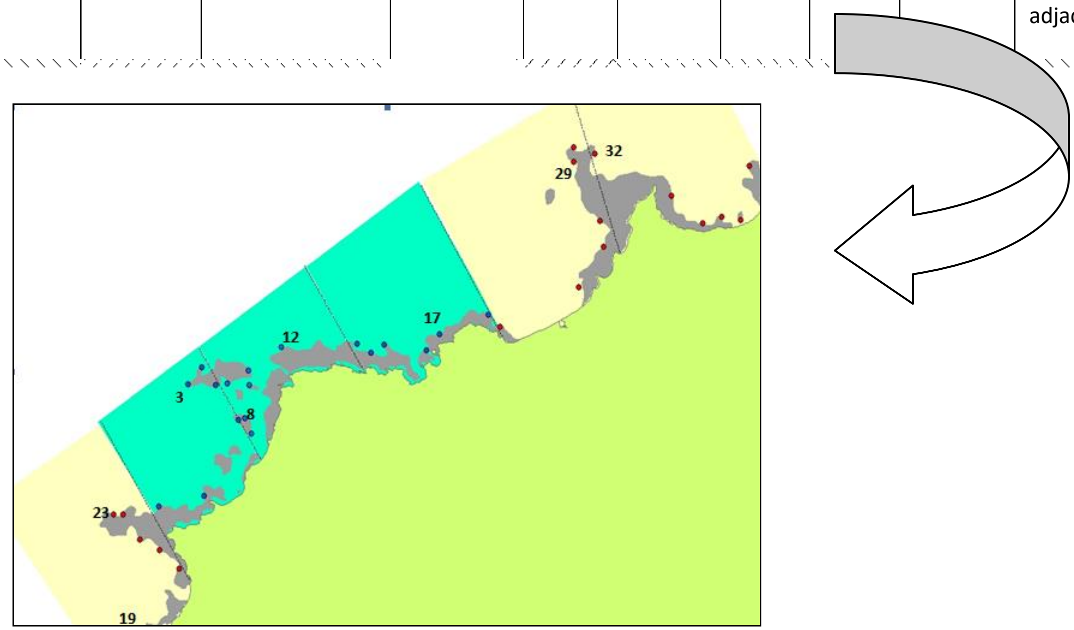


Figure 26. BRUV placed on soft sediment substratum within 20m of rocky reef habitat

Table 6. Example of general supporting information required for each BRUV drop. In this instance two cameras (1 and 2) are being used.

Location:		Vessel:		Surveyor:							
Date	**Site & Status**	**Camera #**	**Waypoint predetermined**	**Waypoint adjusted**	**Waypoint final**	**Depth (m)**	**Time In**	**Time Out**	**UW Visibility**	**Habitat**	**Notes**
9/04/13	12- R	1	**3**	**31**	**33**	**9.6**	08:14	08:50	Fair	Coarse sand approx. 5m from rocky reef	Flat conditions; mid flood tide; overcast; 0.5m swell. No wind
9/04/13	32-NR	2	**19**	**32**	**34**	**12.2**	08:36	09:12	Fair	Fine sand approx. 15m from rocky reef	Flat conditions; mid flood tide; overcast; 0.5m swell. Wind light and variable
9/04/13	17-R	1	24	35	37	6.1	09:23	09:58	Poor	Fine sand/mud immediately adjacent rocky reef	Slight chop from sea breeze mid flood tide 0.5m swell. Wind light and variable. Visibility poor
9/04/13	29-NR	2	4	36	38	13.2	09:45	10:22	Fair	Fine sand immediately adjacent rocky reef	Slight chop from sea breeze mid flood tide 0.5m swell. Wind light and variable
9/04/13	12-NR	1	11	39	41	12.9	11:39	12:05	Fair	Fine sand immediately adjacent rocky reef	Slight chop from sea breeze flood tide 0.5m swell. Wind strengthening from NE- camera may have drifted slightly



8.0 Post sampling data management

8.1 Video data management and storage

It is essential that all raw (unprocessed) video data are labelled and stored in a suitable manner. Depending on the storage medium (hardrive, DVD, digital tape etc) ensure that as a minimum the survey date, and sites surveyed accompanies each format (Fig. 27). Other supporting notation (surveyors, boat, etc) may also be of value. Generally adhesive writeable lables are supplied with DV tapes and DVD roms can be written on with permanent marker.

Figure 27. Example of labelling for raw BRUV data stored on digital video tape

Following field sampling, raw (unprocessed) video data should be immediately backed up or captured to a computer harddrive. Appropriately labelled folder and subfolders should be created and used to archive the raw video data (Fig. 28). To ensure multiple copies are in existence copies of the dowloaded data should be backed up further to external hard drives.

Paper forms e.g,. Table 6, should be photocopied or scanned so that multiple copies are in existence. If possible, physical and eletronic copies of the data should be stored at separate physical locations.

8.2 Video capturing

If capturing data from DV tape to computer, a fire-wire cable will be required that bridges the two devices. Video will need to be captured directly from the camera using specialised software. Specialised software such as Adobe Premire Pro, and Pinnacle software are leader brands and resultantly are expensive. Software such as Windows Movie Maker, which is adequate for capturing video data are incoporated as part of Microsoft Office packages, as is Movie for Apple computers.

Newer digital video recorders with built-in harddrives have the option of transfering data directly from the camera hardrive (via USB connection) to an external hard drive or DVD writer device, which can then be transferred to the computer. Consult the camera handbook for the data capture proceedures and required hardware prior to purchase.

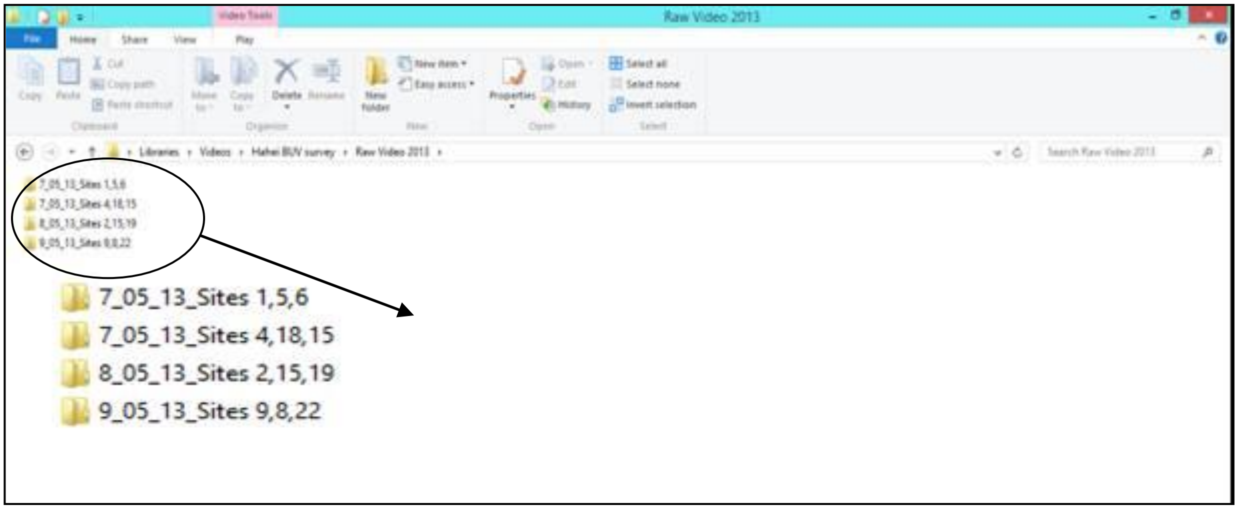


Figure 28. Example of folder specification for raw BRUV data. Each folder has survey date and corresponding sites numbers that were surveyed on that date.

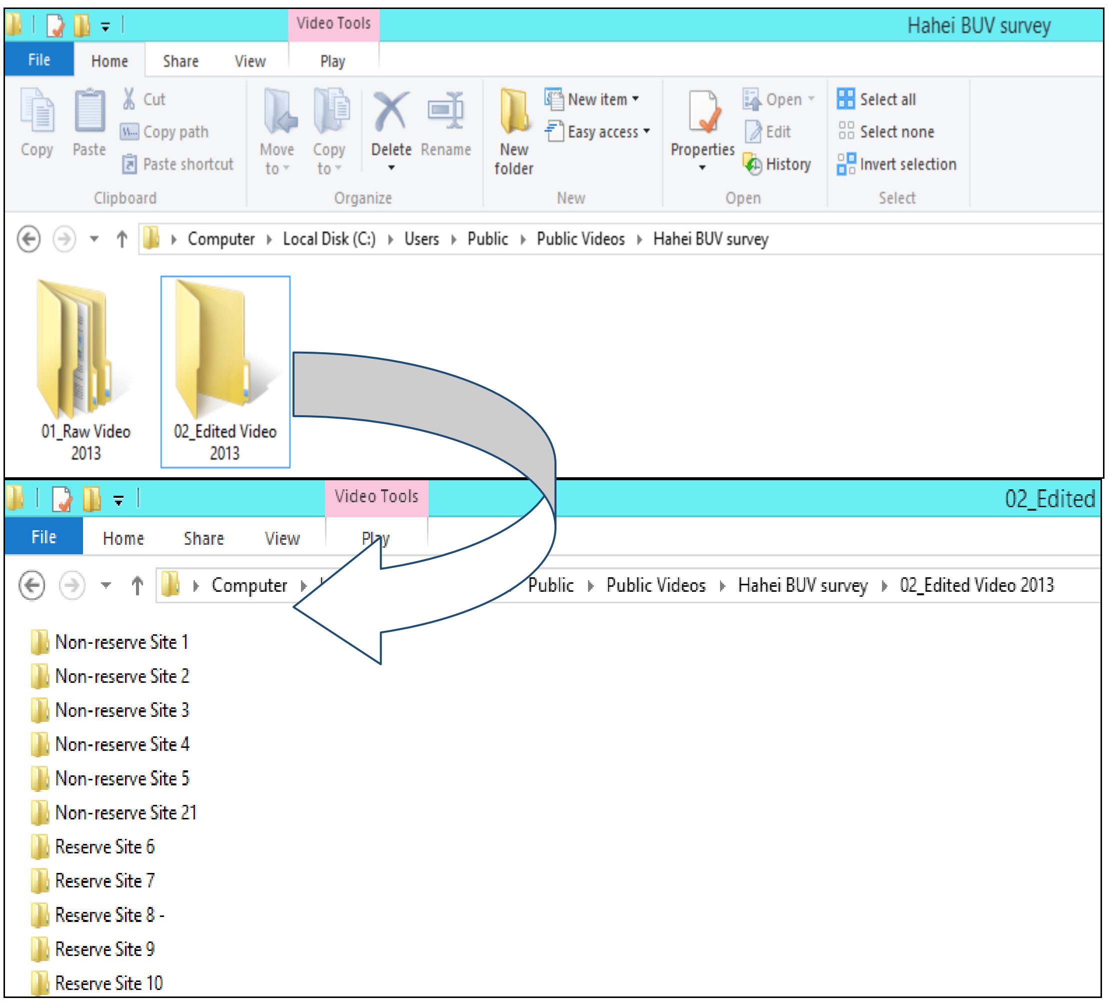


Figure 29. Example of folder specification for edited BRUV data. Each folder is specifed by protection status (reserve or non-reserve) and site number.

8.3 Video editing

Due to continuous filming over consequtive video drops raw video will conatin a range of unnecessary material that will require editing (removal) before formal analysis and archiving. Again, editing can be done in programes such as Windows Movie Maker, but ensure that when rendering edited data that the highest video quality settings are used, i.e., do not sacrifice storage space for video quality.

It is preferable to capture and edit data for each site and place it into a separate video folder with corresponding date and site name (Fig. 30). For each site-specific video, be sure to include the frames that contain the site details and entire descent of the BRUV unit from vessel to the seabed.

9.0 Data analysis

Data anlaysis will require access to spreadsheet software such as MS-Excel and image analysis software.

9.1 Data metrics

The key abundnace metric is **MAX*count*** (Willis *et al*. 2000) for each species of interest and can be measured at either 30s or 60s. 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 the MAX*count* index. Individuals that comprise the MAX*count* are then used for size analysis. Size analysis will utilise image measurement software.

9.2 Abundance anlaysis

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

- Set up a spreadsheet with corresponding columns for species of interest and rows for time replicates (e.g., Fig. 30).

- The example spreadsheet below (Fig. 30) starts at 00:06:38 (six mintues and 38 seconds) on the DV recording. Abundance data are to be colleted at 30 second intervals, therefore the first count point is at 07:08; second count point is 07:38; third count point is 08:08 and so on.

- Watch the video for each 30s 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 BRUV setup.

- Count the total number of each fish species in the frame at each count point replicate (n=60 per drop for 30s counts; n=30 per drop for 60s counts). At times fish will obscure one another. To obtain acurate counts it may be necessary to rewind or fast-forward the video footage frame by frame to ensure all fish are counted.

- Once all counts have been made, run a data filter application (MS Excel) to check that no mistakes have been made with data entry. At the same time, use the data filter application to select the time period with the maximum count (MAX*count*) for each species. This MAX*count* will be used for subsequent size analysis.

Home Insert Page Layout Formulas Data Review View Add-Ins

K17 =SUM(G17:I17)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Port Pegasus BUV survey											
2	Site	Disappointment	Time	Count	Tape Time		MAX	MAX	MAX	MAX	Total	Notes
3	Replicate	1	0:00	replicate	00:06:38	0:00:30	Blue cod	Tarakihi	Girdled wrasse	Scarlet wrasse		
4	Tape	Pegasus 02.avi	0:00:30	1	00:07:08		5	0	0	0	5	
5	Analysis date	22/10/2012	0:01:00	2	00:07:38		9	0	0	0	9	
6	Recorder	K. Slater	0:01:30	3	00:08:08		12	0	0	0	12	
7			0:02:00	4	00:08:38		14	0	0	0	14	Largest blue cod attacking bait holder
8			0:02:30	5	00:09:08		11	0	1	0	12	Movement of the BUV array/Largest blue cod attacking bait holder
9			0:03:00	6	00:09:38		13	0	1	0	14	
10			0:03:30	7	00:10:08		13	0	0	0	13	1 Blue cod moving up to camera 09:24
11			0:04:00	8	00:10:38		14	0	2	0	16	
12			0:04:30	9	00:11:08		16	0	3	0	19	
13			0:05:00	10	00:11:38		14	0	2	0	16	
14			0:05:30	11	00:12:08		11	0	0	0	11	Fighting between blue cod at bait station
15			0:06:00	12	00:12:38		14	1	2	0	17	Fighting between blue cod at bait station and larger blue cod chasing girdled wrasse
16			0:06:30	13	00:13:08		15	1	1	0	17	
17			0:07:00	14	00:13:38		16	0	1	0	17	
18			0:07:30	15	00:14:08		17	0	2	0	19	
19			0:08:00	16	00:14:38		12	0	3	0	15	Big blue cod at 13:43
20			0:08:30	17	00:15:08		13	0	4	0	17	
21			0:09:00	18	00:15:38		12	0	4	0	16	Blue cod comes in at 15:10
22			0:09:30	19	00:16:08		13	0	4	0	17	
23			0:10:00	20	00:16:38		14	0	3	0	17	
24			0:10:30	21	00:17:08		16	0	6	0	22	
25			0:11:00	22	00:17:38		15	0	4	0	19	
26			0:11:30	23	00:18:08		14	0	6	0	20	
27			0:12:00	24	00:18:38		14	0	4	0	18	Lots of blue cod movement
28			0:12:30	25	00:19:08		15	0	3	0	18	Blue cod attacking bait holder
29			0:13:00	26	00:19:38		10	0	4	0	14	Fighting between blue cod at bait holder
30			0:13:30	27	00:20:08		10	0	5	0	15	Big Tarakihi enter field of view
31			0:14:00	28	00:20:38		10	0	3	0	13	
32			0:14:30	29	00:21:08		14	0	3	0	17	
33			0:15:00	30	00:21:38		12	0	3	0	15	
34			0:15:30	31	00:22:08		20	1	2	0	23	Largest blue cod attacking bait holder
35			0:16:00	32	00:22:38		12	0	2	0	14	Feeding frenzy around bait holder
36			0:16:30	33	00:23:08		12	0	4	0	16	Feeding frenzy around bait holder then fish move off
37			0:17:00	34	00:23:38		13	0	2	0	15	Blue cod attacking bait holder
38			0:17:30	35	00:24:08		9	0	2	0	11	
39			0:18:00	36	00:24:38		13	0	3	0	16	
40			0:18:30	37	00:25:08		14	0	1	0	15	

Figure 30. Spreadsheet depicting MAX*blue cod*, MAX*tarakihi*, MAX*girdled wrasse*, and MAX scarlett wrasse counts. Yellow highlighted rows for Time 1 and 6, correspond to Fig. 21 below.

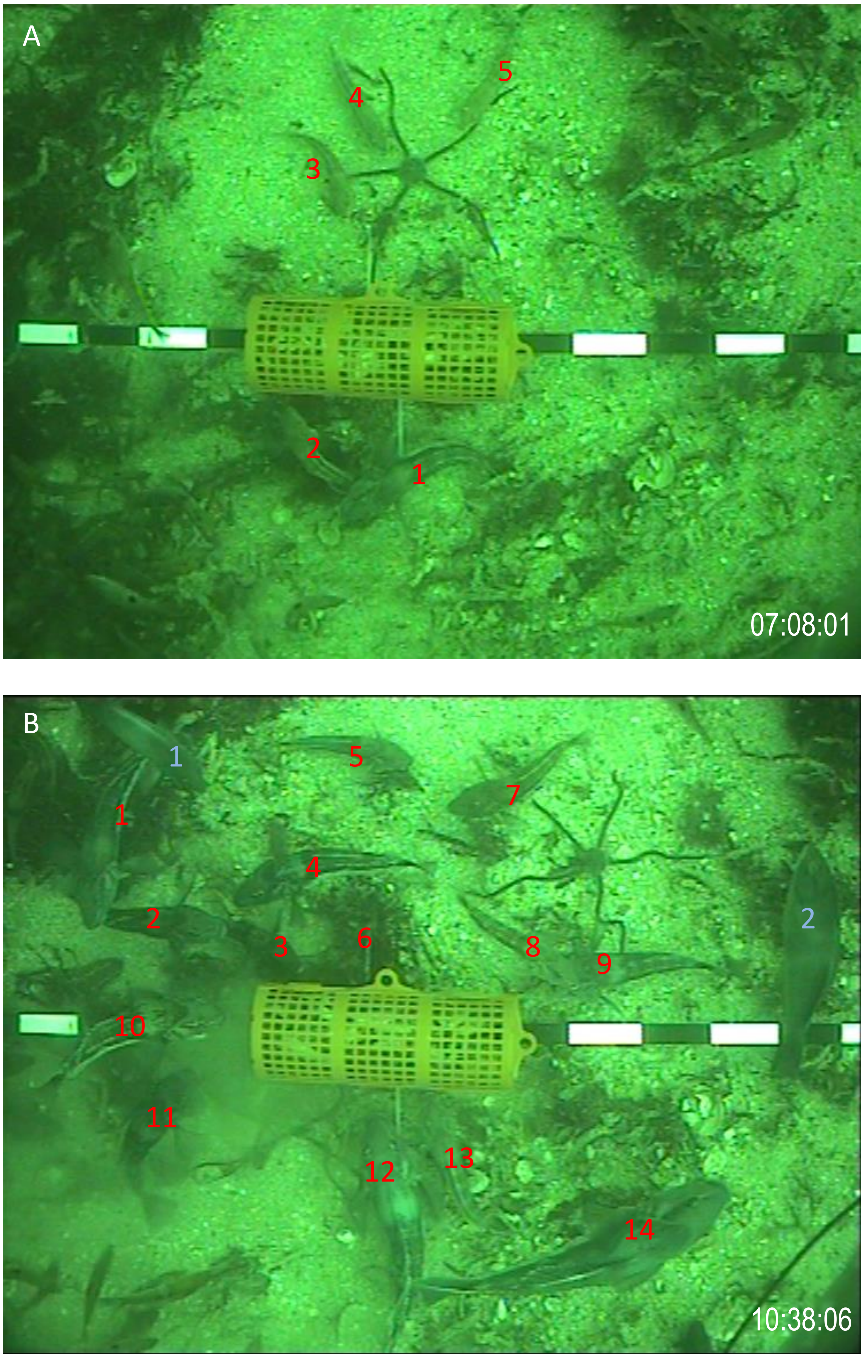


Figure 31. Counts of blue cod (red numbers) and girdled wrasse (blue numbers) coresponding to A: 30 seconds and B: 4 minutes following BRUV deployment. Refer to Fig. 30 for accompanying spreadsheet.

9.2.1 Managing biases

It is very unlikely that a given BRUV survey will not incounter issues that are out of the contol of the researcher, some of which may bias the data acquistion phase. Biases such as BRUV drift and predator-related effects may impinge on abundance analysis. If camera drift is subtle or short-lived then it is likely to be resonably inconsequential. On the other hand, if BRUV drift is prolonged then counts need to cease until the unit stabilises. Data obtained prior to the drift will not be able to be compared to post drift data and typically data obtained prior to the drift should be used in preference to post-drift data, This is because during the period of drift the BRUV unit is effectively sampling a much larger area compared to a deployment with no drift. Ultimately the use of pre- or post-drift data will depend on when the drift occurred within the deployment equence and the incongruity of MAXcounts between phases. Should the deployment be plauged by continual drift then data acquisition will not be possible and a redeployment required (if feasible).

Managing 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, and sharks there is generally a rapid scatter of fishes away from the BRUV unit. In our experience this is often followed by a fairly rapid (several minutes) return of target species to pre-incursion levels. Data aquistion should cease until pre-incursion levels have satbilised. In the instance of multiple incursions for a given deployment it may be prudent to redeploy the unit at a latter satge (if possible).

For octopus and lobster that are primarily attracted to the bait there is very little the researcher can immediately do to eliminate the bias other than if severe redeploying the unit or resuming counts when the bias abaits. 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 anybiases biases that have occurred should be included in data presentation and reporting sections.

9.3 Size analysis

Before beginning size analysis proper revisit the 30 sec sequence that corresponds to the MAX*count* for each speciesof interest. Identify which fish can be easily sized and which may be more difficut to size, i.e., those present at the periphery.

The best freeware software application for obtaining length measurements is ImageTool. It is also straightforward to impliment. Programmes such as SigmaScanPro software have additional features including a three-point callibration but is reasonably expenisive.

For size analysis using ImageTool and SigmaScanPro software, a subsequent capture programme will be required to convert video data e.g., .avi format format into a picture file format e.g., JPEG. To convert video frames to single pictures we recommend Aaoao

Video to Picture converter, which is cheap and effective http://www.aoaophoto.com/. Further, the user can define Outputsize and Output rate (Fig. 32).

Depending on the abundnace of fish to be sized within the field of view, it may be necessary to obtain multiple frame grabs prior to and following the main count frame. This can be achieved using Aoao softwear. In some cases fishes that occur on the margins of the field of view will not be able to be acurately sized due to wide angle lens distortion.

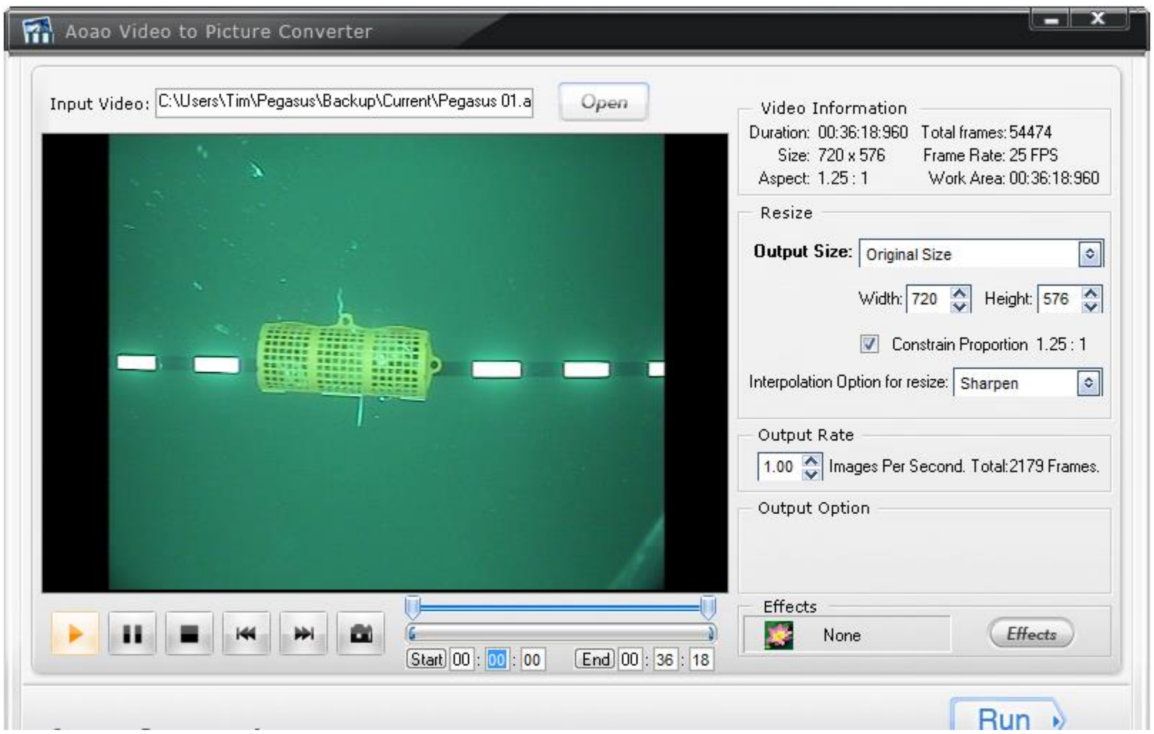


Figure 32. Front end of Aoao Video to Picture Converter software.

9.3.1 Size analysis with ImageTool software

Size analysis will be undertaken with ImageTool software. It can be dowloaded from the following URL http://compdent.uthscsa.edu/dig/itdesc.html. The programme opens directly into a spreadsheet format (Fig. 33).

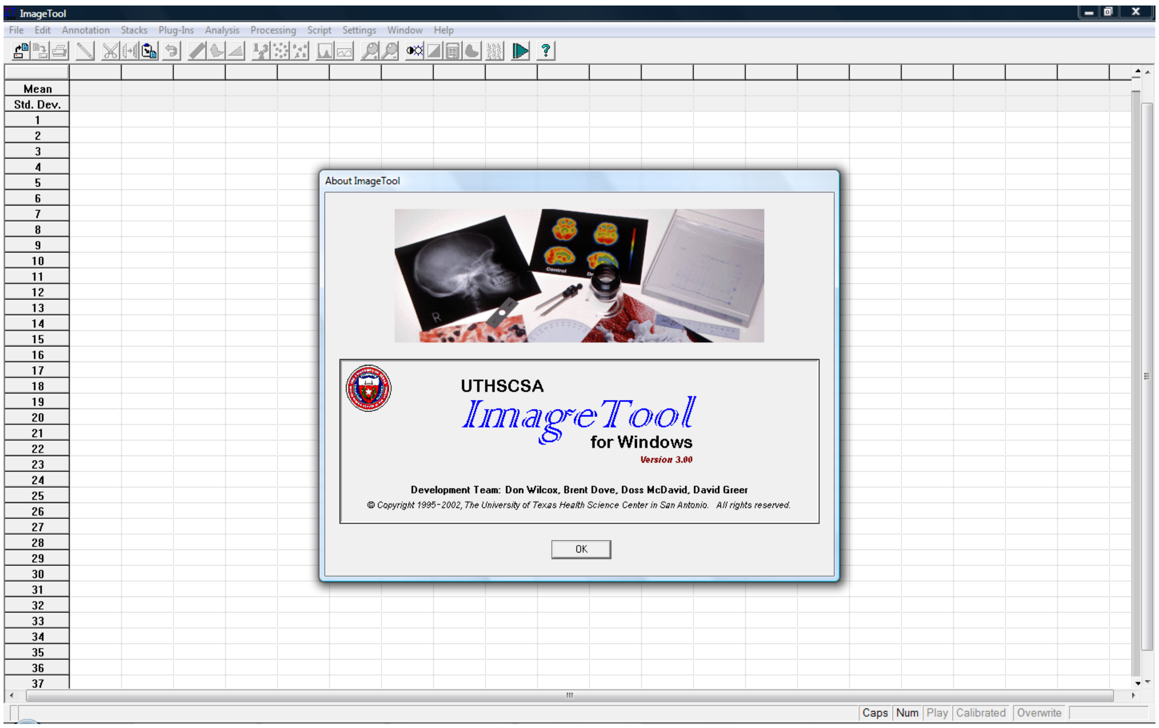


Figure 33. ImageTool frontend screen and associated spreadsheet.

The image(s) that correspond to the MAX*count* will need to be imported into the programme. These should be in a compatible file format, e.g., JPEG, TIF, BMP etc. If multiple images pertain to the MAX*count* these can be imported as a stack.

Image inport

To import JPEG image: ☝File→☝Open Image→Select and ☝☝ File with specific JPEG image, e.g., C:\ BRUVHahei_2013 →image will open into the programme (Fig. 34).

Check that the displayed image(s) is correct and corresponds to the MAX*counts*. Note: Counts can be re-checked in ImageTool using the "Count and Tag" proceedure - Refer to Appendix 1.0.

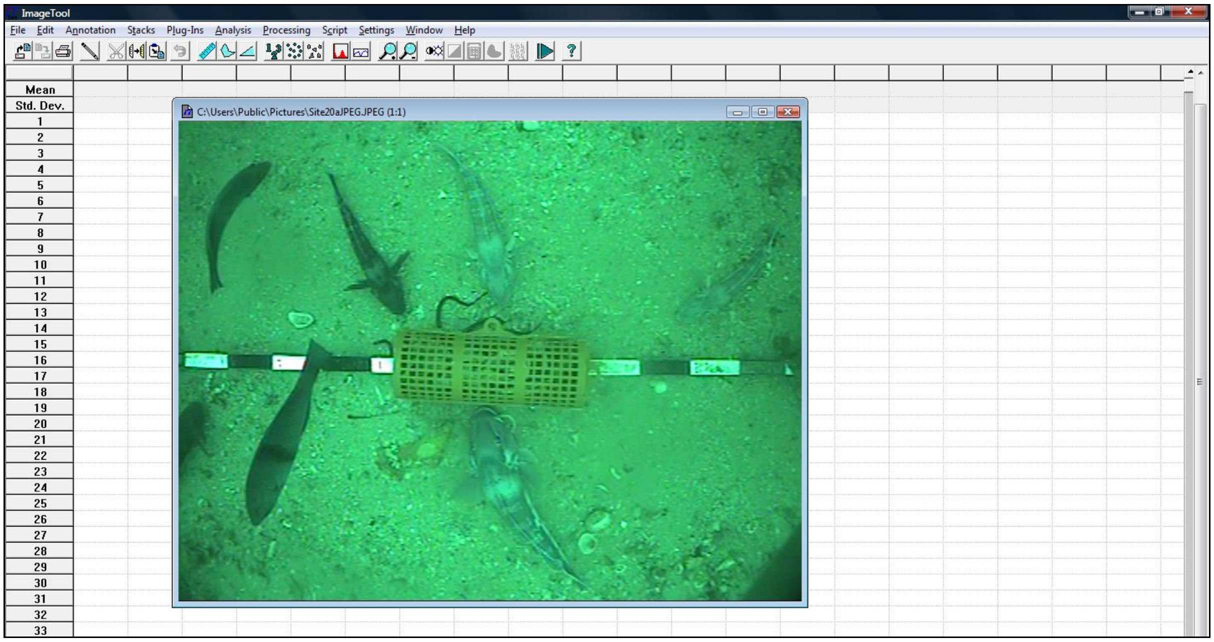


Figure 34. Imported image corresponding to the MAX*blue-cod* count.

Calibration

To calibrate measurement tool: ☝Settings→☝Calibrate Spatial Measurements and the dialog box **Draw a line of known length** will be displayed. The cursor will change to a pencil. Define a line by click-and-dragging the mouse which represents an object or distance of known dimensions (scale on frame or bait container) (Fig. 34).

The **Calibrate** dialog box will be displayed. Enter the length of the line (Fig. 35 =100mm), and select the units of measurement (e.g., millimeters) from the drop-down list box.

☝**OK** button, once you have confirmed the calibration input. All dimensional analyses performed on this image will be based on this calibration. The **Save Spatial Calibration** command saves the current spatial calibration.

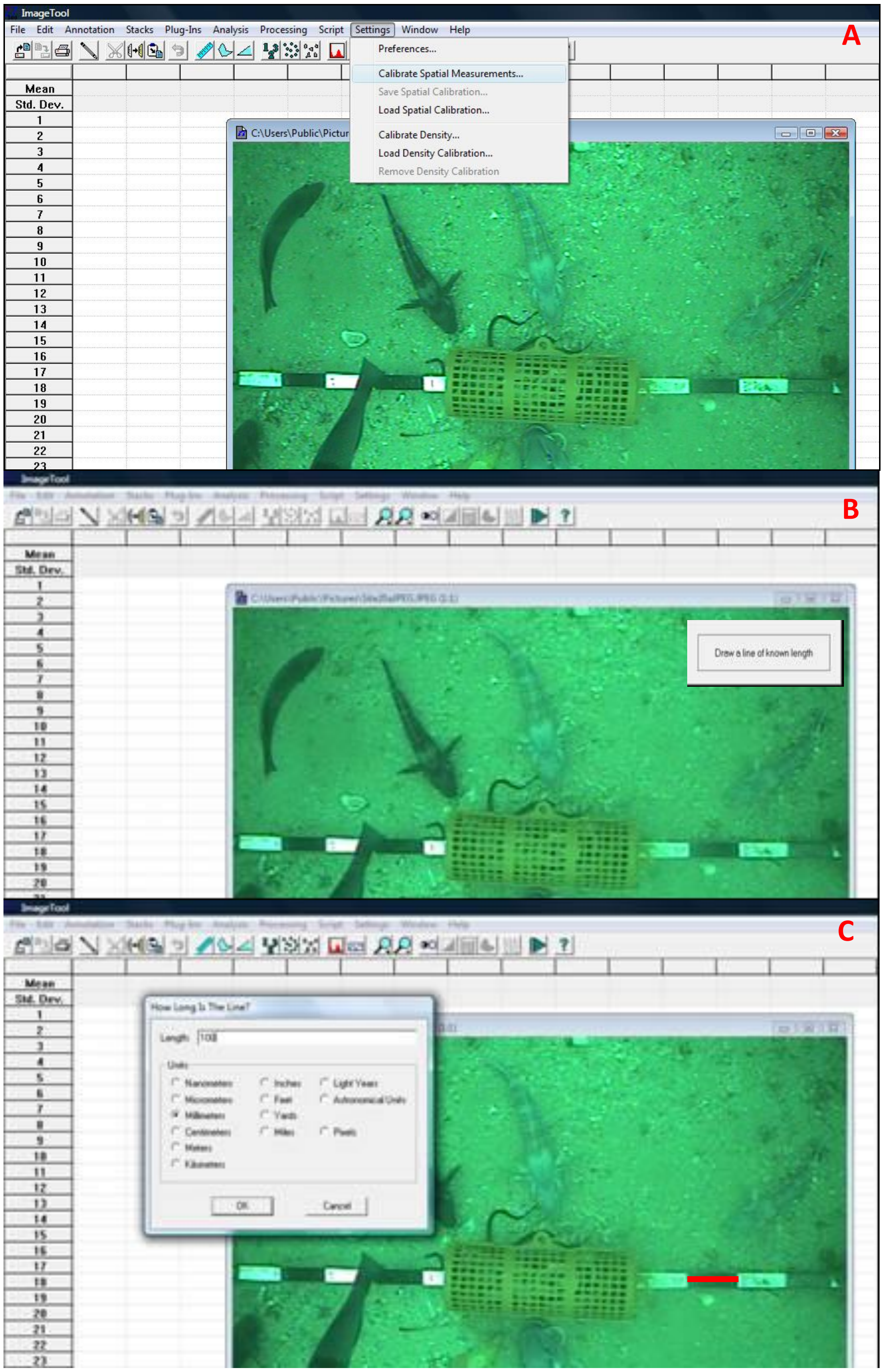


Figure 35. Calibration sequence A-C. The red calibration line in Figure C corresponds to 100mm.

Size measurement

To measure all fish in the frame:

1. ☝**Analysis** on the toolbar and select **Distance.** The distance command is used to determine length of a linear feature (both single and multiple-segment lines) within the digital image.

2. The dialog box **Draw the line to measure** will be displayed (Fig.36). The cursor will change to a pencil. Define a line by click-and-dragging the mouse which represents an object or distance of known dimensions (scale on frame or bait container) - in this case the length of the fish from head to tail.

3. The size for fish # 1 will automatically appear in the first column against row label 1 (Fig. 36). Repeat Step 2 for all remaining fish in this instance 4 blue cod. Each new measurement will automatically occur in the next available row and a new average value (*Mean)* and associated standard deviation (*Std. Dev.*) automatically calculated.

4. At the competion of size analysis ☝**File**→☝**Save Results As** and save results into a corresponding labelled folder using an approprite File name, e.g., Site number (Fig. 37). The file will be saved as a text (.txt) file. Text files can be imported into MS Excel or similar software for analysis.

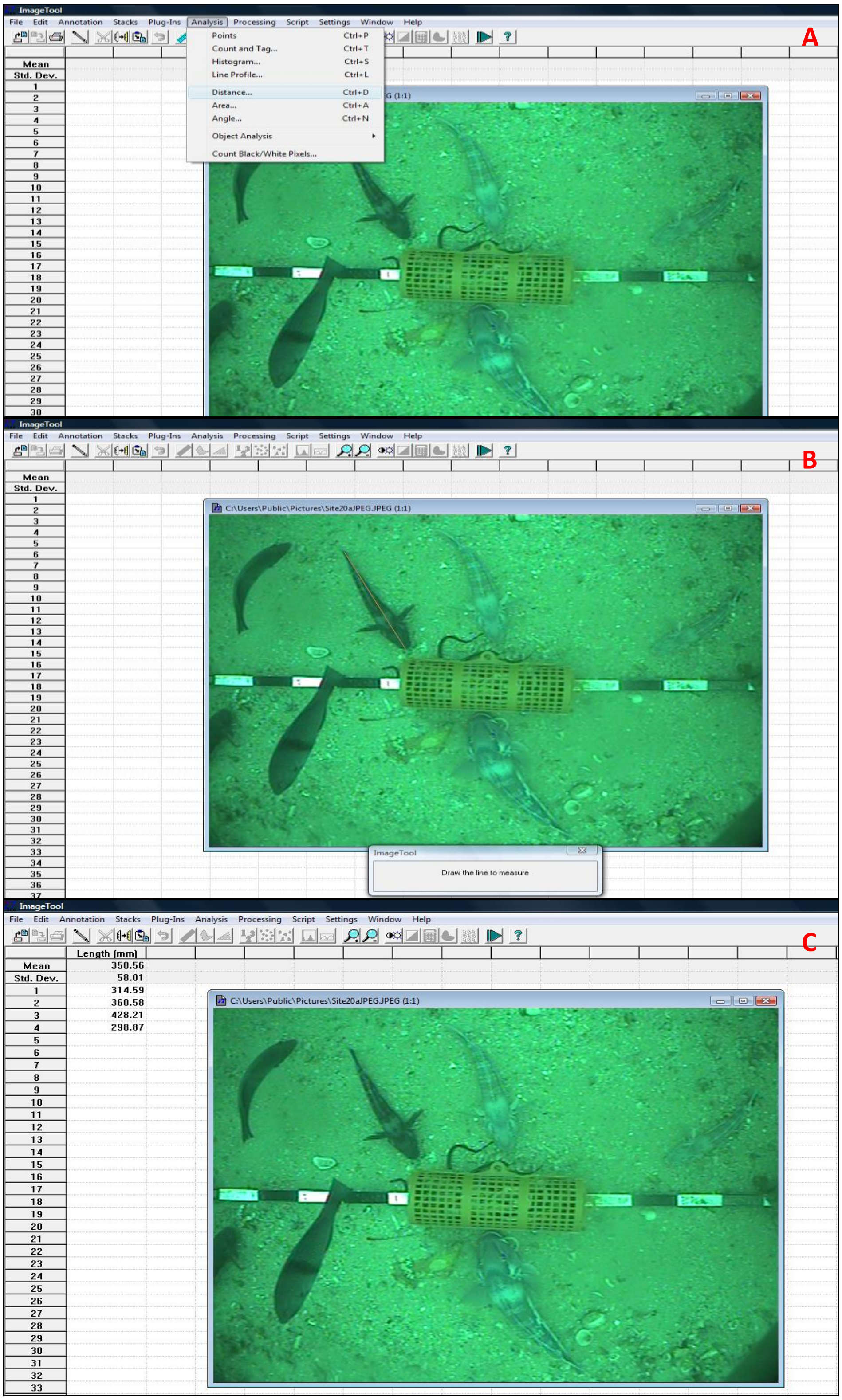


Figure 36. Measurement sequence A-C for the four blue cod in the field of view.

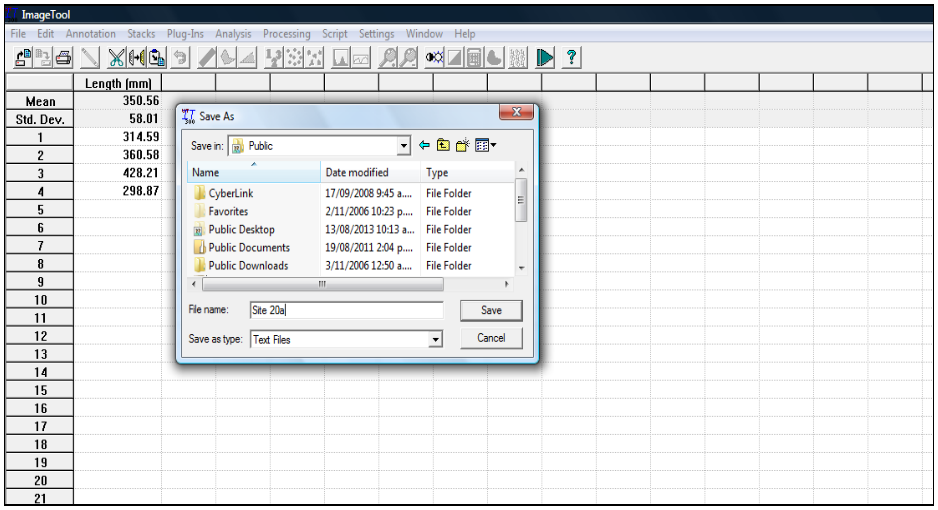


Figure 36. Save data procedure.

9.3.1 Managing biases

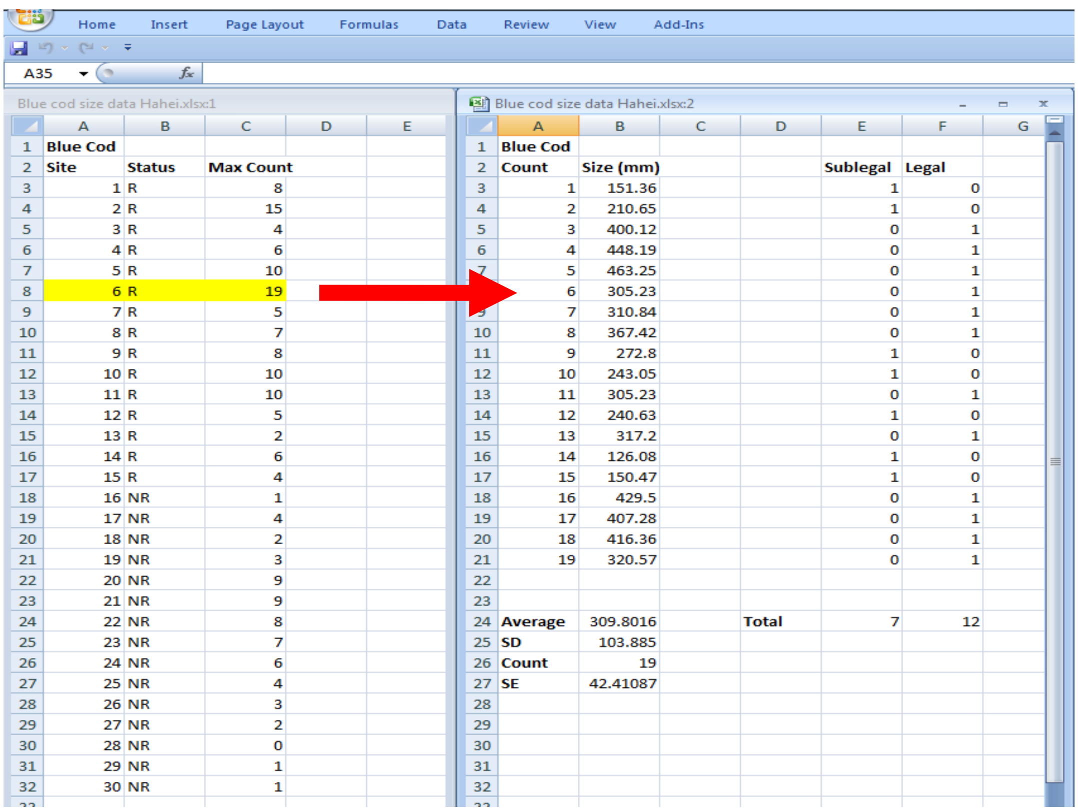
Biases associated with size estimation are typically artifacts of the camera and BRUV unit itself and relate to lens distortion (potential) and measuring the length of target fishes that occur at different heights with the field of view. At the time of writing we do not have a clear understanding of the degree of lens distortion (minor, moderate or major) stemming from the use of the semi fish-eye lens (termed barrel distortion), but this warrants examination so that correction methods can be developed (see Wang *et al*. 1990). Equally, 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 (see Willis and 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. In instances where it is difficult to obtain an accurate length estimate it is best to exclude the measurement from the dataset proper.

Note: Lens distortion can be evaluated by undertaking 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 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 (see Section 11.0).

10.0 Data exploration and analysis

Following the data acquisition phase there should be two sets of data generated for each BRUV drop. The first set corresponds to MAX*counts* for the various species enumerated and the second dataset corresponding to sizes (±0.01 mm) for each individual constituting the MAX*count* (Fig. 37).

Size data should be further divided into legal, and sub-legal (juvenile) size classes based on commercial and recreational minimum size classes limits (Table 7). This will ultimately depend on the fisheries management area and in some instances timing of the survey. Size data can be classified into sub-legal and legal size classes in Microsoft Excel using the =COUNTIF() function (*fx*).



Blue Cod

Site	Status	Max Count
1	R	8
2	R	15
3	R	4
4	R	6
5	R	10
6	R	19
7	R	5
8	R	7
9	R	8
10	R	10
11	R	10
12	R	5
13	R	2
14	R	6
15	R	4
16	NR	1
17	NR	4
18	NR	2
19	NR	3
20	NR	9
21	NR	9
22	NR	8
23	NR	7
24	NR	6
25	NR	4
26	NR	3
27	NR	2
28	NR	0
29	NR	1
30	NR	1

Blue Cod

Count	Size (mm)			Sublegal	Legal
1	151.36			1	0
2	210.65			1	0
3	400.12			0	1
4	448.19			0	1
5	463.25			0	1
6	305.23			0	1
7	310.84			0	1
8	367.42			0	1
9	272.8			1	0
10	243.05			1	0
11	305.23			0	1
12	240.63			1	0
13	317.2			0	1
14	126.08			1	0
15	150.47			1	0
16	429.5			0	1
17	407.28			0	1
18	416.36			0	1
19	320.57			0	1
Average	309.8016		Total	7	12
SD	103.885				
Count	19				
SE	42.41087				

Figure 37. Example datasheet with left datasheet displaying MAX*counts* for blue cod for each survey site and the right datasheet showing the sizes in mm for the 19 blue cod that constitute the MAX*count* and associated summary statistics. Size data are further classified into sublegal (<300 mm TL) and legal (≥ 300mm TL) size divisions.

Table 7. Minimum recreational finfish size limits (cm) for the six fishery management areas (FMAs). Note sizes are in centimeters (cm). Consult www.fish.govt.nz for further details.

Species	Fishery					
	Auckland/ Kermadec	Central Fishery	South East	Southland	Challenger	Fiordland
Blue cod	30	33	30	33	30min-35max[1]; 30[2]; 33[3]	33
Snapper	30	27	25	25	25	25
Blue Moki	40	40	40	40	40	40
Flatfish	25	25	25	25	25	25
Red cod	25	25	25	25	25	25
Red gurnard	25	25	25	25	25	25
Red Moki	40	40	40	40	40	40
Sand flounder	23	23	23	23	23	23
Tarakihi	25	25	25	25	25	25
Trevally	25	25	25	25	25	25
Trumpeter	35	35	35	35	35	35
Kingfish	75	75	75	75	75	75

[1]Blue Cod – Marlborough Sounds Area (closed from 1 September - 19th December inclusive).
[2]Blue Cod – Challenger East
[3]Blue Cod – Challenger West

Once raw count and size data have been collected and collated, e.g., in MS Excel, 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.

10.1 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 can range from producing summary statistics for a particular variable e.g., measures of central tendency - mean, median and mode and measures of data spread include the range, quartiles and the interquartile range, variance and standard deviation.

10.1.1 Graphical presentation of data

Presentation of data in graphical format is a requisite for ecological studies, primarily as a means to convey to the reader patterns (often changes) in specific metrics (size and counts) through space and time. For marine reserve surveys, data are characteristically divided into reserve and non-reserve components and compared in this manner. Plotting can be done adequately in MS Excel; however, it is the authors' preference to use specialized graphing software such as SigmaPlot (Jandel Scientific Software) or R statistical software (R Core development team).

Box plots

Constructing box plots is a useful way to display data and as a "first pass" to examine differences between sample populations (Fig. 38). In essence a box plot depicts groups of numerical data based on quartiles, with the bottom and top of the box representing the first (Q1) and third (Q3) quartiles, with 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, the analysis does not assume data belong to a set distribution, i.e., 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 are by convention are denoted by round symbols.

Box plots can be constructed in graphing software such as SigmaPlot and 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.

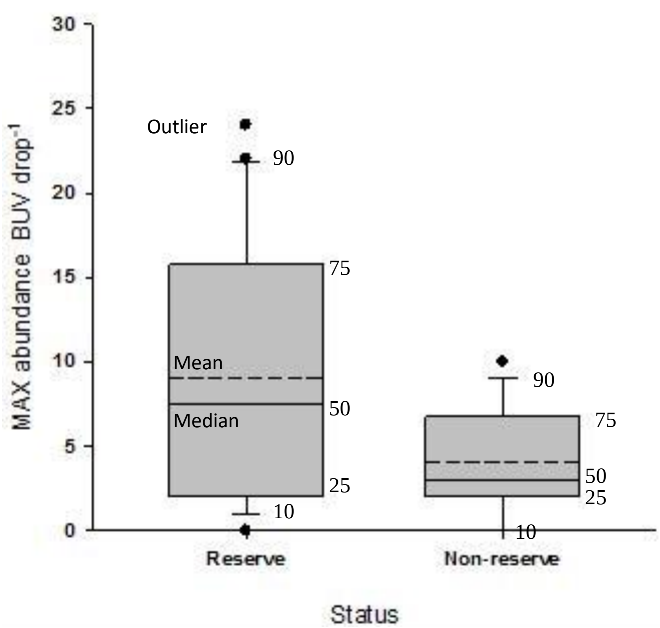


Figure 38. Example box plots generated for snapper MAX abundance within and outside Te-Whanganui-a-Hei Marine Reserve in 2012. Percentiles are depicted accordingly. Whiskers denote 10th and 90th percentiles and outliers are represented by round black symbols.

Count data

Count data for MAX*count*; LEG*count*, and JUV*count* are typically presented as an average of the sample population (sample mean) per BRUV drop. This is computed across reserve and non-reserve sampling stations (Fig. 39) as well as for individual blocks (Fig. 40). As a general rule, 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 (mm) can be effectively presented as frequency distributions (Fig. 41) or in box plot format. 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 and can be done using the =frequency () function in MS Excel. It is necessary to include scores with zero frequency in order to draw the frequency histograms correctly. Size class divisions (defined as "bins array" in MS Excel) can affect interpretation, so here we suggest using 20 mm size increments (or bins) when constructing frequency histograms (Fig. 41). Species-specific size data can also be converted to biomass using length-weight relationships (see Taylor and Willis 1998; Roux de Buisson 2009).

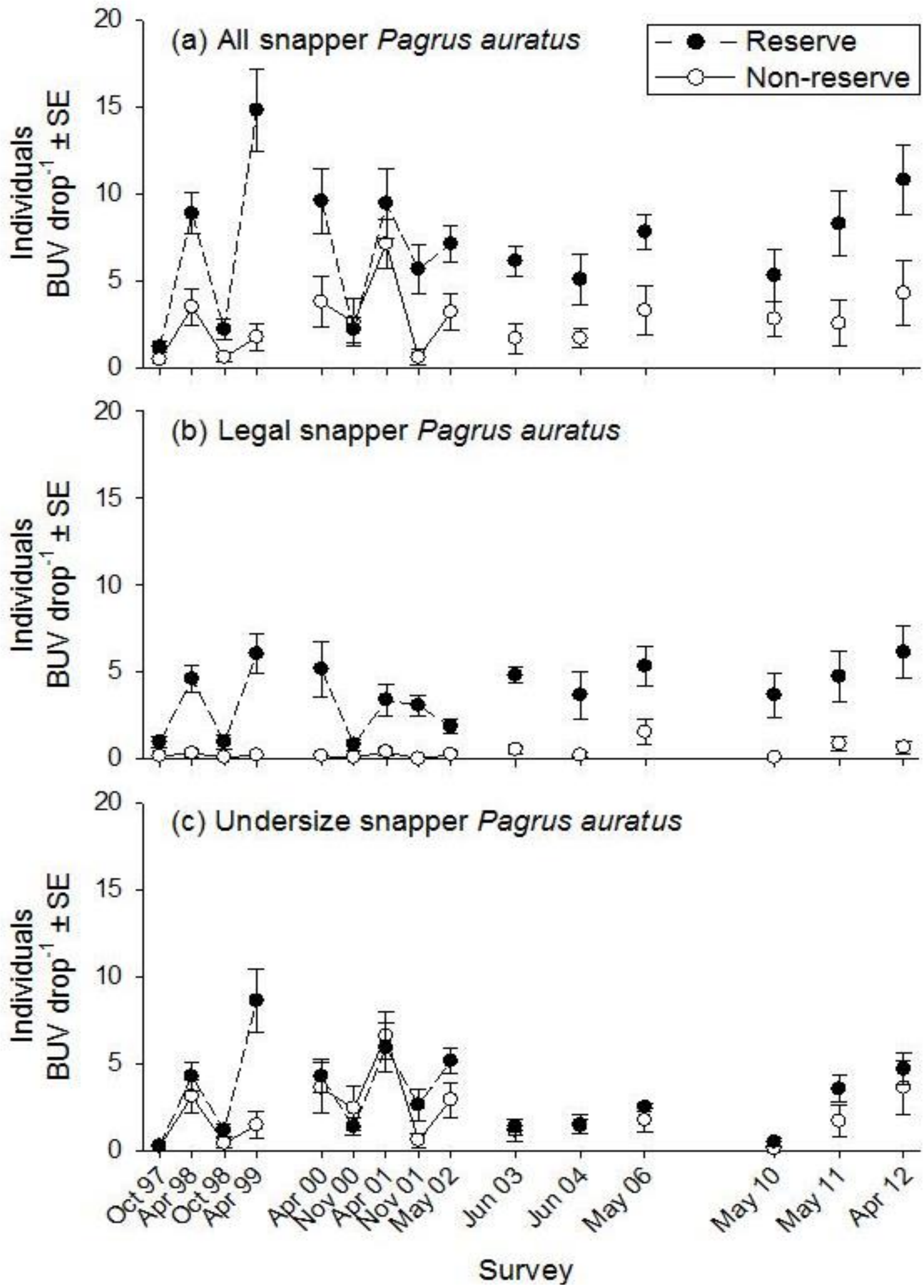


Figure 39. Long-term trends in the relative density of snapper *Pagrus auratus* inside and outside the Te Whanganui-a-Hei Marine Reserve, as measured using BRUV from October 1997 to April 2012. (a) All snapper (MAXsna), (b) legal snapper (LEGsna; > 270 mm fork length), (c) undersize snapper JUVsna; < 270 mm fork length).

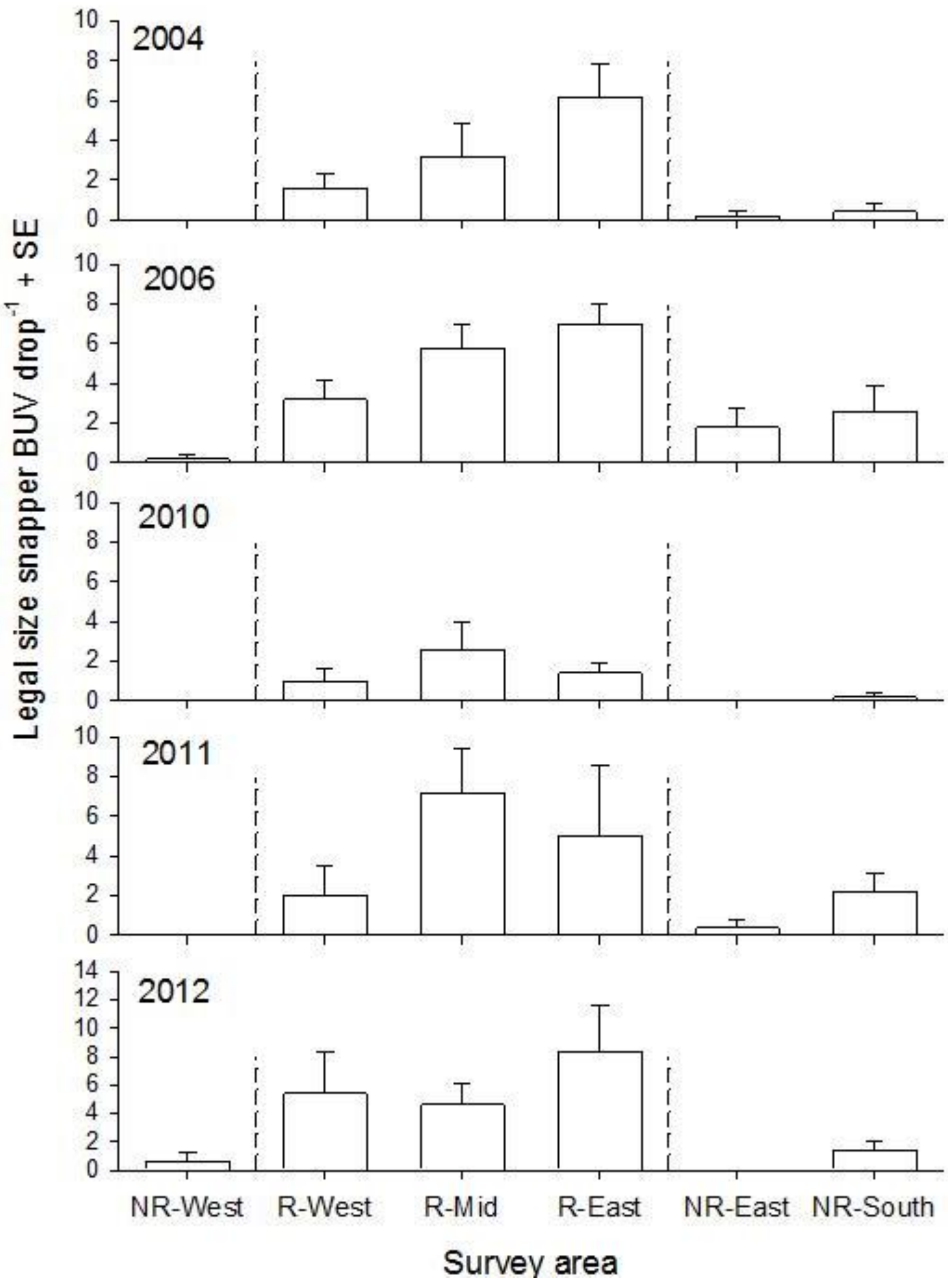


Figure 40. Average number of legal-sized snapper *Pagrus auratus* recorded in the six areas (blocks) surveyed within and adjacent to the Te Whanganui-a-Hei Marine Reserve from 2004-2012, as measured using BRUV. Dashed vertical lines indicate the reserve boundaries.

Frequency distributions

Constructing frequency distributions in tandem with box plots is also useful for identifying patterns of the data, particularly skewness. Skewness can be 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 that score (for example fish size) appears in the set of data. It is necessary to include scores with zero frequency in order to draw the frequency polygons correctly. Bin selection can affect interpretation, so here we suggest 50mm size increments when constructing frequency histograms for displaying data.

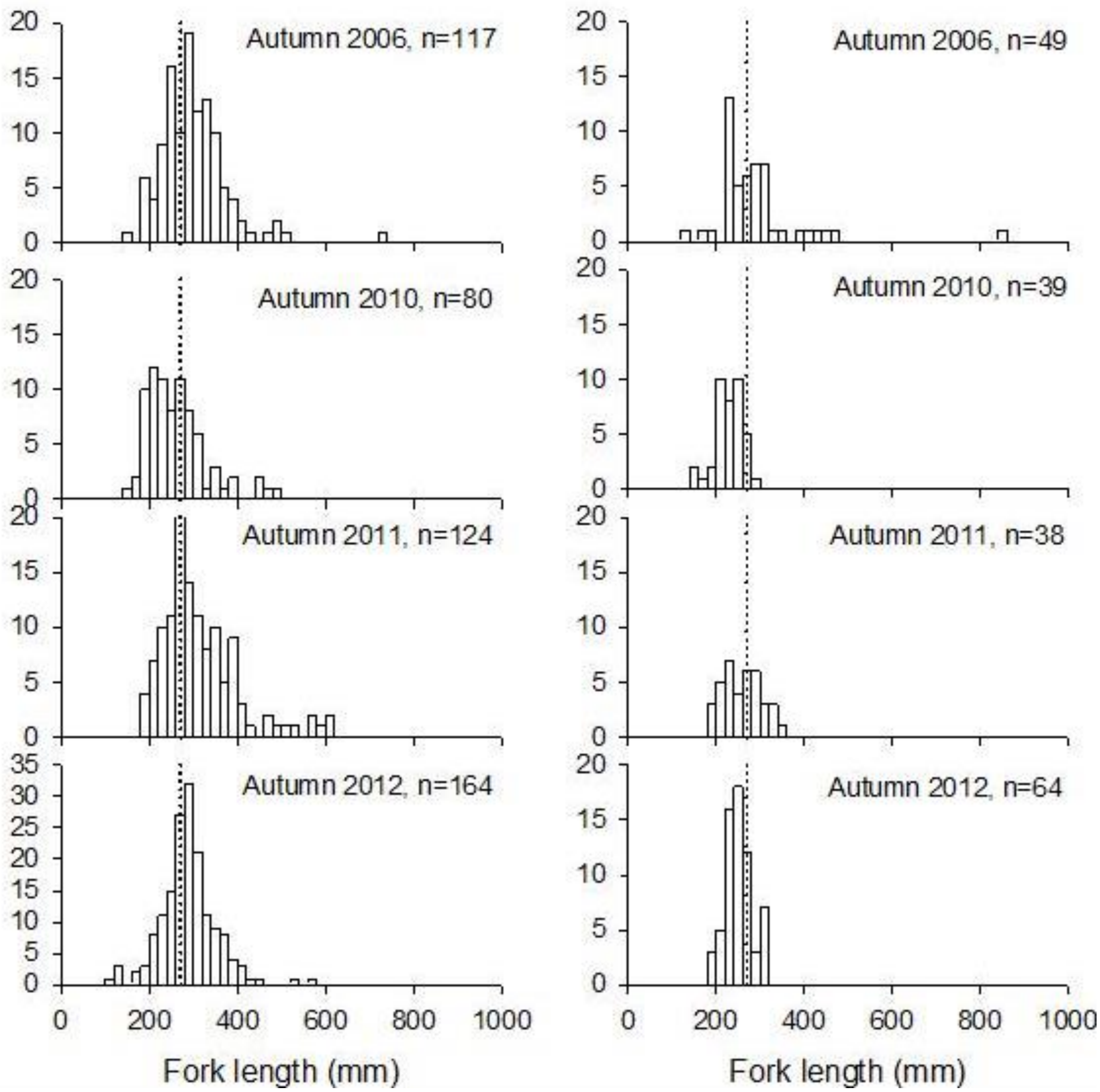


Figure 41. Size frequency distributions of snapper *Pagrus auratus* inside and outside the Te Whanganui-a-Hei Marine Reserve from 2006-2012, as measured using BRUV. Dotted line indicates recreational legal size limit, i.e., 270 mm. Note: y-axis differs among plots.

10.2 Analysis of count data

To test the null hypothesis (H_0) of no statistically significant difference in MAX*count* LEG*count* and JUV*count* for species of interest between reserve and non-reserve sample populations; and, to test the null hypothesis of no statistically significant differences in mean size between reserve and non-reserve sample populations, formal statistical tests are required. A common approach in the ecological literature is to employ analysis of variance (ANOVA), which tests for significant differences between means by comparing (measuring) variances (Sokal and Rohlf 1995). While many ecological studies utilize ANOVA [which is a linear regression approach] in the case of reserve versus non-reserve abundance (count) comparisons, sample data often violates the main assumptions of linear regression. These are: 1) normality of errors; 2) homogeneity of variances; and, 3) independence. If these key assumptions are violated then computed F-tests and confidence intervals can be misleading (Zuur *et al*. 2009). In order to examine whether data violate these assumptions residual (observed – expected) analysis (see Zuur *et al*. 2007; 2009) is a routine application to assess model validation.

In some instances transforming the response variable (e.g., count or size) may yield a dataset for which the above assumptions are satisfied. However, in our experience, BRUV count data routinely fail to satisfy the assumptions underpinning ANOVA even following commonly prescribed transformation procedures (e.g., LOG(x+1 transformations).

Due to these common violations and the fact that count data often follows a Poisson distribution, we recommend that count data are analyzed with a Poisson analysis approach using a generalized linear modeling framework (see McCullagh and Nelder 1989; Willis *et al*. 2003; Zuur *et al*. 2009). Such an approach has been applied to the majority of BRUV surveys over the last decade and a useful précis is provided in Willis *et al*. (2003) with data presented as a Reserve:Non-Reserve ratio with accompanying confidence intervals.

In the context of reserve versus non-reserve comparisons, subsets of the data (most often Legal-sized counts) 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 generalised linear models.

10.3 Analysis of size data

For size data, which are continuous (can take any value within a range), analysis by ANOVA or t-test may be appropriate, providing the assumption of normality, homogeneity of variances and independence are satisfied, which may require transformation, e.g., LOG transformation. If data still fail to satisfy assumption of ANOVA, 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) can be used.

10.4 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 and independence via residual analysis (see Zuur *et al*. 2007; 2009 for summary and worked examples);
- Undertake formal statistical analysis to test main hypotheses – preferably generalised linear modeling using a Poisson distribution framework for count data (sees Zuur *et al*. 2009 for summary and worked examples). Size data may be amenable to ANOVA or t-test analysis.

10.4.1 Statistical software

The majority of statistical programmes on the market have the capability to undertake an assortment of analyses. As a free option we highly recommend R statistical software particularly as there are some well-worked examples in the ecological literature that can be applied directly to the type of data generated from BRUV surveys. We refer the reader to Zuur *et al*. (2007, 2009) which provides in-depth background on the subject.

10.4.2 Data Reporting

Count data should be displayed as in Table 8a with statistically significant ($P < 0.05$) differences denoted by *. In instances where zero fish are encountered (more commonly for the non-reserve sample population) models will not be able to be fitted. As such, the infinity symbol (∞) should be used to denote an infinite ratio. Size data are presented in Table 8b

Table 8. Example of mean a) densities of snapper inside and outside the Te Whanganui-a-Hei Marine Reserve, for the 2011 survey. Statistically significant ($P < 0.05$) ratios of reserve (R) to non-reserve (NR) densities are denoted by *, MAXsna = all fish, LEGsna = fish > 270 mm fork length, and JUVsna = fish < 270 mm fork length.

Survey	**Density Measure**	**Reserve Mean**	**Non-Reserve Mean**	**R:NR Ratio**	**Lower 95% CL for ratio**	**Upper 95% CL for ratio**
2011	MAXsna	10.80	4.27	2.53*	1.90	3.38
	LEGsna	6.13	0.67	9.20*	4.79	17.67
	JUVsna	4.67	3.60	1.30	0.91	1.85

Survey	**Reserve mean fork length (mm)**	***n*: Reserve**	**Non-reserve mean fork length (mm)**	***n*: Non-reserve**	**Difference between means (mm)**	**95% CI**
All snapper						
Autumn 2011	303.70	124	250.82	38	52.89*	26.57
Legal snapper						
Autumn 2011	319.21	92	291.93	10	27.28	55.82

11.0 Recommendations

The guidelines pertaining to the vertical (downward facing) BRUV system described here have been developed in part, to improve the consistency of marine reserve monitoring at a national level. For this review a range of camera systems and associated modifications were considered and we certainly recognize the superiority of stereo video systems in terms of obtaining accurate and precise size estimates. The vertical BRUV system developed by Dr. Tim Langlois and Paul Roux de Buisson at this point in time is favoured by the authors due to its ease of application, cheap construction costs, and both historic and continued widespread use across multiple marine reserves in New Zealand.

At the time of writing, the vertical BRUV system has potential limitations around the accuracy of size estimates particularly for individuals measured at the periphery of the field of view where wide angle lens distortion is likely to be greatest and for those individuals occurring at heights well above the bait container. It is our view that these issues can be evaluated efficiently with the goal of validating and perhaps improving (by way of providing confidence limits and correction factors) the data estimates derived from the technique (see Table 7).

As a first step, an assessment of lens distortion using artificial fish of known size would be of value and if distortion is deemed to be substantial, a simple calibration method (e.g., Weng *et al*. 2002) developed to correct for this. In addition, an assessment of size estimates using artificial fish placed at different heights within the field of view would provide additional information on size estimation issues for species such as snapper and blue cod.

In order to provide information on the height of fishes within the field of view during sampling it would be of value to trial a horizontally facing camera together with an accompanying vertical scale bar attached to the existing the BRUV system (see Fig. 42). This will enable an assessment of fish height in tandem with the usual downward-facing view point and together allowing for better size estimation.

Future research avenues could include assessment of the area of attraction around a BRUV system and assessment of the variability in this among fish species or locations.

Our final recommendation is that the vertical BRUV system is compared constructively with a stereo video system and unbaited system. This is primarily to evaluate how dissimilar the assessments of fish abundance are between the two techniques. This comparison is not however an immediate priority.

Table 7. Key recommendations for improving and evaluating the vertical downward facing BRUV camera.

Limitation	Action
Size accuracy and an assessment of the degree of lens distortion	Calibrate with model fish of known size and develop a correction method should the distortion be substantial
Size accuracy at different heights within the field of view	Horizontal facing camera at positioned at the end of the BRUV frame and calibrate with model fish of known size

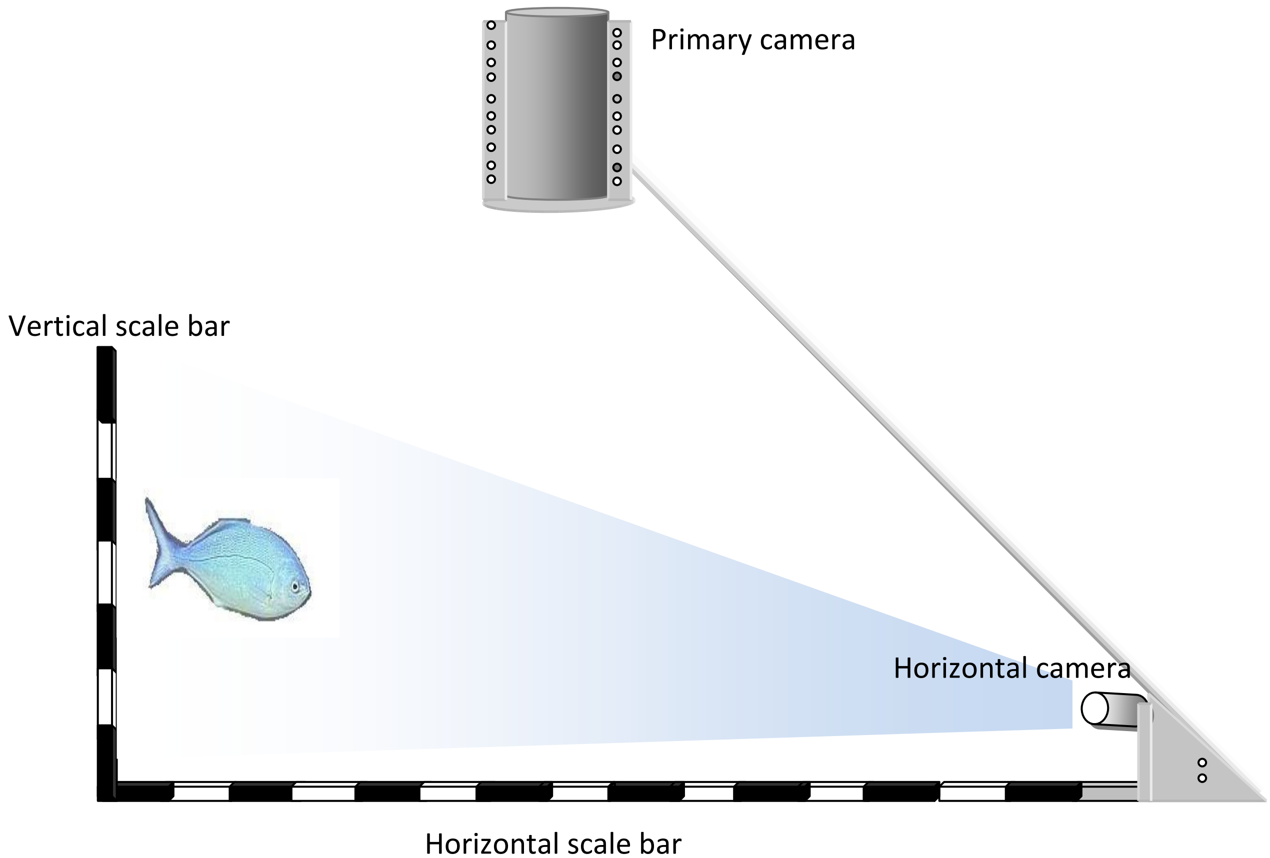


Figure 42. Recommended trial modifications to the existing BRUV system. These include a vertical scale bar and horizontal facing camera unit (e.g., GoPro™), utilised to gauge fish height within the field of view.

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Appendix 1.0

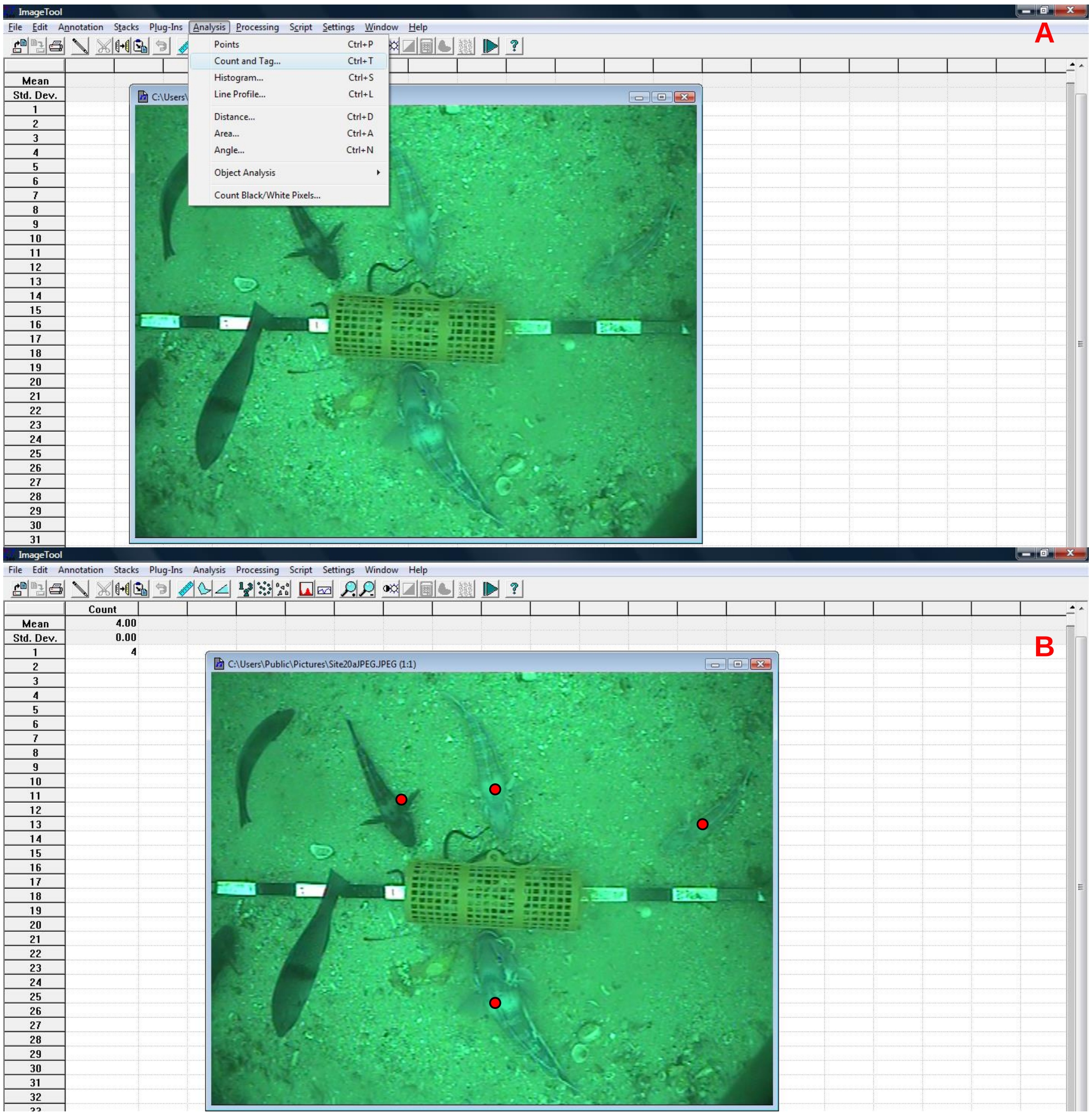

Figure A.1 (A) ImageTool software has a count and tag procedure whereby individual fishes in the field of view can be tagged (red dots) and a cumulative count is produced in the underlying spreadsheet (B). In this instance - 4 blue cod are counted in the frame. The method is useful to check counts prior to undertaking size analysis proper.