Marine: underwater transects for sampling reef fishes

Version 1.0

This specification was prepared by Vincent Zintzen in May 2016.

Contents

Inventory and monitoring toolbox: marine

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Department of Conservation
Te Papa Atawhai

Synopsis

Fishes are important members of the fauna of rocky reefs. Reef fishes in particular can have an important influence on the dynamics of other organisms through herbivory (Hughes et al. 2007) and predation (Babcock et al. 1999). Moreover, their feeding and excretion (Attayde & Hansson 2001), as well as their role as prey, can make an important contribution to the general ecology of reef systems (Jones 1988). Reef fishes are also often sought after for food or sport fishing; consequently, the selective exploitation of certain species makes them particularly good candidates for assessing changes resulting from the reduction (e.g. no-take areas) or increase in some pressures (e.g. fishing pressures).

Reef fishes can be studied using destructive (poisons, trapping, spearing, netting) or non-destructive (different types of belt transects, rapid visual counts, video, manta tows, diver propulsion vehicle, anaesthetic) methods (Kingsford & Battershill 2000). It is hard to obtain accurate measures of abundance for all species using a single method. Therefore, investigators need to be aware of the limitation(s) of their method(s) of choice, and design sampling accordingly.

The purpose of the fish belt transect method (sometimes also called underwater visual census—UVC) is to determine the abundance, size, and species composition of reef fishes within a set volume, which is sampled by swimming inside it. It is an adequate method for quantitative studies that aim to answer questions related to the distribution and abundance of fishes at different spatial and temporal scales. It is frequently used in New Zealand, mostly for assessment of medium to large fish species (Bell 1983; McCormick & Choat 1987; Choat et al. 1988; Buxton & Smale 1989; Cole 1990, 1994; Willis et al. 2000; Davidson 2004, 2011; Davidson & Richards 2013; Davidson et al. 2013, 2014). Transect methods can also be used to sample smaller species (e.g. triplefins—Tripterygiidae) but, due to their cryptic nature, they will require very different methodologies that are usually not compatible with collecting data on larger demersal species, which are the focus of this document.

When divers undertake transects, they count and often size fishes within a defined area. A tape measure is laid out and medium to large fishes are recorded within a certain distance left and right of the tape (usually, 2.5 m each side of the tape in New Zealand studies). Recording is normally done by the divers themselves, although in some cases video or stereo-video systems are used, the latter technique allowing for accurate post-survey measurements of fish size in the lab.

Large- and small-scale spatial and temporal variation in the abundances of fishes is common and should be considered in all sampling designs (Kingsford & Battershill 2000). The investigator will also have to take into account that the abundance of fishes tends to vary significantly with habitat and depth (Syms 1996; Zintzen et al. 2012).

Transects are usually placed haphazardly within defined depth strata (Kingsford & Battershill 2000).

Assumptions

- The taxa of interest can be detected and identified with sufficient accuracy for the research or survey objectives.
- The underwater visibility is sufficient to record adequately the fish species and size over the specified width of the transect.
- Observer effort and skills are similar across sites, locations and/or sampling occasions.
- To minimise biases during ongoing monitoring, divers should be thoroughly trained in fish identification and sizing techniques, with size being regularly calibrated (see 'Full details of technique and best practice' and the 'Fish size calibration underwater training sheet'—doccm-2791243)[1]. If a team of highly skilled divers is not available, preference should be given to video methods so that the data can be processed by a skilled person after the survey.
- If sampling is annual, it will take place at a similar time of the year, usually in the summer, to eliminate any biases associated with seasonal migration behaviour of some species.
- Since reef fish abundance pattern is influenced by habitat type, only fishes typical of reef habitats will be sampled. Depending on the scientific question, the reef habitat can be divided into macroalgae-covered and barren reef, or even other divisions, and recorded as a covariate.
- The width and length of the transect is chosen to adequately sample the fish population at the designated sites. In practical terms this means that the length will be long enough to minimise null counts while short enough to be operationally manageable. Typical length will be 25–50 m. Transect width will be dictated by visibility, but usually 5 m (2.5 m each side of the transect line) is appropriate for New Zealand conditions.
- Swimming speed is constant because it can influence sampling accuracy (Smith 1988). Five metres per minute is the recommended speed to sample medium to large fish species in New Zealand. Slower swimming speeds and the positioning of divers closer to the seabed will be necessary to sample smaller, benthic species.
- The diver distance above the seabed is constant. Two metres is recommended for sampling medium to large fishes in New Zealand, but for smaller, benthic species, the diver will be positioned just above the seabed.
- Transects are done in the middle of the day, outside dawn or dusk periods, to coincide with peak fish activity (Jones 1988; Willis et al. 2006).

Advantages

- Non-destructive method.
- With adequate replication, a precise estimate of fish abundances in the area sampled can be obtained.

[1] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-fish-size-calibration-underwater-training-sheet.pdf

- Abundance and size of fishes can be acquired simultaneously.
- Can be combined with habitat characterisation and counts of invertebrates and macroalgae along the same transect, which will allow for more robust data interpretation.
- Can be used in long-term monitoring.
- Is well suited to Before–After–Control–Impact (BACI) studies.
- The presence of the measuring tape can be used as a continuous reference point and is a useful reminder that fish sizes are magnified underwater.
- If monitoring is conducted using a video system to record fishes:
  - It provides a permanent record of the area that can be re-analysed in the future.
  - There is no need for divers to be competent with fish identification.
  - It also provides a record of fish behaviour.
  - With stereo-video systems, accurate size estimates of fishes can be obtained.

Disadvantages

- Resource-heavy and time-consuming method.
- Fish abundance data collected by this method are often characterised by high variability because fish populations can be influenced by a wide array of factors like habitat, time, physical factors (swell, temperature, etc.) or behaviour.
- Requires a high level of expertise of scientific divers for underwater fish identification and sizing.
- Observer bias can be considerable. Requires a high level of standardisation between observers to obtain comparable results. If different observers are used and have different training backgrounds, biases can be introduced in species identification, counting and size estimates.
- Requires underwater visibility greater than the width of the transect.
- Due to differing species behaviour, this method will give reasonably accurate abundance measures for some species but unreliable measures for others (e.g. cryptic, highly mobile, schooling, diver-negative or -positive, or simply their position in the water column—Sale & Sharp 1983; Thresher & Gunn 1986). This method is, for example, not appropriate for snapper (*Chrysophrys auratus*) because they avoid divers (Willis et al. 2003). For this species, baited remote underwater video techniques are more appropriate (see 'Marine: baited underwater video surveys for fish'—doccm-1450395[2]).
- Difficult to obtain precise estimates of density for schooling species.
- Estimates of fish size are often imprecise.
- If a video system is used to record the fishes, post-processing can be time consuming.

[2] http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-marine-baited-underwater-video-surveys-for-fish.pdf

Suitability for inventory

Because this method generally focuses on medium to large demersal species, it is not suitable for inventory; it will record only part of the fish fauna in the area. Many smaller or cryptic species won't be noticed by the observer. In addition, divers have a deterrent effect on some fish species, which will decrease the likelihood of observing them.

Suitability for monitoring

This method is suitable for the monitoring of medium to large species known to be observable by divers (see Table 1 for a list of species observed by divers on fish transects in New Zealand). It can also focus specifically on smaller species, although this comes at the cost of sampling larger ones because a slower, smaller search pattern would have to be used.

Monitoring can provide information on long-term changes in the relative abundance and size class distribution of several species (Table 1).

Table 1. List of species that have been identified during underwater visual transect studies in New Zealand waters. Species that have been observed regularly enough to study their abundance patterns and size structures in bold.

Family	Scientific name	Common name	Source
APLODACTYLIDAE	***Aplodactylus arctidens***	**Marblefish**	1,2,3,4,5,6,7,8
	Aplodactylus etheridgii	Notch-head marblefish	1
ARRIPIDAE	*Arripis trutta*	Kahawai	1,8,10
BERYCIDAE	***Centroberyx affinis***	**Golden snapper**	1
BLENNIIDAE	*Plagiotremus tapeinosoma*	Mimic blenny	1
CALLANTHIDAE	*Callanthias allporti*	Southern splendid perch	2
	Callanthias australis	Northern splendid perch	1
CARANGIDAE	*Decapterus koheru*	Kōheru	1,8
	Pseudocaranx dentex	**Trevally**	1,8,9,10
	Seriola lalandi	Kingfish	1,3,5,8
	Trachurus novaezelandiae	Jack mackerel	1,8,10
CHAETODONTIDAE	*Amphichaetodon howensis*	Lord Howe coralfish	1
CHEILODACTYLIDAE	*Cheilodactylus ephippium*	Painted moki	1
	Cheilodactylus nigripes	Magpie moki	3,4,5
	Cheilodactylus spectabilis	**Red moki**	1,3,4,5,6,7,8,9,10
	Nemadactylus douglasii	Pōrae	1,8
	Nemadactylus macropterus	**Tarakihi**	1,2,3,4,5,8,9,10
CHIRONEMIDAE	***Chironemus marmoratus***	**Hiwihiwi**	1,6,7,8
CONGIOPODIDAE	*Congiopodus leucopaecilus*	Pigfish	10
CONGRIDAE	*Conger verreauxi*	Common conger eel	2
DASYATIDAE	*Dasyatis brevicaudata*	Short-tailed stingray	1,8
	Dasyatis thetidis	Long-tailed stingray	1,8
DIODONTIDAE	*Allomycterus jaculiferus*	Porcupinefish	1,8
GEMPYLIDAE	*Thyrsites atun*	Barracouta	1
GIRELLIDAE	***Girella cyanea***	**Bluefish**	1
	Girella tricuspidata	**Parore**	1,6,7,8,10

Family	Scientific name	Common name	Source
HEXANCHIDAE	*Notorynchus cepedianus*	Sevengill shark	2
KYPHOSIDAE	*Kyphosus bigibbus*	Grey drummer	1
	Kyphosus sydneyanus	**Silver drummer**	1,6,7,8
LABRIDAE	*Anampses elegans*	Elegant wrasse	1,8
	Bodianus unimaculatus	**Pigfish**	1,8
	Coris picta	Combfish	1,8
	Coris sandageri	**Sandager's wrasse**	1,6,7,8
	Notolabrus celidotus	**Spotty**	1,2,3,4,5,6,7,8,9,10
	Notolabrus cinctus	**Girdled wrasse**	2,3,10
	Notolabrus fucicola	**Banded wrasse**	1,2,3,4,5,6,7,8,9,10
	Notolabrus inscriptus	Green wrasse	1
	Pseudolabrus luculentus	**Orange wrasse**	1,8
	Pseudolabrus miles	**Scarlet wrasse**	1,2,3,4,5,6,7,8,10
	Suezichthys arquatus	Rainbowfish	1,8
	Suezichthys aylingi	**Crimson cleanerfish**	1,8
	Thalassoma amblycephalum	Two-tone wrasse	1
	Thalassoma lunare	Moon wrasse	1
LATRIDAE	***Latridopsis ciliaris***	**Blue moki**	1,2,3,4,5,8,9,10
	Latridopsis forsteri	Copper moki	1,3,5,8,10
	Latris lineata	Trumpeter	2,35
MICROCANTHIDAE	*Mendosoma lineatum*	Telescope fish	2
	Atypichthys latus	Mado	1
	Parika scaber	**Leatherjacket**	1,2,3,4,5,6,7,8,10
	Thamnaconus analis	Morse-code leatherjacket	1
MORIDAE	*Lotella rhacinus*	Rock cod	1,2
	Pseudophycis bachus	Red cod	2,10
	Pseudophycis barbata	Southern bastard cod	2
MUGILIDAE	*Aldrichetta forsteri*	Yellow-eyed mullet	8,10
MULLIDAE	*Parupeneus spilurus*	Black-spot goatfish	1
	Upeneichthys lineatus	**Goatfish**	1,3,4,5,6,7,8
MURAENIDAE	*Enchelycore ramosa*	Mosaic moray	1
	Gymnothorax nubilis	Grey moray	1
	Gymnothorax obesus	Speckled moray	1
	Gymnothorax prasinus	Yellow moray	1,8
	Gymnothorax prionodon	Mottled moray	1
MYLIOBATIDAE	*Myliobatus tenuicaudatus*	Eagle ray	1,8
MYXINIDAE	*Eptatretus cirrhatus*	Common hagfish	2
NOTOTHENIIDAE	*Notothenia angustata*	Māori chief	1,10
ODACIDAE	***Odax pullus***	**Butterfish**	1,2,3,4,5,7,8,9,10
PEMPHERIDAE	*Pempheris adspersus*	Bigeye	1,8
PENTACEROTIDAE	*Evistias acutirostris*	Striped boarfish	1
	Zanclistius elevatus	Long-finned boarfish	1,7
PINGUPEDIDAE	***Parapercis colias***	**Blue cod**	1,2,3,4,5,6,7,8,9,10
POLYPRIONIDAE	*Polyprion oxygeneios*	Hāpuku	1
POMACENTRIDAE	***Chromis dispilus***	**Demoiselle**	1,6,8
	Chromis fumea	Yellow demoiselle	1,8
	Chromis hypsilepis	Single-spot demoiselle	1
	Parma alboscapularis	**Black angelfish**	1,6,8
SCORPAENIDAE	***Helicolenus percoides***	**Sea perch**	2,4
	Scorpaena cardinalis	Northern scorpionfish	1,8
	Scorpaena papillosa	Dwarf scorpion fish	2,5,10
SCORPIDAE	*Bathystethus cultratus*	Grey knifefish	1
	Labracoglossa nitida	Blue knifefish	1

Family	Scientific name	Common name	Source
	Scorpis lineolatus	**Sweep**	1,3,4,5,6,8,10
	Scorpis violaceus	**Blue maomao**	1,3,6,8
SCYLIORHINIDAE	*Cephaloscyllium isabellum*	Carpet shark	1,2
SERRANIDAE	*Acanthistius cinctus*	Yellow-banded perch	1
	Caesioperca lepidoptera	**Butterfly perch**	1,2,3,4,5,8,10
	Caprodon longimanus	**Pink maomao**	1
	Epinephelus daemelii	Spotted black grouper	1
	Hypoplectrodes huntii	Red-banded perch	1,2,10
	Hypoplectrodes sp. B	Half-banded perch	1
	Lepidoperca tasmanica	Red-lined perch	2
SPARIDAE	*Chrysophrys auratus*	Snapper	1,5,6,7,8
SQUALIDAE	*Squalus acanthias*	Dogfish	2
SYNGNATHIDAE	*Hippocampus abdominalis*	Seahorse	3,5
TETRAODONTIDAE	***Canthigaster callisterna***	**Clown toado**	1
TRACHICHTHYIDAE	*Optivus elongatus*	Slender roughy	8
TRIAKIDAE	*Galeorhinus galeus*	School shark	2
TRIPTERYGIIDAE	*Obliquichthys maryannae*	Oblique-swimming triplefin	1
ZEIDAE	***Zeus faber***	**John Dory**	1,8

1: Denny et al. 2003—Poor Knight Islands; 2: Willis et al. 2009—Fiordland; 3: Davidson et al. 2014—Long Island; 4: Davidson & Richards 2013—Tonga Island; 5: Davidson et al. 2013—Horoirangi; 6: Haggitt et al. 2012—Te Whanganui-a-Hei; 7: Cole 1990—Goat Island; 8: Anderson & Millar 2004—north-eastern New Zealand; 9: Pande & Gardner 2009—Wellington South Coast; 10: Pande 2001—Wellington South Coast.

Figure 1. Three typical species sampled during fish belt transects in New Zealand waters. From left to right: red pigfish (*Bodianus unimaculatus*), two-spot demoiselle (*Chromis dispilus*) and snapper (*Caesioperca lepidoptera*).

Skills

Fish transects require a relatively high level of expertise, especially for field sampling.

Pre-survey:

- Survey design skills for determining the number of replicates, stratification (if any) and placement of replicates, and what variables are to be recorded
- GIS knowledge for the positioning of sampling sites
- Transfer of sites coordinates to portable GPS

- Appropriate dive-planning skills (e.g. max depth and times) and knowledge of relevant standard operating procedures

In the field:

- Appropriate SCUBA diving certification
- Ability to identify, count and size fishes along transects
- Ability to assess distances underwater
- For video transects, knowledge of video equipment and its use at sea
- The skills to record and securely manage data
- Use of portable GPS
- Good fitness level

Processing of imagery:

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

Data analysis:

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

Resources

In addition to the usual diving SCUBA and associated safety equipment, this section describes the specific resources required to conduct fish belt transects.

Visual transects

The following items are required for underwater visual fish census:

- Size calibration material — Fish cut-outs and performance recording sheets ('Fish size calibration underwater training sheet'—doccm-2791243)[3] to calibrate diver size estimations prior to every survey (see 'Full details of technique and best practice' for details on the calibration protocol).
- Slates/pencil — Slates with elastics, bungee, rubber band or plastic borders to secure pre-printed A4 data sheets. The best pencils are graphite pencils that are available from art supply shops (they can be sharpened with a diving knife) or push-up pencils whose tips can be easily replaced underwater (Figure 2A–C).

[3] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-fish-size-calibration-underwater-training-sheet.pdf

- On-board data sheet — Used to keep track of the sites, transects and associated metadata sampled by the different divers (see template: 'Survey field data sheet'—doccm-2780650)[4] (Figure 5).
- Pre-printed fish data sheets — Made of waterproof paper. For example:
  - 'Field data sheet (scientific name)'—doccm-1543029)[5]
  - 'Field data sheet (common name)'—doccm-1543359)[6]
  - 'Fieldwork underwater sheets for Poor Knights'—doccm-1561621)[7] (Figure 4)
- Underwater tablets — Fully functional housing for tablets are now becoming commercially available (e.g. http://idivehousing.com/). Once applications have been developed for recording fish species underwater, they will offer the advantage of by-passing the manual encoding of the pre-printed dive sheets, saving time and increasing quality assurance of the data (Figure 2F).
- Tape measure — Minimum size is the transect length + five metres. It should feature an attachment hook or carabiner at its end to secure it to rock or kelp at the start of a transect. The recommended method is to use a short length of soft wire (e.g. copper or steel wire) to temporarily secure the tape to kelp or other features. Release is achieved by a strong tug from the far end of the transect, avoiding the diver having to swim back to the start of the transect to release the tape (Figure 2D&E).

[4] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-survey-field-data-sheet.pdf

[5] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-field-data-sheet-scientific-name.pdf

[6] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-field-data-sheet-common-name.pdf

[7] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-fieldwork-underwater-sheets-for-poor-knights.pdf

Figure 2. A—underwater slates; B—graphite pencils; C—push-up pencils; D—measuring tape, E—steel wire attached to tape for easy release; F—tablet with underwater housing.

Video transects

There is a range of digital video cameras available on the market. Purchase a reputable brand. GoPro cameras also offer a cheap way to record high quality footage in a compact form. Newer camera models offer high definition recording onto a drive or memory card, which preserves battery consumption considerably. The best option is a camera that records on a memory card so that the number of samples achievable in the field is not limited by the size of the hard drive. Simply have several memory cards and swap for a new one when necessary. In the future, tablets may be used instead of video camcorders (see Figure 2F).

When choosing a camera, specifically check:

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

- Lens specifications and level of distortion.

The details associated with the use of stereo-video systems is beyond the scope of this document and the reader is referred to specific papers (Harvey et al. 2001, 2002, 2003, 2004; Zintzen et al. 2012). Stereo-video systems are more complex, comprising two video cameras set apart at a fixed distance. The system must be calibrated before its use at sea. Once calibrated, these systems will allow for accurate and precise measurements of fish lengths, as well as delimiting the 3-dimensional space where sampling should occur.

Figure 3. A stereo-video system. Note the diode (white) at the front of the system, which allows the left and right camera to be synchronised. Newer systems do not need the synchronising diode anymore. The two housings hold the video cameras. Photo credit: SeaGIS.

DOC FISH TRANSECT SHEET

Date:	Location:	Recorder:	Transect dimension:
TRANSECT # :	Site:	Time:	Visibility:
	Habitat:	Depth start:	Depth end:

Species	Count+Sizes	Other species/Notes Species	Count+Sizes
Spotty			
Banded wrasse			
Scarlet wrasse			
Blue moki			
Butterfish			
Blue cod			
Kahawai			
Leatherjacket			

TRANSECT # :	Site:	Time:	Visibility:
	Habitat:	Depth start:	Depth end:

Species	Count+Sizes	Other species/Notes Species	Count+Sizes
Spotty			
Banded wrasse			
Scarlet wrasse			
Blue moki			
Butterfish			
Blue cod			
Kahawai			
Leatherjacket			

TRANSECT # :	Site:	Time:	Visibility:
	Habitat:	Depth start:	Depth end:

Species	Count+Sizes	Other species/Notes Species	Count+Sizes
Spotty			
Banded wrasse			
Scarlet wrasse			
Blue moki			
Butterfish			
Blue cod			
Kahawai			
Leatherjacket			

DOCDM-1543359

Figure 4. Fish transect dive sheet for typical species found in the Wellington region ('Field data sheet (common name)'—doccm-1543359). Other examples are 'Field data sheet (scientific name)' (doccm-1543029) and 'Fieldwork underwater sheets for Poor Knights' (doccm-1561621).

TRANSECT SURVEY ONBOARD SHEET DOCCM-2780650

Survey:	Leader Name:	Contractor:
Location:	Vessel:	DOC Office contact:

UID 1,2,…	Date dd-mm-yy	Time hh:ss	Site Name or Code	Latitude Longitude	Control Site?	Fish			Lobster			Urchin			Paua			Tide	Weather
							Recorder	# tr.		Recorder	# tr.		Recorder	# tr.		Recorder	# tr.		
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Figure 5. Data sheet template to be used to keep track of work achieved during fish belt transect survey ('Survey field data sheet'—doccm-2780650)[8]. Can be used in conjunction with dive data sheets printed on waterproof paper.

Minimum attributes

Consistent measurement and recording of these attributes is critical for the implementation of the method. Other attributes may be optional depending on your objective. For more information refer to '[Full details of technique and best practice](#)'.

DOC staff must complete a 'Standard inventory and monitoring project plan' (doccm-146272).[9]

The minimum set of attributes to be recorded is presented in Table 2. For field purposes, a template is available for recording information on the transects that were achieved (Figure 5), which can be used in conjunction with pre-printed sheets to be used underwater by scientific divers (Figure 4).

Once back from the field, enter your data into a spreadsheet. The importance of entering data using correct formatting cannot be stressed enough. You should have one line per observation, an

[8] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-survey-field-data-sheet.pdf

[9] http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-standard-inventory-and-monitoring-project-plan.doc

observation being one (or several) specimen(s) of fishes of the same size and species from one transect. Each of these lines should also have the metadata presented in Table 2. By using this formatting method, each fish observation made during the survey will have clear metadata associated with it.

Table 2. Minimum attributes to be recorded for fish belt transects.

Field	Description	Value
Location	General locality where the unit was deployed (e.g. Ulva Island)	Short text
SiteName	Site within *Location* where the unit was deployed	Short text
ProtectionStatus	Indicates the protection status of the area sampled	One of the six values: 'Marine Reserve (type 1 MPA)', 'Type 2 MPA', 'Mātaitai', 'Taiāpure', 'Other protection' or 'No protection'
Latitude	Decimal degree latitude for the deployment (WGS84). Example: Latitude for Wellington Conservation House is −41.289904	Number with up to 6 digits after decimal. Values are between −90 to 90, but typically negative for New Zealand.
Longitude	Decimal degree longitude for the deployment; east of Greenwich (WGS84). Example: Latitude for Wellington Conservation House is 174.775043	Number with up to 6 digits after decimal. Values are between 0 and 360.
TransectID	A unique identifier during this survey for this specific transect	Unique number
TransectLength	Length of the transect in metres	Integer
TransectWidth	Width of the transect in metres	Integer
TransectHeight	Height of the transect in metres	Integer
DepthStrata	Depth stratum within which the transect is to be made. The investigator might not have designed different depth strata for his/her study. In this case, a general value encompassing the depth range at which the survey occurred should be entered (e.g. 5–25 m)	e.g. 5–15 m or 16–25 m
ReplicateWithinSite	Number of replicates within the site, starting at 1 and up to the number of deployments achieved at that particular site. Note that if only one deployment was achieved per site, then this field takes the value 1 throughout	Integer
UnderwaterVisibility	Estimation of the water visibility, in metres (as assessed with a Secchi disk if available or by diver otherwise)	Integer
Habitat	Brief description of the nature of the seabed (mud, sand, gravel, cobbles, etc.)	Unlimited text

Field	Description	Value
NZMHCS_abiotic	A number taken from Table 5 of the New Zealand Marine Habitat Classification Scheme (doccm-1354867) (DOC SPECIFIC)	Number up to 4 digits
NZMHCS_biotic	A number taken from Table 6 of the New Zealand Marine Habitat Classification Scheme (doccm-1354867) (DOC SPECIFIC)	Number up to 4 digits
Vessel	Vessel used to deploy the diver, if appropriate	Unlimited text
Recorder	Name of the person who recorded the transect data	Unlimited text
EventDate	Date of sampling	Date (dd/mm/yyyy)
Tide	Simplified tidal level at the time of sampling	One of the four values: 'Low', 'Medium', 'High' or 'Undetermined'
Weather	Description of the atmospheric conditions (wind, sea state, swell, etc.)	Unlimited text
DepthStart	Depth at the start of the transect, in metres	Number
DepthEnd	Depth at the end of the transect, in metres	Number
EventTimeStart	Time at which the transect started	Time in 24h format (hh:mm)
EventTimeEnd	Time at which the transect ended	Time in 24h format (hh:mm)
Notes	Any additional notes of interest in relation to this sampling event	Unlimited text
ScientificName	Scientific name of the species observed	Short text
Sex	Indicate the sex of the fish if the recorder could note this information	One of the four values: 'Male', 'Female', 'Juvenile' or 'Undetermined'
Count	Number of individuals of *ScientificName* observed. Note that if specimens of the same species have different sizes, a line per size group needs to be created.	Integer
Size	Size of the specimen(s) observed in cm	Integer

It is recommended that you collect any additional covariate data that may aid in the interpretation of the fish transect data (e.g. habitat or environmental covariates). A protocol for sampling habitat data is provided in the 'Full details of technique and best practice' section.

Data storage

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

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

Once operational, this methodology will be updated with a description of how to lodge data within the national database. In the interim, data should be recorded within the spreadsheets associated with this methodology. It is essential that all raw data sheets are completed, digitised and backed up. Raw data and associated metadata should be entered into databases/spreadsheets in a standardised format.

Data should be stored in a way that can be easily understood by a third party. To avoid repeating the metadata multiple times, the data could also be subdivided into two sections, the first one describing the metadata associated with the survey and the second comprising the fish data itself. A field with unique values should be created to make the link between the two sections. Each field recorded should be defined to remove any ambiguity in its meaning and use.

The metadata should also include a description of the monitoring objectives and any information that will allow someone unfamiliar with the monitoring to interpret the data and replicate the methodology. Data should be arranged so that each row represents one species with the corresponding data regarding site, replicate number, count and sizes arranged into columns. If the size of a species has been measured for several individuals of the same species, one line per size should be created. Ideally, all data should be located within a single database to facilitate ease of access.

For internal DOC monitoring, information pertaining to each survey within a marine reserve and resultant data/reports should be entered into the Marine Protected Area Monitoring and Research (MPAMAR) data sheet ('MPAMAR metadata—national'—doccm-1163829)[10] so there is an easily accessible account of the survey.

Analysis, interpretation and reporting

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

[10] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-mpamar-metadata-national.xls

Data analyses

The type of analysis most applicable to the data will largely depend on the objectives of the study, and whether additional supporting information (such as physical conditions or biological/physical habitat variables) has been recorded or is available. Table 3 provides a brief description of the more common metrics derived from transect data.

Table 3. Common metrics that can be calculated from transect data, a description of their data requirements, and how to calculate/present them.

Metric	Required data	Calculation/Presentation
Density	• Number of individuals per transect • Area of transect sampled	Convert the number of individuals observed per transect to the number per unit area (typically per m^2) by dividing the number of individuals by the area of the transect sampled. For example, if 100 individuals are counted within a 200 m^2 transect, the density of those individuals within that transect is 0.5 per m^2. Means (and associated variance) can then be calculated from these values across all measured transects.
Relative abundance	• Number of individuals of each species present	How common or rare a species is relative to other species, calculated by dividing the number of individuals from one species by the total number of individuals from all species.
Biomass	• Total weight of the taxa of interest for each transect sampled, derived from length–weight estimates • Area of transect sampled	Mean biomass per site; change in biomass through time; relationship of biomass to other variables.
Presence/ absence	• Which species are present, or which of selected taxa are present and absent	The presence or absence of a species or attribute in a transect.
Frequency	• Record of which species are present, or which of selected taxa are present and absent	The proportion (%) of transects occupied by each species.
Species richness	• Number of species present	Species richness is simply a count of the number of species observed.
Species diversity	• Number of individuals of each species present	Species diversity incorporates both species richness (the number of species in a community) and the evenness of species' abundances (how similar the abundance of each species in a community is).
Size structure	• Size or size class of each individual observed	Population size structure may be presented simply as a mean of the parameter measured, or the full set of data may be presented as size frequency histograms.

Habitat cover	• Either directly measure (if possible) or estimate the proportion of transect area occupied by different habitats, identified to the required level (e.g. functional group, abiotic group)	Calculate the mean (and variance) of cover scores across all transects sampled.

Interpretation

Interpretation of results should be performed with the assistance of a statistician and taking into account the major potential drivers influencing the system being studied (e.g. depth, habitat, exposure). At this stage, it should be determined whether the goals of the original data collection have been achieved and whether the data are sufficient to answer those questions outlaid prior to the initial surveys.

Reporting

Reporting will largely be governed by the duration of the monitoring and data collection. If data collection is ongoing, regular reports should be submitted at 3–5-year intervals, whereas for short data collection terms (< 2 years in duration), reports should be submitted within a year of the final data collection.

Case study A

Case study A: effect of Poor Knights Islands Marine Reserve on demersal fish populations (Denny et al. 2003)

Synopsis

The authors investigate the response of medium to large demersal reef fishes to the establishment of the Poor Knights Islands Marine Reserve (PKI). From 1981 until October 1998, PKI was a ‘marine park’ in which some species could be caught recreationally by fishing lines or spearing. From October 1998, PKI has been designated a fully no-take marine reserve. This study compares the PKI results with two reference locations in similar environments that are commercially and recreationally fished. The focus is on snapper (*Chrysophrys auratus*), but the authors are also looking at other species. The report presents the results from two different sampling methods: baited underwater video (BUV) and underwater visual census (UVC). We focus here on the UVC method.

Objectives

- To record the continual rate of re-colonisation of key fish species at PKI, providing insights into the mechanisms of fish recovery in marine reserves.

Sampling design and methods

- The Poor Knights Islands and two control locations (Cape Brett and the Mokohinau Islands) were sampled in spring and autumn each year between spring 1998 and autumn 2002.
- Between 15 and 23 sites were surveyed at each of the three locations. At each site, nine 25 × 5 m transects were surveyed, with 3,687 transects completed during the study.
- Differences in abundance between locations and changes in abundance through time were analysed using a generalised linear model (GLMER) on a Poisson distribution.
- Differences in sizes among locations and changes in sizes through time were analysed using a general linear model (GLM).
- Reef fish density estimates can be affected by small-scale spatial and temporal variability, caused in part by habitat patchiness as well as fish mobility. The statistical significance of a difference between two samples, therefore, does not necessarily imply a real biological change. Consequently, the authors only regard changes of a magnitude of 100% (i.e. a doubling or halving of density) as being indicative of a biologically significant difference (as opposed to statistically significant difference).
- Species richness was compared among locations for the different surveys (the test used was not specified).
- Patterns in species composition were examined using multi-dimensional scaling (MDS) and canonical analysis of principal coordinates (CAP), based on Bray–Curtis dissimilarities on log transformed data.

Results

- Species richness:
  - A total of 78 fish species were observed across all surveys and locations, of which 76 species were recorded at the PKI, 60 at the Mokohinau Islands, and 64 at Cape Brett (Figure 6). There were, on average, 8.1 ± 1.2 more species recorded per survey at the Poor Knights Islands compared to the reference locations.
  - There was a statistically significant difference in species richness across locations for each survey ($P < 0.01$, but they did not specify the test they used).
- Community analysis:
  - Ordination of sites sampled at PKI, Mokohinau Islands and Cape Brett clearly separated the three locations (Figure 7).
  - The lack of overlap among locations in the ordination suggests that some elements of the fish assemblage are consistently different (either through composition, density, or a combination) at the three survey locations.
- Seasonal variation:
  - Snapper (*Pagrus auratus*) ($P < 0.001$), orange wrasse (*Pseudolabrus luculentus*) ($P = 0.002$), pigfish (*Bodianus unimaculatus*) ($P = 0.01$), and Sandager's wrasse (*Coris sandageri*) ($P < 0.001$) were more abundant in autumn surveys (Figure 8).

  - Conversely, banded wrasse (*Notolabrus fucicola*) ($P < 0.001$), red moki (*Cheilodactylus spectabilis*) ($P < 0.001$) and tarakihi (*Nemadactylus macropterus*) ($P = 0.036$) were more common in spring (Figure 8).

- Density:
  - At PKI, 11 of the 20 species examined changed in density by > 100% relative to 1998, 4 species increased (orange wrasse; blue maomao—*Scorpis violaceus*; pink maomao—*Caprodon longimanus*; and snapper) and 7 species (banded wrasse; butterfish—*Odax pullus*; crimson cleanerfish—*Suezichthys aylingi*; goatfish—*Upeneichthys lineatus*; red moki; scarlet wrasse—*Pseudolabrus miles*; and spotty) decreased.
  - At the Mokohinau Islands, only pink maomao and sweep (*Scorpis lineolatus*) increased in density. No species increased by > 100% at Cape Brett. The density of spotty, orange wrasse and black angelfish (*Parma alboscapularis*) declined at the Mokohinau Islands and Cape Brett locations, respectively.
  - When the spring 1998 survey and spring 2001 survey were compared at PKI, the density of snapper (all sizes) had increased by 14.7 times ($P < 0.001$). However, the density of legal sized (> 270 mm) snapper only increased by 6.3 times ($P < 0.01$). Initial densities of snapper prior to no-take status at PKI were similar to initial densities at the reference locations. There was also no statistically significant change in the density of legal snapper at either reference location over time.
  - Conversely, many species declined in numbers at PKI since the initial survey in spring 1998. Banded wrasse numbers steadily decreased at the Poor Knights Islands and were 4.1 times lower than in the initial survey ($P < 0.001$). Black angelfish numbers were 1.5 times lower in autumn 2002 than in the initial survey in 1998 ($P < 0.001$). Crimson cleanerfish numbers increased by 5 times in the first year ($P = 0.007$), but steadily declined after the peak in spring 1999 and were 2 times lower in the final survey than the initial survey, although not statistically significant. Like crimson cleanerfish, numbers of combfish (*Coris picta*) initially increased after the marine reserve was established, but then steadily declined since autumn 2000 (not shown graphically). Numbers of scarlet wrasse steadily decreased at the Poor Knights Islands and were 5.3 times lower in the final survey than the initial survey ($P = 0.02$). Likewise, spotty steadily decreased at the Poor Knights Islands with densities 2.5 times lower in the final survey than the initial survey ($P < 0.006$) while butterfish numbers declined by 17 times ($P < 0.001$). Goatfish and leatherjacket (*Parika scaber*) were 2.4 and 1.9 times less abundant, respectively, at the Poor Knights Islands in the autumn 2002 survey compared to the initial survey ($P = 0.015$ and 0.0153, respectively). At the Mokohinau Islands, spotty density declined by 3.3 times ($P = 0.008$). The only species that declined at Cape Brett, black angelfish, did so by 2 times ($P = 0.04$).

- Size:
  - The mean size of snapper at PKI was usually greater than 300 mm in length, larger than at the reference locations ($P < 0.001$, Figure 9).
  - The vast majority of snapper recorded by UVC at the reference locations were again under the minimum legal size, with very few large fish recorded at these locations.

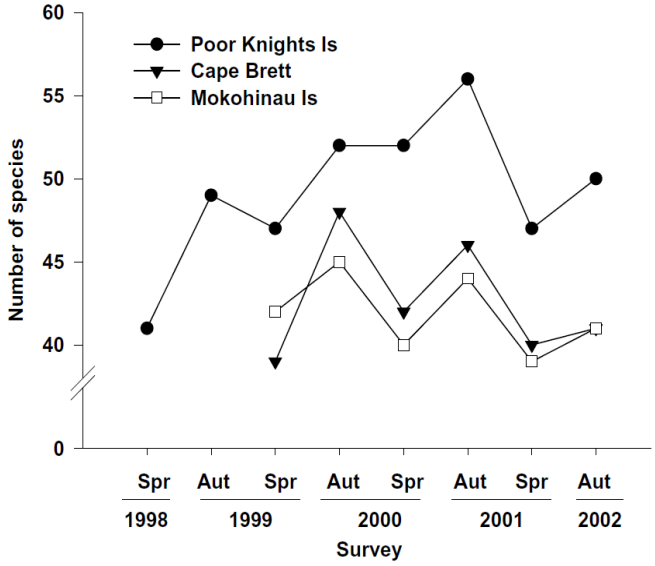


Figure 6. Number of species from underwater visual census at the Poor Knights, Cape Brett, and the Mokohinau Islands from spring 1998 to autumn 2002 (from Denny et al. 2003).

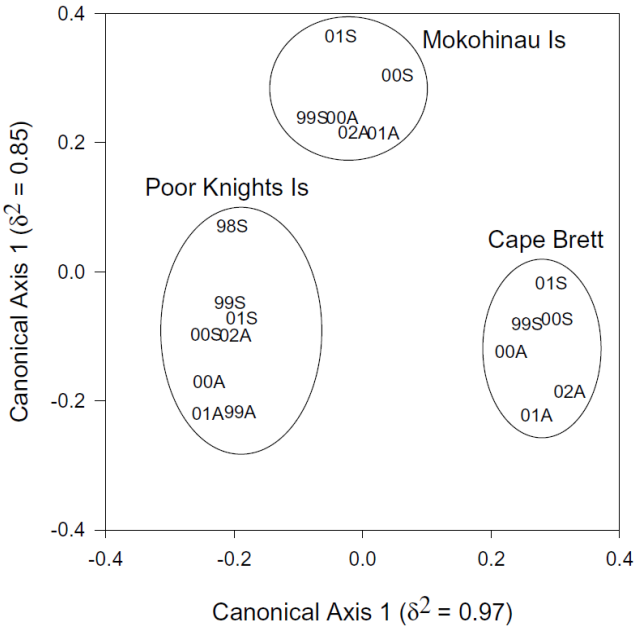


Figure 7. Constrained MDS (CAP) of the reef fish assemblage pooled at the location level from spring 1998 to spring 2002 at the Poor Knights Islands and from spring 1999 to spring 2002 at Cape Brett and the Mokohinau Islands (from Denny et al. 2003).

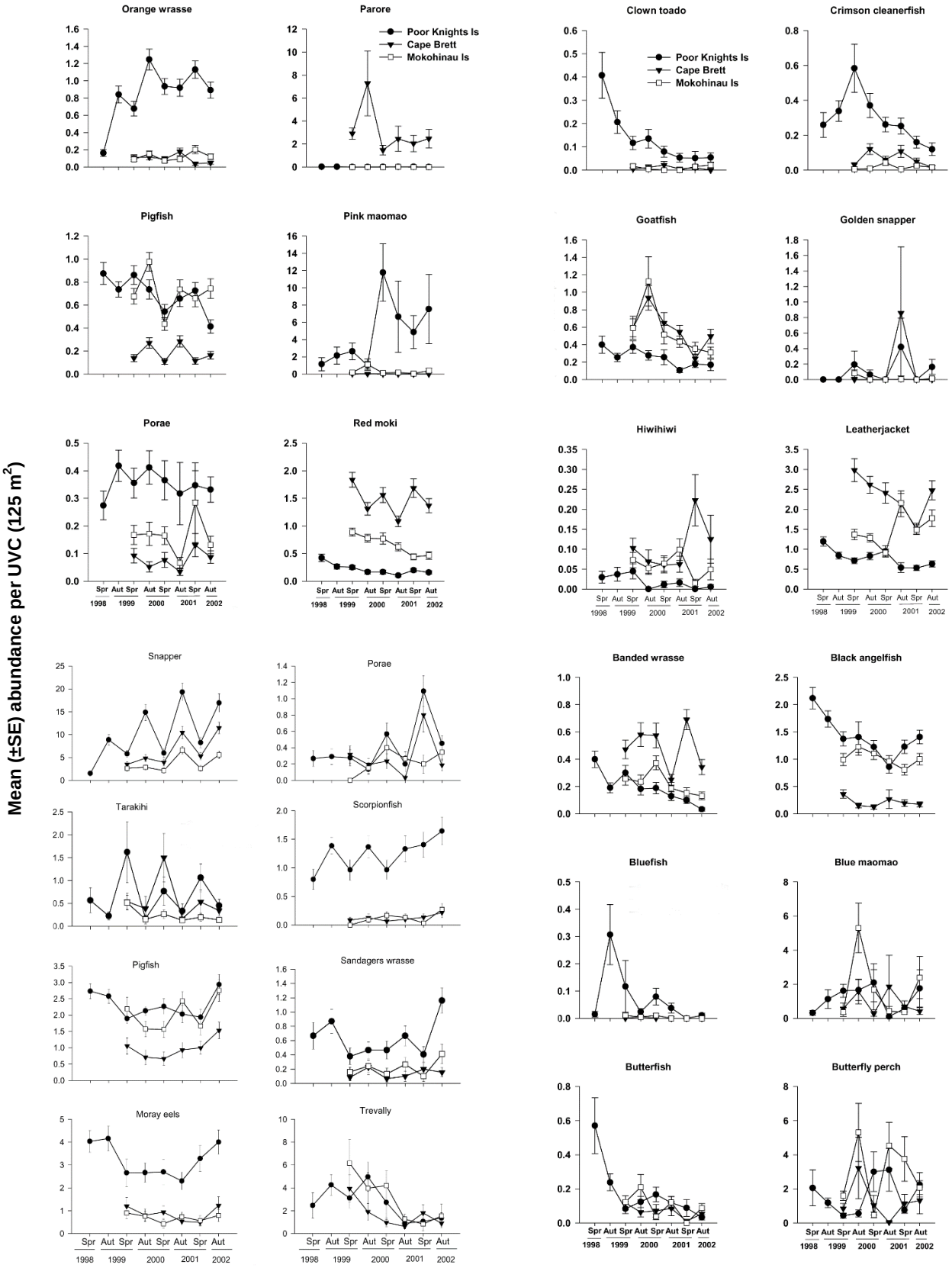


Figure 8. Mean number of species per UVC (125 m^2) (± SE) at the Poor Knights Islands from spring 1998 until autumn 2002 and at the Mokohinau Islands and Cape Brett from spring 1999 until autumn 2002 (from Denny et al. 2003).

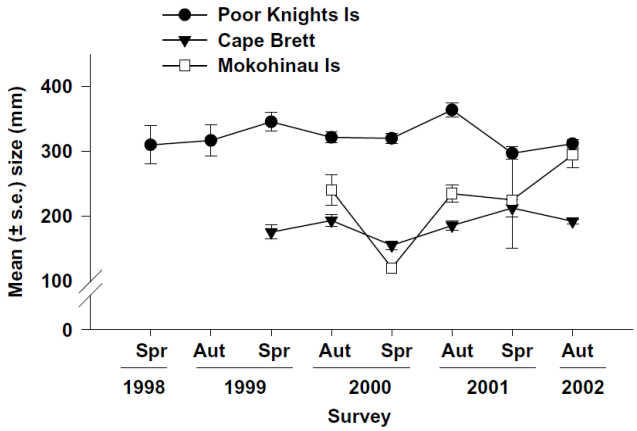


Figure 9. Mean size of snapper per UVC (± SE) at the Poor Knights Islands, Cape Brett and the Mokohinau Islands from spring 1999 to autumn 2002 (from Denny et al. 2003).

Limitations and points to consider

- The authors make a clear and useful distinction between statistical and biological effect. To be significant in a biological sense, an effect size should be large enough to mean something biologically. In this case, they hypothesised that, to be biologically significant, the number of specimens for a species had to double. The size of the effect is something that can vary for different species and locations and would need to be assessed carefully.
- Fish transect data were nicely complemented by baited underwater video data, especially for snapper, which are known to be affected by diver's presence.
- Control locations are the best that could be found in the region, but it should be noted that they are relatively distant from the Poor Knights Islands, and are thus potentially influenced by other environmental factors than those affecting the Poor Knights Islands. This is, however, a limitation that cannot be corrected, but should be considered in the interpretation phase of the results.
- When presenting the *P* value of statistical tests, it is recommended to also present the effect and sample size.

References for case study A

Denny, C.M.; Willis, T.J.; Babcock, R.C. 2003: Effect of Poor Knights Islands Marine Reserve on demersal fish populations. *DOC Science Internal Series 142.* Department of Conservation, Wellington. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.75.3056&rep=rep1&type=pdf

Case study B

Case study B: spatial variation and effects of habitat on temperate reef fish assemblages in northeastern New Zealand (Anderson & Millar 2004)

Synopsis

The authors test the effect of habitat (*Ecklonia radiata* kelp beds v. urchin barrens) on fish communities at several scales ranging from tens of metres to hundreds of kilometres. The study uses a structured hierarchical design, sampling four distant locations using fish belt transects. They show that fish assemblages as a whole (not just abundances of specific species) are influenced by habitat.

Objectives

- To examine the potential effects of habitat on fish assemblages in northeastern New Zealand at several spatial scales
- To assess the hypothesis that there is a significant relationship between fish assemblage structure and the density of kelp forests

Sampling design and methods

- Sampling design:
  - Four locations (factor = Lo) were sampled for fishes (from South to North): Hahei, Leigh, Home Point and Berghan Point.
  - At each location, four randomly allocated sites (factor = Si) were sampled.
  - At each site, two habitats (factor = Ha) were investigated: *Ecklonia radiata* kelp beds and urchin barrens.
  - In each habitat, 10 haphazardly selected 5 × 25 m transects were sampled.
  - Transects were laid along depth contours 2–20 m, but more generally 5–15 m.
  - Kelp density was estimated by counting the number of plants in 1 m^2 quadrats at each of 5 positions along the tape transect.
  - All locations were sampled once in summer 2000 and once in summer 2002, within a period of about 1 month for each sampling year (factor = Ye).
- Analytical methods:
  - Species data were highly skewed with many species occurring in only a few transects, making traditional analyses (which assume normality of errors) unsuitable, so nonparametric approaches were used.
  - Non-parametric multivariate analysis of variance (NPMANOVA, Anderson 2001) was used to analyse the multivariate data set in response to the complete experimental design (including interactions). The analytical design was:

$$Fish\ Assemblage \sim Ye \times Si(Lo) \times Ha$$

- To compare whole fish assemblages to quantitative variables (i.e. depth, average kelp density and the standard deviation of kelp density), non-parametric multivariate multiple regression was used on the basis of the binomial deviance dissimilarity measure (a new measure also developed in the same paper but not presented here), using 4,999 random permutations (McArdle & Anderson 2001).

Results

- The two habitats differed in their spatial distribution with respect to depth. The median depth of transects in kelp habitat was 13.5 m, while for barrens habitat the median depth was 6.7 m.
- Effect of depth and habitat on fish species:
  - The effect of depth on species diversity was not significant.
  - The total number of fish (transformed to $\ln(x+1)$) was significantly and positively related to depth for year 2 but not year 1.
  - There was a statistically significant relationship between the depth of transects and the multivariate fish assemblages. Depth only explained 3.5% of the variation in the multivariate assemblage structure and 1.6% of the variation in total numbers of fish. Furthermore, effects of habitat (kelp v. barrens) were statistically significant over and above effects of depth (Table 4). Thus, although some effects of habitat may be attributable to differences in depth, this analysis shows there were statistically significant effects of habitat on fish assemblages (e.g. structural or other differences) that were unrelated to depth.
  - Observed variation in fish assemblages between transects was not explained by either differences in the density of kelp or depth.

Table 4. Sequential non-parametric multivariate multiple regression showing the relationship between multivariate fish species abundance data (based on the binomial deviance dissimilarity measure) and depth, followed by the effect of habitat, taking depth into account as a covariable.

Source	***DF***	***SS***	***MS***	***F***	***P***
Depth	1	32.660	32.660	22.942	0.0002
Habitat/depth	1	10.050	10.050	7.128	0.0078
Residual	631	889.665	1.410		
Total	633	932.375			

DF = degrees of freedom; *SS* = sum of the squares; *MS* = mean squares; *F* = *F*-statistic; *P* = *P*-value

- Measured variation at different spatial scales:
  - There was statistically significant small-scale variability in the fish assemblages from site to site and year to year, and in different habitats.
  - The largest variation in the data occurred at the scale of individual transects, the next largest being the factor Location.

- Effects of habitat:
  - The effects of habitat (kelp forest v. barrens) on fish assemblages varied significantly across locations. Specifically, the effects of habitat appeared to be strongest at Hahei and Home Point.
  - Pair-wise comparisons showed that there were statistically significant differences in assemblages of fishes between barrens and kelp habitats at either Hahei or Home Point, but not at Berghan Point or Leigh.
  - There were no consistent effects of habitat on the total number of fish; these effects varied from site to site and from year to year.
  - There were no statistically significant pair-wise differences detected in the total number of species in kelp forest versus barrens in either year at any location.
  - *Parika scaber* (leatherjackets) had significantly higher abundances in kelp forests than in barrens habitats for both years at the two northern locations of Berghan Point and Home Point. Their frequency of occurrence was also greater in kelp forests, as was that of *Chromis dispilus* (two-spot demoiselle), *Trachurus novaezelandiae* (jack mackerel), *Nemadactylus douglasii* (pōrae), *Bodianus unimaculatus* (pigfish), *Odax pullus* (butterfish) and *Pseudolabrus miles* (scarlet wrasse).
  - Fish that occurred more frequently in barrens habitats were *Notolabrus celidotus* (spotty), *Notolabrus fucicola* (banded wrasse), *Girella tricuspidata* (parore), *Coris sandageri* (Sandager's wrasse), *Chironemus marmoratus* (hiwihiwi), *Parma alboscapularis* (black angelfish), *Scorpis violaceus* (blue maomao) and *Kyphosus sydneyanus* (silver drummer).
- Effects of location:
  - Due to its interaction with habitat, the potential differences among locations were considered separately for each habitat.
  - The separation in multivariate space of assemblages from different locations was slightly more successful for barrens habitats than for kelp forests (Figure 10). For barrens habitats, fish assemblages from each location differed significantly from all other locations, except for Berghan Point and Home Point, which did not differ significantly. For kelp forest habitats, fish assemblages did not differ between Berghan Point and Hahei, but all other comparisons among locations were statistically significant.
  - Results on the abundance of some common species at kelp sites versus barrens sites are presented for each location and showed a wide range of variability.

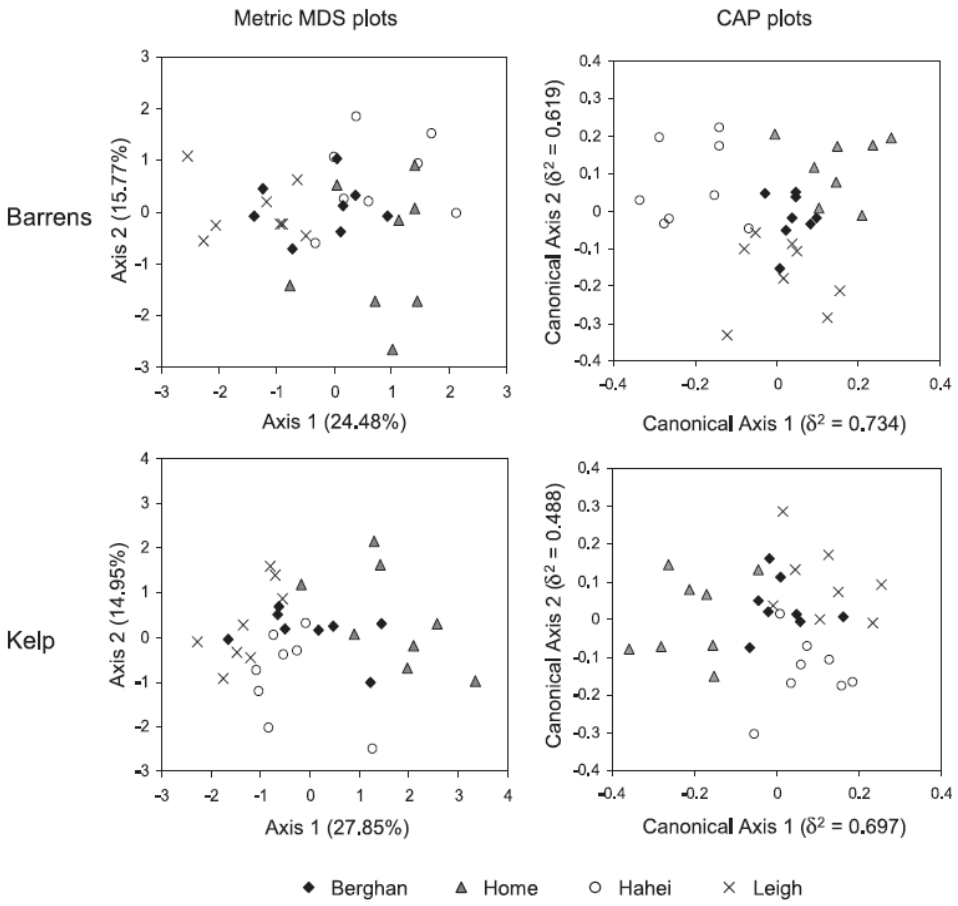


Figure 10. Unconstrained metric MDS plots (left) and constrained CAP plots (right) done separately for each habitat (rows) based on the binomial deviance dissimilarity measure, in each case comparing fish assemblages among four different locations: Berghan Point, Home Point, Leigh and Hahei. There are eight points for each combination of the factors, which correspond to the four sites in each of 2 years. Extracted from Anderson & Millar 2004.

Limitations and points to consider

- The level of statistical methods deployed for this study is complex and requires an in-depth knowledge of this subject for correctly conducting the analysis and interpreting the results.
- The two habitats sampled (kelp and barrens) did differ in their spatial distributions with respect to depth, which might lead to a bias when interpreting the results, i.e. any effect due to habitat could also be attributed to a depth difference. Ideally, both barrens and kelp habitats should have been sampled at similar depths, but in practice, this might be very difficult to achieve. In this instance, the authors acknowledge this limitation but show convincingly that depth is not the only factor explaining variation in fish assemblages.
- Only two types of habitats were studied. Most of the observed species occur in a range of other habitats, so it would be wrong to conclude that because one species was more frequent within, say, kelp forest, this habitat represents its ‘preferred’ habitat.

References for case study B

Anderson, M.J. 2001: A new method for non-parametric multivariate analysis of variance. *Austral Ecology 26*: 32–46.

Anderson M.J.; Millar, R.B. 2004: Spatial variation and effects of habitat on temperate reef fish assemblages in northeastern New Zealand. *Journal of Experimental Marine Biology and Ecology 305*: 191–221. https://doi.org/10.1016/j.jembe.2003.12.011

McArdle, B.H.; Anderson, M.J. 2001: Fitting multivariate models to community data: a comment on distance based redundancy analysis. *Ecology 82*: 290–297.

Full details of technique and best practice

The exact survey/monitoring design will be governed by the research question, but the following text details the techniques and general survey design to be utilised when surveying fish populations with underwater visual transects over rocky reef habitats (also see the very detailed description of these methodologies given in Kingsford & Battershill 2000).

Figure 11. Scientific diver in typical habitat of the Poor Knights Islands. Monitoring of the fish population inside this marine reserve has been regularly achieved using the transect method. Photo @Vincent Zintzen.

Monitoring preparation

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

- Identification of monitoring objectives and the motives for these.
- Statement of clear outcomes of the surveys relative to the original monitoring objectives.
- The creation of habitat maps to identify suitable sites, and the stratification of sampling among habitat types, if required. This step can be time consuming and may require a pilot study.
- Field gear, including backups, and pre-printed data sheets.
- A group of certified scientific divers who are trained in the sampling method. This might require training for length estimates of fishes underwater and/or training in fish identification for the species present at the survey sites. A high level of training is required to reduce bias among observers, which is known to be a frequent major issue in these methods (see 'Training and calibration of divers' on page 34).

Sampling design

- Accounting for natural spatial variation in fish abundances:
  - Large and small-scale spatial variation in the abundance of fishes is common and should be considered in all sampling designs (Kingsford & Battershill 2000).
  - Spatial variation in fish abundance can be large at scales as small as a few metres, and will tend to increase at larger spatial scales.
  - It is common for greater compositional and abundance differences to occur between offshore islands and the mainland. This can be important when choosing relevant control sites for isolated offshore islands like the Poor Knights Islands.
  - Depth and habitat types usually have a strong influence on fish abundance. In addition, some habitats are only found at certain depths; the experimenter should be careful when choosing levels for these factors so that they do no confound interpretation of the results.
  - Usually, more precise estimates of fish abundance can be obtained when stratifying the design by depth and/or habitats.
- Accounting for natural temporal variation in fish abundances:
  - Each fish species displays specific fidelity to reef sites which will influence its variability in abundance through time. Species like triplefins are highly territorial (i.e. they will always be present at the same spot) while others like trevally travel kilometres along a reef system.
  - Season is known to have a strong effect on fish assemblages (e.g. Pande 2001), and the experimenter should choose their sampling season accordingly.
  - If the experimenter is interested in how fish abundances and sizes change through time within a year (e.g. seasonal changes or lunar cycle changes), then the sampling area

should be visited at a frequency that will capture the variability between these time slots (e.g. every season or at several steps during a lunar cycle).

Transect size and number

The following should be considered when designing sample unit size and number (Kingsford & Battershill 2000):

- One or a few very large sample units are much harder to search than many small units, and the efficiency of searching might drop with increase in sample size (Mapstone & Ayling 1998).
- It is easier to keep small sample units within a defined habitat.
- The error in estimates increases with the width of the transects (Sale & Sharp 1983).
- Replication gives an indication of the variation in densities found within a sampling locality.
- Replication enables more rigorous statistical testing.

Although medium to large reef fishes (> 50 mm total length) have often been counted in 50 × 10 m transects in temperate waters of New Zealand (Table 5), comparisons of transect length have shown that this transect size does not give the precision of a larger number of smaller transects. Practice has shown that transects of dimension 25 × 5 m usually give precise estimates for abundances of many species (Kingsford & Battershill 2000). When using wider transects, the diver generally does not thoroughly search the entire area. In addition, accuracy in fish size estimation decreases when they are sighted further than 3 m away. However, in some cases, transects of 50 × 5 m can be a better option. This is the case when, for example around Mayor Island, a large proportion of the samples obtained with 25 × 5 m transects are null (Keith Gregor, pers. comm.). Some guidelines for determining what the optimal transect length should be are presented below.

If the survey focuses on smaller species (e.g. triplefins), a smaller transect size should be used. In this case, the basic unit is usually a 5 × 1 or 2 m transect, which is divided into five individually surveyed 1 × 1 m quadrats (Adam Smith, pers. comm.; Kingsford & Battershill 2000; Feary & Clements 2006; McDermott & Shima 2006).

Table 5. Length of transects in different studies made in the New Zealand coastal region

Study	Location	Length (m)	Width (m)
Ayling 1978	North-eastern North Island (Leigh)	50	10
Leum & Choat 1980	Northland	50	10
McCormick & Choat 1987	Cape Rodney–Okakari Marine Reserve	20	5
Cole 1990	North-eastern North Island (Leigh)	25	5
Pande 2001	Wellington South Coast	25	5
Anderson & Millar 2004	North-eastern North Island	25	5
Willis et al. 2009	Fiordland	25	5
Haggitt et al. 2012	Te Whanganui-a-Hei	25	5
Davidson et al. 2013	North Nelson area	30	2
Davidson & Richards 2013	Tonga Island (Abel Tasman)	30	2
Davidson et al. 2014	Long Island (Marlborough Sounds)	30	2

Replication level is a difficult subject which is still being researched. Recent studies based on northern South Island marine reserve data (Long Island–Kokomohua Marine Reserve, Tonga Island Marine Reserve and Horoirangi Marine Reserve) show that optimal monitoring configuration varies among species, locations and whether assessment was based on precision, accuracy or power (Jones 2014). In general, higher within-site replication (i.e. higher number of transects per site) was required for the least abundant species, whereas greater site replication was required for more spatially heterogeneous species/locations. In very general terms, 12 transects per site appear to be the most cost-effective design, and we recommend that all surveys aim at having this minimum number of replicates per site. This replication level also coincides best with the length of time divers can spend underwater during diving operations.

Procedure for obtaining the best transect size

Major considerations for choosing the appropriate transect size include:

- What size gives the greatest precision (smallest standard error) for a given total area sampled (i.e. is it better to choose many small or a few large transects)?
- Are the counts for each transect accurate (e.g. have you missed any specimens)? Accuracy might be reduced if the transect is too large to be thoroughly searched.
- How long does it take to complete a transect, and how does this relate to the number of transects you can complete during one dive?

Ideally, the best sampling unit size of the study area and species of interest should be assessed during a preliminary study if information is not available.

Andrew & Mapstone (1987) give an accurate account on the procedure for obtaining the most appropriate sample unit size, considering precision, accuracy, and logistic and economic constrains. We summarise their paper here.

Optimisation is achieved by determining the most efficient allocation of resources, i.e. minimising decreases in precision and/or resolution imposed by cost or logistical constraints.

Two main questions that are linked to each other need to be answered:

1. How big should the transects be?
2. How many replicates are needed?

To answer these questions, the experimenter will need to estimate the variances and/or means of species abundances in the sampling area of interest. This can be obtained from (1) pilot studies, (2) previous studies made in similar habitat or (3) published data. Of the three methods, pilot studies are highly recommended. Most of the time, the additional resources required to undertake the pilot study will save time across a programme.

For a given sample size, the precision of a sample estimate is likely to increase with increasing size of the transect. The rate of increase will usually be great at first, but will quickly decline once the

transect size exceeds the average distance between aggregations in the fish population. Past a certain length, it is likely that precision will decrease due to diver fatigue.

In the simplest case (simple random sampling), an equal number of at least three replicate transect sizes should be collected randomly within the area to be studied. For general reef fish study in the New Zealand context, we recommend testing transect sizes of 15 × 5, 25 × 5, 50 × 5 and 100 × 5 m. It is important to allocate randomly the different transect sizes in the area to avoid the effect of size to be confounded with pre-existing differences within the area.

Relative accuracy is estimated by looking at the means (number of individuals per m^2) obtained from the different transect sizes. The means obtained from total counts for all species and from the number of specimens of each species separately can be looked at. Significant differences among the standardised means indicate differences in the relative accuracies of at least some of the transect sizes tested. For fish transects, it is likely that accuracy will increase with transect size up to the point where transect size is sampling across different types of habitat. Increased accuracy will be the results of the patchy and aggregated distribution of many fish species in nature: the transect should be large enough to sample these species.

The formula for obtaining precision (p) is:

$$p = \frac{SE}{\bar{x}} \quad \text{Equation 1}$$

where SE = the standard error and $\bar{x}$ = the mean for the abundance of species$_1$ of the different replicates for a particular transect size. The transect size with the smallest p will be the most precise for that species. Note that you should look at the precision obtained for the different species separately.

If the experimenter is interested in knowing the level of replication (n) needed to attain a certain precision (p), the following formula (derived from Equation 1) can be applied:

$$n = \left[\frac{s}{p \times \bar{x}}\right]^2 \quad \text{Equation 2}$$

where s = the sample standard deviation, $\bar{x}$ = the mean of the different replicates for a particular transect size, and p is precision.

With more complex designs, a number of estimates of precision can be obtained for transects of all sizes and the mean precision compared using analysis of variance with the replicate measure of precision as data. Significant differences among the means of estimates of precision indicate better average precision for one or more transect size than for others.

Once the information on accuracy and precision is obtained, it should be combined with details of costs and logistical constrains to maximise the return for effort.

In practice, our experience is that with transects 25 × 5 m, it is often possible for a team of two divers to execute six replicate transects in shallow water (< 15 m depth) during one dive. In this

configuration, a total of 12 transects can be achieved at one site by two teams of divers. This level of replication will often be acceptable for comparing abundances of common species both inside and outside marine reserves (Jones 2014).

Fixed versus randomly selected versus haphazardly selected transects

How transects are actually positioned underwater can have a profound influence on conclusions that can be drawn after statistical analysis of the data.

The optimal design for transect placement is when they are made randomly within a site. Random sampling is the basic sampling technique where an experimenter selects a series of transects (a sample) for study from a larger group (a population). Each individual transect is chosen entirely by chance and each member of the population has an equal chance of being included in the sample. Every possible sample of a given size has the same chance of selection. Random positioning of transects will often give the greatest statistical power and range of options for analyses (Kingsford & Battershill 2000). In practice, generation of random locations for transects must be computer assisted and pre-assigned before a survey.

Because of the logistical constrains associated with exactly positioning a diver while underwater, it is usually not possible to randomly assign the positions of transects within a site. Most of the time, however, it will be achievable to haphazardly allocate their position. Haphazard sampling is attempting to remove as much human bias as possible on the selection of transect location, but acknowledging that this is not achieved using random selection methods. In statistical terms, there is no way to ensure that the estimates derived from a haphazard sample will be unbiased. In practice, the surveyor will have to assume that haphazard sampling is approaching random sampling. To best achieve this, the divers should try not to ‘think’ about where to start their transects. They should just swim a set length in a randomly chosen direction, stop, and then find something to attach their tape to and start the transect.

Fixed transects are used in some cases. With this design, the surveyor will repetitively sample the exact same area during each sampling event. To this effect, a permanent marker, usually a bolt, rebar or waratah, is drilled into the substrate. Once the marker has been found, the diver will start the transect following a predefined bearing, effectively sampling the exact same area as previously. The reasoning behind using fixed transects is to decrease unaccounted variability between the different sampling events so that a main effect of interest (e.g. a protection effect) can be more easily detected. Although there is some value in reducing variability in the results, the study of this type loses a lot in terms of inference space when using this method. By using fixed transects, the study can only draw conclusions about what is happening within these transects and weakens the ability to draw broader conclusions. This reduction in inference space might, however, be a necessary trade-off to be able to detect the effect of, for example, increased protection over an area compared to equivalent unprotected areas. This is because, in many cases, the variability in data collected with fish transects (variability between transects, sites or years of sampling) is so high that it makes it difficult to obtain statistically significant effects.

Training and calibration of divers

One of the major sources of variation in the data obtained from fish transects can be from observer bias (Kingsford & Battershill 2000). This can happen, for example, when divers consistently count additional specimens located outside their transects, or when an observer is not recording some species they are not familiar with. You will want to minimise this source of variation as much as possible by avoiding an 'observer effect'. The best tool to reduce this source of variation is through rigorous training and calibration of divers.

Training of divers should include (1) fish identifications, (2) fish counting, (3) spatial awareness and (4) fish sizing, and should ideally be planned well in advance of any sampling event.

Fish identifications

Excellent fish identification books (e.g. Francis 2012) are available and their consultation should be followed by training dive(s) devoted to fish identification underwater. Ideally, the trainee should follow a diver with high experience of the area being sampled and compare their identifications. A high level of confidence needs to be gained before becoming an independent observer.

Fish counts

Calibration of fish counts can be achieved during training dives. The trainee will be accompanied by a diver fully trained in the transect method and they will compare their results from practice transects. Alternatively, training dives can be recorded using a video and count results analysed back in the lab.

Spatial awareness

The observers will need to have a good sense of where the width of their transect ends. This can be achieved during a test dive where two divers swim side by side at a distance equivalent to half the transect width (typically 2.5 m). They can use a measuring tape to this effect. In addition, the diver should have awareness of a few body dimensions. It is useful, for example, to know the length of your extended arm (that might include the extra length of the slate) and use that as a reference to estimate transect width.

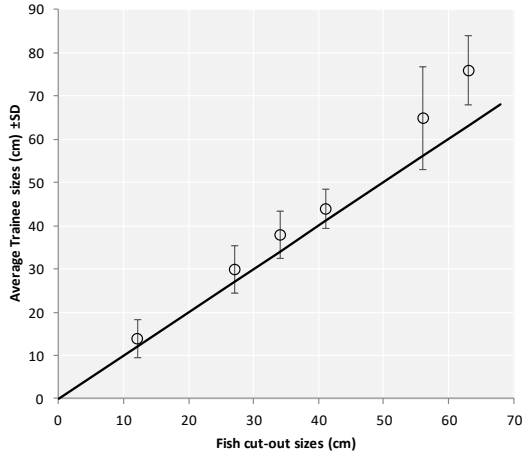
Fish sizing

Accurate sizing of fishes underwater is an essential skill that takes significant practice. The exercise presented here should ideally not be left to the first day of a survey. To confirm that a diver can (1) consistently and (2) accurately size fishes underwater will require a minimum of two separate dives with some length of time in between—a first dive will help calibrate the diver and a second will confirm the calibration.

Learning how to visually estimate the size of fishes is best achieved by having cut-outs of fish of different sizes (e.g. 12, 27, 34, 41, 56 and 63 cm in total length) made of neutrally buoyant material. A trainee will swim down a series of randomly sized cut-out fishes placed on a line. Thirty cut-outs

in six different sizes are good numbers to use. With this set up, the trainee will have to estimate the same fish size five times so that their ability to consistently size specimens of similar sizes can also be assessed. The divers will record their estimations of the total length of the fish on a training sheet (see template to record and keep track of this information—'Fish size calibration underwater training sheet'—doccm-2791243). Results can then be graphed to visualise (1) how accurate (how close size estimates are to the correct values) and (2) how precise (how consistent in their estimates) the trainees are (Figure 12). A coefficient of correlation (R^2) between the true sizes and observations can be calculated to give an overall estimate of the diver's ability to measure fishes and for comparisons with future calibration exercises. A spreadsheet with macro is available for analysing fish length estimates data ('Fish size calibration data analysis tool'—doccm-2806683).[11]

Once the results have been graphed and interpreted (Figure 12), the trainee should be debriefed. If results depart from acceptable, another session of fish size estimates will be required before the actual survey takes place. It is not easy to give definitive guidelines on how a diver should perform but a reasonable estimate should probably be consistently a capacity to estimate fish lengths within 10–20% of the correct size and an R^2 above 0.90.



Fish sizes (cm)	Correct	High	Low
12	4	1	0
27	3	2	0
34	3	2	0
41	4	1	0
56	1	4	0
63	1	4	0

Figure 12. Graphing results from fish size estimates by a diver. In this example, the diver estimated five times the sizes of fish cut-outs (sizes = 12, 27, 34, 41, 56 and 63 cm). Average estimate values are plotted with their associated standard deviation (SD), which represents how consistently the diver estimated the sizes. Larger SD means increased variability in the size estimates. Points would sit on the line if the diver estimated sizes perfectly on average. SD lines would be reduced to nothing if the diver consistently estimated the size of a cut-out to the same value. Results show a tendency of the diver in this example to overestimate the size of the fishes and decreased precision of estimates for the larger fish sizes (this is represented by increased SD of the results for the 56 and 63 cm fish). For a size estimate analysis tool, see 'Fish size calibration data analysis tool'—doccm-2806683.

[11] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-fish-size-calibration-data-analysis-tool.xlsm

Sampling space

The general sampling space for fish belt transects has the shape of a half cylinder. The radius of the half cylinder is equivalent to half the transect width, and the length of the whole cylinder is the length of the transect (Figure 13). However, when the observer is recording fish data, they should only record fish that are within the distance in front of them that is equal to the width of the transect. Therefore, at any one time, the surveyor will only be recording fish within the following portion of the cylinder:

- Radius of the half-cylinder = ½ width of transect
- Length of half-cylinder = width of transect

The rationale for sampling this smaller space is that, if the observer samples again the same area under reduced visibility conditions, she/he will not be able to see fish that are located further away, hence fail recording it. Recording it when the visibility is good would then introduce a bias in the data collection. For example, this means that an observer should not record a fish that they see 7 m ahead of them if the transect width is 5 m.

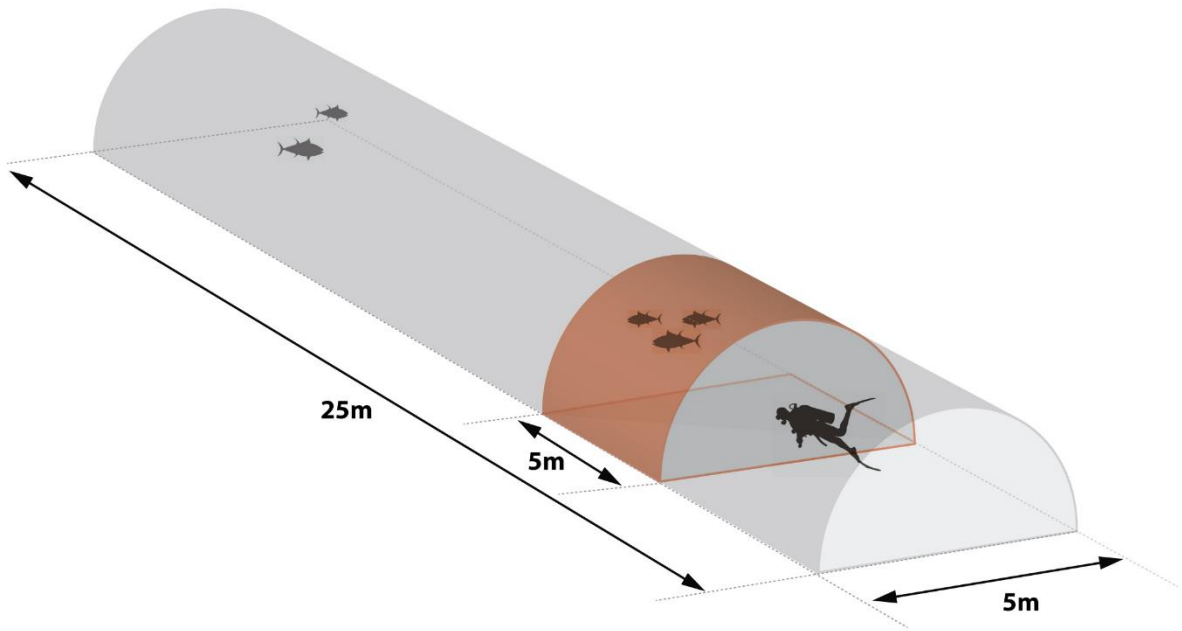


Figure 13. Illustration of a typical 3-dimensional sampling space for fish belt transect. In this example, the width of the transect is 5 m and its length 25 m. Radius of the half-cylinder is 2.5 m. With these transect dimensions, the divers will only count and size fishes that are within a 5 m distance ahead of them (orange volume), moving slowly towards the end of the transect. In this example, the divers will record the three fishes located within the orange volume, but not the two fishes visible further away. The divers might record these two fishes if they are still in the sampling volume later during the transect.

Search pattern and intensity

The amount of time and energy that a diver will devote to search for fishes in a transect is likely to have a strong impact on the number of specimens observed and recorded. For example, one diver in a survey might search for fishes in a zigzag pattern, under boulders or under the canopy of kelps while the other only records specimens they observe swimming in a straight line. This can have a profound effect on the final dataset and ultimately make comparisons between data collected by different observers problematic.

Characteristics of the search for fishes will vary with the general objective of the study. Before a survey, it is essential to standardise how divers will search for fishes, and be specific for each different type of habitat likely to be encountered. Swimming speed will strongly influence the search pattern and intensity and is a good way of standardising divers.

For general marine reserve monitoring of medium to large fishes in New Zealand, the following search pattern and intensity is recommended:

- Keep to a swimming speed of about 5 m per minute.
- Swim in a straight line, avoiding zigzag patterns. This might, however, be unavoidable if a transect width larger than 5 m has been chosen (not recommended in most situations).
- The diver should look on the substrate and in the water column for fishes.
- If the substrate is covered with kelp, the diver should not attempt to go under its canopy to search for fishes. However, they should record any fish seen on or through the canopy.
- If the habitat is made of large boulders creating overhangs and small caves, the diver should look for fish in the most obvious ones but without thoroughly searching any small cave or crevices in the transect.
- If the diver samples a wall, they should be far enough from it to able to observe and identify fishes up and down the wall, paying attention to cracks where some species like to sit and hide.

Sampling in practice

1. All sites should have been identified prior to the survey and their GPS coordinates should be available for navigation. Once onsite, they can be marked with a lead weight and surface buoy. This is especially useful if the area to be sampled is located far from any landmark.
2. Usually, teams made of two divers are ideal because they will disturb the area less compared to larger teams. If several teams are deployed at the same time, it is essential to agree on general direction the different teams will take so that they do not sample the same area or disturb each other’s sampling area.

3. Divers will record the necessary information about the site they are sampling on the pre-printed sheets (see footnote for examples).[12]
4. Once the divers are deployed, the lead diver will swim towards the start of their first transect. In a typical scenario, transects will be allocated haphazardly within the general area to be sampled. To this effect, it is important that the divers do not use personal criteria to choose where to start the transect. It should be chosen as randomly as possible. If a buoy line has been deployed, the first transect can usually be started from the buoy line itself. However, if two teams are deployed at the same site, they should not both start their first transect from the buoy line.
5. When the lead diver has found the starting point of their transect, the measuring tape can be secured to any available structure. The bases of macroalgae often provide good attachment points and can be 'hooked' using wire attached to the tape (see Figure 2E). Calcareous tubes of dead polychaetes (Serpulidae) can provide useful attachment points if there is no suitable macroalgae. Using this technique avoids having to swim back the entire length of the transect to detach the tape; this can usually be achieved by giving a firm tug on the transect line to release the wire when a transect has been completed.
6. The lead diver will usually reel off the line, especially if the second diver is in charge of recording habitat and/or invertebrate data. The easiest way for the leader to reel off the tape and take notes at the same time is to keep the reel under their slate, as support for the slate. The line should be reeled in a direction parallel to the depth contour lines to avoid sampling across depth strata (except if the general objective of the study imposes it).
7. To minimise the impact of attraction or repulsion of some species to divers during the sampling (Cole 1994), species are recorded while reeling off the measuring tape. Fishes are not recorded while reeling back the measuring tape.
8. At a distance of 5 m from the start (indicated by a mark the observer will have made on the line), the diver starts counting fish visible in the volume determined during the design phase of the experiment. This 5 m gap before recording fishes is necessary to get away from the disturbance created by securing the end of the tape to the substrate. Marks on tapes can be created using a little bit of electric tape or a permanent marker (use a bright colour, such as red) and used as a prompt for when to start the transect.
9. The observer records fishes in a volume in front of them that has the shape of a half-cylinder (Figure 13). The observer should record fishes located as far ahead of them as the width of the transect. Fishes that can be seen further away should not be directly recorded. They will be recorded later if they are still within the volume of the transect when the observer approaches them.
10. Transects are swum at a constant, slow speed (5 m per minute is recommended—Clynick et al. 2008), but fast enough to ensure that swimming fish do not overtake the diver. This

[12] 'Field data sheet (scientific name)' (doccm-1543029) (http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-field-data-sheet-scientific-name.pdf)

'Field data sheet (common name)' (doccm-1543359) (http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-field-data-sheet-common-name.pdf)

'Fieldwork underwater sheets for Poor Knights' (doccm-1561621) (http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-fieldwork-underwater-sheets-for-poor-knights.pdf)

can be a problem with species like spotty and wrasse, which might require the observer to adapt their swimming speed.

11. Counts and sizes of fishes should be recorded on pre-printed sheets (see footnote 12 for examples).
12. To assess if a fish falls within or outside the transect, the recorder can use the measuring tape as a reference point.
13. Once the observer arrives at the end of the pre-determined length of the transect, they should wait for their teammate to finish working (usually recording habitat data and data on invertebrate species).
14. Once all the work on the transect is complete, the measuring tape is freed from its anchoring by pulling vigorously on it and reeled back into the spool.
15. Divers will then swim together to the start of the next transect. Usually, a minimum distance equivalent to the length of the transect (or at least 15 m) is swum before starting a new transect.
16. A new transect is then started following points 5–15.
17. After the dive, each diver should thoroughly check their data sheet for completeness and readability, keeping in mind that somebody else will have to interpret their writing. To avoid any confusion at this stage, divers should transfer their transect data into a notebook after each day of work. If apps and underwater tablets are used, the collected information should still be checked by the observer, but it resolves the common problems associated with the interpretation of handwriting.

Common problems encountered while sampling with transects

- *I cannot find anything to attach my transect tape to.*

  ⇒ This can be a problem outside the depth band where you find macroalgae. However, even there, it is usually possible to find a crack where you can wedge your wire or a boulder you can wrap the tape around. Calcareous tubes of dead polychaetes also work well. If you are desperate, it is always possible to hook your wire around an ascidian.

- *Should I search for fishes in the thick understorey of kelps my transect is passing through?*

  ⇒ No. Under normal circumstances, you should not intensively search for fishes in kelp understorey but you should record any fish that you see from above in the understorey. This habitat would require much more time to be adequately sampled and searching it thoroughly would mean you would probably miss specimens above or next to the kelps.

- *What should I do if large predators enter my transect (e.g. sharks, school of kingfish)?*

  ⇒ It is likely that the presence of these predators will have a strong influence on some species of fishes, which will find shelter and hide from the observer. In this case, it is advisable to abort the transect and start a new one once the predators have gone.

- *I broke the tip of my pencil and I have nothing to write with.*

  ⇒ You can try fixing the problem with your dive knife, but this would not happen if you were using either graphite sticks or push-up pencils (see Figure 2B & C), which can always be fixed underwater if a problem arises.

- *I lost my data sheet while getting in the water.*

  ⇒ Hopefully you have a slate that you can write on, as recommended. If you don't, and if there is nobody else in the water with spare sheets, you will have to abort the dive and surface to get new sheets.

- *Should I record data on triplefins?*

  ⇒ If you have not designed a study to specifically look at triplefins, you should not record data on them. Although very common, they usually require specific methods to evaluate their richness and densities (e.g. smaller transects that are searched intensively). An exception may be oblique-swimming triplefins (*Forsterygion maryannae*) because they usually school away from the substrate and can be easily counted.

- *My transect is done on a vertical wall at 10 m depth with the bottom at 20 m. What is my sampling area?*

  ⇒ Your sampling area (see Figure 13) will be rotated 90° so that the wall will be the equivalent to the horizontal surface of the seabed that is normally sampled. If your transect is 5 m wide, you will then sample the wall from a depth of 7.5 to 12.5 m within a radius of 2.5 m from the wall.

- *What should I do if my transect covers a large area of sand when the protocol I follow is supposed to sample for reef fishes?*

  ⇒ There is no clear rule defined for this problem but common sense would dictate that at least 70% of your transect should be completed away from sandy areas. Small patches of sand (3–5 m) between reefs is okay since reef fishes are still likely to use these ecotone zones. However, having a few metres of reef followed by a long stretch of sand is unlikely to sample the desired component of the reef. In this case, the transect should be done again in a more suitable habitat. If habitat data are recorded by the second diver in the team, it is possible to use this information as a covariate during the analysis phase of the project, potentially reducing the variation in species composition and numbers likely introduced by this bias.

- *Should I count fish that are passing in front me (i.e. fishes that were at first outside the transect, then inside for a moment, then outside again)?*

  ⇒ Yes, these fish(es) are part of your transect counts.

- *How do I make sure not to count the same specimen several times during one transect?*

  ⇒ The answer to this lies mostly in your swimming speed. It must be fast enough to avoid having fishes re-appearing in your field of view while slow enough to thoroughly sample your volume. A good basis for swimming speed is 5 m per minute. Some species like spotty and wrasse are particularly attracted by divers and their numbers can accumulate around the diver. Be mindful not recording anything that is behind you or coming from behind you. Focus on what is ahead.

- *How do I estimate the number of specimens in a large school of fish?*

  ⇒ If the school is under about 30 fish, it is often possible to count all the individuals one by one. The technique for this might change from person to person but moving your eyes quickly over each fish and counting in your head is an efficient way of doing it. Beyond 30 fish, it will be too hard to count each of them individually. In this case, the best approach is to count the fish in a limited area of the school (say about 1 m^2) and then count how many of these areas you have in the school.

- *Visibility is reduced and I can barely see further than the width of my transect. Should I keep sampling?*

  ⇒ If you can still see as far as the width of your transect, then you can keep sampling. Note, however, that if you think that your ability to identify and observe fishes is decreased, then you should abort the sampling because this is likely to introduce a bias in your data.

- *Should I record a fish that I see 10 m ahead and would fall in my transect (my transect width is 5 m)?*

  ⇒ No, you should not record that specimen. You should sample as far ahead as the width of your transect. For example, if the width of your transect is 5 m, you should only count and size fishes that are 5 m ahead of you. The rationale for this is that if you sample again the same area under reduced visibility conditions, you will not be able to see that fish located 10 m away, hence failing to record it. Recording it when the visibility is good would then introduce a bias in your results.

- *There are too many species to record and I can't keep up with taking notes of everything.*

  ⇒ If this happens during a single transect or only a restricted number of times during the length of a survey, the transect(s) should be aborted and a note made of what happened. If this is a recurrent problem during a survey, this is a more serious issue. It is likely you will need further training in identifying and counting fishes for this area before proceeding with a full-scale survey, or the survey methodology will need to be reassessed.

- *I did not realise I was beyond my transect length limit and have been recording fishes further than the intended length of the transect.*

  ⇒ This can be avoided by having a clear mark on the tape indicating the end of the transect. Even better, if your mark is made of electrical tape, you can make it thick enough so that you will feel some resistance in the reel when arriving at that length of tape. If this still happens and you have a clear memory of the fishes you recorded since the end of the transect, just rectify your data sheet accordingly. In case of doubt, best practice is to cancel this transect and redo it.

Avoiding pseudoreplication

Pseudoreplication (*sensu* Hurlbert 1984) is defined as the use of inferential statistics to test for treatment effects with data where either treatments are not replicated (though samples may be) or replicates are not statistically independent.

Pseudoreplication is often a consequence of the actual physical space over which samples are taken or measurements are made being smaller or more restricted than the inference space implicit in the hypothesis being tested.

In the case of fish transects, if the study wants to test for an effect of protection at a particular marine reserve, you need to make sure that there is enough replication at the site level. If the study only has two sites—site A inside the marine reserve and site B outside the reserve—even with 20 transects at each site, you will not be able to conclude anything about a reserve effect. All you will be able to conclude is if there is a difference between sites A and B. To be able to test for a marine reserve effect, the study will have to sample multiple sites both inside and outside the reserve.

However, having several sites sampled is not enough *per se*. The study could have 10 sites all clustered on the northern end of the reserve and 10 sites outside the reserve all located close to each other because it is logistically easier to access them. Again, solid conclusions about a reserve effect cannot be deduced from these data because the sites selected do not represent the inference space on which we wish to draw conclusions. It is then important to randomly choose sites within and outside the reserve, encompassing a wide range of conditions, to increase the inference space.

The same applies at the transect level. If we are to test for a difference between sites A and B, we need to replicate the number of samples at the transect level and be sure that they are representative of the site being sampled and independent from each other.

Replication reduces the effects of ‘noise’ or random variation or error, thereby increasing the precision of an estimate—for example, the mean abundance of a species inside compared to outside the reserve. Randomisation eliminates possible bias, thereby increasing the accuracy of such estimates.

To be independent from each other, transects in the study will have to meet the following attributes:

- The starting point of one transect is not directly related to the starting point of the next transect. In this respect, transects 'in star' made from the same origin point should be avoided.
- The distance between two transects should be about the length of a transect (and at least 15 m long), so that what is sampled in one transect is not directly related to what was in the next one.
- Transects should be chosen at least haphazardly if random selection is not possible.
- If sampling is not stratified by habitat, the observer should refrain from being selective about which habitat they are sampling. They should not favour habitats that are 'easier' to sample or habitats that have 'more fish'. On the contrary, they should, as much as possible, randomly select where to start their transects.

Beyond fish transect: habitat data

Often, the investigator will be interested in linking their observations of fish assemblages and sizes to other variables like temperature, current, distance to disturbance or habitat. Fish assemblages are strongly affected by habitat type and it is recommended that you capture some form of habitat data at the same time that fish data are collected. This can be recorded at 5-metre segments along the transect and can be classified into abiotic and biotic categories. Example abiotic categories include large boulder complexes (LBC); small boulder complexes (SBC), platform reef with vertical crevices (fissures) (PRC); platform reef with horizontal ledges (PRL); low-lying platform reef with low complexity (PR); and cobble habitat (CH). Example biotic categories include mixed brown algae, *Ecklonia*, urchin barren, mollusc beds, sponge garden, seagrass beds and encrusting invertebrates.

Timing

Consideration of timing of the surveying activity should include:

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

Safety

Safety is paramount during any survey activity. The safety recommendations below are provided as general guidance, but it is imperative that the survey leader understands all risks associated with the activity, always uses caution, and develops a Safety Plan for the survey activity and location (DOC staff should use RiskManager, and non-Departmental staff should consult WorkSafe New

Zealand's 4-step risk management[13] or their own organisation's safety plans. Safety Plans should include resources (e.g. equipment, boats, communication, support, personal protective equipment), environmental hazards or considerations (e.g. remoteness, surf zones), personnel (experience, training, physical and mental fitness), weather and mission complexity. Following a thorough safety briefing, all team members should read and then sign the Safety Plan.

Specifically, it is recommended that:

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

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[13] https://worksafe.govt.nz/managing-health-and-safety/managing-risks/how-to-manage-work-risks

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Appendix A

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

doccm-1543359	Field data sheet (common name)
doccm-1543029	Field data sheet (scientific name)
doccm-1561621	Fieldwork underwater sheets for Poor Knights
doccm-2806683	Fish size calibration data analysis tool
doccm-2791243	Fish size calibration underwater training sheet
doccm-1450395	Marine: baited underwater video surveys for fish
doccm-1163829	MPAMAR metadata—national
doccm-1354867	New Zealand Marine Habitat Classification Scheme
doccm-146272	Standard inventory and monitoring project plan
doccm-2780650	Survey field data sheet