Australia's National
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Gears and methods used for scientific sampling in Australian Marine Parks

Values, benefits and impacts

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Executive summary

This document supports assessments of scientific sampling in marine parks. This involves considering the needs for different types of scientific sampling within Australian Marine Parks (value and benefit), and the potential consequences of doing so (risks and impacts).

Relevant structural and operational information is presented in a series of information sheets for each of a comprehensive range of individual scientific sampling gears (tools) and methods, and on the potential impacts that may result from using them – including by providing relevant, but general, ecological context. Impact and risk information provided is necessarily brief but draws on a consideration of ecological risk assessment methodology.

Part I: provides context for the concepts of value, benefit, risk, impact and vulnerability used here.

Part II: explains the format and content of the templates used to provide information on sampling gears (tools) and methods, and the terms, definitions and vocabulary used.

Part III: summarises the complex information for each of 71 gears and methods in 47 individual templates, including by using a set of icons to depict the target biota and habitats, and purposes of sampling.

Each template details the construction and components of a gear or method, its size and sampling 'footprint', describes the ways it is used, and identifies the value and benefit of the samples and data collected – including with examples from the published literature. Potential direct, indirect and ecosystem-level impacts are summarised, and emphasis is placed on differentiating between '**extractive'** and **'non-extractive'** sampling.

Many gears and methods covered by this report are non-extractive, that is, collecting is limited to data from sensors, data loggers, gauges, or cameras. These include aerial surveillance methods (planes, drones and airborne sensors); several acoustic tools including sonars and seismic arrays; tethered and free-swimming submersibles; buoys; imaging platforms, landers and gliders. Extractive gears and methods include water samplers that collect suspended particles including plankton, microbes and eDNA, grabs and corers that collect seabed sediments and their biota, and a great variety of gears – trawls, sleds, traps, plates and hooks – used to collect seabed and water column biota including larger and mobile fauna, typically fishes and invertebrates.

Extractive scientific sampling is often essential for advancing scientific knowledge, e.g. to provide biodiversity inventories for marine parks – including specimens enabling accurate taxonomic identifications and museum curation, provide biological tissues for genetics or biochemical tracer studies, or community-scale metrics for biota. These samples are required to understand ecological properties such as patterns in faunal composition and structure, population connectedness, or changes (recovery) following management intervention.

Part I Scientific sampling in Australian Marine Parks

1 Introduction

Up to date science informs adaptive management of over a third of Australian waters within 60 Australian Marine Parks. Science provides valuable evidence to inform priorities, assess performance and adjust management actions. This report and associated templates are focused on sampling to support science regarding natural values (see Hayes et al., 2021) within these parks.

The project's overall aim was to (1) demonstrate the tactical and strategic values and benefits of scientific information provided by different sample types and (2) enable an informed and consistent accounting of sample value and sampling impact. The challenge is to provide summary information for each of a wide range of scientific sampling gears used to sample a highly diverse range of environments, habitats and biota without doing complex risk assessments for each possible scenario. To achieve this, we have firstly explained the concepts of risk assessment and the framework previously adopted by Parks Australia. We then explain how this complex information is summarised and presented in 47 individual templates covering a total of 71 gears and methods. Finally, we provide a rationale for how and why scientific samples are necessary inputs to Australia's evidence-based and adaptive management approach for its marine parks.

1.1 Concepts of impact and risk, and Parks Australia's risk framework

There are many definitions of risk and many approaches to risk assessment (Burgman, 2005). For example, 'risk' can be the type or extent of an adverse impact caused by a specified activity, or the probability that a specified management objective is not achieved. The latter approach is used by Parks Australia, where risk is defined as the "effect of uncertainty on objectives" and is measured in terms of likelihood and consequence (ASNZS, 2009).

It is important to clearly define the terms used to describe the relevant features of risk assessments because the approaches differ, many terms are required, and definitions are not used consistently across applications. In this section, the key terms are underlined, related terms are defined in Table 1. The way in which these terms are applied to individual scientific sampling gears is defined in the following section.

In the present context, the core objective of Australian Marine Park management planning is to provide for the protection and conservation of biodiversity and other natural, cultural and heritage values, i.e. the attributes that make an Australian Marine Park or network unique (DNP, 2021). This objective extends to providing for the ecologically sustainable use and enjoyment of the natural resources in an Australian Marine Park, where these are consistent with protection and conservation.

Here then, we translate the Parks Australia meaning of 'risk' in the context of their core objective to be the "potential risk of scientific sampling adversely impacting marine park values to an extent where their protection and conservation is compromised". Impact, in this context, is an effect or influence, usually physical, direct or indirect, typically adverse and unwanted.

Risk assessment needs to identify the impacts that may stem from a particular sampling gear or method: their nature, spatial extent, and persistence. Reducing uncertainty (and therefore risk) in, for example the Authorisation process, is then achieved by (1) differentiating plausible impacts from implausible impacts, (2) estimating the level of interaction (disturbance), e.g. relative spatial extents of impact and value (ecosystem), and (3) by applying relevant ecological knowledge of the vulnerability of the marine park value possibly being affected – for example, the spatial extent, resistance and resilience of habitats, and the distribution, abundance and life history traits of species and populations.

Two models have been used to assess ecological risk in the Australian marine environment. In the marine parks context, potential risk is assessed using a conventional likelihood-consequence model. This approach has been applied to ecological risk assessment, e.g. in fisheries (Fletcher, 2005), but is more typically used by organisations to assess rare and unpredictable events or unintended 'accidents'. It is a versatile and flexible model, but may have rather general criteria for gauging the consequence of a particular impact – and this is the case for assessing the ecological consequences to conservation values within Australian Marine Parks.

Alternatively, an exposure-effects risk model considers the relative vulnerability of ecosystem components. It has been widely used in Australia and elsewhere when impacts are expected and/or sustained, for example to assess the effects of commercial fishing on biodiversity: species, communities and habitats (Hobday et al., 2011). In this model, potential risk is visualised on two axes describing 'susceptibility' and 'productivity'. These concepts are equivalent to the terms used to describe vulnerability in ecology, for example, the potential susceptibility of a habitat can be thought of as its resistance or ability to avoid impact by a specific sampling gear (high susceptibility = low resistance), and productivity as its resilience or inherent regeneration rate and ability to recover from impact (high productivity = high resilience) (Bax and Williams, 2001; Williams et al., 2011). Similarly, susceptibility and productivity of a species or population is determined by traits and demographic attributes such as body form, longevity, growth rate, fecundity, recruitment, and natural mortality. Thus, the strength of the exposure-effects model when compared to a likelihood-consequence model is that it provides more transparency about its methods, data and assumptions, and therefore enables a more informed method of evaluation.

The model is, however, more complex and time-consuming to implement, and limited knowledge about ecological interactions limits its usefulness to the marine parks application.

In the present context, we have drawn on both models for an approach to rapidly assess the potential risk that scientific sampling may adversely impact marine park values to an extent that compromises Parks Australia's objective to protect and conserve them. We have used specific attributes of vulnerability, i.e. susceptibility and productivity, captured in the exposure-effects approach to inform the choice of consequence criterion in the likelihood-consequence model by:

- quantitatively estimating a 'level of sampling disturbance'
- qualitatively evaluating availability, removal and mortality (susceptibility) of habitats and biota – mainly in the context of extractive sampling
- qualitatively evaluating 'inherent productivity' (resilience) of habitats and biota, and its relationships to environmental gradients

Importantly, the likelihood criterion must be carefully applied in the scientific sampling context: the likelihood of the sampling event is typically 'almost certain' on the grounds that a sampling plan has been proposed, however, the likelihood of the sampling event being a high-risk event is 'rare'.

Table 1 Terms and definitions relevant to risk assessment as used in this report to describe the value, benefit, potential risk and impact of scientific sampling in marine parks

Term	Definition/ usage in the present context
Activities	Sampling (collecting material and/ or data) with gears/ methods during scientific survey.
Benefit	The worth of scientific data/ knowledge to informing management plans/ processes.
Consequence	The extent to which the management objective is compromised (described by the degree of impact on conservation values).
Conservation value	Typically, a held natural (biodiversity) property of a marine park (but also cultural, heritage, social and economic values).
Destructive activities	Sampling that, deliberately or accidentally, causes widespread, catastrophic, or permanent damage to habitats, populations or listed species.
Ecosystem	Marine habitats defined by depth, geomorphology and biotope.
Extractive sampling	Sampling that removes biota and/ or physical material (sediment/ water), or results in in situ mortality of biota.
Habitat	Areas defined by distinctive, co-occurring biota and physical substrata. Used as general labels (our system of icons) to describe ecosystem components and their degree of accessibility to certain scientific sampling gears.
Impact	An effect or influence [of a scientific sampling gear or method], usually physical, direct or indirect, typically adverse and unwanted.
Likelihood	The probability of the risk being realised, i.e. the management objective being compromised (described by a frequency of the risk event).
Objective	Specific goal for marine park management plans.
Potential risk	The possibility that scientific sampling may adversely impact marine park values to an extent where their protection and conservation is compromised
Precautionary approach	For natural values, e.g. restricting the scope or duration of the activity, monitoring its impacts.
Resistance	Inherent ability to avoid impact by sampling gear (high resistance = low susceptibility).
Resilience	Inherent ability to recover from impact by sampling gear (high resilience = high productivity)
Risk	The effect of uncertainty on objectives - measured in terms of likelihood and consequence.
Risk events	Scientific sampling activities posing a potential risk to a conservation value in a marine park.
Scientific value	The relative worth of a sample or data for advancing scientific knowledge, including properties of comparability (e.g. standardised for time-series), cost-effectiveness, novelty, or rarity.
Sensitive	See 'Susceptible'
Susceptibility	A natural value with attributes that confer the degree to which it will be adversely affected by exposure to sampling activities, e.g. delicate, long-lived, slow-growing fauna are intrinsically more susceptible than robust, short-lived, fast-growing fauna.
Uncertainty	Deficiency of information of an event, its consequence or likelihood, i.e. being unsure whether scientific sampling may adversely impact marine park values to an extent where their protection and conservation is compromised.
Vulnerability	A natural value (habitat or species) with attributes that make it susceptible to impact, and with possible exposure to the impact

1.2 Impact and risk for individual sampling gears

A wide range of impacts could result from interactions between the numerous sampling gears used by marine scientists (over 70 in number, Table 5) and the variety of marine ecosystems that exist in marine parks. The need here is to briefly summarise this complexity for individual gears in relation to both impact and risk, and in a way that is informative to authorisation assessments. Such a summary requires that the effects (impacts) of scientific sampling (the gears and methods used to collect research samples and data) and the environmental properties of ecosystems are broadly classified.

The potential ecological impact stemming from scientific sampling can be usefully informed by a range of environmental properties and gradients relevant to understanding both susceptibility and productivity. Susceptibility is determined by the availability of habitat or biota to the gear, and the removals and mortality that results from sampling. Productivity (the accumulation or recovery of biota to pre-disturbance state) is determined by intrinsic growth and reproductive rates that are variable in different regimes of temperature, nutrient and productivity. The general characteristics that can be applied in this context include that:

- Habitat susceptibility is lower (resistance is higher) when characterised by hard, high relief and rugged topography. Importantly, extractive mobile gears – beam trawls and fish trawls – are not able to sample ecosystems characterised by reef habitats.
- Biological susceptibility is higher (resistance is lower) in epifauna and flora with a body form that is erect, large, rugose, inflexible, or delicate because they are preferentially removed or damaged and mortality is assumed (compared to epifauna and flora with body form that is prostrate, small, smooth, flexible and robust). Similarly, in sediments at the depths disturbed by mobile gears, large or delicate and shallow burrowing infauna are more susceptible than small, robust or deep-living infauna.
- Productivity (resilience) will generally be higher where natural disturbance is higher, e.g. higher in shallow environments subject to dynamic tidal and storm-influenced water currents, than in quiescent deep environments where the tempo of natural disturbance is relatively slow.
- Productivity (resilience) will generally decline with increasing depth and increasing latitude, i.e. will be lower in abyssal and deep slope that shelf ecosystems, and lower in temperate than tropical environments.

The two steps by which the risk evaluation model (particularly the consequence criterion) can be informed by the information provided as context and in the template are as follows:

(1) A quantitative estimate of 'level of sampling disturbance' is calculated by expressing the total sampling footprint (gear footprint per sample x number of samples) as a proportion of the areal extent of the ecosystem within the Australian Marine Park being sampled. The areal extents of

ecosystems have been calculated using their mapping based on the Australian Marine Park Ecosystem Model (Hayes et al., 2021), and the gear footprints can be estimated quantitatively when the dimensions of the sampler (from Templates in Part III) and, for towed gears, the tow distance is known (survey specific). This general calculation, applicable to all gears and marine parks, is illustrated in specific examples for four scientific sampling gears (respectively, beam trawls, fish trawls, benthic sleds and demersal longline) in Box 1 to Box 4. The sets of results in Box 1 to Box 4 that include real case examples and realistic maximum sampling intensity (number of samples) show the level of disturbance (total survey footprint/ecosystem area in Australian Marine Park) is negligible (< 1% and typically < 0.1%) in all cases (except in rare cases where an ecosystem has very small representation within certain Australian Marine Parks, e.g. examples illustrated in Box 3 and Box 4).

This demonstrates that surveys involving the use of extractive mobile scientific sampling gears in most cases have an insignificant consequence and no plausible likelihood of risk that compromises Parks Australia's objective of protecting and conserving biodiversity in Australian Marine Parks. This can be stated with high certainty in all but exceptional circumstances. (2) If there is remaining uncertainty about risk to the ecosystem stemming from a concentration of sampling impact on values within the overall sampling footprint, or other factors including cumulative impacts, then two qualitative evaluations can be made:

(a) Is it possible for the sampling gear to access and then remove biota, particularly if biota represent conservation values and especially those with special conservation importance – e.g. areas of high biodiversity and listed species?

(b) What can be inferred about the inherent ecosystem productivity based on environmental gradients?

In the present context, scientific sampling can be usefully classified as either <u>extractive</u> or <u>non-extractive</u>, and as having direct or indirect effects.

Extractive sampling is the removal of biota or physical material (including water) from an environment; in the case of biota, extraction typically results in death. **Non-extractive sampling** is achieved using cameras or sensors, typically with no physical environmental impact, and no impact on biota beyond a minor, localised, and short-term disturbance. Thus, the specific characteristics of extractive gears and methods are useful for qualitatively grading relative impacts and risk across the full range of gears and ecosystems, and their interactions.

Direct sampling effects, such as removals or short-term disturbances, mostly stem from extractive gears such as nets and dredges, and can be thought of as immediate interactions between a gear and the biota and environment. Because these effects are most easily predicted, and may be measurable, they can be better accounted for in a qualitative assessment of potential impact. Indirect effects, for example those on non-target biota such as changes to food-web interactions, or smothering by sediment plumes from mobile sampling gears, are less predictable in terms of certainty or magnitude and are often unmeasurable. Accordingly, they are more difficult to account for – even in a complex risk model.

It is important to note here that extractive scientific sampling is commonly mis-labelled as 'destructive', but this loaded term is inappropriate and inaccurate for science sampling, particularly within marine parks. Destructive 'sampling' can be appropriately defined as deliberately or accidentally causing widespread, catastrophic, or permanent damage to habitats, populations or listed species. As such, its use should be limited to only to a few extreme forms of commercial or industrial extractive processes such as dynamite or poison-based fishing on coral reefs, and interactions between dredges/ trawls and delicate biogenic habitats.

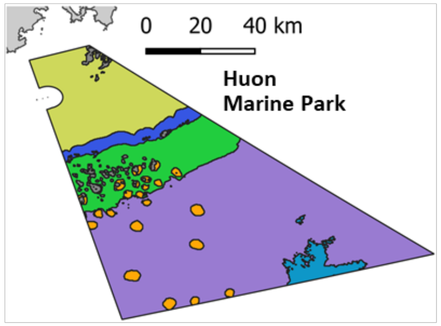
Two general potential "pressures" on the environment that may stem from science sampling are contributions to marine debris (e.g. microplastics and litter on islands) and the introduction of marine pests (e.g. in vessels' ballast water) Hayes et al., (2021). These are not considered further here, partly because they are not gear-specific but also because we assume that best practices would be employed to minimise these avoidable sources of impact.

Box 1 Level of disturbance from BEAM TRAWL for three sampling intensities in the Huon and Montebello Marine Parks. This approach may be used to calculate the level of disturbance in any marine park and for any gear where the area of the ecosystems, the gear's footprint (from templates in Part III) and the intended number of samples are known.

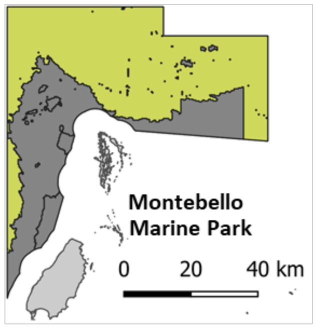
BOX 1: Estimating the **level of disturbance** impact [(collective footprint of samples taken during survey/ecosystem area)x100%] for **beam trawl**. Estimates provided are for a range of sampling intensities in two Australian Marine Parks – the Huon AMP (relatively large) and Montebello (relatively small).

Method: The swept area or 'footprint' per sample (effective sampling width of gear x transect length) is multiplied by the number of samples (transects) to generate a planned total survey footprint.
Parameters: The values used here are representative of scientific beam trawl sampling in the Australian marine environment: a 4-m wide beam trawl with transect lengths used for survey in offshore depths (~50 to 5,000m); these are longer in deeper depths to account for lower abundance of target fauna; the range of sample numbers corresponds to a low sampling intensity (25 samples); likely maximum intensity (50 samples), and indicative extreme (100 samples).

BEAM TRAWL



	Ecosystem type	Ecosystem area (km^2)	Transect length (km)	Footprint (per sample[A] km^2)	Level of disturbance (%) 25 samples	50 samples	100 samples
	Shelf unvegetated sediments	1711	0.5	0.002	0.003	0.006	0.012
	Upper slope unvegetated sediments	332	1	0.004	0.030	0.060	0.120
	Mid slope sediments	1335	1	0.004	0.007	0.015	0.030
	Lower slope reef and soft sediments	5863	5	0.02	0.009	0.017	0.034
	Abyssal reef and sediments	302	5	0.02	0.166	0.331	0.662
	Seamount sediments	262	1	0.004	0.038	0.076	0.153



	Ecosystem type	Ecosystem area (km^2)	Transect length (km)	Footprint (per sample[A] km^2)	Level of disturbance (%) 25 samples	50 samples	100 samples
	Shelf unvegetated sediments	2163	0.5	0.002	0.002	0.005	0.009

[A] 4-m standard beam trawl x transect length

Interpretation: The level of disturbance measured as survey-scale footprint, at the ecosystem spatial scale is negligible in all cases (< 0.7%, mostly < 0.1%). This demonstrates with a high certainty that there is an insignificant consequence and no plausible likelihood of risk that compromises the objective of protecting and conserving biodiversity that will result from extractive beam trawl sampling.

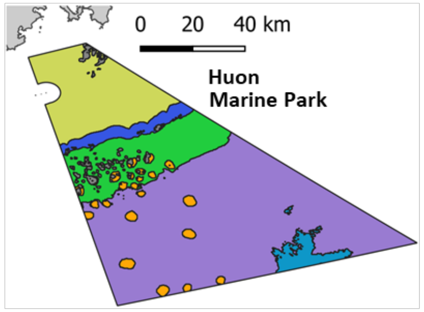
Box 2 Level of disturbance from DEMERSAL FISH TRAWL for three sampling intensities in the Huon and Gascoyne Marine Parks. This approach may be used to calculate the level of disturbance in any marine park and for any gear where the area of the ecosystems, the gear's footprint (from templates in Part III) and the intended number of samples are known.

BOX 2: Estimating the **level of disturbance** impact [(collective footprint of samples taken during survey/ecosystem area)x100%] for **demersal fish trawl**. Estimates provided are for a range of sampling intensities in two Australian Marine Parks – the Huon MP and Gascoyne MP.

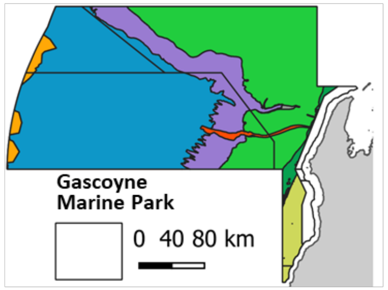
Method: The swept area or 'footprint' per sample (effective sampling width of gear x transect length) is multiplied by the number of samples (transects) to generate a planned total survey footprint. – Here we used the door spread as the effective width as this represents the extreme of the footprint.

Parameters: The values used here are representative of scientific demersal fish trawl sampling in the Australian marine environment: an estimated door-spread of 90 m, with transect lengths used for survey in offshore depths (~50 to 3,000 m – note abyssal depth >4000 m are beyond this sampling gear); these are longer in deeper depths to account for lower abundance of target fauna; the range of sample numbers corresponds to a low sampling intensity (25 samples); likely maximum intensity (50 samples), and indicative extreme (100 samples).

DEMERSAL FISH TRAWL



Ecosystem type	Ecosystem area (km²)	Transect length (km)	Footprint (per sample[A] km²)	Level of disturbance (%)		
				25 samples	50 samples	100 samples
Shelf unvegetated sediments	1711	2.4	0.010	0.014	0.028	0.056
Upper slope unvegetated sediments	332	2.4	0.010	0.072	0.145	0.289
Mid slope sediments	1335	2.4	0.010	0.018	0.036	0.072
Lower slope reef and soft sediments	5863	4.8	0.019	0.008	0.016	0.033
Abyssal reef and sediments	302	n/a	n/a			
Seamount sediments	262	2.4	0.010	0.092	0.183	0.366



Ecosystem type	Ecosystem area (km²)	Transect length (km)	Footprint (per sample[A] km²)	Level of disturbance (%)		
				25 samples	50 samples	100 samples
Shelf unvegetated sediments	2613.06777	2.4	0.010	0.009	0.018	0.037
Upper slope unvegetated sediments	1002.94535	2.4	0.010	0.024	0.048	0.096
Mid slope sediments	25411.0181	2.4	0.010	0.001	0.002	0.004
Lower slope reef and soft sediments	10700.4376	4.8	0.019	0.004	0.009	0.018
Abyssal reef and sediments	39765.078	n/a	n/a			
Seamount sediments	1399.80591	2.4	0.010	0.017	0.034	0.069
Shelf incised canyons	663.944692	2.4	0.010	0.036	0.072	0.145

[A] 90m estimated door spread of Fish trawl x transect length; Abyssal depths (>4000 m) are beyond sampling depth for this gear.

Interpretation: The level of disturbance measured as survey-scale footprint, at the ecosystem spatial scale is negligible in all cases (< 0.4%, mostly < 0.1%). This demonstrates with a high certainty that there is an insignificant consequence and no plausible likelihood of risk that compromises the objective of protecting and conserving biodiversity that will result from extractive demersal fishtrawl sampling.

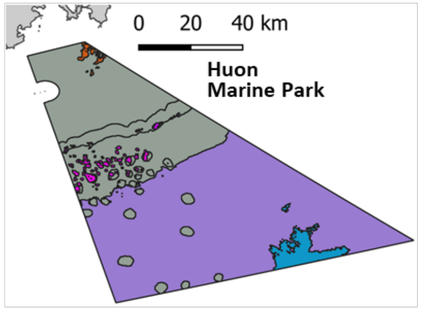
Box 3 Level of disturbance from SHERMAN HARD-BOTTOM SLED for three sampling intensities in the Huon and Perth Canyon Marine Parks. This approach may be used to calculate the level of disturbance in any marine park and for any gear where the area of the ecosystems, the gear's footprint (from templates in Part III) and the intended number of samples are known.

BOX 3: Estimating the **level of disturbance** impact [(collective footprint of samples taken during survey/ecosystem area)x100%] for **hard bottom sled**. Estimates provided are for a range of sampling intensities in two Australian Marine Parks – the Huon MP and Perth Canyon MP.

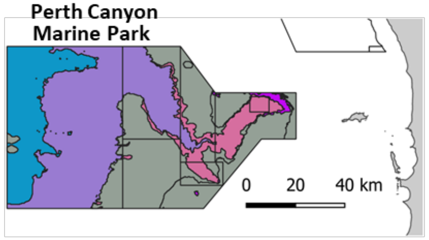
Method: The swept area or 'footprint' per sample (effective sampling width of gear x transect length) is multiplied by the number of samples (transects) to generate a planned total survey footprint.

Parameters: The values used here are representative of scientific hard bottom sled sampling in the Australian marine environment: a 1.2 m wide Sherman sled, with transect lengths used for survey in offshore depths (~50 to 5,000m); these are typically very short in reef habitats, but longer in deeper depths to account for lower abundance of target fauna; the range of sample numbers corresponds to a low sampling intensity (25 samples); likely maximum intensity (50 samples), and indicative extreme (100 samples).

HARD BOTTOM SLED - SHERMAN



Ecosystem type	Ecosystem area (km^2)	Transect length (km)	Footprint (per sample[A] km^2)	Level of disturbance (%)		
				25 samples	50 samples	100 samples
Mesophotic rocky reefs	2	0.25	0.0003	0.375	0.750	1.500
Rariophotic shelf reefs	41	0.25	0.0003	0.018	0.037	0.073
Upper slope reefs	16	0.5	0.0006	0.094	0.188	0.375
Lower slope reef and soft sediments	5863	1	0.0012	0.001	0.001	0.002
Abyssal reef and sediments	302	1	0.0012	0.010	0.020	0.040
Seamount reefs	114	0.25	0.0003	0.007	0.013	0.026
Seamount sediments[B]	262	0.5	0.0006	0.006	0.011	0.023



Ecosystem type	Ecosystem area (km^2)	Transect length (km)	Footprint (per sample[A] km^2)	Level of disturbance (%)		
				25 samples	50 samples	100 samples
Rariophotic shelf reefs	1	0.25	0.0003	0.673	1.346	2.693
Upper slope reefs	67	0.5	0.0006	0.011	0.022	0.045
Mid slope reef	594	1	0.0012	0.003	0.005	0.010
Lower slope reef and soft sediments	2838	1	0.0012	0.001	0.002	0.004
Abyssal reef and sediments	1255	0.25	0.0003	0.002	0.005	0.010
Seamount sediments[B]	38	0.5	0.0006	0.039	0.078	0.156

[A] 1.2-m Sherman sled x transect length. [B] Seamount sediments may also be targeted with Sherman sled

Interpretation: The level of disturbance measured as survey-scale footprint, at the ecosystem spatial scale is negligible in all cases (< 0.4%, mostly < 0.01%) except for the shallowest ecosystem in each AMP, where the high sampling intensity is unreasonable due to its small size. This demonstrates with a high certainty that there is an insignificant consequence and no plausible likelihood of risk that compromises the objective of protecting and conserving biodiversity that will result from extractive beam trawl sampling.

Box 4 Level of disturbance from DEMERSAL LONGLINE for three sampling intensities in the Hunter Marine Park. This approach may be used to calculate the level of disturbance in any marine park and any for gear where the area of the ecosystems, the gear's footprint (from templates in Part III) and the intended number of samples are known.

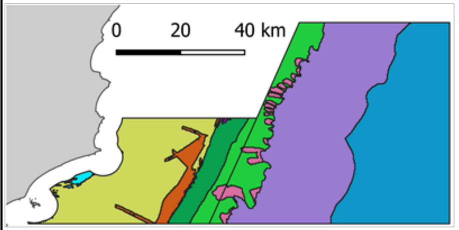
BOX 4: Estimating the **level of disturbance** impact [(collective footprint of samples taken during survey/ecosystem area)x100%] for **demersal longlines**. Estimates provided are for a range of sampling intensities in one Australian Marine Parks – the Hunter MP.

Method: The swept area or 'footprint' per sample (estimated width of gear movement on seafloor x line length) is multiplied by the number of samples (transects) to generate a planned total survey footprint.

Parameters: The values used here are representative of scientific demersal longline sampling in the Australian marine environment: a set of 1500 hooks at 1.4m distance between snoods (typical for auto-longlines) resulting in a line length of 2.25 km; we estimated 5m width of snoods & line movement as the width of interaction with the seafloor . The range of sample numbers corresponds to a low sampling intensity (25 samples); likely maximum intensity (50 samples), and indicative extreme (100 samples).

DEMERSAL LONGLINE

Hunter Marine Park



Ecosystem type 	Ecosystem area (km^2)	Line length[A] (km)	Footprint (per sample[B] km^2)	Level of disturbance (%) 25 samples	50 samples	100 samples
Shelf unvegetated sediments	1095	2.25	0.0027	0.006	0.012	0.025
Mesophotic coral reefs	24	2.25	0.0027	0.282	0.565	1.129
Rariophotic shelf reefs	170	2.25	0.0027	0.040	0.080	0.159
Mid slope sediments	579	2.25	0.0027	0.012	0.023	0.047
Mid slope reef	137	2.25	0.0027	0.049	0.099	0.198
Upper slope unvegetated sediments	276	2.25	0.0027	0.024	0.049	0.098
Upper slope reefs	10[C]					
Lower slope reef and soft sediments	2015	2.25	0.0027	0.003	0.007	0.013
Abyssal reef and sediments	1952	2.25	0.0027	0.003	0.007	0.014

[A] 1500 hooks at 1.4m distance between snoods; [B] 5m estimated width of snoods & line movement x line length;
[C] ecosystem is under-represented in MP, it may be transversed by gear but would not be separately targeted

Interpretation: The level of disturbance measured as survey-scale footprint, at the ecosystem spatial scale is negligible in all cases (< 0.2%), except for the mesophotic reefs ecosystem, where the high sampling intensity is unreasonable due to its small size. This demonstrates with a high certainty that there is an insignificant consequence and no plausible likelihood of risk that compromises the objective of protecting and conserving biodiversity that will result from extractive beam trawl sampling.

1.3 Scientific value and management benefit

To complete the templates developed for individual scientific sampling gears (Part II of this report), the following definitions are used:

- **Scientific Value** is the relative worth of a sample or data for advancing scientific knowledge. The intrinsic value of any sample is enhanced if it has properties of comparability (standardised for method and data structure), cost-effectiveness, novelty or rarity. Comparability is particularly relevant to marine parks because standardised data are necessary for time-series analysis to understand and monitor change, e.g. ecological status of values following management intervention. In some cases, value may be enhanced, or may only be realised, if a complementary suite of samples are taken by different gears or methods. Considerable additional detail on value is provided in Table 2.

  It is important also to note the essential value of extractive sampling, necessary to adequately characterise biodiversity in unexplored areas of Australian Marine Parks – typically the majority of areas within most parks. It has been, and will continue to be, important to establish an inventory baseline in the early years of park management so that conservation values can be identified and monitored, and management effectiveness evaluated over time. Collection of fishes, sessile invertebrates and infauna ('extractive' samples), allows confident and authoritative taxonomic identifications of species to be made, and collections securely curated in museum collections. Management decision-making for Australian Marine Parks is typically at an ecological community level, but this is importantly informed by species-level information – distribution, patterns of endemicity and biodiversity metrics. Biological collections also assist in identifying and validating species to enable the development and increased use of non-extractive sampling, e.g. image-based analysis and monitoring. Extractive sampling of sediments and/ or water is required for analyses of aspects of the physical environment (geology) and for the collection of eDNA.

- **Benefit** is the worth of scientific data/ knowledge to informing management plans/ processes. The intrinsic benefit of science data sets and knowledge is exemplified by the fundamental need for information that documents the identity and composition of biota (biodiversity inventory) because this is typically unknown or incompletely known for most areas of most Australian Marine Parks. There is a wide range of applications beyond inventory that include status monitoring and understanding climate-proofing of individual and networks of marine parks.

  Each research sampling gear, whilst useful in its own right, can have limitations and will often need to be used in combination with others to achieve the science objective of a project or voyage. Thus, benefits in the form of outcomes for management may only stem from integrated sampling. For example, underwater imagery and visual census is an important tool to characterise habitat and abundance and diversity of species within communities, however, to achieve this may require collecting biological samples that are co-located in time and space using nets.

Part II Terminology, Definitions and Vocabularies

2 Gear template lay-out and definitions

2.1 Template lay-out

The main part of this report (Part III) contains a series of 1-page templates that describe sampling platforms, tools and methods commonly used for scientific sampling in Australian Marine Parks (Figure 1). Each template details the general function, components, size range, footprint and operations for a sampling platform, tool or method as used in a research setting.

Icons are used to depict the *sample type(s)* derived from using the gear (Table 2), the *habitat types* the gear is sampling (Table 3), and the *target biota* (Table 4) that is typically sampled using the gear.

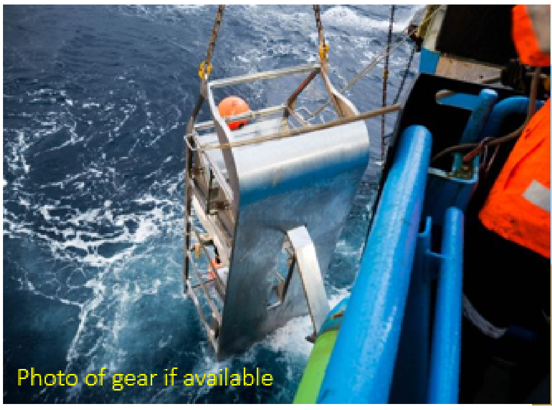
The *scientific values and benefits* of samples, derived from using the gear are detailed in dot-points drawing from literature references; in addition, Table 2 summarise the values and benefits of the sample type in general.

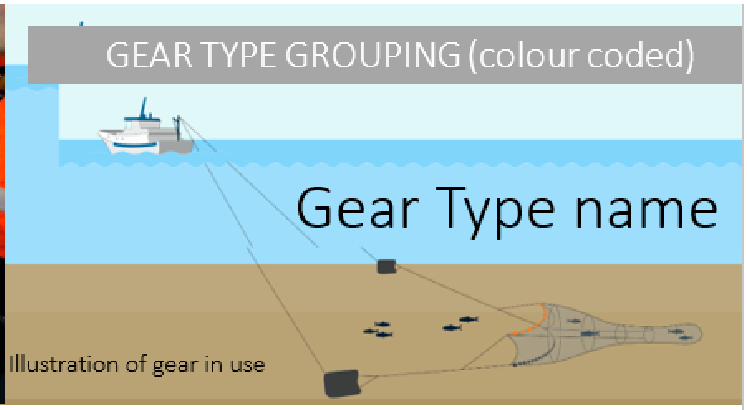
Impacts and vulnerability are detailed under a set of sub-headings:

- **Direct impact** is the direct physical (often mechanical) impact on target biota/ habitat from the gear. Unless stated otherwise, removal of target biota results in their mortality.
- **Indirect impact** is an effect on non-target biota/ habitats or an effect propagated by the gear (such as smothering by resuspended sediments that result from the passage of mobile sampling gear).
- **Ecosystem level impact** is a broader spatial or population-level impact on target biota/ habitat at the level of the ecosystem (ME derived definition) within an Australian Marine Park (see Box 1 to Box 4).
- **Resilience of values to the activity** is the natural ability of the target biota/ habitat to withstand and/ or recover from an impact.
- **Mitigation** is the process to implement structures or actions that reduce (minimise) impacts from sampling (if applicable).

For ease of reference and comparison, the sampling gears are grouped into 11 broad categories, each identified by a separate colour band on the template.

Figure 1 GENERIC TEMPLATE describing the lay-out of the gear templates and describing the general content found under the respective headings.





A short statement of the use and data collected by the gear, followed by a description of the gear's main components, including variations and reference to different designs. Where the interaction with the habitat/ biota of different designs of the same gear type are essentially the same, they are combined in a single template.
While the description aims to encompass the designs currently used in Australia, it is not limited to these, in anticipation of new designs with same generic impact entering the market.

OPERATION

General description of how the gear is typically operated.

SCIENTIFIC VALUE & BENEFIT

Dot points of the scientific value & benefits derived from sampling with the gear

General Value/Benefit of the four *sample types* identified in icons are summarised in the report (Table 2)

IMPACTS & VULNERABILITY

Direct impact: direct impact on target biota / habitat of a **single deployment** of the gear. Unless stated otherwise, where *targe biota* is removed, this means death of *target biota*.

Indirect impact: indirect impact – impacts on non-target biota/habitats of a **single deployment** of the gear.

Ecosystem level impact: Impact on target biota/ habitat at the level of the ecosystem (MERI derived definition) within an AMP.

Resilience of values to the activity: Innate resilience of the target biota/ habitat to the type of impact from the gear

Mitigation: Methods to reduce direct, indirect and ecosystem level impacts from sampling with the gear (if applicable).

SAMPLE TYPE

Icons identifying the sample type derived from using the gear **(Table 2)**

SIZE

Ranges of the dimensions of the gear (general and **not limited** to gears currently available/used in Australia)

FOOTPRINT

Description of how footprint on the **seafloor** can be derived

HABITAT TYPE

Icons identifying the habitat types the gear potentially interacts with **(Table 3)**

TARGET BIOTA

Icons identifying the biota targeted by the gear type. **(Table 4)**
Note: gear types which do not explicitly target biota e.g., cores do not have target biota

REFERENCES: references used are identified by superscripted numbers in the text; here they are identified using referencing style Author et al., YYYY. A full list of collated references is presented at the end of the report.

2.2 Template Icons

Table 2 SAMPLE TYPE

Sample Type	Term	Description	Purpose
	Data – number value	Gear type/ method collects a number value. These are usually sensors that measure physical or chemical properties (e.g., temperature, depth, salinity, current speed/ strength)	Sensor data delivering measurements of the physical and chemical properties of the environment underpin 1) basic mapping of the seabed topography, and 2) physical oceanography that maps and describes the distribution and movements of water masses. These environmental data are used to explain and predict the distribution of biota.
	Representation – image	Gear type/ method collects a pictorial representation of the ecosystem (e.g., video, stills image, echogram)	Imagery data commonly captures the *in-situ* context so information about the community structure and habitat is retained (not the case when collecting physical samples). Commonly used to compliment or validate physical sampling (e.g., acoustic determination of fishes). Non-extractive sampling over broad spatial scales and suitable for multiple habitat types and applications.
	Extractive – physical resources and associated microbes	Gear type/ method collects a physical sample	Collecting water or substrate samples (sediments/ rocks) is essential for baseline data for geology and hydrology, as well as to ground-truth and/or calibrate sensor data. The samples can also provide biological information through microbes, but also eDNA.
	Extractive – living resources	Gear type/ method collects a physical sample (whole or partial) Death of *target biota* is assumed for whole specimen sampling unless stated otherwise.	Collecting faunal samples is essential for baseline data (species inventories), to ground truth image data and advance taxonomic knowledge, inc. molecular methods e.g. eDNA[3,4]; also applied to predictive models, fishery stocks assessment; change/ status monitoring. Specimens can be lodged in museum collections for perpetuity.

Table 3 HABITAT TYPES — (definitions based largely on Hayes et al., 2021)

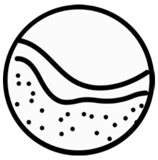
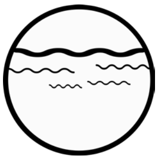
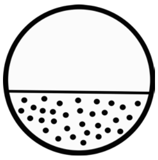
Category	Term	Definition
	Aerial & water surface	Air space above and its interface with the sea surface or ground. Habitats for biota including seabirds and marine mammals
	Rocky shores	An intertidal area composed of rock pools, platforms, boulders or cobbles, hosting sessile and mobile epifauna.
	Beaches	Gently sloping zone of sand and/or gravel and/or biological fragments along the shore, extending from the highest high-tide point to the lowest low-tide point. Habitat for a range of biota including shorebirds, marine reptiles and infauna.
	Water column	The entire water body between the surface of the ocean and the seafloor. Habitat for a range of biota including plankton, nekton, marine reptiles and pelagic fish.
	Water column and all benthic habitats	The entire water body between the surface of the ocean and the seafloor, and all benthic habitat types.
	Sediment unvegetated	Sediments (unconsolidated, e.g., pebble, gravel, sand, mud) without structural biota (e.g., macroalgae, bryozoa)
	Sediment vegetated	Sediments (unconsolidated, e.g., pebble, gravel, sand, mud) with structural biota (e.g., macroalgae, seagrass, bryozoa, octocorallia).
	Rocky reef	Outcrops of rock and other hard or consolidated substratum types. Habitats typically host diverse, attached biota, including cold/deep-water coral communities.
	Coral reef	Reef formed by tropical corals in the photic zone. Habitats for a diverse community of sessile epifauna and fish.

Table 4 TARGET BIOTA — (definitions based largely on Hayes et al., 2021)

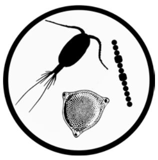
Category	Term	Definition
	Seabirds	Seabirds of the open ocean, beyond the intertidal or surf zone.
	Shorebirds	Shorebirds associated with intertidal areas and fringes of waterways.
	Marine mammals	Mammals (cetaceans and pinnipeds) that live exclusively or primarily in the marine environment.
	Marine reptiles	Reptiles (lizards, crocodiles, turtles and sea snakes) that live exclusively or primarily in the marine environment.
	Sharks and rays	All cartilaginous fishes (sharks, rays, skates and chimeras)
	Plankton	A highly diverse biota including phytoplankton, major invertebrate groups and fish larvae inhabiting the water column that drift in currents and tides.
	Micronekton and nekton	Primarily small fishes and crustaceans, but also including large gelatinous zooplankton and squids, inhabiting the water column that are free-swimming; many are diel vertical migrators.
	Pelagic fishes	Bony fish that are primarily associated with the water column.
	Benthic fishes	Bony fishes primarily associated with the seafloor (including benthopelagic species).
	Mobile invertebrates (epifauna)	Invertebrates (crustaceans, molluscs, sea stars and urchins) that are free moving on the sea floor, some may occasionally burrow into sediments for shelter.

Table 4 continued

Category	Term	Definition
	Sessile invertebrates (epifauna)	Invertebrates (anemones, corals, feather stars) that are sessile and fixed to the substrate or have limited mobility.
	Macroalgae & Seagrass	Marine plants that grow attached to the substrate. They are limited by the extent of light penetration.
	Infauna	Small organisms (nematodes, polychaetes, amphipods) that live within the upper sediment layer of the seafloor.

2.3 Gears included

Table 5 List of Templates presented in Part III, including the template title and a list of individual sampling gears/ methods, where the template title encompasses multiple gears.

Template	Individual sampling gears
Plankton Nets	Surface net Bongo nets Circular Plankton Net Dropnet EZ Net
Midwater Trawl (MIDOC)	Midwater Trawl Nets MIDwater Opening and Closing net system (MIDOC)
Demersal Fish Trawl	e.g. McKenna Market Trawl
Demersal Prawn trawl	
Beam trawl	
Rock Dredge	Rock Dredge Pipe Dredge
Hard bottom Sled	e.g. Sherman sled
Soft bottom Sled	e.g. Brenke sled
Traps	Fish traps Lobster/crayfish Pots
Sediment traps	
Settlement Plates	
Pelagic Longline	
Demersal Longline	
Dropline	
Handline	
Sediment Grabs	Smith-MacIntyre Grab Van Veen Grab Shipek Grab
Box Corer	
Corers	Gravity corer Piston corer Multi-corer Push corer
Observers	Human on ship/ shore/ plane
Coastal & intertidal sampling	
Divers & snorkellers	Diver observer Underwater visual census (UVC) Diver Operated Video (DOV) Manta Tow Diver collection/ experiments
Tagging	Conventional tags Archival tags Satellite tags Acoustic tags
Tissue sampling, Stomach flushing	Tissue sampling (biopsy) Stomach flushing

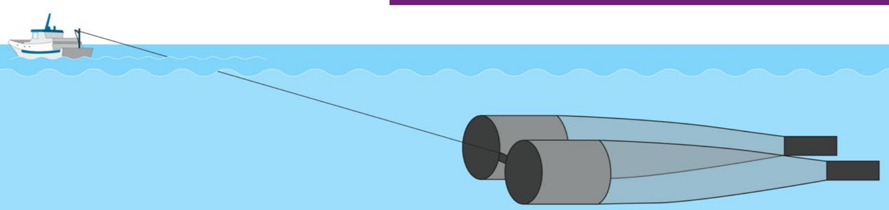
Table 5 continued

Gear type (section title)	Template	Individual sampling gears
Submersibles		
	Human Operated Vehicle (HOV)	
	Remotely Operated Vehicle (ROV)	
	Autonomous Underwater Vehicle (AUV)	e.g. IMOS AUV Sirius & Nimbus
Underwater Imaging Platforms		
	Profiling Langian Acoustic Optical System (PLAOS)	
	Towed Camera	
	Drop Camera	Drop Camera
		Video lander
	Pelagic Baited Remote Underwater Video (BRUV)	Pelagic BRUV
		Mid-water RUV
	Baited Remote Underwater Video (BRUV)	BRUV
		Underwater video (UV) Lander
Acoustic Sensors		
	Multibeam Echosounder (MBES)	
	Singlebeam Echosounder (SBES)	
	Side Scan Sonar (SSS)	
	Seismic Airguns	
	Sub-Bottom Profiler (SBP)	
	Hydrophones	
Other Sensors & Profilers		
	Conductivity-Temperature-Depth Profiler (CTD) & Niskin Bottles	CTD
		Niskin bottles
	Continuous Plankton Recorder (CPR)	
	Ocean Gliders & Argo Floats	Glider- Slocum
		Glider- Sea
		Argo floats
	Sound Velocity Profiler (SVP)	
	eXpendable Bathy Thermograph (XBT)	
	Moored Buoys	
	Drifting Buoys	
	No separate Template. Deployed on moorings, buoys and various other gears	Data loggers- attached
		Data loggers - drifting
		Current Meters/Profilers
		Tide gauges
		Atmospheric sampling
Aerial Methods		
	Aircraft	
	Drone	Drone
		Unmanned Aerial Vehicles (UAV)
		Remotely Piloted Aircraft Systems (RPAS)
	Laser induced Detection And Ranging (LiDAR)	

Part III Sampling Tools Templates

3 Trawls & Nets

Plankton Nets	Surface net Bongo nets Circular Plankton Net Dropnet EZ Net
Midwater Trawl (MIDOC)	Midwater Trawl Nets MIDwater Opening and Closing net system (MIDOC)
Demersal Fish Trawl	e.g. McKenna Market Trawl
Demersal Prawn trawl	
Beam trawl	



Plankton Nets
(Surface, Drop, Bongo, EZ)

Plankton nets are used to sample planktonic biota from near the surface or through the watercolumn. They are large conical or funnel shaped nets held open by a rigid frame, that are either towed along the surface (**Surface net**) or lowered to a predetermined depth and pulled up through the watercolumn, either vertically (e.g. **Drop net**) or obliquely (e.g. **Bongo net**, **EZ net**). Plankton nets may have a multi-net opening/ closing cod-end system (e.g. **EZ net**) for depth-stratified sampling. **Bongo nets** comprise twin circular frames with a net each to collect replicate samples.[1-4]

OPERATION[1,2]

Deployed from a surface vessel and towed with a warp wire connected to the frame of the net. Individual oblique tows and multiple samples from different depth strata require the net(s) to be retrieved through specific and pre-planned depth ranges.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *target biota*, particularly zoo- and phytoplankton[5,6].

* It is effective by representatively collecting *target biota*, and providing specimens in good physical condition.

*Abundance estimates can be quantitative if *volume swept* is estimated accurately, making it an essential sampler where populations statistics are required, e.g. status change following shifts in environmental conditions.

*Sampling over broad spatial scales is possible (transects of km in length) - important when *target biota* have low abundance, high diversity or spatially concentrated patchy distributions.

* Plankton nets have been used for surveys in Australia for 25+ years and represent important standard sources of time-series data[5,6].

* Plankton nets are also used for sampling of microplastics[4,7].

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *pelagic habitats*. *Target biota* are removed from the volume swept.

Indirect impact: None.

Ecosystem level impact: At a population level, impact on target species due to sample mortality is negligible. Target *habitat type* is the watercolumn where no habitat-level impact occurs.

Resilience of values to the activity: There are no habitat impacts; the planktonic *target biota* are typically resilient by virtue of high abundance, high productivity, broad distributions and low catchability.

Mitigation: Not applicable.

SAMPLE TYPE

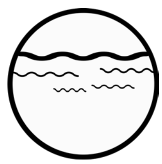
SIZE [2]

Frame diameter: 0.2-1 m
Mesh size various,

FOOTPRINT

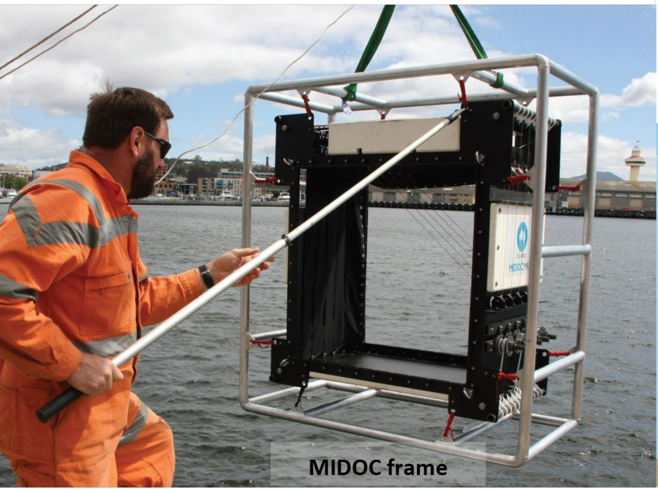
None, no bottom contact. (Volume filtered may be calculated.)

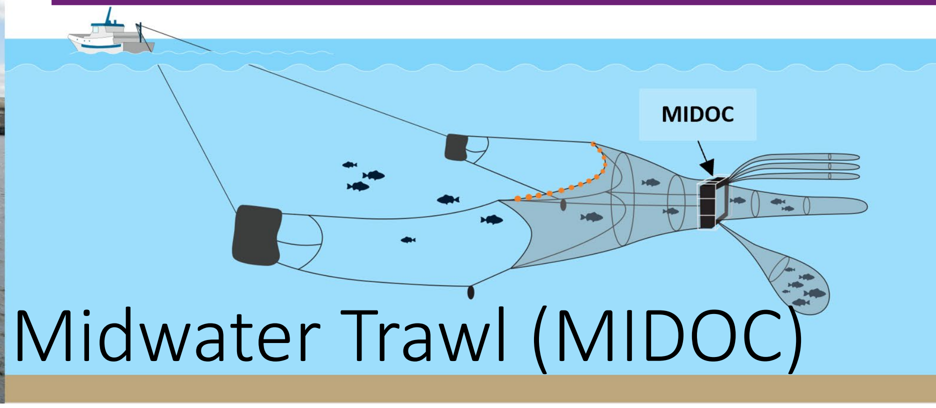
HABITAT TYPE



TARGET BIOTA

REFERENCES: [1]NOAA, 2022; [2]CSIRO MNF, 2022; [3]Everett et al. 2011; [4]Green et al., 2018; [5]Hallegraeff et al., 2020; [6]McEnnulty et al., 2020; [7]Jensen et al., 2019.





Midwater Trawl (MIDOC)

A midwater fish trawl is used to sample nekton and pelagic fishes. It is composed of a large conical or funnel-shaped net held open ('spread') by a trawl door attached to each side of the net with a wire 'sweep' and bridles. The trawl doors and sweeps herd the fish into the mouth of the net. Scientific midwater trawls often have an opening/ closing cod-end systems (e.g. MIDwater Opening and Closing net system – **MIDOC**) of multiple nets for depth-stratified sampling.[1-3]

SAMPLE TYPE

OPERATION[1-4]

Deployed from a surface vessel and towed with a warp wire connected to each of the trawl doors and towed at a target depth through the water column at 2-3 kt for ~30 min per sample. Commonly carries sophisticated telemetry sensors including a positioning beacon. When fitted with an opening/closing codend system, the system is controlled to close one net and open the next as the trawl is lowed across pre-set depth horizons. Operated from ~50 m down to 3000 m.

SIZE [3,5]

15-75 m W, 7-27 m H, Mesh size 10-40 mm depending on codend

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *target biota*, particularly schooling pelagic fishes and nekton.

* It is effective by representatively collecting *target biota*, and providing specimens in good physical condition.

*Abundance estimates can be quantitative if *volume swept* is estimated accurately, making it an essential sampler where populations statistics are required, e.g. status change following management intervention.

*Sampling over broad spatial scales is possible (transects of km in length) - important because abundance is typically low or spatially concentrated[8].

* Midwater Trawls have been used for surveys in Australia for 25+ years and represent a standard source of time-series data[3,6,8].

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *pelagic habitats*. *Target biota* are removed from the volume swept.

Indirect impact: Unintentional capture of marine mammals (seals/ sealions) and other non-target biota is rare but possible.

Ecosystem level impact: At a population level, impact on target species due to sample mortality is negligible. Target *habitat type* is the watercolumn where no habitat-level impact occurs.

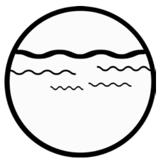
Resilience of values to the activity: There are no habitat impacts; the pelagic *target biota* are typically resilient by virtue of high abundance, high productivity, broad distributions and low catchability.

Mitigation: Impacts are minimised by informed planning and targeting of sample locations and using net sensors and a positioning system on the midwater trawl. Implementing commercially used mitigation methods, e.g. seal exclusion devices[1,7].

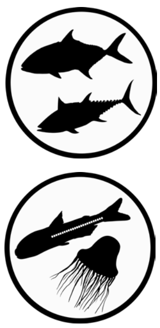
FOOTPRINT

None, no bottom contact. (Volume filtered may be calculated.)

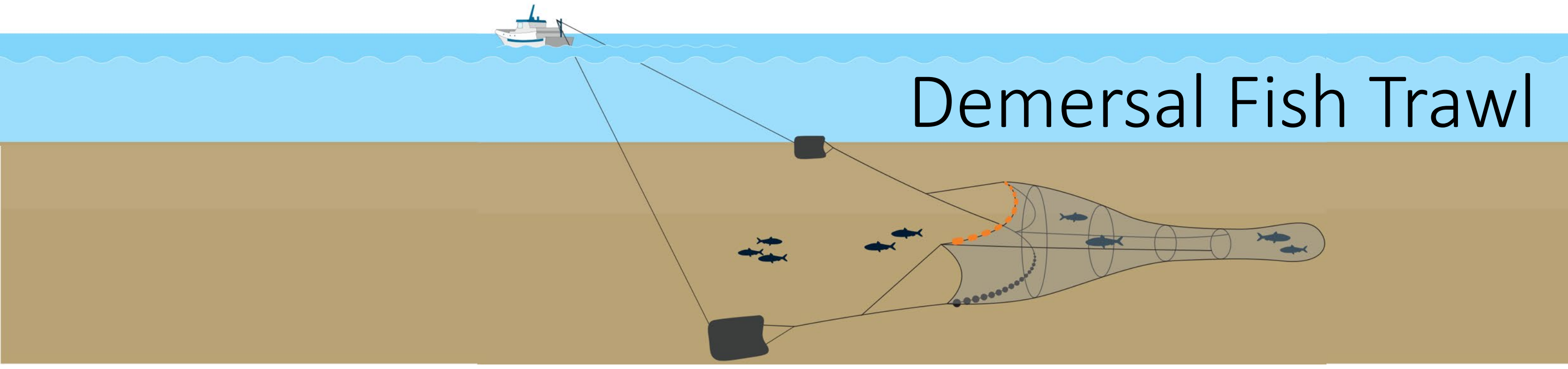
HABITAT TYPE



TARGET BIOTA



REFERENCES: [1] AFMA, 2022; [2] Marouchos et al., 2017; [3] Koslow, 1997; [4] NOAA Fishing Gear, 2022; [5] CANTRAWL, 2022; [6] Zhu et al., 2020; [7]Lyle et al., 2016; [8] Williams and Koslow, 1997.



Demersal Fish Trawl

A demersal fish trawl is used to sample benthic and demersal fishes and large mobile invertebrates on unstructured seafloor. It is composed of a long funnel-shaped net held open ('spread') by a trawl door attached to each side of the net with a wire 'sweep' and bridles. The trawl doors and sweeps stir up sediments, herding fish into the mouth of the net[1]. The net headrope is buoyed by floats, and the footrope may have rubber bobbins or rollers of varying size, variously to reduce seabed contact or enable the trawl to negotiate rough terrain. [1-3]

OPERATION[1-3]

Deployed from a surface vessel and towed with a warp wire connected to each of the two trawl doors, typically towed at 2-3 kt for ~30 min. Telemetry sensors and positioning beacon provide data on door spread, mouth opening (headline height), range from vessel, and net depth. Operated from ~25 m to 3000 m. Rocky habitat types are not accessible to demersal fish trawls.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of a wide variety of *target biota* – especially larger and faster swimming demersal fishes that are poorly sampled by smaller gears such as beam trawl.

* Because of the high diversity and abundance of biota collected – including commercially important fishes - it is exceptionally cost-effective from a $ per sample perspective.

* It is effective by representatively collecting *target biota*, and providing specimens in good physical condition.

*Abundance estimates can be quantitative if *footprint* is estimated accurately, making it an essential sampler where populations statistics are required, e.g. status change following management intervention.

*Sampling over broad spatial scales is possible (transects of km in length) - important where abundance is low, e.g. the deep sea.

* The '**McKenna Trawl**' has been used for surveys in Australia for 25+ years and represents a standard source of time-series data[4,5], including in marine parks[5].

IMPACTS & VULNERABILITY

<u>Direct impact</u>: A sampling gear for *sediment habitats*. *Target biota* are removed from the area swept; depending on ground gear there may be some penetration into the sediments.

<u>Indirect impact</u>: Resuspension of fine-grained (e.g., muddy) sediments in the path of the trawl doors and sweeps; the extent is local. Unintentional capture of marine mammals (seals/ sealions) or reptiles is rare but possible[5].

<u>Ecosystem level impact</u>: Quantitative estimates of typical and extreme survey-scale sampling footprints (*footprint*/area of ecosystem) show no ecosystem or population impacts are expected (BOX 2).

<u>Resilience of values to the activity</u>: Target *habitat types* host biota that are typically more resilient to disturbance than reef biota.

<u>Mitigation</u>: Impacts are minimised by informed planning and targeting of sample locations, i.e. pre-survey mapping of substrate types and using net sensors and a positioning system on the demersal trawl. Accurate estimation of *ecosystem level impact* provide verification.

SAMPLE TYPE

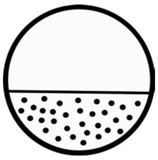
SIZE [5]

Footrope: 37 m L; headrope 41 m L; Door 1.8 m W;
When sampling:
Door spread: 80-100 m,
Footrope: ~19 m,
Mesh size various depending on cod end.

FOOTPRINT

Width of the door spread (*fish*) or of footrope (*epibenthos*) multiplied by the distance travelled. Door/ footrope spread depends on tow depth and speed.

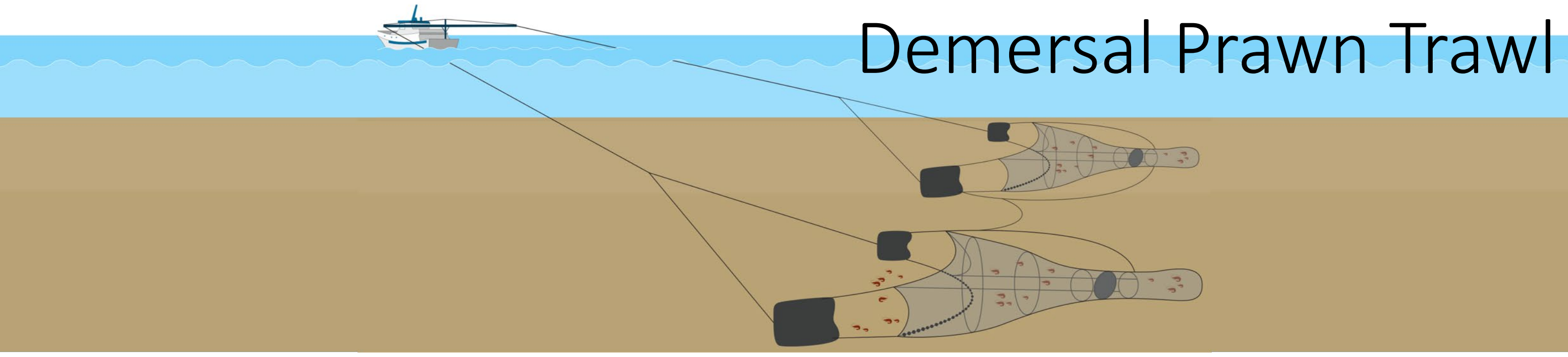
HABITAT TYPE



TARGET BIOTA

REFERENCES: [1] AFMA, 2022; [2] Clark et al., 2016; [3] Przeslawski et al., 2020a; [4] Bax and Williams, 2000; [5] Keesing et al., 2021

Demersal Prawn Trawl



A demersal prawn trawl is used to sample highly mobile demersal crustaceans and associated biota on unstructured seafloor. It is composed of up to four long funnel-shaped nets held open ('spread') by small doors attached directly to the nets. The net headropes are buoyed by floats, and the ground gears may include chains that skim the seafloor causing prawns to swim up off the bottom into the mouth of the nets[1,2].

OPERATION[1,2]

Deployed from a surface vessel and towed with one warp wire connected to the outside trawl doors via a bridle, typically towed at 2-3 kt for ~30 min. Telemetry sensors and positioning beacon provide data on door spread, mouth opening (headline height), range from vessel, and net depth. Operated from ~25 m to 200 m. Multiple prawn trawls (up to 4 nets) can be deployed from a single vessel, towed from booms extending out from each side. Rocky habitat types are not accessible to Prawn trawls.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of a wide variety of *target biota* – especially highly mobile crustacea.

* It is effective by representatively collecting *target biota*, and providing specimens in good physical condition.

*Abundance estimates can be quantitative if *footprint* is estimated accurately, making it an essential sampler where populations statistics are required, e.g. fishery surveys, and status change following management intervention.

*Sampling over broad spatial scales is possible (transects of km in length) - important where abundance is low, e.g. the deep sea.

IMPACTS & VULNERABILITY

<u>Direct impact</u>: A sampling gear for *sediment habitats*. *Target biota* are removed from the area swept; depending on ground gear there may be some penetration into the sediments.

<u>Indirect impact</u>: Resuspension of fine-grained (e.g., muddy) sediments in the path of the ground gear; the extent is local. Unintentional bycatch of sharks and rays occurs; capture of marine mammals (seals/ sealions or reptiles is rare but possible[3].

<u>Ecosystem level impact</u>: Quantitative estimates of typical and extreme survey-scale sampling footprints (*footprint*/area of ecosystem) show no ecosystem or population impacts are expected (cf. BOX 2).

<u>Resilience of values to the activity</u>: Target *habitat types* host biota that are typically more resilient to disturbance than reef biota.

<u>Mitigation</u>: Impacts are minimised by informed planning and targeting of sample locations, i.e. pre-survey mapping of substrate types and using net sensors and a positioning system on the trawl. Accurate estimation of *ecosystem level impact* provide verification.
Bycatch Reduction Devices (BRD) minimise unintended bycatch and are commercially adopted best practice [3].

SAMPLE TYPE

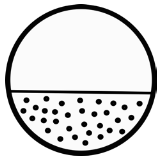
SIZE [3]

Per net: 25 m W; Mesh size various depending on cod end.

FOOTPRINT

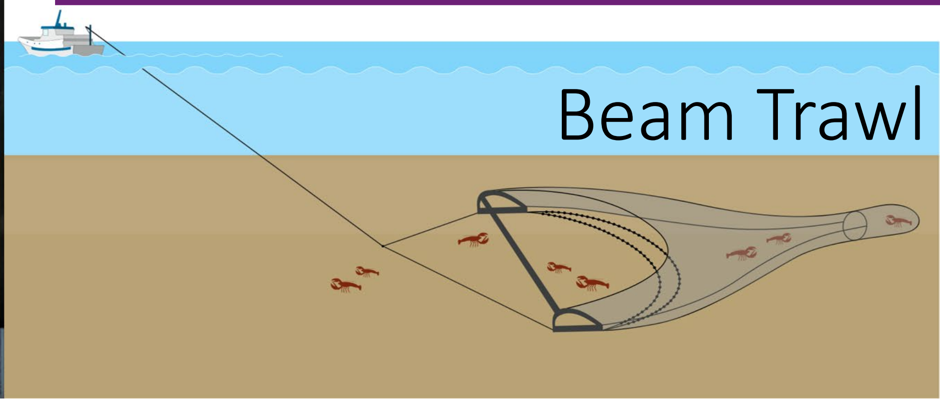
Width of the net multiplied by the number of nets plus distance travelled.

HABITAT TYPE



TARGET BIOTA

REFERENCES: [1] AFMA, 2022; [2] Balash et al., 2014; [3] Brewer et al., 1998



Beam Trawl

A beam trawl is used to sample epibenthos and slow-moving demersal fishes on unstructured seafloor. It is composed of a fine mesh net with a solid beam acting as the 'headrope' and a rope or chain footrope, joined by a steel plate ('shoe') which also acts as a skid enabling the beam trawl to skim the seabed. The footrope may have bobbins to reduce seabed contact or tickler chains to increase contact, e.g. to increase catch rates of shallow burrowing or dorso-ventrally compressed fauna, e.g. flatfishes.[1-3]

OPERATION[1,2]

Deployed from a surface vessel and towed with a wire bridle, typically at 2-2.5 kt for 20-60 min; tow duration depends on faunal density and depth. Positional and depth information reported by a positioning beacon. Operated from shallow depths down to 5000 m. Structured habitat types (i.e., coral reef) are not accessible to this gear.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *target biota* - sessile and relatively small-bodied benthic biota.

* Its simple construction means it is reliable and relatively easy to maintain and repair at sea, and therefore it is cost-effective from a $ per sample perspective.

* It is effective by representatively collecting *target biota*, and providing specimens in good physical condition.

*Abundance estimates can be quantitative if *footprint* is estimated accurately.

*Sampling over broad spatial scales is possible (transects of km in length) - important where abundance is low, e.g. the deep sea.

*One beam trawl design[2] has been used extensively for deep sea surveys in Australia for 2 decades and represents a standard source of time-series data[5], including in marine parks[6].

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *sediment habitats*. *Target biota* are removed from the area swept, but there is only shallow penetration into sediments.

Indirect impact: Resuspension of fine-grained (e.g., muddy) sediments is possible, but the extent is local.

Ecosystem level impact: Quantitative estimates of typical and extreme survey-scale sampling footprints (*footprint*/area of ecosystem) show no ecosystem or population impacts are expected (BOX 1).

Resilience of values to the activity: Target *habitat types* host biota that are typically more resilient to disturbance than reef biota.

Mitigation: Impacts are minimised by informed planning and targeting of sample locations, i.e., pre-survey mapping of substrate types and using a positioning system on the beam trawl. Accurate estimation of *ecosystem level impact* provide verification.

SAMPLE TYPE

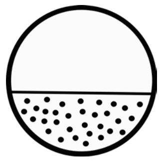
SIZE[2,4,5]

2-6 m W, 0.5 m H, $2\ m^2$ mouth area, Mesh size 10-12 mm

FOOTPRINT

Width of the beam trawl multiplied by the distance travelled.

HABITAT TYPE



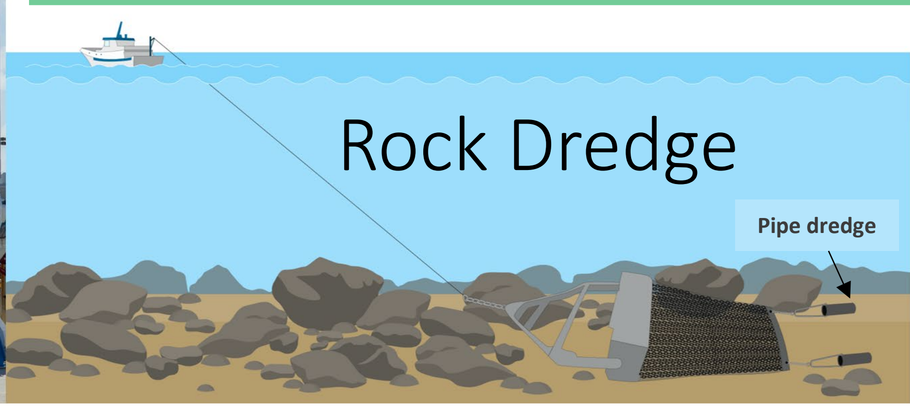
TARGET BIOTA

REFERENCES: [1] Przeslawski et al., 2020a; [2] Lewis, 2010; [3] Przeslawski et al., 2018; [4] Clark et al., 2016; [5] Williams et al., 2018a&b; [6] O'Hara et al., 2020.

4 Sleds & Dredges

Rock Dredge	Rock Dredge Pipe Dredge
Hard bottom Sled	e.g. Sherman sled
Soft bottom Sled	e.g. Brenke sled

Rock Dredge



Rock dredges are designed to collect rocks and associated benthic fauna and thus are considerably studier than sleds. They are composed of a heavy metal frame or collar and a chain bag which collects the sample as the dredge is towed across the seafloor. Two pipe dredges, steel pipes open at the front end, are commonly attached to the base of the chain bag to collect fine material. [1-6]

OPERATION [1,3,4,7]

Deployed from a surface vessel and towed with a single wire and solid steel bridle, typically at low speeds (1-2 kn) for 10-20 min; tow duration depends on terrain and depth. Operated from shallow depths (~50 m) down to 5000 m. Typically, a Rock dredge does not carry a location beacon because the risk of damage or loss is high.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool, routinely used for *physical collection* of *geological samples*, but *sessile benthic biota* are also collected (opportunistic/ targeted) [3,4,5,6,7].

* Its simple and rugged construction means it is relatively easy to repair or replace at sea; it is cost-effective from a $ per sample perspective.

* The listed *target biota* - sessile and usually relatively small-bodied benthic biota – are, in general, incidental bycatch, but represent biodiversity not collected by other methods that are retained for museum collections, as presence records.

* Rock dredges have been used to effectively sample *molluscs* and *corals* and assess their abundance (presence/absence) and diversity [4,5,6,7].

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *rocky reef habitats* (including cold-water corals). During each tow rocks and associated fauna are removed from the area swept and there is penetration into unconsolidated sediments.

Indirect impact: Biota that are not collected from the area swept may be dislodged and crushed.

Ecosystem level impact: Tow distances on rocky seabed are typically very short and the footprint very narrow. Quantitative estimates of typical and extreme survey-scale sampling footprints (*footprint*/area of ecosystem) show no ecosystem or population impacts are expected from sampling with dredges or sleds (cf. BOX 3).

Resilience of values to the activity: Target *habitat types* host biota that are typically less resilient to disturbance than soft sediment biota.

Mitigation: Impacts are minimised by informed planning and targeting of sample locations, i.e., pre-survey mapping of substrate types.

SAMPLE TYPE

SIZE [1,3,6,7]

0.8-1 m W, 0.3-0.5 m H, 410 kg. Cod end: chain bag 6-10 mm galvanised chain mesh of 70 mm side squares.
Pipe dredge: diameter 0.2 m, length: 0.5 m

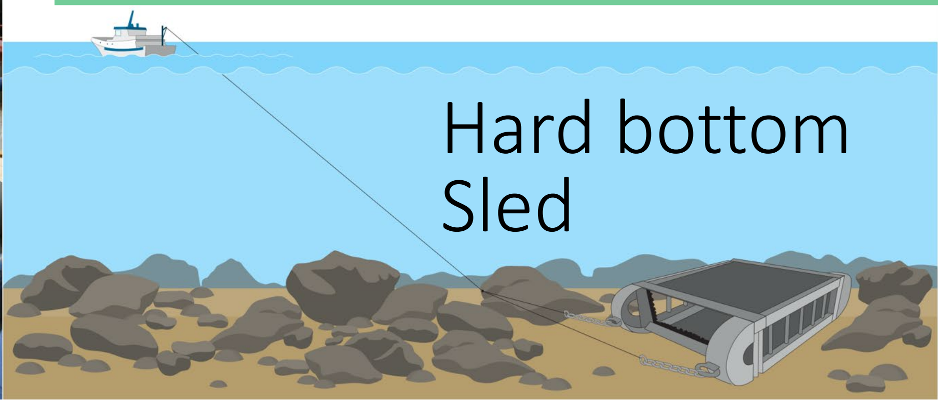
FOOTPRINT

Width of sled x distance travelled

HABITAT TYPE

TARGET BIOTA

REFERENCES: [1] CSIRO MNF, 2021; [2] Przeslawski et al., 2018; [7]Heap et al., 2009; [4] Bridge et al., 2012; [5] Webster et al., 2008; [6] Grosjean and Logan, 2007; [7] Troncoso and Aldea, 2008



Hard bottom Sled

Hard bottom sleds (or sledges) are used to sample benthic fauna from structured habitats. Composed of a heavy, ruggedized box-like frame, sometimes with runners beneath and a cutting bar at the mouth that scrapes the seafloor; the sample net at the rear is usually protected by chafing mats. The **MNF Sherman sled** has tow bridles with weak links and recovery chains that allow for recovery of the sled in case of snagging. The **AIMS benthic sled** is a more light-weight design, with a larger mouth, used to sample all shelf substrates. A positioning beacon may be present.[1-6]

OPERATION[1,2,3,4,7,8]

Deployed from a surface vessel and towed with a single wire and chain bridle, typically at low speeds (1-2 kt) for 10-20 min; tow duration depends on terrain and depth. Positional and depth information reported by a positioning system. Operated from shallow depths down to 4000 m (**AIMS sled** <1000 m).

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *target biota* - sessile and relatively small-bodied *benthic biota* on rough terrain[2,3,4,8].

* Its simple construction means it is reliable and relatively easy to maintain and repair at sea, and therefore it is cost-effective from a $ per sample perspective.

* It is effective by collecting *target biota*, and providing specimens in reasonable physical condition, from terrains that are extremely difficult to sample. Beyond diving depth, hard bottom sampling can otherwise only be achieved with a relatively slow and expensive methods, i.e. ROV.

* Abundance estimates can be semi-quantitative if footprint is estimated accurately.

* One sled design[3,4] has been used extensively for deep sea surveys on seamounts and the Australian sub-Antarctic for 2 decades and represents a standard source of time-series data[8], including in marine parks.

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *rocky reef habitats* (including cold-water corals). During each tow *target biota* are removed from the area swept.

Indirect impact: Biota that are not collected from the area swept may be dislodged and crushed.

Ecosystem level impact: Tow distances on rocky seabed are typically very short (< 400 m) because sleds become snagged. Quantitative estimates of typical and extreme survey-scale sampling footprints (*footprint*/area of ecosystem) show no ecosystem or population impacts are expected from sampling with dredges or sleds (BOX 3).

Resilience of values to the activity: Target *habitat types* host biota that are typically less resilient to disturbance than soft sediment biota.

Mitigation: Impacts are minimised by informed planning and targeting of sample locations, i.e. pre-survey mapping of substrate types and using a positioning system on the sled.

SAMPLE TYPE

SIZE[1,3,4,5,6]

1.1-1.5 m W, 0.4-1 m H, up to 1200 kg. Cod end: Polyethylene, 25 mm stretch mesh, sometimes with a finer (10 mm) liner.

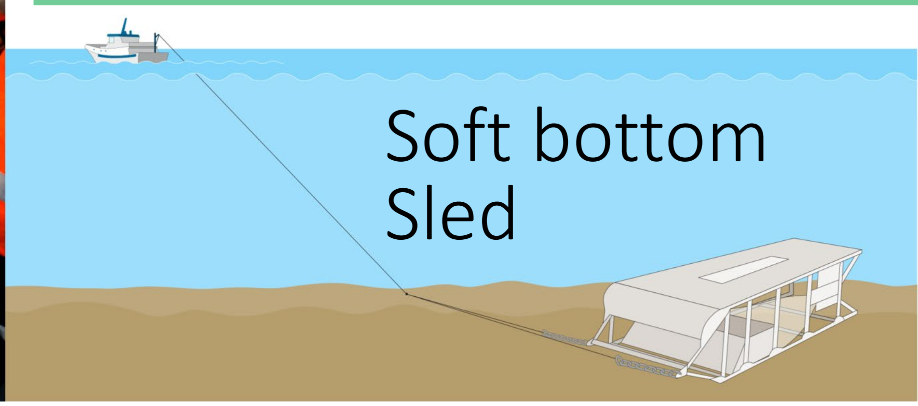
FOOTPRINT

Width of sled x distance travelled

HABITAT TYPE

TARGET BIOTA

REFERENCES: [1] Przeslawski et al., 2020a; [2] Kaiser and Brenke, 2016; [3] Lewis, 1999; [4] Lewis, 2009; [5] Clark and Stewart 2016; [6] Colquhoun et al., 2007; [7] CSIRO MNF, 2021; [8]Wlliams et al., 2020



Soft bottom Sled

Soft bottom sleds (or sledges) are used to sample benthic fauna from soft sediment habitats. Composed of a solid box-like frame, with either mesh or solid sides, sometimes with runners beneath, and with a single or twin sampling nets at the rear. A cutting bar is sometimes present at the mouth that bites into soft sediments with varying depth, depending on the design. Soft bottom sleds can also have chains in front of the mouth to stir up shallow burrowing infauna and near bottom mobile epifauna to be swept into the fine-meshed nets. Various designs are used in Australia, including a specialized sled to collect seabed surface macrofauna (**Brenke sled**). [1-4]

OPERATION[1,3,4]

Deployed from a surface vessel and towed with a single wire and a chain bridle, typically at 1-2 kt (up to 3 kt for the **Brenke sled**) for 5-20 min, depending on depth of deployment and density of *target biota*; slower tow speeds allow the sled to penetrate sediments at a greater depth. Deployed in shallow waters down to 4000 m. Commonly carries a positioning beacon.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *target biota* – particularly small or fragile benthic biota, including *infauna* that are ineffectively sampled by beam trawls[5].

* Sleds are reliable and relatively easy to maintain and repair at sea, and therefore are cost-effective from a $ per sample perspective.

* Sleds are effective by representatively collecting *target biota*[3,4,5], and essential to collect small, fragile *macrofauna* in good physical condition for taxonomic studies.[4,5]

*Relative abundance estimates[4] can be quantitative if *footprint* is estimated accurately.

* The internationally-used **Brenke sled** has been successfully used for recent deep-sea surveys off eastern Australia, including marine park surveys. [5]

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *sediment habitats*. During each tow *target biota* are removed from the area swept, either by the sled's penetration into sediments, or by the pressure-wave produced above sediments (e.g. **Brenke sled**)

Indirect impact: Resuspension of fine-grained (e.g. muddy) sediments is expected, but the extent is localised.

Ecosystem level impact: Quantitative estimates of typical and extreme survey-scale sampling footprints (*footprint*/area of ecosystem) show no ecosystem or population impacts are expected from sampling with dredges or sleds (cf. Box 1).

Resilience of values to the activity: Target *habitat types* host biota that are typically more resilient to disturbance than reef biota.

Mitigation: Impacts are minimised by informed planning and targeting of sample locations, i.e. pre-survey mapping of substrate types and using a positioning system on the sled.

SAMPLE TYPE

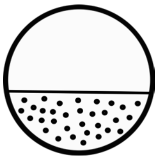
SIZE[2,3,4]

Sled: 0.3 – 1.8 m W, 0.5 – 1.3 m H. Cod end: 0.5 - 10 mm mesh.

FOOTPRINT

Width of sled x distance travelled

HABITAT TYPE

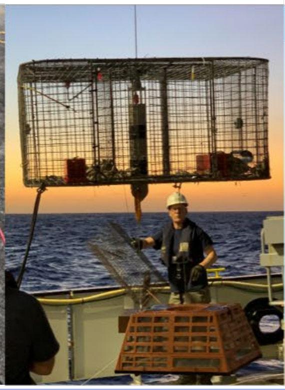


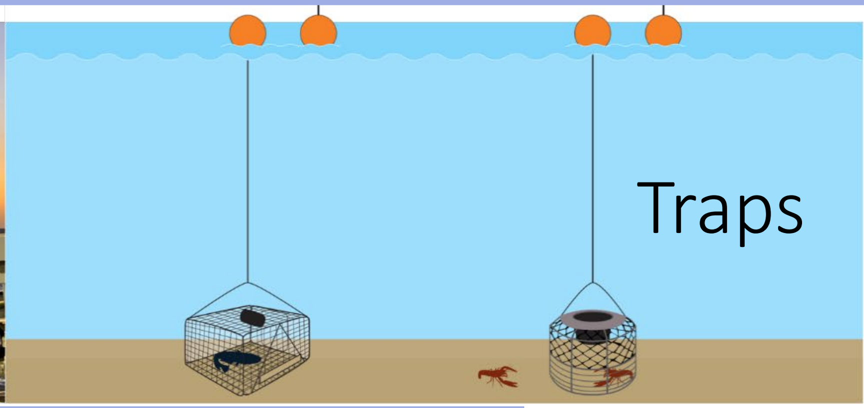
TARGET BIOTA

REFERENCES: [1] Kaiser and Brenke, 2016; [2] Przeslawski et al., 2020a; [3] Ward et al., 2006; [4] Brenke, 2005; [5] O'Hara et al., 2020.

5 Traps, Pots & Plates

Traps	Fish traps Lobster/crayfish Pots
Sediment traps	
Settlement Plates	





A trap or pot is an internally baited cage or box used to collect fish and crustaceans. Typically consisting of a metal or wooden frame and wire or string mesh cover with an entrance that allows the target species to enter but not leave. The bottom of the trap is weighted to ensure it sinks rapidly, lands the correct way up, and holds position. A surface float and marker buoy are attached to the frame to aid with relocation and retrieval. There are many designs that are commonly used depending on target species, local preferences and regulations, including small plastic box or tube traps for macrofauna that can be attached to other static seafloor samplers, e.g. camera landers or larger traps. [1,2,3,4]

OPERATION [1,2,3,5]

Traps are deployed from a surface vessel (small units may be diver deployed) and landed on the seafloor, in or adjacent to the preferred habitat type of the target species. The gear is 'set' and left unattended; it is retrieved by grappling the main line between the marker buoy and float and pulling it back on board. Traps for deep deployments may have a sacrificial weight, an acoustic release system and floats to bring them to the surface. Operated from shallow depths (2 m) down to 2000 m in a range of *habitat types* (e.g. soft-sediments, rocky reefs). Set times vary from 20 min to 72 h for fish traps; 6 h to several days for lobster pots. Multiple traps connected by a bottom line can be deployed in a single set, but this is not common practice.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *target biota* – especially *demersal fishes* and *crustacea*, and including from rocky seabed where it is difficult to make physical collections using alternative gears. Highly effective for small scavenging crustacea and fishes, particularly in deep water.

* It is a commonly used commercial gear allowing efficient and highly selective sampling of the *target biota* using charters of experienced operators[5,6].

* It is effective by collecting *target biota* and providing specimens in good physical condition, although selective for certain species[5].

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for most *benthic habitats*. *Target biota* are removed from the environment.

Indirect impact: Some impact on epifauna beneath trap expected although trap footprint is small; movement of traps – especially when connected in a line - due to currents and/or during retrieval can expand the footprint. Traps may be snagged and lost in high profile reef habitats, resulting in ghost-fishing. Bycatch of non-target species is possible. Sacrificial weights are inert steel plates of sufficient mass to compensate for the gear's buoyancy, but typically 10s kg.

Ecosystem level impact: At a population level, impact on target species due to sample mortality is negligible. At the ecosystem level, the area of contact with the benthos is minimal.

Resilience of values to the activity: Resilience of the targeted fish and crustacea depends on population parameters such as fecundity and age at maturity.

Mitigation: Minimising mortality, including non-target bycatch by limiting set times and using commercially adopted best practice, e.g. escape gaps or hatches for non-target and undersized individuals[1,2,3]. Minimising movement of multiple traps set on a line during retrieval by employing 'straight down the line' or 'zipper' retrieval method as used for longlines.

SAMPLE TYPE

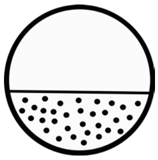
SIZE [3,4,5,7]

Variable: *Crustacea traps*: 0.5 x 0.9 m, up to 1.5 m diameter; height: 0.2 – 0.9 m. *Fish traps*: 0.2 x 0.15 x 0.1 m, up to 1.8 × 1.5 × 1.2 m; ~15 kg

FOOTPRINT

Minimal: W x L of unit when landed (m^2).

HABITAT TYPE



TARGET BIOTA

REFERENCES: [1]AFMA, 2022; [2]Butcher et al., 2012; [3]FRDC, 2022; [4]PRISA, 2022; [5]Williams and Bax, 2001; [6]Richards et al., 2018; [7]Slack-Smith, 2001.

Sediment Traps

A sediment trap is used to collect particulate matter, including microscopic inorganic sediments and larger organic accumulations ('marine snow'), as it sinks through the water column in a range of habitat types. Sediment traps consist of a tube or funnel shaped receptacle that is open towards the water surface, with one or multiple collection container/s at the bottom. Where multiple containers are used, they are deployed on a tray or rosette that can be pre-programmed to seal and swap containers during a single deployment. Sampling containers may be primed with a fixative solution (e.g. borax-buffered 5% formaldehyde solution in 0.20 µm filtered sea water), to prevent sample degradation during long-term deployments. Baffles over the top of the trap prevent clogging by large material. Sediment traps can be moored by an anchor weight, on a surface buoy, or be free drifting. Surface floats and locator beacons may be attached to the traps for relocation and recovery.[1-7]

SAMPLE TYPE

OPERATION [1,3,5,6,7,8]

Sediment traps are deployed from a surface vessel, with smaller units able to be hand-deployed. Moored sediment traps are attached to a mooring line of a surface or sub-surface buoy (drifting or stationary) at predefined depths, or held near the seafloor by sacrificial anchor weights. The gear is 'set' and left unattended; it is retrieved by recovering the mooring or releasing the trap from the sacrificial weight. Free drifting units are designed to be neutrally buoyant at a defined depth in the water column and may be programmed to move on a predefined path and return to the surface for retrieval. Sediment trap deployment periods can range from days to more than a year, particularly for traps making multiple collections.
*Also see 'Mooring' and 'Sensor and Profiler' templates.

SIZE[1,10,11]

Variable: 0.1-3 m H x 0.3-1 m diameter.

FOOTPRINT

Minimal: surface area of anchor.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *sediment* and marine snow to identify the physiochemical composition and rate of transport of material from *surface waters to the seafloor*[3-8].

* Primary applications are to measure biological carbon transfer from surface waters to the deep ocean[3,6] and dispersion of hydrocarbons from natural seeps from surface slicks via sinking settling particles to sediments[9].

IMPACTS & VULNERABILITY

<u>Direct impact</u>: A sampling gear operating in the *water column*. No impact on biota.

<u>Indirect impact</u>: Minor impact on epifauna beneath the anchor weight of moored sediment traps and dragging during retrieval may occur but the footprint is very small. Sacrificial weights are inert steel plates of sufficient mass to compensate for the gear's buoyancy, but typically 10s kg.

<u>Ecosystem level impact</u>: Not applicable.

<u>Resilience of values to the activity</u>: Not applicable.

<u>Mitigation</u>: Not applicable.

HABITAT TYPE

TARGET BIOTA

No biota are targeted.

REFERENCES: [1] WHOI – Sediment Trap, 2022; [2] Storlazzi et al., 2010; [3] Ebersbach et al., 2011; [4] Palanques and Puig, 2018; [5] Roberts et al., 2011; [6] Closset et al., 2015; [7] Rigual-Hernández et al., 2015; [8] Estapa et al., 2017; [9] Burns et al., 2010; [10] Technicap, 2022; [11] MEC, 2014.

Settlement Plates

A settlement ‘plate’ is an object deployed in the environment for a set time period to allow settlement of sessile biota. Tiles are most commonly used, but a plate can be any shape, size and material (both natural and artificial), and its surface can be smooth or rough. Plates may be pre-conditioned or pre-treated with chemicals. The plate may be imaged/ observed in situ, and/or retrieved and examined in the laboratory after elapse of the experimental time period.[1-6]

OPERATION[2,3,4,6,7,8,9]

Settlement plates are deployed individually or as multiple plates on a frame and placed into a pre-determined position in a particular habitat, typically by a diver, a submersible (e.g. HOV/ROV), or suspended in the water column. Plates or frames typically remain in place under their own weight. A marker (e.g. buoy and weight) may be deployed to identify the plate’s position, especially in deep sea deployments. Plates are ‘set’ and left unattended for the time of the experiment (or up to years) but may be monitored or visually inspected in situ by divers or imaging methods described in separate templates. Retrieval involves careful removal of the plate from the environment by divers, or submersible to ensure that settled biota are undisturbed.

SCIENTIFIC VALUE & BENEFIT

* A proven method to observe settlement dynamics of sessile invertebrate *target biota* in situ [1,2,7,8], particularly recruitment and growth of early life history stages [4,7,9], to make *physical collections* of new recruits of the *target biota,* and to monitor biodiversity (‘colonisation traps’[10]); more recently applied to collect eDNA samples[11].

IMPACTS & VULNERABILITY

Direct impact: Settlement plates can be used in *all habitats* and are removed at the end of the experiment.

Indirect impact: Minor impact on epifauna beneath plates or deployment frame expected; the footprint is usually very small. Sacrificial weights (if used) are inert steel plates of sufficient mass to compensate for the gear’s buoyancy, but typically 10s kg.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: Careful placement of plates to avoid unnecessary impact on sensitive habitats.

SAMPLE TYPE

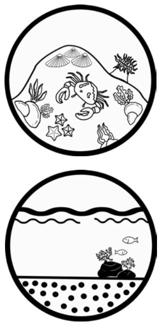
SIZE[3,4,5,7]

Variable depending on experimental set-up. Typically floor or wall tiles (<0.5 x 0.5 m) are used but these can be attached to a deployment frame for experimental designs.

FOOTPRINT

W x L of the tile or frame when landed (m^2)

HABITAT TYPE

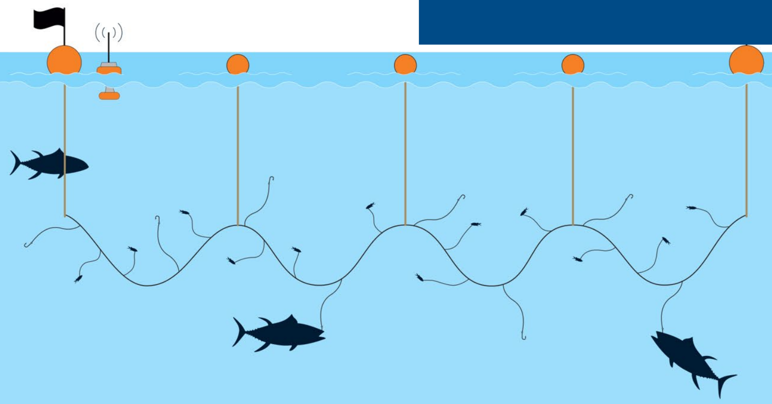


TARGET BIOTA

REFERENCES: [1]Harriott and Fisk, 1987; [2] Kennedy et al., 2017; [3] Marraffini et al., 2017; [4] McAfee and Connell, 2020; [5] McKenzie et al., 2012; [6] Williams et al., 2020; [7] Lacharité and Metaxas, 2013; [8] Ells et al., 2016; [9] Price et al.,2019; [10] Duffy et al. 2013; [11] Koziol et al., 2019.

6 Hook & Line

Pelagic Longline
Demersal Longline
Dropline
Handline



Pelagic Longline

Pelagic longlines are used to collect pelagic fish and consist of a main line suspended from down-lines designed to keep it at a desired depth range in the water column with marker buoys and floats at each end and at intervals along the line. Side lines (snoods), each with a baited hook are placed at regular intervals. A locator beacon attached to the buoy at one end of the line is used to track the gear as it drifts.[1,2]

OPERATION[1,2]

Pelagic longlines are deployed from a specialised commercial vessel with pre-baited hooks and snoods attached to the main line by hand as it is set at a speed of 3-5 kt. Auto-longlines are baited automatically at a speed of ~2 hooks/sec allowing for efficient setting of a greater number of hooks at closer spacing than hand-baited longlines. The gear is 'set' and left to drift unattended. It is retrieved by grappling the main line between the marker buoy and float and winding it back on board. Hooked fish are landed manually, dehooked individually, and processed using best practice guidelines – including for euthanasia. *Pelagic fish* (e.g. tuna) intended for release after being tagged, are processed rapidly. The number of hooks and set times can be adjusted to suit the objectives of the study.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *target biota* - especially fast swimming and/ or deep-living *pelagic fishes*, e.g. tuna, sharks, swordfish[1,2].

* It is a commercial gear allowing highly efficient scientific sampling of *target biota* by using charters of experienced vessel and operators (the typical strategy).

* It is effective by representatively collecting *target biota* at sufficiently high abundance for population studies and monitoring, and providing specimens in good physical condition.

*Abundance estimates are quantitative if a standardised effort (set time, number of hooks, bait, etc.) is used.

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *pelagic habitats,* typically with removal (mortality) of *target biota* and/ or bycatch species. Barotrauma causes mortality of most fishes, especially those with gas-filled swimbladders, and is greater with increased sampling depth, (e.g. > 50 m).

Indirect impact: Potential for unintended bycatch of pelagic sharks, turtles, marine mammals, and seabirds. Gear loss possible.

Ecosystem level impact: Impact on *target biota* due to mortality is negligible at a population level.

Resilience of values to the activity: Higher for *target biota* with relatively high fecundity, and low age at maturity, and higher post-release survival rate.

Mitigation: Impact on *target biota* minimised by limiting sampling effort (set times and number of hooks). Effort needs to be tailored to the study objectives (e.g. based on power analyses of catch rates). Bycatch minimised by commercially adopted best practices including setting lines quicky and in darkness, use of weighted hooks to ensure quick sinking, and by using bird scarers (Tori line), and by reducing gear loss.

SAMPLE TYPE

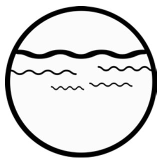
SIZE

Pelagic longlines are typically several km long, depending on the mean distance between snoods and the number of hooks that are set per longline.

FOOTPRINT

None, no bottom contact. Pelagic 'footprint' (area of influence) can be determined by length of line x drift distance.

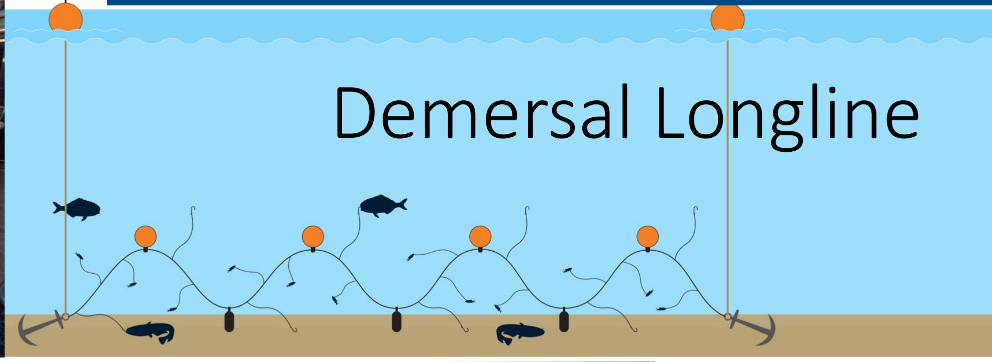
HABITAT TYPE



TARGET BIOTA

REFERENCES [1] AFMA, 2022; [2] SEAFDEC, 2022.

Demersal Longline



Demersal longlines are used to collect demersal fish and consist of a main line, typically with an anchor weight, and down-lines with marker buoys and surface floats at each end. Side lines (snoods), each with a baited hook are placed at regular intervals. Floats and weights are placed strategically along the main line to variously keep it near the seafloor or raise it over obstacles. Longlines for scientific sampling typically range from 1500 to 2000 m in length. [1,2,3]

OPERATION[2,3]

Demersal longlines are deployed by a specialised commercial vessel with pre-baited hooks and snoods attached to the main line by hand as it is set at a speed of 3-5 kt. Auto-longlines are baited automatically at a speed of ~2 hooks/sec allowing for efficient setting of a greater number of hooks at closer spacing than hand-baited longlines. The gear is 'set' and left unattended; it is retrieved by grappling the main line between the marker buoy and float and winding it back on board. Hooked fish are landed manually, dehooked individually, and processed using best practice guidelines – including for euthanasia. *Demersal fish* (e.g. sharks) intended for release after being tagged are processed rapidly. The number of hooks and set times can be adjusted to suit the objectives of the study.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *target biota* - especially in deep (continental slope) depths and for *sharks* and strong swimming *demersal fishes*[3].

* It is a commercial gear allowing highly efficient scientific sampling of *target biota* by using charters of experienced vessel and operators (the typical strategy).

* It is effective by representatively collecting a diverse suite of *target biota* at sufficiently high abundance for population studies and monitoring, and providing specimens in good physical condition.

* It is an effective and proven sampling method for catch-release (tagging) studies, with high survival rates of released fish that do not have gas-filled swimbladders, e.g. *sharks*.

*Abundance estimates are quantitative if a standardised effort (set time, number of hooks, bait, etc.) is used.

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for benthic *habitat types* including rocky reefs, typically with removal (mortality) of *target biota* and/ or bycatch species. Barotrauma causes mortality of most fishes with gas-filled swimbladders, and is greater with increased sampling depth (e.g. > 50 m).

Indirect impact: Movement of the main line and weights on the seafloor due to currents and/ or during retrieval can exert shear stress on benthic fauna such as corals and sponges causing damage or mortality. Potential for unintended bycatch of seabirds during setting/ retrieval. Capture of marine mammals or reptiles is rare but possible[1]. Gear loss possible, but no ghost fishing.

Ecosystem level impact: Impact on *target biota* due to mortality is negligible at a population level. The area of contact with the seafloor is minimal (BOX 4)

Resilience of values to the activity: Higher for *target biota* with relatively high fecundity, and low age at maturity, and higher post-release survival rate.

Mitigation Impact on *target biota* minimised by limiting sampling effort (set times and number of hooks). Effort needs to be tailored to the study objectives (e.g. based on power analyses of catch rates). Bycatch minimised by commercially adopted best practices including setting lines quicky and in darkness, use of weighted hooks to ensure quick sinking, and by using bird scarers (Tori line). Lateral movement of lines minimised during retrieval by employing 'straight down the line' or 'zipper' retrieval methods[4].

SAMPLE TYPE

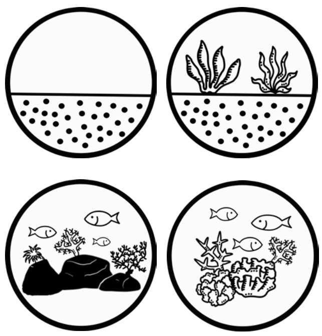
SIZE[3]

Demersal longlines can be up to several km long, depending on the mean distance between snoods and the number of hooks that are set per longline. Distance between snoods: 2-5m (manual longline); 1.3m (auto-longline). Weights: e.g. inert steel rods >0.5 m L

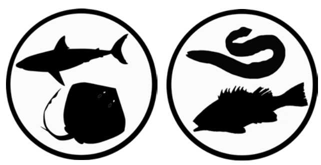
FOOTPRINT

Line length on bottom x width of potential of side-ways movement, dependent on bottom currents and line weighting – and typically difficult to estimate.

HABITAT TYPE



TARGET BIOTA



REFERENCES: [1] AFMA, 2022; [2] SEAFDEC, 2022; [3] McLean et al., 2015; [4]Welsford et al., 2014

Dropline

Droplines are used to collect pelagic and demersal fishes and consist of a main line with an anchor weight, a surface float and marker buoy and several short (30-50 cm long) nylon side lines (snoods) typically close to the anchor. Each snood has a baited hook. Snoods may be attached to a short branch line that trails on the seafloor.[1,2,3]

OPERATION[1,2,3]

Droplines are deployed from a vessel by paying out enough main line for the weight to reach the seafloor and the float and marker buoy to remain at the surface in ambient conditions of wind and current. The gear is 'set' and left unattended; it is retrieved by grappling the main line between the marker buoy and float and winding it back on board. Hooked fish are landed manually, dehooked individually, and processed using best practice guidelines – including for euthanasia. *Fish* intended for release, e.g. after being tagged, are processed rapidly. The number of hooks and set times can be adjusted to suit the objectives of the study.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for physical collection of *target biota* - especially *demersal fish*[2].

* It is a simple gear allowing efficient sampling of *target biota* including by using charters of experienced vessel and operators.

* It is effective by representatively collecting *target biota*, and providing specimens in good physical condition, particularly because they are not left on the hook for extended periods.

* It is an effective and proven sampling method for catch-release (tagging) studies, with high survival rates of released fish that do not have gas-filled swimbladders, e.g., *sharks*.

*Abundance estimates are quantitative if a standardised effort (set time, number of hooks, bait, etc.) is used.

IMPACTS & VULNERABILITY

<u>Direct impact</u>: A sampling gear for *demersal and pelagic fish* in a range of *habitat types,* typically with removal (mortality) of *target biota* and/ or bycatch species. Barotrauma causes mortality of most fishes with gas-filled swimbladders, and is greater with increased sampling depth (e.g. > 50 m).

<u>Indirect impact</u>: Minimal interaction with the seafloor and potential interactions with seabirds. Capture of marine mammals or reptiles is very rare but possible[1]. Some dragging movement may be expected depending on currents and weighting, but this is negligible and impossible to measure accurately.

<u>Ecosystem level impact</u>: Impact on *target biota* due to mortality is negligible at a population level.

<u>Resilience of values to the activity</u>: Higher for *target biota* with relatively high fecundity, and low age at maturity, and higher post-release survival rate.

<u>Mitigation</u>: Impact on *target biota* minimised by limiting sampling effort (set times and number of hooks). Effort needs to be tailored to the study objectives (e.g., based on power analyses of catch rates). Seabird bycatch minimised by commercially adopted best practices including setting lines quicky and in darkness, use of weighted hooks to ensure quick sinking, and by using bird scarers (Tori line).

SAMPLE TYPE

SIZE

Line lengths are adjusted to the depth they are deployed in. Where a branch line is used, its length depends on the mean distance between snoods and the number of hooks that are set per shot.

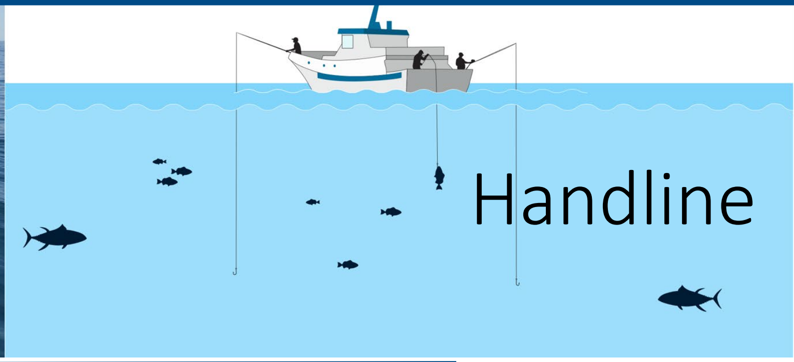
FOOTPRINT

Minimal: surface area of weight (and if used lengths of branch line).

HABITAT TYPE

TARGET BIOTA

REFERENCES [1] AFMA, 2022; [2] Williams et al. 2013; [3] Lloyd, 2001



Handline

Handlines are used to collect pelagic and demersal fish and mobile invertebrates. Typically consists of a main line stored on either a hand-held or rod-mounted reel, with a terminal weight to sink baited hooks to depth (from a few meters down to >1100 m). Handlines may also be just a pole and short line, e.g., for poling tuna. Reels may be hydraulically powered ('power handlines'), and several handlines may be deployed simultaneously.[1-3]

OPERATION[1,2,3]

Handlines are deployed by a person on a vessel, jetty or beach by free-spooling the line from the reel, allowing the baited hook(s) to sink to the desired depth; lines are attended to feel for biting fish. Detailed fishing methods depend on individual style and intended *target species* – e.g. poling for tuna. Handlines are typically deployed for short time periods and retrieved when a bite is felt by spooling them on a reel either manually or mechanically. Experienced fishers may delay retrieval to ensure several fish are hooked on multi-hook rigs. Hooked fish are landed manually, dehooked individually, and processed using best practice guidelines – including for euthanasia. *Fish* intended for release, e.g. after being tagged, are processed rapidly. The depth to which the line is deployed, and the number of hooks set can be adjusted to suit the target species and the objectives of the study.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *physical collection* of *target biota* - especially *fishes* (demersal and pelagic) and *squid*[1,3,4].

* It is a diverse and commonly used gear, including commercially, that allows efficient and often highly selective sampling of *target biota*[4].

* It is effective by collecting *target biota* and providing specimens in good physical condition due to being on a hook for very short periods[3].

* It is an effective and proven sampling method for catch-release (tagging) studies[6], with high survival rates of released fish that do not have gas-filled swimbladders.

IMPACTS & VULNERABILITY

<u>Direct impact</u>: A sampling gear for all *habitat types,* typically with removal (mortality) of *target biota* and/ or bycatch species. Barotrauma causes mortality of most fishes, especially those with gas-filled swimbladders, and is greater with increased sampling depth (e.g., > 50 m).

<u>Indirect impact</u>: Most non-target fishes caught as bycatch are alive when they reach the boat and can be returned to the sea with high level of survival expected[4]. Weights may touch the seafloor during a deployment.

<u>Ecosystem level impact</u>: Impact on *target biota* due to mortality is negligible at a population level.

<u>Resilience of values to the activity</u>: Higher for *target biota* with relatively high fecundity, and low age at maturity, and higher post-release survival rate.

<u>Mitigation</u>: Impact on *target biota* minimised by limiting sampling effort (set times and number of hooks). Effort needs to be tailored to the study objectives (e.g., based on power analyses of catch rates). Bycatch minimised by commercially adopted best practices

SAMPLE TYPE

SIZE

Line lengths are adjusted to the desired deployment depth.

FOOTPRINT

Minimal: surface area of weight if seafloor is reached.

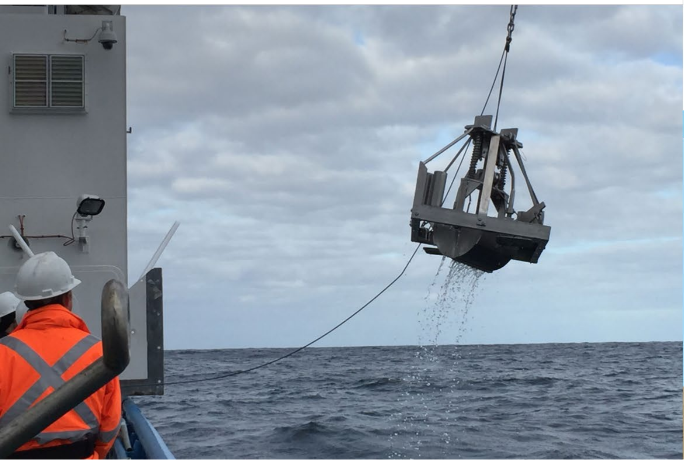
HABITAT TYPE

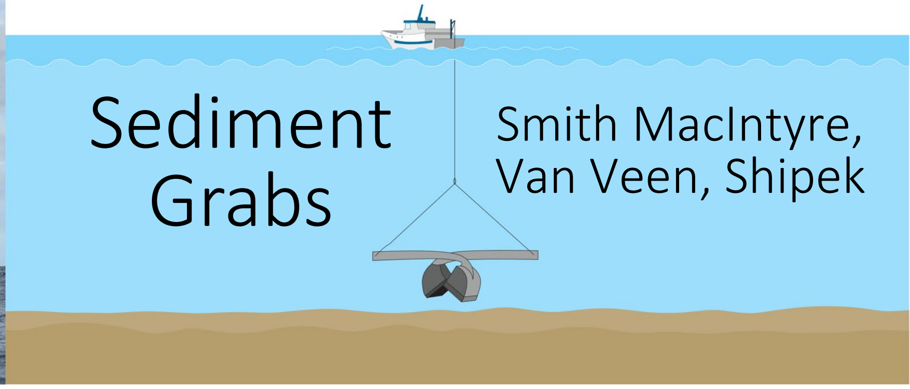
TARGET BIOTA

REFERENCES: [1] AFMA, 2022; [2] Fujioka et al. 2010; [3] Williams et al. 2013; [4] Williams et al. 2016; [5] Stevens et al., 2000.

7 Grabs & Corers

Sediment Grabs	Smith-MacIntyre Grab Van Veen Grab Shipek Grab
Box Corer	
Corers	Gravity corer Piston corer Multi-corer Push corer





Sediment Grabs

Smith MacIntyre, Van Veen, Shipek

Used to collected sediment and infauna, sediment grabs consist of spring-hinged jaws (**Smith-McIntyre** or **Van Veen**), or a rotating scoop (**Shipek**), that bite into and retain a sample of sediment. The three grab types differ in size and triggering mechanism. The **Smith McIntrye** grab (pictured) has supporting jaws and trigger springs on either side of the grab frame whereas the Van Veen grab uses a pinch-pin tensioned by the deployment cable.[1-4]

OPERATION [3,4,5]

The grab is loaded at the surface by compressing the springs and setting the jaws/ scoop in the open position, then lowered to the seafloor where the closing mechanism is automatically triggered, driving the jaws/ scoop into the sediments as they close. During retrieval the jaws are forcibly held closed by the retrieval cable or the trigger mechanism. The **Smith McIntyre** and **Shipek** designs retrieve a relatively undisturbed sediment sample; they have trapdoors in the top of the sample box to allow subsampling of undisturbed sediments before the scoop is opened to retrieve the bulk of the sample.

SCIENTIFIC VALUE & BENEFIT

*A reliable scientific sampling tool for physical collection of *sediments* and *target biota – infauna* including macro and meiofauna - from the top layers of unconsolidated sediments[1,2].

* It is effective by collecting *sediments* in conjunction with the *target biota*, allowing for direct comparison and linkages in analyses.

* Grab samples can be sub-sampled for multiple purposes, including grain-size and biochemical analyses, microbial composition, eDNA, and collection of *infauna*[1].

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *sediment habitats*. *Target biota* are removed together with the sediment, a maximum volume of ~$0.042 m^3$ is collected per deployment.

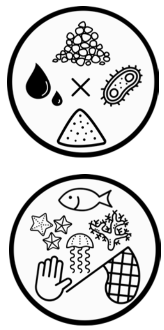
Indirect impact: Local-scale (meters) resuspension of fine-grained (e.g. muddy) sediments around the sample *footprint*.

Ecosystem level impact: No ecosystem or population impacts are expected; the area of contact with the seafloor is minimal, even with repeated sampling at a site.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE



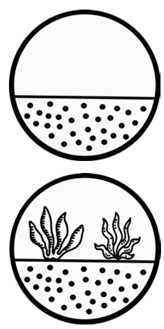
SIZE [3,4,5]

Shipek & **Van Veen**: 1.4 L to 15 L capacity; Weight: 3 kg to ~80 kg.
Smith-McIntyre: Frame: 0.8 x 0.8 m; jaw mouth area 320 mm^2; Weight 280 kg.
Penetration: up to 200 mm, all designs.

FOOTPRINT

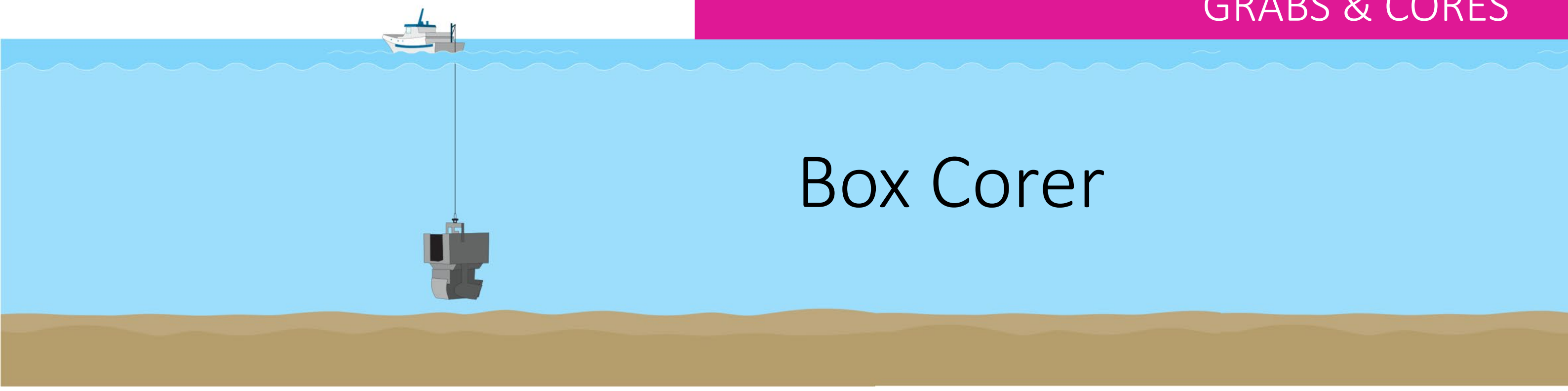
Jaw mouth area: 0.02 m^2 to 0.21 m^2.
Sample size: Jaw mouth area x penetration
Smith-McIntyre: Frame footprint 0.64 m^2

HABITAT TYPE



TARGET BIOTA

REFERENCES: [1]Przeslawski et al., 2020b; [2]Colquhoun et al., 2007; [3]CSIRO MNF, 2022; [4]WildCo ,2010; [5]FERITECH, 2022



Box Corer

Box corers are used to collect a known volume of sediment, as well as the overlying bottom water. They consist of a square or rectangular metal box with a spring-loaded or weighted swing arm or jaw mechanism to scoop and capture sediment after being triggered on contact with the seafloor.[1]

OPERATION [1,2]

The open box corer is attached to the vessel via a warp wire and when deployed it is lowered to a predetermined height above the seafloor before being allowed to freefall. The weight of the box core allows it to penetrate into sediments. When the box is pulled up for retrieval, the swing arm or jaw mechanism closes the box, retaining the sample.

SCIENTIFIC VALUE & BENEFIT

*A reliable scientific sampling tool for *physical collection* of *sediments* and overlying bottom water from *unconsolidated sediments* and including incidental collection of *infauna* [3].

* Designed to recover a relatively undisturbed sample of the seafloor to preserve surface and sub-surface structures[4].

* It is effective by collecting *sediments* in conjunction with bottom water and *infauna*, allowing for direct comparison and linkages in analyses[5].

* Box core samples can be sub-sampled for multiple purposes, including grain-size and chemical analysis, microbial composition, eDNA, and collection of *infauna*[5].

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *sediment habitats*. *Target biota* are incidentally removed together with the sediment, small volumes (~litres) are collected per deployment

Indirect impact:
Local-scale (metres) resuspension of fine-grained (e.g. muddy) sediments around the box core footprint.

Ecosystem level impact: No ecosystem or population impacts are expected; the area of contact with the seafloor is minimal, even with repeated sampling at a site.

Resilience of values to the activity:
Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE

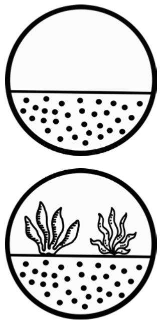
SIZE[1.5]

Variable: 150 mm^2 – 2 m^2; weight 40 – 1100 kg.

FOOTPRINT

Box area x sample depth over the total number of samples collected.

HABITAT TYPE



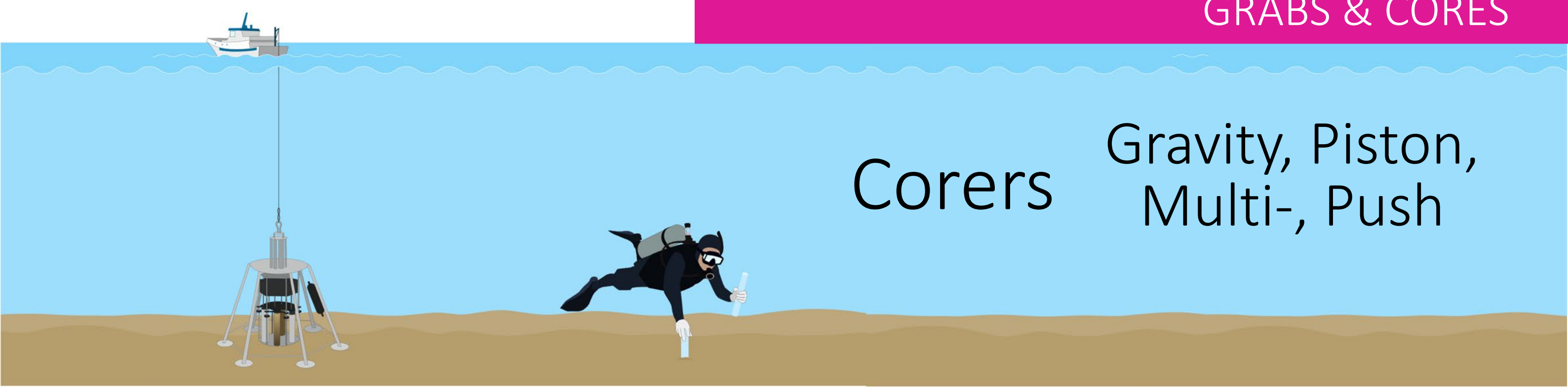
TARGET BIOTA

Incidental

REFERENCES: [1] FERITECH, 2022; [2] Przeslawski et al., 2020b; [3] Przeslawski et al., 2018; [4]Eleftheriou and McIntyre, 2005; [5] Daniell et al., 2010.

Corers

Gravity, Piston, Multi-, Push



Corers are used to collect a known volume of sediment, as well as the overlying bottom water. They consist of a tube of specific diameter designed to penetrate unconsolidated sediments either propelled by gravity (**Gravity** and **Piston** cores) or by mechanical force, being pushed into the sediments by hand or a submersible manipulator arm (**Push** cores), or by a weight (multi-core). A **Multi-corer** is essentially a frame with a rosette of push cores allowing for the collection of up to 12 pseudo-replicate cores from a defined area of seafloor. The sediment core is retained in the tube by a vacuum created during sampling, or by a core catcher.[1,2]

OPERATION[1,2]

Gravity and piston corers are deployed from a vessel. They are lowered into the water by a warp wire and allowed to freefall from a predetermined altitude onto the seafloor using gravity to push them into the sediments. Gravity corers are released manually, while Piston corers are released by a trigger mechanism which also activates an internal piston that aids core collection by creating a vacuum. Push corers can be deployed from a vessel, by divers or using submersibles. Cores are pulled out of the surrounding sediments and retrieved contained inside the collection tube.

SCIENTIFIC VALUE & BENEFIT

*A reliable scientific sampling tool for *physical collection* of *sediments* and overlying bottom water from *unconsolidated sediments* and including incidental collection of *infauna* [3].

* Designed to recover an undisturbed sample of the seafloor to preserve surface and sub-surface structures[3].

* It is effective by collecting *sediments* in conjunction with bottom water and *infauna*, allowing for direct comparison and linkages in analyses.

* Core samples can be sub-sampled for multiple purposes, including grain-size and chemical analysis, microbial composition, eDNA, and *infauna*[4,5].

* Undisturbed samples enable patterns in biota and sediment chemistry to be understood at fine scale through the length of the core[3].

IMPACTS & VULNERABILITY

Direct impact: A sampling gear for *sediment habitats*. *Target biota* are incidentally removed together with the sediment, small volumes (~litres) are collected per deployment

Indirect impact: Local-scale (metres) resuspension of fine-grained (e.g. muddy) sediments, particularly around the footprint of multi-corer or submersible.

Ecosystem level impact: No ecosystem or population impacts are expected; the area of contact with the seafloor is minimal, even with repeated sampling at a site.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE

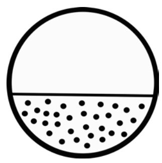
SIZE

Tube diameter: 60 to 140 mm. Multi-core frame: 2.5 x 2.5 m; weight 900 kg.

FOOTPRINT

Tube diameter x sample depth over the total number of samples collected. Sample depth of Gravity & Piston core up to 12 m; Push cores up to ~2 m.

HABITAT TYPE



TARGET BIOTA

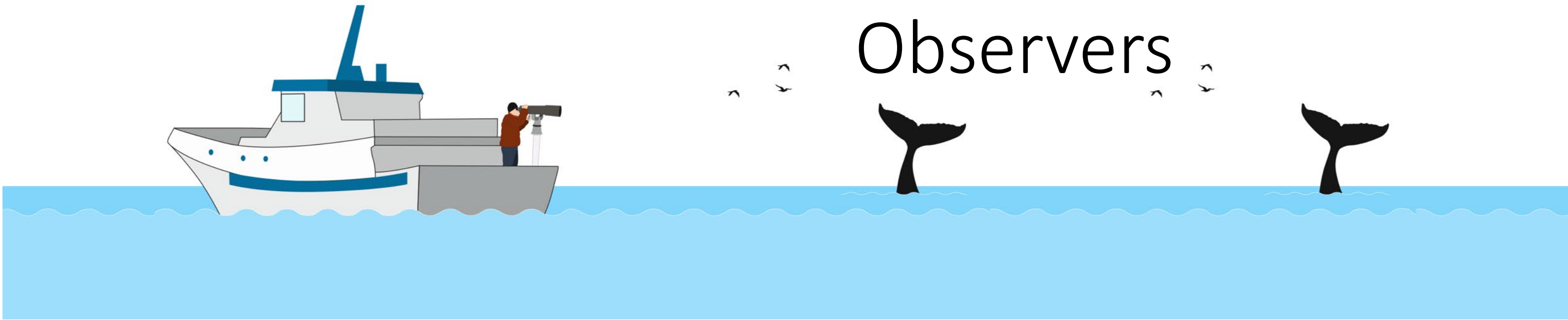
Incidental

REFERENCES: [1] Geoscience Australia, 2022; [2] CSIRO MNF, 2021; [3] Przeslawski et al., 2018; [4] van de Kamp et al., 2019; [5] MacIntosh et al., 2018

8 Human

Observers	Human on ship/ shore/ plane
Coastal & intertidal sampling	
Divers & snorkellers	Diver observer Underwater visual census (UVC) Diver Operated Video (DOV) Manta Tow Diver collection/ experiments
Tagging	Conventional tags Archival tags Satellite tags Acoustic tags
Tissue sampling, Stomach flushing	Tissue sampling (biopsy) Stomach flushing

Observers



A wide variety of direct data collections are made by human observers, typically from distant vantage points on land-based platforms, vessels, planes and helicopters. These include identifications, counts and behaviour of target biota or signs of its presence such as burrows or nests. Observation data may be stand-alone, e.g. aerial counts of coastal colonies of seals/ birds or of large marine vertebrates at sea, or collected in conjunction with other sampling to document potential interactions with the target biota (e.g. observations of seabirds during other fishing operations).[1-7]

OPERATION

The observer spends a pre-determined period at the observation vantage point, recording all observations of the *target biota*. Where the observer is on a vessel or in an aircraft (see Aircraft template), observations may be collected along a pre-defined transect path. Cameras may be used to augment observations.

SCIENTIFIC VALUE & BENEFIT

*Direct and real time observation of behaviours of a wide variety of *target biota* – e.g., birds[1], marine mammals, turtles[5] and large bodied pelagic fishes[3] - by scientific experts.

*Observers collecting data during other operations can evaluate if mitigation practices are effective[6].

* There are many proven long-standing applications including land-based observation of cetaceans on migrations routes[4], vessel-based observations of populations of seabirds[1,8] and cetaceans[2] and aerial observations of broad-scale distribution and changes in shallow water habitats – seagrass meadows, macrophyte stands, coral– and for population census of *target biota* without direct interaction[5,3].

IMPACTS & VULNERABILITY

Direct impact: Not applicable.

Indirect impact: Expected to be nil, unless the presence of human science observers during other operations, e.g. when in vessels or aircraft, has the potential to create additional disturbance to biota.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable to distant and stand-alone scientific observation but employ experienced personnel and best practice techniques for sensitive *habitats* and/ or *biota*.

SAMPLE TYPE

SIZE

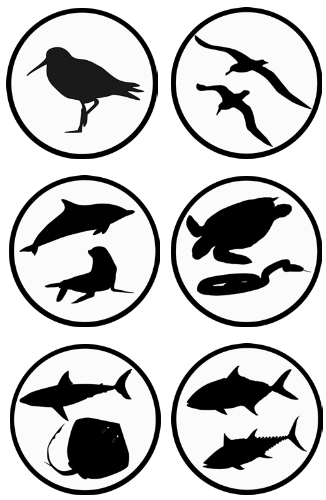
Not applicable

FOOTPRINT

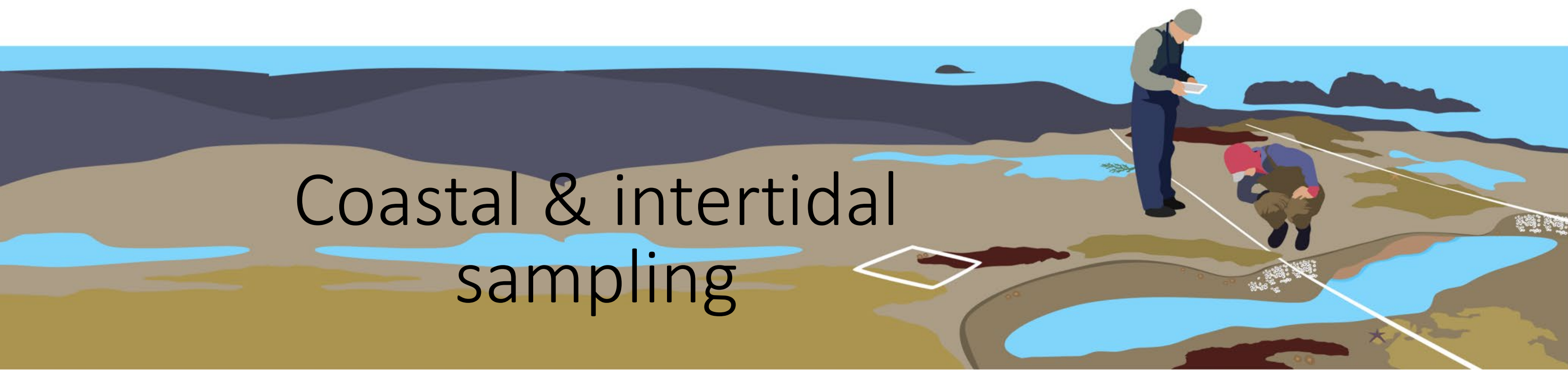
Not applicable

HABITAT TYPE

TARGET BIOTA



REFERENCES: [1]Barbraud and Thiebot, 2009; [2]Bruce et al., 2014; [3]Bauer et al., 2015; [4]Charlton et al., 2019; [5]Marsh et al., 2019; [6]Koopman et al.,2018; [7]Hughes et al 2022; [8] Blaber, 1986



Coastal & intertidal sampling

A wide variety of direct data collections in coastal and intertidal environments are made by researchers using sensors, cameras (stills and or video), push corers, shovels, water samplers, and gears such as nets, traps, pumps to sample target biota for collection or tagging, and in situ experiments. [1-6]

OPERATION[1-5]

Humans may access the sampling area using a suitable vehicle (e.g. car, ATV), but while sampling are typically on foot. Common sampling methods include recording *target biota* along transect lines, or in randomly placed quadrats, and detecting and documenting animal tracks, burrows or nests. Markers may be installed for repeat surveys or transects in *target habitats*.

SCIENTIFIC VALUE & BENEFIT

* Direct and real time observation by scientific experts of habitats experiencing relatively very high direct and indirect human pressures, particularly beaches and intertidal rocky reefs.

* Opportunity to make adaptive decisions for and during sampling/ observations, including on-ground verification of remote observations [1].

* Long-established and highly repeatable survey techniques, e.g. transects or quadrats, suited to collect time-series data[4].

* There are many proven and long-standing applications including counts of turtle nests and tracks [1,5], abundance and distribution of invertebrates in intertidal zones[3]; impact studies on crab burrows[6], pollution studies of beach and intertidal sediments[4], human uses and impacts on beach fauna[7].

* Interaction with *target biota* is precise: biological samples are collected using a range of specialised tools, and are carefully handled during collection; live collection, tissue sampling and tagging is possible. In situ measurements and experiments can be conducted[2].

IMPACTS & VULNERABILITY

Direct impact: Highly variable in a diverse range of coastal and intertidal *habitats* depending on study types; ranges from negligible, e.g. collection of *observational data* and *in situ imagery* to limited, e.g. removal of *target biota* and *physical samples*. Extractive/experimental activities are targeted and localised.

Indirect impact: Presence of humans and noise has the potential to influence the behaviour of some coastal fauna, e.g. nesting seabirds, and some compacting of substrate and trampling of habitat may occur, but the extent is highly localised.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Coastal and intertidal habitats are typically highly dynamic and are expected to have high resilience to physical disturbance. *Biota* targeted for collection are expected to be characterised by high resilience, e.g. highly abundant, broadly distributed, short-lived and with high fecundity.

Mitigation: Experienced personnel conduct surveys using best practice techniques, especially where entering sensitive habitats (e.g. nesting sites).

SAMPLE TYPE

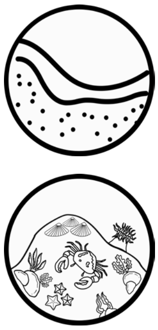
SIZE

Not applicable

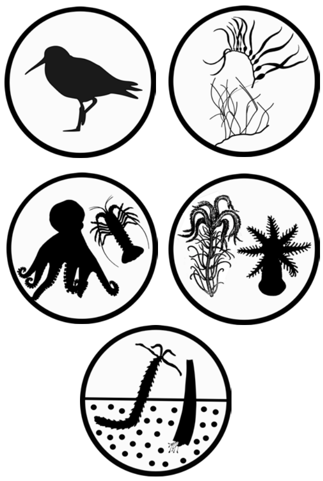
FOOTPRINT

Highly variable depending on study

HABITAT TYPE



TARGET BIOTA



REFERENCES: [1] Tucker et al.,2021; [2] Gemelli et al., 2019; [3] Kwon et al., 2020; [4] Nordberg et al., 2019; [5] Scheibling and Black, 2020; [6] Lopes Costa et al., 2021; [7] Schlacher et al., 2016.

Divers & Snorkellers

Humans can directly observe water column and seafloor environments and collect data or samples by diving using SCUBA (a tank of compressed breathable gas) to ~70 m depth or by breath-hold snorkeling (~15 m depths). Sampling tools include sensors, push corers, water samplers, cameras (stills and or video), as well as gears for biota collection and conducting in situ experiments.[1-6]

OPERATION [1,2,3]

Divers/ snorkellers typically swim in the water column above the substrate, avoiding unintentional contact with the habitat and biota. Taking samples or conducting experiments may require divers to set down on the seafloor. For repeat surveys or transects markers may be installed in the *target habitat*.

*Common sampling methods employing divers/ snorkellers are described and illustrated on the reverse of this template.

SCIENTIFIC VALUE & BENEFIT

* Direct and real time observation by scientific experts.

* Opportunity to make adaptive decisions during sampling and/ or observations.

* Highly repeatable survey techniques, e.g. transects or quadrats, suited to collect time-series data[1,2,3].

* There are many proven long-standing applications including, notably, Underwater Visual Census (UVC) - for determining composition and abundance of fishes and invertebrates in shallow water environments – e.g. the Reef Life Survey Program[1,7,8] and Manta tows used in long-term monitoring of crown-of-thorn seastars on the Great Barrier Reef[3,9].

* Interaction with *target biota* is precise: biological samples are collected using a range of specialised tools, are carefully handled during collection, live collection is possible. In situ experiments can be conducted by divers[5,6].

IMPACTS & VULNERABILITY

<u>Direct impact</u>: Collection of observational data, in situ imagery, *target biota* and physical samples from a range of benthic and pelagic *habitats*. Minimal or no contact with the seafloor; extractive/experimental activities are targeted and localised.

<u>Indirect impact</u>: Movement and noise may influence the behaviour of some mobile animals. Resuspension of fine-grained (e.g., muddy) sediments, and unintended contact with the habitat may occur, but the extent is highly localised.

<u>Ecosystem level impact</u>: Not applicable.

<u>Resilience of values to the activity</u>: There is very limited direct interaction with AMP values. Shallow marine habitats are typically highly dynamic and are expected to have high resilience to disturbance. Coral and rocky reef *habitats* are expected to have lower resilience than sediment habitats; in addition, tropical *habitats* may have higher productivity and resilience than cool climate habitats. Where physical samples are taken, resilience of the targeted biota depends on population parameters such as fecundity and age at maturity.

<u>Mitigation</u>: Experienced personnel conduct surveys using best practice techniques.

SAMPLE TYPE

SIZE

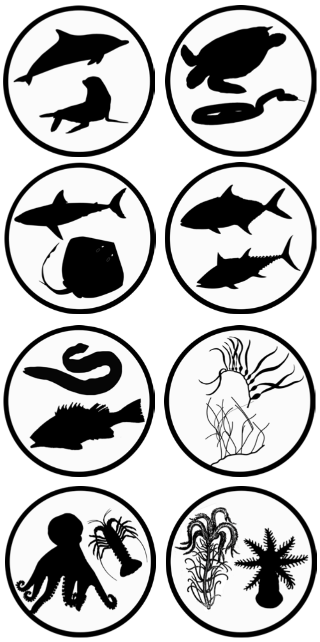
Not applicable

FOOTPRINT

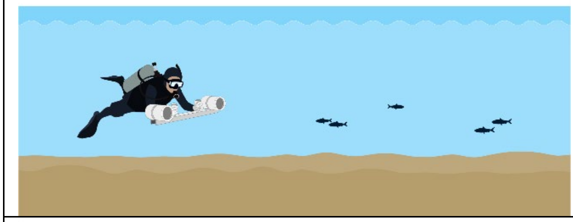
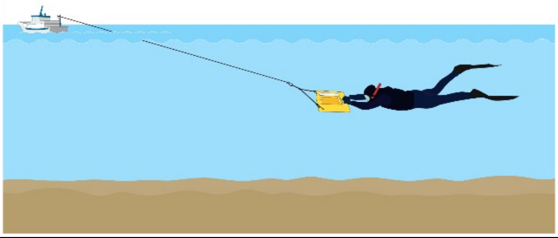
Not applicable unless samples are taken
*see relevant gear

HABITAT TYPE

TARGET BIOTA



REFERENCES: [1] RLS, 2022; [2] Goetze et al., 2018; [3] Miller et al., 2018; [4] Layton et al., 2020; [5] Kendrick and Walker, 1991; [6] Barker et al., 2011; [7] Stuart-Smith et al., 2017; [8] Strain et al. 2018; [9] Moran and De'ath, 1992; [10] Haskel et al., 2014.

	**Diver observer**[10] The diver/ snorkeller observes the *target biota,* recording data/behaviours, while swimming or maintaining position in the water column. Observations may also be recorded using still or video cameras.
	**Diver - Underwater Visual Census (UVC)**[1,7,8] The diver/ snorkeller follows a laid-out transect line and/or quadrats recording observations or taking a visual census of *target biota.* Observations may also be recorded using still or video cameras.
	**Diver Operated Cameras (DOV)**[2] Diver operated video (DOV) consist of a frame carrying single or stereo cameras, designed to be carried by a diver/ snorkeller. DOV may be used to record observations for later analyses.
	**Manta tow**[3,9] A Manta Tow involves towing an observer (snorkeller) at a constant speed behind a vessel. Observer holds on to a manta board attached to the boat by a long length of rope. The observer makes a visual assessment during the tow and records the data at the end. Manta tows are used as broad-scale reconnaissance tools; they can efficiently cover large areas.
	**Diver collection/ experiments**[4,5,6] The diver/ snorkeller directly interacts with the *target biota* or the substrate, collecting a sample or whole specimen. The diver typically holds position in the water column during sampling, but may sit down on the seafloor while collecting the sample.

Tagging

Various types of tags (see reverse for short descriptions) are used to generate data on population size, behaviour, growth, geographical movements and physiology in a wide variety of target biota including mammals, birds, fishes, reptiles as well as sessile and mobile invertebrates. Tagging is the process of attaching the tag to the target biota and involves direct interaction (usually human contact) to capture, handle, tag and release live individual animals. Depending on the tag type, information is collected when the animal is recaptured, via data loggers deployed on moorings or from vessels, or via satellite.[1-10]

SAMPLE TYPE

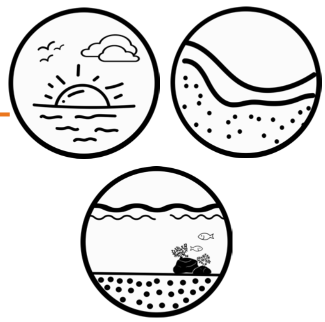
SIZE

Variable

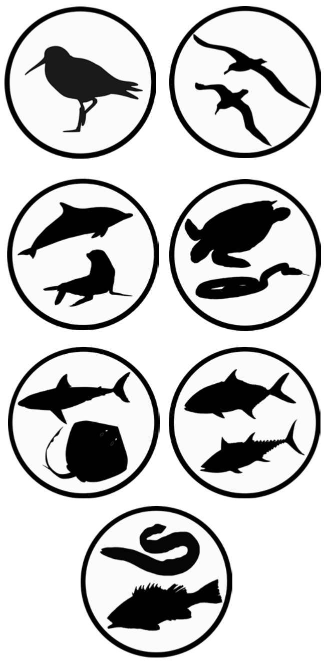
FOOTPRINT

Not applicable

HABITAT TYPE



TARGET BIOTA



OPERATION[11]

Target biota are captured live using various gears e.g. hand nets, hook and line or traps, and using best-practice methods, to minimise the impact upon them. Key environmental parameters (e.g. location and depth of capture) and measurements (e.g. sex, length, health), are taken when fitting the tag, before each individual is released. Tissue samples for genetics or biochemical tracer studies are often also collected. Tagged animals may be photographed to provide individual visual records. *Common tag types are described on the reverse of this template.

(Note: Sampling methods involving live animals are closely assessed by the Animal Ethics Committee.)

SCIENTIFIC VALUE & BENEFIT

* Tagging is a proven scientific method providing estimates of populations size [12,13], animal movement[5,6,7,10] and behaviour[2,5,14] in a wide variety of *target biota*, including many that represent natural conservation values.

* Applications include studies of *marine mammals*[2,14], *birds*[4], *turtles*[10] *fishes*[5-9].

* Tagging may be a secondary sampling activity within a broader study, e.g. to enable future analysis of movement during a baseline assessment of population abundance and distribution[3,6].

* Tissue sampling completed in conjunction with tagging has strong potential to add value to results, e.g. by assessing stock structure from genetic markers[6] or dietary/ health characteristics from biochemical tracers. – see Tissue Sampling template

IMPACTS & VULNERABILITY

Direct impact: Sampling is non-lethal, but can cause stress to *target biota*. There is a possibility of occasional accidental mortalities of *target biota* resulting from the capture process, e.g. fishing[3,6], but this is highly variable across target species and study types. Mortality rates are typically very low and documented for conservation-sensitive species, e.g. sharks[6].

Indirect impact: Non-target biota may be captured if the sampling process is unable to discriminate the *target biota*, e.g. fishing[6].
Tags may be shed; some tags are designed to drop off and stay in the environment (*see reverse)

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable

Mitigation: *Target biota* are captured and handled using best-practice methods that minimise the impact upon them[11]. Surgical procedures may use antibiotics to mitigate possible infections.

REFERENCES: [1] Wildlife Computers, 2022; [2] Gales et al., 1992; [3] Ainley et al., 2013; [4] Lavers et al., 2019; [5] Jakobs and Braccini, 2019; [6]Williams et al., 2012; [7] Block et al., 2001; [8] Bradford et al., 2020; [9] Griffiths, 2020; [10] IMOS News, 2022; [11] Bradford et al., 2015; [12]Premarathna et al., 2018; [13]Tourani, 2021; [14]Campbell et al., 2008.

Tag type	Description and deployment on animal	Data collection and use
Conventional tags[2-5, 11, 12]	External tag that has a unique recorded number. Relies on recapture (or reported sightings) of the tagged animal.	Data include location of, and size at, tagging & location of recapture, time-at-large, growth rates. Used for estimating population size (mark – recapture studies), site fidelity, geographical movement, growth parameters.
Archival tags[8]	Electronic tags, usually surgically implanted, to record and store data (e.g. TDRmark9[1]) Relies on recapture for tag recovery.	Data including depth, light intensity, temperature (ambient and internal). Used for studying behavioural trends, migration routes, diving/ haul-out behaviours.
Satellite tags [7-10]	Mostly externally deployed tags that either send data to a satellite when the animal is at or near the surface (Satellite-linked radio tags – SLRT[8]), or that are programmed to record and store data (archival satellite tag) until they are released from the animal after a set time period and float to the surface from where data are transferred via satellite (e.g. Pop-up satellite-linked archival tags – PSAT[8]). If required, stationary terrestrial listening stations can be used to log data from satellite tags within a range of ~200km [1,13]. No need for recapture of the animal, tags are designed to be released into the environment.	Data include geolocation and temperature when the tag is in contact with satellite (non-archival). Used to identify haul-out areas, movement and migration paths. Tags with archival capability – see archival tags.
Acoustic tags[5,6]	Externally or internally deployed tags that broadcast an acoustic signal that is detected by a receiver (hydrophone) that can be deployed on a fixed mooring[6] or from a vessel. (See Moorings and Hydrophone templates) No need for recapture of the animal.	Movement/ behaviour information without need for animal to surface – used to define home ranges, migration paths, site fidelity.

Tissue sampling, Stomach flushing

Biological samples taken from tissue sampling or stomach flushing enable the study of genetic properties (e.g. population structure), diet, health, and physiology of the target biota. Sample collection involves direct interaction (usually human contact) to capture, handle, sample and, typically, release live individual animals. The collected samples are retained and analysed in the laboratory.[1-4]

OPERATION[1]

Mobile *target biota* are typically captured live using various gears and methods, including e.g. hand nets, hook and line or traps, and use best-practice methods, to minimise the impact upon them. Key environmental parameters (e.g. location and depth of capture) and measurements (e.g. sex, length, health), are taken during the procedure, before each individual is released. Specialised biopsy darts or harpoons may be used to collect samples without capturing and handling the target animal. Sessile *target biota* are accessed and sampled in situ. Sampled *biota* may be photographed to provide individual visual records. *More detailed descriptions are detailed on the reverse of this template.
(Note: Sampling methods involving live animals are closely assessed by the Animal Ethics Committee.)

SCIENTIFIC VALUE & BENEFIT

* Tissue sampling and stomach flushing are proven and commonly employed methods used for genetic studies of population structure and size[2], and studies of diet, health and physiology using stable isotopes or biochemical tracers in a wide variety of *target biota*[1], including many that represent natural conservation values.

* Applications include studies of physiology and genetics of *marine mammals*[1] from biopsy, and using *fish* fin clips to understand feeding ecology[4] or population size[5]; stomach flushing is used for dietary analyses of *birds*[6] but also *sharks*[3].

IMPACTS & VULNERABILITY

Direct impact: Sampling is typically non-lethal (although tissues can be taken from freshly dead animals if they are deliberately harvested or culled), but can cause stress to target biota. There is a possibility of occasional accidental mortalities of *target biota* resulting from the capture and/ or sampling process. Accidental mortality is highly variable across target species and study types, and mortality rates and risks are typically very low and documented for conservation-sensitive species.

Indirect impact: Non-target biota may be captured if the sampling process is unable to discriminate the target biota, e.g. fishing.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: *Target biota* are captured and handled using best-practice methods that minimise the impact upon them. Non-capture methods (e.g. biopsy darts) are used when feasible.

SAMPLE TYPE

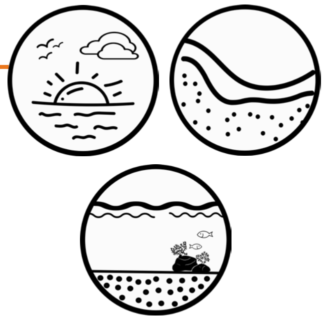
SIZE

Not applicable

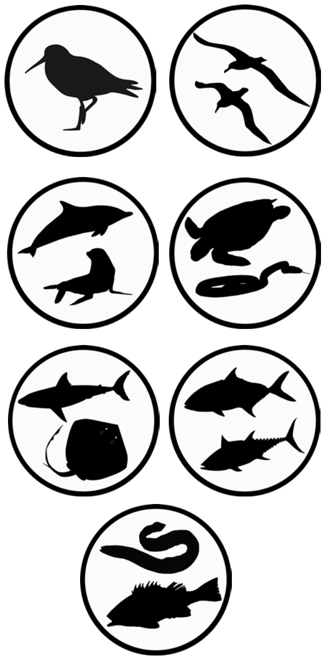
FOOTPRINT

Not applicable

HABITAT TYPE



TARGET BIOTA

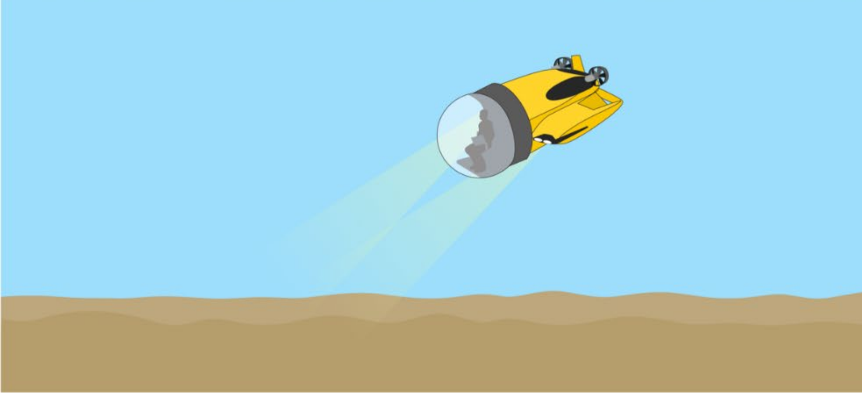


REFERENCES: [1] Mathews et al., 1988; [2] Wasko et al., 2003; [3] Barnett et al., 2010; [4] Jardine et al., 2011; [5] Bravington et al., 2016; [6] Verlis et al., 2018.

Procedure	Interaction with animal	Data collection and use
Tissue sampling (including biopsy)	A small piece of tissue is collected from the animal – this may be done in conjunction with applying a tag. E.g. fin clip[2,4,5], tissue punch[1], part of colony.	Analysis of genetics for population studies – e.g. close kin relationships[5] Analysis for stable isotope signatures, or biochemical tracer studies
Stomach flushing	The animal's stomach is intubated, and water is used to flush the stomach content into a container[3,6].	Analysis of diet composition

9 Submersibles

Human Operated Vehicle (HOV)	
Remotely Operated Vehicle (ROV)	
Autonomous Underwater Vehicle (AUV)	e.g. IMOS AUV Sirius & Nimbus



Human Operated Vehicle (HOV)

A manned, untethered submersible with a pressure hull that can transport 1 or 2 scientists to the deep water column and seafloor to make direct observations and sample with sensors and tools. Fitted with multiple sampling tools (e.g. acoustic sounders, robotic arms, sediment core and water samplers), sensors (e.g. pH, dissolved O_2, temperature), lights and cameras (stills and/ or video) used to conduct experiments, make observations, collect data, physical and biological samples, and imagery of the water column and seafloor. Electrically powered and propelled by multiple thrusters that allow movement in all directions.[1,2]

OPERATION [1,2,3,4,5,7]

Deployed from a surface vessel using a dedicated Launch and Recovery System (LARS) and manned by a specialist pilot onboard the vehicle. The addition of robotic arms – which are highly variable in their capability – confer high versatility for selective extractive sampling (e.g. push coring or tissue sampling). Surveys may follow either a random exploratory path or systematic transects across a range of habitat types. High endurance with survey missions typically of 4 to 20 h duration. Used to sample and image a range of marine ecosystems and *habitat types* from from shallow depths down to > 10 000 m and at speeds of up to 5 kt.

SCIENTIFIC VALUE & BENEFIT

*As for ROV plus:

*HOV enable delicate and selective multidisciplinary *sampling* (physical sensor data, water, sediment, and faunal samples) in sensitive *habitats* (e.g. coral reefs) beyond SCUBA diving depths, and apart from ROV the only tool capable of collecting high quality imagery and fauna from rugged terrain and complex geological features (e.g. boulders, walls, ledges) [1,2].

*Direct and real time observation by scientific experts [5]

*High resolution colour imagery used for species identification, linking with taxonomic specimen collection, habitat association studies, and evaluation of condition (e.g. live, dead), to ground truth MBES, as well as to generate spatially accurate photomosaics (colour) and fine scale (1-10 cm) digital elevation models.

*Applications include the discovery of unique deep-sea habitats (e.g. Alvin discovery of hydrothermal vent communities)[6], detection and exploration on wrecks (e.g. *RMS Titanic*)[7], species discovery [8], substrate characterisation, documenting and assessing the impacts of trawling on benthic communities[9], observations of faunal distribution and abundance[10].

IMPACTS & VULNERABILITY

Direct impact: Collection of *observational data*, *in situ imagery*, *target biota* and *physical samples* from a range of benthic and pelagic *habitats*. Minimal or no contact with the seabed; extractive activities are targeted and highly localised.

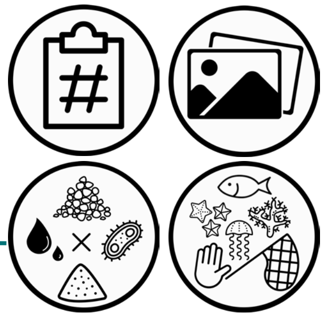
Indirect impact: Light and movement may influence the behaviour of some animals, but the potential effects are unknown at this stage. Resuspension of fine-grained (e.g. muddy) sediments may occur, but highly localised.

Ecosystem level impact: Not applicable

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE



SIZE [1,2,3,4,8]

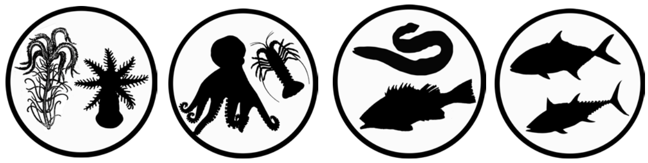
Variable: 7-10 m L, 2.6-3.3 m W, 3-4.4 m H; weight 18.6 – 35 t; observation port 120-280 mm; payload 200-290 kg

FOOTPRINT

Minimal: W x L of vehicle if landed (m^2)

HABITAT TYPE

TARGET BIOTA



REFERENCES: [1] Cui, 2018; [2] Moorhouse, 2015; [3]WHOI – HOV Alvin; [4]WHOI – HOV Challenger, 2022; [5]Bergman, 2012; [6]Corliss et al., 1979; [7]Humphris et al., 2014; [8]Zhang, 2021; [9]Moser et al., 2022; [10]Vinogradov et al., 2005

Remotely Operated Vehicle (ROV)

An unmanned, usually tethered submersible fitted with sensors (e.g. pH, dissolved O_2, temperature), lights and cameras (stills and or video) and a payload of sampling tools (e.g. robotic arms, sediment core and water samplers), used to collect data, physical and biological samples, and imagery of the water column and seafloor. ROVs are propelled by multiple thrusters that allow movement in all directions. Sizes can vary from small hand-deployed devices to large, heavy duty (~5t) vehicles that differ in depth rating and sampling capability.[1,2]

OPERATION [1,2]

Large ROVs are deployed from a surface vessel using a dedicated Launch and Recovery System (LARS) and usually tethered; smaller, battery powered units may be untethered and hand-deployed. Surveys are typically designed to follow either a random exploratory path or systematic transects. Imagery and sensor data (e.g. depth, orientation) are transmitted in real-time to the surface and used by pilots to manipulate and control the vehicle across a range of habitat types and depths. ROVs can be deployed for extended periods of time. The addition of robotic arms – which are highly variable in their capability – confer high versatility for selective extractive sampling (e.g. push coring or tissue sampling) and differentiate this platform from AUVs and towed systems. Sampling of target biota is precise: samples collected with specialised tools are carefully handled, placed in individual containers to ensure the condition and form of animals is maintained in pristine condition (live collection possible). Used to sample depths down to 4700 m, being maintained at an altitude of > 1 m and speeds of up to 3 kt.

SCIENTIFIC VALUE & BENEFIT

*ROVs enable delicate and selective multidisciplinary sampling (physical sensor data, water, sediment, and faunal samples)

*Used in sensitive habitats (e.g. coral reefs) beyond SCUBA diving depths, and the only unmaned tool capable of collecting high quality imagery and fauna from rugged terrain and complex geological features (e.g. boulders, walls, ledges) [1].

* Advanced positional accuracy allows for precise repeated transects to be conducted over time [1].

*High resolution colour imagery used for species identification linking with taxonomic specimen collection, habitat association studies, and evaluation of condition (e.g. live, dead), to ground truth MBES, as well as to generate spatially accurate photomosaics (colour) and fine scale (1-10 cm) digital elevation models.

*Quantitative estimates of substrate and faunal cover, abundance, density, and length measurements using non-destructive methods are possible from systematic sampling designs [2,3,4,5,6,8].

*Applications include monitoring impacts of invasive species[3], assessing the effectiveness of marine protected areas[4], mapping benthic habitats[5,6], assessing diversity and abundance of fish and invertebrate communities, particularly associated with artificial structures (e.g. oil and gas platforms) [7,8].

IMPACTS & VULNERABILITY

Direct impact: Collection of *in situ imagery*, *target biota* and *physical samples* from a range of benthic and pelagic *habitats*. Minimal or no contact with seabed; extractive activities are targeted and highly localised.

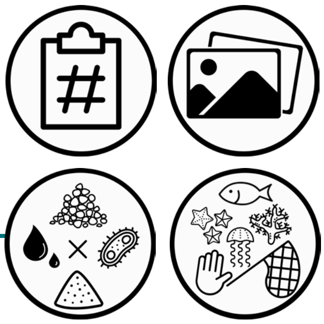
Indirect impact: Light and movement may influence the behaviour of some animals, but the potential effects are unknown at this stage. Resuspension of fine-grained (e.g. muddy) sediments may occur, but highly localised[9].

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE



SIZE [1,2]

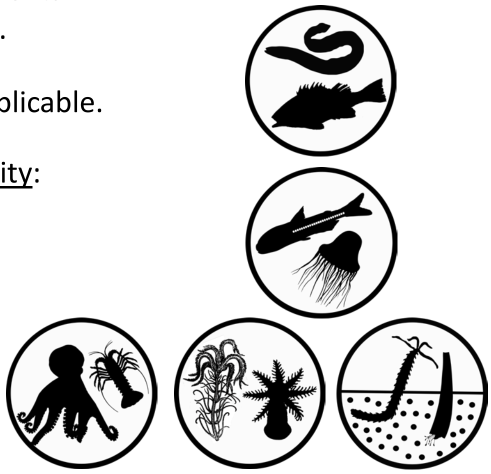
Variable: small, observation-class vehicles (<40 kg), larger vehicles (100-150 kg) carrying a higher payload and work-class, heavy duty (<5000 kg) models, which vary in power and sampling capabilities.

FOOTPRINT

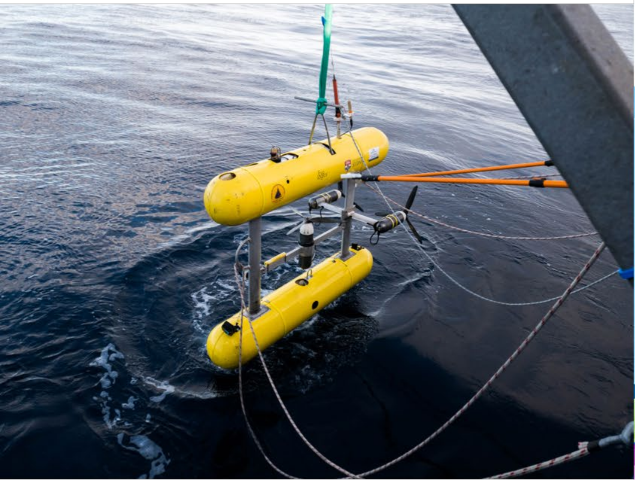
Minimal: W x L of vehicle if landed (m^2)

HABITAT TYPE

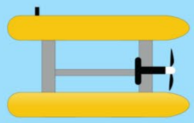
TARGET BIOTA



REFERENCES: [1] Monk et al., 2020a; [2] Sward et al., 2019; [3] Sward et al., 2021; [4] Huvenne et al., 2016; [5] Button et al., 2021; [6] Post et al., 2022; [7] McLean et al., 2017; [8] McLean et al., 2021; [9] de Mendonça and Metaxas 2021



Autonomous Underwater Vehicle (AUV)



An unmanned and untethered submersible fitted with multiple sensors (e.g. pH, dissolved O_2, temperature), acoustic systems, lights and cameras (stills and/or video) used to collect data, and imagery of the water column and seafloor. AUVs sample autonomously (independently) along a pre-programmed survey path at a pre-set altitude, typically 1 to 10 m above the seafloor using multiple thrusters to control heading and direction, including object avoidance at low speeds. 'Cruising' AUVs are fast moving (2 ms^{-1}) while 'hovering' AUVs undertake precision 'slow-motion' operations. The configuration and orientation of cameras (mono or stereo) varies but is generally downward-facing (rarely oblique) with a fixed field of view. AUVs that are fast moving or flown at high altitude may not be suited to seabed imaging; these are comparable to 'Gliders' (see 'Sensors and Profilers').[1-3]

OPERATION [1-3]

Large AUVs are deployed from a surface vessel using a dedicated Launch and Recovery System (LARS); small units can be launched from a beach or jetty. Imagery and sensor data (e.g. position, depth, orientation) are recorded on-board the AUV and downloaded to computers after retrieval of the unit. Used to sample and image a range of marine ecosystems and *habitat types* from shallow depths down to 6000 m depending on the AUV size and construction, e.g. Australian IMOS AUV Facility '**Sirius**' to 700 m depth and '**Nimbus**' to 300 m depth. AUVs are typically tracked using a positioning beacon/s while on mission.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *non-extractive sampling* of *target biota* – particularly sessile flora and fauna communities – in a great variety of shallow to deep sea *habitat types*, e.g. mesopelagic zone, coastal seas, coral reefs [1, 2, 3].

* Suited to use in sensitive *habitats* (e.g. seagrass meadows and coral reefs) for collecting high quality imagery from complex geological features, including steep rock walls, if AUV has the appropriate sensors[1].

* Advanced positional accuracy allows for precise repeat sampling – AUVs have been successfully used in monitoring programs[1,2] of shelf habitats, and to sample seamounts[4].

*Produce spatially accurate photomosaics (colour) and fine-scale (1-10 cm) digital elevation models.

IMPACTS & VULNERABILITY

Direct impact: Collection of in situ *imagery*, from a range of *habitats*. No contact with the seafloor.

Indirect impact: Light, movement and noise may influence the behaviour of some animals, but the potential effects are unknown at this stage.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE

SIZE [1,2]

IMOS AUV **Sirius**: 2 m L x 1.5 m H x 1.5 m W; 200 kg
IMOS AUV **Nimbus**: 2.8 m L x 0.5 m H x 0.3 m W; 120 kg

FOOTPRINT

None, no bottom contact.

HABITAT TYPE

TARGET BIOTA

REFERENCES: [1] Monk et al., 2020b; [2] IMOS, 2022;[3] WHOI - ABE, 2010; [4] Thresher et al. 2014.

10 Underwater Imaging Platforms

Profiling Langian Acoustic Optical System (PLAOS)	
Towed Camera	
Drop Camera	Drop Camera Video lander
Pelagic Baited Remote Underwater Video (BRUV)	Pelagic BRUV Mid-water RUV
Baited Remote Underwater Video (BRUV)	BRUV Underwater video (UV) Lander

Profiling Lagrangian Acoustic Optical System  (PLAOS)

The Profiling Lagrangian Acoustic Optical System (PLAOS) is used to simultaneously collect acoustics and image data of pelagic biota during a free-fall transect through the water column down to ~ 1000 m depth. The PLAOS consists of a frame to which a scientific echosounder transceiver, lights and high-definition stills and video camera/s are attached to acquire a matching echogram (a 2D visual representation) and photographic image of target biota. The camera/s are orientated downward-facing and have a fixed field of view. Additional sensors may be mounted on the PLAOS frame.[1]

OPERATION[1]

Deployed from a surface vessel and tethered to it for the duration of the operation. The platform sinks through the *water column* at an approximate descend rate of 0.4 m/sec. The depth and position of the PLAOS is monitored via USBL. Once it reaches its maximum deployment depth (~1000 m) it is winched back on board the vessel. The buoyancy of the PLAOS may be adjusted using a buoyancy engine. Its echosounders operate at 38 and 120 kHz, or at 70 and 200 kHz; an internal computer runs the EK80 echosounder software for data acquisition and storage. (An untethered system is in development).

SCIENTIFIC VALUE & BENEFIT

* The PLAOS platform is relatively new experimental system designed at CSIRO, to address the need for close-proximity and matching high-quality images and in situ acoustic target strength measurements of the *target biota*[1].

* Applications include collecting biomass information of *pelagic biota* – notably gelatinous zooplankton which are poorly sampled by nets – through the water column using acoustics (echosounder) and simultaneous confirmation of the species composition using optics (stereo camera)[2,3].

IMPACTS & VULNERABILITY

Direct impact: Due to the characteristics of the acoustic signal of the PLAOS (low power, short signals, and narrow beam widths) they are not considered to physically harm marine life[4].

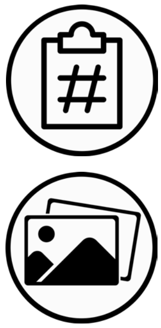
Indirect impact: Marine mammals are known to be sensitive to acoustic disturbance. This depends on the hearing range of the species, the acoustic frequency being used, the distance of the animal from the source, and the duration of exposure. Some studies have observed behavioural responses in marine mammals (vocalisation and avoidance)[4,5].

Ecosystem level impact: No ecosystem level impact.

Resilience of values to the activity: Not applicable.

Mitigation: Consider which species of marine mammal may be encountered during a survey.

SAMPLE TYPE



SIZE

3.2 m H, 1.4 m diameter

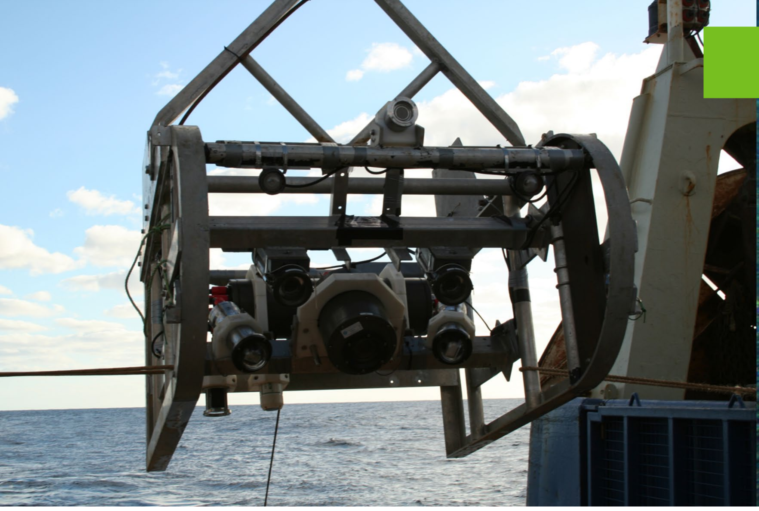
FOOTPRINT

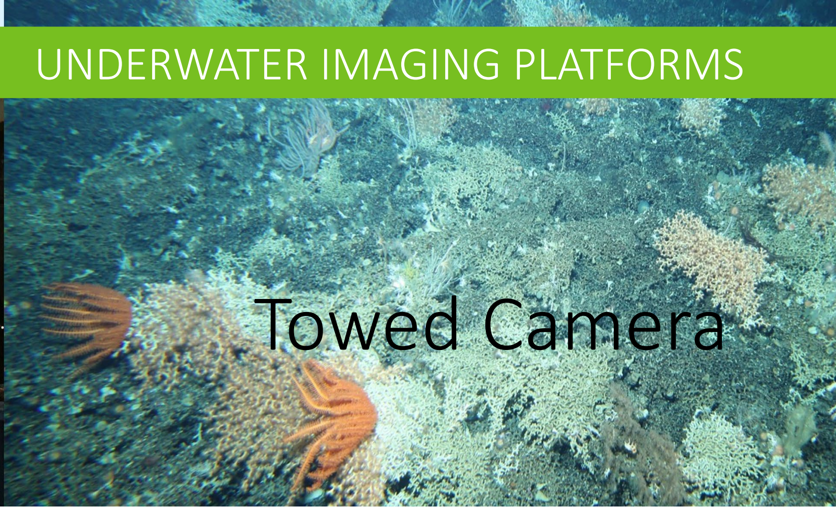
None, no bottom contact.

HABITAT TYPE

TARGET BIOTA

REFERENCES: [1]Marouchos et al., 2016; [2] Kunnath et al., 2018; [3] Kloser et al., 2016a; [4]Deng et al., 2014; [5]Cholewiak et al., 2017.





Towed Camera

A platform consisting of a frame to which sensors, lights and cameras (stills and or video) are attached to acquire imagery of the seafloor or, less commonly, the water column. The configuration and orientation of cameras varies but in general there are forward-looking, oblique stereo cameras, or downward-facing cameras with a fixed field of view. Also carries a positioning beacon and possibly other sensors. [1,2,3]

OPERATION[1,2,3]

Deployed from a surface vessel and tethered to it for the duration of the operation. Collected imagery and positional information are stored and subsequently downloaded or transmitted directly to the surface in real-time via a coaxial or fibre optic cable. Real-time positional data and imagery enables precise control by the surface pilot. Operated from shallow depths down to 3500 m, in a range of *habitat types* and maintained at an altitude of 2-3m above the seafloor.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *non-extractive sampling* of *target biota* and *habitats – demersal fish species, mobile and sessile invertebrates* that live at or near the seafloor[3].

* Suitable for use in sensitive *habitats* (e.g. coral reefs) and those with complex geological features (e.g. seamounts)[4-6].

* Cost effective, reliable, highly repeatable sampling over broad spatial and temporal scales.

* In situ context of communities is captured (e.g. large octocorals with brittle star associates) and can be used for a range of applications extending beyond the life of a survey.

*Abundance estimates can be quantitative if the field of view is known[6].

*Augments physical sample collections, where baseline biodiversity is well established[2].

IMPACTS & VULNERABILITY

<u>Direct impact</u>: Collection of in situ *imagery* from a range of benthic *habitats*. There is no contact of the gear with the seafloor and *target biota* are not removed.

<u>Indirect impact</u>: Light and movement may influence the behaviour of some animals, but the potential effects are unknown at this time.

<u>Ecosystem level impact</u>: Not applicable.

<u>Resilience of values to the activity</u>: Not applicable.

<u>Mitigation</u>: Not applicable.

SAMPLE TYPE

SIZE[1]

Variable:
0.3-2 m L;
0.4-1.2 m W;
0.35-1.3 m H.

FOOTPRINT

None, no bottom contact.

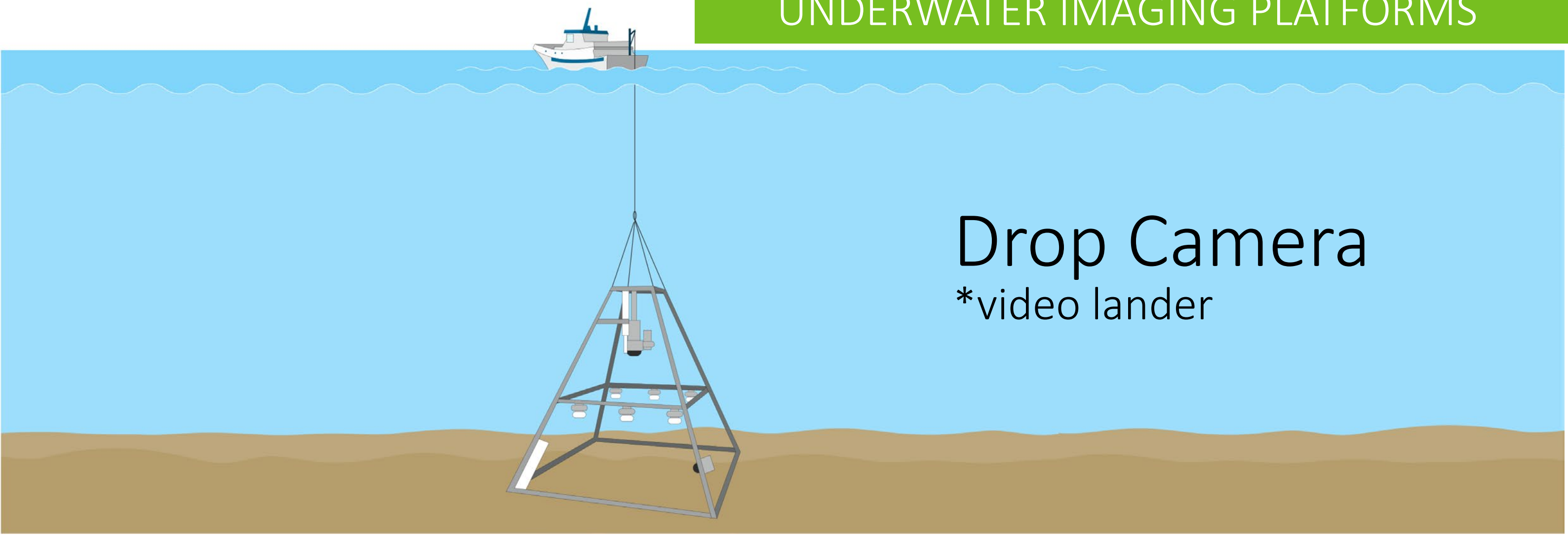
HABITAT TYPE

TARGET BIOTA

REFERENCES: [1] Carroll et al., 2020; [2] Sherlock et al., 2016; [3] Przeslawski et al., 2018; [4] Clark et al., 2016; [5] Williams et al., 2020; [6] O'Hara et al., 2020.

Drop Camera

*video lander



A landed platform consisting of a frame to which sensors, lights and camera/s (stills and or video) are attached to acquire imagery of the seafloor. The camera/s can be orientated in varying directions, but are typically downward-facing, with a fixed field of view (0.2–5 m^2). Weights may be added to the frame to aid stability and speed up deployment to the seafloor. [1,2,3,4,6]

OPERATION[1,2,6,8]

Deployed from a surface vessel and tethered to it for the duration of the operation. The platform is landed, and then slightly raised to repeatedly hop it across the seafloor to collect imagery from point locations. Imagery data are, either stored and subsequently downloaded, or transmitted directly to the surface in real-time via a coaxial or fibre optic cable. Operated from shallow (~4 m) depths down to ~250 m, in a range of *habitat types*.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *non-extractive sampling* of *target biota* and *habitats – demersal fish species*, *mobile* and *sessile invertebrates* that live at or near the seafloor.

* Suitable for use in sensitive *habitats* (e.g. coral reefs) and those with complex geological features (e.g. seamounts)[4,3,6].

* Cost effective, reliable, highly repeatable sampling over broad spatial and temporal scales[6].

*Imagery with a known field of view, enabling the collection of quantitative data: abundance, density, percentage cover and size [1-5].

* Applications include substrate and benthic habitat classification (e.g. assessing seagrass cover)[3], assessing fish abundance and distribution (e.g. associated with artificial reefs)[7], ground truthing predictive species models, determining scallop density and size for fisheries stock assessments[5,8].

IMPACTS & VULNERABILITY

Direct impact: Collection of in situ *imagery* from a range of benthic *habitats*. There is limited contact of the gear with the seafloor and *target biota* are not removed.

Indirect impact: Potential impact on epifauna beneath *footprint*. Resuspension of fine-grained (e.g. muddy) sediments is possible, but is highly localised.

Ecosystem level impact: No ecosystem or population impacts are expected; the area of contact with the seafloor is expected to be minimal (*footprint*/ number of deployments), even with repeated sampling at a site.

Resilience of values to the activity: Not applicable.

Mitigation: Impacts are minimised by informed planning and targeting of sample locations, i.e. pre-survey mapping of substrate types.

SAMPLE TYPE

SIZE

Variable: 0.25 L x 0.25 m W to 2m L x 2 m W x 1.4 m H.

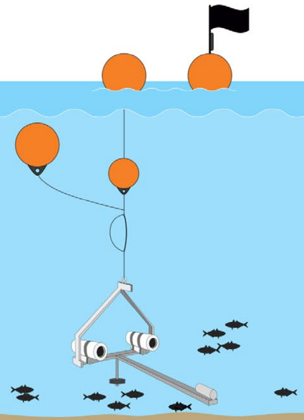
FOOTPRINT

(L x W of platform) x number of deployments

HABITAT TYPE

TARGET BIOTA

REFERENCES: [1] Przeslawski et al., 2018; [2]de Mendonça and Metaxas, 2021 ;[3]Carter et al., 2021; [4]Langlois et al., 2021; [5]Bethoney and Stokesbury, 2018; [6]Easton et al., 2015; [7]Smith et al., 2017; [8]Bethoney et al., 2019



Pelagic Baited Remote Underwater Video System (BRUVS) *mid-water RUV

A platform suspended in the water column that acquires imagery of pelagic fauna (mostly fishes) typically attracted by bait. Pelagic BRUVS consist of a frame (e.g. aluminum, carbon fibre) to which sensors (e.g. temperature, depth), lights, camera/s and an arm carrying a bait container (not present in un-baited platforms). The camera/s are in a forward facing mono or stereo configuration. The suspension system consists of weights, rope, bungee cord and buoys attached to the frame. Moored units have an anchor and anchor line.[1-5]

OPERATION [1-5]

Deployed by hand from a surface vessel and either drift in the water column near the surface or closer to the seafloor (e.g. 50 m above), or are anchored (e.g. 10 m) above the seafloor in depths down to 120 m). Drifting units may sample over open ocean (e.g. depths down to 1600 m) Cameras record for a set period (up to 3 h). Capable of sampling over sensitive *habitat types* (e.g. coral reef) with complex terrain (e.g. seamounts, canyons), whereas moored systems are used in *unstructured habitat types*. [1-5]

SCIENTIFIC VALUE & BENEFIT

* A proven scientific sampling tool for *non-extractive sampling* of *target biota – pelagic fish* - including *sharks* and *rays*, *marine mammals* and *reptiles* - with highly variable (spatial and temporal) distributions, that are under threat (e.g. fishing impact), commercially important and are attracted to bait plumes[1, 3, 4, 5].

* Suitable for use in sensitive *habitats* (e.g. coral reefs) and those with complex geological features (e.g. seamounts) [1, 4, 5].

* Cost-effective, reliable, and highly repeatable sampling over broad spatial and temporal scales, including the remote open ocean [1-5].

* Applications include assessing species richness and composition, relative abundance (not density) and behaviour of pelagic biota, insights into inter or intra-specific interactions and the impacts of artificial reefs[2, 7, 8].

*Stereo pelagic BRUVS enable determination of body size (essential for biomass)[1,4].

* Widely used to assess the effectiveness of MPAs for pelagic species[4, 5], including in Australia [6, 7, 8].

IMPACTS & VULNERABILITY

Direct impact: Collection of in situ *imagery* from the *water column* in a range of *habitats*. Only moored systems have contact with the seafloor and *target biota* are not removed.

Indirect impact: Potential impact on epifauna beneath footprint of moored units, particularly if dragged across the seabed by currents. Resuspension of fine-grained (e.g. muddy) sediments is possible, but highly localised.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable

SAMPLE TYPE

SIZE[1,4]

1.8 m L x 0.95 m W x 1.45 m H; Lightweight < 12 kg

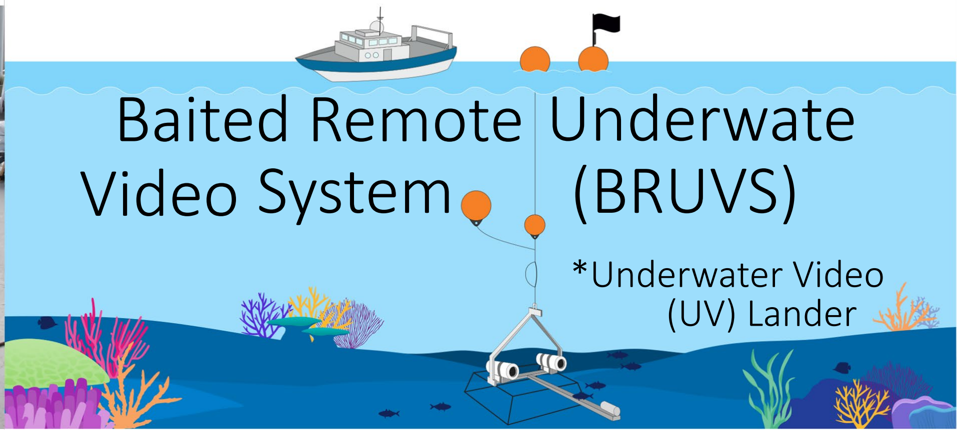
FOOTPRINT

Minimal: W x L of anchor (m^2) for moored units.

HABITAT TYPE

TARGET BIOTA

REFERENCES: [1]Bouchet et al., 2020; [2]Whitmarsh et al., 2016; [3]Heagney et al., 2007; [4]Bouchet and Meeuwig, 2015; [5]Cambra et al., 2021; [6]Forrest et al., 2021; [7]Harvey et al., 2021; [8]Meeuwig et al., 2021



Baited Remote Underwater Video System (BRUVS)

*Underwater Video (UV) Lander

A landed platform that acquires imagery of fauna (mostly fishes) attracted by bait, and a snapshot of adjacent seabed habitat. BRUVS consist of a frame (e.g. stainless steel, aluminum, plastic) to which sensors (e.g. temperature, depth), lights, camera(s) and an arm carrying a bait container (not present in un-baited platforms) are attached. The mono or stereo camera configuration can be downward-facing or, more commonly, horizontally facing. Weights, rope and a surface buoy are also attached to the frame to aid in deployment, relocation and retrieval. Deep BRUVS have a mooring system, which is acoustically released, allowing the system to float to the surface. [1-6]

OPERATION [1-6]

Deployed from a surface vessel (small units may be diver deployed) and landed on or near the seafloor, where cameras record for a set period (30 min – 20 h). Operated from shallow depths (~4 m) down to ~1000 m in a range of *habitat types* (e.g. soft-sediments, rocky reefs).

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for *non-extractive sampling* of *target biota* and *habitats – demersal fish species*, *mobile* and *sessile invertebrates* that live at or near the seafloor[1-6].

*Suitable for use in sensitive *habitats* (e.g. coral reefs) and those with complex geological features (e.g. seamounts).

*Cost-effective, reliable, and highly repeatable sampling over broad spatial and temporal scales [1-3].

*Applications include assessing species richness, relative abundance (not density) and behaviour of fish and their associated benthic habitat[6,7], few studies have assessed the diversity and relative abundance of *cephalopods*[8] and *crustaceans*[9].

*Stereo-BRUVS enable determination of fish length data (essential for biomass) and provide comparable body size distribution data to extractive methods such as trawling[1-3].

*Used extensively in Australia and to assess the effectiveness of MPAs [10].

IMPACTS & VULNERABILITY

Direct impact: Collection of in situ *imagery* from a range of benthic *habitats*. There is limited contact with the seafloor and *target biota* are not removed.

Indirect impact: Potential impact on epifauna beneath footprint, particularly if BRUVS units are dragged across the seafloor by currents. Resuspension of fine-grained (e.g. muddy) sediments is possible, but highly localised. Sacrificial weights are inert steel plates of sufficient mass to compensate for the gear's buoyancy, but typically 10s kg.

Ecosystem level impact: No ecosystem or population impacts are expected; the area of contact with the seafloor is expected to be minimal (*footprint*/survey area), even with repeated sampling at a site.

Resilience of values to the activity: Not applicable.

Mitigation: Impacts are minimised by avoiding sensitive habitats and the likelihood of gear dragging in currents.

SAMPLE TYPE

SIZE

Variable: small mono BRUVS: 45 cm L x 30 cm W x 7 cm H; larger stereo-BRUVS: 1.25 m diameter x 1.4 m H and weigh up to 250 kg.

FOOTPRINT

Minimal: W x L of unit when landed (m^2)

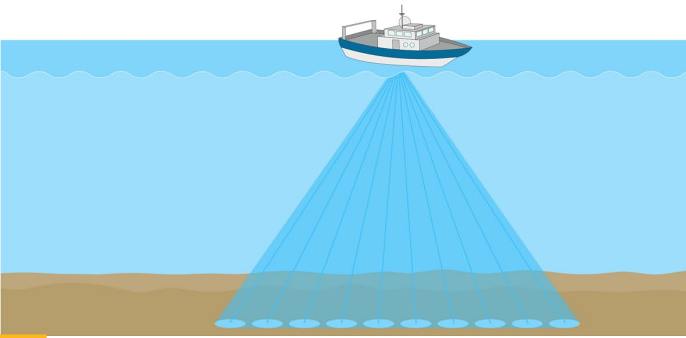
HABITAT TYPE

TARGET BIOTA

REFERENCES: [1]Langlois et al., 2018; [2]Langlois et al., 2020; [3]Jones et al., 2021; [4]Marouchos et al., 2011; [5]Whitmarsh et al., 2017; [6]Kiggins et al., 2018; [7]Logan et al., 2017; [8]Barord et al., 2014; [9]Tanner and Williams, 2015; [10]Harvey et al., 2021

11 Acoustic Sensors

Multibeam Echosounder (MBES)
Singlebeam Echosounder (SBES)
Side Scan Sonar (SSS)
Seismic Airguns
Sub-Bottom Profiler (SBP)
Hydrophones



Multibeam Echosounder (MBES)

Multibeam Echosounders (MBES) produce 3D visual representations ('maps') of water column features (e.g. fish schools) and the seabed (bathymetry and texture/ substrate types). MBES consist of multiple transceivers (combined transmitter and receiver) and transducers (an electrical device that converts electrical energy to sound, and vice versa). The transducers transmit 100s of narrow (0.5 - 1°) directional beams of sound (pings) into the water column, in a fan shaped pattern that can span a swathe of up to 150°. Sound reflections (backscatter) from targets (e.g. fish school or the seabed) are converted by the transducer to voltage for processing and analysis using specialised software. [1,2,3]

OPERATION [1,2,3,4,5]

MBES produce a fan of sound beams which cover a large sample area (swathe) along a vehicle track, operated in the *water column* at all ocean depths (i.e. 1 m down to many 1000s of m) depending on their power and operating frequency which ranges from ~1 kHz to several MHz (high frequency data are more finely resolved). Data are acquired in relatively narrow swathes in shallow depths and relatively wide swathes in deep depths because the width of the fan-shaped swathe increases with depth. Transceivers and transducers are typically mounted to a ship's hull but can be configured to provide higher quality data by operating more closely to the targets (e.g. fish schools) either by (1) being connected via cables to remote towed platforms, or (2) being completely autonomous (e.g. AUVs). MBES are highly versatile sensors providing data from a wide range of marine ecosystems (e.g. mesopelagic zone, coastal seas, coral reefs) and depths.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for the continuous, near real-time sampling of the *water column* and *seafloor* (backscatter: seafloor geomorphology and *substrate* and *bathymetric data*).

* Seafloor applications are primarily the systematic mapping of the seabed to create fine-scale resolution bathymetric or texture maps that represent geomorphology[2,4] and habitats at a range of relevant ecological scales[6].

* Water column applications include measuring the distribution and abundance of *fisheries* resources[7], studying interactions between *marine mammals* and renewable energy devices[8], detecting *sharks* in coastal waters[9], estimating *zooplankton* abundance[10], studying *kelp* ecology, as well as detection of shipwrecks, gas plumes, suspended sediment, seeps and hydrothermal vents[3].

* Allows the observer to examine a 3D surface rather than interpolate between sparse 2D profiles (such as those generated by SBES)[2].

IMPACTS & VULNERABILITY

Direct impact: Due to the characteristics of MBES (high frequency sound waves, short signals, and narrow transmitting lobes) they are not considered physically harmful to marine life[4].

Indirect impact: *Marine mammals* are known to be sensitive to acoustic disturbance. This depends on the hearing range of the species, the source level, the acoustic frequency being used, the distance of the animal from the source, and duration of the exposure. Some studies have observed behavioural responses in marine mammals (vocalisation, avoidance), and in an extreme case a mass stranding of melon-headed whales in a shallow estuary was linked to a MBES survey[11].

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Other *target biota* are not affected by sampling with MBES.

Mitigation: Consider which species of marine mammal may be encountered and avoid periods when larger numbers are expected. As a precaution the MBES could be turned off in the vicinity of marine mammals and use limited while stationary.

SAMPLE TYPE

SIZE

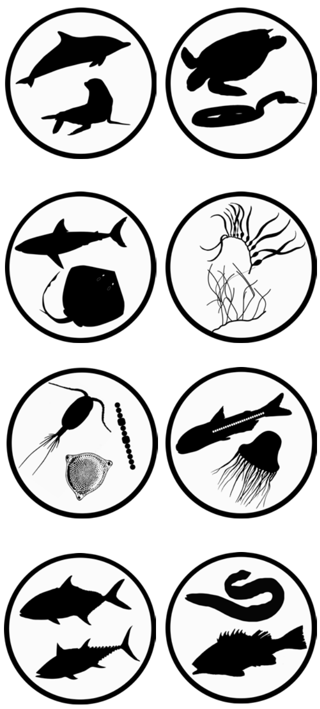
Transceivers and transducers can vary greatly in size and weight depending on the manufacturer and technical specifications.

FOOTPRINT

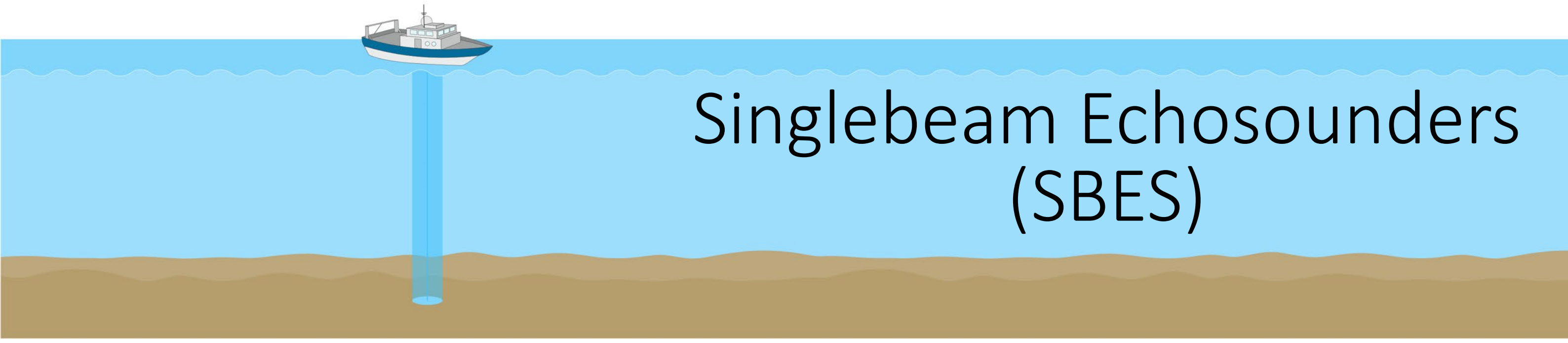
None, no bottom contact.

HABITAT TYPE

TARGET BIOTA



REFERENCES: [1]Urick, 1983; [2]Hughes Clarke, 2018; [3]Colbo et al., 2014; [4]Lurton, 2016; [5]Dunlop et al., 2018; [6]Brown et al., 2009; [7]Trenkel et al., 2008; [8]Hastie et al., 2019; [9]Lieber et al., 2017; [10]Korneliussen et al., 2009; [11]Southall et al., 2013.



Singlebeam Echosounders (SBES)

Singlebeam Echosounders (SBES) produce 2D visual representations ('maps') of water column features (e.g. fish schools) and the seabed (bathymetry), typically in the form of an echogram, which displays acoustic intensity by range (from the transducer) and time/ distance. SBES consist of a transceiver (a combination of transmitter/receiver) and one or more transducers (an electrical device that converts electrical energy to sound, and vice versa). The transducer(s) transmits short, narrow, (2-30°) pulses of sound (ping) down into the water column. Sound reflections (backscatter) from targets (e.g. fish school or the seabed) are converted to voltage for processing and analysis using specialised software. [1,2,3]

OPERATION [1,2,3]

SBES can be used in narrowband or broadband configurations and typically operate at frequencies between 12-500 kHz; they can be used in very shallow (1 m) down to very deep waters (many thousands of m). Transceivers and transducers are connected via cable(s), with the transducer(s) typically mounted to a ship's hull, but can be configured to provide higher quality data by operating more closely to the targets (e.g. fish schools) either by (1) being connected to towed/moored platforms, or (2) being completely autonomous (e.g. AUVs). SBES are operated in the *water column* to provide data from a wide range of marine ecosystems (e.g., mesopelagic zone, coastal seas, coral reefs).

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for the continuous, near real-time sampling of the water column and seafloor (*backscatter data*).

* A diverse range of applications including in *fisheries science*, *plankton* and *zooplankton research*, ecosystem studies, seafloor and benthic habitat mapping, and gas seep detection.

* A quantitative sampling method used in stock assessments of commercially important fish[4,5] (e.g. orange roughy and blue grenadier).

* Can be used to characterise substrate and the behaviour, distribution, and abundance of *zooplankton*, *pelagic fishes,* and *marine plants* [2,6,7,8,9].

*Provides fine-scale resolution spatial and temporal information [6].

*Simpler and more cost effective than MBES but provides more limited coverage of the study area [7].

IMPACTS & VULNERABILITY

Direct impact: Due to the characteristics of SBES (low power, short signals, and narrow beam widths) they are not considered physically harmful to marine life[1].

Indirect impact: *Marine mammals* are known to be sensitive to acoustic disturbance. This depends on the hearing range of the species, the acoustic frequency being used, the distance of the animal from the source, and the duration of exposure. Some studies have observed behavioural responses in marine mammals (vocalisation and avoidance)[1,2].

Ecosystem level impact: Not applicable.

Resilience of values to the activity: *Target biota* are not affected by sampling with SBES.

Mitigation: Consider which species of marine mammal may be encountered and avoid periods when larger numbers are expected.

SAMPLE TYPE

SIZE

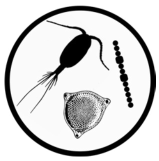
The transceiver can be as large as a desktop computer and the transducers can have a diameter >1 m, although they are typically much smaller.

FOOTPRINT

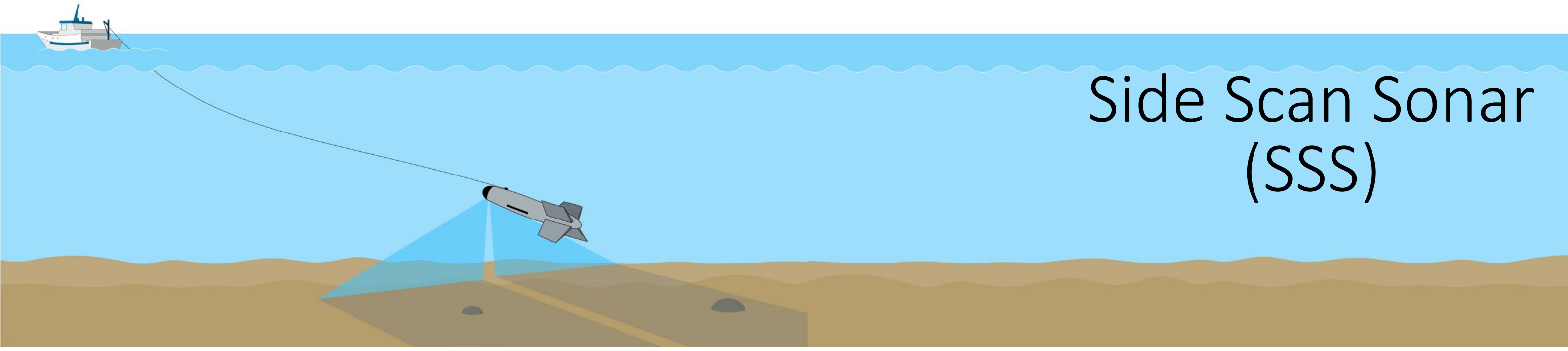
None, no bottom contact.

HABITAT TYPE

TARGET BIOTA



REFERENCES: [1]Deng et al., 2014; [2]Cholewiak et al., 2017; [3]Simmonds and MacLennan, 2005; [4]Kloser et al., 1996; [5]Kloser et al., 2016b; [6]Gavrilov et al., 2005; [7]Landero Figueroa et al., 2021; [8]Tseng, 2009; [9]Murphy and Jenkins, 2010



Side Scan Sonar (SSS)

Side Scan Sonars (SSS) produce 2-D visual representations ('maps') of the seabed showing differences in seabed texture and substrate types. SSS consist of a transceiver (a combination of transmitter/receiver) and two transducers (electrical devices that convert electrical energy to sound, and vice versa). The transducers emit many narrow-angle (0.2 - 1°), directional (along and across track) sound pulses to the seafloor that can span a swathe of up to 1500 m. Sound reflections (backscatter) from the seabed are converted to voltage for processing and analysis using specialised software.[1,2,3,4,5]

OPERATION[1,2, 3,4,6]

SSS are generally ship-borne or towed systems but can also be mounted to autonomous underwater vehicles (AUVs). Ship-borne systems usually consist of acoustic transducers installed on both sides of the hull. Towed systems are towed high above or close to the seabed with the transducers mounted on both sides of a towed platform ('towfish') that is tethered to a surface vessel and towed at speeds of 3 – 6 kts. SSS operate at frequencies ranging from 50-500 kHz, with frequency, height above seafloor, and swath width determining the resolution of acoustic data. SSS can be used in very shallow (1 m) down to very deep waters (1000s m), operate in the *water column* and are used in a range of marine ecosystems (e.g., coastal seas, coral reefs).

SCIENTIFIC VALUE & BENEFIT

* Applications include marine archaeology[7], submarine cable and pipeline inspection[8], obstacle recognition and search and rescue operations[2], marine habitat mapping, marine geology and lithology (description of the physical characteristics of rocks)[3,6], *fisheries science*[9] and *marine reptile*[10] and *mammal* research[11].

* Provide fine scale resolution seafloor images over comparably large swaths, but does not collect bathymetric data[1,3,6].

* Compared to other acoustic systems used for mapping the seafloor, sidescan sonar are relatively low cost and easy to use[3].

* Sidescan sonar allows imaging of very small-scale relief and provides important indications of the nature and composition of the seafloor[1,3,6].

IMPACTS & VULNERABILITY

Direct impact: Sidescan sonars are considered not to physically harm marine life.

Indirect impact: Some marine mammals are known to be sensitive to acoustic disturbance. This depends on the hearing range of the species, the acoustic frequency being used, and the distance of the animal from the source. We are not aware of an indirect impact to marine mammals, in fact sidescan sonar is used to monitor some *marine mammal* species[11].

Ecosystem level impact: Not applicable.

Resilience of values to the activity: *Target biota* are not affected by sampling with sidescan sonar.

Mitigation: Not applicable.

SAMPLE TYPE

SIZE

The majority of side scan sonars are small portable devices.

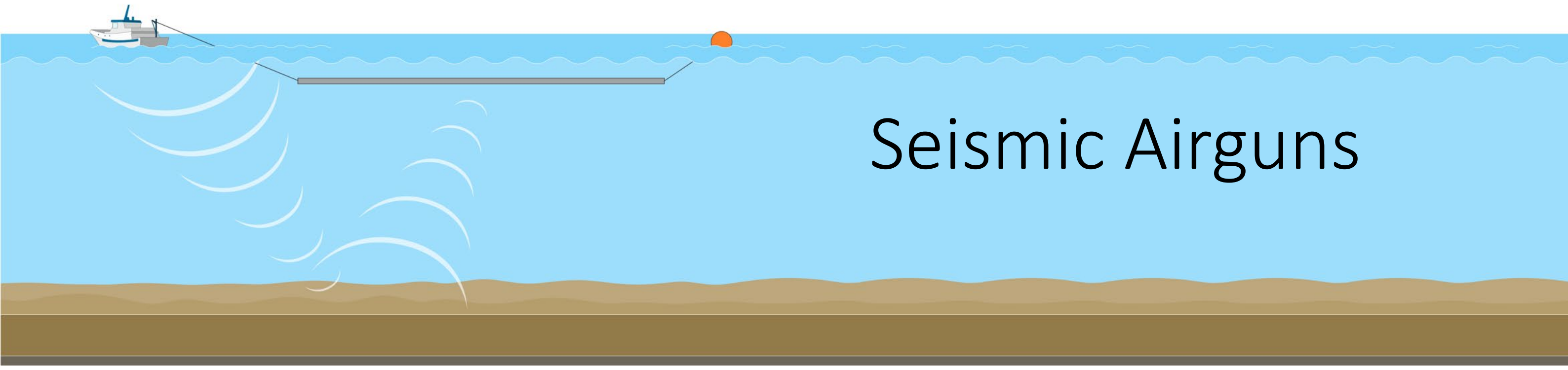
FOOTPRINT

None, no bottom contact.

HABITAT TYPE

TARGET BIOTA

REFERENCES: [1]Klaucke, 2018; [2]Schultz et al., 2013; [3]Le Bas and Huvenne, 2009; [4]Wu et al., 2021; [5]Kenny et al., 2003; [6]Brown et al., 2011; [7]Hobbs et al., 1994; [8]Bagnitsky et al., 2011; [9]Lucchetti et al., 2018; [10]Davy and Fenton, 2012; [11]Gonzalez-Socoloske et al., 2009.



Seismic Airguns

Seismic airguns are used to describe the geophysical properties below the seafloor, including, predicting the presence of oil or gas. They produce compressed air bubbles that collapse under the pressure of water causing a sharp concussive 'explosion' (peak sounds levels up to 260 dB re 1mPa) which can be heard up to 4000 km from the source. The total volume of an individual airgun can vary greatly. The sounds reflect off geologic formations below the seafloor (up to 100s of kms below) and are detected by long arrays of hydrophones towed at the surface of the water. Time of arrival and other characteristics of the reflected signal are measured and interpreted.[1,2,3,4,5]

OPERATION[1,6,7]

Seismic data are acquired by towing arrays of airguns behind a vessel. Sound is produced every 10-15 sec. Note that airguns used for research purposes (e.g. behavioural response studies) are usually much smaller than commercial airgun arrays and may only consist of a small number of low-volume airguns. Seismic airguns are operated in the *water column* over a range of marine ecosystems.

SCIENTIFIC VALUE & BENEFIT

* A proven and widely used method, primarily used to find oil, gas, and mineral products below the seafloor, but also used to identify potential stores for carbon in carbon capture and storage projects[8], for monitoring petroleum recovery from producing fields, for shallow, engineering-related 'site' surveys, and in scientific surveys of the Earth's geology[9].

*No viable alternative methods available to meet these aims.

IMPACTS & VULNERABILITY

Direct impact: The considerable amounts of acoustic energy produced have the potential to negatively impact marine life (including marine mammals, marine reptiles, fishes, zooplankton, and invertebrates) [5,7,10,11]. The explosive sounds can cause damage to various body tissues and temporarily or permanently lead to a hearing threshold shift.

Indirect impact: May cause behavioural alterations such as avoidance responses, displacement, or a change in vocalisations, or through masking of vocalisations. It has been observed to induce a negative behavioural response in marine mammals (e.g., humpback whales[12]) and can also indirectly impact their prey. May also impact local/ regional fisheries[13].

SAMPLE TYPE

SIZE

Two low volume (230 in^3) seismic airguns are available for research use on the MNF RV *Investigator*

FOOTPRINT

None, no bottom contact.

HABITAT TYPE

TARGET BIOTA

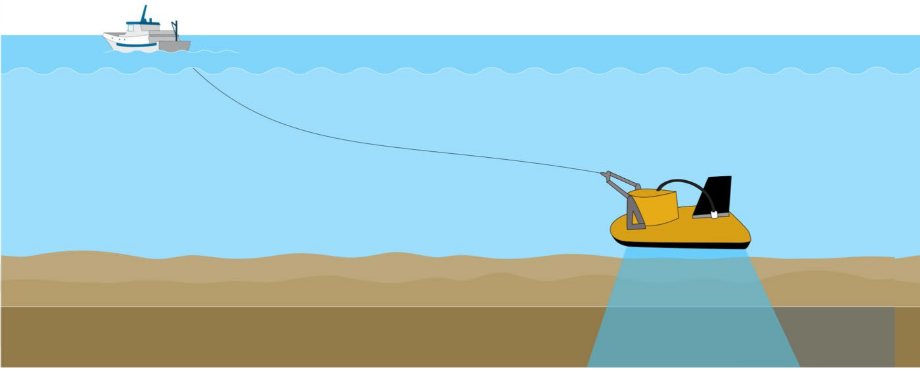
No biota are targeted

Ecosystem level impact: Repeated and persistent seismic activity may have an impact at the population level; however, this is highly uncertain based on current knowledge[5].

Resilience of values to the activity: Although a seismic survey is not associated with *target biota*, its direct and indirect impacts may be profound, widespread and involve many and varied biological elements. As such, resilience needs to be considered on a case-by-case basis with a full assessment of risk to conservation values.

Mitigation: Limit the size of the airgun array, volume of individual airgun and number of operations. Consider which species of marine mammal may be encountered and avoid periods when larger numbers are expected. Have Marine Mammal Observers on board to provide advice. Implement slow start-up procedures and shutdown zones if marine mammals move within a pre-determined range.

REFERENCES: [1]Ruppel et al., 2022; [2]Popper et al., 2005; [3]Nieukirk et al., 2012; [4]Rako-Gospic and Picciulin, 2019; [5]Carroll & Przeslawski, 2020; [6]Wardle et al., 2001; [7]McCauley et al., 2017; [8]Chadwick et al., 2014; [9]Moulin et al., 2005; [10]Weilgart, 2013, [11]Richardson et al., 2017; [12]Dunlop et al., 2017; [13]Hirst and Rodhouse, 2000



Sub-Bottom Profiler (SBP)

Sub-Bottom Profilers (SBP) produce 2D visual representations (‘maps’) of the seafloor. SBP are echosounders that consist of transceivers and transducers contained in a housing (‘towfish’). They transmit sound pulses through the water column which penetrate bottom sediments and from their reflections generate images to determine physical properties of the seafloor and characterise its geology a few metres below the seafloor.[1,2]

OPERATION[3,4]

SBP are typically deployed from a vessel with the transmitter/ receiver housed in a ‘towfish’ towed behind the vessel or installed on autonomous underwater vehicles (AUVs). There are different types of SBPs, e.g. single frequency SBPs, chirp SBPs and parametric SBPs, each of which operate using various types of sound sources and frequencies (e.g. 500 Hz to 500 kHz) depending on the survey objectives, water depths, desired penetration depth, and prior knowledge. SBPs are operated in the *water column* and can be used in very shallow (1 m) down to very deep waters (many thousands of m).

SCIENTIFIC VALUE & BENEFIT

* An important tool for fine scale detection of stratigraphic structure beneath the seafloor as well as for locating objects embedded within the seafloor (e.g., maritime archaeological surveys).

* Used to measure small scale sedimentary structures and processes in fine-scale temporal and spatial resolution.

* Widely adopted by marine scientists because of their ability to collect sub-seafloor data rapidly and non-intrusively.

* Three-dimensional imaging of the sea floor shallow sub-surface and sediment layering.

* Ancillary quantitative classification maps for seabed habitats[5].

IMPACTS & VULNERABILITY

Direct impact: SBPs are considered not to physically harm marine life.

Indirect impact: Some *marine mammals* are known to be sensitive to acoustic disturbance. This depends on the hearing range of the species, the acoustic frequency being used, the distance of the animal from the source, and the duration of the sound.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: SBPs do not target a specific biota.

Mitigation: Not applicable.

SAMPLE TYPE

SIZE

Variable: small portables devices to ‘towfish’ the size of a small car.

FOOTPRINT

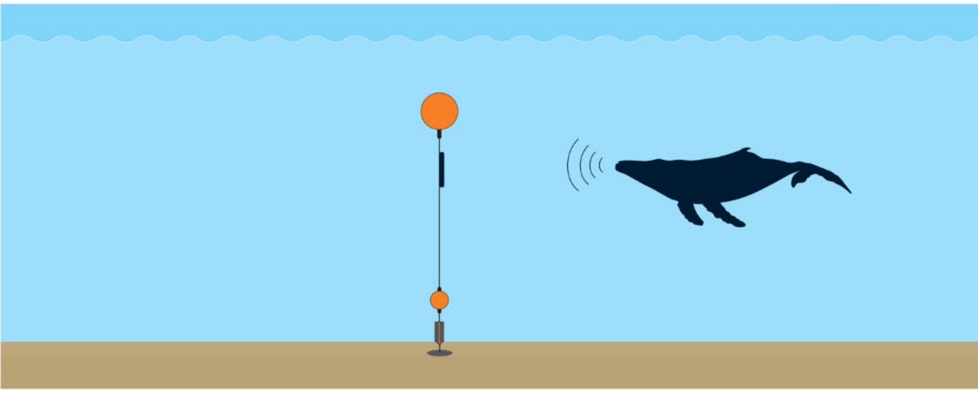
None, no bottom contact.

HABITAT TYPE

TARGET BIOTA

No biota are targeted

REFERENCES: [1] Wu et al., 2021; [2] Grøn et al., 2007; [3] Schock et al., 1989; [4] Saleh and Rabah, 2016; [5] Keesing et al., 2021.



Hydrophones

Hydrophones are passive listening devices for measuring and recording sound underwater. They work by converting sound into a voltage that can be recorded and analysed and typically represented as a spectrogram image which displays changes in frequency and amplitude. Hydrophones differ in acoustic frequencies that can be measured, and the choice of hydrophone will therefore depend on the intended application. They can be used individually, or as part of an array.

OPERATION[1-4]

Hydrophones can be hull-mounted, lowered from vessels (via a cable), fixed to, or suspended from seafloor moorings or subsurface floats/ cables, used on underwater vehicles, or mounted in passive drifting recorders. Hydrophone arrays may be placed in a line on the seabed, moored in a vertical line in the water column, or towed in a horizontal line behind a vessel. Hydrophones may be used in very shallow (1 m) down to very deep waters (1000s of m), operated in the *water column*, and are used in a range of marine ecosystems (e.g. mesopelagic zone, coastal seas, coral reefs).

SCIENTIFIC VALUE & BENEFIT

*A non-extractive tool commonly used for locating *sound-producing marine animals* or detecting acoustic tags[5].

* Other applications include environmental impact assessments (e.g. effects of anthropogenic noise on *marine mammals*), biological, ecological, and behavioural studies (e.g. aggression, courtship, spawning), characterising underwater soundscapes (comprising biological, geological, and anthropogenic sound sources), marine mammal tracking and seismic research (see separate seismic airguns template).

IMPACTS & VULNERABILITY

<u>Direct impact</u>: Hydrophones are a passive listening device and therefore have no direct impact on the marine environment or marine life.

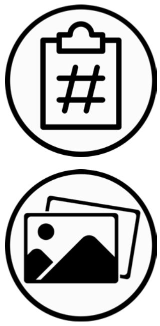
<u>Indirect impact</u>: Not applicable.

<u>Ecosystem level impact</u>: Not applicable.

<u>Resilience of values to the activity</u>: Not applicable.

<u>Mitigation</u>: Careful placement of seafloor moorings and seafloor arrays to avoid sensitive habitats (if they occur within sediment habitats).

SAMPLE TYPE



SIZE

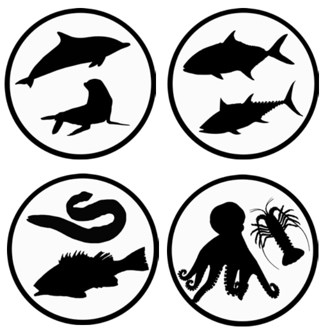
Individual hydrophones are generally quite small: size of a table tennis ball to several m in length. Hydrophone arrays may be several kms in length.

FOOTPRINT

Individual hydrophones fitted to seafloor moorings may have a footprint of ~1 m^2. Hydrophone arrays laid along the seafloor can have narrow footprints several kms in length.

HABITAT TYPE

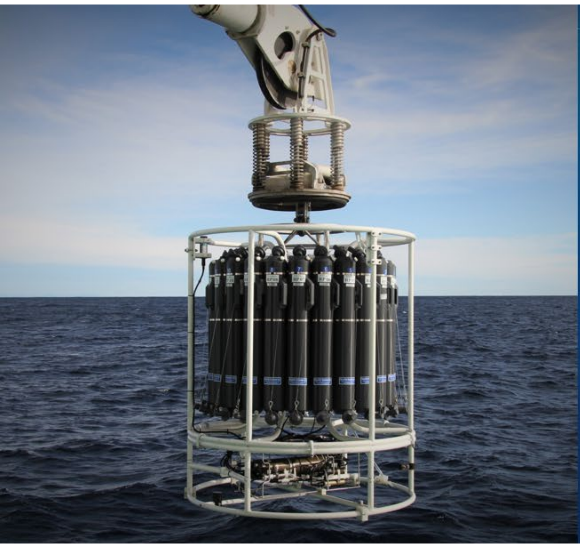
TARGET BIOTA

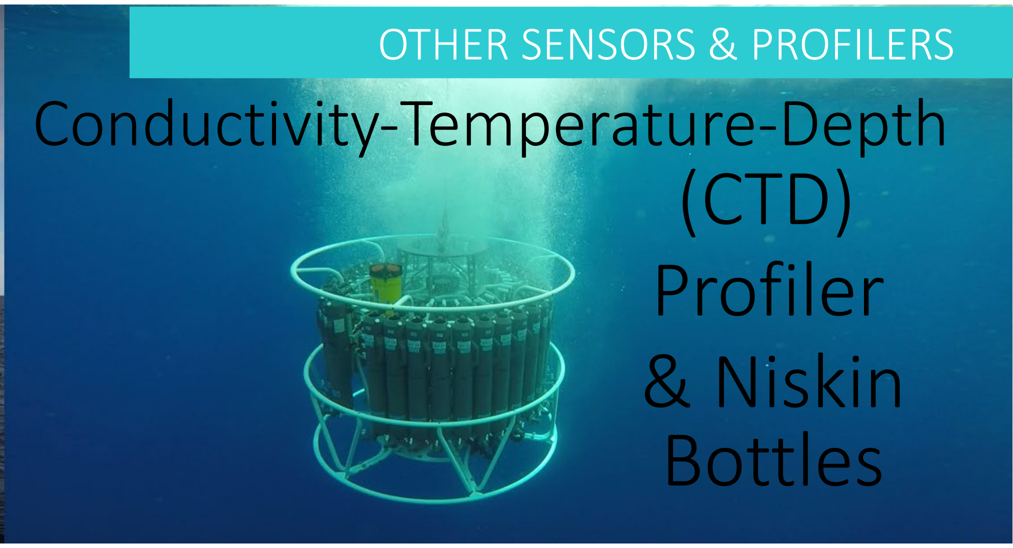


REFERENCES: [1] Lillis et al., 2018; [2]Wang and Yuan, 2021; [3]Stafford et al., 1999; [4]Thode, 2004; [5]Williams et al., 2012

12 Other Sensors & Profilers

Conductivity-Temperature-Depth Profiler (CTD) & Niskin Bottles	CTD Niskin bottles
Continuous Plankton Recorder (CPR)	
Ocean Gliders & Argo Floats	Glider- Slocum Glider- Sea Argo floats
Sound Velocity Profiler (SVP)	
eXpendable Bathy Thermograph (XBT)	
Moored Buoys	
Drifting Buoys	
No separate Template. Deployed on moorings, buoys and various other gears	Data loggers- attached
	Data loggers - drifting Current Meters/ Profilers Tide gauges Atmospheric sampling





Conductivity-Temperature-Depth (CTD) Profiler & Niskin Bottles

A Conductivity, Temperature, Depth (CTD) profiler is used to acquire physical oceanographic data using finely calibrated sensors, including salinity, temperature and density, and collect water samples using Niskin bottles (either 24 or 36 in number) mounted in a circular frame. Niskin Bottles are free-flushing, open ended tubes with spring-loaded endcaps that can be triggered remotely to close the tube, trapping water inside. Niskin Bottles can also be deployed on other sampling platforms. The CTD platform can carry other sensors and instruments.[1]

OPERATION[1]

Deployed from a surface vessel and tethered to it with a conducting cable for the duration of the operation. Niskin bottles are set in open position before the platform is lowered through the *watercolumn*; it can operate from the surface down to 10000 m. The data recorded by the CTD sensors are logged electronically onboard. During the ascent of the platform, the bottles can be closed individually to collect water samples at predefined depths or where features of interest are detected by sensors in real time. On board the vessel the water samples are transferred to sample bottles or processed for analyses.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool used internationally to profile the physical properties of the *watercolumn* across a depth gradient, and to collect water samples at defined depth horizons. CTD data are routinely collected on the Marine National Facility (MNF) RV Investigator and form part of their published data stream from every voyage[2].

* Water samples are used to measure seawater properties, including inorganic macro-nutrients (ammonium, silicates, phosphate, nitrate and nitrite)[3], carbon dioxide and oxygen, and to collect chlorophyll, microbes, phytoplankton[4] and samples for eDNA analyses[5].

IMPACTS & VULNERABILITY

Direct impact: A sampling gear operating in the *water column*. No impact on biota.

Indirect impact: Not applicable.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE

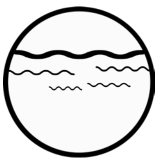
SIZE[1,4,6]

CTD frame: height 1.8 m H, 1.6-2.1 m diameter.
Niskin bottles: 1.2 l -20 l capacity

FOOTPRINT

None, no bottom contact.

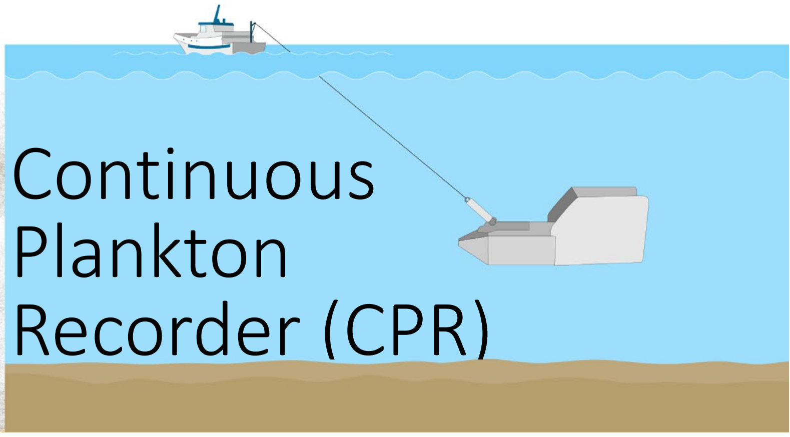
HABITAT TYPE



TARGET BIOTA

No biota are targeted

REFERENCES: [1]CSIRO MNF, 2021; [2]CSIRO MNF – Data, 2022; [3]Anonymous, 2012; [4]Garcia-Corral et al., 2021; [5]Koziol et al., 2018; [6]General Oceanics, 2022.



Continuous Plankton Recorder (CPR)

A Continuous Plankton Recorder is towed behind a vessel to sample near-surface plankton (phytoplankton and zooplankton) communities. The CPR is a metal box (stainless steel, nickel coated), with an aperture in the narrowed front area (cone) and an impellor at the rear. The CPR can carry other sensors and instruments (e.g. temperature recorders, flow meters).[1-6]

OPERATION[1-6]

Deployed from a surface vessel (often a commercial vessel of opportunity) and tethered to it, typically for long transits (100s – 1000s km). As the CPR is towed ~8-10 m below the surface at speeds of 15-20 kt, water enters through a small aperture (1.27-1.6 cm^2) on the nose cone. *Plankton* is filtered from the water onto a band of silk (270 µm) that is moved across the flow of the water by a gearing system (and rollers) powered by the impellor at a speed proportional to the towing speed so that typically 10 cm of silk band corresponds with a distance of 10 n mile of tow. The portions of the silk band that have collected *plankton* are covered with another piece of silk and both are wound into a cassette (analogous to camera film) which is stored in a preservation (formaldehyde) bath. A full cassette of silk corresponds to 450 n mile of tow distance.

SCIENTIFIC VALUE & BENEFIT

*Provides standardised and long-term time series data for *plankton* communities (phytoplankton and zooplankton) over large geographical scales, e.g. through the Continuous Plankton Recorder survey, the Southern Ocean CPR survey and the Australian CPR survey which have collected data for over 90, 30 and 13 years, respectively [1,2,5,7].

*Used to study regional, seasonal, interannual and long-term variability in *phytoplankton* and *zooplankton* abundance and species distribution contributing to taxonomic discovery, fisheries research and climate change studies[2,3,4,5].

*A cost effective, robust and standardised sampling gear that easily deployed and retrieved from a range of vessels (e.g., ‘ships of opportunity’, commercial vessels) under their normal operating conditions, gathering scientific data[5].

IMPACTS & VULNERABILITY

<u>Direct impact</u>: A sampling gear used in the water column. Plankton *target biota* are removed from the volume of seawater filtered (see *footprint*).

<u>Indirect impact</u>: Not applicable.

<u>Ecosystem level impact</u>: Not applicable.

<u>Resilience of values to the activity</u>: Not applicable.

<u>Mitigation</u>: Not applicable.

SAMPLE TYPE

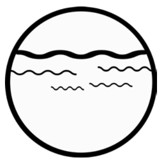
SIZE[7]

1.05 m L, ~0.5 m H

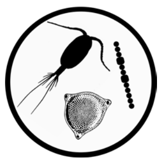
FOOTPRINT[7]

None, no bottom contact. Volume of seawater filtered – average of 3.1 m^3 every 10 nm of tow

HABITAT TYPE

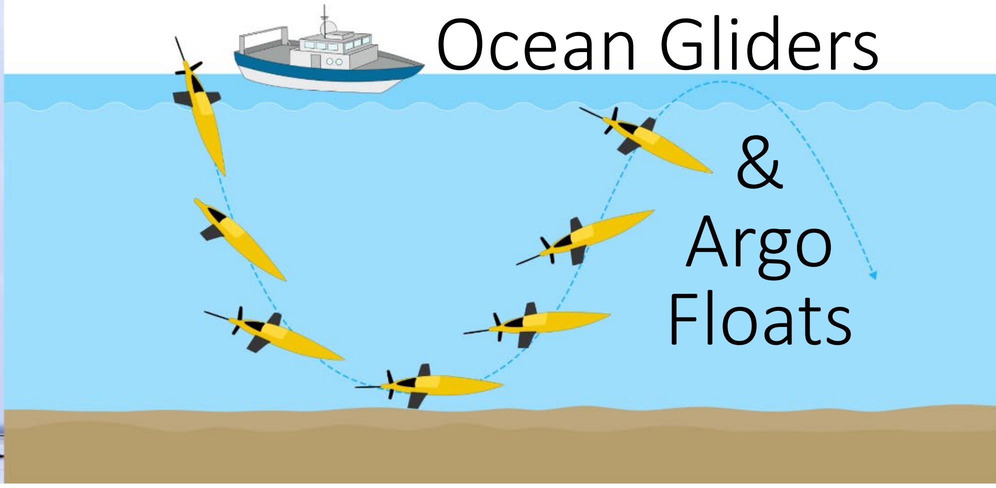


TARGET BIOTA



REFERENCES: [1] Reid et al., 2003; [2] Hosie et al., 2003; [3] Stern et al., 2022; [4] Pitois et al., 2012; [5] Slotwinski, 2010; [6] Jonas et al., 2004; [7] Pinkerton et al., 2020.

Ocean Gliders & Argo Floats



Ocean gliders and Argo floats are ocean profiling platforms fitted with multiple sensors (e.g., pH, dissolved O2, temperature), and sometimes acoustic systems that operate independently using changes in buoyancy to descend and ascend through the water column and do not come into contact with the seafloor.[1]

OPERATION[1]

Deployed from a surface vessel, Ocean gliders and Argo floats are left unattended during their pre-set missions, at the end of which they are located using their GPS signal and recovered at the sea surface. Gliders have wings that allow the momentum from descending through the water column to generate forward motion and use GPS, internal dead reckoning and altimeter measurements to autonomously navigate their way to a series of waypoints. Argo floats passively drift with ocean currents only changing buoyancy to descend, hold position at depth and ascend. Sensor data are recorded during the dive and transmitted via satellites when the system is at the water surface.

SCIENTIFIC VALUE & BENEFIT

* Gliders and Argo floats deliver ocean observation *data* to the marine and climate science community through Australia's Integrated Marine Observing System (IMOS)[2].

* The IMOS glider fleet consists of Slocum gliders (for use in shallow water ~200 m) and Seagliders (for use in deeper water >1000 m)[1]; one application is to track and monitor marine heatwaves[3].

* The Argo Program has delivered continuous ocean temperature and salinity data from surface to 2000 decibar (dbar) over almost two decades from an array of 4000 profiling floats globally; under IMOS, Argo Australia is a world leading contributor to the program.[1]

IMPACTS & VULNERABILITY

Direct impact: Non-extractive sampling and no contact with seafloor.

Indirect impact: Not applicable.

Ecosystem level impact: No impact.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE

SIZE

Slocum gliders 1.8 m L, diameter: 0.21 m, weight 52 kg.
Argo floats: 1.1 m H, diameter: 0.15 m.

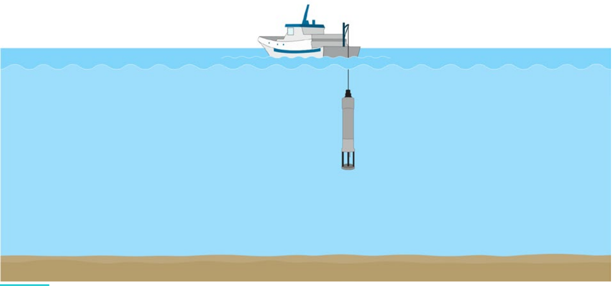
FOOTPRINT

None, no bottom contact.

HABITAT TYPE

TARGET BIOTA

REFERENCES: [1] IMOS, 2022; [2] Lara-Lopez et al., 2019; [3] Holbrook et al., 2020.



Sound Velocity Profiler (SVP)

A Sound Velocity Profiler (SVP) measures the speed of sound throughout the water column by sending a small acoustic signal to a receiver at a known distance or by measuring the variables affecting sound velocity in water (salinity, temperature, and pressure).

OPERATION[1]

Typically lowered from a surface vessel via a cable. May be fitted to another platform such as a ship, water column profiler, or surface/ seafloor mooring. Operational from shallow depths down to ~6000 m.

SCIENTIFIC VALUE & BENEFIT

* A simple to use passive device for measuring speed of sound through the *water column*.
* SVPs are used to inform data collection with acoustic sensors

IMPACTS & VULNERABILITY

Direct impact: Not applicable.

Indirect impact: Not applicable.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE

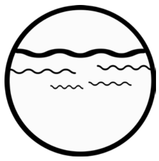
SIZE

Small portable devices.

FOOTPRINT

None, no bottom contact.

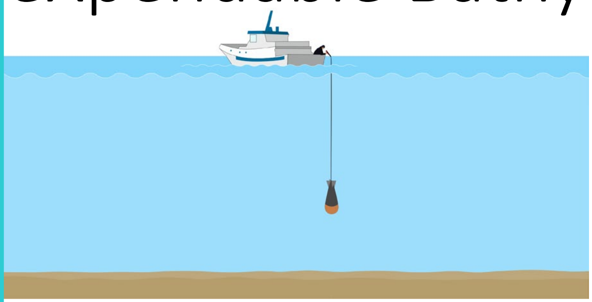
HABITAT TYPE



TARGET BIOTA

No biota are targeted

eXpendable Bathy Thermograph (XBT)



An XBT is a small, single-use probe that measures the temperature as it falls through the water. It is a hand-held device that consists of an expendable probe, a data processing and recording system, and a launcher.[2]

OPERATION[2]

XBTs are mostly deployed from ships along pre-defined transects. When launched, the very thin copper wire connecting the probe and launcher unwinds as the probe descends through the water. Once the electrode in the probe contacts the water, temperature is transmitted back processing equipment until the wire is expended and snaps off.

SCIENTIFIC VALUE & BENEFIT

* A simple to use passive device for measuring temperature through the *water column*.
* A proven sampling tool providing ocean temperature profile data since the late 1960s[3].

IMPACTS & VULNERABILITY

Direct impact: Not applicable.

Indirect impact: The device is left on the seafloor.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE

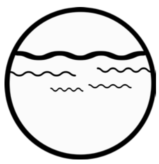
SIZE

Small (~0.5 m) handheld devices

FOOTPRINT

Minimal: probe sinks to seafloor.

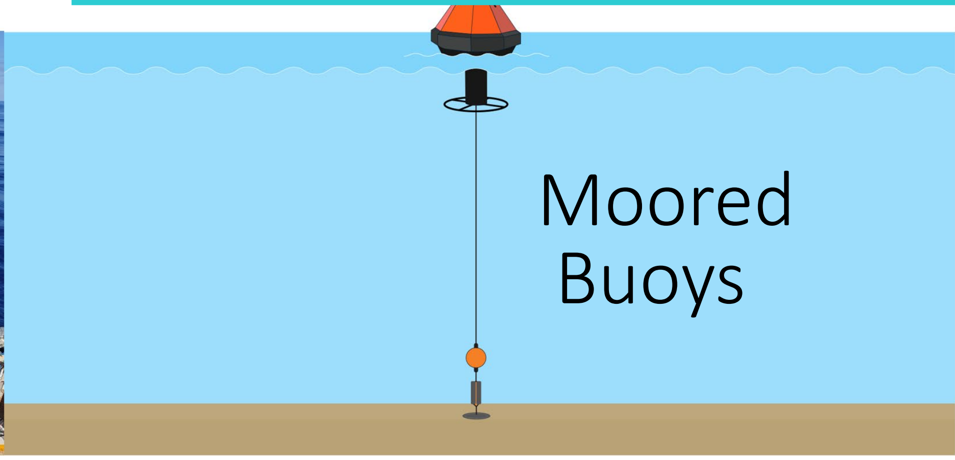
HABITAT TYPE



TARGET BIOTA

No biota are targeted

REFERENCES: [1]Geo-matching, 2022; [2]NOAA XBT, 2022; [3]Domingues et al. 2008.



Moored Buoys

Moored instrumented moorings are long-term ocean sub-surface and/ or surface observatories comprised of anchors, wires, chain, weights, floats, and buoys, and equipped with various instruments including data loggers and sensors to observe and record oceanographic, meteorological and biological processes. Transmitting equipment mounted on the surface buoy is used to send the observed data to collecting centres. Instruments that may be fixed to a mooring include hydrochemistry sensors measuring conductivity, temperature, and dissolved oxygen (CTD), salinity, nutrients, chlorophyll fluorescence and turbidity; physical sensors in the water and at the surface such as current meters or acoustic Doppler current profilers (ADCP), wave measuring sensors, atmospheric samplers, a weather station, and cameras. For sediment traps and hydrophones (see separate templates).[1-5]

OPERATION[1,2,6,7]

Instrumented moorings are deployed from a vessel from shallow depths down to 5000 m. Sensors can be attached to the mooring line at various depths through the water column. The gear is 'set' and left unattended. Instrumented moorings may be deployed long-term (~permanently) as part of global or regional long-term oceanographic observation arrays; these are regularly retrieved for servicing and replaced by new, updated systems. Smaller versions with limited instrumentation may be used for specific time-limited studies; these are set for the duration of the study and retrieved by hauling them back on board the vessel at the end of the experiment.

SCIENTIFIC VALUE & BENEFIT

* Instrumented moorings deliver ocean observation data to the marine and climate science community through Australia's Integrated Marine Observing System (IMOS)[8].

*A proven scientific sampling tool for the collection of oceanographic *data* [4,5], taking in situ observations that can be used in their own right to improve forecasting systems, as well as to calibrate and validate satellite remote sensing data and data assimilation[2].

*Data derived from instrumented moorings may be used to define key components of climate change and associated responses of ocean ecosystems[1], to characterise and monitor regional processes in shelf waters[1], but also for early detection and real-time reporting of tsunamis in the open ocean[2].

* Instrumented moorings are one of the long-term sustaining ocean observatories, building on technology used since the 1940s and have expanded from single moorings into oceans spanning arrays that feed data into ocean observing systems such as the Global Oceans Observing System (GOOS)[1,2,5].

IMPACTS & VULNERABILITY

Direct impact: Non-extractive sampling.

Indirect impact: Minor impact on epifauna beneath the anchor weight of mooring and dragging during retrieval may occur but the footprint is very small. Sacrificial weights are typically relatively inert steel weight of 100s kg and remain on seafloor.

Ecosystem level impact: No ecosystem or population impacts are expected; the area of contact with the benthos is minimal, or no contact.

Resilience of values to the activity: Coral and rocky reef habitats are expected to have lower resilience than sediment habitats.

Mitigation: Not applicable.

SAMPLE TYPE

SIZE

Size of anchor weight – variable, typically relatively inert steel weight of 100s kg (e.g. train wheels)

FOOTPRINT

Minimal: surface area of anchor

HABITAT TYPE

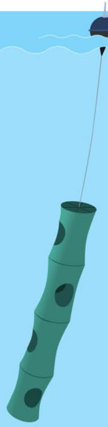
TARGET BIOTA

No biota are targeted

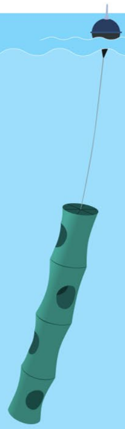
* The Integrated Marine Observing System (IMOS) National Mooring Network comprises National Reference Stations (NSR) and mooring arrays strategically positioned in Australian coastal, shelf and deep-sea areas to measure physical and biological parameters [1].

*Acoustic moorings can be used to determine home ranges of animals with acoustic tags, and track far ranging tagged animals across ocean basins[6,7,9].

REFERENCES: [1]IMOS, 2022; [2]Venkatesan 2019; [3]Roughan et al., 2022; [4]Berteaux, 1976; [5]Nichols and Raghukumar, 2020; [6]Heupel et al., 2006; [7]Williams et al., 2012; [8]Lara-Lopez et al., 2019 [9]Bruce et al., 2019.



Drifting Buoys



Drifting buoys are long-term oceanographic and meteorological observatories comprised of a small surface float with integrated transmitter and barometric sensor, tethered to a sub-surface non-fray synthetic cloth drogue that extends to around 15 m depth. They normally measure sea surface temperature (SST) and air pressure, and by tracking their positions the surface currents can be determined. Some drifters also have sensors to measure wind, temperature profile and salinity. Measurements are normally made at regular intervals (e.g. hourly) and the data are transmitted by satellite.[1,2,3]

OPERATION[2,3]

Drifting buoys are deployed from a surface vessel at a predetermined location. The gear is deployed and left unattended; typically, it is not retrieved, unless it is washed ashore.[2,3]

SCIENTIFIC VALUE & BENEFIT

* Instrumented moorings deliver ocean observation data to the marine and climate science community through Australia's Integrated Marine Observing System (IMOS)[4].

*A proven scientific sampling tool for the collection of oceanographic *data*, taking in situ observations that can be used in their own right to improve forecasting systems, as well as to calibrate and validate satellite remote sensing data and data assimilation[3, 5].

* Data derived from drifting buoys may be used in global and regional weather forecasting models, SST data feed into climatology data sets, and are used as independent validation of satellite sensed measurements of SST, sea surface height, large-scale surface currents and transport[6].

* Current data derived from ocean observation systems including drifting buoys are used to describe biological assemblages[7].

* SST data derived from ocean observation systems including drifting buoys are used for evaluation of coral bleaching events, turtle tracking and commercial fisheries management[8].

IMPACTS & VULNERABILITY

Direct impact: Non-extractive sampling and no contact with seafloor.

Indirect impact: Not applicable.

Ecosystem level impact: Not applicable.

Resilience of values to the activity: Not applicable.

Mitigation: Not applicable.

SAMPLE TYPE

SIZE

Various

FOOTPRINT

None, no bottom contact.

HABITAT TYPE

TARGET BIOTA

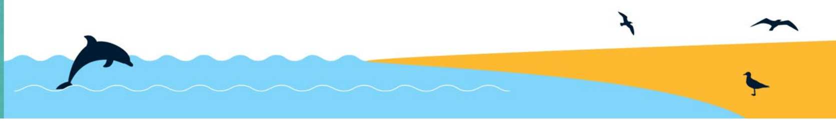
No biota are targeted

REFERENCES: [1]Sybrandy 2009; [2]BOM, 2021; [3]Climate Policy Watcher 2022; [4]Lara-Lopez et al., 2019; [5]Govekar et al., 2022; [6]Cancet et al., 2019; [7]Benthuysen et al., 2022; [8]Beggs, 2019.

13 Aerial Methods

Aircraft	
Drone	Drone Unmanned Aerial Vehicles (UAV) Remotely Piloted Aircraft Systems (RPAS)
Laser induced Detection And Ranging (LiDAR)	

Aircraft



Aircraft collect data and imagery, and enable human-observations, during surveys of coastal habitats (e.g. shallow water coral reefs) and the water surface of the open ocean. They are piloted, fixed wing aircraft or helicopters (more dynamic and responsive in movement positioning) fitted with camera/s (stills and/or video), sensor/s (e.g. multispectral) and/ or with human observer/s onboard). The configuration and orientation of cameras varies, but are generally downward facing, with a fixed field of view. [1-5]

OPERATION [1-5]

Aircraft are launched from a vessel or land-based airfield and perform grid or transect based surveys designed to monitor *target biota* and *habitat types* over shallow coastal waters and open ocean, many kms offshore, covering large survey areas (1000s km^2) during flights of up to several hours. Human observers on board record faunal and environmental data (e.g. abundance and location of whales or tuna schools), sensor(s) record associated physical data and cameras collect high-resolution imagery. Aircraft are generally maintained at an altitude of >100 m and groundspeeds of <200 km/h.

SCIENTIFIC VALUE & BENEFIT

* A proven scientific sampling tool for non-extractive sampling of shallow benthic *habitats* (e.g., shallow *coral reefs*) and *target biota* – including threatened, endangered and protected species of marine mammals, turtles, seabirds and fishes including tuna and sharks.

* Efficient, reliable and highly repeatable sampling over broad spatial scales, including areas that may be impractical to sample by other gears/ methods[1,2,3].

*Applications include mapping the extent of coral bleaching, mapping *kelp and seagrass* cover, assessing the behaviour and distribution of *target biota*, species identification and abundance estimates for *marine mammals, reptiles, sharks, tuna and seabirds*, insights into locations of nurseries and mass aggregations of *whale* and *shark* populations[1-8].

* High resolution imagery supplements observer data and provides a permanent record with applications extending beyond the life of the survey (e.g., individual identification over time)[3,5].

* Provide data that complement baited methods (e.g., long lines) and tag-recapture studies[1].

IMPACTS & VULNERABILITY

<u>Direct impact</u>: Collection of observation and sensor *data* and *imagery*; no direct contact with *target biota*.

<u>Indirect impact</u>: Marine mammals may be sensitive to noise disturbance from aircraft, but this depends on the species, flying altitude, water depth, the distance of the animal from the source, and duration of the exposure [9].

<u>Ecosystem level impact</u>: Not applicable

<u>Resilience of values to the activity</u>: Not applicable

<u>Mitigation</u>: Pilots/ observers should be trained and experienced with mitigation needs for marine mammals, e.g., proximity to shore, water depth and altitude of aerial survey[2,3,9].

SAMPLE TYPE

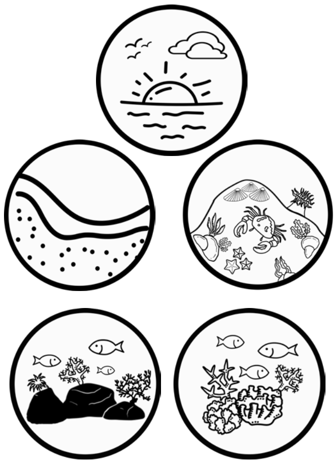
SIZE

Variable: *Cesna 260*: 960 kg, maximum speed 289 km/h; *Robinson Clipper II*: 1134 kg, maximum speed 196 km/h; *Partenavia P68B*: 1230 kg, maximum speed 322 km/h

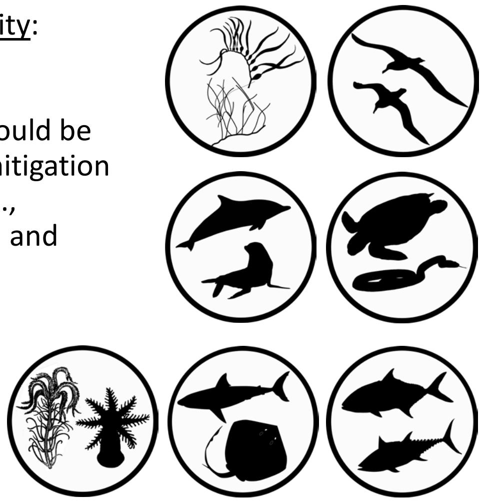
FOOTPRINT

None

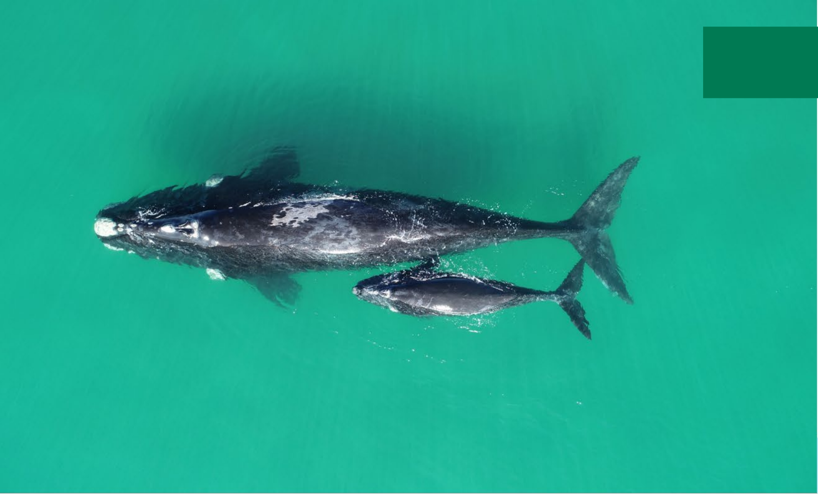
HABITAT TYPE

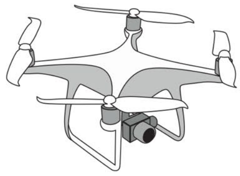


TARGET BIOTA



REFERENCES: [1]Kessel et al., 2013; [2]Angliss et al., 2018; [3]Raudino et al., 2022; [4]McKenzie et al., 2001; [5]Kelaher et al., 2020a&b; [6]Buckland et al., 2012; [7]Carnell and Keough, 2019; [8]Hughes et al., 2018; ;[9]Luksenburg and Parsons, 2009.





Drone

* Unmanned Aerial Vehicles (UAVs),Remotely Piloted Aircraft Systems (RPAS)

This variety of tools, collectively referred to as 'drones', collect physical, biological samples and high-resolution imagery during near-shore surveys of coastal habitats e.g. shallow water coral reefs and offshore surveys of surface-dwelling biota, e.g. cetaceans. Drones are a fixed wing or multirotor (more dynamic and responsive in movement positioning) aircraft operated by a pilot from a ground control (communications) station. Drones are fitted with camera/s (sills and/or video), a GPS unit, and sensor/s (e.g. thermal, multispectral) used to collect high-resolution imagery of the water surface and shallow seafloor. The configuration and orientation of cameras varies, but oblique-angle viewing is typical. Some drones have the added capability of collecting physical (air) and biological (whale exhalate) samples. [1-6]

SAMPLE TYPE

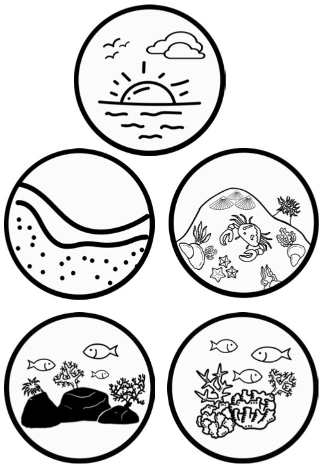
SIZE [11]

Variable, but in general, as size increases, so does payload capacity, operation time, cost and resolution of imagery data.

FOOTPRINT

None

HABITAT TYPE



OPERATION [1,2,5,6,7]

Drones are launched from a vessel or land (assisted or unassisted) and perform grid or transect based surveys in a tightly controlled flight path designed to monitor *target biota* and *habitat types*. In general, fixed wing drones require larger areas for take-off and landing. The spatial extent of drone surveys may be limited due to requiring 'line of sight' or by battery endurance, to cover small survey areas (10s km^2) during flights of several hours for fixed wing, and < 1 h for multirotor drones. Drones are generally maintained at an altitude of 30-120 m and groundspeeds of <40 km/h.

SCIENTIFIC VALUE & BENEFIT

* A modern but proven scientific sampling tool for *non-extractive sampling* of shallow *habitats* (e.g. *coral reefs*) and *target biota* – including threatened, endangered and protected species of sharks, marine mammals, turtles, reptiles, and seabirds[1-5].

*In some cases, *physical samples* are collected from the air near the sea surface for marine aerosol research. *Biological samples* of whale exhalate can also be collected and used to assess the health of populations/ individuals over time[6].

* Safe (remote), efficient, reliable and highly repeatable sampling over small spatial scales, including in remote areas that may be impractical to sample by other methods/ gears[1,2,3,4].

*Applications include determining the extent of impacts (e.g. tailings discharge, coral bleaching) on coastal benthic *habitats*, mapping *macroalgal* and *seagrass* cover, assessing the behaviour of marine mammals, and distribution, species identification and abundance estimates for *seabirds*, *sharks*, *marine mammals, reptiles, some pelagic fishes* (e.g. yellowtail kingfish) and *jellyfish*[1-7].

* High resolution imagery (higher than manned aerial surveys) can be used to construct 3D photomosaics of the benthic *habitat* and provides a permanent record with applications extending beyond the life of the survey (e.g. monitoring of reef health)[1-4,6].

IMPACTS & VULNERABILITY

<u>Direct impact</u>: Collection of *imagery* and *physical samples* (air); no direct contact with *target biota*.

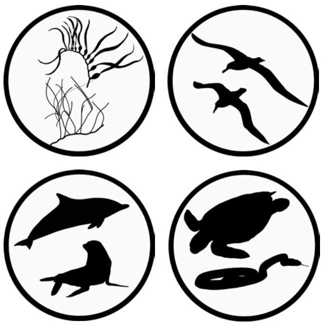
<u>Indirect impact</u>: Seabirds and some marine mammals may be sensitive to drones (noise, shadows, silhouette) but this depends on the species, group size, flying altitude, water depth, the distance of the animal from the source, and duration of the exposure. There is no evidence that large whales are disturbed by close approaches by drones either when they are at the surface, or submerged[7].

<u>Ecosystem level impact</u>: Not applicable.

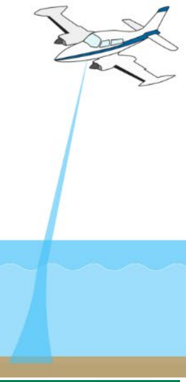
<u>Resilience of values to the activity</u>:
Not applicable.

<u>Mitigation</u>: Pilots should be trained and experienced in survey techniques, e.g. observe strict distancing of drone to seabirds and dolphins (50-100 m), limit flight time over the same group, avoid flying over mother-calf cetacean pairs, avoid close approaches to socialising groups and stop data collection when there are strong behavioural responses[7].

TARGET BIOTA



REFERENCES: [1]Colefax et al., 2018; [2]Kelaher et al., 2020b; [3]Tait et al., 2021; [4]Joyce et al., 2019; [5]Barreto et al., 2021; [6]Johnston, 2019; [7]Raoult et al., 2020.



Laser induced Detection And Ranging (LiDAR)

Laser Induced Detection And Ranging (LiDAR) systems emit high power, short wavelength laser light beam pulses (4-10 nsec) and measure their reflection/ scattering to produce 3D visual representations ('maps') of shallow water (<50 m) bathymetry, substrate types (composition and texture) and elevated features (e.g. vegetation) on the seafloor. LiDAR consists of a laser (light emitting) scanner, an optical receiver that measures the backscattered light intensity and multiple electronic and electro-optical components, including fine-scale resolution (4k) cameras. The laser scanner emits laser beams in an arc or rectilinear scan across the direction of travel with the swathe width typically half of the altitude (typically < 500m). Light is reflected off of objects (e.g. sea surface, seafloor) in its path and the backscatter is detected by an optical receiver and combined with position (GPS) and orientation data to obtain a 3D digital elevation model (DEM) of the shoreline, sea surface, water column and seabed. [1-5]

OPERATION [1-5]

LiDAR systems can be mounted to light aircraft or drones or on underwater platforms (stationary and mobile) and are typically used for surveys of the coastal zone and shallow seabed (<50 m) but can be used down to many 1000s m (e.g. when mounted on ROVs). Underwater LiDAR provide higher resolution spatial and temporal bathymetry data with a higher accuracy, when compared with airborne systems. Topographic LiDAR emits pulses of infrared (IR) laser beams (1064 nm). Topo-bathymetric LiDAR systems emit pulses of IR and green (515-532 nm) laser beams. IR beams are reflected by the sea surface, while the green beams travel through the water to the seafloor, where they are backscattered by the substrate or submerged objects (e.g. vegetation). Water depth is determined by the elapsed time between these two reflection/scattering events.

SCIENTIFIC VALUE & BENEFIT

*A proven scientific sampling tool for fine-scale resolution (< 1 cm) mapping of the *water column and seafloor* (backscatter: seafloor geomorphology and *substrate* and *bathymetric data*) in shallow coastal (< 50 m) areas inaccessible to acoustic gears (e.g. MBES) [1-4].

* Primarily used for the systematic mapping of the seabed to create fine-scale resolution bathymetric or Digital Elevation Model (DEM) maps that represent geomorphology and characterise coastal, benthic *habitats* and *target biota* over a large geographical extent [1-4].

*Augments acoustic and image data to map underwater features (e.g. whale remains, shipwrecks) measure the extent of *macroalgal* cover, shallow *reef* cover and *phytoplankton* blooms, detect *fish* schools and estimate *fish* biomass and density over large spatial scales [2,5,7,8].

*Cost effective and rapid coverage of large areas (20-50 $km^2 h^{-1}$), providing continuous topographic and bathymetric mapping from the coastal zone to shallow waters [1,4,5].

*More efficient and provides data at finer scale resolution (< 1 m) than acoustic methods, but use is limited by environmental factors (e.g. water clarity) [1,2].

IMPACTS & VULNERABILITY

Direct impact: Due to the characteristics of LiDAR systems used in the marine environment and the fact that they meet human laser safety standards, LiDAR will have no harmful effect on marine life, as they are known to have a poorer visual acuity than humans [6,9].

Indirect impact: Not applicable

Ecosystem level impact: Not applicable.

Resilience of values to the activity: *Target biota* are not affected by sampling with LiDAR.

Mitigation: Ensure environmental conditions (e.g. weather, water clarity) are suitable for capture with airborne LiDAR systems.

SAMPLE TYPE

SIZE

LiDAR systems can vary greatly in size and weight depending on the manufacturer and technical specifications.

FOOTPRINT

None

HABITAT TYPE

TARGET BIOTA

REFERENCES: [1]Filisetti et al., 2018; [2]Zavalas et al., 2014; [3]Wedding et al., 2008; [4]Letard et al., 2022; [5]Churnside et al. 2021; [6]Zorn et al., 2000; [7]Churnside and Donaghay, 2009; [8]Mills et al., 2022; [9]Dalgleish et al., 2017

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