Guidelines for Undertaking Rapid Biodiversity Assessments in Terrestrial and Marine Environments in the Pacific

2014




SPREP
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SPREP Library/IRC Cataloguing-in-Publication Data

Patrick, Brian ... [et al.]

Guidelines for undertaking rapid biodiversity assessments in terrestrial and marine environments in the Pacific / Brian Patrick – Apia, Samoa : SPREP, Wildlands, 2014.

p. cm.

ISBN: 978-982-04-0513-4 (print)
978-982-04-0514-1 (ecopy)

Prepared by Wildlands for SPREP.

1.Biodiversity conservation – Oceania – Handbooks, manuals etc. 2. Natural resources conservation areas – Oceania – Handbooks, manuals, etc. I. McCllelan, Rachel. II. Martin, Tim. III. Tocher, Mandy. IV. Borkin, Kerry. V. McKoy, John. VI. Smith, Des. VII. Pacific Regional Environment Programme (SPREP) VIII. Wildlands. IX. Title.

574.52623

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Contents



1. Introduction

The Secretariat of the Pacific Regional Environment Programme (SPREP) presents these guidelines for undertaking rapid biodiversity assessments in its Pacific island member countries and territories: Micronesia, Melanesia, and Polynesia. These assessments are referred to as BIORAPs. The guidelines are recommended to be used by SPREP members for the planning and implementation of terrestrial and marine BIORAP surveys, and subsequent monitoring of important sites.

Survey methodologies and systems selected as part of the guidelines should:

- Take account of the IUCN Red List status of species.
- Enable the identification of priority habitats or areas based on those species.
- Enable the identification of Key Biodiversity Areas (KBAs), Important Bird Areas (IBAs) and/or other ecological significant areas.
- Address the identification of threats posed by invasive plants and fauna.
- Take account of climate change implications.
- Address approaches for the assessment of both marine and terrestrial ecosystem resilience and vulnerability.
- Involve local communities in all aspects of the BIORAP.

The guidelines will support the implementation of regional, national, and international biodiversity-focused plans, including the Convention on Biological Diversity Strategic Plan and Aichi Targets, Pacific Oceanscape Framework, SPREP Strategic Plan and the Regional Framework for Nature Conservation and Protected Areas 2014–2020.

A comprehensive BIORAP of the Vava'u group of islands in the Kingdom of Tonga was undertaken by SPREP in 2014.

2. General principles and definitions

2.1 Origins – Conservation International's RAP programme

The rapid assessment programme approach (RAP) was developed in 1990 by Conservation International to collect biological information to inform conservation decision-making (Alonso *et al.* 2011). RAP methods are designed to rapidly assess the biodiversity of highly diverse areas, identify the threats to this biodiversity, identify priority areas for conservation, strengthen community involvement and participation in conservation management, train local scientists in biodiversity survey techniques, and to develop management policies and sustainability options. Criteria used to identify priority areas for conservation include: overall species richness, presence of local endemics, rare species, threatened species, and habitat condition. Surveys undertaken for the RAP are often limited to species lists, but sometimes include information on abundance.

Conservation International undertook 80 RAP surveys within 20 years of the programme's implementation, initially in the world's tropical forests but then extending to freshwater and marine ecosystems as the programme developed. With sound science underpinning RAPs, and the support of local communities, significant protected areas have been created in the world's biological hotspots and hundreds of students from the relevant local country have been trained in conservation science. Over 1,300 species previously unknown to science were discovered and vast amounts of information on poorly known species collated which has led to a much better understanding of tropical ecosystems (Alonso *et al.* 2011). The RAP method highlighted the fact that species information is essential for both conservation and development planning and action. RAP surveys are a catalyst for conservation action.

Other benefits of the RAP programme are to draw attention to regional hotspots of biodiversity and the effects of habitat loss to the decision-makers and wider community. This can be especially effective while the RAP is in progress and exciting results are made available in a timely fashion.

2.2 Types of biodiversity assessments

Rapid biodiversity assessment - sometimes called rapid ecological assessments or REAs, RAPs or BIORAPs - is an important technique for terrestrial, freshwater, marine, and estuarine system management, especially in areas where there is very little published or unpublished information. Rapid assessments of biodiversity require the development of a conceptual framework for the design and implementation of the assessment, and a clear definition of the scope of the assessment.

This process is well described in the guidelines on methods for rapid assessment of marine and coastal biodiversity provided by the Convention on Biological Diversity Expert Meeting on Methods and Guidelines for the Rapid Assessment of Biological Diversity of Inland Water Ecosystems (Convention on Biological Diversity (CBD) 2003a,b,c) and the technical series report compiled for CBD and RAMSAR (Secretariat of the Convention on Biological Diversity 2005). These guidelines are directly applicable to terrestrial ecosystems. The five general types of assessment that have been identified include:

- Baseline inventory – focuses on overall biological diversity rather than extensive or detailed information about specific taxa or habitats.
- Species-specific assessment – provides a rapid appraisal of the status of a particular species or taxonomic group in a given area.
- Change assessment – is undertaken to determine the effects of human activities or natural disturbances on the ecological integrity and associated biodiversity of an area.
- Indicator assessment – assumes that biological diversity, in terms of species and community diversity can inform us about water quality and overall health of particular ecosystems.
- Resource assessment – aims to determine the potential for sustainable use of biological resources in a given area.

The SCBD (2005) guidelines stress the importance of clearly establishing the purpose as the basis for design and implementation of the assessment in each case.

A BIORAP is essentially a reconnaissance, a preliminary baseline inventory, which may lead to more detailed study and action depending on the results of the "recce". Recognising that a high proportion of land and resources in the Pacific is managed under customary tenure, a BIORAP is also a vital tool for raising awareness within local communities of their biodiversity, as they are its permanent stewards.

2.3 Designing rapid assessments

When designing data-gathering exercises it is important to distinguish between inventory, assessment, and monitoring, as they require different types of information. In general, BIORAPs, or baseline inventories, provide the basis for guiding the development of appropriate assessment of areas as priority protected areas and future monitoring.

Important elements to take into account when designing any rapid assessment include:

- The type of assessment;
- The timing of stages (design and preparation, implementation and reporting);
- Spatial scale;
- Compilation of existing data;
- Dissemination of results.

Design should consider:

- Resources available, including time, money and expertise;
- Scope, including taxonomic and geographic scope and site selection;
- Sampling data and analysis, including identification of what data are required, how to collect it, how much to collect, how to enter it into a database, analysis, and integrate it into a report;
- Partnership opportunities including with governments, NGOs, and community groups.

Rapid assessment techniques are particularly relevant at the species-level of biological diversity, and the SCBD (2005) guidelines focus on assessments at that level. Certain other rapid assessment methods, including remote sensing techniques, using data derived from satellites or aerial photography, can be applicable to the ecosystem/wetland habitat level, particularly for rapid inventory type assessments.

The following steps should be considered prior to undertaking assessments (Maragos and Cook 1995):

- Define with resource managers and users the purpose and objectives of the rapid assessment;
- Define geographic scope, based upon the objectives and constraints;
- Select survey team and assign responsibilities;
- Undertake review of literature, maps, and aerial photographs;
- Undertake interviews with knowledgeable resident resource users (fishermen, hunters, village elders, historians, curators, other scientists);
- Select field sites, relying heavily on the above inputs and steps;
- Schedule and accomplish field work;
- Each participant analyses results and prepares preliminary technical report for review by REA leadership – leaders prepare preliminary synthesis reports and send to other team members and user groups for review and comment;
- Finalise and submit synthesis report including recommendations on possible priority protected areas;
- Finalise and publish technical reports.

2.4 Compilation of existing data

Before determining whether field-based assessment is required, an important first step is to compile and assess as much relevant existing data and information as readily available. This part of the assessment should establish what data and information exists, and whether it is accessible. Data sources can include geographic information systems (GIS) and remote sensing information sources (Mellin *et al.* 2012), published and unpublished data, and traditional knowledge and information accessed through the contribution, as appropriate, of local people. Such compilation should be used as a "gap analysis" to determine whether the purpose of the assessment can be satisfied from existing information or whether a new field survey is required.

It is important to review and evaluate existing biological surveys, including rapid surveys, of both terrestrial and marine biota in the Pacific region in terms of methodology, systems, weaknesses, key gaps and reporting. This thorough and extensive literature review should be done in close liaison with the client.

An important resource that should be fully utilised is the SPREP Pacific Environmental Information Network: http:/www.sprep.org/Pacific-Environment-Information-Network/pacific-environment-information-network-pein-country-profiles-directory

3. Terrestrial vegetation and flora

3.1 Introduction

Internationally, BIORAP surveys for vegetation and flora tend to focus on understanding the key environments present within a study area, and the main determinants of vegetation patterns. Within this context, further detail is then sought on the flora of each major environment, including the location of any less-modified vegetation types, and the habitats of any threatened or endemic species. Mueller-Dombois and Fosberg (1998) provide an overview of vegetation in the tropical Pacific, drawing on numerous vegetation surveys undertaken over the last *c*.100 years or so. Whilst not necessarily identified as BIORAP surveys, many of these studies share strong affinities with BIORAP methods due to the remote nature of many of the study sites, and limited staffing resources. The first step in understanding the vegetation and flora of a study area is typically the division of the vegetation into broad classes or types, and the production of a vegetation map. Once this has been achieved, species lists are often compiled for each vegetation class or type present, sometimes with accompanying frequency data.

BIORAP surveys have recently been undertaken on Nauru (Whistler *in press* 2013) southern Lau, Fiji (Tuiwawa and Aalbersberg 2013), and in upland Savai'i, Samoa (Whistler *et al.* 2012). The BIORAP for southern Lau classified the vegetation into key vegetation types, and compiled floral checklists for each island. For Nauru and upland Savai'i - which are primarily covered in forest or shrubland habitats - the BIORAP surveys focused on forests, which were studied with a series of sample plots. Within these plots, basal area of canopy tree species was measured, and checklists for all vascular plant species were compiled. Species checklists were also compiled for other areas surveyed opportunistically during the course of the field work. For the upland Savai'i BIORAP, most of the field survey was based on an existing access road, and the eastern parts of upland Savaii were not visited.

Data collation and field survey preparation:

- If available, obtain colour aerial photography, geological maps, and topographical maps for the survey area.
- Obtain all relevant literature regarding vegetation and flora for the site, including species lists, papers, reports, and herbarium records. Compile a brief history of previous botanical exploration (if any), including where and when threatened plant species have been recorded. Prepare maps that overlay the locations for threatened species on topographical maps, and if available, colour aerial photography.
- Prepare images of threatened plant species, ideally colour photographs and/or photographs of herbarium specimens.

Identify major environments present based on the following variables:

- Drainage/soils;
- Climate/altitude.

For example, an area to be surveyed might comprise lowland and montane environments, and lowland environments might be further subdivided into beach flats, swamps (saline, brackish, or freshwater), deltas, alluvial plains, and hills/low mountains. At some survey locations a key environmental variable may be rainfall, with a major division of habitats occurring between windward (high rainfall) and leeward (low rainfall) areas.

- Historically rare ecosystem types are those that have always been very limited in extent, even prior to human settlement, and are often characterised by the presence of rare or endemic species (Williams *et al.* 2007). If possible, identify any unusual features that may support historically rare or uncommon ecosystem types (e.g. outcrops of unusual geology, ultrabasic soils rich in iron and magnesium, cloud forest, geothermal sites, e.g. hot springs, bogs, cliffs, ephemeral lakes, and cave entrances). Additional historically rare ecosystem types not shown on maps (e.g. seabird guano deposits) may also be identified during consultation with local communities.
- Overlay available resources - colour aerial photography, geological maps, and topographical maps - to identify the likely location of natural areas within each major environment present. Natural areas can be defined as habitats within which indigenous plant species are dominant (equal or greater than 50% cover), and may include an exotic component.

- If the survey area is extensive and time limitations will prevent the survey of all areas, assign higher priority to:
  - Larger, more contiguous natural areas;
  - Areas that will ensure that natural areas within each major environment are included;
  - Areas that may contain historically rare ecosystem types;
  - Areas that are likely to support rare or endemic species.

3.2 Local community engagement

Immediately prior to the field survey, explain the objectives of the vegetation and flora survey to interested local people. Using maps and the images of threatened plants, record any additional known locations or potential sightings of target species. If someone who has seen a target species is willing to assist in its relocation, encourage their involvement in the field survey. Gather any additional information that may assist in the interpretation of current vegetation types and patterns, e.g. location of seabird colonies, and historic locations of abandoned villages, forest clearings, and fires.

Local people, especially those that frequent natural areas, such as hunters, can be invaluable to a botanical survey for their knowledge of paths and access routes, sources of drinking water, forest types, and rare plants. If people with these skills are available and willing to assist, the survey should engage their assistance. Their involvement might also allow for the development of a dictionary of local plant names (Hawthorne 2012).

3.3 Field survey

3.3.1 EQUIPMENT REQUIREMENTS

- Laminated colour aerial photographs of the survey area.
- Laminated geological and topographical maps of the survey area (if available).
- Laminated images (preferably colour) of threatened or endemic plant species.
- Fine-tipped indelible marker pens.
- Water-proof paper and pencils.
- Two GPS units.
- Binoculars (8-10´ minimum).
- Compass.
- Secateurs.
- Bush knife.
- Strong catapult (for collecting specimens from tall trees).
- Plastic clip-seal bags (for collection of fleshy specimens such as ripe fruit).
- Field plant press.
- Digital camera (plus spare memory cards, and backup).
- Spare batteries for camera and GPS.

3.3.2 RECONNAISSANCE SURVEY

A brief reconnaissance survey at the onset of field work is often critical to success. Ideally, all team members achieve a broad overview of the project area by whichever means are available (e.g. viewing from roadside or summit vantage points, from a boat, or by air). Key objectives of the reconnaissance survey are as follows:

- To identify and map any major environments not identified during the desktop phase.
- To ground-truth the location of natural areas identified from the aerial photographs, including checking for any natural areas omitted (e.g. locations omitted due to their incorrect identification as "pasture" or "exotic grassland" may be freshwater marshes dominated by indigenous species).
- For the field surveyor/s to become familiar with the main vegetation types present in the survey area, if necessary, including the identification of canopy species based on shape, colour, and texture. Identification of canopy species based on these characteristics will be needed to complete landscape-scale mapping and description of vegetation types from vantage points. A useful method for achieving this is to briefly survey areas with diverse vegetation on foot and to identify the canopy species present, based on botanical characteristics, e.g. flowers, leaves, fruit. The same areas are then viewed from a distant vantage point (e.g. 300 m or more) using binoculars, and the canopy plant species should be identified based on shape, colour, and texture.

On completion of the reconnaissance survey, the remaining field time can be divided into the following:

- Mapping and description of vegetation types;
- Compilation of a checklist of the flora, with accompanying voucher specimens;
- More intensive, targeted surveys of habitats most likely to support threatened or endemic species.

3.4 Vegetation mapping and description

Natural areas within a survey area are best mapped and described as ecological units that reflect their environmental, structural, and floral characteristics. If there is a common or local name for a species that is of widespread usage, this should be used preferentially over its botanical name, to increase non-specialist understanding and engagement. All common or local names used will be referenced in the flora checklist. Species mentioned within the names of ecological units will be restricted to those that are most common within that unit (c.f. Paijmans 1976, Atkinson 1985).

3.4.1 VEGETATION STRUCTURE

Within each natural area, vegetation will be further classified and mapped according to its major environment (e.g. lowland freshwater swamp), and the dominant structural form (e.g. trees, shrubs, grasses, vines, or herbs). These are physiognomic-environmental vegetation types and can be regarded as comprising a vegetation classification at a landscape level. As such, this level can then be applied on a global basis (Mueller-Dombois and Fosberg 1998). The following list of vegetation structural types is derived from Atkinson (1985), with minor modifications for applicability in the tropical Pacific. This classification method is objective, repeatable, and able to be applied to a wide range of terrestrial habitats. Based on percentage cover, this method can be rapidly applied to all vegetation types using visual estimates of cover. Further refinement of the structural classes given here may be needed to ensure inclusivity of all vegetation types.

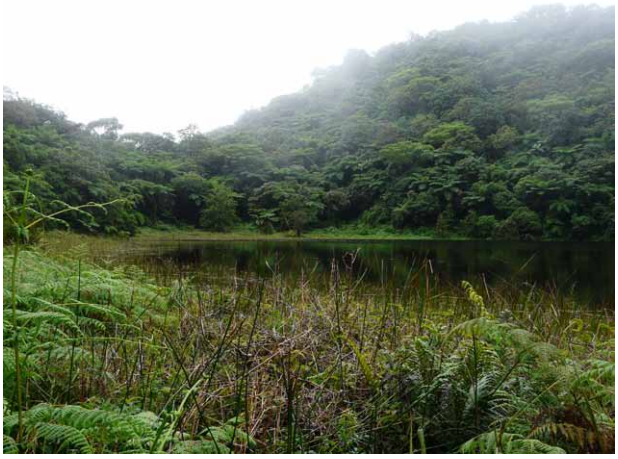


Table 1: Structural classes for mapping and classification of vegetation types

Structural Class	Definition
Forest (including cloud forest)	Woody vegetation in which the cover of trees in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm dbh. Tree ferns ≥10 cm dbh are treated as trees. Examples include *Ficus prolixa*, *Cocos nucifera*, *Pisonia grandis*. In montane forests with persistent cloud cover, stunted trees, and dense epiphytic growth of bryophytes and ferns, forest can be given the subcategory "cloud forest'.
Treeland (including woodland savanna)	Vegetation in which the cover of trees in the canopy is 20-80% with tree cover exceeding any other growth form, and in which the lower canopy is non-woody vegetation. This structural type can be termed "savannah woodland" if tree cover is 50-80%.
Vineland	Vegetation in which the cover of unsupported woody vines in the canopy is 20-100% and in which the cover of these vines exceeds any other growth form. Vegetation containing woody vines supported by trees or shrubs is classified as forest, scrub, or shrubland. Examples include *Ipomoea*, *Merremia*.
Scrub	Woody vegetation with the cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds trees. Shrubs are defined as woody plants ≤10 cm dbh. Examples include *Scaevola taccada*, *Morinda citrifolia*, *Cytandra*.
Shrubland	Vegetation in which the cover of shrubs in the canopy is 20-80% and in which the cover of shrubs exceeds any other growth form or bare ground.
Fernland	Vegetation in which the cover of ferns in the canopy is 20-100% and in which the cover of ferns exceeds any other growth form or bare ground. Tree ferns≥10 cm dbh are excluded as trees. Examples include *Dicranopteris, Nephrolepis, Pteridium.*
Grassland (including savannah)	Vegetation in which the cover of grasses or grass-like plants in the canopy is 20-100% and the cover of grasses exceeds any other growth form or bare ground. Examples include *Phragmites, Lepturus. Eragrostis, Digitaria.* This structural type can be termed "savanna" if it includes tree cover of >1% (Collinson 1988).
Sedgeland	Vegetation in which the cover of sedges in the canopy is 20-100% and the cover of sedges exceeds any other growth form or bare ground. Examples include *Cyperus*, *Gahnia*, *Lepidosperma*, *Carex*, *Fimbristylis*
Reedland	Vegetation in which the cover of reeds in the canopy is 20-100% and the cover of grasses exceeds any other growth form or open water. Reeds are herbaceous plants growing in shallow water that tall, erect, unbranched leaves or culms. Examples include *Typha.*
Herbfield	Vegetation in which the cover of herbs in the canopy is 20-100% and the cover of herbs exceeds any other growth form, bare ground, or open water. Herbs include all herbaceous and semi-woody plants not separated as ferns, grasses, reeds, mosses, or lichens. Examples include *Triumfetta procumbens, Euphorbia atoto.*
Mossfield	Vegetation in which the cover of mosses in the canopy is 20-100% and the cover of mosses exceeds any other growth form or bare ground. Examples include *Campylopus, Rhacomitrium, Sphagnum.*
Lichenfield	Vegetation in which the cover of lichens in the canopy is 20-100% and the cover of lichens exceeds any other growth form or bare ground. Examples include *Parmelia, Cladonia, Stereocaulon vulcani.*
Rockland	Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth form. Cliffs often include rockland. Rocklands are named from the leading plant species when cover ≥1%. If known, the geology of the rockland should be recorded e.g. aa lava rockland.
Boulderfield	Land in which the area of unconsolidated bare boulders (>200 mm diameter) exceeds the area covered by any one class of plant growth form. Boulderfields are named from the leading plant species when cover ≥1%. If known, the geology of the boulderfield should be recorded e.g. basaltic boulderfield.
Stonefield/ Gravelfield	Land in which the area of unconsolidated bare stones (2-20 mm diameter) and/or gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth form. The appropriate name is given according to whether stones or gravel covers the greater area of ground surface. Stonefields and gravelfields are named from the leading plant species when cover ≥1%. If known, the geology of the stonefield/gravel field should be recorded e.g. limestone gravelfield.
Coralfield	Land in which the area of broken coral, of any diameter, exceeds the area covered by any one class of plant growth form. Coralfields are named from the leading plant species when cover ≥1%.
Sandfield	Land in which the area of bare sand (0.02-2 mm mm diameter) exceeds the area covered by any one class of plant growth form. Sandfields are named from the leading plant species when cover ≥1%.
Loamfield/ Peatfield	Land in which the area of loam and/or peat exceeds the area covered by any one class of plant growth form. The appropriate name is given according to whether loam or peat covers the greater area of ground surface. Loamfields and peatfields are named from the leading plant species when cover ≥1%.

3.4.2 VEGETATION COMPOSITION

For each vegetation structural type, the floristic characters are described to complete the description of an ecological unit. It is at the floristic level of classification that vegetation types, often called associations, have limited geographical ranges (Mueller-Dombois and Fosberg 1998). For each ecological unit, the species composition of the canopy, or uppermost vegetation layer, is recorded in the following four categories: greater than 50% cover, defined as "abundant", 20-49% cover, defined as "common", 5-19% cover, defined as "frequent", and less than 5% cover, defined as "occasional".

Compositional names are derived from the names of the most common canopy species as follows:

- If one canopy species is ≥50% cover by percentage cover or basal area, this species is assigned to the structural class and major environment to complete the name of the ecological unit. For example, forest on a beach flat with a cover of ≥50% *Barringtonia asiatica* would be given the name '*Barringtonia asiatica* forest on beach flat'.
- If no single canopy species exceeds 50% cover by percentage cover or basal area, any species ≥20% cover is assigned to the name (Atkinson 1985). For example fernland on a lowland hillslope with a cover of 45% *Dicranopteris linearis* (tangle fern), 30% *Miscanthus floridulus* (miscanthus grass), and 15% *Wikstroemia foetida* (wikstroemia), would be called 'tangle fern-miscanthus grass fernland on lowland hillslope'.
- If no species reach the 20% level, the two most abundant species from 1-20% cover by percentage cover or basal area are assigned to the name (Atkinson 1985). For example, on a beach flat where the cover was 70% sand, and 15% *Ipomoea littoralis*, the ecological unit would be named '*Ipomoea littoralis* sandfield on beach flat'.

This semi-quantitative method allows for extensive areas to be mapped and described during rapid biodiversity surveys. The data obtained can be subsequently modified through quantitative sampling if time and resources permit (Atkinson 1985). The key strength of this method is its ability to rapidly determine the location and approximate composition of all vegetation types present within a site. This ensures the inclusion of any uncommon vegetation types which may support threatened or endemic species.

3.4.3 MAPPING OF ECOLOGICAL UNITS

The scale of mapping will be dependent on the available imagery and the extent of the survey area. Ideally, ecological units will be mapped at a scale of 1:5,000. This allows an area of approximately 2,000 ´ 1,300 m to be depicted on an A3 sheet. However for survey areas which are very extensive, a scale of 1:25,000 or even 1:50,000 will be appropriate.

3.4.4 ADDITIONAL DESCRIPTION OF ECOLOGICAL UNITS

Ecological units with complex vertical stratification, such as some forest habitats, are unlikely to be described adequately by the canopy species alone. In these vegetation types, the canopy is only one of many layers or tiers that can also include canopy emergents, a subcanopy, a shrub layer, and a ground tier (Clapham 1973). Epiphytes and lianas are also common in some vegetation types and may not be present in the uppermost vegetation layer. Wherever possible, all multi-layered vegetation types should be further investigated and described. Walk-through surveys should be undertaken at multiple sites within each ecological unit, and the species composition of each of the layers described, using the abundance categories described above. Any localised variations that do not warrant classification as a separate ecological unit, for example canopy gaps created by tree falls or landslides, should be noted and briefly described. For example within koka (*Bischofia javanica*) forest on lowland hillslope, the vegetation within canopy gaps might be described as "abundant peltate morning-glory (*Merremia peltata*) with frequent balloon vine (*Cardiospermum grandiflorum*)".

3.5 Flora survey

3.5.1 CHECKLIST

Compile checklists for all plant species encountered during the field survey, with identification of all vascular plants to species level. Checklists should be made for each major environment encountered within each study area and then, at the completion of the survey, combined to make one comprehensive check list for the survey area as a whole. By compiling field checklists for each part of a survey site (e.g. beach flats, freshwater swamps, lowland forest, montane forest), distributional patterns with regard to habitat types are likely to be apparent for each species. The comprehensive checklist will then be annotated with general comments on the distribution and abundance of each species (e.g. "common in forest habitats at the northern end of the island").

Hawthorne (2012) outlines a suitable method for the compilation of a checklist within a vegetation type. If time permits, this method should be followed as it is able to be replicated, and ensures a similar level of sampling intensity per vegetation type. This method prevents tree species from being overlooked, as observers often focus on understory species. The method is as follows:

- The extent of the sampling site is defined. This may be all of a vegetation type, or a subset, e.g. all of a south-facing cliff, or an area of floodplain forest between an adjacent hillslope and a river. Multiple sampling locations may be required within one vegetation type if it is particularly extensive, variable, or includes rugged landscapes.
- A convenient central point is selected as the start point.
- All species present at the start point are recorded and collected.
- The field team then identifies all species present within 5 m of the sampling point, with the collection of any further species encountered.
- If the vegetation type is forest, one person counts and identifies the canopy trees within the sample area. This data gives an indication of canopy tree species composition in the area. Tree size will need to be determined on a site-by-site basis, and will typically be 30 cm diameter at 1.2 m height, with a minimum of 5cm diameter (e.g. in low cloud forest) The count, summed separately for each species, continues until the tally is at least 40 trees, or all trees present have been counted.
- The remaining field team members radiate out through the sample area, continuing to record all vascular plant species. Specimens are returned to the central point and vouchered if they are new records for the site.
- In forest habitats, searching continues at least until the tally of 40 canopy trees is reached. Ideally searching within all vegetation types should continue until the rate at which further species are encounters significantly declines (e.g. less than one additional species for five minutes searching by all of the field team) or until a minimum of 40 vascular plant species have been encountered.

3.5.2 VOUCHER SPECIMENS

Each species in the checklist will be accompanied by a voucher specimen, unless collection of a specimen would endanger the population of an indigenous species (e.g. only one seedling of a species was located). In this situation, photographs will be taken to document the find. If there is adequate material, four duplicates of each species will be collected, with distribution to herbaria throughout the Pacific, e.g. University of Hawaii Botany Department Joseph Rock Herbarium, the University of South Pacific Regional Herbarium, the Auckland War Memorial Herbarium, and the National Tropical Botanical Garden, Hawaii.

Multiple voucher specimens will be collected for species which have notable variation in botanical characteristics, as these may indicate differences at species or subspecies levels.

If present, voucher specimens will include flowers and/or fruit. All specimens will be labelled with a number, location, date, and collector, and placed in a plant press between sheets of newspaper with cardboard separators. Specimens will either then be (1) dried in a warm, dry location, with the newspapers changed as needed to prevent build-up of moisture, or (2) placed in a plant drier. A temporary plant drier can be constructed from hollow concrete blocks with light bulbs as a heat source (Whistler In press 2013). Once dried, specimens will be collated and wrapped in newspaper prior to transportation.

3.6 Surveys for threatened or endemic species

On completion of the mapping and description of all ecological units, these should be assessed to identify those that are most likely to support threatened or endemic plant species, including all species included in the IUCN Red List. Additional field time should be spent completing more thorough searches of likely habitats (Mueller-Dombois and Fosberg 1998), including:

- Habitats that are likely to have been historically rare;
- Habitats now very restricted in extent due to human settlement,;
- Habitats that are the best remaining examples of their type (e.g. large in extent, little impacted by invasive plants);
- Habitats that often have high levels of endemism, for example montane bogs.

Surveys should also be undertaken with a focus on:

- Areas or habitats within which threatened or endemic species were last recorded (if known);
- Ecological units that often provide refuge for plants threatened by invasive plant and animal species (e.g. cliffs).

If threatened or endemic plant species are found, the survey should collect data that would allow for the preparation of submissions to the IUCN Red List, if the species is not currently listed. The following information should be collected:

- Location (including GPS coordinates, altitude);
- Associated species;
- Population size;
- Population size structure (relative abundance of seedlings, mature plants;
- Presence of flowers or fruit;
- Any actual or potential threats (e.g. invasive plants, browse, vegetation clearance, landslides).

3.7 Quantitative survey methods

3.7.1 RATIONALE

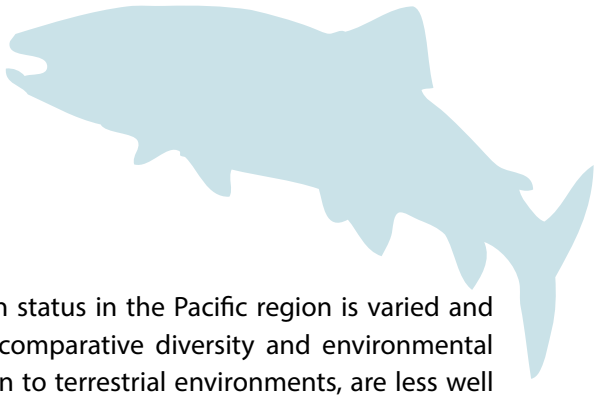
Quantitative survey methods, such as the measurement of basal area within forest plots, or point-intercept methods along transects, should only be embarked upon if allocated survey time and terrain permits, and if there are specific needs for the data that will be obtained. Measurement within plots is time consuming, and will only result in accurate assessments of vegetation composition if sample size is adequate. The number of plots required to describe the vegetation of a site varies according to factors such as the variability of vegetation within a site, plot size, plot shape, and the type of analysis to be undertaken, and pilot studies are needed on a case-by-case basis to determine the sampling is needed for each study site (Daubenmire 1968).

Within tropical forests, a large number of plots within each vegetation type are likely to be needed to adequately describe composition. The exception to the requirement for a large number of plots is if the objective of measurement is to detect changes in composition through time. In this case, the size, shape, and number of plots is less critical (Daubenmire 1968). The establishment of permanent plots is worthwhile only if the resulting data will help inform management decisions, and if future funding for their measurement and analysis is secure.

The use of plots is not able to be universally applied to all vegetation surveys due to terrain, and in some cases, the vulnerability of a vegetation type to damage from foot traffic. Many areas within the Pacific Islands have uneven terrain or very steep slopes that will prevent the safe use of sample plots. Additionally, foot traffic across steep slopes can result in significant damage to vegetation and surface substrates, through trampling, plant breakage, and loosening of root systems used as foot holds. In environments such as cloud forest shrubland, where many species are fleshy or soft-wooded, this damage can lead to the creation of canopy gaps, and increased vulnerability to invasion by pest plant species. In areas of very steep terrain, or with vegetation vulnerable to human disturbance, surveys will need to be restricted to low impact methods such as visual estimates of cover abundance.

It is envisaged that most rapid biodiversity surveys will target areas where relatively little is known of the vegetation and flora. Vegetation maps are unlikely to exist, and flora checklists will often be incomplete or out of date. These two components need to be addressed before more intensive, quantitative methods are considered.

4. Fish



4.1 Biodiversity of fishes

Biodiversity information on fishes and understanding of fish conservation status in the Pacific region is varied and irregular. There is very little, or fragmented knowledge at best, of the comparative diversity and environmental condition of many areas. Coastal and marine environments, in comparison to terrestrial environments, are less well surveyed but in many areas are highly threatened due to many environmental pressures, including those associated with population growth, fishing and coastal development (Allen and Werner 2002)

The primary focus of Marine RAP has been to provide a critical missing layer of information on coral reef biodiversity, rather than generating data on all coral reef management variables. The most direct approach is to make an inventory of all species present at a given locality. However, given that it is normally impossible to undertake a comprehensive inventory, a satisfactory alternative is to concentrate on certain 'key' taxa that function as indicators of overall biodiversity (Allen and Werner 2002).

Fish biodiversity in most rapid assessments that have been carried out so far has been assessed as a key part of surveys which target a number of important taxa in an area. Most surveys have selected reef corals as one of the most important biodiversity indicators because they provide the major environmental framework for a host of organisms. Without reef-building corals, there is limited biodiversity. This is dramatically demonstrated in areas consisting primarily of sand, rubble or weeds. Fishes are also an excellent indicator as they are the most obvious inhabitants of the reef, are generally well documented, and they account for a large proportion of the reef's biomass. Fishes depend on a huge variety of plants and invertebrates for their nutrition. Therefore, areas rich in fishes invariably have a wealth of other organisms. Molluscs have been utilised as a third indicator, basically because they are diverse, relatively well known, and conspicuous.

4.2 Fish survey methods

Field survey methods for rapid assessment of fish are critically dependent on the accessibility of the habitat selected. Most assessments that have been attempted to date are in coral reef areas which are accessible by divers for visual assessments accompanied by sampling using other techniques as required.

Habitats which are not accessible by divers, such as deeper reef areas, seamount structures and deeper pelagic habitats, need to be assessed using a combination of fishing techniques (see the summary of techniques and types of sampling for which they are suitable in: Secretariat of the Convention on Biological Diversity 2005) or remote visual techniques such as underwater photography (Page *et al*. 2001) and baited camera systems. In these habitats the knowledge and experience of local fishers is invaluable. However, no recent attempts to do BIORAP assessments and surveys in such habitats have been reported.

4.2.1 REEF FISH SAMPLING

An example of the fish sampling approach used for the majority of rapid assessments carried out in coral reef areas to date by the Conservation International teams is detailed below (Allen and Werner 2002; Allen and McKenna 2001; Allen *et al.* 2003). A very similar technique was used by Maragos and Cook (2005), Donaldson (1992, 1993) in Palau and Jenkins *et al.* (2005) in Fiji. A transect based technique was used by Fiu *et al*. (2010) and Smith *et al.* (2006).

The technique usually involves a rapid descent by one or more divers to a maximum depth of 40 m, and then a slow, zigzag path is traversed on the ascent towards the shallows. The majority of time is spent in the 2-12 m depth zone, which often harbours the largest number of species. The diver records every species encountered at each site on waterproof paper. Only the names of fishes whose identification is absolutely certain are recorded. However, usually very few (less than about 2% of the total) are not identified to species level.

Visual surveys are supplemented with small collections procured with the use of the ichthyocide rotenone and a rubber-sling propelled, multi-prong spear. The rotenone collections flush out small, crevice and subsand-dwelling fishes (for example eels and tiny gobies) that are difficult to record with the visual technique. Underwater photography

is one other option that can be used to assist with identifications, but this approach has not often been used in the fish component of the assessments described below. Most recent surveys attempt to develop as full an inventory as possible by sampling carefully in a range of habitats such as beaches, seagrass beds, fringing reefs, lagoons, passes, channels, reef holes, patch and pinnacle reefs, barrier reefs, atolls, submerged reefs, mangroves, and "rock" islands.

Such approaches are critically dependent on the availability of a significant degree of expertise in fish identification.

4.2.2 REEF FISH ANALYTICAL TECHNIQUES

Analytical techniques will vary depending on the objectives of any survey and need to be carefully researched before commencing field surveys.

An important example is the technique devised by Allen and McKenna (2001) for assessing and comparing coral reef fish diversity by developing a coral reef fish diversity index (CFDI). The technique consists of recording the number of species in six key indicator families: Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae. All selected groups are important components of reef communities, have circumglobal distributions closely corresponding with those of coral reefs, and include a representative cross-section of the dominant feeding and behavioural patterns characteristic of reef fishes. Moreover, members of each group are conspicuous diurnal inhabitants that are easily recognised after minimal training.

The total number of species in each of the six families for a given site, restricted geographic locality (e.g. complex of reefs, bay, island), or region is combined to obtain a CFDI. The CFDI allows rigorous comparison of fish diversity throughout the Indo-west Pacific and extrapolation of the approximate total number of coral reef species at a given location by using a simple regression formula. Moreover, the CFDI predictor value can be used to gauge the thoroughness of a particular short-term survey that is either currently in progress or already completed. For example, 816 species were recorded during a RAP at the Togean and Banggai Islands off central eastern Sulawesi, Indonesia (Allen and McKenna 2001). However, according to the CFDI predictor formula a total of 1,106 species could be expected, indicating that about 74% of the fauna was actually surveyed. Thus, a visual census survey of two to three weeks duration is generally adequate for comprehensive documentation of an area's CFDI species, but usually inadequate for recording the entire reef fauna.

4.3 Recent examples of rapid assessments of fish communities

CONSERVATION INTERNATIONAL RAP SURVEYS

Recent good examples of the use of rapid assessment techniques in the marine environment in the western Pacific region are the surveys reported in the Marine Rapid Assessment Program (RAP), run by Conservation International (CI). The goal of this programme is to rapidly generate and disseminate information on coastal and nearshore shallow water marine biodiversity for conservation purposes – with a particular focus on recommending priorities for conservation area establishment and management. The surveys conducted within this program are focused on key indicators of biodiversity including, in particular, corals, fishes and molluscs. The methods used and general results for fishes are summarised in Allen & Werner (2002). Detailed descriptions of the surveys are reported in the RAP Bulletin of Biological Assessment series published by CI. Key examples include Allen and McKenna (2001) (in Sulawesi, Indonesia), Allen *et al.* (2003) (in Milne Bay, Papua New Guinea), McKenna *et al.* (2009) (in New Caledonia), Werner and Allen (2001) (in Palawan Province, Philippines).

NORTHERN NSW COAST INSHORE REEFS

The suite of methods used by Smith *et al*. (2006) was chosen to provide as wide an assessment of reef "condition" as practicable. Thus, measures of biodiversity were combined with assessments of anthropogenic debris load as well as surveys of coral health and condition. Fish communities were compared using quantitative counts within a corridor measuring 2.5 m either side of the tape-measure and to a height of 5 m above the substratum. Using this method, the identity and number of pelagic fish (i.e. those associated with the water column) are assessed during the first passage of the transect and benthic and demersal fish are documented during the return swim within the same corridor. The time taken to complete each transect is dependent on the abundance and diversity of the fish assemblage; an upper limit of 30 minutes per transect was applied in all cases. The methods use fully quantitative and semi-quantitative

assessments of different variables as well as generating basic descriptive information on reef habitat (complexity). The main sampling unit for data collection was a 25 m transect across which the majority of the quantitative data are collected. Thus, at each reef, four 25 m transects were randomly placed within a depth-range of 7-12 m and each of the main sampling methods was used sequentially across each transect. For the most part, and to reduce confounding associated with differences in depth, transects were deployed in a narrower depth range (8-10 m) wherever possible. Experience from previous surveys using the same method indicated that four replicate transects provide data that are both precise and cost effective for descriptions of biotic patterns on nearshore reefs.

PALAU CORAL REEFS

At the request of the Palau and US governments, a team of 30 scientists completed a rapid ecological assessment (REA) of nearshore marine resources in Palau in 1992 (Maragos and Cook 1995). This is an example of a particularly well planned assessment.

The REA provided ecological input to Palau's ongoing master plan for economic development and identified 45 marine sites worthy of special protection. A combination of qualitative and quantitative techniques were used to assess stony corals, other reef invertebrates, reef and shore fishes, macroscopic algae, seagrasses, turtles and other marine organisms. The REA covered a variety of coral reef habitats including beaches, seagrass beds, fringing reefs, lagoons, passes, channels, reef holes, patch and pinnacle reefs, barrier reefs, atolls, submerged reefs, mangroves, and "rock" islands. Major stresses to Palau's coral reefs include sedimentation from soil erosion, overfishing, and damage from periodic storms and waves. Minor stresses include dredge-and fill activities, sewage pollution, anchor damage, tourism use, ship groundings, aquarium fish collecting, and minor crown-of-thorns (*Acanthaster*) infestations.

The REA involved:

- Meetings and interviews with officials and government leaders.
- Acquisition of high-resolution, low-altitude aerial photographs.
- Thorough literature review of all previous scientific investigations in Palau.
- Interpretation and mapping of ecological areas using the aerial photographs and maps.
- Interviews with knowledgeable or interested island residents including the fishing community.
- Field work including shoreline and underwater surveys.
- Analysis and write up of technical reports.
- Preparation and revision of the synthesis reports.

Exact details of techniques used during underwater surveys varied according to the investigator and subject, but all involved underwater observations recorded during a half hour scuba dive at each site. The use of preprinted waterproof forms accelerated the recording of notes underwater. On reef slopes each half hour survey began at a depth of 20 m. Divers then began to ascend slowly to the top of the reef. Horizontal distances during ascent averaged 100 m in the absence of currents. Otherwise divers drifted with the current.

FIJI'S GREAT SEA REEF: CAKAULEVU AND ASSOCIATED COASTAL HABITATS

This report (Jenkins *et al.* 2005) presents the results of a 12 day survey expedition (5-16 December, 2004) and represents the first systematic effort to document the marine biodiversity of the Great Sea Reef (GSR), locally known as Cakaulevu, to the north of Vanua Levu in the Fiji Archipelago.

Each survey dive was conducted in an ascending zigzag search pattern, covering roughly a 100 metre wide search zone along the reef front. Each dive was structured to maximise search time by concentrating on certain "focus groups". These groups were generally (i) deep slope (40-30 m) fast-moving open water fish, (ii) mid-slope (30-10 m) large highly conspicuous mid-water fish, (iii) Reef crest/flat (10-0 m) with coral and sand-dwelling fish. Snorkel surveys were also conducted in very shallow water and around mangroves. Species seen were recorded on pre-prepared underwater data sheets with space to write in additional species seen.

For potentially new fish taxa, voucher specimens were collected using a three- pronged Hawaiian sling spear, fixed in a 10% formalin solution and transferred to 70% ethanol solution after five days of fixation. Some specimens were stored

directly in 70% ethanol for DNA analysis. As colour loss is rapid, accurate preservation of colour patterns was recorded by photography.

For purposes of fish fauna comparison the Coral Reef Fish Diversity Index (CFDI) (Allen *et al.* 2003) was used in analysis. The diversity of marine biota on the Great Sea Reef and its associated habitats was revealed to be of high importance on a global, regional, national and local scale. This survey alone documented the reef to have approximately 55% of the known coral reef fish in Fiji (with a predicted actual value of 80%),

NAURU CORAL REEF FISH

The most recently completed of the BIORAP surveys in the region (SPREP and CI Biological Rapid Assessment Program Nauru, 17-27 June 2013) serves as a good example of an appropriate approach to coral reef fish baseline inventory assessment. The objective of this work was to produce a comprehensive list of the reef fish fauna. The survey built upon the first complete survey of reef associated fish species in Nauru undertaken by CoFish (2005).

A list of fish species was compiled for 20 subtidal dive sites, and four reef flat areas surrounding Nauru Island. The fish diversity method employed here closely follows the methods utilised in previous Conservation International rapid biodiversity surveys (Allen *et al.* 2003; Evans 2006). The survey involved approximately 29 hours of scuba diving, with the maximum depth surveyed being 35 m, and four hours of reef walks. A list of all fish species observed was compiled for each site surveyed.

The SCUBA survey approach involved the author covering the full range of depths and habitats during a single dive of 60-110 minutes duration at each site. The full scientific name of each observed species was recorded. The survey technique involved descending to the 35 m level on the reef. SCUBA survey effort was divided between the various depth zones of the reef with a larger amount of time devoted to the 1-12 m zone, where typically the greatest abundance and diversity of reef fish species were located. The diver moved through the habitats in a slow meandering manner looking for free swimming species as well as spending as much time as possible searching for more cryptic species in amongst the reef substrate. Each dive included a representative sample of all major bottom types and habitat situations present at the site.

The survey utilised the data recorded by the author, and also the results of the previous reef fish survey (CoFish 2005) and a species list of reef fish species collated during a survey of aquarium fishes during June 2013 (Secretariat of the Pacific Regional Environment Program, SPREP). In addition, this study utilised local knowledge of reef fish biodiversity. These data were collected by undertaking a verbal assessment of reef fish diversity with two experienced Nauruan fishermen over the survey time period. This data collection involved sitting with the two fishermen and allowing them to point out species that they had seen on their reefs as illustrated within Allen *et al*. (2003), (Reef Fish Identification Tropical Pacific). This method provided an insight to the wider diversity of fishes within Nauruan reefs.

The Coral Reef Fish Diversity Index (CFDI) method developed by Allen (1998) to assess and compare the overall reef fish diversity was applied to Nauru waters.

4.4 Method(s) recommended for fish BIORAPs

Given that the most accessible habitats are coral reef areas, it is recommended that the technique described by Allen and Werner (2002) or appropriate modifications (such as a transect based approach to provide a more quantitative element to the survey) to suit the detailed objectives of the survey, the time and logistical support available.

The technique involves a rapid descent by one or more divers to a defined maximum depth, followed by a slow, zigzag path traversed on the ascent towards the shallows. The majority of time can be spent in the shallower depth zones, which often harbour the largest number of species. The divers record every species encountered at each site on waterproof paper.

Visual surveys are supplemented with small collections procured with the use of the ichthyocide rotenone and a rubber-sling propelled, multi-prong spear. The rotenone collections flush out small, crevice and sand-dwelling fishes that are difficult to record with the visual technique.

The survey should attempt to develop as full an inventory as possible by sampling carefully in a range of habitats as appropriate and as time and personnel allow.

Careful preparation and planning is important, particularly including (where possible):

- Acquisition of high-resolution, low-altitude aerial photographs.
- Thorough literature review of all previous scientific investigations.
- Interpretation and mapping of ecological areas using the aerial photographs and maps.
- Interviews with knowledgeable or interested local residents including the fishing community.

It is particularly important that suitably trained and qualified divers are available and that appropriate expertise in the identification of fishes is part of the team.



5. Marine Mammals

5.1 Marine mammal biodiversity

Approaches to evaluating marine mammals from a biodiversity perspective are significantly different to most other marine organisms because of the geographic scale of distributions, the high cost of field evaluations, and the conservation status of many of the species which are found in the region. Moreover, distributions vary seasonally for many species.

Any need to carry out a rapid assessment of biodiversity of marine mammals will primarily be met by an examination of existing reports and investigating local and traditional knowledge in the areas of interest. Reeves *et al.* (1999) compiled all available data on marine mammals in the SPREP area up until about 1996, and reported 27 species of whales and dolphins in Oceania waters, emphasising the importance of the area for conservation of marine mammals.

A later key summary of knowledge and of threats to marine mammals in the Pacific Islands was well summarised by Miller (2006). This thorough report provides an overview of the current state of knowledge of cetacean diversity, habitat and threats in the Pacific Islands Region. The Region serves as habitat to many cetacean species that selectively use the region on a year-round, seasonal, or more sporadic basis. However, for a vast majority of cetacean species a detailed understanding of the life history, geographic range, and habitat of individuals and populations is lacking. An initial examination of country-specific cetacean diversity in the region was undertaken, which provides a checklist of cetacean diversity rather than an analysis of relative composition and densities. The analysis indicated that a core group of species made up the majority of cetacean records for the nations of the Pacific Islands Region. A complete listing of the species identified as occurring within the Pacific Islands Region was produced. For each of cetacean species habitat description, subspecies classification, possible issues with identification, and status (in terms of IUCN criteria) were listed.

Known species and distributions were summarised in SPREP (2007) as part of the Pacific Islands Regional Marine Species Programme.

5.2 Marine mammal surveys

Field data collection for marine mammals is generally based on visual sighting surveys from boats (e.g. Garrigue *et al*. 2004; Garrigue and Russell 2004; Kahn 2006), sometimes supported by aerial sightings (Andrews 2013). In some regions passive acoustic techniques are used to assist with estimates of relative abundance (Noad *et al.* 2006; Andrews 2013; Garrigue *et al.* 2004).

Recently reported surveys include:

- Andrews 2013 – Palau (yet to be fully reported). A boat-based survey supported with aerial sightings and acoustics.
- Garrigue *et al.* 2004 – Vanuatu. A boat-based visual survey supported with acoustics.
- Garrigue *et al.* 2008 – New Caledonia. Dugong survey using strip aerial transect methods.
- Kahn 2006 – Solomon Islands. A boat-based visual survey.
- Noad *et al.* 2006 – Samoa. A boat-based visual survey supported with acoustics.
- Paton *et al.* 2009 – Lomaiviti Island Group, Fiji.
- Walsh and Paton 2003 – Samoa.
- Ward and Asotasi 2007 – Samoa. A boat-based visual survey.

5.3 Method(s) recommended for marine mammal BIORAPs

Rapid assessment of biodiversity of marine mammals will include a careful review of existing reports and an investigation of local and traditional knowledge in the areas of interest.

The most cost-effective field data collection for marine mammals is generally based on visual sighting surveys from boats, taking account of the seasonal occurrence of many species, the habitats usually occupied by relevant species, and the limitations of the vessels available.

Preliminary reconnaissance and surveys of larger areas are best carried out from suitable aircraft.

Appropriate design of tracks of boats and aircraft can yield estimates of abundance.

6. Bats

6.1 Evaluation of recent surveys

There have been few BIORAP studies in the Pacific reported in peer-reviewed literature that have included bats. Studies that have taken place with BIORAP or with similar goals, have used a variety of techniques including mist netting, harp trapping, acoustic monitoring and undertaking roost searches to detect a full suite of bat species.

Background research into the ecosystem to be surveyed has proved useful to bat surveys in the Pacific region. Additionally the use of variety of techniques to maximise species lists, and a good knowledge of previous work that has taken place (Palmeirim *et al.* 2005, Scanlon *et al.* 2013). For example, one investigation into Fiji's bats were able to prioritise their search to cave-dwelling bats because a large amount of data was available from a prior study by the Australian Museum, who used mist-netting capture techniques to capture tree-roosting species (Palmeirim *et al*. 2005). Prior to field work beginning, the ecologists searched literature (zoological, speleological and geological) and maps for limestone regions, lava tubes and other natural cavities, such as mudstone or karstic caves. They undertook interviews with local people whose work or habits were likely to put them into contact with bats or caves and other geological features that bats may have used. These conversations targeted both young people, whose knowledge was relatively contemporary, and older people, whose good knowledge of their region and its fauna generally referred to a relatively distant past (Palmeirim *et al.* 2007). This gave a list of specific sites to visit during their BIORAP survey. Specifically targeting local hunters, tourism operators, geologists, conservation workers, hikers, and other users of the outdoors, for interviews prior to field surveys taking place could help identify colonies of fruit bats or caves with bat colonies or even high activity areas. This approach proved effective at locating bat colonies previously unrecorded in the scientific literature.

Scanlon *et al.* (2013) also used a variety of techniques to maximise species detection during their investigation into the conservation status of bats in Fiji. This investigation used nylon mist nets to capture and record bats, recorded and standardised mist net hours, conducted surveys of caves, overhangs, and rocky outcrops using local guides, and used Anabat technology (Titley Scientific, Australia) to record bat calls. Experienced local field guides were used that were recommended during discussions with local people, chiefs, and turaga-ni-koro (village spokespeople). This approach proved effective and recommended that surveys focusing on cave roosts are needed to determine the status of *Notopteris macdonaldi* and *Chaerephon bregullae* (Synonym *Tadarida bregullae*) in Vanuatu; that surveys for *Emballonura semicaudata* are also required and should focus on cave roosts and detection in forests in Fiji, and the islands of Rotuma, Lau, Taveuni, Gau and Ovalau that are most likely to harbour this species.

Studies in other regions also recommended using a variety of techniques to confirm the most complete species list possible. Most of the records in an assessment of Borneo bats were derived from captures using mist nets (Pteropodidae) or harp traps (for bats of the forest interior) but also included were reported sightings (Struebig *et al.* 2010). Researchers considered that the only bat species likely to be identified correctly by non-specialists were large flying foxes (Pteropodidae). Consequently, they used opportunistic records from local people and conservation practioners to identify locations where these species were likely to be present, but only included them in distribution records when similar information was given by more than one source in the same area.

6.2 Possible methods

6.2.1 BAT CAPTURE

The bat capture methods outlined here are used widely in both species surveys and for research, and allow positive species, age, and sex determination by trained personnel (Hayes *et al*. 2009). They are able to be used at dawn, dusk, and throughout the night. Bat capture can be time-consuming and labour-intensive; requires advanced training to set up the equipment, and handle and identify bat species; and requires special permits. Capture can also provide biased samples as some species avoid capture. The cost relative to other methods is considered to be moderate (Hayes *et al*. 2009).

Bats are generally targeted for capture in the following two situations:

- Emerging from their roosts: This includes placing either mist nets (banks of microfilament nets held between either ropes or poles), harp traps (consisting of a frame that supports fine strings that are kept taut with a canvas bag below. Bats are captured by hitting the strings and falling into the bag below), or other small nets (such as landing nets designed for fishing) over known roost entrances. Roosts can be in a variety of locations including: trees (in cavities within their trunks, under peeling bark, curled into leaves or hanging from branches); caves and other natural rock formations; mines; and buildings.
- Commuting or foraging: This includes placing either mist nets or harp traps across known or suspected commuting or foraging routes. These capture devices, or banks of them, can be placed across possible flight paths such as trails, tracks, logging skid sites, stream and swamp beds (Struebig *et al.* 2008), under trees in open fields, under small bridges, and at waterholes (Tuttle 1974). The aim for placement of both mist nets and harp traps is that entire flight paths are covered.

Forest interior insectivorous bat species that forage in cluttered habitats and edge foragers can be captured in mist nets or harp traps, but placement needs to be different. Areas where bats are commuting but not foraging may be the most profitable capture sites for insectivorous edge foragers, because of their reduced frequency of echolocation calls whilst commuting in comparison to whilst foraging.

Mist nets will be useful in the Pacific region for capturing fruit bats (Pteropodidae) because Pteropodidae are too large to be captured in harp traps. Mist nets can be placed to cover large areas where bats are likely to fly. However, mist nets require continuous monitoring to ensure that captured bats or other animals do not become too tangled and difficult to remove, injure themselves, or chew their way out.

Harp traps are specifically used for the capture of smaller bats. They are most useful for fast-flying bats (Tuttle 1974). As harp traps cover an area of only a few metres naturally "closed-in" sites along a flight path are often chosen, or brush or netting is used to funnel bats into the trap. They do not require continuous monitoring, however, relatively frequent monitoring is recommended throughout the night because bats could be consumed by predators if they enter the harp trap, and also so that bats are not smothered due to the capture of large numbers. Removing a bat from a harp trap is relatively simple compared to disentangling a bat from a mist net (Tuttle 1974). As you can leave harp traps unattended, multiple sites can be targeted at the same time. Both mist nets and harp traps need to be covered or pulled down during the day if not being monitored.

Capture techniques do involve species' and age biases. For example, bat species that are likely to forage along edges and in open areas are notoriously difficult to capture (Kingston *et al*. 2003). Some species frequently fly higher than the height at which usual capture devices are set (Anon 1998). Juvenile individuals are frequently easier to capture than adults so capture efforts may be most effective when juveniles are newly volant (Anon 1998).

Capture and acoustic monitoring techniques should be used, especially when there are likely to be bats present that are difficult to capture. Bat calls should be recorded when capturing bats, as per Harrison *et al*. (2012), so that their calls are available for future use in call libraries with technology such as Anabat.

The "capture per unit effort" metric should be recorded (e.g. the number of harp traps or mist nets set for each hour of the night), as well as site data – location and vegetation description – so that input can be compared between sites.

6.2.2 ACOUSTIC (ECHOLOCATION) MONITORING

Acoustic monitoring is a widely used, useful, technique for determining the presence of some bat species (Harrison *et al.* 2012). Using automatic bat detection units to detect bats' ultra-sonic echolocation calls can be a very effective use of surveyors' time and is relatively low cost. Equipment is easily transported and battery life is long, so units can be placed in the field for many nights, with low labour input. Whilst only a low level of training is required for data collection, data analyses can be time-consuming and require skilled technicians (Hayes *et al.* 2009). Costs of acoustic monitoring are considered moderate to high by Hayes *et al*. (2009).

Acoustic monitoring has a short range of detection and detectability of calls differs between species (Hayes *et al*. 2009). Some forest-dependent tropical bat species use calls that are difficult to detect because they are relatively quiet, with short-duration echolocation pulses (Harrison *et al*. 2012). Ultra-sonic acoustic detectors are unable to detect non-echolocating species, therefore excluding all Old World Fruit bats from monitoring programmes that solely use these techniques (Pteropodidae, Harrison *et al.* 2012). Therefore a combination of techniques including monitoring of calls

in the non-ultrasonic range (for fruit bats), and physical capture are suggested so that a wider variety of species is monitored (Harrison *et al.* 2012).

Where well-documented echolocation call libraries have been developed these can be used with automatic bat detection devices (such as Anabat) to identify the species present. With call libraries analyses are much easier and less time consuming. However, call libraries have not been developed for all regions (Harrison *et al*. 2012).

The "capture per unit effort" metric should be recorded (e.g. the number of bat detection units set for each hour of the night), as well as site data – location and vegetation description – so that input can be compared between sites.

6.2.3 SEARCHES FOR ROOSTS

Searches for potential roost locations can be a successful technique for locating bats. Possible roost locations can be identified during a series of interviews with local people that encompass both past and current users of a local area. Interviewees should include hunters, particularly in those areas where bats are taken for meat, conservationists, tourism operators, and any people who are likely to come into contact with caves or other possible roost sites. Searches through literature (geological, speleological, and ecological) can also identify potential roost locations such as caves and other natural cavities. These locations should then be checked both during the day with detection devices (for echolocation), for faeces (placing mats on the ground within and around roosts can indicate current use by accumulating faeces), and all entrances watched during the evening for emergence of bats. Infrared cameras can be placed at entrances to capture images of bats emerging, although it is could be difficult to identify species from these images alone. If images or acoustic monitoring do not allow identification of species, sites should be re-visited to watch in person.

6.2.4 DIRECT OBSERVATION

Whilst bats are generally most active at night, it is possible to observe them using the naked eye during dusk or at dawn; with spotlights, infrared lights, or night vision equipment (Hayes *et al.* 2009). Direct observation is most useful at food or water sources that bats might use or when they are emerging from their roosts. Direct observation is labour-intensive, and susceptible to observer error, and has limited situations when effective (Hayes *et al*. 2009). It may be useful, however, to make some direct observations to determine flight paths or roost entrance locations for later placement of capture or acoustic monitoring devices.

6.2.5 THERMAL INFRARED IMAGING (CAMERA TRAPS)

Camera traps using thermal infrared cameras can be used for detecting bats, especially when there are food sources, such as flowers or fruit, or water sources that bats are likely to use (Harrison *et al.* 2012). Thermal infrared cameras detect objects, such as active bats, that are warmer than ambient temperature (Hayes *et al.* 2009). However, the use of camera traps is a developing field so methods are not well-established and costs and the likelihood of gear failure remain high (Hayes *et al.* 2009). This technique has only short range detection capabilities (Hayes *et al.* 2009), but should remain a consideration as technology and related costs change quickly. The "capture per unit effort" metric should be recorded (e.g. the number of camera traps set for each hour of the night), as well as site data – location and vegetation description – so that input can be compared between sites.

I6.2.6 IUCN RED LIST AND RARE SPECIES

Targeting IUCN Red List and rare species requires knowledge of their habits, including possible roost locations, and foraging areas. Multiple techniques should be used to confirm the presence of threatened and rare species including attempts at capture, acoustic monitoring particularly where call libraries are available, and roost searches. Interviews with local people, and searches of the literature, can provide useful information on where to begin searches or to place capture devices.

6.3 BIORAP method(s) recommended

BIORAP surveys should include at least both capture and acoustic monitoring methods as these techniques complement each other (Anon 1998). Roost searches should be used as a third technique where useful information has been gathered prior to surveys starting. A combination of techniques is needed to determine which species are present because some species are either difficult to capture, or detect, and many are difficult to identify without some training. Local people should be trained, particularly local conservation workers, during BIORAP surveys to teach them useful techniques for later surveys or monitoring. Local people can be helpful with placement of sampling (capture and acoustic monitoring) devices because generally they know landscape features best and may already know potential flight paths or roost locations, such as caves. However, care must be taken when involving local people in bat conservation in the Pacific region. In Fiji, for example, bat conservation is associated with the prohibition of hunting of *Pteropus tonganus tonganus* (Scanlon *et al*. 2013), so discussions with local people must take place in a gentle and non-judgmental manner.

Standardisation of methods and effort (capture per unit effort; and total input) should be recorded to allow for comparisons between sites (Struebig *et al.* 2010). Factors that need to be taken in to account include:

WEATHER CONDITIONS

Bats are generally more active and easily captured in dry weather, because mist nets and harp traps are less conspicuous. Bats are more likely to be active during fine nights with little wind.

PLACEMENT OF SAMPLING DEVICES

Knowledge of a bat species habits and height that they fly at, is useful so sampling devices can be placed accordingly. It could be effective to detect bats by placing devices where bats commute, forage, or drink, but data gained in this way may not reflect abundance and should only be used for presence/absence surveys. This type of data could be biased towards species that use selected habitat features and against those that do not (Hayes *et al*. 2009). If your purpose is to gather data that reflects relative abundance then sampling locations should be established using a random sampling design to reduce bias (Hayes *et al.* 2009).

Whilst larger indigenous habitat remnants are most likely to support greater bat diversity, even small fragments can contribute to landscape-level diversity (Struebig *et al.* 2008). Exotic habitats are increasingly being identified as important habitats for bats, particularly in areas where large-scale indigenous habitat loss has occurred (Jenkins *et al*. 2007; Borkin and Parsons 2010). Consequently, all habitat types should be considered for monitoring, dependent on the species likely to be present.

7. Reptiles

There are two classes of Rapid Biodiversity Assessments for reptiles: those that seek to inventory the reptile species of a pre-defined area and those that seek to use rapid techniques to monitor reptile assemblages across an area over time, between sites, or following a disturbance/perturbation (e.g. a predator-control operation). Although many methods used to sample reptiles are labour-intensive and can involve the use of expensive equipment, both forms of rapid biodiversity assessments are driven by the need to adopt cost-effective methods, i.e. those that quickly produce robust data on the reptiles of an area for the lowest cost in terms of time and resources.

The Pacific contains a diverse reptile fauna that includes both terrestrial and marine species from four major groups: turtles, crocodiles, snakes, and lizards. More than 300 reptile species are thought to occur across the Pacific, many of which are listed on the IUCN Red List , and many more await discovery and formal description. New Caledonia deserves a special mention as an area of high reptile endemism and species from this area make up a significant number of the Red List Critically Endangered reptiles.

In general, much of Micronesia, Polynesia, and parts of Melanesia have similar assemblages of widespread species with only a few endemics and for these areas (at least where the reptile fauna is well-known), rapid biodiversity assessment methods designed for monitoring are most likely to be appropriate (e.g. MacKinnon lists). For Papua New Guinea and the high islands of the Pacific's southwest (most of Melanesia), which contain higher levels of reptile diversity, rapid biodiversity assessment methods for inventory can be usefully employed, followed by those designed for monitoring once priority areas/species for further work have been identified. Lastly, for many individual reptile species of the Pacific, such as the Critically Endangered Fiji crested iguana or Lauan ground skink, rapid biodiversity assessments have little applicability, and targeted monitoring, research and survey is required to address conservation concerns for these species.

7.1 Key considerations for reptile BIORAPS in the Pacific

7.1.1 SPECIES IDENTIFICATION

The biggest impediment to effective rapid biodiversity assessment of reptiles across the Pacific is the difficulty associated with species identification, due to so many taxa still being discovered and/or described, and others cryptic and remarkably alike in appearance. Training of observers prior to surveys is vital. In particular, observers need to be up-skilled on how to collect and preserve specimens (including DNA samples), what diagnostic traits to photograph, and how to use field guides (which are generally absent for much of the Pacific). The over-riding principle for reptile species identification is: when in doubt get a photograph (include a scale marker), and collect a DNA sample.

7.1.2 PREDICTORS OF HIGH REPTILE-SPECIES DIVERSITY AREAS

Adler *et al*. 1995 show that Pacific reptile diversity and endemism can be explained by the size, relative isolation, and elevation of the archipelago and this effect is stronger for reptiles - compared to birds - due to their relatively limited dispersal capabilities. Also, relatively high reptile biodiversity can be expected on islands without mongoose (widespread on the Fiji islands) and other exotic mammal and invertebrate predators.

7.1.3 THREATS TO PACIFIC REPTILES

Multiple threats affect Pacific reptiles but it is widely accepted that introduced predators - cats, rats, and mongoose - pose the greatest threats to their ongoing survival, with invasive ants also a serious problem. Other threats include population growth/urban expansion, mining and its associated effects on land and waterways, dam development, deforestation and habitat fragmentation, conversion of reptile-habitat to sugar cane and other crops, invasive reptiles and insects, fires, climate change (sea-level rise, flooding, increased storm-frequency), introduced ungulates (pigs and deer), and poaching for the pet trade.

7.1.4 BIOSECURITY

Researchers can minimise the risk of disease-spread (e.g. chytrid fungus which affects frogs), and spread of invasive "hitchhiker" animals and plants (e.g. ants, Asian house geckos, mice, brown-tree snake, seeds) by ensuring that excess soil is removed from boots, outdoor clothing, scientific and camping equipment, and equipment is checked for 'hitchhikers' when moving between catchments and between islands. Where practicable, boots can be soaked in or sprayed with bleach or an anti-fungicide between site-visits and packs and camping gear should be unpacked in a secure room upon arrival to new islands.

7.1.5 VENOMOUS SNAKES

Many venomous snakes appear very similar to non-venomous varieties and it is often not obvious that they are dangerous until they are keyed out and identified. All snakes should be considered to be venomous and only handled by skilled handlers with appropriate capture and storage equipment. Snake handling is a specialist skill, and even experienced handlers can be bitten. Anti-venom has a shelf-life and it can be expensive to stock all anti-venoms that maybe required on a "just-in-case" basis and some anti-venom is rare, even internationally. As such, supplies need to be organised ahead of time, including streamlining of transport to ensure that the right anti-venom reaches the patient in the quickest possible time.

7.1.6 COMMUNITY ENGAGEMENT

Interviewing of local people can help with records for reptiles commonly included as dietary items, such as freshwater turtles. Community knowledge is also useful for detection of habitat of large, conspicuous reptiles and snakes and gaining knowledge of reptiles that occupy areas frequented by local people, such as fields, lakes, rivers, beaches, and houses.

7.2 Recent rapid biodiversity assessments for reptiles

Very few rapid biodiversity assessments – for the purposes of either inventory or monitoring – have been documented for reptiles across the Pacific and of the few available, some do not detail the methods used (e.g. the assessment of Southern Lau, Fiji), and all cover terrestrial rather than marine species. Other relevant rapid assessments carried out to date include:

- A rapid biodiversity assessment over upland Savai'i (Samoa) in 2012 that used a combination of transects (both day and night visual encounter surveys) and glue trap-stations;
- On Niue Island in 2012, information gained from locals (for large lizards), glue trap-stations, day and night visual encounter surveys, and aural surveys were used to assess reptiles;
- In 2011 Conservation International produced Rapid Biodiversity Assessment-guidelines for Papua New Guinea advocating the use of leaf litter plots and night-transects;
- In Fiji, feeding-habitat of the Fiji crested iguana was targeted by carrying out day and night walk-through surveys (2010).

Alonso *et al*. 2011 review the first 20 years of the international Rapid Assessment Programme (RAP) and provide guiding principles for a successful assessment, some of which are included in recommendations provided here. Generally, however, rapid assessments of reptile fauna from other parts of the world offer little additional information on suitable methods that are not already recommended in Fisher (2011). An exception is Ribeiro-Junior *et al*. 2008, who compared a variety of methods (pitfall traps, funnel traps, glue traps, and time-constrained searches) and demonstrated that all methods, – used together – produced the best outcome, in terms of sample representation, rather than any one method used alone. These authors advocated for the use of pitfall traps for rapid biodiversity assessment surveys for cryptic reptile species. Fisher (2011) provides a summary of the most useful methods used to date in the Pacific to detect reptiles (all included below) and notes that pitfall traps may have limited applicability in the Pacific; especially in tropical areas with high numbers of arboreal skinks and geckos. Also, traps of any kind can be problematic in areas with predatory animals – including other reptiles – that can quickly prey on the reptiles captured.

The use of pitfall trapping for reptiles is probably the most commonly used technique world-wide, especially for monitoring of reptile species assemblages. Pitfall traps are open containers that are buried in the ground such that

the tops of the containers are flush with the ground. Reptiles fall into containers as they move across the ground; the size (depth and width) of the pitfall has a large effect on the ease of use and the number and size of reptiles captured. Large pitfall traps are time-consuming to put in place – especially in rocky habitat – but they can catch large reptiles. Pitfall trapping is a cost-effective method that detects many species, but especially ground-active species or arboreal species that feed in leaf litter, and pitfall traps can detect cryptic species that are not detected with other techniques (Ribeiro-Junior *et al.* 2008).

There are, however, multiple drawbacks of the technique and, in the context of rapid biodiversity assessments, the scale with which they can be effective is a major limitation. Pitfall traps need to be cleared regularly to enable the safety of trapped reptiles: at least daily and even more frequently in areas with high reptile-predator numbers. As such, the number of traps, and the land area they can be used to cover, is directly related to the number of observers available to clear them.

Overall, Fisher's (2011) conclusion that the applicability of pitfall traps for Pacific reptiles is limited is appropriate, and as such their use should not be promoted suffice to say they could be used to sample areas where cryptic day-active species are thought to occur, and where the scale of the search-area is not vast. As noted above, Fisher (2011) specifically mentions some of the limitations of pitfall trapping in the Pacific, and given issues over much of the Pacific with invasive ant species and also land-crabs, leaving pitfall traps open overnight puts trapped reptiles in danger of predation and is not recommended here for any purpose.

7.3 Rapid assessment methods recommended for inventory of terrestrial reptiles

Combinations of various methods, used simultaneously, are required to effectively inventory reptiles of the Pacific. No single technique can detect all species given the variety in habitat specificity, behaviour, preferred activity times, size, and abundance and each inventory needs to be tailored to meet the specific objectives for that particular area (see Ribeiro-Junior *et al*. 2008). Alonso *et al*. 2011 recommend that, regardless of site, habitat-complexity, and species-diversity, a minimum of five survey-nights (presumably including day-searches too) per site is used as a guiding principle, and that methods must be simple, fast, and inexpensive. These principles are appropriate and are endorsed for inventories across the Pacific where a good proportion of the reptile fauna is cryptic or taxonomically indeterminate. With these principles in mind the use of two inventory methods is suggested: nocturnal and diurnal visual encounter surveys (VES) and glue trap stations and transects, as discussed further below.

7.3.1 NOCTURNAL AND DIURNAL VISUAL ENCOUNTER SURVEYS (VES)

This method is most commonly used either alone or in combination with other methods (e.g. glue traps) and involves walking roads, beaches, existing trails, or purposely cut trails throughout a representative selection of all habitat-types – including freshwater habitats – in search of as many reptiles-species as possible. Positioning of trails can be aided with aerial photography, satellite imagery, topography maps, and other forms of remote sensing e.g. light detection and ranging (LIDAR).

Detection of reptiles along trails can be assisted with the use of binoculars (scanning ahead for basking animals) and for nocturnal searches, geckos can be detected by listening for their calls (aural surveys) and torches alone, or torches mounted on binoculars to improve identification (noting that other faunal groups also have eye-shine that can be confused as reptile eye-shine). Nocturnal searches can also be useful for detecting diurnal reptiles that roost in the canopy at night. Destructive searches – lifting logs and/or peeling back bark and debris from trees – can also be carried out if required. Small, bright torches are very useful for detecting reptiles in crevices or tree holes, and lizard-nooses can be essential to capture some species of reptiles for identification or to collect DNA samples.

Diurnal VESs are useful for detecting all day-active species (diurnal skinks, geckos, monitor lizards, agamids, and iguanids (including the invasive *Anolis* and *Iguana*; Fisher 2011), and nocturnal searches work best for nocturnal geckos and boids.

Conservation International advocates the use of litter plots in their guidelines for rapid biodiversity assessments for Papua New Guinea, and these methods can be integrated into VESs for small sites (Mack and Wright 2011). For large tracts of habitat, litter plots are likely to prove too time-consuming and for this reason it is suggested that their use

is primarily for assessments aimed at monitoring (see Section 7.4 below). The same applies to pitfall trapping (see Section 7.2) and the use of any other trap (other than glue traps).

It is considered best practice when conducting VESs for the purposes of undertaking a rapid reptile inventory to also:

- GPS each reptile species and individual collected;
- Record details and photograph the habitat where each species and each collected-individual is found;
- Record additional biological notes (e.g. interesting behaviours, activity-time, record vocalisations (geckos), diet, feeding plants, nesting site, number of individuals sighted);
- Document the importance of the reptile to local people;
- Document any observed threats for each species;
- Attempt to map the extent of broad habitat types in the survey area;
- Diligently label specimens, photographs, and vouchers with a unique code that matches the field notes and GPS coordinates for each individual.

7.3.2 GLUE-TRAP STATIONS AND TRANSECTS

Glue (or sticky) traps come in a variety of brands, some of which have the glue impregnated with cockroach odour or banana essence, to lure reptiles to them. Glue traps have multiple benefits: they are cheap, quick and easy to deploy, can remain operational despite rain (some brands) and, if used carefully, cause minimal harm to the trapped reptiles, which can then be released once identified. Glue traps are a good way of capturing and confirming the identity of reptiles observed during visual surveys by day or night and in this way they collect separate, but complementary, data to the VESs outlined above. They are also useful in dense vegetation where reptiles are quick to flee before they can be viewed, or in areas where the reptiles cannot be accessed easily for identification e.g. rocky areas. Traps can be left in place until the glue stops catching reptiles, and checked regularly: every 30 minutes at some sites, or twice daily at others. Captured reptiles are vulnerable to overheating, stress and predation, so traps need to be checked regularly. Reptiles can be removed from traps with the use of vegetable oil on observers' fingers (use sparingly and avoid excessive coating of the reptile with oil).

A typical glue trap station has three glue traps: one on a tree, another on a log, and the third on the ground, but each station can have as many as appropriate. Fisher (2011) suggests, for the Pacific, that trap stations are placed every 10-25 metres in transects that are 100 (or 250 m) long but notes that the number of glue traps per station, the distances between stations and the length of transects will differ depending on the objectives of the inventory.

7.4 Rapid assessment methods for monitoring of reptile assemblages

Monitoring of reptile assemblages is generally focussed on a smaller area (relative to inventory) and on a known (at least to some extent) reptile specie assemblage. Both methods recommended for inventory (VES and glue traps) can also be used for monitoring, with minor modifications. Weather, habitat-type, trail-width and age of trail, as well as the number and skill level of observers, can all effect the likelihood of detection for reptiles on any given trail section. As such, in order to compare species assemblages through time, between sites or after a perturbation, data in all of these variables need to be collected in order to "standardise" the data on reptile assemblages collected for each sampling unit.

Transects of a fixed length can be used as sampling units for VESs or alternatively, a fixed length of time can be employed for each transect of a certain length. Transects can be surveyed only in certain weather conditions (e.g. avoid rain), or a combination of these constraints can be used to help standardise the data. The number of observers (and their names), time of day, approximate area searched on each side of a trail (smaller total transect width is expected for dense forest with tangled undergrowth), transect length, weather and time taken to complete transects is also collected to assist with standardisation (also termed calibration; see also Section 8.2.2. for data requirements for MacKinnon lists).

Extra rigour can be placed around the collection of reptiles from glue-traps, to assist monitoring, by standardising the weather, time of day, intervals between checking traps, habitat at each station (e.g. height above ground, circumference of tree) and glue trap brand, between sites.

In addition to VESs and glue traps stations and/or transects, one further method is suggested: litter plots, as outlined below.

7.4.1 LITTER PLOTS

This method involves the random positioning of multiple 5 m ´ 5 m quadrats over each reptile-habitat identified within the monitoring area, or habitat, of the target species. The number of quadrats and the habitat targeted depends on the objectives of the monitoring project (Ribeiro-Junior *et al*. 2008 provide a good description of how to randomise sampling to minimise bias). As noted above, litter plots are recommended by Mack and Wright (2011) for Papua New Guinea and they note that fixed-size plots make good standard sampling units for statistical analysis.

In terms of working the plots to search for reptiles, the most common method involves four people, one on each side of the quadrat. Each person moves slowly forward lifting debris, logs, rocks and disturbing the leaf litter, catching all reptiles sighted and placing them temporarily out of harm's way into cloth bags for processing when the quadrat search is complete.

Alternatively, a low fence can be made using shade-cloth that is anchored to the ground with pegs, effectively trapping, or at the very least, temporarily slowing down any trapped reptiles. The fence can be rolled up and carried to each quadrat and put in place at the beginning of each search. This method assists in capturing fast snakes and reptiles that attempt to flee from the search area before they can be identified. This method allows the plot to be effectively searched by 1-2 observers (rather than four) and with practice the setting-up of the fence can be done very quickly.

For each quadrat data is collected on:

- The time of day and time taken to search the plot;
- Broad habitat description;
- All species identified, photographed and measured (snout-to-vent length) and DNA samples if required;
- Weather.

All reptiles – unless required for vouchers – are then released back into the plot and habitat features of the plot are restored e.g. logs are put back in place.

7.5 Rapid assessment methods for inventory of marine reptiles turtles, crocodiles, sea snakes

There are six widespread species of marine turtles across the Pacific, over 30 species of sea snakes (not a well-known fauna, with many taxonomically indeterminate species), and one species of marine crocodile. Refer to the marine section for rapid assessment methods that can be also adapted to detect marine reptiles.

7.6 Rapid assessment methods for inventory of freshwater reptiles turtles, snakes, and crocodiles

As noted above, community engagement is a useful tool to inventory reptiles commonly included as dietary items, such as freshwater turtles. In addition, freshwater species maybe collected by researchers using seine nets for fish or by dip-netting in rivers and swamps while carrying out VESs for other reptiles, both day and night. Baited turtle traps can also be useful in areas away from human habitation. Scanning – with binoculars – of partially submerged logs, riverbanks and looking for drag marks and/or footprints in soft-mud and sand can all help to detect freshwater reptiles, or at least detect areas worthy of more search-effort to assist with species identification.

8. Birds

8.1 Bird surveys in the Pacific

The bird fauna of the Pacific is relatively well documented compared to other faunal groups. Papers and reports are numerous, and include vast compendiums such as the Ornithology of the Marshall and Gilbert Islands (Amerson 1969), seminal papers such as Diamond and Mayr's species-area curve study on Solomon Island birds (Diamond and Mayr 1976), and many rapid assessments.

Methods for rapid assessments vary. Many surveys are observational, and document bird species seen and heard, with some locational information and anecdotal abundances (e.g. Prasad 2010; Watling 1998). Mostly, authors have employed a combination of observational and standardised techniques including transect and point count methods (e.g. Atherton and Jefferies 2012; Butler *et al.* 2012; Champeau *et al.* 2011). The reports or papers produced from these are sometimes insufficient to allow for later accurate repetition by other teams. The MacKinnon List technique has been used to rapidly survey the species-rich New Guinea avifauna (Dawson *et al.* 2011). Few surveys address nocturnal birds, burrowing seabirds, or coastal seabirds and waterbirds.

Sufficient information may be known about the bird species present that plans for surveys are at least partly species-focused. For example, a rare burrowing seabird is known from an island, and a survey is planned to assess its continued presence, distribution and/or abundance. Surveys that aim to address the status of Red List species are not rapid baseline inventories and are better termed species-specific assessments. It may be appropriate to undertake such assessments in addition to an inventory, but the objectives need to be clear at the outset.

Important Bird Areas (IBAs) are an important consideration when undertaking rapid assessments of bird communities in the Pacific. The IBA programme was developed by BirdLife International to "identify, protect and manage a network of sites that are important for the long-term viability of naturally occurring bird populations, across the geographical range of those bird species for which a site-based approach is appropriate" (O'Brien and Waugh 2010). Criteria used to identify IBAs are largely identical to those used to identify Key Bird Areas (KBAs), and can therefore be considered as the avian subset of KBAs: all IBAs can be considered KBAs, but KBAs are not necessarily IBAs.

Marine IBAs have more recently been developed to take greater consideration of the requirements for the protection of seabirds and waterbirds. Four types of marine IBAs have been defined: seaward extensions to breeding colonies; non-breeding (coastal) concentrations; migratory bottlenecks; and areas for pelagic species. A provisional list of marine IBAs has been compiled, and a total of 187 terrestrial IBAs have been proposed or confirmed within the Pacific (O'Brien and Waugh 2010). People undertaking rapid bird surveys in the Pacific should familiarise themselves with the state of IBA progress within their area of concern, as results from rapid assessments are likely to be able to feed directly into IBA development within the Pacific, particularly in poorly known countries and territories.

Conservation International has undertaken extensive rapid assessment programmes worldwide, though mostly outside of the Pacific. The general objective of Conservation International bird surveys is to cover as many of the natural habitats present within an area as possible, with focus on specific habitats of certain species if necessary. Methods include transects, general observation, acoustic recording, and mist-netting, and may not be standardised, but sometimes include estimates of relative abundance (Alonso *et al*. 2011).

8.2 Bird survey methods

8.2.1 POINT AND TRANSECT COUNTS

- Point counts and transect counts are the most widely utilised form of standardised survey methods for birds. Point counts tend to range from five to 30 minutes in length. Transect lengths are variable, and the maximum distance from the transect at which birds are recorded is largely dependent on the habitat type (e.g. thick vegetation may necessitate smaller maximum distances given the difficulty in sighting birds). These methods provide indexes of abundance based on the conspicuousness of each bird species at that time (which can vary through the year). Point counts, in particular, are generally done in conjunction with a description of the habitat at that location. Either method can also include distance sampling – recording the distance from the bird to the transect or point. This

facilitates calculations of densities which can then be related to availability of habitat, thus producing estimates of abundance. Distance sampling, however, is reliant on high counts of individual species (i.e. a minimum of 60 detections per species is recommended; Buckland *et al.* 2001)

Advantages of point counts and transect counts:

- Can be standardised and data statistically analysed.
- Produces species abundance indices with error margins.
- Widely used, understood and tested in a variety of habitats.
- Habitat descriptions can be recorded at count stations.
- Better at describing community structure, e.g. presence of abundant flocking species, than MacKinnon lists (see Herzog *et al.* 2002, O'Dea *et al.* 2004).
- Can use distance sampling to produce estimates of abundance.

Disadvantages of point and counts transect counts:

- More time consuming than observational surveys and MacKinnon lists. Distance sampling requires even greater amounts of time, and is probably no longer able to be considered as being rapid assessment.
- Potential data is lost when walking between point count stations.
- Less likely to record inconspicuous or rare species.
- Likely to record less species overall than observational surveys or MacKinnon lists.

8.2.2 MACKINNON LISTS

MacKinnon and Phillips (1993) described a quantitative approach to visual/auditory surveys of birds whereby an observer starts walking a transect route, and records the first species heard or seen, and then the second species heard or seen. This process is continued until a list of 20 species (or some other number) has been completed. If more than one individual of the same species is observed before the list of 20 unique species is complete, the repeat observations are discarded. At the completion of the list, a second list is started from new; this process is continued until sufficient lists are completed. Herzog *et al.* (2002) provided the first quantitative assessment of the method based on statistical simulations and six years of field testing, and recommended standardisations to allow quantitative comparisons between studies. The authors concluded that the method is a useful technique for rapid assessments of species richness in tropical bird communities. Further assessment of the method was undertaken by MacLeod *et al.* (2011). They demonstrated that the method was robust for differences between observer experience and different stages of the breeding season in highly diverse species assemblages.

Advantages of the MacKinnon list technique:

- Can be standardised and data statistically analysed.
- Produces species abundance indices with error margins.
- Measures the magnitude of species richness.
- Allows the calculation of species accumulation curves which helps determine when a site is adequately surveyed.
- One of the most rapid of standardised assessment techniques in that the accumulation of data is largely continuous. For example, in the MacLeod *et al.* (2011) study, observers spent an average of 14 hours surveying to produce an average of 34 10-species lists, providing abundance indices for 156 of 211 (74%) species known to be present in the study area.
- Because observations are recorded chronologically, the data from many observers across a site can be pooled.
- Surveys can be undertaken throughout the day.
- Analyses show the method is not particularly sensitive to observer experience with the avifauna community in question (however, the evaluation only included ornithologists) or to changes in species detectability over time.
- Potential applications for other taxonomic groups including mammals, bats, coral reef fish and some insect groups.

Disadvantages of the MacKinnon list technique:

- Not yet widely used.
- Though inter-observer consistency in species abundance indices was high, observers experienced with the avifauna of the area recorded significantly more species than the least experienced.
- The sequence recording species may have a large influence on the relative abundance of a given species (e.g. if two individuals of a species occur at the end and beginning of consecutive lists, their relative abundance will double compared to that if they fell in the middle of a list sequence (O'Dea *et al.* 2004).
- Not fully tested (e.g. consistency of abundance at lower survey efforts, applicability and consistency in habitats with lower avifauna diversity).

Lower Waria Valley Study, Morobe Province, Papua New Guinea

Dawson *et al.* (2011) employed the MacKinnon list technique to survey avifauna in four habitats grading from agricultural land through to primary forest. The authors noted the suitability of the method for rapid surveys in tropical habitats. Three primary observers spent one month in the field familiarising themselves with the bird species present before undertaking surveys, and also trained a further four observers who accompanied the primary observers for a number of days before working solo. The authors investigated the differences between habitats in the contexts of species diversity, species richness, and community composition as defined by feeding guilds. Species discovery curves indicated that more surveys would likely detect further species.

8.2.3 ACOUSTIC SURVEY AND MONITORING

Sound recordings have been used for various means in surveys and monitoring for decades and have been employed as part of rapid surveys. Parker (1991) describes how a team of seven ornithologists undertook 54 days of intensive field work within a 2 km^2 area in Bolivia (which included 36,804 mist-net hours) and inventoried 287 bird species. In seven days, Parker recorded the vocalisations of 85% of those species.

However, significant developments in the use of automated recording of bird song are presently occurring. Large-scale deployment of devices throughout Australia and New Zealand natural ecosystems is being undertaken, and their ecological applications and methods for use are being developed and assessed. This developing research field should be closely followed as it may change or improve the preferred method for rapid assessment of birds (and other fauna).

Playback has been used to elicit cryptic bird species to call in a variety of habitats, and can be used as part of standardised surveys targeting these species. Playback has the potential to be integrated into rapid bird surveys, but is a species-specific assessment.

Advantages of acoustic surveys:

- Can be standardised and data statistically analysed.
- Produces species abundance indices with error margins.
- Can reduce the variability associated with different observers undertaking point and transect counts (some studies suggest that acoustic surveys are preferable to trained observers without recorders; see references in Brandes 2008).

8.3 Recommended method(s) for bird BIORAPs

A combination of survey methods are required to effectively inventory Pacific bird species. Ideally, methods should be repeatable to allow for comparison with future surveys. However, this is a fine balance between ensuring survey methods remain rapid, while allowing for sufficient standardisation for robust evaluation of trends. It is recommended to standardise methods as, in the long run, this will be a more efficient use of funds.

8.3.1 LINE TRANSECTS

Line transects are recommended for rapid assessments in order to sample the greatest area of interest more-or-less continuously. This is an index and not a census, as not all birds present will be observed. The placement and length of transects will depend on the habitats. Ideally, transect locations will follow a sampling design (e.g. stratified, systematic).

However, in practice, this may be too logistically difficult in some habitats. Transects that follow rivers, tracks and roads will introduce bias (for example, birds observed near to a road through a forest may be different from those that would be observed 200 m away from the road). Practitioners need to be aware of the potential for such biases and identify them.

The maximum distance within which all birds seen and heard are recorded is also dependent on the habitat type. Very dense habitats will restrict visual observations to within close proximity of the surveyor. The estimation of distances to each bird (distance sampling) is not recommended as this requires extra time, greater training, and very high numbers of encounter rates (50-80 observations per species) to provide accurate density estimations.

Ideally, a GPS should be used to track the observer along each route taken. At a minimum, the coordinates of the start and finish of the track should be recorded. Date, time of day, and weather conditions should be recorded. Species abundance and conspicuousness varies throughout the year and the day, and consequently the best time for survey will differ between species. If transect counts are able to be repeated (to provide greater accuracy) this must be taken into account. Future surveys of the same transects must take the timing of the original counts into consideration.

As a rule of thumb, a good description of the birds of a particular forest community may require 10 km of transect (Bibby *et al.* 2000). Depending on the terrain, an observer could reasonably expect to cover 4 km of transect a day, up to 10 km in a very easy landscape.

Methodological references include Bibby *et al.* (2000) and Department of Conservation (2013) http://www.doc.govt.nz/Documents/science-and-technical/ inventory-monitoring/im-toolbox-birds-incomplete-line-transect-counts.pdf

8.3.2 MACKINNON LISTS

It may be preferable to use MacKinnon lists for rapid surveys on the island of New Guinea due the high diversity of its avifauna and its large land area. This is a tentative recommendation given the relatively low use of the method in comparison to line and points counts and because its potential biases have still not been fully tested. Use of the method should follow the instructions above for transect counts, but observers should all keep the exact same time, and record the times of all observations to allow for later combining of lists.

8.3.3 OTHER METHODS

Line transects and MacKinnon lists will not identify nocturnal species and burrowing seabirds, and may not observe inconspicuous and cryptic species. Transects are also not a particularly good method of estimating the abundance of colonially nesting or roosting seabirds.

We recommend the use of automatic acoustic monitoring devices as a valuable addition to transect counts. Devices can be programmed to obtain data on a standardised schedule, or can be 'sampled' once removed from the location. They can be set to record during dawn choruses, during the night for nocturnal birds and burrowing seabirds, or within habitats thought to contain cryptic species. The use of acoustic monitoring devices also allows for later analysis by species experts who might not have been part of the rapid assessment team. They can be left in situ, if required, for extended periods of time.

Playback can be used for species-specific assessments, particularly for cryptic species. Exact methods of use should be described in the resultant report.

If the location of interest is known or thought to support congregations of seabirds and/or waterbirds, focused searches need to be undertaken. Systematic counts of roosting, nesting, and/or feeding birds can be made, as usual taking care to note weather, time of day and year, and recording GPS coordinates of key sites. Photographs can assist with counts and provide useful information for future surveys.



9. Invertebrates

9.1 Why survey for invertebrates in a rapid assessment programme?

Invertebrate groups, particularly insects, but also spiders, myriapoda (millipedes and centipedes), and molluscs (land snails) underpin all terrestrial ecosystems in terms of ecological services (pollination, soil formation and nutrient recycling, regulation of the populations of other organisms through predation and parasitism), their specialised and differential feeding, as a food resource, species richness, population numbers and biomass, and the different assemblages of species that characterise and shape these ecosystems in measurable ways.

The tropical Pacific has thousands of islands, many with surprisingly high mountains, and is a recognised hotspot for global biodiversity (Parsons 1999). For invertebrate groups that are well-researched, such as Polynesian butterflies, endemism is high, at 70% (Patrick & Patrick 2012).

9.2 Global view of invertebrates in rapid biological surveys

Addressing such a diverse group of organisms, found in every corner of every ecosystem, and many with staggering species richness, it is understandably a challenge to know where to begin, but Oliver & Beattie (1996) offer four approaches to rapid biological surveys of invertebrates:

- Sampling surrogacy: restricted sampling in place of intensive sampling.
- Species surrogacy: use taxonomic levels higher than species such as orders and families.
- Taxon surrogacy: the use of RTUs (recognisable taxonomic units) instead of species and using non-specialists to identify these.
- Taxon focusing: sample few taxa rather than all taxa.

There has, understandably, been much debate on the merits of the various approaches, with species surrogacy and taxon surrogacy being widely criticised, particularly because these methods do not produce traditional species lists and the existence of rare or threatened species (IUCN Red Lists) cannot therefore be verified. The merits, or otherwise, of these four methods are probably best summed up by New (1996) and Ward & Lariviere (2004) when they recommend that the detailed study of a limited number of carefully chosen taxonomic groups will be more productive and realistic than attempting to superficially evaluate a larger number of groups.

Taxon focusing combined with sampling surrogacy will therefore produce the most cost-effective result, especially in rapid biological surveys. New (1996, 1999) discussed how to choose the invertebrate groups to sample by grouping all invertebrates into three major categories: well-known, catch-up, and black-hole groups, based on their taxonomic status and available knowledge: recently revised, availability of keys and illustrated guides, availability of expertise, numbers of undescribed taxa. He suggested that concentrating on well-known groups while also simultaneously choosing a few catch-up groups, so that they can become well-known over time, is the best approach. Table 2 gives an indication of the current state of taxonomic knowledge of the various insect orders represented in the Pacific. There will be some families within the orders where taxonomic knowledge is better understood than indicated in this list.

This approach – which has been developed in Australia and New Zealand - is also applicable to Polynesia, Micronesia, and Melanesia.

9.3 Analysis of BIORAP surveys

Two BIORAP surveys have been sponsored by SPREP in recent years: firstly, the uplands of Savai'i, Samoa (Atherton & Jefferies, 2012), and more recently Nauru (in progress). Several invertebrate groups – butterflies, moths and land snails – of the Savai'i uplands were surveyed over 12 days in May 2012 by a team of four entomologists, including one macologist (mollusc specialist). The uplands of Savai'i comprise 700 km^2 of the island above 1,000 m, with the highest summit at 1,860 m. This is one of the largest tracts of tropical rain forest in Polynesia (Atherton & Jefferies, 2012). In this study, the survey team established two base camps. The first was at Mata o le Afi at 1,640 m, which provided access to

an altitudinal sequence to Mauga Silisili, the 1,860 m summit of the island, and also down to 1,000 m; the other base camp was at south crater Manga Te'elagi at 1,360 m, 11 km distant from the other base camp.

The entomological survey targeted moths, butterflies, spiders and invasive ants and used hand collecting, malaise traps and light trapping to collect species at both locations and the surrounding ecosystems. Various other insect groups were collected, such as spiders, wasps, flies, beetles, and cicadas but they are not addressed in any detail in the report. Malaise traps do collect a lot of flies, beetles, and wasp species, in particular. It is evident that a lot of invertebrate specimens, across more groups than were reported on, were collected for analysis and the report states that all voucher specimens will be stored in NZAC at Landcare Research, Auckland, New Zealand. This is important, so that the results of the survey can be checked, and to provide a legacy of material for future taxonomic studies. There doesn't seem to be any mention in the report of where the land snails were to be stored long-term. Te Papa, Wellington may be a logical repository given its large holdings, and collection management and curatorial support.

Several issues are evident with this entomological survey. Firstly, no justification is provided for the selection of Lepidoptera (moths and butterflies), although one could easily be made based on the availability of fairly recent literature, identification guides, and taxonomists to assist with identification. Additionally, Lepidoptera have specialist relationships with the indigenous plants in particular communities, providing a meaningful linkage to botanical and ecological findings.

Secondly, of the 135 Lepidoptera species detected in this BIORAP, only 70 have been placed in a genus and most of those to species. Understandably it is the smaller-sized moths across 11 families which provided the biggest challenges to identify, many of which may prove to be new species. But placing them in their genus would provide so much more information on biogeography and ecology. Perhaps limiting the survey to the larger, better-known moths and butterflies would make better sense in terms of resources and interpretation of results.

Additionally, the fact that only 26 (report also states 25) of the 135 species were found at both collection sites underscores the need to collect widely when dealing with such a large area. Limiting of sampling to a relatively small part of the study area will inevitably lead to under-estimation of the species-richness of an area. Lastly, the choice of malaise trapping seems anomalous given the concentration on Lepidoptera, and the need to set up, maintain, and service the traps. Malaise traps are excellent for trapping flies, beetles, and wasps but are not a specialised method for moths and butterflies. Additionally, the invertebrate material in a malaise trap is collected into alcohol; again not ideal for the study of moths and butterflies which are kept dry for curation and identification. There are no obvious results in the report from the analysis of the possibly vast invertebrate material from the malaise trapping programme.

Land snails were the other invertebrate group studied, and while from a biogeographic and ecological viewpoint they are another good choice to survey for, they are poorly known at high altitude in Samoa (Brook, in Atherton & Jefferies, 2012). Only nine of 50 species found were named to species level. So, while the survey results are highly interesting and useful for future taxonomic purposes, discussion of the findings has been limited because the material from this and earlier surveys of the uplands of Savai'i have not been determined taxonomically. Timing of the survey at the end of the wet season was probably a good choice, but a full discussion of options and the rationale for this timing is missing.

Despite these issues, discussion of the significance of the moths, butterflies, and land snails is thorough and useful in characterising the fauna of the sites sampled. Photography was used to good effect too. These studies have more thoroughly sampled the uplands of Savai'i than ever before and both have produced good quality material for future studies. But were they the best use of limited resources to fulfil the objectives of a BIORAP? Probably not in terms of coverage of the uplands and therefore detection of rare, Red List species and new species, and identification of KBAs based on the above.

9.4 Other rapid survey methods

The need to rapidly survey invertebrates over a given area is a common theme, with an associated lack of time or resources, or both. This issue has been dealt with by many (New 1996), including the present author. Patrick and Patrick (2012) used the following "rapid butterfly survey method" in the Pacific:

- Search the literature and collections where possible for previous records.
- In terms of timing, choose a "wet-ish" period, but not too stormy or wet, but not too dry either, although anytime is actually quite good in the tropics.
- Hire a reliable air-conditioned vehicle from the local airport on arrival.
- Obtain detailed topographical maps, and sufficient food and drinks.
- Reliable equipment and back-ups for collection including a variety of different sized nets and length of handles to sample up to 10m high on flowering trees and lianes.
- Explore roads that provide a transect from the airport to the highest points of the island, including villages and coastal areas.
- Two persons – one to drive other to spot butterflies – be flexible and be prepared to stop anywhere!
- Talk to locals, for information on local roads and local knowledge of butterflies.
- Collect and observe butterflies along all of the transect, not just in reserves.
- Keep good notes and take photographs, to back up field observations.
- Repeat method day after day on different roads and build up a comprehensive picture of the island's butterfly fauna: biodiversity, key locations, and threats.
- If time allows, follow up this "recce" by returning to the best locations for a more detailed survey.

In this way we have been able to quickly and efficiently survey many Pacific Islands for butterflies, from large islands such as Vanua Levu and Viti Levu (Fiji) and Tahiti (French Polynesia), to small islands such as Niue, and the Ha'apai group (in the Kingdom of Tonga). We have repeatedly found new island records in this way, adding up to 33% to each island's butterfly fauna, and re-discovering butterflies not seen for over 80 years.

This is an enjoyable method of sampling and it is effective for a group such as butterflies as many of the species frequent a range of modified areas along roadsides, in suburban areas, and in the coastal fringe. Based on several thousand years of human occupation, much of the Pacific is highly modified so butterfly geography and ecology is indicative of most terrestrial groups. All of the aspects of this method are applicable to BIORAPS.

9.5 Discussion on BIORAP protocols and systems

A key decision of any invertebrate BIORAP the selection of groups to sample, as unlike vertebrate groups, species richness is very high and taxonomic knowledge is very patchy and uneven. This will require knowledge of the published literature of the geographical area in question, and maybe also unpublished information held by government agencies, institutions, or private individuals. Other relevant factors include the personnel available, relevancy of certain invertebrate groups to the vegetation, and area, as some invertebrate groups are completely missing for many small islands, particularly those without running water or freshwater tarns or lakes.

Invertebrate groups where there is some taxonomic certainty - with recent literature, illustrated keys, popular books, back-up taxonomists available, and easily accessible collections - will always be more rewarding, as a discussion of findings will be meaningful and conclusions can be validly drawn. Choosing groups that previous BIORAPS have covered will also be beneficial as comparisons can then be made between areas and results standardised. The identification of KBAs, climate change scenarios, and identification of threats will therefore be consistent and more likely to be respected and, ultimately, more likely to be implemented.

There is much recent and well-illustrated literature available on the butterflies of the Micronesian, Melanesian, and Polynesian regions (Parsons 1998; Tennent 2002, 2009; Patrick and Patrick 2012) and with more than 1,200 species spread across this vast area combined with high rates of endemism (at least 70%) make them an ideal group with which

to perform BIORAPS. Some authors have promoted the survey of butterflies and moths as useful indicators of habitat quality, habitat change, and climate change (Merckx *et al.* 2013) as over-exploitation of developed environments and the spread of exotic pests has had a negligible impact on them. Additionally, they are well covered by the IUCN Red Lists, and are possibly amongst the invertebrate groups most noticed by local communities.

Once the invertebrate group(s) to be surveyed for is/are chosen, then the most appropriate survey method can be matched with that group. Table 2 summarises the most effective methods for the 17 most conspicuous insect Orders. Each method is listed below, along with relevant advantages and disadvantages:

SWEEP NETTING

Advantage is that it can be done quickly by day, and at many locations on any given day, in conjunction with hand collecting. Disadvantage is that it requires dry vegetation/dry weather to be effective. Suitable for a BIORAP.

HAND COLLECTION

Searching under rocks and logs, checking tree trunks and foliage. Advantage is it can be done quickly at many locations and in conjunction with sweep netting and not so weather dependent. Suitable for a BIORAP.

CHASING DOWN DAY-FLYING INSECTS WITH A NET

Can also be done in conjunction with hand collection and sweep netting and only requires sunny weather and lots of energy and stamina.

PITFALL TRAPPING

While it is effective for certain insect groups, it is only relevant to BIORAPs where it is possible to return quickly to the sites to retrieve the samples after about one week. This will not always be possible on a rapid survey, where a return visit may not be feasible. Only suitable for BIORAPS under certain conditions.

LIGHT TRAPPING

A night-time activity that perfectly complements the daytime surveying methods such as netting, sweeping, and hand collection. Requires safe access to suitable places, either camp sites or close to a base camp. Huge catches are possible across many insect orders on calm, warm, and cloudy nights. A very cost-effective method. May be suitable for BIORAPS.

MALAISE TRAPPING

Requires a return trip, so will not always be possible under the BIORAP prescription. They are very effective for collecting samples but require at least five days of trapping, taking into account weather conditions. Only suitable for BIORAPS under certain conditions.

SPOTLIGHTING

Searching of vegetation at night for invertebrates is effective for finding species that would otherwise not be found. It can be done in conjunction with light trapping. Dry, calm nights are best. Suitable for BIORAPS, especially if light trapping is being undertaken.

Table 2: Insect Orders and the most effective methods of field collection

Key: M = Main method and S = Some success, is likely. BIORAP category indicates the state of taxonomic knowledge for the order as a whole in the Pacific. WK = Well Known groups, CU = Catch-Up groups with medium or patchy taxonomic knowledge, and BH = Black Hole groups with low or poor knowledge overall.

Order	Hand	Sweep/Beat	Net	Pitfall	Light	Malaise Trap	Spot light	BIORAP Category
Neuroptera		M	S		S	S		WK
Trichoptera	S	S			M	S		WK
Plecoptera	M	M			S			WK
Ephemeroptera	S	M			M			WK
Megaloptera	S				M			CU
Blattodea	M			S	S		M	BH
Phasmatodea	M	M			S			BH
Mecoptera		M			M			WK
Lepidoptera		M	M		M	S		WK
Diptera		M	M		S	M		BH/CU
Orthoptera	M		M	M			M	CU
Dermaptera	M			S				BH
Hymenoptera	M	M	M		S	M		BH
Coleoptera	M	S		M	M	M	M	BH/CU
Hemiptera	M	M	M		S			CU
Odonata	S		M					WK
Mantodea	M	M			S			WK

Additionally, once the invertebrate groups to be sampled have been selected, then a literature search can be undertaken for species lists, including IUCN Red List species and other rare species. The location of curated collections that either contains specimens from the area in question, or that will be useful for later identification of the voucher specimens, is also important. The more accessible this collection is to those working on the field survey, the better.

9.6 Proposed BIORAP survey methods and protocols

Given that it will be feasible to undertake day and night invertebrate surveys on any BIORAP, it is proposed that, once the taxonomic group(s) to be surveyed for has been chosen, that Table 2 is used to select the methods that will efficiently utilise the time available, and cover as much of the survey area as possible. Planning must be flexible in terms of coverage of invertebrate groups and include other significant species that are encountered, as the intent of a BIORAP is to find the characteristic species and to formulate KBAs, and any unanticipated significant finds must also be accommodated.

Based on previous work in rapid biological surveys in the Pacific and elsewhere, and the author's experience with rapid invertebrate surveys, an invertebrate BIORAP must address the following:

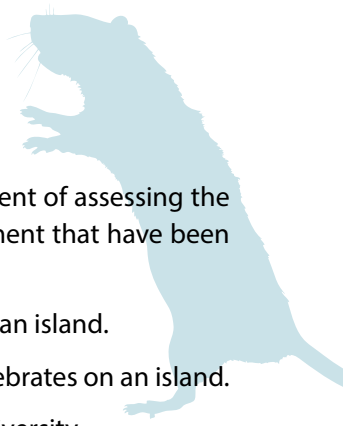
- Define overall BIORAP objectives, in terms of scope, detail, timing, duration, and timeline. Also, an ability to share personnel, transport, and equipment with other teams. Everything depends on and is shaped by these objectives.
- Time the survey to maximise invertebrate collection within the resources available, which will require some research on the most productive times of the year. Damp times of year and not extremes of weather are generally best.
- Geographic scope of survey: plan to quickly and efficiently visit as much of area as possible, and revisit key sites once initial coverage is complete.

- Research and plan to sample all the known vegetation communities, including rare ecosystems, in addition to geological features such as rock cliffs and caves.
- Invertebrate group(s) to be sampled/ surveyed for – two well-known groups plus one "catch-up" group, plus other significant species encountered.
- Field personnel must be appropriate to the group(s) chosen: usually at least two persons, with one at least a specialist.
- Taxonomic expertise to back-up field personnel. Identify non-travelling back-up.
- Obtain access to existing reports, specimens, and data, including vegetation surveys and geological reports.
- Special knowledge of any rare, local, IUCN Red List, threatened species that may be present or have been recorded within the project area.
- Tools to maximise efficiency, such as photography, collection, curation equipment, and back-up equipment, including batteries and battery chargers.
- Appropriate sampling methods for the invertebrate group(s) chosen and relevant equipment and collection protocols, including thorough note-taking and photography.
- Obtain any necessary permits or authorisations required to visit, collect, and disturb the invertebrate life of the survey area.
- Implementing survey of chosen group(s) and detection of threats to species and habitats (e.g. invasive ants; mammalian predators).
- Synergies between team members in other fields, particularly between botanists and entomologists, to maximise results. Follow-up botanical findings, and preferably work together in the field.
- Comfortable accommodation and convenient base camp facilities for field curation and identification of samples. This assists with morale, energy levels, and overall efficiency.
- Logistics to maximise efficiency – movement of personnel across the project area – reliable vehicles, and a contingency plan.
- Back-up plan to take account of adverse weather conditions.
- Curation of specimens and analysis of data on return to home base: send specimens to experts, identification of rare species, IUCN Red List species and discussions that lead to identification of KBAs.
- Safe and permanent storage of specimens once survey/ analysis has been completed.
- Brief for write-up, for consistency in final reporting, so that results are comparable.
- Dissemination of the results: report quality and marketing, designed for identified audiences (include in project objectives).

Other more generic issues must also be addressed, such as:

- Biosecurity: many BIORAPs will be targeting small, possibly uninhabited islands without the full suite of weeds and predators that are present on the larger islands with a long history of human occupation, so care must be taken not to introduce alien biota that will adversely affect the biota the project is striving to conserve.
- Ecological footprint: the actual ecological damage done by the BIORAP, such as camp sites, helicopter landing sites, new vehicle tracks, trampling of botanical plots, must be minimised and protocols established so that, for instance, all rubbish is removed, all equipment such as traps are also removed, and the environment is left as it was found.
- Safety of personnel in the field: a safety plan must be formulated identifying risks and a plan to avoid or minimise them. The plan must include communication details in the event of an incident. Address all known medical conditions of participants.

10. Pest animals



Invasive vertebrates threaten biodiversity and their inclusion in a BIORAP is an essential component of assessing the vulnerability of flora and fauna on an island. Of the five general types of rapid biological assessment that have been identified, the following modified versions apply to invasive vertebrates:

- Baseline inventory: this focuses on detecting the presence of an invasive vertebrate species on an island.
- Species-specific assessment: rapid appraisal of the abundance and distribution of invasive vertebrates on an island.
- Impact assessment: rapid assessment of the impacts of invasive vertebrates on an island's biodiversity.

Management and control of invasive vertebrates requires careful planning and follow up monitoring and therefore would not form part of a rapid biological assessment.

10.1 Baseline inventory

The following is a set of methods for a rapid baseline inventory of invasive vertebrates on an island:

LOCAL KNOWLEDGE

On inhabited islands local knowledge will be an important starting point in terms of determining the presence of invasive species. Often locals living in, or using an area may be aware of the presence of larger species – such as feral goats (*Capra hircus*), and feral pigs (*Sus scrofa*) – but they may also be aware of the presence of rodents, particularly if they have interfered with food storage.

TRAINED DOGS

Trained dogs are an effective method of determining the presence of invasive vertebrate pests on islands. Dogs can be trained to detect a wide range of species, with individual dogs often specialising in the detection of a given species. On the rat (*Rattus* spp.) free Rangitoto Island, in New Zealand a trained dog found the tracks of a single invading rat during routine surveillance (DOC 2011). In New Zealand dogs have also been used to detect the presence of mustelids and feral cats, so it is likely dogs could be trained to detect species like the small Indian mongoose (*Herpestes javanicus*). Appropriately trained dogs are also able to detect and locate feral goats and feral pigs. The following link provides information on the Department of Conservations, Conservation Dog Programme:

http://www.doc.govt.nz/Documents/getting-involved/volunteer-or-start-project/ conservation-dog-programme.pdf

TRACKING TUNNELS

Ink footprint tracking tunnels are an effective method for detecting the presence of small mammals. In some situations tracking tunnels may be more sensitive than traps because the animal can see straight through them and does not have to climb into, or over anything. When clear footprints are recorded it is possible to distinguish between various genera and orders of small mammals (Ratz 1997). However, if tracking tunnels are to be used on species or genera not previously sampled then some preliminary research may be necessary to develop a key for accurate identification. Prefabricated tunnels can be purchased from companies such as Gotcha Traps Ltd, or they can be built following the instructions provided by Gillies and Williams (2013). Methods have also been developed that enable tracking tunnels to be used to index both rodents and small carnivores by switching the bait that is used, these techniques are also described in Gillies and Williams (2013). Tracking tunnels are light to carry, simple to construct and user friendly to set up. It may be possible to use tracking tunnels to identify taxa other than mammals, e.g. lizards or snakes, but the user would need to be confident in their ability to identify the footprints of these taxa. Feral cats are too large to pass through tracking tunnels.

WAX TAGS AND BAIT STATIONS

Wax Tags™ (Connovation Ltd) contain a cube of wax attached to a wedge shaped piece of plastic that can be nailed to a tree. Small mammals that are omnivorous will gnaw on the wax and it is possible to distinguish between rats and mice and species such as possum. However, Wax Tags may not attract obligate carnivores. Wax Tags are light to carry and can be deployed rapidly. A quick and easy to use guide and data collection form is available at the following website:

http://www.kiwisforkiwi.org/wpcontent/uploads/2012/09/Possum_and_rodent density monitoring_Basic_form.pdf

It is also possible to monitor rodents using poison bait stations containing non-toxic pre-feed. Bait stations can be left and if bait removal is observed this monitoring tool can quickly be turned into an eradication method (Roberts 2003).

TRAPPING

If trained dogs are not available then the best way to rapidly monitor for species such as feral cats (*Felis catus*) will be live-trapping either using cage traps, or leg-hold traps (Nogales *et al*. 2004). Night time spotlight surveys can also be used to detect feral cats.

FERAL GOATS AND FERAL PIGS

Feral pigs can be detected by the presence of rooting (burrowing or digging up the earth) when walking transects or undertaking surveys on islands. Feral goat browse may be found on leaves or other parts of plants and faecal pellets may also be found during walking surveys. It is recommended that photos of rooting and browse be taken.

BROWN TREE SNAKES

To date there is no established technique for the monitoring of brown tree snakes (*Boiga irregularis*). Most brown tree snake detections have been made by locals living on the island or by quarantine agencies (D. Vice pers. comm. 2013).

10.2 Species-specific assessments

Species-specific assessments should be used when there is a need to know more about a species than presence or absence. For example, a measure of abundance may indicate the level of infestation of an invasive species on an island.

CATCH PER UNIT EFFORT

Catch per unit effort (CPUE) is an indirect measure of the abundance of a species that is the target of a harvest or control operation (Sutherland 2000). The aim of CPUE is to generate population index values that are comparable to others collected for that species, by adjusting for the amount of effort expended in the detection of the species.

Cunningham and Moores (1983) developed a method of deploying snap traps to calculate a CPUE index for rats and mice (*Mus musclus*) that could be used during a rapid biological assessment. In brief the method involves running lines of 25 tunnels (25 m apart) each with two snap traps in them for three nights to generate 150 uncorrected trap nights. CPUE is calculated and expressed as captures per 100 trap nights. In the following sample calculation, 7 rats have been caught and 13 traps sprung without catching anything:

50 traps set for three nights = 50 ´ 3 = 150 total trap-nights.

Trap-nights lost = 1/2 (captures + sprung, empty traps) = (7 + 13) ÷ 2 = 10

Therefore corrected number of trap-nights = Total trap-nights – trap-nights lost

= 150-10 = 140

Index of abundance = Captures × 100 ÷ Corrected trap-nights

= 7 ×100 ÷ 140 = 5.0 captures per 100 trap-nights.

King *et al.* (1994) provide similar CPUE calculations for mustelid trapping operations. Given traps and tunnels designed for controlling mustelids have been used to control small Indian mongoose in the pacific (N. Doherty pers.comm. 2013) these calculations could be used to calculate CPUE for mongoose.

For feral goats and feral pigs CPUE can be calculated and expressed as kill-rates per hour of hunting, and this method has been shown to provide linear indices of goat population size (Brennan *et al.* 1993). If species-specific assessments are required for feral goats or feral pigs then a hunting team could form part of the BIORAP assessment.

CAPTURE-MARK-RECAPTURE

Sometimes indices of abundance like CPUE can be biased if the target species has variable detection probabilities. For instance if the daily probability of the target animal going into a trap is 40% on one island and 60% on another island, then you may assume the latter island has a higher abundance. The only way around this is to use Capture-Mark-Recapture methods (White 1982). This involves live trapping animals individually marking them (e.g. ear tagging) and re-trapping to get recapture rates. These techniques typically require careful design and large sample sizes, so in most cases will be impractical for a BIORAP.

GENETICS

If the sampling method for a rapid biological assessment allows the removal of samples from individuals for genetic analysis (e.g. hair removal from kill-trapped or live-trapped animals) then this will allow for powerful post-hoc assessment. Genetic analysis can provide information on the relatedness of individuals on the island, fecundity, survival and if coupled with sampling on adjacent islands can lead to inferences on the rate and distance of dispersal events (Veale *et al*. 2011). Companies like EcoGene® are now available to undertake genetic analyses under contract.

10.3 Impact assessment

An impact assessment is desirable if evidence of the threat posed by invasive vertebrates is necessary for further investment in the island. Generally impacts will be hard to assess in the short timeframe of a rapid biological assessment of an island, with that caveat in place we make the following recommendations.

CAMERA TRAPPING

If a suspected impact is predation then camera trapping is an option. The use of camera trapping would require the BIORAP be undertaken during the breeding season of vulnerable taxa. Camera traps could be set up on the nests of birds or on the dens of other vulnerable taxa for the duration of the BIORAP. Information on camera traps and techniques is provided by O'Connell *et al.* (2011), but see also Sanders and Maloney (2002). It is important to keep in mind that most camera trapping studies of predation have been longer term. If a predation event is not observed during a BIORAP this does not mean predation is not occurring.

SCAT ANALYSIS

If trained dogs or other methods turn up scats from an invasive vertebrate predator, then these scats can be dissected for prey remains and the percentage frequency of occurrence of that prey remains calculated (Reynolds and Aebischer 1991). If vulnerable species are present in scats then this will provide circumstantial evidence of predation. However, more often than not there will be a high frequency of occurrence of common prey species, which may not necessarily be vulnerable. Again if vulnerable species are not found in scats this is not evidence that predation is not occurring, particularly if sample sizes are small.

BROWSING ANIMALS

For browsing animals such as feral goats and feral pigs there may not be a way of rapidly assessing their impacts because measurement of change in forest composition involves either long-term monitoring or the availability of sites where these animals are absent on a permanent or longer-term basis. Browse observations and photographs of denuded areas will provide anecdotal evidence. However, one possibility is that fenced exclosure plots could be established as part of a BIORAP and these could be re-measured in the future if the island is revisited.

11. Discussion

Being larger than all the dry land on earth, the Pacific Ocean is immense and contains thousands of islands renowned for their high levels of endemism for both flora and fauna. Potential costs and logistics of intensive ecological surveys of all these islands and their adjacent marine environment – given the small economies of the countries and territories involved – has led to the application of rapid biological survey methodology (Alonso *et al.* 2011, Atherton and Jefferies 2012). It is timely that this review of existing methodologies has been carried out, before further investment is made in rapid surveys.

11.1 Engagement of local communities

Local communities are fundamentally important to long-term conservation and therefore they must be an integral part of any BIORAP. Local people will have knowledge of, for example, bat roosting sites, rodents interfering with food, and other invasive pests, and can help to direct a survey and save an enormous amount of time and effort. Additionally, it is the local communities who are the long-term stewards of the local indigenous habitats and biota, so arming them with knowledge of its significance can only strengthen their connection with their local environments, and thereby increase opportunities for ecological sustainability. Engagement with local communities must include the following:

- Contact local communities at the earliest possible stage to discuss the proposed BIORAP and gain their support and assistance in its planning and survey implementation.
- Keep them informed of progress with planning, timing, and local needs, such as accommodation and logistical requirements.
- Involve them in the survey, as guides, research assistants, and helpers, and also to up-skill them in survey techniques, some of which will be useful in any follow-up survey or monitoring.
- Provide (and leave) relevant equipment and literature to enable local people to undertake ongoing survey and monitoring.
- Supply BIORAP results and any recommendations relating to protection/KBAs, if possible in person.
- Maintain contact and seek feedback on any protection initiatives.

If feasible it is desirable to take relevant survey equipment (e.g. tracking tunnels) to the first meeting with the local community, to get the process of detection of mammalian predators started and also to begin the process of engagement with practical aspects of the project. Some training in the use of such devices should also start at that point. This type of dialogue would signal to a local community any potential opportunities associated with a BIORAP on their "patch".

11.2 Climate change implications

The implications of Global Climate Change are already a reality for parts of the South Pacific. The myriad of Pacific islands are particularly vulnerable to the effects of Global Climate Change because, even on the high islands, significant proportions of the people and economy operate at or near sea level, adjacent to the coast, which is also where the greatest terrestrial biodiversity occurs (Patrick & Patrick 2012). Remoteness and the sheer number of islands, many of which are very small, increases this vulnerability.

Potential impacts are poorly known and understood and communication of the situation for individual islands and communities is inevitably also poor or uneven.

As the coastal fringe is often the most species-rich terrestrial ecosystem in the Pacific, potential sea level rise threatens local indigenous biodiversity, directly through inundation and elimination and indirectly through competition with local communities with less space to live, grow food, and for infrastructure.

It is essential that all BIORAPS assess the anticipated effects of global climate change on the project area and its biota.

11.3 BIORAP systems and methods

In the preceding sections, various methodologies have been outlined and discussed for BIORAP surveys in the Pacific, addressing marine and terrestrial environments, and ecosystems, habitats, and species. For some groups such, as terrestrial vascular plants, it is proposed that all families of plants and all species would be covered as well as all main vegetation and habitat types, By comparison, only a few carefully chosen groups of terrestrial invertebrates should be surveyed, due to the much higher level of species richness, patchy taxonomic knowledge, the difficulty, in many cases, of locating literature, and lack of available expertise. All indigenous vertebrates can be covered by a BIORAP, as species richness is manageable and taxonomic knowledge is generally sound and readily available.

Rare species, by definition, are rare across the landscape and can therefore be difficult to find unless good information is available on their biology or ecology. A BIORAP may gather good information on the status of threatened and rare species of birds, reptiles, bats, and terrestrial plants, but only if experts in those groups perform the surveys. Information is often lacking on terrestrial invertebrates, making it difficult to assess relative rarity.

Each of the preceding sections provides a set of proposed survey methods and operational details relating to that area of work, and various over-riding principles are evident:

- A BIORAP is a reconnaissance survey of a chosen area. It is vital to cover as much of the project area as possible, to document key ecosystems, habitats, and species of conservation and scientific interest, so survey techniques must be tailored to fit this principle. If time allows, repeat visits to key places are particularly useful and will help to confirm and provide additional information relating to any KBA recommendations.
- It is important to have experts in charge of and carrying out surveying the various habitats and groups, as this will save time and give more credibility to the results, and it also allows for training opportunities for others working on the BIORAP.
- Thorough planning is vital: timing, personnel, liaison with local community, liaison with government, NGOs and local officials; permits, logistics, floral and faunal groups to be targeted, methods, recording, brief for reporting and recommendations, and dissemination.
- Utilise and, if necessary, train interested local people as guides, research assistants, workers, and colleagues, and leave relevant equipment and literature, and knowledge.
- Carefully consider the health and safety of all personnel, identifying and addressing all potential hazards, including pre-existing health issues.
- Biosecurity measures must be addressed and steps taken to not introduce pests or weeds to the project area.
- Ensure that all rubbish and equipment is removed when the survey is completed. Overall, it is important to minimise the ecological impact of the survey.
- It is important to know what invasive plants and animals are present in the project area, so that the threats to indigenous biodiversity can be assessed. Information can be obtained from local communities and during the field survey.
- Each survey must consider the potential effects, direct and indirect, of global climate change on the project area. The Pacific is especially vulnerable to global climate change because much of the human population lives and depends on the coastal fringe, with a high ratio of "coastal edge" to "land area".
- It is important to consider collection and lodgement of voucher specimens for the groups surveyed and lodging of them in recognised collections. This is especially important with botanical and invertebrate surveys, to increase taxonomic and distributional knowledge, and provide evidence to back up the species lists.
- Involvement of local people and communities in the BIORAP from start to finish will pay dividends in relation to sustainable protection of key sites (KBAs) and IUCN Red List and other threatened and rare species.
- Follow up with the local community is important, to provide findings and resulting reports and/or publications, including possible protection initiatives.

Acknowledgments

Bruce Jefferies (SPREP) provided project liaison. We thank William Shaw and Margaret Honey of Wildlands for editing and improvement of the manuscript.

References

Adler G.H., Austin C.C., and Dudley R. 1995: Dispersal and speciation of skinks among archipelagos in the tropical Pacific Ocean. *Evolutionary Ecology* 9(5): 529-541.

Allen G.R. 1991: Damselfish of the World. Melle, Germany: Mergus Press. 271 pp.

Allen G.R. 1993: Reef Fishes of New Guinea. Christensen Research Institute, *Publication No. 8*. Madang, PapuaNew Guinea.

Allen G.R. 1997: Marine Fishes of Tropical Australia and South-East Asia. Western Australian Museum, Perth.

Allen G.R., Steene R., and Allen M. 1998: A guide to angelfish and butterflyfish. Tropical Reef Research, Rolystone, Western Australia. 250pp.

Allen G.R. and Steene R. 1996: Indo-Pacific Coral Reef Guide. Tropical Reef Research, Perth, Australia. 378 pp.

Allen G.R., Steene R., Humann P., and Deloach N. 2003: Reef Fish Identification Tropical Pacific. New World Publications, Jacksonville, Florida. 457pp.

Allen G. R. and S. A. McKenna (eds.) 2001: A Marine Rapid Assessment of the Togean and Banggai Islands, Sulawesi, Indonesia. *RAP Bulletin of Biological Assessment 20*. Conservation International, Washington, DC, USA.

Allen G.R., Kinch J.P., McKenna S.A., and Seeto P. (Eds.) 2003: A Rapid Marine Biodiversity Assessment of Milne Bay Province, Papua New Guinea—Survey II (2000). *RAP Bulletin of Biological Assessment* 29. Conservation International, Washington, DC, USA.

Allen G.R. and Werner T.B. 2002: Coral reef fish assessment in the 'coral triangle' of southeastern Asia. *Environmental Biology of Fishes 65*: 209-214.

Alonso L.E., Deichmann J.L., McKenna S.A., Naskrecki P., and Richards S.J. 2011: Still Counting. Biodiversity Exploration for Conservation. The First 20 Years of Rapid Assessment Program. Conservation International, Arlington, Virginia, United States. 315 pages.

Amerson A.B. Jr. 1969: Ornithology of the Marshall and Gilbert Islands. Smithsonian Institution, Washington. 334p.

Anonymous 1998*:* Inventory methods for bats: Standards for Components of British Columbia's Biodiversity No. 20. Ministry of Environment, Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force, Resources Inventory Committee, The Province of British Columbia 51 pp http://www.ilmb.gov.bc.ca/risc/pubs/tebiodiv/bats/index.htm

Atherton J. and Jefferies B. (Editors) 2012: Guidelines for Undertaking Rapid Biodiversity Assessments in Terrestrial and Marine Environments in the Pacific. SPREP. Apia, Samoa. 174p.

Atkinson I.A.E. 1985: Derivation of vegetation mapping units for an ecological survey of Tongariro National Park, North Island, New Zealand. *New Zealand Journal of Botany 23*: 361-378.

Bibby C.J., Burgess N.D., Hill D.A., and Mustoe S.H. 2000: Bird census techniques. 2nd edition. Academic Press, London.

BirdLife International 2000: Threatened Birds of the World. The official source for birds on the IUCN Red List. Senior editors: Stattersfield A.J. and Capper D.R.. Additional editors: Dutson G.C.L., Evans M.I., McClellan R.K., Peet N.B., Shutes S.M., Stuart T.E.H., Tobias J.A., and Wege D.C. BirdLife International and Lynx Edicions. Barcelona and Cambridge, UK. 852 pp.

Borkin K. M. and Parsons S. 2010: The importance of exotic plantation forest for the New Zealand long-tailed bat (*Chalinolobus tuberculatus*). *New Zealand Journal of Zoology 37*(1): 37-51.

Brandes T.S. 2008: Automated sound recording and analysis: techniques for bird surveys and conservation. *Bird Conservation International 18*: S163-S173.

Brennan M., Moller H., and Parkes J. 1993: Indices of density of feral goats in a grassland/forest habitat, Marlborough, New Zealand. *New Zealand Journal of Ecology 17*: 103-106.

Buckland S.T., Anderson D.R., Burnham K.P., Laake J.L., Borchers D.L., and Thomas L. 2001: Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press.

Butler D.J., Powlesland R.G., and Westbrooke I.M. 2012: Status of birds, peka (flying foxes) and reptiles on Niue Island. SPREP, Apia, Samoa. 34 pp.

Cavarzere V., Vieira da Costa T.V., and Silveira L.F. 2012: On the use of 10-minute point counts and 10-species lists for surveying birds in lowland Atlantic forests in southeastern Brazil. *Papéis Avulsos de Zoologia 52*: 333-340.

Champeau J., Butard J.-F., Waugh S.M., and Cranwell S. 2011: The first comprehensive bird survey of Hatu-iti Island, Marquesas Islands, French Polynesia. *Marine Ornithology 39*: 255-259.

Clapham W.B. Jr. 1973: Natural Ecosystems. The MacMillan Company, New York. 248 pp.

Collinson A.S. 1988: Introduction to World Vegetation. Unwin Hyman Ltd, London. 325 pp.

Convention on Biological Diversity 2003a: Rapid assessment of marine and coastal biological diversity: a progress report on the development of methods and guidance UNEP/CBD/SBSTTA/8/INF/13.

Convention on Biological Diversity 2003b: Methods for rapid assessment of marine and coastal biodiversity. UNEP/CBD/SBSTTA/9/INF/25.

Convention on Biological Diversity 2003c: Report of the expert meeting on methods and guidelines for the rapid assessment of biological diversity of inland water ecosystems UNEP/CBD/SBSTTA/8/INF/5.

Cunningham D.M. and Moors P.J. 1983: A guide to the identification and collection of New Zealand rodents. Wildlife Service, Department of Internal Affairs. http://www.issg.org/database/species/reference_files/CUN%20MOOR%20rodents.pdf

Daubenmire R. 1968: Plant Ecology: A textbook of plant synecology. Harper and Row, New York. 300 pp.

Dawson J., Turner C., Pileng O., Farmer A., McGary C., Walsh C., Tamblyn A., and Yosi C. 2011: Bird communities of the lower Waria Valley, Morobe Province, Papua New Guinea: a comparison between habitat types. *Tropical Conservation Science 4*: 317-348.

Department of Conservation 2011: DOC detection systems deals to incursion. *Department of Conservation Media Release*. 17 June 2011.

Diamond J.M. and Mayr E. 1976: Species-area relation for birds of the Solomon Archipelago. *Proceedings of the National Academy of Sciences of the USA 73*: 262-266.

Donaldson T.J. 1992: Fishes of the Southwest Palau Islands. Palau Rapid ecological assessment, Part 1, Palau SW Islands. Prepared for The Nature Conservancy, Pacific Region, Honolulu

Donaldson T.J. 1993: Distribution patterns of the marine fishes of Palau. Palau Rapid ecological assessment, Part II, Main Palau Islands. Prepared for The Nature Conservancy, Pacific Region, Honolulu.

English S.,Wilkinson C., and Baker V. 1997*:* Survey Manual for Tropical Marine Resources. 2nd edition. Australian Institute of Marine Science, Townsville, 402 pp.

Fisher R.N. 2011: Considering native and exotic terrestrial reptiles in island invasive species eradication programmes in the Tropical Pacific. Island invasives: eradication and management. IUCN, Gland, Switzerland, 51-55.

Friend, G. R., Smith, G. T., Mitchell, D. S., and Dickman, C. R. 1989: Influence of pitfall and drift fence design on capture rates of small vertebrates in semi-arid habitats of Western-Australia. *Wildlife Research 16*(1), 1-10.

Fiu M.,Tokece M., and Areki F. 2010: The Ono-i-Lau cluster of islands. *Marine Biological Survey 2008 Report*. Suva, Fiji, WWF South Pacific Programme.

Gillies C. and Williams D. 2013: DOC tracking tunnel guide v.2.5.2: using tracking tunnels to monitor rodents and mustelids. Inventory and monitoring toolbox: animal pests. http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-animal-pests-using-tracking-tunnels-to-monitor-rodents-and-mustelids.pdf

Halford A.R. and Thompson A.A. 1994: Visual Census Surveys of Reef Fish: Long-term monitoring of the Great Barrier Reef, Standard *Operational Procedure Number 3*, Australian Institute of Marine Science, Townsville.

Harrison M.E., Boonman A., Cheyne S.M., Husson S.J., Marchant N.C., and Struebig M.J. 2012: Biodiversity monitoring protocols for REDD+: can a one-size-fits-all approach really work? *Tropical Conservation Science 5*(1):1-11

Hawthorne W.D. 2012: A manual for rapid botanic survey (RBS) and measurement of vegetation bioquality. Department of Plant Sciences, University of Oxford, United Kingdom.

Hayes J. P., Ober H. K., and Sherwin R. E. 2009: Survey and monitoring of bats. In: Kunz T.H. and Parsons S. (Eds) Ecological and behavioural methods for the study of bats. 2nd ed. The John Hopkins University Press, Baltimore, Maryland, United States of America. 112-129.

Herzog S.K., Kessler M., and Cahill T.M. 2002: Estimating species richness of tropical bird communities from rapid assessment data. *The Auk 119*: 749-769.

Hitchmough R.A., Tocher M.D., Hoare J.M., Newman D., Jamieson H., Whitaker A.H., Lettink M., and Anderson P. 2010: Conservation status of New Zealand reptiles, 2009. *New Zealand Journal of Zoology*. Published online.

Hutchins J.H.2001: Biodiversity of shallow reef fish assemblages in Western Australia using a rapid censusing technique. *Records of the Western Australian Museum 20*: 247-270.

Jenkins A., Sykes H., Skelton P., Fiu M., and Lovell E 2005: Fiji's Great Sea Reef: the first marine biodiversity survey of Cakaulevu and associated coastal habitats, WWF Fiji Country Program. http://awsassets.panda.org/downloads/gsr_fullcopy_1_1.pdf

Jenkins R.K.B., Andriafidison D., Razafimanahaka H.J., Rabearivelo A., Razafindrakoto N., Ratsimandresy Z., Andrianandrasana R. H., Razafimahatratra E., and Racey P.A. 2007: Not rare, but threatened: the endemic Madagascar flying fox *Pteropus rufus* in a fragmented landscape. *Oryx 41*(2): 263-271.

IFAW 2005: Marine mammals and marine turtles of the Pacific islands region: a concise and comprehensive waterproof guide.

Jones G.J., Caley M.J., and Munday P.L. 2002: Rarity in coral reef fish communities. In: P.F. Sale (ed.) Coral Reef Fishes. Dynamics and diversity in a complex ecosystem, Academic Press, San Diego. 81-102.

King C.M., O'Donnell C.F.J., and Phillipson S.M. 1994: Monitoring and control of mustelids on conservation lands Part 2: field and workshop guide. Department of Conservation Technical series.

Kuiter R.C. 1992: Tropical Reef Fishes of the Western Pacific -Indonesia and Adjacent Waters. Percetakan PT Gramedia Pustaka Utama, Jakarta.

Kingsford M.J. 1998: Reef fishes. In: M.J. Kingsford and C. Battershill (ed.) Studying temperate marine environments. *A handbook for ecologists*, Canterbury University Press, NZ, Canterbury.

Kingston T., Francis C.M., Zubaid A., and Kunz T.H. 2003: Species richness in an insectivorous bat assemblage from Malaysia. *Journal of Tropical Ecology 19*: 67-79.

Lieske E. and Myers R. 1994: Coral Reef Fishes – Indo-Pacific & Caribbean. London: Harper Collins.

Mack A.L. and Wright D.D. 2011: Training Manual for field biologists in Papua New Guinea. Green Capacity Publications One, USA. Free PDF download from www.pngibr.org, www.greencapacity.org or www.conservationinternational.org

Maragos J.E. and Cook C.W. 1995: The 1991-1992 rapid ecological assessment of Palau's coral reefs. *Coral Reefs* 14: 237-251

McKenna S.A., Baillon N., and Spaggiari J. 2009: Rapid Marine Biodiversity Assessment of the coral reefs of the northwest lagoon, between Koumac and Yandé, Province Nord, New Caledonia. *RAP Bulletin of Biological Assessment 53*. Conservation International, Arlington, Va, USA.

Mellin C., Parrott L., Andréfouët S., Bradshaw C.J.A., MacNeil M.A., and Caley M.J. 2012: Multi-scale marine biodiversity patterns inferred efficiently from habitat image processing. *Ecological Applications 22*: 792-803. http://dx.doi.org/10.1890/11-2105.1

Myers R.F. 1999: Micronesian Reef Fishes (Third Edition). Coral Graphics, Guam.

Miller C. 2007: Current state of knowledge of cetacean threats, diversity and habitats in the Pacific Islands Region. Report by the Whale and Dolphin Conservation Society.

Martin T.J. 2012: Survey of endemic flora of Rarotonga and preparation of IUCN threat assessments. *Wildland Consultants Contract Report No. 2497*. Prepared for Cook Islands Natural Heritage Trust.

MacKinnon J. and Phillips K. 1993: A Field Guide to the Birds of Borneo, Sumatra, Java and Bali, the Greater Sunda Islands. Oxford University Press, Oxford.

MacLeod R, Herzog S.K., Maccormick A, Ewing S.R., Bryce R., and Evans K.L. 2011: Rapid monitoring of species abundance for biodiversity conservation: Consistency and reliability of the MacKinnon lists technique. *Biological Conservation 144*: 1374-1381

Merckx T., Huertas B., Basset Y., and Thomas J. 2013: A Global Perspective on conserving butterflies and moths and their habitats. *Key Topics in Conservation Biology 2*. John Wiley and Sons.

Mueller-Dombois D. and Fosberg F.R. 1998: Vegetation of the Tropical Pacific Islands. Springer-Verlag, New York. 733 pp.

Muir A.P. and Muir M. 2011: A new rapid assessment technique for amphibians: introduction of the species list technique from San José de Payamino, Ecuador. *Herpetological Review 42*(2): 184-186.

New T.R. 1996: Taxonomic focus and quality control in insect surveys for biodiversity conservation. *Australian Journal of Entomology 35*: 97-106.

New T.R. 1999: Descriptive taxonomy as a facilitating discipline in invertebrate conservation. In: Ponder W., Lunney D. (Editor), The Other 99%. The Conservation and Biodiversity of invertebrates, ppages 154-158. *Transactions of the Royal Zoological Society of New South Wales,* Mosman, Australia.

Nogales M., Martin A., Tershy B.R., Donlan C.J., Veitch D., Puerta N., Wood B., and Alonso J. 2004: A review of feral cat eradications on islands. *Conservation Biology 18*: 310-319.

O'Brien M., Waugh S., and BirdLife International (Birdlife Pacific) 2010): Important bird areas in the Pacific, a compendium. BirdLife International, Birdlife Pacific, Suva, Fiji.

O'Connell A.F., Nichols J.D., Karanth K.U. 2011: Camera Traps in Animal Ecology. Springer, New York.

O'Dea N., Watson J.E.M., and Whittaker R.J. 2004: Rapid assessment in conservation research: a critique of avifaunal assessment techniques illustrated by Ecuadorian and Madagascan case study data. *Diversity and Distributions 2010*: 55-63.

O'hara T.D., Addison P.F.E., Gazzard R.., Costa T.L., and Pocklington J.B. 2010: A rapid biodiversity assessment methodology tested on intertidal rocky shores. *Aquatic Conservation: Marine and Freshwater Ecosystems* 20(4): 452-463.

Oliver I. and Beattie A.J. 1996: Designing a cost-effective invertebrate survey: a test of methods for rapid assessment of biodiversity. *Ecological Applications 6*: 594-607.

Paijmans K. 1976: Vegetation. In *New Guinea Vegetation*. K. Paijmans Ed. Australian University Press, Canberra. 23-184.

Page C., Coleman G., Ninio R., and Osbourne K. 2001: Surveys of benthic reef communities using underwater video. Long-term monitoring of the Great Barrier Reef. Australian Institute of Marine Science, Townsville.

Parker T.A. III. 1991: On the use of tape recorders in avifaunal surveys. *Auk 108*: 443-444.

Parsons M. 1998: Butterflies of Papua New Guinea. Princeton University Press.

Patrick B.H. and Patrick H.J.H. 2012: Butterflies of the South Pacific. Otago University Press. 240 pp.

Palmeirim J. M., Champion A., Naikatini A., Niukula J., Tuiwawa M., Fisher M., Yabaki-Gounder M., Thorsteinsdótter S., Qalovaki S., and Dunn T. 2005: Distribution, Status, and Conservation of bats in the Fiji islands. The University of the South Pacific, Suva: Fauna and Flora International, Cambridge; Universidade de Lisboa, Lisbon.

Palmeirim J. M,. Champion A., Naikatini A., Niukula J., Tuiwawa M., Fisher M., Yabaki-Gounder M., Thorsteinsdótter S., Qalovaki S., and Dunn T. 2007: Distribution, Status, and Conservation of bats in the Fiji islands. *Oryx 41*(4): 509-519.

Prasad B.C. 2010: Natural Resource Inventory Report of the Fiji Islands. Vol. 3: Land Resources Inventory of the Fiji Islands.

Ratz H. 1997: Identification of footprints of some small mammals. *Mammalia 61*(3): 431-441.

Reynolds J.C. and Aebischer N. 1991: Comparison and quantification of carnivore diet by faecal analysis: a critique with recommendations, based on a study of foxes *Vulpes vulpes*. *Mammal Review 15*: 151-186.

Ribeiro-Júnior M.A., Gardner T.A., and Ávila-Pires T.C. 2008: Evaluating the effectiveness of herpetofaunal sampling techniques across a gradient of habitat change in a tropical forest landscape. *Journal of Herpetology 42*(4): 733-749.

Roberts A. 2003: Island Biosecurity Best Practice Manual. Department of Conservation, Unpublished Report.

Sanders MD, Maloney RF. DATE?: Causes of mortality of ground nesting birds in the Upper Waitaki Basin, South Island, New Zealand: a five-year video study. *Biological Conservation 106*: 225-236.

Secretariat of the Convention on Biological Diversity 2005: Guidelines for the rapid ecological assessment of biodiversity in inland water, coastal and marine areas, Montreal, Canada, CBD Technical Series No. 22 and the Secretariat of the Ramsar Convention, Gland, Switzerland. *Ramsar Technical Report No. 1*.

Scanlon A., Petit S., and Bottroff G. 2013: The conservation status of bats in Fiji. *Oryx*

Struebig M.J., Kingston T., Zubaid A., Mohd-Adnan A., and Rossiter S.J. 2008: Conservation value of forest fragments to Palaeotropical bats. *Biological Conservation 141*: 2112-2126.

Struebig M.J., Christy L., Pio D., and Miejiard E. 2010: Bats of Borneo: diversity, distributions and representation in protected areas. *Biodiversity and Conservation 19*: 449-469.

Sutherland W.J. 2000: Monitoring the Conservation Handbook: Research, Management and Policy. Wiley-Blackwell. 36-64.

Randall J.E., Allen G.R., and Steene R.C. 1990: Fishes of the Great Barrier Reef and Coral Sea. Bathurst, Australia. Crawford House Press.

Secretariat of the Pacific Regional Environment Programme 2012: Pacific Islands Regional Marine Species Programme 2013-2017. SPREP Apia, Samoa.

Smith S.D.A., Malcolm H., Rule M.J., Dalton S J. and Harrison M. 2006: Rapid Biodiversity Assessment of Inshore Reefs. Sustainable Marine Resource Management Project, Part A: Research, Mapping, Assessment and Planning. *National Marine Science Centre Report to the Northern Rivers Catchment Management Authority*. December 2006. 53 pp.

Tennent J. 2002: Butterflies of the Solomon Islands, their systematics and biogeography. Storm Entomological Publications.

Tennent J. 2009: A Field Guide to the Butterflies of Vanuatu. Storm Entomological Publications.

Tuiwawa M. and Aalbersberg W. 2013: Conservation International Pacific Islands Programme 2013. *Biodiversity Conservation Lessons learnt from Technical Series 22*: Rapid Biological Assessment Survey of Southern Lau, Fiji. Conservation International, Apia, Samoa.

Tuttle M. 1974: An improved trap for bats. *Journal of Mammalogy 55*(2): 475-477.

VanderWerf E.A. 2007: 2005 Bird surveys in the Republic of Palau. Prepared for U.S. Fish and Wildlife Service, Honolulu.

Veale A.J., Clout M.N., and Gleeson D.M. 2011: Genetic population assignment reveals a long-distance incursion to an island by a stoat (*Mustela erminea*). *Biological Invasions 14*: 735-742.

Ward D.F. and Lariviere M.C. 2004: Terrestrial invertebrate surveys and rapid biodiversity assessment in New Zealand: lessons from Australia. *New Zealand Journal of Ecology 28*(1): 151-159.

Ward J. and Asotasi I. 2007: *Status of whales and dolphins of Samoa.* Scientific and Watching Feasibility Surveys Report. Ministry of Natural Resources and Environment, Division of Environment and Conservation November 2007.

Ward T.J., Kenchington R.A., Faith D.P., and Margules C.R. 1998: Marine BIORAP guidelines: Rapid assessment of marine biological diversity. CSIRO, Perth. 52 pp.

Watling D. 1998: Funafuti Marine Conservation Area, Tuvalu report of the bird survey (August 31-September 11 1998). Environmental Consultants Fiji Ltd., Fiji. 44p.

Werner T.B. and Allen G.R. 1998: Conservation International's Marine Rapid Assessment (RAP). *Proceedings: International Tropical Marine Ecosystems Management Symposium,* November 1998: 336-340

Werner T.B. and Allen G.R. (eds.) 2001: A rapid marine biodiversity assessment of the Calamianes Islands, Palawan Province, Philippines. *Bulletin of the Rapid Assessment Program 17*. Washington, DC: Conservation International.

Williams P.A., Wiser S., Clarkson B., and Stanley M.C. 2007: New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. *New Zealand Journal of Ecology 31*(2): 119-128.

Whistler A. 2012: Rapid Biodiversity Assessment of Upland Savai'i: Plants and Vegetation. Edited by Atherton J. and Jeffries B. SPREP, Apia, Samoa.

Whistler A. 2013: Rapid Biodiversity Assessment of Nauru: Plants and Vegetation. Edited by Atherton J. and Jeffries B. SPREP, Apia, Samoa.

White G.C., Anderson D.R., Burnham K.P., and Otis D.L. 1982: Capture-Recapture and Removal Methods for Sampling Closed Populations. Los Alamos National Laboratory, Los Alamos.

Appendix 1

Fish and bat surveys

ONLINE RESOURCES

ReefBase Pacific (http://pacific.reefbase.org) is a regional focus of the global ReefBase project (http://www.reefbase.org). This website is an online database containing extensive information specifically related to the status, use, management and knowledge of reef resources in the Pacific region. Accessible through this website is a wide range of published and grey literature, images, spatial information, and Pacific reef project summaries and project contacts.

FishBase (http://www.fishbase.org) is a global information system with all you ever wanted to know about fishes. FishBase is a relational database with information to cater to different professionals such as research scientists, fisheries managers, zoologists and many more. FishBase on the web contains practically all fish species known to science. FishBase 2004 is also available on DVD or CD-ROMs with full information on 28,500 species.

SURVEY TECHNIQUES AND RESOURCES

Reef Check – Information on techniques for surveys of coral reef habitats suitable for non-specialists is available through Reef Check (www.reefcheck.org). This includes training opportunities, and field manuals and the organisation of groups to carry out surveys in selected reef areas.

Mack A.L. and Wright D.D. (2011) Training Manual for field biologists in Papua New Guinea. Green Capacity Publications One, USA. Free PDF download from www.pngibr.org, www.greencapacity.org or www.conservationinternational.org

FISH IDENTIFICATION

Key sources for fish identification in the tropical Pacific. See:

- Allen (1991) – Damselfish
- Allen (1993) – Reef fishes of New Guinea
- Allen (1997) – Marine fishes of tropical Australia and South-East Asia
- Allen, Steene & Allen (1998) – Angelfish and Butterflyfish
- Allen & Steene (1996) – Indo Pacific coral reefs
- Allen, Steene, Humann and Deloach (2003) – Tropical Pacific reef fish
- Kuiter (1992) – Tropical reef fishes of the Western Pacific
- Lieske and Myers (1994) – Indo Pacific and Caribbean coral reef fishes
- Myers (1999) – Micronesian reef fishes
- Randall, Allen and Steene (1990) – Fishes of the Great Barrier Reef and Coral Sea

Bats (Detailed Descriptions of Bat-Related Techniques)

Anonymous 1998: Inventory methods for bats: Standards for Components of British Columbia's Biodiversity No. 20. Ministry of Environment, Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force, Resources Inventory Committee, The Province of British Columbia ISBN 0-7726-3471-8. 51 http://www.ilmb.gov.bc.ca/risc/pubs/tebiodiv/bats/index.htm

Sedgeley J., O'Donnell C., Lyall J., Edmonds H., Simpson W., Carpenter J., Hoare J., McInnes K. 2012: DOC best practice manual of conservation techniques for bats. Inventory and monitoring toolbox: bats DOCDM-131465 Department of Conservation, New Zealand.

http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-bats/im-toolbox-bats-doc-best-practice-manual-of-conservation-techniques-for-bats.pdf

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ISBN 978-982-04-0514-1