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Tactical Research Fund – ASFB 2009 Workshop

Biodiversity of aquatic ecosystems – What to measure and monitor for fisheries and ecosystem management

FRDC Project No. 2008/353

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Fish for the future

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OBJECTIVES:

1 Synthesise expert opinion on current and past research on fish and aquatic biodiversity.

2 Document options for establishing cost-effective biodiversity monitoring protocols.

3 Identify any current or impending gaps in our ability to achieve effective monitoring of biodiversity in aquatic ecosystems.

Outcomes Achieved

The key outcome for the workshop is that gaining national or even state-wide agreement on how to best assess the biodiversity status of fish communities may not be warranted; this applies to what indicators (or metrics) should be assessed and how these would be measured. Rather, there is a need to first determine the management objectives at a relatively localised level before determining what to measure (i.e. choose an indicator) and then tailor implementation of methods into cost-effective protocol. There remains a challenge for managers and scientists who are tasked with developing biological objectives to meet the public and industry expectations to provide a defensible balance between extractive and non-extractive users. A range of individual indicators (or suites of indicators) to assess the biodiversity status of fish communities, along with methods to collect the data, have already been developed so are available for implementation. Some promising fishery-independent methods are currently undergoing further testing, while in some cases existing data sets (e.g. from fishery records or current survey programs) could be better utilised. It is likely that for any particular region the local research and monitoring strengths that currently exist could be rapidly mobilised if the decision to direct resources towards a biodiversity monitoring program was made. However, some gaps exist in expertise, particularly for taxonomy of fish and aquatic invertebrates.

The enactment of the *Environment Protection and Biodiversity Conservation Act 1999*, along with other government policies and guiding principles such as the FAO Code of Conduct for Responsible Fishing, has seen Australian fisheries become considerably more aware of the need to be managed in an ecosystem context. However, the ability to explicitly manage biodiversity has only recently received attention and requires considerably more collaboration and alignment between management-jurisdiction requirements and research-provider activities. The co-convening of the 2009 *Australian Society for Fish Biology* annual workshop with the 8th *Indo-Pacific Fish Conference*, with a theme focused on biodiversity conservation, provided an opportunity to improve the alignment between biodiversity management requirements and research and monitoring activities. The workshop was conducted on 3rd June 2009 at Fremantle in Western Australia.

The workshop identified a range of potential biodiversity indicators from simple measures of species richness to more complex indices such as size distribution for particular species. A single metric may not be applicable to monitor biodiversity of all types of fish community assemblages. However, starting with a simple metric is better than doing nothing while waiting to ascertain and gain agreement among stakeholders and managers about which metric(s) provide the most reliable means of measuring biodiversity with reference to management needs.

The workshop concluded that metrics had to be tailored to local conditions. This is generated by different jurisdictions often having different objectives, or even having different approaches for addressing the same objectives. Regional variability in ecosystems was also seen to require flexibility in what metrics might be applied. Thus, it was not deemed necessary to adopt a standardised indicator for assessing the biodiversity of fish community assemblages among all regions and jurisdictions. The workshop concluded that this was not an impediment because a local approach is usually valued above the imposition of an approach from elsewhere.

An important consideration highlighted at the workshop was the social impacts and competitive nature of natural resource management groups, including the research community. Issues, such as lack of alignment or shared-vision, can at times create tension amongst both researchers and managers; this tension is partly attributable to the competition for the limited opportunities to obtain long-term funding. In turn, this can tend to delay the selection of biodiversity indicators and, consequently, also the implementation of biodiversity monitoring programs. Thus, delays in the implementation of biodiversity monitoring programs result from governance issues (including lack of consistent funding) rather than a lack of choice of indicators and methods.

In conclusion, the specific management objective(s) will ultimately determine which indicator is required, the scales (temporal and spatial) of coverage required and what level of precision is expected. In turn, cost-benefit analysis will determine which method(s) and monitoring protocol will best deliver consistent measures of biodiversity.

KEYWORDS: Indicators, biodiversity, governance.

Acknowledgements

This workshop was co-funded by FRDC, the Western Australian Marine Science Institution and the Department of Fisheries in Western Australia. Thanks to all of the expert panel members and other presenters at the workshop. Thanks also to all workshop participants for the foresight to attend a meeting that attempted to bridge a known gap in aquatic resource management by transparently laying out the issues.

1.0 Introduction

1.1 Background

The *Australian Society for Fish Biology* (ASFB) annually facilitates a national workshop on a contemporary issue or topic relevant to managing fisheries and aquatic natural resources. Previous workshops have focussed on topics as diverse as conserving habitat to assessing the status of data-poor fisheries. These annual workshops align with the Society's annual conference and have rotated between Australian states and territories, and New Zealand.

The enactment of the *Environment Protection and Biodiversity Conservation Act 1999*, along with other government policies and guiding principles such as the FAO Code of Conduct for Responsible Fishing, has seen Australian fisheries become considerably more aware of the need to be managed in an ecosystem context. Australia's world-leading ESD system for assessing the activities of export fisheries relative to ecosystem impacts is now well embedded within fisheries management systems in this country. However, our ability to explicitly manage biodiversity is only now being developed but requires considerably more collaboration and alignment between management jurisdictions and research providers.

The co-convening of the 2009 ASFB workshop with the 8th *Indo-Pacific Fish Conference* (IPFC), with a theme focused on biodiversity conservation, provided an opportunity to address the apparent gap between biodiversity research and biodiversity management. The workshop was conducted on 3rd June 2009 at Fremantle in Western Australia.

1.2 Need

Central to Ecosystem Based Fisheries Management is the need to conserve biodiversity. However, management agencies responsible for the maintenance of fish and aquatic biodiversity are faced with real uncertainty about what is meant by biodiversity and significant debate around what temporal/spatial scales should be considered in relation to measuring and monitoring biodiversity. The implementation of biodiversity management plans create issues for the various state- and federal-level jurisdictions, such as (i) the need to manage anthropogenic impacts on aquatic ecosystems that are beyond the control of any one level of jurisdiction (e.g. climate change), (ii) Commonwealth initiatives (e.g. Bioregional planning) that have potential to influence the management of biodiversity at the state-level and (iii) human activities that can impact aquatic biodiversity e.g. fishing, securing water supply and coastal development. There is a need for the expert opinions of scientists from the relevant disciplines to be summarised and presented to managers in a way that allows policy-makers to understand what the management of fisheries and aquatic ecosystem biodiversity means in real terms. Scientists need to provide workable options for managers in relation to the measurement and monitoring of aquatic biodiversity. The ASFB proposed to facilitate this exchange of information via a dedicated workshop to be held in Fremantle in June 2009 as part of the 8th Indo-Pacific Fish Conference and the annual ASFB conference.

1.3 Objectives

1. Synthesise expert opinion regarding current and past research on fish and aquatic biodiversity.
2. Document options for establishing cost-effective biodiversity monitoring protocols.
3. Identify any current or impending gaps in our ability to achieve effective monitoring of biodiversity in aquatic ecosystems.

2.0 Workshop Structure

An expert panel **(Table 1)** was assembled to provide guidance for the discussions and assist with consolidating the outcomes from the day. The panel contained a mix of experts involved in various aspects of natural resource management, but not necessarily with direct experience in biodiversity research/management.

A mix of these experts and other practitioners provided focused presentations to set the scene for the workshop. The presenters were requested to address the following points:

1) Managers – their needs for managing biodiversity, and to explicitly request of scientists what should be measured now to begin meeting these management needs.
2) Scientists – how best to address the specific needs of biodiversity management.
3) The development of a better understanding of how strategic objectives for biodiversity can be turned into operational objectives.

Table 1. Expert panel members.

Expert	Affiliation (at time of workshop)
Jim Barrett	Murray Darling Basin Commission
Heather Brayford	Northern Territory Fisheries
Kate Brooks	FRDC Social Science Subprogram
Jeff Dambacher	CSIRO Mathematics & Information Services
Michael Fogarty	National Marine Fisheries Service, USA
Beth Fulton	CSIRO Marine & Atmospheric Research
Ed Jebreen	QLD DPI & Fisheries
Verena Trenkel	French Research Institute for Exploitation of the Sea (IFREMER)

Table 2. List of presentations.

Presenter	Affiliation	Topic
Peter Rogers	Chairman, WAMSI Board of Directors	Introduction, overview & challenges.
Heather Brayford	NT Fisheries	A fisheries management and agency-level perspective.
Jim Barrett	Murray Darling Basin Commission, Victoria	A manager’s perspective for the Murray Darling system.
Ed Jebreen	Queensland Dept. Primary Industries & Fisheries	A fisheries manager’s perspective for trawl fishing in QLD.
Kate Brooks	FRDC Social Science Subprogram	Consideration of social issues in natural resource management.
Marie-Joëlle Rochet	IFREMER, France	A scientist’s perspective on providing advice pertaining to developing ecosystem indicators relevant to marine fisheries.
Mervi Kangas	Dept. of Fisheries, Western Australia	A scientist’s perspective on providing biodiversity measures relevant to trawl fishing in Western Australia.
Euan Harvey & Tim Langlois	University of Western Australia	A scientist’s perspective on providing advice on measuring fish community assemblages.

Table 2. cont

Presenter	Affiliation	Topic
John Koehn	Dept. Sustainability & Environment, Victoria	A scientist's perspective on providing advice on management models and monitoring systems, with a focus on multi-use freshwater systems.
Martin Gomon	Museum Victoria	A scientist's perspective on the importance of taxonomic expertise to underpin biodiversity studies.

Following the introductory presentations, which included time for questions and discussion, the workshop broke into two groups to address the following criteria. The final criterion (*What could be implemented tomorrow?*) was included as a specific challenge to keep the workshop focused on the ultimate objective of science delivering advice to management in the near-term, not at some indeterminate point in the future.

Criteria To Address

1. Relevance to management objectives.
2. Relevance to stakeholders (understood & accepted; social drivers).
3. Precision/robustness of the measure.
4. Costs (implementation; ongoing/recurrent).
5. Ability to achieve (implementation; longevity; partnerships; governance).
6. Transparency, accountability and communication.
7. What Indicators are available (i.e. understood and tested)? How many indicators are required?
8. What could be implemented tomorrow?

3.0 Workshop Outcomes

3.1 General issues and concerns

In the opening session of the workshop it became apparent that some issues were of a more strategic nature than could be adequately covered within the focus of the workshop. Consequently, although relevant to the issue of managing and monitoring biodiversity, all such issues were not necessarily covered in detail. The key underlying issues for choosing biodiversity indicators raised at this workshop included the following:

1. Lack of unambiguous objectives (or lack of explicitly described objectives) and poor understanding of objectives by direct stakeholders and the public (e.g. industry or community resistance) were deemed serious problems. Whole-of-government objectives for conserving aquatic biodiversity are lacking, or policies for managing biodiversity have neither been translated into agreed operational objectives nor well articulated to direct stakeholders, let alone the broader public. This is seen as an impediment to addressing the question of what could be implemented immediately, i.e. lack of understanding of why an indicator is required thwarts selection of an indicator.
2. What level of change for a potential biodiversity indicator (e.g. biomass) is acceptable? This question was beyond the scope of the workshop to deal with, but was recognised as an important consideration when attempting to choose a suitable metric. This is primarily a governance issue. Scientists called for clarity from managers in terms of defining objectives, however, scientists are often better placed through their hands-on expertise to provide informed comment on how to set objectives. Objectives for biodiversity need to be articulated at a policy level so that researchers can respond (e.g. contribute) in an informed manner. This requires a cycle of continuous improvement from legislation – research – management – policy – legislation – etc.
3. Institutional impediments (e.g. cultural resistance to change, management structures), such as inter-agency competition (e.g. competition, aggressive business tactics), were seen as issues that could cause negative impacts on the ability to reach agreement on implementing a biodiversity monitoring system. Similarly, whole-of-government sign-off on a hierarchy of objectives is required before the responsible jurisdictions can commit investment into measuring and monitoring. Lack of such sign-off thwarts serious efforts to decide on what indicators could be implemented now.
4. Scientists and managers involved with managing ecosystems, or components of ecosystems (e.g. fisheries), often do not have shared visions, however overlapping goals or visions provide common ground for consideration of what could be implemented.
5. Funding and research models are inconsistent, leading to blurring of what constitutes strategic and applied research; this causes an imbalance regarding what constitutes high-quality science. Both applied and strategic funding/research are required but both need to be carefully managed to ensure balanced delivery of services. In the case of strategic research, increased knowledge is required to underpin choices of what should be monitored, but the actual monitoring requires a different funding model. Similarly, tactical research to deal with immediate high-risk issues typically requires a different funding/research model. Increased competition for funds has seen an erosion of the demarcation between strategic and tactical research. This was seen to be important because competitive research funding that is not directly linked to recurrent government budgets often requires a strong

element of innovation and, ultimately, submission to the world's most prestigious scientific journals. Such outcomes do not necessarily meet the requirements for tactical research that can be innovative in its application to a critical management problem but that may not be considered innovative at the level of prestigious scientific publications.

These issues for implementing biodiversity monitoring fall broadly within the realm of "governance", rather than specifically being science or management problems. Consequently, the types of issues that fall within the above categories tended to impede discussion because many participants felt it was premature to discuss details of biodiversity monitoring until the governance issues had been clarified. However, because it was clearly recognised that governance issues would not be resolved at this workshop, the workshop was refocused on the key question pertaining to measuring the biodiversity of fish community assemblages. Nonetheless, the importance of governance problems was not ignored. Indeed, concerns subsequently raised in the breakout sessions confirmed the critical relevance of some of the key themes identified in the morning session.

3.2 Specific issues and concerns

Management jurisdictions operate under a number of inherent constraints, e.g. resources, balancing conflicting opinions or objectives. Consequently, such jurisdictions typically require a range of options when making decisions on natural resource management. Scientific advice for managing biodiversity will need to provide a range of potential solutions that have different costs and, most likely, different outcomes. Managers can then determine which options best meet their needs to address management objectives.

The breakout sessions were tasked with developing options for addressing the workshop question (biodiversity indicators and monitoring protocols for fish community assemblages, i.e. fish biodiversity) by considering the specific criteria provided above.

Indicator Criteria

1. Relevance to management objectives

The workshop focus was not on particular impacts and how to deal with them but in some cases researchers/managers could not divorce the nature of the impact from the problem of what indicator or metric to chose. The need to specifically consider an impact or expected "recovery measure" in some cases was acknowledged, as was the need to also measure ecosystem components other than fish, such as water quality. However, dealing with specific impacts constitute separate or ancillary issues, depending on the management objectives, from that of how best to monitor the biodiversity status of an assemblage of fish.

An issue pertaining to management objectives was that of "what management model to use"? While this was categorised above as a governance issue, it is again mentioned here due to its direct relevance to management objectives. There was a demarcation in views regarding the monitoring-management model and hence also of the ultimate use of an indicator(s) to assess the status of an ecosystem. Similarly, choice of what to monitor was somewhat dependent on the level of acceptable change insofar that the ability to detect change can be dependent on the monitoring method and the scales to which it is applied.

The Expert Panel noted that the choice of monitoring-management model was not necessarily important in the context of deciding what metric to use to assess the biodiversity status of a fish community assemblage. This point is relevant regardless of whether or not there is institutional bias (or impediment) for (or against) a particular management model.

The issue of what scales of effects to monitor also depends on the specific intent of particular management objectives. The issue of what scales should be considered or can be monitored may be one of cost, but if management requests that a large area needs to be monitored with a given budget, this will effect what method(s) is chosen.

The workshop concluded that metrics had to be tailored to local conditions, which would often have differing objectives that reflected local socio-politics and industry values. Notwithstanding that different jurisdictions often have different objectives, or even different approaches for addressing the same objectives, regional variability in ecosystems also generated a need for flexibility in what metrics might be applied. There was general agreement at the workshop that there was little value in attempting to implement a standardised indicator of biodiversity status of fish community assemblages between different regions and jurisdictions.

2. Relevance to stakeholders (understood & accepted; social drivers)

Managers and scientists need to think about the question of why they are worried about biodiversity and what this means to stakeholders. The considerable gulf between what biodiversity means for direct stakeholders (e.g. fishing industry and recreational fishers) and indirect stakeholders (i.e. the general public) was stressed. Furthermore, an important question regarding stakeholders' perceptions of biodiversity management was "what's in it for them?" Flow-on benefits to the market and the consumer expected from improved biodiversity management needs to be identified and articulated/communicated; currently most scientists and managers (and governments) would struggle to enunciate how ecosystem resilience and ecosystem services translate into benefits for members of the public.

It was suggested that communities don't necessarily make decisions for sustainability. As such, if communities don't really care about or understand biodiversity then they are not going to be concerned with indicator-selection for monitoring biodiversity. Following the discussion in the above criterion, stakeholders would be more likely to understand and care about issues relevant to their local ecosystem so this would be the best starting place to increase the relevance of biodiversity management.

The workshop concluded that social projects are needed to better understand how the broader community perceives the value of biodiversity in regard to the acceptable tradeoffs.

3. Precision/robustness of measure

Precision and robustness were considered in terms of some of the specific measures suggested below, but the workshop did not discuss these in detail. Nonetheless, the workshop did conclude that all techniques have detectability biases. In deciding whether biases would unduly interfere with precision of a metric, such biases would need to be considered with reference to the specific monitoring needs for a particular management situation. Consequently, an appropriate suite of techniques appropriate to different habitats or suite of habitats is required, at least initially, until surrogates can be determined. Ultimately, loss of biodiversity (or a change in the biodiversity status of a fish community assemblage) is what must be able to be detected.

4. Costs (implementation; ongoing/recurrent)

The issue of ongoing/recurrent costs received little specific consideration in terms of possible metrics or monitoring methods. Rather, the focus was on the related issues discussed elsewhere, including:

- what management model to use,
- funding streams within broader government and natural resource management systems,
- the need for long-term monitoring programs to generate long-term data sets,
- trading off precision and robustness against the ongoing costs, and
- the need to investigate current data sets, such as those generated by some commercial fishery monitoring programs, to assess if these can provide a basis for developing useful biodiversity metrics.

In some cases biodiversity management is quite different to fishery management so may need a different funding model, at least in the initial stages of research. Importantly, indicators for biodiversity must be underpinned by research to ensure that they are meaningful; this means that there is an up-front cost before monitoring can begin. This point was stressed with respect to the decline in taxonomic expertise for fish in Australia.

5. Ability to achieve (implementation; longevity; partnerships; governance)

This criterion was not considered explicitly, but was linked to the issues of governance and costs. As with consideration of costs and funding, some workshop participants expressed considerable frustration while others took the pragmatic view that managers and scientists deliver to government only what government pays for. A key aspect of the ability-to-achieve is ongoing costs (commitment from government) and expertise. A lack of government commitment was seen as an impediment to achieving long-term monitoring programs which, in turn, thwarts the development of long-term data sets considered important for detecting changes in ecosystems. As already mentioned, a growing problem in this regard is that the changing nature of scientific funding now means that there is little ongoing taxonomic work for marine fish (and for other taxa). Given the acknowledged agreement that there are many species of fish yet to be identified, the decreasing ability to properly identify fish species is a serious impediment to establishing the baseline knowledge for fish community assemblages.

Some contended that research institutions may struggle to provide a monitoring service because governments require consistency and cost effectiveness whereas academic institutions should be pursuing cutting edge science. Research institutions risk becoming a monitoring group reliant on government funding or drifting towards blue-sky science and failing to deliver to government – if universities want government funds for monitoring research there will need to be service delivery contracts in place. While not all workshop participants shared this opinion, it does highlight the tensions that exist in some case between government departments and other institutions.

Some also contended that research and monitoring are the same thing, but this would not be the case for those research providers expected to focus on blue-sky science. Routine monitoring programs provide long-term comparisons, which, while suitable for publishing, may not be seen as sufficiently innovative or novel to be accepted by high-ranking science journals in the timeframes to match the funding and review-cycles of universities.

6. Transparency, accountability and communication

There was limited discussion of transparency and accountability regarding indicators that might be used. Rather a lack of understanding by stakeholders of the need to manage biodiversity was again highlighted as a prerequisite to examining the pros and cons of particular indicators. Once stakeholders understood and supported the need, then the methods employed would need to be communicated so that these too were understood and supported.

7. What indicators are available (i.e. understood and tested)? How many indicators are required?

In general the workshop recognised that there are already suites of indicators that account for (or attempt to account for) ecosystem status in terms of both functioning and structure, and thereby broadly meet the needs of an indicator of biodiversity for fish community assemblages.

There is benefit in monitoring multiple species (or variables) as some are more sensitive to specific environmental factors than others. The workshop concluded that both univariate and multivariate methods should be considered, and that the benefits and limitations of each should be examined. An obvious solution would be to measure as many indicators as affordable, focusing on those that are most cost-effective. However, funding constraints often mean that only a few can be measured. There are well documented and tested approaches worldwide; these should be investigated rather than reinventing the wheel. Ultimately, the choices of what should be implemented, or considered for implementation, should be decided by risk-based (cost-benefit) approaches that consider potential cumulative impacts to the ecosystem(s) in question.

The choice of biodiversity indicators may require consideration of whether: (a) an ecosystem has top-down or bottom-up control, (b) the management is explicitly for either fisheries or ecosystems, or (c) both. A single metric may not be applicable to monitor the biodiversity status of all types of fish community assemblages, however if there is no monitoring in place then starting with a simple metric is better than doing nothing while waiting to ascertain, and gain agreement among stakeholders and managers about which metric(s) provide the most reliable means of assessing health.

Summary of indicators

The workshop recognised that considerable literature already exists on potential indicators: by way of an example, the summary results for a multi-national (i.e. the Indiseas Working Group) examination of possible indicators is shown in Table 3 (reproduced from Shin and Shannon, 2010). Several indicators or issues about the selection of biodiversity indicators for fish community assemblages discussed at the workshop are listed below. The workshop did not include a detailed investigation or description of all possible indicators or suites of indicators.

Species richness is of prime importance when considering biodiversity status but the number of species to monitor is partly dependent on the objectives for a particular ecosystem and will influence the method applied. Presence/absence monitoring can measure changes over time and is meaningful across different habitats, but suffers from false absences.

Abundance (biomass or numbers) of (a) selected species, (b) all species vulnerable to a particular sampling method or functional/trophic groups. Biomass, as a metric, reflects numbers and average size/weight. The expert panel noted that biomass (or relative biomass) may miss information on size composition for individual species so can be less informative. Given that biomass estimates from video techniques are based on numbers (Max_n) and lengths along with a pre-determined length/weight relationship to estimate weight, both the numbers and length distribution of species should be used as individual metrics.

Information on the relative abundance of functional groups or trophic groups may be useful for particular situations. The status (e.g. instantaneous rate of fishing mortality, F) of highly targeted species can be used as a surrogate indicator for non-targeted members of the same functional/vulnerability group; this approach assumes that if the highly targeted species are maintained then the less exploited species should also be at levels that would not unduly impact on a fish community assemblage. Similarly, changes in growth rates, size structure and age at maturity for exploited populations can be included in a suite of indicators of the status of a assemblage. If deemed useful, then these variables could also be determined for a range of non-exploited species or functional groups.

NE USA uses aggregate measure of biomass conditioned on species vulnerable to gear. This has similarities to using key exploited species as indicators, assuming if populations of the most vulnerable species are at acceptable levels then the remainder of the community must also be at acceptable level by virtue of their lower exploitation rates.

Table 3. (From Shin et al, 2010. ref no.1). Initial list of candidate indicators evaluated against four screening selection criteria (ecological significance, sensitivity, measurability, awareness of the public). Crosses (X) meaning that the indicator satisfies the selection criterion, according to the expertise of the IndiSeas Working Group. Numbers refer to reference.

Indicator	Ecological Significance	Sensitivity	Measurability	Awareness of the Public	Management Objective
Size-based indicators (5, 8, 10)					
Mean length/weight in community	X	X	X	X	EF
Maximum length in community	X	X			
Mean maximum length in community	X	X			
Slope of size spectrum	X	X			
Slope of diversity size spectrum	X				
Proportion of large fish	X	X			
Proportion of large species	X	X	X	X	CB
Trophodynamic indicators (3, 6, 7, 9)					
Trophic level landings	X	X	X	X	EF
Trophic level community	X	X	X	X	EF
Fishing-in-Balance index	X	X	X		
Proportion of predatory fish	X	X	X	X	CB
Pelagic to demersal fish biomass ratio	X	X	X		
Piscivorous to zooplanktivorous fish biomass ratio	X	X	X		
Species-based indicators (3, 6, 7, 8, 11)					
Species richness	X			X	
Shannon and Hill's index of diversity	X		X		
K-dominance, ABC curves, W-statistic	X	X	X		
Ratio of endangered to unendangered species	X	X		X	
Ratio to target to non-target species	X		X	X	

Indicator	Ecological Significance	Sensitivity	Measurability	Awareness of the Public	Management Objective
Proportion of under-/ moderately exploited stocks	X	X	X	X	CB
Mean lifespan	X	X	X	X	SR
Pressure indicators (4, 5, 6)					
Overall fishing mortality rate	X	X	X	X	RP
Exploited fraction of ecosystem surface	X		X	X	
Mean distance of catches from the coast	X				
Catch rate by community	X	X			
Discard Rate	X			X	
Biomass-related indicators (2, 6, 7)	X	X	X	X	RP
Total community biomass	X	X	X	X	SR
Coefficient of variation in biomass					

[a]CB, Conservation of biodiversity; SR, maintaining ecosystem stability and resistance to perturbation; EF, maintaining ecosystem structure and functioning; RP, maintaining resource potential.

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Summary of methods/tools

Fishing methods (e.g. trawl, trap, net, line) can provide time series of catches from which indicators of fish assemblages could be determined. This is often restricted to commercial fisheries for which consistent records of all retained fish have been kept; trends in species composition, trophic level, size or biomass can be determined from such records. Consistent time series of non-retained bycatch are rare, but along with retained catch would provide a much better understanding of the status of fish assemblages in exploited ecosystems.

There are a variety of fishery-independent extractive techniques (e.g. trawl, trap, net, line, rotenone) that could be applied in certain situations. The benefits of specialised, fishery-independent sampling techniques such as the application of rotenone or methods employing nets need to be weighed against the obvious destructive nature of removing fish from the water. Careful application of “destructive” techniques can potentially provide cost-effective data collections with negligible impact on the sustainability of fish communities. Taxonomists in particular highlighted the benefits of judicious use of rotenone as an extremely effective sampling technique for cryptic species.

There are currently few non-extractive or non-intrusive sampling techniques for fish communities. Visual observation was promoted as perhaps the main non-intrusive method for assessing composition of fish assemblages, although the use of traps in shallow water and or for species with resilience to barotrauma was proposed as an alternative approach. Non-destructive electrofishing remains a viable technique for use in some freshwater systems.

Visual observation could be undertaken directly by divers in shallow water or by remote video systems at virtually any depth. Baited remote underwater video systems (BRUVS) have been used extensively in Western Australia and some comparisons with other methods undertaken. Some of the benefits of BRUVS over other observational methods that have been documented include:

1) The detection of significantly more species than trap methods,
2) The provision of the maximum number of each species (Max_n) seen in the sampling period
3) The use of stereo video systems enables the size of fish to be estimated,
4) The technique is cheaper than diver surveys, and
5) The technique attracts more than just carnivores or scavengers. Herbivores tend to be found in similar proportions compared with diver surveys.

Notwithstanding these benefits, the following issues with BRUVS require further investigation which may be required for each new application.

- Sampling area is not always consistent, at least in terms of comparability between different sites (e.g. issues with different hydrodynamics, times of day, tide changes, swell)
- Uncertainty regarding vulnerability to the method.

If the goal is to measure species richness within a particular area, few methods are so encompassing as larval-fish surveys. Because nearly all marine teleost fish species have a pelagic larval stage, and because plankton nets are not selective, this method captures a more complete spectrum of the fish community than any other single method. All species are captured from small, cryptic species, to large commercial species, regardless of the habitat they occupy as adults. This also applies to many invertebrates, in particular to crustaceans.

A major obstacle in the past for larval fish surveys has been the taxonomic difficulties; that is the larval stages of many species are difficult to identify. However, the increasing use of DNA technology has eased this problem and it is now possible to establish the identity of nearly all the larvae. In the foreseeable future, it may be possible to identify all the species (fish and invertebrate) in an unsorted plankton sample using DNA technology.

8. What could be implemented tomorrow?

Species richness would provide a useful base-level indicator of the biodiversity status of fish community assemblages that could be applied immediately. However, no consensus was achieved on what methods should be applied, and as mentioned previously a locally derived approach would likely prevail for most jurisdictions. Similarly, more than one method could be applied if warranted by the objectives. Besides agreeing that species richness was an acceptable starting point, the workshop group did not choose any further specific indicators, although it was widely recognised that traditional fishing assessment methods focussed on the targeted species often remained the cornerstone of managing biodiversity in particular areas. The inability to reach a consensus on any new indicators (i.e. besides species richness) with a specific focus on the biodiversity of a community assemblage rather than on targeted species assessments was not attributable to the lack of choices of potential indicators. Rather, it was largely attributable to a lack of consensus as to (1) what the indicators really meant, along with (2) what methods should be adopted first, in balance with what funds were available.

Ultimately, there was reluctance to agree to too much at this time since such agreement was viewed as a restriction on future funding possibilities. In essence, an answer could not be obtained due to governance constraints – this was a common though not ubiquitous theme from the range of science participants at the workshop.

Most agreed that if management objectives required a suite of indicators there was a need to keep the suite to a pragmatic number. The IndiSeas Working Group derived a reduced suite of eight ecological indicators (Table 4) from the more extensive list shown in Table 3. Notwithstanding that species richness was not chosen by the IndiSeas Working Group in their final suite of indicators, the body of work behind the selection of this suite shown in Table 4 provides an example of where a dedicated process can develop some consensus about indicators across a broad range (23) of research and management agencies. In this case, the indicators chosen could be applied to different scenarios depending on availability of data (e.g. fisheries data time-series), research expertise and funds. This suite of indicators was based on data collected from commercial fishery operations (i.e. monitoring of commercial catches) or established survey programs.

Table 4. Summary of ecological indicators selected by the IndiSeas Working Group and the corresponding management objectives (from Shin et al, 2010).

Indicators	Headline Label	Used for State or Trend	Management Objective[a]
Mean Length	Fish size	S, T	EF
Trophic levels of landings	Trophic level	S, T	EF
Proportion of under - and moderately - exploited stocks	% healthy stock	S	CB
Proportion of predatory fish	% predators	S, T	CB
Mean lifespan	Lifespan	S, T	SR
1/CV of total biomass	Biomass stability	S	SR
Total biomass of surveyed species	Biomass	T	RP
1/ (landings/biomass)	Inverse fishing pressure	T	RP

[a]CB, Conservation of biodiversity; SR, maintaining ecosystem stability and resistance to perturbation; EF, maintaining ecosystem structure and functioning; RP, maintaining resource potential.

Methratta and Link (2006) provide another example where a long list of potential indicators were evaluated, this study proposed the following suite of eight indicators for marine fish communities in the Northeast USA Large Marine Ecosystem:

1. Total finfish biomass,
2. Total fisheries landings,
3. Planktivore biomass,
4. Benthivore biomass,
5. Mean individual fish length,
6. Mean individual fish weight,
7. Flatfish biomass (or some species benthic species associated with some habitat type of interest), and,
8. Biomass of an indicator population (chosen at the local level).

Methratta, E.T. and Link, J.S. 2006. Evaluation of quantitative indicators for marine fish communities. Ecological Indicators, 6: 575-588.

As with the more wide-ranging IndiSeas project (Tables 3 & 4), this study by Methratta and Link also relied on data that could be collected from commercial fishery operations (i.e. monitoring of commercial catches). These examples highlight the need to consider using existing data collections methods (e.g. commercial fishing activities) as the basis for developing cost-effective indicators; this is particularly useful in those cases were the effects of fishing is a prime management requirement.

4.0 Conclusion

A range of currently available indicators of biodiversity (or ecosystem effects of fishing) are generally sufficient to be used as the basis for deciding what indicators could be implemented. In particular, current knowledge, current data and existing data-collection opportunities should be fully explored in the first instance, as these would likely provide a more cost-effective platform for ongoing monitoring. The lack of baseline data for some regions is seen as a major gap that must be filled before monitoring can begin. Examples contrary to this view indicated that, in some cases, a level of monitoring can begin without full knowledge of a community assemblage; the initial monitoring thus builds the baseline knowledge.

As a standalone indicator, species richness was predicted to ultimately be ineffective for conserving biodiversity because it is over-simplistic. Practitioners at the workshop were unwilling to commit to selecting further indicators in isolation of knowledge regarding factors identified in the preceding criteria, including:

- Clear whole of government agreement on the objectives;
- Commitment to ongoing funding;
- Ongoing funding for further taxonomic investigations.

Finally, the objectives for managing biodiversity of fish communities will vary depending on local social and economic conditions. The social dimensions of what the public want in a region tend to drive the acceptable level of impact, which in turn was seen to influence the choice of measures. However, measures of the status of fish community assemblages are not well conveyed or understood by the broader public. The issue here is not what to measure, but what will be the acceptable level of whatever measure is chosen. This became a circular argument – we cannot agree on what to measure until we know if that will provide a good measure, but we cannot assess what will be a good measure until we understand how better to ascertain what levels of change will be acceptable.

The problem of deciding what level of change is acceptable (or where to set a biological reference point) was considered in terms of specific sampling methods and indicators. The workshop saw merit in investigating the use of directional trends, for example through qualitative modelling incorporating expert opinion, rather than specific biological reference points for indicators. This approach is relevant in those cases where the pristine state of an ecosystem (structure and or function) is not known, which makes setting reference points difficult. An example by Rochet et al. (2005), and which formed part of the presentations at the workshop, uses trends in a combination of eight population- and community-level indicators to assess the status of exploited fish communities. As in the previous examples, the data for such indicators come from commercial fishing operations or existing survey programs.

Table 5. Population and community Indicators from Rochet *et al.* (2005).

Level	Indicator	Expected Effect of Fishing
Population	Population abundance for species	Decrease
	Average length of population	Decrease
Community	Total biomass	Decrease
	Total abundance in the community	Decrease
	Average weight	Decrease
	Average length	Decrease
	Size spectrum slope	Decrease
	Size spectrum intercept	Unknown

Rochet, M.-J., Trenkel, V., Bellail, R., Coppin, F., Le Pape, O., Mahe, J.-C., Morin, J., Poulard, J.-C., Schlaich, I., Souplet, A., Verin, Y. and Bertrand, J. 2005. Combining indicator trends to assess ongoing changes in exploited fish communities: diagnostic of communities off the coasts of France. ICES Journal of Marine Science, 62: 1647-1664.

Objective 1

Synthesise expert opinion on current and past research on fish and aquatic biodiversity

Current opinion was divided. Jurisdictions with a program in place are understandably reticent to change what they are doing. Jurisdictions without a program in place still struggle to get clear advice on options from researchers, who in turn cannot get clear objectives from managers/government. Some researchers appear unwilling to consider anything but their own area of specialisation in terms of methods. There were few if any examples of new ideas on what to measure to assess fish biodiversity. An exception was to use larval stages combined with automated techniques to genetically identify species.

A key element of discussion was that relatively simple uni-metric measures such as species richness would not provide adequate protection for biodiversity. However, such simple measures also provided the standout example of something that all could agree on. That is, simple basic measures of diversity should constitute the starting point for assessing biodiversity condition. Size structure of constituent species was considered a starting point for measures more complex than relatively simple descriptors of assemblage taxonomic composition.

Objective 2

Document options for establishing cost-effective biodiversity monitoring protocols.

Current directions are acceptable, but ongoing work is required.

Overarching commonalities can be decided so as to harmonise across jurisdictions, but local options will ultimately need to be developed.

More use should be made of current data sets and existing data collection methods.

Confirmation of significant long-term funding would likely see the question of funding constraints answered. Consistency in even medium-term funding would likely generate documentation of biodiversity monitoring protocols that managers could use; these could act as a platform to underpin longer-term strategies for monitoring biodiversity.

Objective 3

Identify any current or impending gaps in our ability to achieve effective monitoring of biodiversity in aquatic ecosystems

The impediments are focused around governance issues such cultural differences both amongst and between research providers and management agencies. Thus, there exists lack of agreement and/or shared understanding amongst and between:

(i) government departments (even within single states);

(ii) research institutions;

(iii) scientists;

(iv) managers;

(v) direct stakeholders (resource users); and

(vi) indirect stakeholders (broader public and conservation groups)

Insufficient funding is seen as a major constraint, along with lack of agreed model to distribute what funds may be available. This has resulted in pessimism regarding continuity of funding constrains development of monitoring protocols.

Clearly communicated management objectives for biodiversity management appear to be lacking.

5.0 Benefits, adoption and further development

The operational aim of the 2009 Australian Society for Fish Biology workshop was for scientists to provide an overview of what biodiversity measures could potentially be adopted and then monitored into the future to meet the biodiversity objectives of aquatic ecosystem management. The minimum expected outcomes from the workshop were for

- managers to gain a better understanding of what can be measured and monitored, and
- scientists to gain a better understanding of what types of research are particularly relevant to meet the current needs of managers.

Despite the range of problems identified at the workshop there was broad agreement on the types of indicators that should be considered, and that a suite of indicators would be required since no single metric could adequately represent changes in an ecosystem. However, rather than generating an agreed suite of indicators the workshop determined that these had to be agreed to at local scales to meet the needs of local communities and jurisdictions. That is, one suite of pre-defined generic indicators would not suit all situations. Instead, reviews of indictors and or suggested development of new indicators for both fishery dependent and fishery–independent sources of data should be consulted to determine applicability to specific objectives and issues for any particular region or jurisdiction.

This workshop confirmed that the combination of funding constraints and an apparent lack of shared understanding (including confusion over the management objectives) can be sufficiently divisive to preclude making decisions on what measures of biodiversity could be implemented in the short term. The workshop highlighted the need for clear management objectives to be formulated, with explicit consideration of both fishery and ecosystem outcomes, and for these to be communicated to research providers. Further governance issues that constrain implementation of biodiversity monitoring included a lack of understanding by stakeholders and a considerable decrease in taxonomic expertise. The solution to these should include programs to extend the biodiversity science and management to grass-roots stakeholders, and reform of the Australian taxonomy sector.

6.0 Appendices

Appendix 1: Intellectual Property

The results of this research are in the public domain, there are no intellectual property implications.

Appendix 2: Staff

Staff employed on the project were:

D. Gaughan, G. Jackson, S. Metcalf.