Establishing a common environmental currency to build environmental accounts

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Introduction

Our political systems were built to manage the industrial revolution where the great contest of the age was between capital and labour.

We have become as a nation highly skilled in economic management, highly skilled in the social sciences – education, health, law and order.

Our problem is that our political institutions were designed to manage economic growth and distribute wealth at a time when the natural world seemed endless – where nature was there for the taking – where land clearing was part of a heroic vision to develop the nation – where fresh water flowing to the sea was thought to be wasted – when nobody dreamed that carbon dioxide emitted from the power stations that drove the industrial revolution could change the world's climate.

The pursuit of economic growth is built on a paradigm of an infinitely expanding economy, where advances in personal and national well-being are measured by a growth in the exchange of goods and services. Throughout modern history, economic growth has been achieved in large part from the conversion of nature into products for direct human consumption: each time the economy grows, so does the impact on our natural capital - our natural resource[1] assets and the health of ecosystems.[2,3]

This economic development pathway is now depleting our natural capital at a scale that is approaching (and in many cases has already exceeded) the ability of our ecosystems to sustain the demands being place in them.

Humanity has converted over half of the world's forests, degraded river basins, depleted agricultural soils of essential minerals and carbon and depleted and polluted much of the world's available freshwater resources. As a consequence, global species extinction is now up to 1,000 times higher than evidenced in the fossil record.[4]

It doesn't have to be this way.

These are the defining issues of our age, ones which will increasingly challenge our notion of progress.

In 1992 at the Rio Earth Summit, environmental accounts were proposed as a way of integrating the environment in decision-making.[5] Many of you here in this room will remember those heady days, we were convinced that we were on the right track, and the world had decided to fix it.

Soon after, the Commonwealth government commissioned Australia's first State of the Environment Report. I remember well the day Ian Lowe, the Chair of 1996 SoE launched this landmark report.

He also warned us then that "we urgently need better information and understanding … (that) Australia lacks the integrated national systems and databases to measure environmental quality, manage it and evaluate the effectiveness of that management".

So what happened? Fast forward 10 years and the 2006 SoE says "it is still impossible to give a clear national picture of the state of Australia's environment because of the lack of accurate, nationally consistent, environmental data".[6]

Eighteen years since Rio and information about the environment is still not incorporated in the processes we use to make decisions that impact our economy and our society.

This is because we have failed to establish the institutional frameworks to track, in quantifiable and comparable units, the health of our environmental assets.

We all care for our environment, but until we can put in place a system that tells us what is happening to our landscape, we have no chance of leaving this world in a better condition than the one we have been so fortunate to inherit.

If we are to have any hope of addressing these challenges, we are going to have to apply the same discipline to environmental management that we apply to managing our economy.

We have economic accounts to manage economic growth: what we also need are environmental accounts to manage its impact.

We need to build a set of environmental accounts that measure the condition of key environmental assets, so that for the first time in our history, we will be able to systemically measure change, account for impact of our actions and monitor the success of our investments in improving or maintaining the health of our environment.

If you don't measure it, you can't manage it.

In 1993 a handbook for integrated environmental and economic accounting was published by UNEP and the World Bank[7] as a way of responding to concerns about the impact of economic growth on the health of the world's ecosystems.[8,9,10] This was updated in 2003 by the UN, EU, IMF and OEDC into a draft framework for "statistical accounts … of the interaction between the economy and the environment".[11]

The focus of this work to date has been on how natural resources such as logs and water contribute to the economy and how economic activity depletes these resources, reflecting perhaps its origins from the Club of Rome.[8]

Revealing the prices associated with stocks and flows of physical assets is an important step towards more efficient use of natural resources; it can tell us how efficiently natural resources are being used to support our economy and how this activity impacts on the stocks of those physical assets.

The great challenge for environmental accounting however, is not the ability to measure the rate or economic efficiency in how humanity uses natural resources – as worthy an objective as that is – the great challenge of our age is to understand the impact an economic activity is having on the health of the world's ecosystems.

In Australia, water accounts[12] are being used to evaluate economically efficient ways of returning overallocated river systems in the Murray Darling Basin to sustainable levels of extraction.[13]

This is important, but what these accounts are not currently able to do is measure the condition (or 'health') of this river system. They are therefore of little value in determining the primary public policy question as to what the sustainable level of extraction should be.

What is needed is a science-based unit of measure to account for the health of ecosystems. This is the missing link between science and policy: if you don't measure it, you can't manage it.

What do environmental accounts need to do?

The Wentworth Group's interest in this process is very specific: the great urgency today is not to build bigger information systems. You could count all the feathers on every bird in Australia and it would not make one jot of difference to environmental outcomes if that information is not assembled in a way that enables people to make economic decisions.

Environmental accounts need to be constructed so that they can improve the quality of environmental decisions, in different ways, at multiple scales:

- Firstly, they need to provide annual national, state/territory-wide and regional (catchment) scale reports which measure the health and change in condition of our major environmental assets;
- Secondly, they need to be data based and geographically specific, so that they can underpin the long-term catchment management and land use planning decisions by all levels of government; and
- Thirdly, they need a common accounting metric so that these environmental accounts can be used to improve the cost effectiveness of public and private investments in environmental management and repair.

We want to use existing environmental monitoring systems to build such a system.

The challenge for environmental accounting in Australia today is to take existing environmental data, at scales that can inform management decisions and begin the long process of using and establishing trend data at these scales.

A Common Currency for Accounting for Nature

National accounts are built using a national currency (a Dollar, Yuan, Euro, etc) which assigns a common value for the exchange of goods and services. Without a common currency it is not possible to construct economic accounts.

While it is possible to express many physical environmental assets as quantities, there is no established unit for measuring the health (quality) of ecosystems.[14,15,16,17]

The starting point for building a system of environmental accounts is dependent on the creation of a common unit of measure that is capable of assigning a value for all environmental assets and indicators of ecosystem health.

Creating a measure for ecosystem health must address a number of challenges: no two environmental assets are the same; often different indicators are needed to measure the same asset in different locations; the cost of data collection creates significant variation in the quality of information collected; and no single indicator can provide a complete picture of ecosystem health.

In 2008, the Wentworth Group of Concerned Scientists, in association with other scientists and economists, developed a model for building a regional system of national environmental accounts that we believe will address each of these challenges.

This *Accounting for Nature* model[18] creates a common unit of account for all environmental assets and indicators of ecosystem health, irrespective of the unit of measurement. It does this by using the science of reference condition benchmarks.

The common currency for environmental accounts does not imply a monetary value: it is simply a scientific method for standardising the measurement of environmental assets so that we can compare the relative state of one asset with another and aggregate information at different scales and for different assets.

This methodology plots the condition of all environmental assets and indicators of ecosystem condition on a common scale (stocks), and measures how each is tracking towards or away from a healthy condition over time (flows).[19]

In a paper we produced recently for the international environmental accounts review[20], we describe a four stage process for establishing a standard for *environmental (ecosystem) accounts*:

1. Adopt *reference condition benchmarks* as the scientific standard for accounting for all environmental assets and indicators of ecosystem health;
2. Develop scientifically accredited methods for combining *ecosystem health indicators,* based on reference condition benchmarks;
3. Develop *standards for ecosystem accounts and scientific accreditation of ecosystem indicators*; and
4. Use the ecosystem health indicators as the standard for incorporating *environmental (ecosystem) accounts* into the international "System of integrated Environmental and Economic Accounts".

The Science of Reference Condition Benchmarks

This model for environmental accounts is based on the science of reference condition benchmarks. Reference condition is the status of an ecosystem's components as they would be if significant human intervention had not occurred in the landscape.[21]

Describing the existing stock of an environmental asset against a reference condition benchmark does not imply or suggest that landscapes should be returned to this pre-disturbance condition. Reference condition benchmarks simply provide a common base to measure change against a common denominator.

Reference condition accounting is used extensively in the scientific literature to describe a standard or benchmark against which to compare the condition of an environmental asset or ecosystem.[22] It is also an appropriate measure for describing where ecosystems are approaching critical thresholds, which are common in complex ecosystems.[23,2425,26]

A reference condition score is a numerical comparison of an observed condition and that expected under a reference condition.[21] It is a number between 0 and 100, where 100 is a reference condition of an ecosystem as it would be had significant human intervention not occurred in the landscape, and 0 is where that ecosystem function is absent.

For example, one indicator of the condition of a terrestrial ecosystem is the extent of native vegetation cover. In many landscapes, the change in percentage of native vegetation can be directly related to a change in biodiversity.[27.] If there has been a decline in native vegetation in a region by 72% against a benchmark condition, that indicator would produce a reference condition score of 28(%).

Whilst a number of published definitions for reference condition exist, they all feature the common ecological principle that a healthy ecosystem can be described against a standard pre-disturbance baseline.[17,25,18, 32]

The reference condition can be a fixed point in time,[29]observed at reference condition sites,[30] or a scientifically accredited model that estimates the naturalness of the biota in the absence of significant human alteration.[22]

Using Reference Condition to construct Ecosystem Health Indicators

The task of accounting for the complexity of ecosystems is made possible by using the science of ecosystem health indicators. Ecosystem health indicators are quantifiable and transparent measures of the characteristics of the ecosystem that can detect change. With careful selection, they are capable of providing a simple measure for a complex system.[31]

The advantage of using ecosystem health indicators based on reference condition benchmarks is that it provides a context for interpreting change, and the magnitude and direction of that change.[32]

In order to capture the complexity of an ecosystem into numerical values, several indicators may need to be integrated to generate an index.[33] Standard accounting practices can be used to express this index, again on a scale between 0 and 100.

Ecosystem health indicators based on reference condition benchmarks are also conducive to statistical accounting because they create a standardised numerical unit capable of addition and comparison. They can assess and compare ecosystem status across regions and across ecosystems, upscale and aggregate across multiple spatial scales.

Ecosystem health indicators using reference condition methodologies were pioneered through the study of rivers, where there is a complex interaction of spatial, temporal and physical variation.[34,35,36] The reference condition approach for freshwater ecosystem assessment has been adopted by many countries because it allows different water bodies in different locations, including rivers, lakes or coastal waters to be compared on a common scale.[37,38,39]

This reference condition approach has now also been applied to terrestrial landscapes[40,41,42,43] and marine ecosystems.[44,45,46,47.]

There are many examples in Australia and internationally that use reference condition based ecosystem health indicators.

Examples from Europe and North America include:

- a legislated reference condition standard in EU countries (through the EU Water Framework Directive) for the ecological assessment of all EU water bodies;[48,49,] (this concept is currently being transferred across Europe to soil ecosystem assessment and monitoring);[50]
- river assessment systems in Britain (River Invertebrate Prediction and Classification System)[51] and the Canadian Aquatic Biomonitoring Network;[52]
- ecosystem indices (Index of Biotic Integrity[53]) have become the standard in the United States for assessing watershed health;[54] and
- fisheries management strategies which use an 'unfished biomass' benchmark to measure the current stock relative to that reference condition, set maximum sustainable yield levels and to identify thresholds of collapse.[55]

Examples in Australia include:

- the Australian River Assessment System (AUSRIVAS);[56]
- the 2008 Sustainable Rivers Audit for the Murray Darling Basin;[21]
- the 2009 Great Barrier Reef Outlook Report;[57]
- farm scale assessments of native vegetation in NSW[58] and Victoria;[41] and
- the South East Queensland Ecosystem Health Monitoring Program.

Fundamental to the acceptance of environmental accounting will be the level of confidence that the information being collected and choice of ecosystem health indicators is scientifically robust, accurate and reliable, and comparable across time and space.

Environmental accounting standards will therefore be required to guarantee the quality of data collection and a formal scientific accreditation process is required to ensure that the selection of indicators are suitable measures of the key environmental assets at the scale and location in which the accounts are constructed.

Why the focus on Regional Accounts?

While there have been many attempts to systematically measure the condition of environmental assets and ecosystems,[59,60] few have succeeded in providing comprehensive mechanisms that regularly measure and report on the state and change in condition of environmental assets or ecosystems.

Those that have been successful, have all been local or regional in scale, and/or asset specific.

As a consequence, those charged with managing the environment do not have the information they need to inform effective land use and environmental policy, nor make informed investment decisions.

There is an enormous amount of environmental monitoring and data collection already taking place in Australia: in local Councils, regional NRM groups, State government agencies, universities, Commonwealth research agencies, and non-government institutions.

Our problem is that almost none of the data currently being collected is in a form that can be used to guide policy and investment decisions.

The *Accounting for Nature* model starts with a fundamentally different premise, taken from the 100 years of experience in economic management of the industrial revolution: you create a common currency for all environmental assets, at all scales, make use of the vast range of existing information that is already being collected, and then aggregate this information to produce the environmental accounts that can be used (by Local government, regional, State, and national accounts), to guide investment decisions.

A regional reporting system is necessary simply because every region or catchment has unique environmental characteristics which need to be managed to cater for the specific pressures on these landscapes and environmental assets.

As a consequence, indicators of landscape health may vary from region to region so that they can best describe the health of an environmental asset in that locality.

Being able to use different indicators for different regions resolves the issue of having to agree on a set of common national indicators: you don't. At last count it was still about 200 after 10 years of argument.

Regional accounting also allows an essential feedback loop where monitoring informs on delivery and visa versa.

Regional Environmental Accounts Trials in Australia

In an effort to address one of the great failures of environmental policy, a trial of Regional Environmental Accounts is to be conducted across Australia, using the accounting concepts described in the *Accounting for Nature* model.

The regional natural resource management groups have decided to run these trials because monitoring, evaluation, and reporting is an integral part of their charter, and the quality of their decisions is dependent on the quality of information they have to inform those decisions.

They have come together with the single purpose of building a set of environmental accounts that measures the condition of key environmental assets, so that for the first time in our history, we will be able to systemically measure change, account for impact of our actions and monitor the success of our investments in improving or maintaining the health of our environmental assets.

Regional Environmental Accounts trials will be conducted in up to 10 of the 56 natural resource management regions across Australia over the next 12 to 18 months.

They will use reference condition benchmarks to construct ecosystem health indicators as a basis for building Regional Environmental Accounts.

These trials are not going to try and design and build a Ferrari. They are going to build a practical vehicle that we can roll off the production line in 12 months time, and we are going to design it so that over time it can evolve into a Ferrari.

The first set of regional accounts will draw on existing data wherever possible to create the environmental (ecosystem) stock accounts, and use time series information to establish historical trend (flow) accounts.

These trials will test, at a landscape scale and whether regional accounts are able to be aggregated to construct State and National Environmental Accounts.

If those of us in this conference here today truly seek to leave this world in a better condition than the one we inherited, we need to support these people who are at the coalface where lasting reform is created.

If they succeed, we will all be successful.

Conclusion

Let me conclude with these thoughts.

Every single environmental conflict, both here in Australia and across the world, has been hampered by the lack of environmental accounts that regularly measure the health and change in condition of our major environmental assets.

Without such information, it is impossible for government or the community to make informed judgements on these issues.

The lack of an environmental accounting framework is one of the great failures of public policy of our generation and is at the core of our environmental problems.

Public policy decisions on population, water reform, climate change, biodiversity loss and food security, are taking place in a vacuum, because we have no accounting system in place that can measure the impact these pressures are having on the Australian environment.

It has resulted in policy and land use decisions that have caused significant and unnecessary damage to our natural environment, it has resulted in the massive waste of billions of dollars of public funds aimed at repairing this damage, and now as climate change imposes its footprint on the Australian landscape, it means we do not have the tools in place to adapt to these changes.

The data will never be perfect and there will never be enough data. But environmental accounts that measure ecosystem health, even if they are built on imprecise data, are of far greater value than a system that is able to measure quantity more precisely.

There is no doubt that modern science is capable of providing the required information. There are decades of science dedicated to developing methods of measuring the health of ecosystems so that different assets and different indicators can be compared.

Satellites, computers, and the Internet have made it possible to choose from a range of possible ecosystem health indicators, and we are only at the beginning of this environmental information revolution. Satellites with photographic resolutions of two metres are now readily available,[61] Lidar and radar measurements are coming on line which can measure forest structures and observe forest cover change through cloud.[62]

We didn't have these tools in 1992, or in 1996 when Ian Lowe released our first SOE. But that was 14 years ago. It's 2010 and we have run out of excuses. Society has the right to expect better from us.

We are actually choosing not to use all this information and technology in the lame excuse we need more data before we do anything.

The science of reference condition based ecosystem indicators provides what economics already have – a common currency. With a common currency, environmental accounts allow decision-makers to make better decisions.

We should make better decisions.

Notes and References

1 "Natural resources consist of naturally occurring resources such as land, water resources, uncultivated forests and deposits of minerals that have an economic value" – definition in the System of National Accounts 2008.

2 "Natural capital is the extension of the economic notion of capital (manufactured means of production) to environmental goods and services. A functional definition of capital in general is: "a stock that yields a flow of valuable goods or services into the future". Natural capital is thus the stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future. For example, a stock of trees or fish provides a flow of new trees or fish, a flow which can be sustainable indefinitely. Natural capital may also provide services like recycling wastes or water catchment and erosion control. Since the flow of services from ecosystems requires that they function as whole systems, the structure and diversity of the system are important components of natural capital".

3 Robert Costanza; Cutler J. Cleveland (Topic Editor);. 2008. "Natural capital." In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [First published in the Encyclopedia of Earth February 26, 2007; Last revised July 31, 2008; Retrieved August 26, 2010]<http://www.eoearth.org/article/Natural_capital>

4 Stoneham paper (p2) references smith 1993, Morris 1997, Balmford 2003 and Jenkins 2003

5 UN 1993. Agenda 21: Earth Summit - The United Nations Programme of Action from Rio. *Integrating Environment and Development in Decision-making* (Chapter 8).

6 Australia State of the Environment 2006 Independent report to the Australian Government Minister for the Environment and Heritage. Beeton RJS (Bob), Buckley Kristal I, Jones Gary J, Morgan Denise, Reichelt Russell E, Trewin Dennis (2006 Australian State of the Environment Committee)

7 United Nations, 1993. SNA Handbook on Integrated Environmental and Economic Accounting, Statistical Office of the United Nations, Series F, No. 61, New York.

8 Meadows, D.H, D. L. Meadows, J. Randers, and W. W. Behrens III, 1972. The Limits of Growth. A Report for The Club of Rome's Project on the Predicament of Mankind. Universe Books, New York.

9 World Commission on Environment and Development, 1987. Our Common Future, Report of the World Commission on Environment and Development. Published as Annex to General Assembly document A/42/427, Development and International Co-operation: Environment.

10 United Nations, 1993. Agenda 21: Earth Summit - The United Nations Programme of Action from Rio. *Integrating Environment and Development in Decision-making*, Ch8.

11 United Nations, European Union, International Monetary Fund, Organisation for Economic Co-operation and Development, 2003. *Integrated Environmental and Economic Accounting.* Handbook of National Accounting, Ch1, p1.

12 Vardon, M., Lenzen, M., Peevor, S. and Creaser, M. (2007) Water Accounting in Australia. *Ecological Economics* 61: 650-659.

13 Council of Australian Governments, 2004. Intergovernmental Agreement on a National Water Initiative, and *Water Act 2007*.

14 As for note 5, p258

15 Weber, J., 2003. Development of Land and Ecosystem Accounts in Europe: Implementation of land cover accounts. *London Group meeting*. Rome.

16 Weber, J., 2007. Implementation of land and ecosystem accounts at the European Environmental Agency. *Ecological Economics*. 61: 695-707.

[17] Weber, J., 2007. Land and ecosystem accounts in the SEEA revision. *London Group meeting*, Brussels.

[18] Wentworth Group of Concerned Scientists, 2008. Accounting for Nature: A Model for Building the National Environmental Accounts of Australia. May 2008.

[19] For the purposes of environmental accounts in this paper we treat the condition (or health) of an environmental asset or ecosystem indicator as a 'stock', and a change in condition of that asset or indicator as a 'flow'.

[20] Cosier and McDonald, 2010. A Common Currency for Building Ecosystem Condition Accounts. *Paper prepared for the London Group on Environmental Accounting Meeting*, Chile, October 2010.

[21] Davies, P.E., J.H. Harris, T.J. Hillman and K.F. Walker, 2008. Sustainable Rivers Audit Report 1: A Report on the Ecological Health of Rivers in the Murray–Darling Basin, 2004–2007. Prepared by the Independent Sustainable Rivers Audit Group for the Murray–Darling Basin Ministerial Council.

[22] Stoddard, J.L, Larsen, D.P, Hawkins, C.P., Johnson, R.K. and Norris, R.H., 2006. Setting expectation for the ecological condition of streams: A concept of reference condition. *Ecological Applications*. 16(4): 1267-1276.

[23] Raudsepp-Hearne, C., Peterson, G.D., Tengo, M., Bennet, E.M., Holland, T., Benessaiah, K., MacDonald, G.K and Pfeifer, L., 2010. Untangling the environmentalist's paradox: Why is human well-being increasing as ecosystem services degrade? *Bioscience*. 60(8): 576-589.

[24] Chapin, F.S. III, Zavaleta, E.S.,Valerie, S.,Eviner, T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C., and Sandra Díaz. 2000. Consequences of changing biodiversity. *Nature,* 405, 234-242

[25] Scheffer, M., Carpenter, S., Foley, J.A. and Walker, B., 2001. Catastrophic shifts in ecosystems. *Nature,* 413: 591-596.

[26] Walker, B., and J.A.Meyers. 2004. Thresholds in ecological and social-ecological systems: A developing database. *Ecology and Society,* 9: 3.

[27] Rosenzweig, M. L., 1995. Species diversity in space and time. Cambridge University Press, Melbourne.

[28] Reference condition for fisheries stocks (mean equilibrium unfished biomass): "average biomass level if fishing had not occurred. Sometimes the pre-exploitation level is used as a proxy". (Australian Department of Agriculture, Fisheries and Forestry. 2007. Commonwealth Fisheries Harvest Strategy – Policy and Guidelines).

[29] For example, Australia often uses a 'pre-European settlement' date of 1750 (Norris, R.H. and M. Thomas, 1999. What is river health? *Freshwater Biology*. 41:197-210), North America uses a 'pre-Columbian' benchmark (Hughes, R. M., P. R. Kaufmann, A. T. Herlihy, T. M. Kincaid, L. Reynolds, and D. P. Larsen. 1998. A process for developing and evaluating indices of fish assemblage integrity. *Canadian Journal of Fisheries and Aquatic Sciences,* 55: 1618–1631) and Europe uses a 'pre-intensive agriculture' date. For Great Britain this has been defined as approx. 1850 (Wallin, M., T.Wiederholm, and R.K.Johnson, 2003. Final guidance on establishing reference conditions and ecological status class boundaries for inland surface waters. EU Common Implementation Strategy (CIS) for the Water Framework Directive.

[30] Reynoldson, T.B., Norris, R.H., Resh, V.H., Day,K.E., & Rosenberg, D., 1997. The reference condition: a comparison of multimetric and multivariate approaches to assess water-quality impairment using benthic macro-invertebrates. *Journal of North American Benthological Society*, 16: 833-852.

[31] Karr,J., 2006. Measuring Biological Condition, Protecting Biological Integrity. In: *Principles of Conservation Biology*, Third Edition, by Martha J. Groom, Gary K. Meffe, C. Ronald Carroll, and contributors, published by Sinauer Associates.

[32] Andreasen, J.K, O'Neill, R.V., Noss, R., and Slosser, N.C., 2001. Considerations for the development of a terrestrial index of ecological integrity. *Ecological Indicators*. 1: 21-35.

[33] Costanza, R., 1992. Toward an operational definition of ecosystem health. In Constanza, R Norton, B. and Haskell, B. (eds.). *Ecosystem Health: New Goals for Environmental Management*. Island Press, Washington.

[34] Karr, J.R., 1991. Biological integrity: a long-neglected aspect of water resource management. *Ecological Applications,* 1: 66–84.

[35] Wright, J. F., Moss, D., Armitage, P.D. & Furse, M.T., 1984. A preliminary classification of running-water sites in Great Britain based on macro-invertebrate species and the prediction of community type using environmental data. *Freshwater Biology,* 14: 221–256.

[36] Andersen, J.H., Conley, D.J. and Hedal, S., 2004. Palaeoecology, reference conditions and classification of ecological status: the EU Water Framework Directive in practice. *Marine Pollution Bulletin*, 49: 283–290.

[37] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities L 327, Brussels.

[38] Tett, P., Carreira, C., Mills, D.K., Leeuwen, S.van., Foden, J., Bresnan, E. and Gowen, R.J., 2008. Use of a phytoplankton community index to assess the health of coastal waters. – ICES *Journal of Marine Science*, 65: 1475-1482.

[39] Rheinhardt, R., Brinson, M., Brooks, R., McKenney-Easterling, M., Rubbo, J.M., Hite, J., Armstrong, B., 2007. Development of a reference-based method for identifying and scoring indicators of condition for coastal plain riparian reaches. *Ecological Indicators,* 7: 339–361.

[40] Swetnam, T.W., Allen, C.D., Betancourt, J.L.,1999. Applied historical ecology: using the past to manage for the future. *Ecological Applications,* 9: 1189–1206.

[41] Parkes, D., Newell, G., Cheal, D., 2003. Assessing the quality of native vegetation: the 'habitat hectares' approach. *Ecological Management and Restoration*, 4: S29–S38.

[42] Boer, M. and J. Puigdefabregas, 2003. Predicting potential vegetation index values as a reference for the assessment and monitoring of dryland conditions. *International Journal of Remote Sensing,* 24: 1135-1141.

[43] Nielsen, S.E., Bayne, E.M., Schieck, J., Herbers, J. and Boutin, S., 2007. A new method to estimate species and biodiversity intactness using empirically derived reference conditions. *Biological Conservation,* 137: 403–415.

[44] Pandolfi, J.M., Bradbury, R.H., Sala, E., Hughes, T.P., Bjorndal, K.A., Cooke, R.G., McArdle, D., McClenachan, L., Newman, M.J.H., Paredes, G., Warner, R.R., Jackson, J.B.C., 2003. Global trajectories of the long-term decline of coral reef ecosystems. *Science,* 301: 955–958.

[45] Worm, B., Hilborn,R., Baum, J.K., Branch, T.A.Collie, J.S., Costello, Fogarty, M.J., Fulton, E.A., Hutchings, J.A, Jennings, S., Jensen, O.P., Lotze, H.K., Mace, P.M., McClanahan, T.R., Minto, C., Palumbi, S.R., Parma, A.M., Ricard, D., Rosenberg, A.A., Watson, R. and D. Zeller, 2009. Rebuilding Global Fisheries. *Science,* 325: 578.

[46] Kruse, G.H., Ishida, Y. and C.I.Zhang. Rebuilding of depleted fish stocks through an ecosystem approach to fisheries. *Fisheries Research,* 100: 1–5.

47 Australian Department of Agriculture, Fisheries and Forestry, 2007. Commonwealth Fisheries Harvest Strategy – Policy and Guidelines.

48 R.C. Nijboer, R.K. Johnson, P.F.M. Verdonschot, M. Sommerhäuser and A. Buffagni, 2004. Establishing reference conditions for European streams. *Hydrobiologia*, 516(1): 9-105.

49 European Commission (DG Environment). Water Note 7 Intercalibration: A common scale for Europe's waters. Water Notes on the Implementation of the Water Framework Directive.

50 Breure, A.M., Mulder, C.M., Ro¨mbke, J., 2005. Ecological classification and assessment concepts in soil protection. *Ecotoxicol Environ Saf,* 62: 211–229.

51 Built on the methodologies of: Wright, J.F., Moss, D., Armitage, P.D. & Furse, M.T., 1984. A preliminary classification of running-water sites in Great Britain based on macroinvertebrate species and the prediction of community type using environmental data. *Freshwater Biology*, 14: 221-256, Moss, D., M.T. Furse, J.F. Wright, and P.D. Armitage, 1987. The prediction of the macro-invertebrate fauna of unpolluted running-water sites in Great Britain using environmental data. *Freshwater Biology.* 17: 41-52, and Wright, J.F. 1995. Development and use of a system for predicting macroinvertebrates in flowing waters. *Australian Journal of Ecology,* 20:181-197.

52 Environment Canada. 2004. www.ec.gc.ca/rcba cabin/default.asp?lang=En&n=D70D3175-1

53 Karr, J.R., 1981. Assessment of biotic integrity using fish communities. *Fisheries*, 6: 21-27.

54 http://www.epa.gov/bioiweb1/html/multimetric.html

55 Inter-American Tropical Tuna Commission, 2010. Tunas and Billfishes in the Eastern Pacific Ocean in 2008. Fisheries Status Report No. 7.

56 Simpson, J.C. and Norris, R.H., 2000. Biological assessment of river quality: development of AUSRIVAS models and outputs. Assessing the biological quality of fresh waters: RIVPACS and other techniques. 125-142.

57 Great Barrier Reef Marine Park Authority, 2009. Great Barrier Reef Outlook Report, 2009. Australian Government, Townsville.

58 Gibbons, P., Ayers, D., Seddon, J., Doyle, S. and S Briggs. 2005. BioMetric Version 1.8. A Terrestrial Biodiversity Assessment Tool for the NSW Property Vegetation Plan Developer. Operational Manual. New South Wales Department of Environment and Conservation.

59 Internationally, examples include the 2005 UN Millennium Assessment; the 2007 UNEP Global Environmental Outlook; and the 2010 World Bank World Development Report: Development and Climate Change.

60 In Australia, examples include national State of the Environment Reports in 1996, 2001, 2006, and 2011; the 2001 National Land and Water Resources Audit; and the Australian Bureau of Statistics, 2008. *Australia's Environment: Issues and Trends 2007.*

61 Asner, G. P., Palace, M., Keller, M., Pereirs Jr., R., Silva, J. N. M. and Zweede, J. C., 2002. Estimating canopy structure in an Amazon forest from laser range finder and IKONOS satellite observations. *Biotropica,* 34: 483-492.

62 G. P. Asner, G. V. N. Powell, J. Mascaro, D. E. Knapp, J. K. Clark, J. Jacobson, T. Kennedy-Bowdoin, A. Balaji, G. Paez-Acosta, E. Victoria, L. Secada, M. Valqui, R. F. Hughes, 2010. High-resolution forest carbon stocks and emissions in the Amazon. *Proceedings of the National Academy of Sciences,* 107 (38): 16738-16742.