Marine Reserves : The need for systems

W. J. Ballantine and T. J. Langlois

Leigh Marine Laboratory, University of Auckland.
Box 349, Warkworth, New Zealand. E-mail b.ballantine@auckland.ac.nz

Keywords: marine reserves; systems; scientific benefits; professional duty

Abstract

Highly-protected Marine Reserves are areas of the sea in which human disturbances are minimised so that the full natural biological diversity is maintained or, more often, allowed to recover to a more natural state.

Europe has very few Marine Reserves, they are very small and almost all are in the Mediterranean. There are at present no official plans to create effective systems of Marine Reserves.

Europe has many so-called Marine Protected Areas (MPAs). These are marine areas with some extra regulations or planning procedures. MPAs aim to make human activities more efficient and more sustainable. MPAs are user-orientated, knowledge-based, locality-dependent, problem-solving extensions of standard marine planning and management.

Marine Reserves are quite different. All extractive and potentially-disturbing human activities are prohibited. The burden of proof is reversed; no evidence of damage or danger to particular species or habitats is required; all marine life is protected on principle.

The concept of Marine Reserves is simple and practical, but because it is new, different and additional to existing marine management, the idea is seen by many as revolutionary.

Basic biological principles and practical experience in many countries make it clear that Marine Reserves are important to science and education, essential for conservation, and useful in resource management. These features apply in all regions and ecosystems. They are independent of climate, biogeography, current human activities, and the present management. Representative and viable systems of Marine Reserves are needed in all regions.

Fishing and other human disturbances have been widespread and intensive for so long that it is very difficult to predict the stages of recovery that occur in Marine Reserves. Furthermore, while some features change rapidly (e.g. numbers of previously targeted species), recovery continues for a long time (e.g. 4^{th} and 5^{th} order trophic and structural changes after >25 years).

None of this alters the fact that in scientific terms, Marine Reserves are controls not manipulations. Such controls are required if scientists are to understand the intrinsic processes and obtain data that are not confounded by human activities (e.g. separating natural variation from fishing effects).

No significant progress will be made to establish Marine Reserves in Europe until scientists speak out strongly and clearly on the issue. We consider it is part of our professional duty as marine biologists to state publicly and frequently the need for a representative, replicated, networked and sustainable system of highly-protected Marine Reserves. We doubt if our grandchildren will accept any excuses if we fail.

I Introduction

Marine Reserves are places in the sea that are left undisturbed so that they continue in their natural state or recover towards a more natural state. No fishing of any kind is permitted, no removal of anything (living, dead or mineral), no dumping, dredging, constructions or direct pollution. Within these restrictions, people are encouraged to appreciate and study the marine life that develops in the reserves.

Europe has very few Marine Reserves, they are all small and largely restricted to the Mediterranean. For instance, the UK has only one such reserve ($3km^2$ off Lundy Island, in the Bristol Channel). There are no official plans to develop systems of such reserves anywhere in Europe.

Europe has many Marine Protected Areas (MPAs) under a very wide range of labels. MPAs are areas with some extra regulations or planning procedures. They may be organised at local, regional or national levels by a large number of authorities (e.g. fishing, transport, defence, conservation, mining, erosion or pollution control, etc.). MPAs are problem-orientated. They aim to reduce conflicts between human activities and make these activities more efficient, more effective or more sustainable. They are extensions of standard marine planning. MPAs concentrate on solving problems that have arisen. They depend on detailed information about the activities in each area, and what impact these have on particular species and habitats.

Marine Reserves are completely different. All potentially-disturbing activities are prohibited. The burden of proof is reversed, no evidence of damage or danger is needed. All marine life is protected. The concept is simple to state and can be understood easily by non-experts. Marine Reserves are a practical idea, because most people (once they think about the idea at all) feel it is sensible and worthwhile to ensure the continued existence of the full range of marine life and its processes.

But it is a new idea, it requires new laws and new attitudes. It is different and additional to existing forms of marine planning and management. Because of these features, Marine Reserves are generally regarded by policy makers as revolutionary. Most professional marine planners and managers are restricted to specific sectors (fishing, shipping, mining, etc), have little knowledge of wider aspects and are not asked to concern themselves with the total effect of human activities on marine life (Ballantine, 1999 and 2001)

In this paper we argue that Marine Reserves are essential for conservation, have important benefits to science and are necessary for effective management. These benefits are so basic that we believe it is the professional duty of marine scientists in general, and marine biologists in particular, to propose and support the establishment of systems of reserves.

II Background

Although Marine Reserves have scarcely been considered in Europe, there is considerable practical experience in other regions (Roberts & Hawkins, 2000; Sobel & Dahgren, 2004). In New Zealand the first Marine Reserve was established in 1975 adjacent to the laboratory where we work. There are now 32 reserves, covering a wide range of latitude, biogeography and habitat. Some are around remote oceanic islands, others are within the boundaries of metropolitan Auckland. They include fiords, harbours, and open coasts. At least 12 of these are more than 10 years old.

While there is often considerable and lengthy discussions before a reserve is established (the first took 12 years!), within a few years of creation they prove to be socially popular, scientifically useful and important in conservation terms.

Action in New Zealand was continuous and has accelerated recently, but it was slow and included many unhelpful side tracks. The present scatter of marine reserves in New Zealand is still far from a adequate system. However the experience to date has allowed the recognition and development of the essential principles for such systems. It is now possible for other regions to move much more rapidly and effectively, provided these principles are accepted.

This is already happening. The first representative system of Marine Reserves in the world was established in Victoria, Australia in 2002. A year later a representative and replicated system was created round the northern Channel Islands off the California coast. In 2004 a major system, comprising at least 25% by area of 73 bioregions, was established in the Great Barrier Reef Marine Park (Australia). For more details see Chapter 11 in Sobel & Dahlgren (2004). In August 2006, the California Fish and Game Commission approved a set of no-take marine reserves in Central Region of the mainland coast comprising 8% of state waters (see www.dfg.ca.gov/news/news06/com06004.html).

III The Benefits of Marine Reserves to science

Marine Reserves provide many benefits to science and these cover a wide range, from simple practicalities, through improved research opportunities to advances in basic theory and understanding. Although, with hindsight, most of these benefits seem straightforward, indeed, rather obvious, few were planned or predicted, and each year more benefits are being discovered and demonstrated.

A. Practicalities

Scientists have no more rights in marine reserves than anyone else, but the managers of reserves will generally permit and licence scientific projects if these are carefully designed to involve only trivial and temporary disturbance and to provide interesting and useful information. This licensing is very important. It means that the protection of the reserve is extended to the scientific project including apparatus, markers and actual experiments. It is difficult to explain to those who have not seen this happen how much it increases the scientific opportunities and freedom of action. In effect, the entire reserve becomes an extension of the scientist's laboratory bench and aquarium tanks.

(i) **Protection**

This can cover:

(a) All forms of apparatus and equipment, from simple temperature sensors, through tide gauges, wave buoys, current meters, video cameras and microphones to complex multi-level systems.

(b) Marker buoys, pegs, tagged individuals, transplanted specimens, permanent quadrats, acoustic trackers and fixed photographic sites.

(c) Experiments and manipulations on the shore and sub-tidally, including settlement plates, cages and fences for density manipulation, habitat alterations and in-situ samplers.

In theory such protection can be arranged without a marine reserve, but this usually involves complex negotiations with a range of authorities and the problem of informing the public that special protection exists.

(ii) **New levels of interest**
Marine reserves automatically generate new levels of interest in scientists, policy makers and the general public. They also provide a practical focus and reason for action. Many types of study, while possible anywhere, are greatly encouraged and supported by the existence of a marine reserve.

These include (examples from the Leigh reserve):
(a) Detailed behavioural and taxonomic studies
e.g. the separation of 13 species of Tripterygiidae each with 3 colour forms.
(b) Provision of identification guides (printed and photographic) and biological reviews. e.g for fish (Thompson, 1984)
(c) Detailed surveys and habitat mapping
e.g. a habitat map at 1: 2000 was made at the time of establishment (Ayling et al. 1981), and a second survey (using modern techniques) was made in 2006.
(d) Long-term physical monitoring
e.g. Daily air and sea climate recording, e.g. Ballantine (1982).

(iii) **More support and cooperation**
The increased levels of interest and focus produce positive feedbacks (the actual examples are from the Leigh reserve).
(a) The greater number of scientists increases the chances of observing and recording events that are rare, local or sudden but ecologically important (e.g. free spawning in gastropods, disease mortality in echinoids, die-back in kelp, and algal blooms).
(b) The greater range of scientific projects encourages interdisciplinary studies (e.g. the relation between climate anomalies and any biological phenomena, Rhodes et al, 1993).
(c) With more workers and projects, equipment and facilities can be shared and financial support is possible where no single project would warrant it (e.g. aerial photography with helicopters and long-term monitoring of phytoplankton chlorophyll, Rees, 2003).

B. Opportunities for improved understanding

(i) **Ecological changes within marine reserves**
As soon as a high level of protection from human disturbance is provided by the establishment of a marine reserve a wide range of changes begin to develop in the reserve. There are so many of these that, even in the best-studied and longest-established reserves, more changes are recognised every year.

The examples given in Table 1 are from NE New Zealand and include 3 replicate reserves. All the examples have been measured and those in **bold** type have been published. For more details see Babcock (2003) and Langlois & Ballantine (2005).

These changes are multiple, complex and often ecologically important. Some changes (e.g. Stages 1- 3) form a trophic cascade, but others are the result of changes in structure. Few of the species in Stage 4 feed on kelp, but they require it as a substrate or shelter.

The changes continue to develop (for at least 30 years at Leigh) and there is no theoretical limit to this development. New changes are still being discovered and pre-existing ones recognised. The changes interact with large and small scale natural variations (e.g. El Nino events and local storms), and with each other.

Once the changes are observed, explanations are often clear, but the changes were not predicted or, in most cases, even thought about beforehand. For new reserves, the trends, amplitudes and timing of the changes are not predictable, because of the large number of variables involved. In the Te Angiangi reserve, snapper have not yet increased but the rock lobster increases were very large and rapid. The opposite occurred at the Poor Knights reserve.

Table 1 Ecological changes in marine reserves (NE New Zealand)

Stage	Sign	Organisms involved
1st stage	Increases	**Snapper** (sparid) and **rock lobster** (palinurid)
		Numbers, sizes, biomass and fecundity
2nd stage	Decreases	**Sea urchin** (echinoid) **numbers and dominance**
		Large bivalves
		Cryptic fish
3rd stage	Increase	**Kelp forest** (laminarian) and coralline algal turf
4th stage	Increases	Mobile epifauna (small crustaceans) around kelp
		Sessile fauna on kelp fronds
		Canopy sheltering fish
		Kelp derived POC and DOC
5th stage	Increase	Juvenile spotties (labrid) feeding on mobile epifauna

An example of some of the complexities affecting the recover of kelp forest (*Ecklonia radiata* (C.Ag) is given in Table 2. The driving force is the reduction of grazing by the sea urchin *Evechinus chloroticus* (Valenciennes) due to predation by large crayfish *Jasus edwardsi* (Hutton) and snapper *Pagrus auratus* (Bloch and Schneider**)**, but many factors can speed up or delay the recovery of the kelp

Table 2. Factors affecting the recovery and of kelp forest (*Ecklonia radiata*)

Slower development	Faster development
a) Severe wave action tearing off larger plants, especially in shallow water **	a) Calm weather conditions increasing *Ecklonia* growth *
b) Lengthy algal blooms reducing light, especially in deeper water *	**b) Urchin mortality** due to toxic or smothering algal blooms *
c) Development of coralline algal turf, inhibiting *Ecklonia* recruitment	c) Urchin mortality due to disease
d) Increased (compensatory) grazing by gastropods (e.g. *Cookia sulcata* (Gmelin))	**d) Increased *Ecklonia* recruitment**
e) Increased sand movement and/or deposition inhibiting *Ecklonia* recruitment**	e) Deceased sand movement and/or deposition *
f) Increased urchin recruitment	f) Reduced urchin recruitment
References: Babcock et al. (1999)	**Bold type** effects have been measured
Parsons et al. (2004)	* more likely in El Nino conditions
	** more likely in La Nina conditions

(ii) New comparisons

In most of science, and especially in ecology, improved understanding develops mainly from comparisons. The establishment of Marine Reserves allows a whole range of new comparisons, at least 8 of which have already been used in experimental designs.

Table 3 Ecological comparisons possible with marine reserves

Comparative study	No. of examples
Inside a single marine reserve to outside it	++
Inside a reserve to outside over time	++
Replicated marine reserves to outside	++
Different distances from marine reserve boundary	+
Different sizes of marine reserves	+
Inside and outside reactions to severe natural changes	+
Different dates of reserve establishment	++
Degree of protection (no-take reserves versus partial bans)	+
References: Edgar & Barrett (1999); Langlois et al. (2006); Shears et al. (2006); Willis et al. (2001); Willis et al. (2003).	+ 1 or 2 ++ >2

As systems of reserves are established a further range of comparison will be possible including changes outside reserves, which will vary with the proportion of the region in marine reserve (Ballantine, 2003b).

C. Increased scales of time and space

Most manipulative experiments in marine ecology have space scales measured in metres, marine reserves offer the opportunity to operate in kilometres. Scale effects can be very important and are not necessarily predictable. Small scale manipulations of sea urchins at Leigh did not suggest the changes that occurred at a reserve scale.

Most research projects are limited by the time scales of grants and individual careers. Marine reserves are permanent and do not have any direct cost to the scientists.
Time lags in trophic cascades at Leigh included 5-7 years for the main predators to recover, a further 10 years for them to abolish grazer control and at least 3 more years for kelp recovery. This picture was built up through several projects and multiple researchers (Babcock et al, 1999).

D. Provision of controls and baseline information

Controls are essential for scientific understanding and baselines are important for scientific measurements. Marine Reserves provide controls for all direct human disturbances and more natural baselines for impact measurements.

In a standard experimental design, the scientist arranges the manipulation and merely selects the control areas. But Marine Reserves need to be set up, and manipulations continue to occur everywhere else. Normally, no changes are expected in the control areas (except natural variation), Marine Reserves continue to change in many ways, while the manipulated areas (outside) may not.

None of this alters the fact that in scientific terms, Marine Reserves are controls not manipulations. Such controls are necessary if scientists are to obtain data and understanding that is not confounded by human activities (e.g. separating natural variation from fishing effects). Despite the shifting baseline, marine reserves provide the only objective measures of human-induced impacts and, hence, ecosystem health (Ballantine, 2003a and b).

IV The wider benefits of marine reserve

Politicians do not rush to make new arrangements simply because these offer special advantages to scientists, especially if such arrangements require new and, possibly controversial, legislation. Fortunately, marine reserves have many wider benefits, which have strong appeal to the general public, as well as scientific value.

A. Advanced training

This includes:

(i) Practical courses for tertiary students in many aspects of marine science.
(ii) Special courses for post-graduate students (e.g. underwater fish identification).
(iii) A range of professional courses (e.g. habitat classification and mapping).
(iv) Advanced diving courses (e.g. night diving and fish behaviour).

B. Education

Primary and secondary school trips to the Marine Reserve at Leigh are now common, and several educational tour operators specialise in arranging these. Whole classes as young as 11 years old go snorkelling in the reserve. Education kits have been published (e.g. Whitley et al, 1995 and Walsby, 2003). An education centre with an aquarium and library has set up nearby. The reserve is a favoured location for dive training.

C. Public awareness and recreation

Large numbers of the public visit marine reserves (~300,000 per year at Leigh). These numbers are at least 10 times greater than for nearby areas where fishing is permitted. Many programmes exist to increase public knowledge and enjoyment of the marine life they find there. These include displays on adjacent land, a glass-bottomed boat at Leigh, hire centres for snorkel and SCUBA gear, dive charter boats, videos (e.g. Ballantine, 1993), popular books (e.g. Enderby, 2006), magazine articles (e.g. Warne, 2006 and 2007), and pamphlets (e.g. Walsby, 2001).

D. Conservation

The primary aim of marine reserves is the conservation (or recovery) of the full range of marine life and its intrinsic processes. This primacy has four aspects: its importance, practicality, self-evidence and the inter-relationships with other benefits.

(i) It would be difficult to exaggerate the level of importance. Although our knowledge of biogeochemical cycles and climate control processes is still limited, it is already clear that marine life is an essential part of these. The future of the human race depends on maintaining these processes, regardless of our present levels of understanding.

(ii) Even in Europe, our knowledge of marine life is still at a low level. Many species remain to be described, many habitats are not yet mapped and we only know some examples of the ecological processes that are involved. While we must use the knowledge we have, it would very unwise to assume it is sufficient for all purposes. The only practical way to ensure full conservation is to keep representative areas free from all exploitation.

(iii) The fact that marine reserves are less disturbed and more natural than areas that are fished, dredged, mined, dumped on, etc. is self-evident and requires no detailed data.

(iv) All the other aims and benefits of marine reserves are largely dependent on the success of conserving a high level of undisturbed marine life.

Standard science - which involves the determination of detailed facts, their careful analysis and the 'reduction' of problems so that precise conclusions can be clearly stated - is not very helpful when we are trying to conserve the full range of marine life and its processes (including those that are little known or even undiscovered).

In particular, it is not helpful to reduce biodiversity to some simple indices of species or groups. As well as the major phylogenetic groups, their species richness, and abundance, biodiversity includes many aspects, for example –

- Size ranges
- Metabolic diversity (including mutualisms and parasites)
- Genetic, physiological and developmental diversity within, as well as between species
- Behaviour and movement
- Life histories
- Biogeography
- Ecosystems, habitats and communities
- Patterns in time, including large-scale biogeochemical cycles, ENSO. etc.

The general public is very ignorant about marine life and its diversity because it is so different from their terrestrial experience. However, for precisely the same reason, the public is very interested in any aspect of marine life that is brought to their attention and they intuitively recognise the range of diversity.

E. Resource management

Most discussion about marine reserves focuses on fishing. This is unfortunate for three reasons.

(i) We need marine reserves whether or not they do anything for fishing.

(ii) Although it is likely that marine reserves will assist fishing in various ways, it is not possible to predict these in any precise sense.

(iii) It is rarely possible to prove such effects even when they have occurred (because fishing adapts rapidly to every type of change, Ludwig et al. 1993).

The most important use of marine reserves for marine management is the provision of better information. In particular, marine reserves allow us (for the first time) to unequivocally separate natural changes from human-induced events (especially fishing). For example –

(i) The major decline in crayfish in the Leigh region in the mid 1990s was not a fishing effect since it occurred (proportionately) inside the reserve as well as outside (Kelly et al. 2000).

(ii) The 'urchin barrens' habitat at Leigh is a fishing effect, since it slowly disappears inside established reserves but remains (or increases) in fished areas. (Babcock et al. 1999).

(iii) Snapper abundance at Poor Knights Is. was severely limited by recreational fishing, since it recovered spectacularly when the area became a fully-protected marine reserve (Denny et al. 2004)

Recently the phrases – 'sustainable development', 'ecosystem health' and 'spatial planning' – have become popular in marine policy and planning circles (e.g. Defra, 2006). Without systems of Marine Reserves such slogans are likely to remain pious hopes, but marine reserves would provide the objective standards necessary to make them a practical reality. How could we know the state of health of an ecosystem unless some parts of it were free from human disturbance ? How could we determine what was sustainable unless we had areas that were not exploited ? The spatial planning of a region needs a standard zone which provides the unexploited baseline for the major habitats.

V The need for principles and systems

The main benefits of marine reserves to science are largely independent of region, ecosystem or habitat, and are completely independent of political boundaries. It is important to science to establish a full system of such reserves in every region. These systems need to be based on principles which are acceptable to both professionals and the public. Such principles must be clear and either self-evident or demonstrable. It is the responsibility of scientists to provide and explain these principles. Fortunately, most of this work has already been done, but the results have not yet been given much publicity, even in scientific circles.

The wider benefits of marine reserves, especially those to conservation, are sufficiently obvious to warrant the support of any thoughtful citizen, but the ordinary public needs its intuitive views given formal and public backing by scientists, if the politicians are to resist the claims of those profiting from the status quo.

The United Nations technical expert group on the conservation of marine biodiversity produced its final report in 2004 (CBD, 2004). This includes the necessary principles for marine reserves (described there as Highly-Protected Marine and Coastal Areas). These are summarised below. Statements in “quotation marks” are from pages 23-25 of CBD (2004).

A. For each reserve:

1. High levels of protection
All species are protected “because ecological interactions are complex and mostly unknown. Allowing any fishing jeopardizes goals of maintaining ecological structure and function and confounds the scientific ability to achieve understanding.”

2. Permanence
“The protection …. should be permanent” because reversion to more natural conditions continues for a long time and the benefits accumulate over time. “Long term changes cannot be effectively measured if highly protected areas are temporary.”

3. Viability
Each reserve should be “large enough so that most ecological processes will be able to operate within the area”. Reserves “should also be legally and socially viable”. “Boundaries should be simple to identify and enforce.”

B. For the system

1. Representation
“All biogeographic regions should be represented. Within each region, all major habitats should be represented.” We must resist attempts to restrict this representation by the application of any theory or assumption. We do not want just the well-studied areas, the biodiversity hotspots, the rare or beautiful, the places considered important with existing information, those known to be under threat, or those under any particular jurisdiction.

2. Replication
“All habitats in each region should be replicated within the network, and these should be spatially separate, to safeguard against unexpected failures or collapse of populations.”

3. A network arrangement
"A network design should be prepared for each national or regional area, including the exclusive economic zones and the High Seas". The reserves should be spread across the whole region to provide –

Maximal connections (including larval dispersal) between all areas.
An additional range of natural variation (both known and unknown).
Spread of benefits (and any inconveniences).

4. A sustainable amount
"The ultimate objective is to create a network of geographically dispersed sites that is self-sustaining, independent (as far as possible) of what happens in the surrounding area." Each reserve should be as ecologically viable as possible, but the whole system must be capable of sustaining itself. System size would be measured as the percentage of the area at each level – region, ecosystem and habitat.

Some guidelines -
At least 10% by area of all bioregions and habitats is needed for science and education.
To ensure conservation, we would need at least 20% of each region, ecosystem and habitat.
To maximise benefits to fisheries this should rise to 30%.
In regions of very intensive use, it would be sensible to aim for at least 50%.

VI Conclusions

1. When marine reserves are established the range of benefits proves to be large, and many of these are important, but most of them are surprises and were not predicted even by the proponents.
2. When high-levels of protection are provided by marine reserves the ecological changes that occur are multiple, complex and on-going. Again, few if any, of these are predictable.
3. It is self-evident that marine reserves are a highly-effective means for conserving (or recovering) the full range of marine biodiversity. Indeed, marine reserves are the only practical method for ensuring this.
4. Marine reserves are important to science in many ways. The most important is that by acting as controls for the effects of human disturbance, they provide for the first time a practical and objective method for determining the basic (natural) content and processes of marine life.
5. It is time for Europe to take action to establish systems of marine reserves that are representative, replicated, networked and sufficiently large to be sustainable.
6. It will be necessary for marine biologists to lead in this matter, and we have a professional duty to do so. At present no one in government has the job of promoting marine reserves. There is a policy vacuum. Unless we, as professionals capable of understanding the issues, speak out clearly and strongly, little will happen. The planners, politicians and the public need to be told that, while the interests of existing user groups are important, the key issue is what will be maintained for the next generations. The great majority of the general public, once the idea is presented to them, find this reasonable and worthwhile. The politicians take their cue from the public (voters). The existing policy makers and planners will tend to resist, but will take instructions from the politicians.

Acknowledgements

This review covers more than 30 years of investigations by a large number of workers. We wish to thank them all - especially (in alphabetical order) Tony Ayling, Russ Babcock, Chris Battershill, Howard Choat, Bob Creese, Chris Denny, Debbie Freeman, Roger Grace, Dennis Gordon, Tim Haggitt, Geoff Jones, Shane Kelly, Vince Kerr, Mike Kingsford, John Morton, Allie MacDiarmid, Darren Parsons, Emma Rushcombe, Nick Shears, Sue Thompson, Natalie Usmar, Jarrod Walker, Kathy Walls, John Walsby, Kim Westerskov, and Trevor Willis.

References

Ayling, A.M., A. Cumming, & W. J. Ballantine, 1981 Map of shore and sub-tidal habitats of Cape Rodney to Okakari Point Marine Reserve, North Island, New Zealand in 3 sheets, scale 1: 2000. Department of Lands and Survey, Wellington.

Babcock, R.C. 2003 The New Zealand marine reserve experience: the science behind the politics. 105-119 in Hutchings. P. & S.D. Lunney, Conserving marine environments: Out of sight, out of mind. Royal Zoological Society of New South Wales, Mossman.

Babcock, R. C., S. Kelly, N. T. Shears, J. W. Walker, & T. J. Willis, 1999 Changes in community structure in temperate marine reserves. Marine Ecology Progress Series 189: 125-134.

Ballantine, W. J. (ed), 1982 Sea surface temperatures. Leigh Laboratory Bulletin No 5. 43pp. University of Auckland.

Ballantine, W. J., 1999 Marine reserves in New Zealand: The development of the concept and the principles. In Proceedings of an International Workshop on Marine Conservation for the New Millenium, 3-38. Cheju Island, Korea: Korean Ocean Research and Development Institute. Available at www.marine-reserves.org.nz

Ballantine, W. J., 2001 Marine Reserves. Paper presented to the first meeting of UN experts on marine biodiversity (AHTEG). 10 pages. Available at www.marine-reserves.org.nz

Ballantine, W. J., 2003a Scientific principles for marine reserve systems. MPA News 4 (9): 5.

Ballantine, W. J., 2003b Practical action with marine reserve systems. MPA News 4 (10): 5.

CBD (Convention on Biological Diversity), 2004 Technical advice on the establishment and management of a national system of marine and coastal protected areas. Secretariat of the Convention of Biological Diversity. 40 pp. CBD Technical series 13.

Defra, 2006 A Marine Bill: A consultation document. 309 pp. Department for Environment, Food and Rural Affairs, London.

Denny, C. M., T. J. Willis & R. C. Babcock, 2004 Rapid recolonisation of snapper *Pagrus auratus* Sparidae within an offshore island marine reserve after implementation of no-take status. Marine Ecology Progress Series 273: 183-190.

Edgar, G.T. & N. S. Barrett, 1999 Effects of marine reserves on Tasmanian reef fish, invertebrates and plants. Journal of Experimental Marine Biology and Ecology 242: 107-144.

Enderby, J. & T. Enderby, 2006 A guide to New Zealand's marine reserves. 176 pp. New Holland Publishers, Auckland.

Kelly, S., D. Scott, A. B. MacDiarmid, & R. C. Babcock, 2000 Spiny lobster, *Jasus edwardsi*, recovery in New Zealand marine reserves. Biological Conservation 92: 359-369.

Langlois, T. J., M. J. Anderson, R. C. Babcock, & S. Kato, 2006 Marine reserves demonstrate trophic interactions across habitats. Oecologia 147: 134-140.

Langlois, T. J. & W. J. Ballantine, 2005 Marine ecological research in New Zealand: developing predictive models using no-take marine reserves. Conservation Biology 19: 1763-1770.

Ludwig, D., R. Hilbron, & C. Walters, 1993 Uncertainty, resource exploitation and conservation: lessons from history. Science 260: 17 and 35.

Parsons, D. M., N. T. Shears, R. C. Babcock, & T. R. Haggitt, 2004 Fine-scale habitat change in a marine reserve, mapped using acoustically positioned video transects. Marine and Freshwater Research 55: 257-265.

Rees, T. A.V., 2003 Safety factors and nutrient uptake by seaweeds. Marine Ecology Progress Series 263: 29-42.

Rhodes, L. L., A. J. Haywood, W. J. Ballantine, & A. L. MacKenzie, 1993 Algal blooms and climate anomalies in north-east New Zealand August-December 1992. New Zealand Journal of marine and freshwater research 27: 419-430.

Roberts, C. M. & J. P. Hawkins, 2000 Fully Protected Marine Reserves: A Guide. WWF Endangered Sea Campaign, Washington D.C.

Shears, N.T., R. V. Grace, N. R. Usmar, V. Kerr, & R. C. Babcock, 2006 Long-term trends in lobster populations in a partially protected vs. no-take Marine Park. Biological Conservation 132: 222-231.

Sobel, J. & C. Dahlgren, 2004 Marine Reserves: A guide to Science, Design and Use. 383 pp. Island Press, Washington D.C.

Thompson, S., 1981 Fish of the Marine Reserve: A guide to the identification and biology of the common coastal fish of north-eastern New Zealand. Leigh Laboratory Bulletin No 3. University of Auckland.

Walsby, J.R., 2001 Cape Rodney – Okakari Point Marine Reserve: The Underwater World. A3 pamphlet. Department of Conservation, Auckland.

Walsby, J. R., 2003 (3rd edition) Marine Reserves Education Kit. 158 pp. Department of Conservation, Auckland.

Warne, K., 2006 Poor Knights – Rich Seas. New Zealand Geographic 78: 52-75.

Warne. K. 2007 Blue haven. National Geographic 211 (4) : 70-89.

Whitley, J. & W. J. Ballantine, 1995 Marine Reserves: An education resource kit. 86 pp. Leigh Marine Laboratory, University of Auckland.

Willis, T.J., R. B. Millar, & R.C. Babcock, 2003 Protection of exploited fish in temperate regions. Journal of Applied Ecology 40: 214-227.

Willis,T.J., D. M. Parsons, & R. C. Babcock, 2001 Evidence for long-term site fidelity of snapper (*Pagrus auratus*) within a marine reserve. New Zealand Journal of marine and freshwater research 35: 581-500.