

7 Conclusions

After somewhat tentative global assessments of climate change in the 1990s, the latest IPCC (2001a) Third Assessment Report has concluded that human-induced global warming is already a detectable reality. Global average sea level has already risen by 0.1 to 0.2 m over the 1900s. Most likely projections on global sea-level rise are for a further 0.14 to 0.18 m by 2050 and 0.31 to 0.49 m by 2100. The IPCC projects that sea level will continue to rise for several centuries, even with abatements in greenhouse gas emissions and stabilisation in concentrations.

In New Zealand, western parts are projected to be wetter, but it should be drier in the east. This change in rainfall distribution, coupled with any changes in waves, winds and storms, could well alter the sediment supply to estuaries and the coast. Any reduction in sediment supply, along with storm impacts that ride on the back of a higher sea level, will lead to more coastal erosion.

There will be regional and local differences from the global projections. More targeted research, modelling and monitoring are required to translate global projections to likely regional effects.

Impacts on coastal margins arising from climate change are summarised in Figure 13. Sea-level rise and changes in sediment supply will dominate the effects on the physical environment, while rising sea and estuary temperatures, high doses of silts/muds during storms, and human intervention (such as stopbank protection, which may decrease intertidal flats) will be key drivers of changes in aquatic ecosystems.

Three broad options have been proposed to respond to coastal climate change threats in coastal margins: planned retreat, accommodation or adaptation, and protection. Figure 21 summarises the range of response options for open coasts and estuaries.

Protection measures such as seawalls, stopbanks, beach renourishment and pumping systems may protect property for several decades, but these are likely to be increasingly ineffective as sea-level rise accelerates and/or storm intensity and frequency increase. However, some regional councils and territorial authorities will be faced with difficult situations. For instance, existing communities that will be seriously threatened may have capital investment sources available locally to implement protection measures, but the current resource management framework under the RMA focuses on enhancing the natural character of the coast and minimising environmental effects. Hard protection measures usually result in further environmental loss of salt marshes, estuary intertidal areas and beaches – with detrimental effects on ecosystems, sources of kaimoana, recreation, and tourism. Soft protection options, such as raising the elevation of beaches and adjacent land by way of renourishment with additional sand or fill respectively, are more appropriate options. However, they will not be feasible in many locations, and would require extraordinary financial and political commitments into the indefinite future to maintain, in situations where they only benefit a small number of people.

Adaptation or retreat measures – such as elevation of structures, infrastructure (roads, railways) and land surfaces, and land-use designations that only allow shorelines to retreat naturally – are less disruptive response strategies. However, most of these options will require strategic action; few will occur autonomously. They will be challenging to implement in areas already highly developed.

Confronting coastal squeeze and the eventual loss of some beaches, coastal marshes/wetlands and estuary intertidal areas will require better information on the existing and future value of these recreational assets and habitats. Susceptibility of marshes and intertidal areas to future loss to sea-level rise, storms, temperature rise and altered freshwater run-off, and what these mean to ecosystems, will have to be addressed in the context of geomorphic setting, degradation that has already occurred and the extent of physical constraints on further landward retreat, such as bunding, stopbanks, housing estates, and road or rail causeways.

Solutions for mitigating damage caused by sea-level rise are complex, particularly where they involve people's homes and recreation areas, or are culturally significant (for example, marae, urupa, middens, sources of kaimoana). Because climate change effects will be widespread along the coastline, there will be no reasonable or cost-effective method of reversing or holding back the sea along extensive sections of coast. Further, sea-level rise due to the greenhouse effect is generally regarded by the insurance industry as an impending known event, which is likened to the recent Y2K issue, so the industry is unlikely to provide general insurance cover for such follow-on damage (Chris Ryan, Insurance Council, personal communication). Increasingly, liability issues from climate change related damage in developed coastal margins will arise between territorial authorities and property owners.

Ultimately, there is no silver lining to the sea-level rise story. The hope is that people and local communities will plan long term for its inevitable consequences, even though the rate of rise is currently small and the impacts likely to take a few decades to materialise. But the rise in sea level is insidious, so it is too easily ignored or forgotten until the problem surfaces during a major storm event. Unfortunately, society is much more prone to respond to a crisis situation with band-aid approaches.

Hopefully, common sense will prevail as long-term hazard mitigation plans and land designations are set in place through existing planning instruments such as regional policy statements, coastal and regional plans, district plans under the umbrella of a soon-to-be revised New Zealand Coastal Policy Statement and the existing Resource Management Act. The proposed changes to the Local Government Act 1974 also signal the need for councils to develop long-term plans that integrate social, environmental, cultural and economic activities, moving beyond the current requirement to look at a long-term financial strategy.

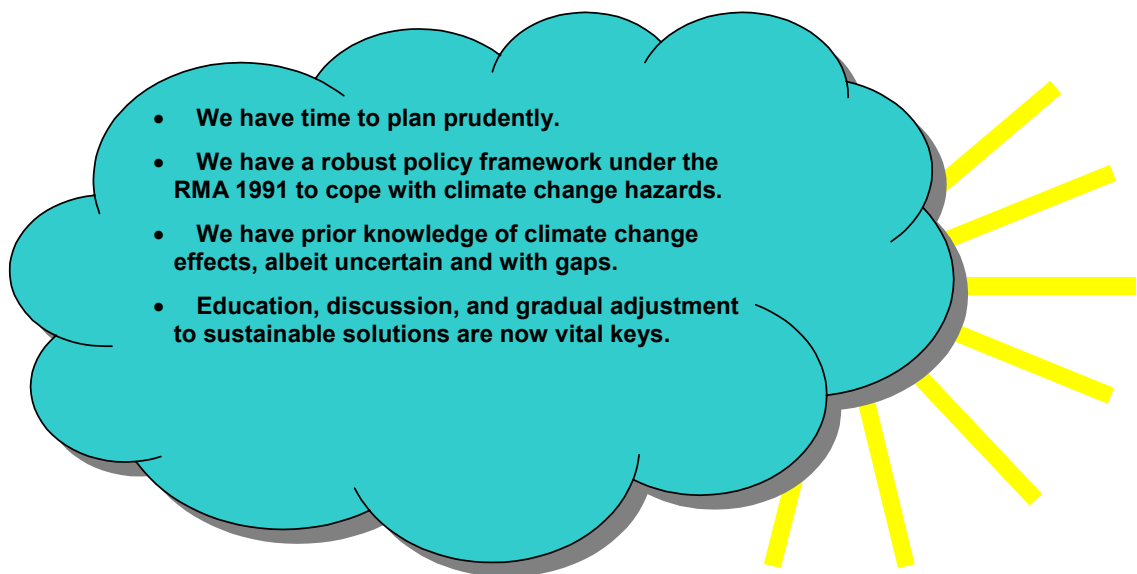
The biggest challenge will be changing the mindsets of New Zealanders: from one of complacency, to one that recognises that coastal margins will increasingly be under threat from climate change (even if it hasn't happened *yet*). Following a change in

mindset, the next challenge will be to work through the issues of how humans can adapt and adjust to the changing coastal and estuarine landscape for generations to come.

In essence, climate change decision-making has been, and will continue to be, a sequential process under general, but gradually reducing, uncertainty of the impacts.

The challenge is not to find the best policy today for the next 100 years, but to select a prudent strategy and to adjust it over time in the light of new information.

[Source: IPCC 1996]



Glossary and Abbreviations

adaptive capacity	the ability of a human system or ecosystem to adjust or respond to climate change (including both variability and extremes), to reduce potential damages, to take advantage of new opportunities arising from climate change, or to cope with and absorb the consequences.
climate	average weather patterns over medium to long time scales of seasons, decades and centuries.
climate change	any significant change or trend in climate over time, either in the mean state of climate and/or in its variability (e.g. extremes of temperature or rainfall, retreat or advance of glaciers, El Niño–Southern Oscillation). The IPCC include both ‘natural’ change and that attributable to human activities (e.g. use of fossil fuels).
coastal erosion	a long-term trend of shoreline retreat and/or loss of beach sand volume over several decades. ‘Cutback’ is a more suitable term to use on a dynamically stable shoreline to describe the temporary loss of beach volume or shoreline retreat during a storm, before it gets replenished over ensuing weeks and months.
Coastal margin	in this report, defined as sub-environments such as shallow coastal waters, beaches, dunelands, lowland rivers, estuaries, salt marsh and all adjacent land areas that are affected by potential and actual impacts caused by the dynamic marine environment, including long-term impacts of climate change. The coastal margin includes the coastal marine area.
coastal marine area	(or CMA) is that area of the foreshore and seabed of which the seaward boundary is the outer limits of the territorial sea (12 nautical miles) and the landward boundary is the line of mean high water springs, except that where that line crosses a river, the landward boundary at that point shall be whichever is the lesser of 1 km upstream from the mouth of the river, or the point upstream that is calculated by multiplying the width of the river mouth by five (Resource Management Act 1991).
ENSO	El Niño–Southern Oscillation, the climate system that governs year-to-year climate variability in the Pacific and Indian Oceans.
hazard	a situation with the potential to cause harm or damage; a hazard does not necessarily lead to harm.
intertidal	the areas of an estuary or harbour that are exposed at low tide.
IPCC	Intergovernmental Panel on Climate Change, a group set up by the United Nations Environment Programme and World Meteorological Organisation to regularly assess climate change.
IPO	Interdecadal Pacific Oscillation, a 20 to 30-year climate cycle in the Pacific that modifies the ENSO system.

MHWS	mean high water spring, which is the level of the average spring tides predicted around full or new moon periods.
natural character	the qualities of the coastal environment that together give the coast of New Zealand recognisable character. These qualities may be ecological, physical, spiritual, cultural or aesthetic in nature, whether modified/managed or not.
natural hazard	any atmospheric or earth- or water-related occurrence (including earthquake, tsunami, erosion, volcanic and geothermal activity, landslip, subsidence, sedimentation, wind, drought, fire or flooding), the action of which adversely affects or may adversely affect human life, property or other aspects of the environment (Resource Management Act 1991).
risk	related to both the likelihood (how often it will occur) and the magnitude of an impact. It also has an element of subjective assessment by humans.
sea level	the level of the sea over a certain averaging period (days, weeks, years, decades) after averaging out the tides.
sea-level rise	the trend of annual mean sea level over time scales of at least two to three decades: <i>global</i> sea-level rise is the overall rise in absolute sea level in the world's oceans; <i>relative</i> sea-level rise is the net rise relative to the local landmass (which may be subsiding or being uplifted).
storm surge	a temporary elevation in sea level above the predicted tide height caused during storms by a combination of both low barometric pressure and on-shore winds that cause a set-up in coastal sea levels.
vulnerability	susceptibility to potential harm or damage, considering factors such as the ability of a system to cope or absorb stress or impacts and to 'bounce back' or recover.

Appendix A: Information Gaps and Monitoring Needs

It is clear from this report that there are considerable uncertainties about how New Zealand's beaches, estuaries and salt marshes will respond to local, regional and global changes in climate caused by global warming. Some of the uncertainties stem from a lack of good-quality information on coastal features and habitats, which could be met by a commitment to strategic information gathering and long-term monitoring. Many other uncertainties would require dedicated additional research to determine how humans, physical environments and ecosystems are likely to respond to climate change, and how that should be managed.

A substantial body of knowledge already exists, with ongoing research funded by the Foundation for Research, Science and Technology and, in some areas, local government. The lists of recommendations for additional research and information gathering were compiled by the authors during the process of writing this report, with additional inputs from contributors and reviewers. The recommendations are provided to assist, amongst others, the National Science Strategy Committee for Climate Change in its development and review of a comprehensive national climate research strategy and its advice to government on the overall balance of climate change research priorities.

Information and technology gaps

Following are some of the most important information and technology gaps that have been identified.

- Planners, engineers, scientists and the public need to have a GIS mapping tool available to identify layers of fundamental coastal-margin properties (for example, sediment type, intertidal areas, vegetation, active or non-active dunes, habitat types, ecology, marshes and wetlands, salt meadows, settlements, areas of cultural significance, planning boundaries and topography). Some of this work is currently being done by the Ministry for the Environment and NIWA to develop a marine and estuary classification system.
- An accurate topography (land and dune heights at many different locations) of the coastal margin is a key requirement for planning and researching the likely impacts of climate change, locally, regionally and nationally. Some city and regional councils have made progress, but it is a daunting task, made easier with the advent of modern remote-sensing techniques. Currently, on a national scale we have little idea of the overall physical, ecological and socioeconomic losses and impacts that would result from various stages of sea-level rise; for example, land areas that would be inundated or occasionally flooded by storms for different sea-level heights. This contrasts with the US, where maps showing vulnerable coastal margins at 1.5 m increments are now viewable on the internet.³ Topography for New Zealand is currently only available in 10 to 20 m contour

³ Maps at: <http://www.epa.gov/globalwarming/publications/impacts/sealevel/maps/index.html>

increments in the LINZ topographic database, which is much too coarse to ascertain coastal hazard impacts. Ideally, a topography database with small height and distance increments of less than 0.3 m and 1 m respectively would be of huge benefit in assessing climate change effects. The technology is available, but it may require both national and regional co-ordination and approximately \$1 million to achieve such an outcome.

- The Digital Cadastral Database (DCDB) is a computer register containing data on land parcels throughout New Zealand. It represents the geographic location, shape, area, land appellation and street address for each land parcel and the legal definition of roads, road centrelines, railways and hydrographic features. The DCDB also contains administration boundaries such as local authority and electoral districts. Updating the DCDB (or the replacement LINZ *Landonline* program) is required in vulnerable coastal margins. Legal boundaries can be out by 20 m in places, and more accurate location of the coastal marine area (as defined by the MHWS) and an updated shoreline would greatly improve its utility for coastal-impact assessments. The DCDB or *Landonline* should build in a mechanism to include regular updates of the mean shoreline and MHWS tide mark, utilising modern remote-sensing techniques.
- Mapping on-land and offshore sand supplies could potentially be used for mitigation and beach renourishment. An alternative would be to research methods of better utilisation of dredged materials from ports/marinas.
- There are some gaps in the baseline monitoring of coastal drivers, such as sea level, waves, winds, sea-surface temperature, catchment exports (sediment and flow). Research should be aimed primarily at separating long-term trends and climate change effects from natural variability over years and decades. Present systems would need an injection of capital upgrading to improve their accuracy and put in place robust quality assurance systems.
- Regular updates of the magnitude and direction of predicted climate change are needed for the major regions of New Zealand (as outlined in Section 4.3).
- Lack of knowledge about subsidence and uplift along coastal margins is a major gap in the process of translating IPCC global projections into regional values of relative sea-level rise. The Institute of Geological and Nuclear Sciences (GNS) and the University of Otago are operating a pilot project using global-positioning sensor (GPS) units on top of four sea-level gauges in major ports. Leaving these units recording over long periods yields information on land stability (whether the land is subsiding or being uplifted) and tectonic activity. An allied gap nationwide is the need to establish – or re-establish in some cases – a set of ‘bedrock’ benchmarks associated with strategic sea-level gauges. Historical benchmarks are in poor condition for our port gauges (for example, located on wharf structures) or non-existent for some of the open-coast gauges (see Case Study 1). These bedrock benchmarks ideally should be surveyed and levelled annually, or at intervals no longer than five years (RJ Beavan, GNS, personal communication).
- There needs to be a regular (every decade) update of a national analysis of the extent of erosion and accretion of coasts (along the lines of Figure 4, but expanded in scope) and remaining areas of estuaries (including intertidal areas) and salt marshes. This could be achieved through co-ordinating the supply of relevant data from regional councils, while plugging any gaps with remote-sensing techniques, databases, aerial photos, etc. It would be important to extend the scope of this analysis to what is happening on sub-tidal beach profiles below the low-tide mark. By updating this every decade or so, it would reveal on a national scale if sea-level rise, sediment supply changes, or engineering protection works were having an overall effect on New Zealand’s coastal margins. Local effects will be up or down, and that needs managing locally, but a national sweep would isolate the trend of shoreline movement and estuarine/marsh areas overall across the country.

- There needs to be more concerted effort put into regular monitoring (and developing efficient techniques) of full beach profiles that go beyond the surf zone, and of sedimentation rates in estuaries, including marshes, mangrove areas, and intertidal flats, to benchmark climate change effects.

Research gaps

- Better quantitative methods and models for determining coastal set-back or coastal hazard zones for rising sea-level scenarios are needed that incorporate factors other than sea-level rise (for example, changes in waves and windiness, frequency of storms, impacts on sediment budgets, such as river flows, flood sequencing and catchment contributions).
- Three-dimensional morphodynamic models (driven by hydrodynamics and sediment transport) should be developed to predict the impact on sandy coastlines of sea-level rise, and climate change effects on the various physical drivers (Figure 5), over long time scales covering El Niño/La Niña cycles and the Interdecadal Pacific Oscillation. These types of models would need to be calibrated for particular long sandy shorelines, such as Bay of Plenty, North Island west coast, Poverty Bay, Tasman Bay, Wanganui–Manawatu and Pegasus Bay. Different models would need to be developed for mixed sand/gravel coastlines, such as Canterbury Bight and Hawke’s Bay.
- Integrated coastal-impact assessments of climate change need to be trialled for a few particular coastal units, based on consistent databases and scenarios of local and regional effects. We also need to look at analyses across various sectors (research, social, economic, governance), involving outreach to and inputs from the residents, iwi, stakeholders and policymakers in a region.
- The resilience and adaptation capacity of New Zealanders living along the coast needs to be determined. Social-impact studies are needed that will identify and begin quantifying the full range of social impacts on people facing, or likely to face, damage to property, and on communities wrestling with coastal hazards and the impacts of response options on both public and private assets. (Is their home their castle? Do they think they are safe if no previous erosion or flooding event has occurred? What is the effect on the well-being of residents once the threat of coastal hazard damage can no longer be ignored?)
- It would be highly desirable to have a database of the coastal hazard provisions in regional and district plans and policy statements under the Resource Management Act framework. We also need to undertake research into the way councils have implemented section 106 of the Resource Management Act and the coastal hazard provisions of the NZCPS, and regional policies and plans, and how climate change impacts on hazards may be built in to these planning instruments.
- Future impacts on Maori, who treasure the coast for its kaimoana and spiritual significance, need to be assessed. What is the adaptation capacity for Maori, and what response options do they favour, especially if middens, urupa or marae are in vulnerable coastal margins?
- Are New Zealand sandy beaches likely to follow the Bruun (1962) rule, which is so widely relied on, and erode? In particular, what is the likely response of intertidal sand/silt estuary beaches to sea-level rise? Further research could be carried out on sites that may act as surrogate beach systems under a rising sea level, such as large hydro lakes, where lake levels vary slowly with the seasons.

- There needs to be a review of information already available from overseas literature on likely physical and biological responses to climate change in coastal margins and marine ecosystems, including a summary of impact assessment techniques based on available New Zealand data and climate projections. This should also include a compilation of temperature tolerance ranges for species where data exist, and identify significant species (rare or economically important) for which data do not exist.
- We need to begin to devise methods (models) of possible changes in ecological function and diversity, given the difficulty predicting the details of the local ecological response due to uncertainties in the magnitude of change in coastal drivers and the interaction between these drivers and biological processes that produce emergent patterns or trends. Initially it may be better to tackle the simpler shifts in the re-distribution of species associated with new temperature regimes (for example, higher air and sea temperatures and associated decreasing frequency of frost will influence plants in estuarine and coastal fringing habitats).
- We need to identify potential response times to change for ecological systems in different coastal sub-environments (for example, temperature, increase in water depth, sedimentation, loss of intertidal areas, increased tidal prism volumes in estuaries as the waters edge retreats landward).
- Areas where freshwater inflows presently have a significant influence on the structure or functioning of the coastal ecosystem need to be identified, as do significant species and fisheries in these areas, and an assessment made of the risks associated with changes in river inflows or an ingress of seawater.
- We need to assess techniques that could be used to rehabilitate historically reclaimed land back to salt marsh and other fringing habitats to mitigate the likely progressive loss of such habitats in other areas where the shoreline is constrained by structures or geology.
- Salinisation effects on lowland freshwater ecosystem processes, including fringing habitats and vegetation, need additional research.
- The likely changes to continental shelf upwelling zones, and potentially affected coastal areas, need to be identified, as do important species and fisheries that presently depend on upwelling, and an assessment made of the risk from disruption of upwelling on the functioning of these coastal ecosystems, abundance of important species, and fisheries.
- We need to carry out research on sea-level variability on time scales of years to decades, and determine from global sea-surface heights whether there are regional differences in response of the southwest Pacific, compared with the global average rise.
- Robust real-time and forecasting techniques for sea storms and coastal flooding in vulnerable areas are needed.
- A more rational and pragmatic planning boundary for the coastal marine area (other than MHWS?) is needed to facilitate more co-operative planning between regional councils and territorial authorities, especially in the light of projected climate change, which will see the coastal marine area progressively encroach on to adjoining land in the coastal margin.

Appendix B:

Contributors and Reviewers

A number of people across a range of sectors provided input through discussions, invitations to contribute comments and case studies, or requests for reviews. The contributions of the following are gratefully acknowledged.

Research sector

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References

- ARC. 2000. *Coastal Hazard Strategy and Coastal Erosion Management Manual*. Auckland Regional Council Technical Publication No. 130. Auckland Regional Council, Auckland.
- Barnes P, Lewis K. 1996. How the Southern Alps are making North Island wider. *NIWA Water & Atmosphere* 4(3): 6–8.
- Basher RE, Zheng X. 1995. Tropical cyclones in the Southwest Pacific: Spatial patterns and relationships to the Southern Oscillation and sea surface temperature. *Journal of Climate* 8: 1249–60.
- Bell RG, Goring DG, de Lange WP. 2000. Sea level change and storm surges in the context of climate change. *IPENZ Transactions, General* 27(1): 1–10.
(Also on web site: <http://www.ipenz.org.nz/ipenz/publications/transactions/>).
- Bell RG, Goring DG, Walters RA. 2001b. Advances in understanding sea-level variability around New Zealand. In: *Coastal Engineering 2000*, Billy L Edge (ed.), Vol. 2: 1490–1500, *Proceedings of 27th International Conference on Coastal Engineering, Sydney*, American Society of Civil Engineers, New York.
- Bell RG, Green MO, Hume TM, Gorman RM. 2001a. What regulates sedimentation in estuaries? *NIWA Water & Atmosphere* 8(4): 13–16.
- Berryman K, Beanland S. 1988. Ongoing deformation of New Zealand: Rates of tectonic movement from geological evidence. *IPENZ Transactions, General* 15(1): 25–35.
- BRANZ. 2001. *Fact File: Climate Change and the Built Environment. Advice to Territorial Local Authorities*. Media statement (24 January 2001) by the Building Research Association of New Zealand (<http://www.branz.org.nz/branz/news/news.htm>).
- Brookes H. 2000. Chances beckoning: Integration in New Zealand's coastal management. In: *Proceedings of the NZ Coastal Society Seminar 2000, Coastal Management in New Zealand: Theory vs Practice*, Auckland, October 2000.
- Bruun P. 1962. Sea-level rise as a cause of shore erosion. *Journal of Waterways and Harbors Division* 88: 117–130.
- Burns NM, Hume TM, Roper DS, Smith RK. 1990. Estuaries. In: *Climatic Change: Impacts on New Zealand*. Ministry for the Environment, Wellington.
- Camilleri MJ. 2000. *Implications of Climate Change for the Construction Sector: Houses*. Study Report SR-94. Building Research Association of New Zealand.
(<http://www.branz.org.nz/branz/publications/study.htm>)
- CGER. 1996. *Data Book of Sea-level Rise*. Center for Global Environment Research Report CGER–D009–'96, National Institute for Environmental Studies, Environment Agency of Japan, Tokyo.
- Council of Europe. 1999. *European Code of Conduct for Coastal Zones*. Report No. CO-DBP (99) 11. Committee for the Activities of the Council of Europe in the Field of Biological and Landscape Diversity (CO-DBP) (<http://www.coastalguide.org/code/>)
- Dahm J. 2001. Coastal subdivision and site visit to Omaha Beach. *Coastal News* 16: 5–6.
- Dean RG. 1990. Beach response to sea level change. In: B Le Mehaute, DM Hanes (eds.). *Ocean Engineering Science* 9, Part B of *The Sea*, Wiley, New York.
- de Lange WP, de Lange PJ. 1994. An appraisal of factors controlling the latitudinal distribution of mangrove (*Avicannia marina* var. *resinifera*) in New Zealand. *Journal of Coastal Research* 10(3): 539–48.
- DoC. 1994. *New Zealand Coastal Policy Statement 1994*. Department of Conservation, Wellington.

- Duder JN, Crawford SA, Reinen-Hamill R, Jensen CP. 1999. Design and construction of inundation protection for Moanataiari subdivision, Thames. *Proceedings of the 1999 IPENZ Technical Conference*, University of Auckland, Auckland.
- Edgar GJ, Barrett NS. 2000. Effects of catchment activities on macrofaunal assemblages in Tasmanian estuaries. *Estuarine, Coastal & Shelf Science* 50: 639–54.
- Ellis JI, Norkko A, Thrush SF. 2000. Broad-scale disturbance of intertidal and shallow sublittoral soft-sediment habitats: Effects on the benthic macrofauna. *Journal of Aquatic & Ecosystem Health Recovery* 7: 57–74.
- Environment Waikato. 1999. *Coastal Erosion Risk Mitigation Strategy for the Waikato Region*. Environment Waikato Policy Series 1999/03, Environment Waikato, Hamilton.
- Feenstra JF, Burton I, Smith JB, Tol RSJ. 1998. *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*. Version 2.0. United Nations Environment Program and Institute for Environmental Studies, Vrije Universiteit, Amsterdam.
Web site: http://www.vu.nl/english/o_o/instituten/IVM/research/climatechange/Handbook.htm
- Folland CK, Salinger MJ. 1995. Surface temperature trends and variations in New Zealand and the surrounding ocean, 1871–1993. *International Journal of Climatology* 15: 1195–218.
- Gibb JG. 1984. Coastal erosion. In: I Speden, MJ Crozier (eds.). *Natural Hazards in New Zealand*. New Zealand National Commission for UNESCO, Wellington.
- Goff JR, Chagué-Goff C. 2001. *Catastrophic Events in New Zealand Coastal Environments*. Conservation Advisory Science Notes No. 333. Department of Conservation, Wellington.
- Hannah J. 1990. Analysis of mean sea level data from New Zealand for the period 1899–1988. *Journal of Geophysical Research* 95(B8): 12,399–405.
- Healy TR. 1991. Coastal erosion and sea level rise. *Zeitschrift für Geomorphologie* 81: 15–29.
- Healy TR, Harray KG, Richmond B. 1977. *Bay of Plenty Coastal Erosion Survey*. University of Waikato Occasional Report No. 3. University of Waikato, Hamilton.
- Hicks DM. 1990. Coastal impacts: Physical. In: *Climatic Change: Impacts on New Zealand*. Ministry for the Environment, Wellington.
- Hicks DM, Hume TM. 1996. Morphology and size of ebb-tidal deltas at natural inlets on open-sea and pocket-bay coasts, North Island, New Zealand. *Journal of Coastal Research* 12: 47–63.
- IPCC. 1996. *Climate Change 1995: Economic and social dimensions of climate change*. Contribution of the Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge.
- IPCC. 2001a. *Climate Change 2001: The Scientific Basis*. Summary for Policymakers & Technical Summary of the Working Group I Report. Part of the Working Group I contribution to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK. See also web site: <http://www.ipcc.ch/>
- IPCC. 2001b. *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK. For Summary for Policymakers, see web site: <http://www.ipcc.ch/>
- IPCC. 2001c. *Climate Change 2001: Mitigation*. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK. For Summary for Policymakers, see web site: <http://www.ipcc.ch/>
- Keillor JP. 1998. *Coastal Processes Manual*. 2nd edition. Sea Grant Institute, University of Wisconsin.
- Kirk RM, Weaver RJ. 1985. Coastal hazards and experimental beach renourishment at Washdyke, South Canterbury, New Zealand. *Proceedings of 7th Australasian Coastal & Ocean Engineering Conference, Christchurch* 1: 519–24.
- Komar PD. 1998. *Beach Processes and Sedimentation*. 2nd edition. Prentice Hall, New Jersey.

- Leatherman SP. 2001. Social and economic costs of sea level rise. In: BC Douglas, MS Kearney, SP Leatherman (eds.). *Sea Level Rise: History and consequences*. Academic Press, San Diego.
- McLean RF. 1978. Recent coastal progradation in New Zealand. In: JL Davies, MAJ Williams (eds). *Landform Evolution in Australasia*. Australian National University Press, Canberra.
- MfE. 2001. *Climate Change Impacts on New Zealand*. Ministry for the Environment, Wellington.
- Moon VG, Healy TR. 1994. Mechanisms of coastal cliff retreat and hazard zone delineation in soft flysch deposits. *Journal of Coastal Research* 10(3): 663–80.
- National Academy of Sciences. 2001. *Climate Change Science: An analysis of some key questions*. Report prepared for the White House by the Committee on the Science of Climate Change, Division on Earth and Life Studies, National Research Council, National Academy of Sciences. National Academy Press, Washington DC.
Web site: http://www.nap.edu/catalog/10139.html?onpi_newsdoc06062001
- Norkko A, Thrush SF, Hewitt JE, Norkko J, Cummings VJ, Ellis JI, Funnell GA, Schultz D, MacDonald IT. Catastrophic sedimentation and macrofaunal colonisation: the role of wind-wave disturbance and bioturbation in site-dependent recovery. *Marine Ecology Progress Series* (in press).
- National Research Council. 1987. *Responding to Changes in Sea Level: Engineering implications*. Committee on Engineering Implications of Changes in Relative Sea-level Rise and the Marine Board Commission on Engineering and Technical Systems, National Research Council. National Academy Press, Washington DC.
- Peltier WR. 2001. Global glacial isostatic adjustment and modern records of relative sea level history. In: BC Douglas, MS Kearney, SP Leatherman (eds), *Sea Level Rise: History and consequences*. Academic Press, San Diego.
- Pilkey OH, Hume TM. 2001. The shoreline erosion problem: Lessons from the past. *NIWA Water & Atmosphere* 9(2): 22–3.
- Priestley SJ, Consedine PT. 1991. Mission Bay beach replenishment. In: *Coastal Engineering–Climate for Change: Proceedings of 10th Australasian Coastal & Ocean Engineering Conference, Auckland*. DSIR Water Quality Centre Publication No. 21: 499–504.
- Ridgen J. 2000. *Perception of Risk from Coastal Hazards at South Brighton Spit*. Report for Christchurch City Council, Christchurch.
- Salinger MJ, Renwick JA, Mullan AB. Interdecadal Pacific Oscillation and South Pacific climate. *International Journal of Climatology* (in press).
- SCOR Working Group 89. 1991. The response of beaches to sea-level changes: A review of predictive models. *Journal of Coastal Research* 7(3): 895–921.
- Swales A, Williamson RB, van Dam LF, Stroud MJ. Reconstruction of urban stormwater contamination of an estuary using catchment history and sediment profile dating. *Estuaries* 24(6) (in press).
- Todd DJ. 1989. *Washdyke-Seadown Coastal Erosion*. South Canterbury Catchment & Regional Water Board Publication No. 62A.
- UMR. 2001. *Climate Change Issues: A study of public awareness and level of concern*. Report prepared for NZ Climate Change Programme by UMR Research Ltd.
Web site: <http://www.climatechange.govt.nz/sp/resources/resources.htm>
- van Rijn LC. 1998. *Principles of Coastal Morphology*. Aqua Publications, Amsterdam, The Netherlands.
- Williams DAR. 1997. *Environmental and Resource Management Law in New Zealand*. 2nd edition, Butterworths, Wellington.