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NIWA

Taihoru Nukurangi

Cover

NIWA's Atmospheric Sampling Station at Baring Head. Located on the southern coast of the North Island, near Wellington, the Baring Head Station is one of NIWA's key research facilities. The station is an ideal site for sampling clean air. A number of New Zealand-based, as well as international collaborative, research programmes are conducted using the facilities at the station.

(Photo: Lloyd Homer)

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NIWA

Taihoru Nukurangi

The Baring Head Clean Air Sampling Station

19 JAN 1996

FOREST RESEARCH INSTITUTE
DUNEDIN

Gavin Fisher

NIWA OPERATES a comprehensive air sampling station at Baring Head, near Wellington, as part of its extensive research on the properties of New Zealand's atmosphere. Located beside the historic Baring Head lighthouse (41°24.6'S 174°52.2'E), at the top of a majestic 80 m cliff, the site commands an imposing vista over the oceans to the south of New Zealand. Measurements taken at the site have been used in programmes studying atmospheric trace gases, greenhouse gases, atmospheric pollutants, the atmospheric sulphur cycle, aerosols, radioactivity, air quality, and the interaction between the air and the sea.

History

The site has long been recognised as an ideal clean air sampling site. Although air sampling began at Makara, near Wellington, at least as early as 1954, Baring Head became the key site in the 1970s. In 1972, a systematic programme of carbon dioxide measurements at Baring Head was established by the New Zealand Department of Scientific and Industrial Research (DSIR). The site was run at a modest level through the 1970s and early 1980s, focussing mainly on building up a high quality, long term record of carbon dioxide concentrations in the air around New Zealand. The programme was run by DSIR, and partially supported by the New Zealand Meteorological Service of the Ministry of Transport. Scripps Institute of Oceanography, California, an early leader in the field of global carbon dioxide monitoring, was a collaborator.

By the late 1980s, the value of the site as a long-term, southern hemisphere monitoring location had been well established. A number of new monitoring and research programmes commenced, many in collaboration with overseas research agencies. By the 1990s, the work carried out at Baring Head had a strong international profile. This has been recognised by New Zealand's major science funding agency and, at present, the research programmes at the site are well supported.

Immediately adjacent to the buildings housing the scientific equipment is the historic Baring Head lighthouse. It was demanned in 1989 and now functions automatically. Since 1938, the lighthouse has been one of the network around New Zealand's coast, and it helps to ensure the safety of shipping in the often treacherous Cook Strait waters. Previously, lighthouse staff lived in a small community at the site, which included a farm and communications station. The farm buildings, radio masts and support

buildings remain, but have been uncoccupied for several years.

The station

The scientific work is carried out in several small, specially constructed buildings which house a wide range of equipment. In 1991, a 12-metre high tower was built to obtain air samples well above the surface, and to provide a better platform for specific field measurements and meteorological sensors.

There are facilities to enable collaborating researchers to install equipment for shorter term projects.

The site has good road access, and reliable power and communications facilities. It is convenient for NIWA science staff – it is just 40 minutes drive from their offices and laboratories at Gracefield, Wellington.

Programmes

A wide range of scientific programmes has been, and is, conducted at the Baring Head station, particularly over the last six or seven years. These programmes make use of the fact that Baring Head is one of only a handful of good sampling sites in the southern hemisphere.

The main work has been measurements of the concentrations of various atmospheric trace gases and their isotopes in order to study how these are transported around the globe, what affects them, and how the concentrations are changing over periods ranging from hours to decades. Some programmes involve running equip-

ment at the station for real-time analysis, whilst others involve collecting flask samples for analysis at the Gracefield laboratory or for sending to collaborating institutions in the USA, Australia, and Germany.

A particularly strong link has been established with the Australian CSIRO sampling station at Cape Grim in Tasmania. Exchange visits, data sharing, intercomparisons, and equipment sharing ensure that the Australian and New Zealand programmes are complementary.

Table 1 lists some of the measurements made at Baring Head.

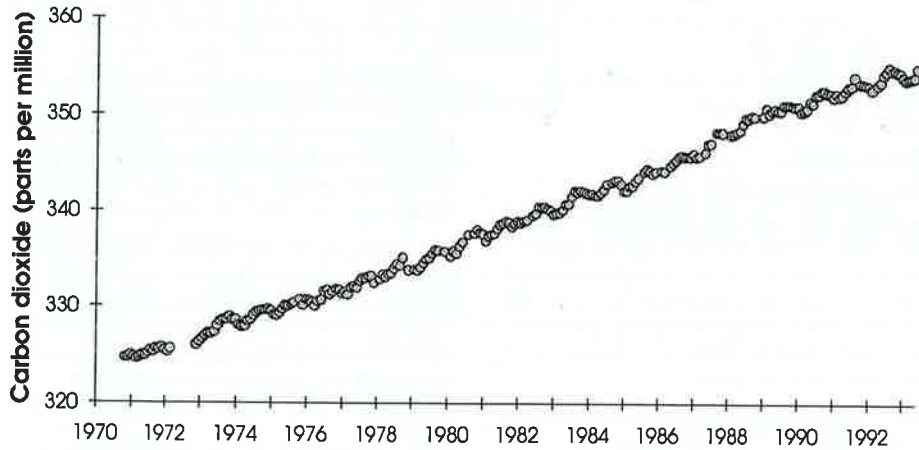
Carbon dioxide (CO₂) has been a major species of interest. It is known to be increasing in concentration and is a primary "greenhouse" gas. A great deal of effort is taken to ensure that Baring Head measurements are precise. Thus, regular intercalibrations are held, with worldwide data exchange. NIWA scientists have been amongst the world leaders in pioneering new techniques using measurements of carbon isotopes as tracers. In collaboration with the Institute of Geological and Nuclear Science, NIWA is able to undertake some of the most advanced and accurate isotope measurements in the world. The very long ¹⁴CO₂ record is especially valuable in that it pre-dates the major testing programmes of nuclear weapons in the atmosphere, which added considerably to the previous natural concentrations of this carbon isotope in the atmosphere.

Table 1. Measurements made at Baring Head Clean Air Sampling Station.

Species	Start date	Collaborators
¹⁴ CO ₂	1954	(From Makara initially)
CO ₂ (continuous)	1972	Scripps, USA
CO ₂ (flask)	1977	Scripps, USA
¹³ CO ₂	1985	Scripps, USA; CSIRO, Australia
¹⁴ CH ₄	1986	
Radionuclides	1987	University of Miami, USA; Env. Meas. Lab., USA
¹³ CH ₄	1988	
CH ₄	1989	University of Washington, USA
¹⁴ CO	1989	Kernforschungsanlage, Germany
¹³ CO, ¹⁸ O	1989	
CO	1989	CSIRO, Australia
O ₂ /N ₂	1991	University of Rhode Island, USA
Hydrocarbons	1989	Kernforschungsanlage, Germany
DMS*	1991	University of Auckland, NZ
Ozone	1991	
Aerosol	1991	
Radon	1993	CSIRO, Australia
CCN*	1994	CSIRO, Australia (planned)

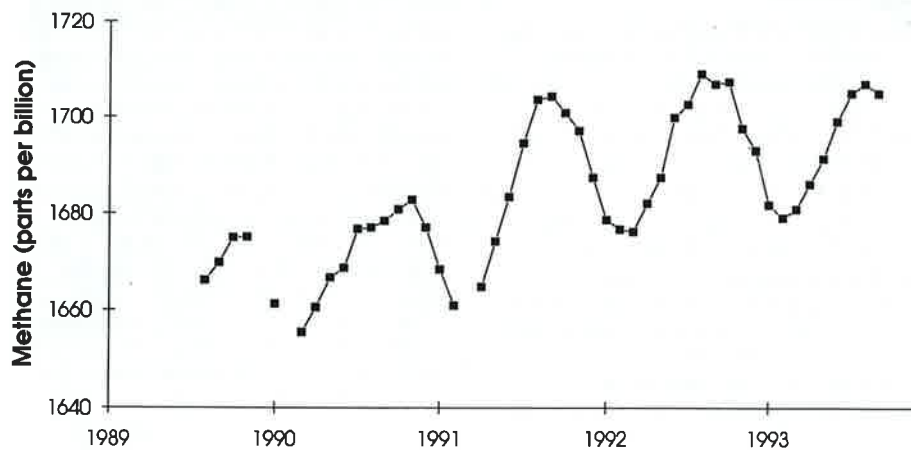
*DMS: dimethylsulphide; CCN: cloud condensation nuclei.

Carbon dioxide, Baring Head, 1970-1993



Carbon dioxide concentration in the air measured at Baring Head, 1970-1993. This record shows the level of carbon dioxide in the atmosphere increasing by about 0.5% per year over the last 20 years. (Data courtesy of Dr Martin Manning)

Increasing concentrations of methane



Methane concentration in the air measured at Baring Head. This shows the level of methane increasing by about 1% per year. (Data courtesy of Dr David Lowe)

Methane (CH₄) is measured using accelerator and stable isotope mass spectrometry, and gas chromatography. Methane is also a major "greenhouse" gas which is as important as carbon dioxide in potential climate effects. Analysis of ¹³C/¹²C and ¹⁴C/¹²C ratios in methane samples is a particularly effective method for studying the implications and reasons for the global methane increase. Because of its agricultural activity and use of natural gas as a fuel source, New Zealand is one of the world's highest per capita methane emitters.

Carbon monoxide (CO) measurements commenced in 1989 and are used to study the oxidising power of the atmosphere in the New Zealand region. A very accurate time series has been obtained by taking flask samples every few days. Isotope analyses are a powerful method of determining the sources and sinks of carbon monoxide, and aid in studies of the hydroxyl radical (OH) which features

in many chemical reactions in the atmosphere.

Oxygen/nitrogen (O₂/N₂) ratio is measured as part of a global programme to study the long term changes in this vital component of the atmosphere. The oxygen/nitrogen ratio is a key indicator of photosynthetic activity in the atmosphere and can be used to study the oxygen abundance variations and thus the carbon cycle.

Hydrocarbons are measured in collaboration with Kernforschungsanlage (KFA - a Max Planck Institute) in Germany, and the National Center for Atmospheric Research (NCAR) in the USA. The gas chromatographs used for the measurements are loaned from KFA and NCAR. We are interested in the light, non-methane, hydrocarbons which are important components in atmospheric chemistry studies. Heavier hydrocarbons (C₂-C₅) are detected from flask samples,

which are analysed using a gas chromatograph at Gracefield.

Aerosols are an important component of the atmosphere, affecting both global climate and also local air quality. The small particles comprising the atmospheric aerosol affect clouds, solar radiation, atmospheric chemistry, and air quality. A system of samplers, including real-time particle size samplers and aerosol collection on filters, is used to define and study the nature of particles in New Zealand's air.

Sulphur compounds have recently been included in the monitoring programme because of their importance in global climate and air quality. Various sulphur species (such as dimethylsulphide, DMS) are measured using gas chromatographs. Studies are undertaken to relate these to other important parameters such as the aerosol concentration and conditions in the sea which is a major source of biogenic sulphur.

In all of these cases, measurements and study programmes are integrated with a number of other projects being undertaken by NIWA. These include measurements at other New Zealand locations, laboratory studies, modelling and transport studies, aircraft and shipborne projects, and measurements in the Antarctic and South Pacific.

Some results

Amongst the many important research results produced from measurements at Baring Head, the biggest impact is from the carbon dioxide monitoring. Not only has this shown that concentrations in New Zealand are increasing, but detailed concentration and isotope analyses are showing that the sources, sinks, and transport of carbon dioxide around the southern hemisphere are complex, and different from those in the northern hemisphere.

Methane, also, is an important greenhouse gas which is increasing in concentration in the air even faster than carbon dioxide in percentage terms (around 1% per year). Isotope methods developed at NIWA are producing results which show a strong impact on New Zealand of tropical biomass burning, natural gas field emissions, mining, and agriculture.

Carbon monoxide and hydrocarbon measurements are compared directly with those from the northern hemisphere and show a strong gradient between the hemispheres. These data are being used in models to determine how trace gases and pollutants are transported around the globe and what roles they play in important chemical reactions.

The sulphur and aerosol work has started to show the nature of the extremely complex interactions between oceanic and atmospheric processes. It has been postulated that the world's climate is controlled by a feedback process involving biological

production of sulphur-based gases, which in turn form particles of sulphur compounds, which in turn influence cloud production, which in turn controls temperatures and the solar radiation reaching the surface, which gets back to influencing biological activity. Initial results from Baring Head show that the relationships between biological production and the sulphur cycle are not obvious and that a wider range of parameters needs to be included in the studies. This work is to be enhanced in the near future with the addition of an automatic cloud condensation nuclei (CCN) monitor at Baring Head.

Many of the measurements made at Baring Head are also analysed according to weather conditions and air trajectories. Using such analyses, it is possible to prepare a detailed summary of background air quality parameters for the lower North Island region. This then

provides input to regional air quality studies. The measurements also serve to define existing atmospheric composition and air quality for state of the environment reporting.

Future

The future of the station relies on continued high quality of research output from its scientific programmes. NIWA currently supports the station out of contract funding for research from the Foundation for Research, Science and Technology. Contributions from overseas collaborators are a minor but important source of support. It is anticipated that the work NIWA conducts at the station will continue to show excellent results, both for New Zealand science and as an important contribution to international science. It should, thus, continue to be well supported.

Acknowledgments

Facilities and research programmes conducted by NIWA at Baring Head are supported under several grants from the New Zealand Foundation for Research, Science and Technology. A large number of people have contributed to the development of the Baring Head station over the last twenty years. Unfortunately it is not possible to fully acknowledge all of them.

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Quality: "Fitness for purpose", or something more?

Paul Mosley

WHAT DOES NIWA have in common with Telecom, Interlock Industries, Formica, New Zealand Rail, University of Waikato, and the Ministry of Commerce?

The answer? All are demonstrating their commitment to quality by supporting the New Zealand National Quality Awards. Each company has made available staff members to act as "evaluators of applications" for the inaugural 1993 award. The process entails, for each of the 30 evaluators, a four-day training course (completed in August), up to two weeks carrying out a detailed evaluation of two applications, and a four day "site visit" to a single applicant's premises. Applications were due on 16 August, and evaluators' had until 16 October to submit their reports to the judges. This is a significant addition to the evaluators' normal duties, but a tremendous opportunity for them to see, first hand, how other organisations manage the quality of their products and entire business operations.

NIWA's representative in this process is Paul Mosley. Paul's commitment to quality led to ISO 9002 certification, by Telarc NZ, for the quality assurance system used in the monitoring and calibration work now carried out within NIWA. We believe that the section of NIWA responsible is unique in the world, in this area of work, in having received such third-party confirmation that its quality assurance system meets recognised international standards.

The New Zealand National Quality Awards Foundation

The New Zealand National Quality Award is modelled on the now world-famous Malcolm Baldrige National Quality Award introduced by the US Government several years ago as a means of promoting a quality-conscious culture in American industry. Companies which have won this award include, in 1992, the Ritz-Carlton Hotel Company; Texas Instruments Incorporated; Defense Systems & Electronics Group; Granite Rock Company (a quarry and aggregate business); and AT&T Network Systems Group. Earlier winners include such famous names as Motorola, Cadillac, Federal Express, and Xerox. These firms have made their commitment to quality the foundation for their continued prosperity.

The New Zealand National Quality Awards have been established by a Foundation consisting of representatives of industry, with the support of the Government. The twelve Founding Patrons include many of New Zealand's leading companies; Founding Members (of which NIWA is one) include many more. The purpose of the awards is to recognise New Zealand organisations which excel in quality management and quality achievement. They promote an awareness of quality as a vital element in competitiveness. They also aim to encourage companies to understand the requirements for quality excellence, and to share information on successful quality strategies and their benefits.

There are two categories for the awards: organisations with up to 199 employees, and those with 200 or more employees.

All applications must include a detailed document describing the key features of their quality systems. Evaluation of the applications is based upon quality excellence criteria. So each applicant provides information on its quality processes and record of quality improvement. The submission must demonstrate that the applicant's methods could be replicated or adapted by another organisation.

The award evaluation process is more than a reliable and repeatable means to select winners. It also results in a diagnosis of each applicant's overall quality management. Every applicant receives a feedback report prepared by the Judges' Panel, to assist in further improvement of its quality system.

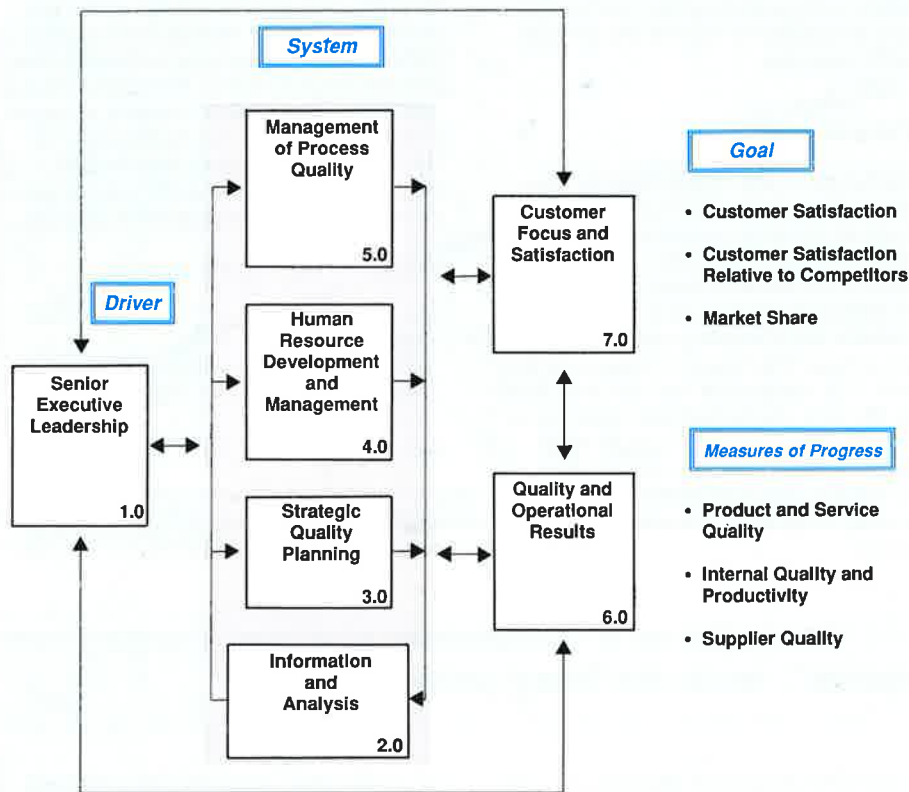
The quality excellence criteria

The award criteria aim to answer two questions:

- What does a company have to do to ensure ever-improving value to customers?
- How can a company maximise its overall productivity and effectiveness?

A set of "core values" provides solutions to both questions. These are: customer-driven quality; leadership; continuous improvement; full participation; fast response; design quality and prevention of defects; long-range outlook; management by fact; partnership development; public responsibility.

These core values parallel the concepts behind Total Quality Management (TQM). Formal and comprehensive implementation of TQM is an indispensable require-



Framework showing the dynamic relationship between the seven categories of core values used as criteria for the New Zealand National Quality Awards.

ment for an intending applicant for an award.

The core values and concepts are embodied in seven categories. These are shown in the diagram, grouped into a framework of four basic elements, the Driver, System, Measures of Progress and the Goal.

In the evaluation process, each applicant's performance in these categories is examined in detail. Evaluators focus on continuous improvement cycles, consistency of all processes and systems, and alignment towards the organisation's financial, market, and other goals.

Quality: "fitness for purpose" or something more?

A strong school of thought holds that quality is defined in terms of the fitness for purpose of the product or service – how well does it meet the client's requirements? Requirements include price. Thus if quality, and therefore price, are higher than the client requires, then the product's fitness for purpose is reduced. This concept is to an extent implicit in the ISO 9000 approach to quality management, in which standards of product or

service are defined in terms of client requirements. The quality system must confirm that those standards are being achieved, but not exceeded.

In contrast, the TQM approach seeks continuous improvement, the logical endpoint of which is perfection – "zero defects". One might suspect that this state of zero defects might be achieved only at infinite cost. However, the experience of winners of the Baldrige Award is clearly that ever-increasing quality is associated with ever-increasing profitability, and declining unit costs.

Another essential characteristic of the TQM approach is that it does not focus entirely on the characteristics and documentation of the product or service delivery, as the ISO 9000 approach tends to do. Instead, it places considerable emphasis on support services, corporate leadership, human resource planning, staff training and participation, the organisation's involvement in public affairs – in other words, on all aspects of the organisation's activities. TQM provides a comprehensive set of criteria and tools for ensuring that desired levels of product quality are attained and exceeded; it complements the ISO 9000 approach, but goes further.

NIWA's approach to quality

NIWA's vision for itself, expressed in its Business Plan, contains many elements which are consistent with TQM. These include:

- We wish to become a quality organisation, meeting or exceeding the requirements of all our clients, both within New Zealand and overseas
- We believe in growth, based on empowering all our staff to reach their full potential through provision of training, appropriate resources, and creating opportunities to develop
- We believe that the future of our organisation depends on the knowledge, creativity, skills, adaptability, teamwork, and integrity of our employees. We value these qualities very highly.

"Culture of quality"

Many parts of the Institute already have a "culture of quality". Scientists traditionally strive for excellence in their scientific work, and NIWA's international reputation in many areas of work attests that its scientists attain that goal. As "management by fact" is progressively extended, indices of scientific quality are being introduced, such as those relating to rates of acceptance of proposals to funding agencies, the nature of reviewers' comments on proposals, acceptance rates for publications, and so forth. In the support area, our laboratories operate stringent quality management procedures, and participate in national and international programmes to assure the comparability of the results of chemical analyses. Laboratory accreditation by Telarc NZ has been achieved by NIWA's laboratories in Hamilton, and is being sought for the laboratory in Christchurch. And, of course, Environmental Data has attained ISO 9002 certification by Telarc NZ for all aspects of its technical operation.

For the future, NIWA considers that it should strive to achieve ISO 9001 certification. This is in recognition of growing client expectation that suppliers should be able to demonstrate adherence to internationally accepted standards of quality management. However, NIWA is also committed to the principle, expressed in the Crown Research Institute Act, that NIWA should pursue excellence in all its activities. This is very much a statement that NIWA believes that quality is not simply "fitness for purpose", but implies continuously striving for something more – for excellence itself. ■

Paul Mosley is the General Manager within NIWA, responsible for the NIWA field teams.

Ecological impacts of shellfish dredging on coastal soft-sediment communities

Simon Thrush, Vonda Cummings and
Judi Hewitt

MARINE FISHING is one of New Zealand's major industries, and an important recreational activity. Fisheries are sustained by natural productivity, yet very little is known about how fishing and marine ecosystems interact. Unlike other human influences on the marine environment, fishing occurs throughout New Zealand's Exclusive Economic Zone from deep to near-shore waters. There is therefore potential for effects on marine ecosystems to be extensive.

The issue of adverse environmental impacts of fishing is important for both conservation and the fishing industry, because commercially exploited species are integral components of natural systems. This means that understanding these impacts could have positive benefits for the fishing industry, in terms of management and sustainability.

Study of scallop dredging

NIWA recently completed a 3-year study, commissioned by the Department of Conservation, to investigate the impact of scallop dredging on the structure of marine soft-sediment communities. Two sites in the Mercury Bay area of the Coromandel Peninsula were chosen for experimental dredging. One was located in the centre of Opito Bay, an area regularly used by commercial scallop fishers. The other was situated at Cathedral Cove, Hahei (now a marine reserve). Both sites were on bare sandflats at about 24 m depth. These habitats can seem quite barren places but they actually contain a large number and wide variety of animals which play important roles in ecosystem functioning. In this study we collected over 200 different types of sediment-dwelling animals.

We used various techniques to sample these seafloor communities: visual observations (diving), cores (the best way to sample such areas), and a suction dredge (to collect larger animals). Initial sampling of each site revealed no pre-experiment differences in the densities of animals within sites, but considerable differences in the communities between sites. Small crustaceans were common at Hahei, while polychaete worms were common at Opito Bay.

The experiment commenced in autumn by dredging half of each site with a commercial scallop dredge. Samples were collected from both the dredged half and reference (undredged) half of each site as



An undisturbed, coastal soft-sediment community.

soon as possible after dredging and again three months later.

Impacts of dredging

Similar effects were immediately apparent at both sites. The dredge had smoothed over the natural sediment surface and partially exposed animal burrows. As these animals are usually buried in the sediment, this could expose them to higher levels of predation. At both sites, scavenging snails were highly active. Starfish were also active, although many were torn to pieces by the dredge.

Because the animal communities at the two sites were different, we carried out separate analyses on the changes in density of common animals and community structure. At both sites, eight of the 14 common animals were affected by dredging immediately and/or three months later. In general, the dredged plots had lower densities of animals. In core samples from Hahei, dredging reduced the variety of animals immediately and the total number of individuals was still lower in the dredged plot after 3 months. At Opito Bay, both the variety and total number of animals were still lower in the dredged plot three months after dredging. For the larger animals collected in suction dredge samples, a greater number and a larger variety were found in the dredged plot both times at Hahei. At Opito Bay, only the variety of larger animals increased with dredging. These effects were a result of large mobile scavengers/predators being attracted to the disturbed plots.

Survey of dredged sites

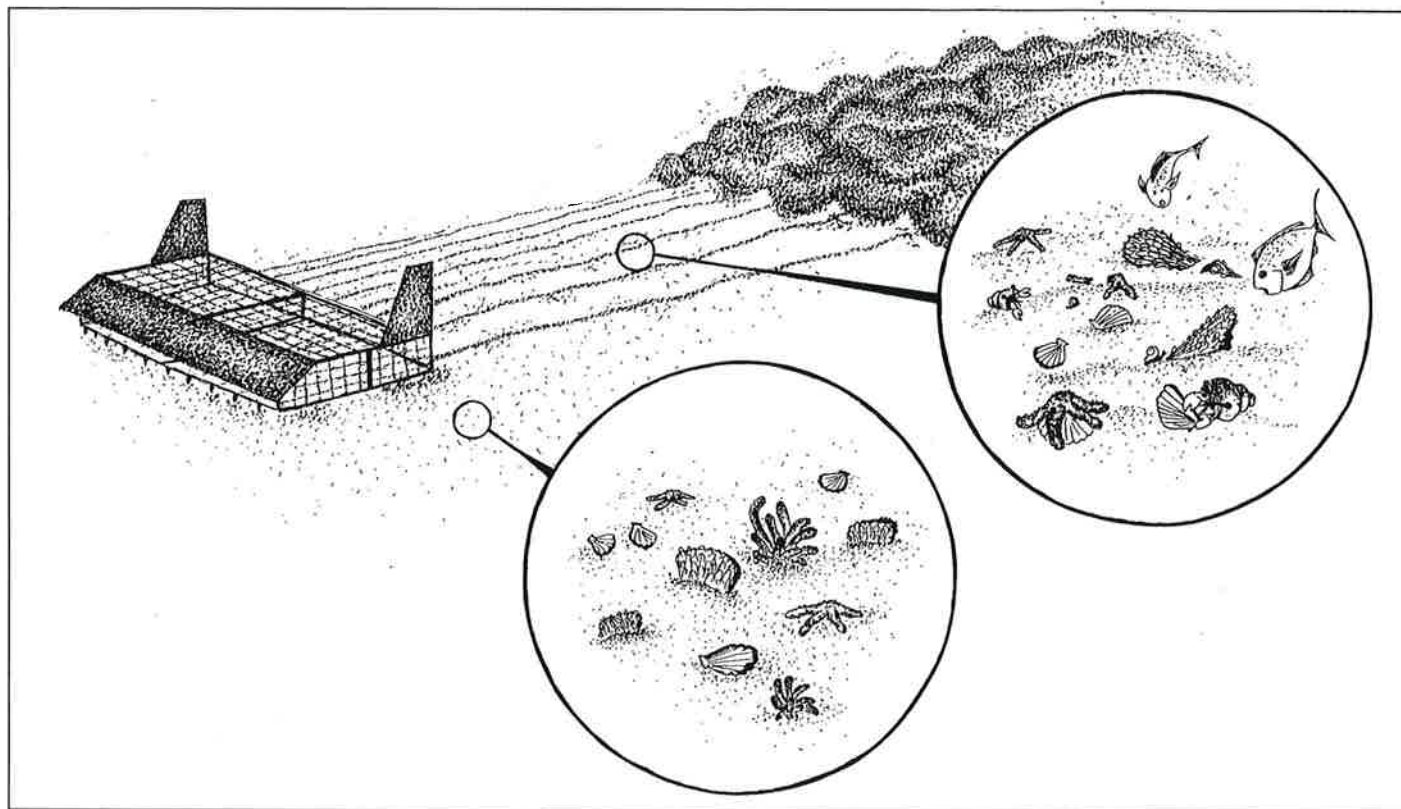
To complement the dredging experiment, larger-scale surveys were conducted of

other sites in Mercury Bay with different dredging histories. Sites which had not been commercially dredged had a higher variety and number of surface dwelling animals (e.g., sponges) and a greater diversity of surface sediment features. Tremendous variation was evident in the composition of the seafloor communities, e.g., the common animals at each site were mostly different. This variation among sites in a small length of coastline with basically similar sandy bottom habitats emphasises the diversity of these coastal seafloor communities. Despite this variation, two animals (a cumacean and a shellfish) which showed increased densities with dredging in the experiment, were also higher in the commercially dredged sites.

Ecological effects of dredging

This study was designed to assess a once-only dredging effect on seafloor communities in sandy habitats. It thus concentrated on the effects on the mostly hidden residents of marine sediments. These animals are very important in soft-bottom marine systems. They influence the movement of chemicals between sediments and water. They stabilise the seafloor, making the habitat suitable for other species. They also provide food for many larger bottom-dwelling animals, such as octopus, starfish and fish. Repeat dredging of the same patch of seafloor, which commonly occurs in commercial dredging operations, must result in much more disturbance than observed in our experiment. Habitats with more obvious residents, such as reef or garden-forming animals, may be expected to show even greater effects.

Our results highlight the damage or death of non-target organisms caused by one



Artist's impression summarising the immediate effects of dredging. In dredged areas, fine sediments are resuspended and sediment composition modified; damaged or partially excavated animals are attacked by scavenging invertebrates and fish. (Drawing: Vonda Cummings)

fishing method (scallop dredging) in one area. While different communities in different habitats can be expected to respond differently to habitat disturbance by fishing, in general fishing gear which removes surface-dwelling organisms, modifies sediment topography. When used over large areas it is likely to result in reduced diversity in seafloor communities. Communities subjected to repeated disturbance are likely to become

dominated by juvenile stages, mobile, rapid colonists and quick-growing species.

A broad, ecosystem-wide perspective of fisheries issues is necessary in order to achieve well-managed, sustainable exploitation of natural fisheries. It is likely that this can be achieved in harmony with objectives set for the conservation of marine ecosystems. Our results were used to make recommendations minimis-

ing the negative side-effects of dredging, ranging from development of fishing gear and practices which create less disturbance to creation of Marine Protected Areas in coastal soft-sediment habitats.

Simon Thrush, Vonda Cummings and Judi Hewitt are all science staff with NIWA, at Hamilton.

New benthic ecologist at NIWA, Hamilton

DR STEPHANIE TURNER, a benthic ecologist, recently joined NIWA at Hamilton. Stephanie has spent the past four years working as a marine scientist with the Department of Conservation and Land Management in Western Australia. Her research in Western Australia focused on the early life history of *Drupella cornus*, a marine gastropod that has been responsible for extensive coral mortality on several Indo-Pacific reefs. She has undertaken extensive studies of the larval biology of *Drupella*, both under laboratory conditions and in the field. Most recently she has been involved with a project to document the

temporal and spatial variability associated with the recruitment of *Drupella* into areas of reef differing in their previous history of *Drupella* predation, with a view to establishing a long-term prognosis for the recovery of the reef.

Before moving to Australia, Stephanie undertook her PhD studies in marine ecology at the University of St Andrews in Scotland. Through this research she was involved with work examining the community dynamics of intertidal and sublittoral epifaunal assemblages. She was particularly interested in larval recruitment, the influence of herbivorous grazers on developing as-

semblages, and the significance of competition for space among encrusting bryozoans in structuring these assemblages. Some of her work will be an extension of this work, using epifaunal communities to assess the cumulative effects of marina operations.

She will also be involved with work on soft sediment communities, including an assessment of the feasibility of the restoration of impoverished shellfish beds. She is also hoping to become involved with further coral reef projects in the Pacific.

Dr Kevin Collier joins NIWA



DR KEVIN COLLIER recently joined NIWA in Hamilton. This has been a bit like stepping back in time for Kevin, who completed a BSc at Waikato University in 1979 and is now working for one of his old laboratory supervisors. After leaving the Waikato, Kevin spent several years searching for the meaning of life until he eventually discovered "stream ecology" at Canterbury University. He entered the PhD programme there under the supervision of Professor Mike Winterbourn, and was involved in studies into the effects of natural acidity on aquatic life in brownwater streams in Westland. In association with this work, Kevin also studied the effects of forestry development on streams draining "pakihī" wetlands.

Kevin completed his degree in 1988 and was then employed as a freshwater ecologist with the Science and Research Division of the Department of Conservation in Wellington. While there he was involved in a wide range of work such as studying the diet and habitat requirements of blue duck, developing flow preference curves for aquatic invertebrates, assessing the conservation status of freshwater invertebrates, and devising methodologies for determining the conservation value of aquatic ecosystems. Some of Kevin's fondest memories of this time are his work with the blue duck which provided him with "a rare opportunity to work with real animals".

Since starting at NIWA, Kevin has been completing his blue duck work under contract to DOC, and is becoming involved in the riparian research programme at Whatawhata. One of his projects will be to investigate the use of riparian vegetation by the adults of aquatic insects, a phase of the insect life cycle which is poorly understood in New Zealand. Kevin will also be undertaking a variety of contract work and is looking forward to the new challenges provided by a commercial environment.

A new book: Colour and Clarity of Natural Waters

A new book by Rob Davies-Colley, Bill Vant and Dave Smith, of NIWA, Hamilton, is aimed specifically at environmental managers and the water-using industries. In his foreword to the book, reproduced here, John T.O. Kirk, of CSIRO, Canberra, outlines its contents and their significance.

Foreword

There is one area of water quality where human beings can detect degradative changes without the assistance of scientific measurement, and that is optical water quality. We can see for ourselves when a previously clean river is turned brown by effluent, or turbid by soil particles from an eroding catchment. And while our initial response may be primarily aesthetic – humankind has, after all, found beauty in limpid streams and clear blue seas since time immemorial – our concern at such changes is well founded. Not only do they mar the visual quality of our lakes, rivers and seashores, and lessen their attractiveness for water-based recreation, but they also have serious implications for the health of the aquatic ecosystem. The plants which form the base of the food chain cannot photosynthesize, and the fish and other fauna cannot seek their food, if deprived of sunlight. The murkier the water becomes, the shallower the surface layer within which solar heat is trapped, so that stratification is intensified, deep circulation is impeded, and anoxic layers grow.

Given that impairment of the optical quality of our surface waters is of common occurrence, and is so obvious when it occurs, it is puzzling that, by comparison with concerns about chemical and microbial quality, it has received so little attention from the wastewater industry and environmental managers. Part of the problem might perhaps have been the perceived difficulty in establishing clear cut and physically meaningful, but ecologically and psychologically relevant, criteria in terms of which to assess optical water quality.

Fortunately, however, to arrive at such criteria has now become much easier. It has been made possible by the establishment, mainly over the last 50 years, of a sound body of physical theory and observation concerning the nature of the underwater light field. This has arisen more from studies in marine, than in freshwater, ecosystems, but the principles of hydrologic optics are everywhere the same, and can be applied with as much confidence to a muddy lowland river as to the clearest ocean. The task of setting up criteria has also been made easier by the ready availability in recent years of photoelectric instrumentation for characterizing the underwater light field, and by the development of laboratory methods for measuring the inherent optical properties of natural waters and wastewater.

Armed with the new instruments and methods, and basing ourselves firmly within the robust theoretical framework of hydrologic optics, we can now hope to arrive at criteria for water quality that can be applied universally and interchangeably throughout the world. Indeed a beginning has already been made, and some proposals for the establishment of practical standards of optical water quality, for the benefit of environmental managers and industrial water users, have already appeared in the scientific literature.

The time is therefore ripe for just such a book as Robert Davies-Colley, William Vant and David Smith have written. A book to carry the message to that audience – wastewater engineers, industrial dischargers of effluent, environmental protection agencies, limnologists, coastal oceanographers – who need to hear it, to grasp its implications, and to frame policies in its light. This book provides, for anyone interested in, or charged with the responsibility for, the management of the optical quality of our surface waters, a comprehensive treatment which outlines the fundamental concepts, explains what the problems are, describes the sort of measurements that need to be made, and discusses the criteria in terms of which we can assess optical water quality together with possible specific guidelines which could be applied.

The authors are well qualified to address this topic: they have been actively engaged in research into optical water quality for a number of years, and have made notable contributions to it. The valuable case studies described in the book arise directly from their own professional involvement in problems relating to colour and clarity of water bodies in New Zealand.

There already exist, of course, other books and reviews dealing with the optics of our surface waters, but these have been aimed primarily at research scientists and students, in oceanography and limnology. This book is the first to be written specifically for the environmental managers and the water using industries. I believe it will become a standard work, and I commend it to all those in our society who have a responsibility for, or whose activities have an impact on, the quality of our inland or marine waters.

John T.O. Kirk
CSIRO, Canberra, March 1993

Colour and Clarity of Natural Waters – science and management of optical water quality. R.J. Davies-Colley, W.N. Vant and D.G. Smith. Published by Ellis Horwood, U.K., 1993. Approximately 310 pages; cloth cover. Price US\$101.95.

Order forms available from: the authors, at NIWA, PO Box 11-115, Hamilton; or order direct from: Ellis-Horwood, Publishers, Market Cross House, Chichester, U.K.

The early 1993 shellfish poisonings and toxic algal blooms in New Zealand – an update

F. Hoe Chang

IN EARLY JANUARY 1993, several cats in the Whangarei area, on the north-east coast of North Island, New Zealand, were reported to have been poisoned after eating shellfish (see reference 1). Further inquiries by the local area health board showed that owners of these animals had also been affected by eating shellfish. By the end of the outbreak more than 180 people were reported to have suffered illnesses related to shellfish poisoning.

Range of toxic effects

Shellfish such as mussels, pipi, cockles, tuatua, scallop, and oysters accumulate toxins from some dinoflagellates and diatoms when they filter the water as they feed. People who eat shellfish containing the toxins can become seriously ill. The kinds of symptoms typical of shellfish poisonings are listed in Table 1.

At the height of the shellfish poisoning outbreak in early 1993, neurotoxic shellfish poisoning (NSP) was the major health problem. Paralytic shellfish poisoning (PSP), and possibly diarrhetic shellfish poisoning (DSP) also occurred locally. Amnesic shellfish poisoning (ASP) was also detected, but it was not considered to have posed any problem to human health.

The toxic shellfish events in New Zealand were characterised by the simultaneous occurrences of several toxic species. As many as 14 species of toxic and potentially harmful phytoplankton species were recorded over a wide geographic area. These are listed in Table 2. Some of these species can cause illnesses which are related to the following types of poisoning.

Neurotoxic shellfish poisoning

Until now, this illness has been largely confined to the Atlantic coast of the USA. Records from as long ago as last century, in Florida, report this kind of poisoning. Usually, sickness follows after eating shellfish contaminated by a dinoflagellate, *Gymnodinium breve* (formerly *Ptychodiscus brevis*). It is a relatively mild form of shellfish poisoning, and all victims recover in a few days. *G. breve*, found in the Gulf of Mexico and Florida, produces neurotoxins known as brevetoxins, as well as a number of other poisonous substances. Also, there are reports of the species causing "red tides", which have been linked with fish kills.

During the early 1993 toxic outbreaks in New Zealand, there were complaints of a rasping cough and sneezing, suffered by several hundred residents and school stu-

Table 1. Clinical symptoms of various illnesses [neurotoxic shellfish poisoning (NSP), paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning (DSP), and amnesic shellfish poisoning (ASP)] associated with toxic shellfish consumption.

Type of poisoning	Symptoms
NSP	Neurological symptoms: numbness and tingling of the mouth, lips, and extremities; reverse sensation to hot and cold; respiratory distress. Gastrointestinal symptoms (under 50%): vomiting, diarrhoea, nausea.
PSP	Neurological symptoms: within 30 minutes, tingling sensation or numbness around lips, gradually spreading to face and neck; prickly sensation in fingertips and toes; headache, dizziness; muscular paralysis, pronounced respiratory difficulty; death through respiratory paralysis. Gastrointestinal symptoms: diarrhoea, vomiting, nausea.
DSP	Gastrointestinal symptoms only: diarrhoea, vomiting, abdominal pain, nausea.
ASP	Gastrointestinal symptoms, headache, hallucinations, disorientation, short-term memory loss, seizures, coma.

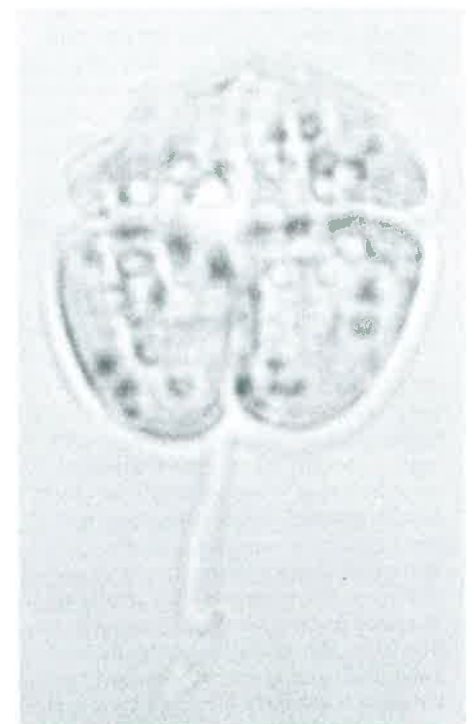
dent visitors in the Red Beach and Whangaparoa areas, north of Auckland. The illness was NSP. We identified a new species, *Gymnodinium* sp. nov. (cf. *breve*), in the area, and believe that it was the culprit causing poisoning, as reported in reference 2. This is the first time that such an illness has been reported outside the USA. Professor Yasumoto, an expert in this field from Tohoku University, Japan has analysed contaminated

shellfish. He found brevetoxin, and possibly some other new forms of toxins from the New Zealand species.

In the New Zealand outbreaks, NSP was by far the most common toxin detected. It appeared to be confined mainly to the north-east coast of North Island. This is consistent with the general distribution of *Gymnodinium* sp. nov., and with the number of illness related to NSP found in the same areas (see reference 1).

Table 2. Toxic and potentially harmful phytoplankton species identified during the early 1993 toxic shellfish outbreaks.

Phytoplankton taxa	Type of toxins
<i>Gymnodinium</i> sp. nov. (cf. <i>breve</i>)	NSP
<i>Alexandrium minutum</i>	PSP
<i>A. tamarense</i>	PSP
<i>Dinophysis acuminata</i>	DSP
<i>D. acuta</i>	DSP
<i>D. fortii</i>	DSP
<i>D. tripos</i>	DSP
<i>Prorocentrum lima</i>	DSP
<i>Pseudonitzschia pungens</i> f. <i>pungens</i>	Non-toxic
<i>Pseudonitzschia australis</i>	ASP
<i>Chrysochromulina</i> cf. <i>polylepis</i>	Fish-killing
<i>Gymnodinium mtknotot</i>	Fish-killing
<i>Heterosigma akashiwo</i>	Fish-killing
<i>Prorocentrum minimum</i>	Hepatotoxin



Gymnodinium sp. nov. (cf. *breve*), magnified approximately 2500 times.

Paralytic shellfish poisoning

PSP intoxication is far more life-threatening than either NSP or DSP. The toxins which cause PSP are alkaloids, known collectively as saxitoxins. We know of at least 12 types. These toxins are so potent that a pinhead-size quantity (about 0.0005 g), which can easily accumulate in just one 100 g serving of shellfish, could be fatal to humans. (See reference 3 for details.) The poisoning is caused by eating shellfish contaminated with dinoflagellates (e.g. *Alexandrium* [= *Gonyaulax*, *Protogonyaulax*] *tamarense*, *A. minutum*, *A. catenella*, *Gymnodinium catenatum*, and *Pyrodinium bahamense*).

Both *Alexandrium minutum* and *A. tamarense* were found in the recent shellfish poisoning episode in New Zealand. *A. minutum* was very widespread, from Kaitiaki in the far north to Bay of Plenty on the north-east coast of North Island, and from Dunedin to Invercargill in South Island, as shown in the map. Only a very small number of *A. tamarense* was found, in the Bay of Plenty area – a first record for New Zealand. Although PSP toxin was also quite widespread, it was detected mainly in the Bay of Plenty. The toxicity levels in the region appeared to coincide with the occurrence of *A. minutum*. The PSP levels were generally not very high (max. 412 g PSP equivalent per 100 g shellfish tissue), but were higher than the level considered unfit for human consumption, which is 80 g PSP equivalent per 100 g shellfish tissue. This toxin is not considered to have played a major role in the early 1993 shellfish poisoning in New Zealand.

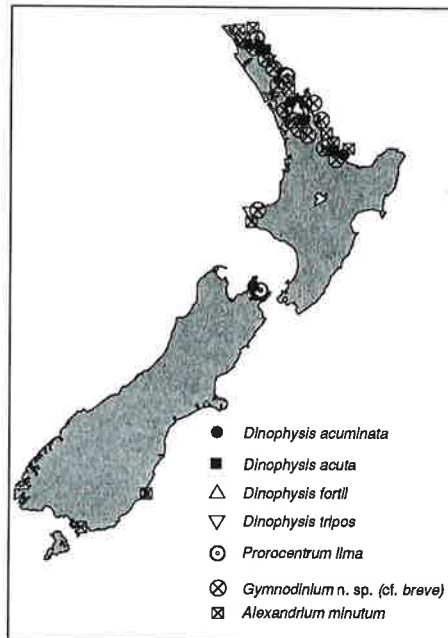
Diarrhetic shellfish poisoning

Diarrhetic shellfish poisoning is usually accompanied by diarrhoea. It has been known for many years, particularly in Japan, Netherlands, Chile, and Spain. We now know that several species of *Dinophysis* and *Prorocentrum lima* are the offenders. The poisoning is caused by diarrhetic shellfish toxins (okadaic acid). Eight different types have been isolated from contaminated shellfish.

Post-doctoral fellow: Dr Edward Abraham

DR EDWARD ABRAHAM has recently taken up a one-year post-doctoral fellowship at NIWA in Wellington.

Edward completed an undergraduate degree in Physics at the University of Canterbury. He was then awarded a Commonwealth Scholarship to do a PhD in the applied mathematics Department of Cambridge University, in the U.K. There, he joined the Relativity group, headed by Stephen Hawking, the cosmologist. For three years, he worked on models of relevance to the physics of the early universe. This has given him math-



Geographical distribution of *Dinophysis acuminata*, *D. acuta*, *D. fortii*, *D. tripos*, *Prorocentrum lima*, *Gymnodinium sp. nov.* (cf. *breve*), and *Alexandrium minutum*.

DSP toxin has been identified in New Zealand mussels before, but no outbreaks were ever reported. During the early 1993 shellfish poisoning events, *Prorocentrum lima*, and several species of *Dinophysis* – *D. acuta*, *D. acuminata*, *D. fortii* and *D. tripos*, were found in low concentrations in Hauraki Gulf and Bay of Plenty, as shown in the map. A low level of DSP toxin was also detected in these areas during this period.

Amnesic shellfish poisoning

Amnesic shellfish poison is usually accompanied by memory loss. The only known cases of ASP in humans occurred in Atlantic Canada in 1987. Over 100 people became ill, and four died, after eating commercially grown mussels. The toxin was identified as domoic acid and the culprit was a diatom, *Pseudonitzschia pungens* f. *multiseries* [= *Nitzschia pungens*]. Since 1978, several other diatom

species have been implicated in these ASP outbreaks. They include *Nitzschia pseudodelicatissima*, *Pseudonitzschia australis* [= *Nitzschia pseudoseriata*], and *Amphora coffaeiformis*. A non-toxic form, *Pseudonitzschia pungens* f. *pungens*, was identified by Hoe Chang, during a bloom in Whakatane in 1991.

In the recent toxic shellfish outbreak, the same non-toxic form of *Pseudonitzschia pungens* f. *pungens* was found to be the only very widespread species along the north east coast of the North Island. A second species, *Pseudonitzschia australis* was also recorded, but, in comparison, it occurred only sporadically, and in low concentrations. The very small amounts of ASP toxin detected in this toxic episode were more likely to have been associated with *P. australis*. The levels of toxin detected are considered to have posed no problem to human health.

Blooms triggered by climatic conditions?

The two most widespread and most abundant toxic dinoflagellate species found in the early 1993 toxic events were *Gymnodinium sp. nov.* and *Alexandrium minutum*. Their occurrences coincided with a prolonged period of westerly and south westerly winds, an effect of *El Niño*. Between September 1992 and April 1993, the northern North Island experienced unusual weather conditions. Temperatures were lower than usual, rainfall was higher and conditions were calmer. Freshwater run-off from land and rivers due to higher rainfall up until November may have enriched nearshore waters, and increased the haline stratification early in spring before seasonal heating produced stability in the water column. The less saline conditions may be important to species like *A. minutum*, where blooms were implicated to be initiated from existing "seed" beds.

These conditions however, may not be favourable to *Gymnodinium sp. nov.*, as blooms of *Gymnodinium breve* on the Atlantic coast of the USA are known to initiate offshore, and have occurred in a drought year. It is possible that, like *Gymnodinium breve*, the appearance of the New Zealand *Gymnodinium sp. nov.* was also initiated offshore, and brought into nearshore waters by incursion of offshore waters.

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Hoe Chang is a scientist with NIWA, at Greta Point, Wellington.

New Zealand oceans as a sink of atmospheric carbon dioxide

Rob Murdoch

IN JUNE 1993, NIWA staff undertook a 21-day research voyage on the chartered Russian research vessel *Akademik M.A. Lavrentyev*. Its purpose was to assess the roles of the different water masses which comprise the ocean surrounding New Zealand, as sinks for atmospheric carbon dioxide. An understanding of this is important for predicting global climate change associated with the increasing carbon dioxide levels in the atmosphere. There have been many studies on the flux of carbon from the atmosphere into the oceans of the northern hemisphere. However, there have been very few similar studies in southern hemisphere seas. This voyage was the first of its kind in the Australasian region. It was also one of the first to assess the flux of carbon in the region where subantarctic and subtropical waters meet, the subtropical convergence.

The voyage circumnavigated South Island, and scientists measured the flux of carbon in nearshore and offshore waters off the Westland coast, subantarctic waters to the east of Otago, subtropical convergence waters over the Chatham Rise, and subtropical waters east of the Wairarapa coast.

Carbon in the oceans

Carbon in the atmosphere is transferred to the deep ocean via the planktonic food web. Carbon dioxide that diffuses across the air-sea boundary is taken up by photosynthetic organisms to form cellular carbohydrates. This carbon is then available to organisms of higher trophic levels, such as micro and mesozooplankton. The difference between the carbon released as carbon dioxide through respiration by planktonic organisms and the carbon bound in dead planktonic organic material sinking to the deep ocean, will therefore represent the net loss of carbon from the atmosphere, as shown in the diagram.

Wide-ranging measurements

To quantify the flux of carbon from the atmosphere to the ocean depths required a range of expertise. So, staff on the voyage came from several NIWA research groups (from Hamilton, Wellington and Christchurch), as well as from the University of Otago. Measurements included: atmosphere and surface water CO₂ concentration, CO₂ uptake rates by photosynthetic bacteria and phytoplankton, concentrations of nutrients, rates of transfer of carbon to higher trophic levels through the grazing of photosynthetic organisms by zooplankton, the rates of sedimenta-



Scientific staff associated with the June research voyage on the Akademik M.A. Lavrentyev. From top left: Bridget Alexander, Peter Hill, Scott Nodder, Rob Smith, Mark Gall, Mark James, Michelle McLean, Patrick Perl. From bottom left: Julie Hall, Mike Page, Dick Singleton, Janet Grieve, Rob Murdoch, Kim Currie (Stu Pickmere not present).

tion of carbon into the deep ocean (in the form of dead planktonic organisms and zooplankton faecal material), and the biomass of the different groups of organisms that comprise the pelagic food web. The structure of the water column and the vertical distribution of planktonic organisms were also determined. From these shipboard measurements and experiments it will be possible to quantify the flux of carbon in the different water masses sampled.

The sampling equipment used included a CTD (conductivity-temperature-depth) probe, MOCNESS (multiple opening/closing net system), and sediment trap arrays.

Voyage a success

This inter-disciplinary voyage met all of its sampling objectives. Only one of the planned sampling locations had to be

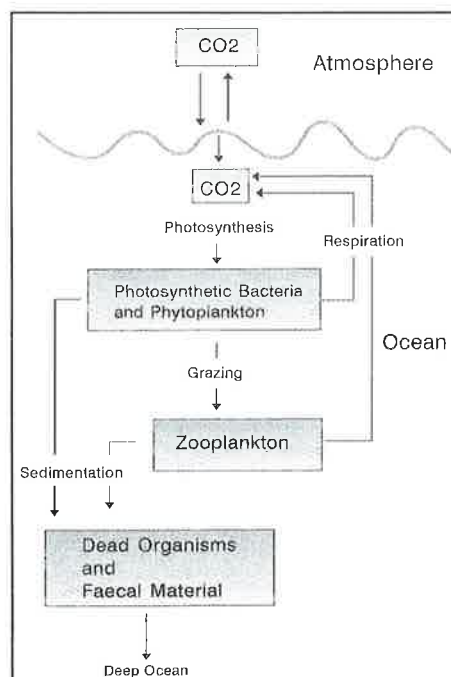
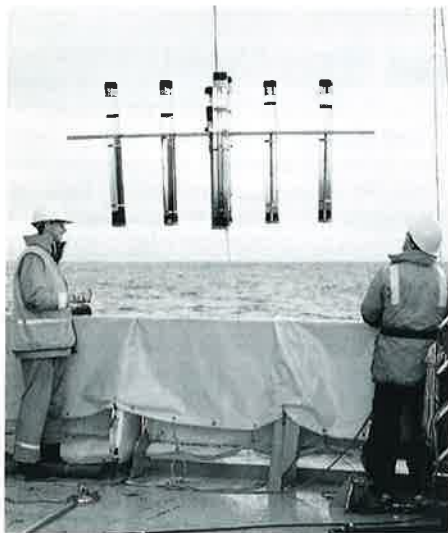


Diagram showing the flow of carbon from the atmosphere to the deep ocean via a simplified planktonic food web.



Rob Smith (left) and Mark James unloading Niskin water bottles from the rosette of the CTD probe. Water from the bottles was used for analysis of nutrients and early food chain processes.



Scott Nodder (left) and Mike Page deploying sediment trap arrays.

omitted because of rough seas. Equipment failure was restricted to the loss of one sediment trap array during a storm on the Chatham Rise.

Initial analysis of the voyage data is yielding interesting results. For example, samples collected with the MOCNESS indicate that at the time of the voyage (winter) the biomass of the larger

zooplankton was similar in all water masses.

Repeat voyage planned

During winter, we expect values of carbon flux to be low. So, for comparison, a repeat voyage is planned for October 1993. It is timed to coincide with the spring bloom in the oceans around New Zealand. At this stage, we expect that the greatest flux of carbon from the atmosphere to the ocean.

This study forms a part of two NIWA programmes funded by the Foundation for Research, Science and Technology: "Marine Environment of West Coast" and "Subtropical Convergence and Chatham Rise". The sampling protocols employed in this study have been designed to enable New Zealand to contribute to and collaborate in two important international oceanographic programmes - JGOFS (Joint Global Ocean Flux Study) and GLOBEC (Global Ocean Ecosystems Dynamics Research). Both are designed to examine the impact of human activities on the ocean ecosystem and the global climate system. ■

Rob Murdoch is a scientist with NIWA, at Greta Point, Wellington.

Ron Hicks Memorial Prize

AT THE the recent New Zealand Water and Wastes Association Annual Conference (Havelock North, 31 August - 1 September 1993), two NIWA scientists, based at Hamilton, Dr Jim Cooke and Dr Bryce Cooper, were jointly awarded the Ron Hicks Memorial Prize in recognition of significant work in solving a water pollution problem during the previous year. The prize was for their respective contributions to the International Conference on Wetland Systems in Water Pollution Control, held in Sydney, December 1992: "Nutrient transformations in a natural wetland receiving sewage effluent and the implications for waste treatment" (Cooke), and "Coupling wetland treatment to land treatment: an innovative method for nitrogen stripping?" (Cooper). These, and other papers on wetlands, are described in *Water & Atmosphere* 1(2).

New Zealand's arrow worms now monographed

A new volume in the Marine Fauna of New Zealand series of memoirs published by NIWA, has just been published. It documents, for the first time, the arrow worms of New Zealand.

Arrow worms constitute the small phylum Chaetognatha. There are only about 115 species worldwide. Nevertheless, what they lack in diversity they make up for in their impact on oceanic food webs - arrow worms are the primary predators of copepod crustaceans, the most numerous of zooplankton organisms in the millimetre size range. Arrow worms are also significant in being indicators of particular oceanic water masses.

Austrian biologist, Dr Sigrid Lutschinger did the study, based on the arrow worm collection held at NIWA, Greta Point, Wel-

lington. From 5865 worms sent to her, she identified 18 species in New Zealand waters. Nearly half of the worms belonged to the most numerous species, *Serratosagitta tasmanica*. Other numerically important species included *Mesosagitta minima*, *Serratosagitta serrotodentata*, *Eukrohnia hamata*, *Pseudosagitta lyra*, and *Sagitta bipunctata*. As these planktonic species tend to be fairly widely distributed, no new species were described, but Dr Lutschinger recorded several new occurrences for the region. Based on the NZOI samples, the area of greatest species diversity in New Zealand coastal waters is between East Cape and the Subtropical Convergence over the Chatham Rise, with 10 species.

Dr Lutschinger's volume includes a key

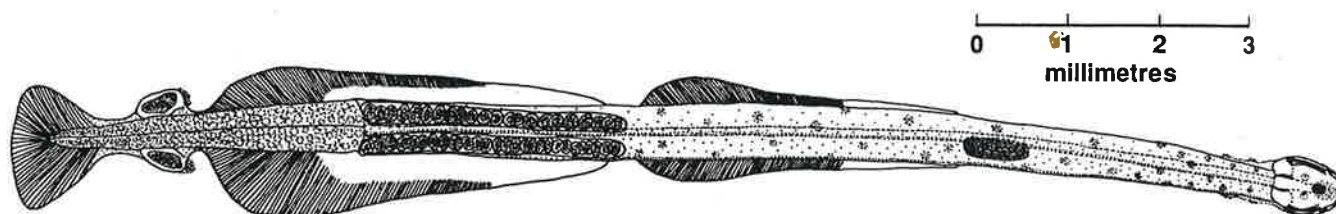
to the genera, and illustrations and descriptions of all the species.

Lutschinger, S. 1993. The marine fauna of New Zealand: Chaetognatha (arrow worms). *Memoirs. N.Z. Oceanographic Institute* 101. 61 p.

Available from:

The Publications Officer,
NIWA,
PO Box 14901, Kilbirnie, Wellington.
Price: \$27.00 (including GST).

Dennis Gordon,
Coordinator,
Marine Taxonomy Programme,
NIWA, Greta Point, Wellington



Serratosagitta tasmanica.

Modelling primary productivity off the New Zealand West Coast

Jonathan Sharples and Mark Hadfield

UNDERSTANDING the seasonal and inter-annual variability of the growth of phytoplankton (tiny plants) in the sea off the west coast of South Island is an important aspect of our understanding of the marine ecosystem. The phytoplankton lie at the start of a food chain that eventually results in human consumption of the fish caught in the region. Changes in their growth – called “primary productivity” – can ultimately affect both local livelihoods and the region’s economy.

The west coast marine ecosystem responds to variations with the seasons through one year. It also responds to changes from year to year, for example, those caused by *El Niño* events. It will also be affected by human pressure: on a short term through the pressure of commercial fisheries, and on a longer term by possible climatic changes.

For practical reasons, we can gain only limited knowledge by direct observation and measurement of such ecosystems. A research ship can spend only a short time in the area in any one year. So, we end up with a series of short bursts of experimental data, between which are long periods lacking in observations. However, the ecosystem can respond quite quickly to changes in, for instance, the weather. So, measurements taken during a research voyage cannot be regarded as representative of conditions a short time after the ship has left the area. How can we “fill the gaps”?

Models could be the answer

In the West Coast Marine Environment programme we are developing coupled physical-biological numerical models to help our understanding of the important processes involved in the system. By using the available observational data we can check whether the model is accurate for times when a research ship was in the area. If the data fits the model, this then gives us some confidence that the model includes the relevant processes. Hence, model output between periods of observations can be treated as a reliable source of information. However, the model cannot be regarded as a reliable substitute for field data. Our trust in the model predictions is based entirely on the real data available to validate them.

Physical processes

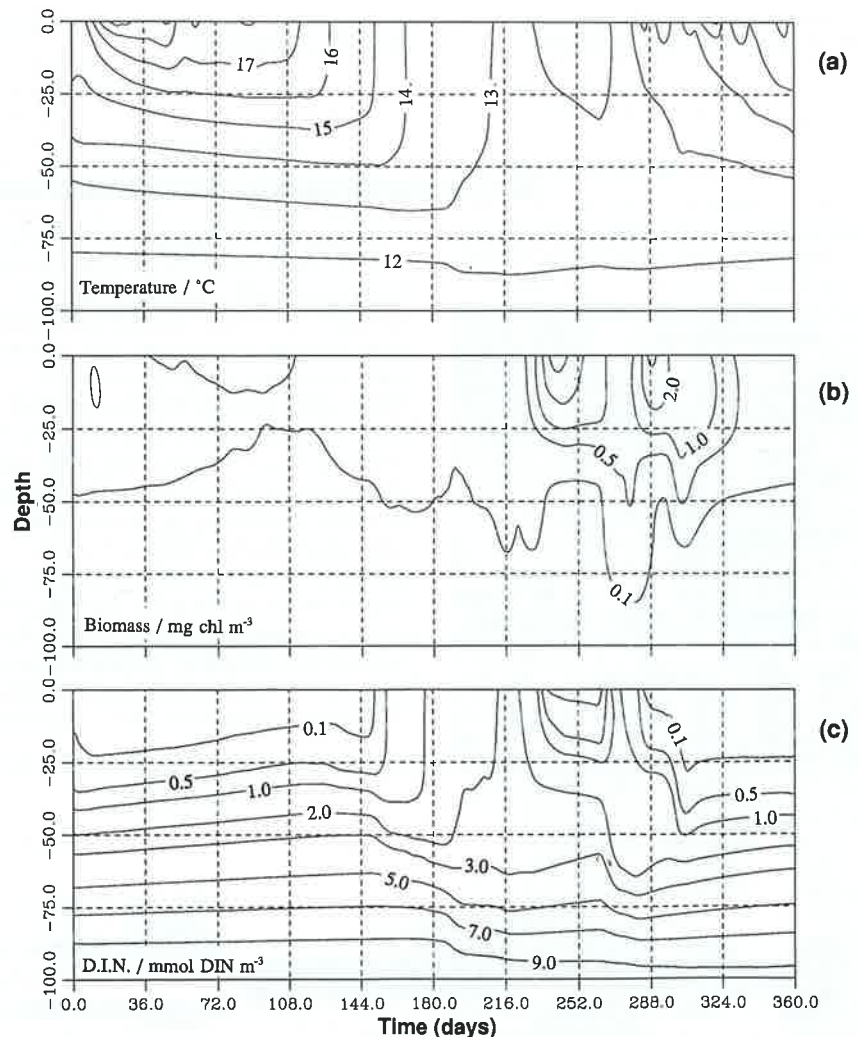
By using a 12-month time-series of meteorological data (wind speed, dewpoint temperature, solar radiation, and cloud cover), the physical part of the model can produce a realistic picture of how the temperature structure of the upper ocean

changes over the seasons. This is shown in the figure as depth plotted against time contours of temperature. The figure begins on 1 January. It shows the expected stratified surface water through summer with a surface mixed layer extending generally no deeper than 15 metres. Through autumn and into winter the depth of this mixed layer increases, reaching a maximum in August of almost 90 metres. This maximum depth of the surface mixed layer strongly depends on the meteorological conditions and can reach as deep as 150 metres.

The biological model is coupled to the physical one by using the turbulent transport generated by the evolving physical conditions, and the surface solar radiation. The seasonal change in the depth of the mixed layer is fundamental in the control of phytoplankton growth. The amount of ambient light decreases with depth in the water column. So, the deep mixing conditions of winter slow down phytoplankton growth because

there is insufficient light for photosynthesis. As spring approaches, and the mixed layer becomes shallower, the phytoplankton receive more light and grow quickly. This growth does not last long, however, because the same stratification process that is holding the phytoplankton nearer to the surface also prevents nutrients from the deeper water being transported to the phytoplankton. Thus, growth eventually slows down as the phytoplankton use up the original supply of nutrients. Short pulses in growth are often seen during the summer following storms, as brief increases in wind strength mix extra nutrients into the surface layer. As the wind reduces in strength at the end of a storm event, the water column restratifies under the influence of solar heating, nutrients again become limiting, and the rapid growth ceases.

This behaviour is illustrated in the figure. The two lower graphs show the seasonal change of phytoplankton biomass (in mil-



Physical and biological components of the model, as depth plotted against time contours, over one year, of (a) temperature; (b) phytoplankton biomass; (c) nutrient level (dissolved inorganic nitrogen).

ligrams of chlorophyll per cubic metre) and nutrient levels (millimoles of dissolved inorganic nitrogen per cubic metre) in response to changes in the temperature structure of the water column. Our results agree with the few available datasets for the region, though a better test of the model results requires more information at the start of spring.

Our future work will concentrate on the more episodic events, such as upwelling and the intrusion of fresher water from the coast: How do the basic biological processes respond to them? The biological part of the model is also to be developed to include more realistic interactions between the different types of

phytoplankton and the grazing zooplankton. ■

Jonathan Sharples and Mark Hadfield are scientists with NIWA, at Greta Point, Wellington.

The problem of early maturity in farmed salmon

Ceri Hopkins

IN NEW ZEALAND, salmon are the basis of commercial fish farming. But salmon farmers would face fewer problems if they could eliminate males from their stocks, apart from their occasional and necessary contribution to broodstock production. Why such discrimination? The reason is that males of the salmonid fish species (trout and salmon) have a tendency to mature early. The phenomenon is definitely evident in the most commonly farmed salmon species in New Zealand, the chinook salmon, *Oncorhynchus tshawytscha*.

Once a fish has matured, most of its food intake supplies the reproductive process. On a salmon farm, of course, the idea is to feed the fish to make them grow bigger and more valuable. So, early maturity disrupts harvesting programmes and reduces the value of the males, because they have to be harvested when they are still quite small.

Over the past few years NIWA scientists (formerly the MAF Fisheries salmon aquaculture group) have been working on ways to prevent this problem. The solution lies in controlling the reproductive development of the species. Several options have been developed and tested.

All-female stocks

Why not simply make sure that all the fry produced on the farm are female? This is done by "masculinising" females using the hormone testosterone. These new "males" are then used as sires. However, their genes are still female, so all their progeny are female too.

NIWA staff produced the first all-female chinook salmon in New Zealand. Since then, some commercial companies have used the same method to produce their own all-female stocks.

Sterile fish

Another possibility is to stock fish farms with sterile salmon that will never mature. In theory, such fish will grow continuously, allowing extended harvesting.

Sterility can be induced by altering the number of chromosome sets present in

the cells. Normally, there are two sets, one from each parent. During the final maturation processes of eggs or sperm, two special reduction divisions of the primary germ cells halve the chromosome complement. In the salmonid egg, the second of these divisions occurs after entry of a sperm. However, if the eggs are given a suitable "shock" shortly after fertilisation, the second reduction division is disrupted, and the full double (diploid) set of female chromosomes is retained. The eggs also contain the half set from the sperm, so the fertilized eggs or "zygotes" end up with three sets of chromosomes. We refer to this as "triploid". Shock conditions which induce triploid eggs include high temperatures and high pressures.

Triploid female salmon never develop ovaries and never mature. In males, the testes will still develop, but these fish are usually infertile.

Controlling growth rates

There is evidence from several species of salmonids that fast growth results in early maturation. Therefore, another possibility for reducing the incidence of early maturation is to cut back food supply, and hence growth rate. This may appear to be a negative approach, producing small fish. But the trick is to reduce growth rate for just a short period during the spring, when fish growth should be rapidly increasing and energy being stored (as fat) for subsequent gonad development in the summer. Restricted spring feeding has been shown experimentally to reduce the incidence of maturation in male Atlantic salmon.

Triploids vs diploids

During 1987-89, I was involved with some early experiments with triploid chinook salmon. Although the induction of triploidy successfully produced sterile females, there was evidence that they did not grow as fast as normal diploids. Slower growth of triploids relative to diploid controls has been reported for other salmonids. However, some trials have shown no difference in growth. Others have shown that triploid rainbow trout in fact grow faster than diploids. Another problem with triploids is that

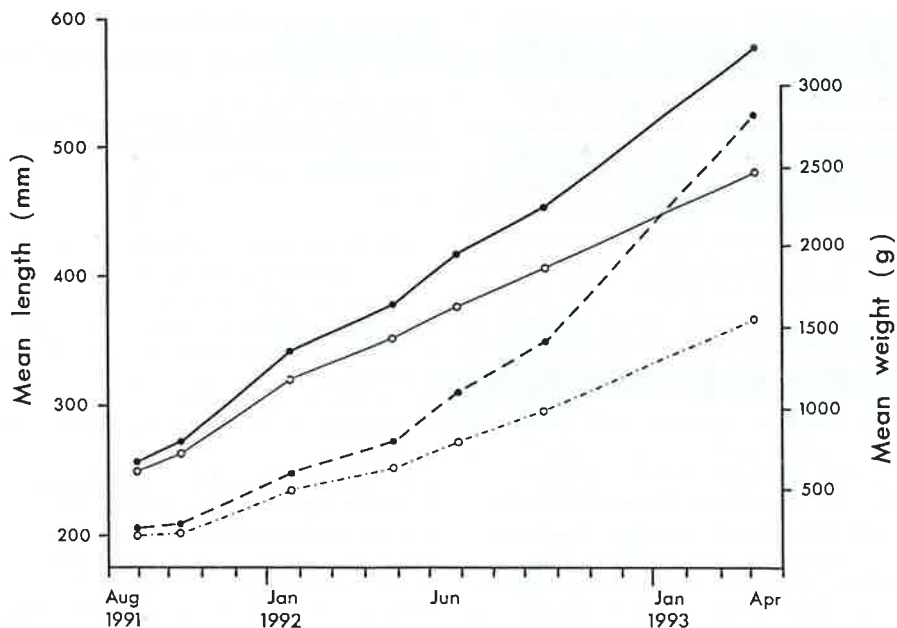
they often suffer high mortality during the embryonic stage. This may be related to the shock treatment given to the eggs as much as to their triploidy. What salmon farmers need to know is: are the advantages of triploidy outweighed by disadvantages (low early survival and slower growth rate relative to normal diploids)?

Between 1990 and 1993 we compared growth and survival of triploid and diploid female chinook salmon. Incubation and early fry rearing took place at the NIWA Silverstream hatchery, near Christchurch. The salmon were on-reared to adulthood at NIWA's Glenariffe Salmon Research Station. Masculinised females were used as sires. Several batches of eggs were fertilised and heat-shocked to induce triploidy by holding them for 8 minutes in warm recirculating water at temperatures between 28.0°C and 29.5°C. Survival to hatch varied between 5% and 54%. Control batches of diploids showed 77-96% survival. Shock at 28.5°C and 29°C gave the best mix of survival and triploid yield. Three batches which had the highest incidence of triploidy (94-95%) and survival to hatch (46-51%) were kept for on-rearing.

Diploids grow better ...

In late spring of 1990, 600 triploids were ponded together with an equal number of diploids at Glenariffe, for on-rearing. Triploids were marked by removal of the adipose fin. To prevent overcrowding, the fish were culled to 200 of each type in their second spring and then reared through to autumn 1993, when most of the diploid fish matured. During this period there was no significant difference in survival between the two ploidy types. In the first year there was little difference in growth rate either, except that the triploids had significantly higher condition factors. But from the start of the second year diploids grew faster than triploids. The figure shows the growth history of the fish in length and weight. When final sample measurements were made, in autumn of the third year, average weight of diploids approached twice that of triploids.

At age 3, 76% of the diploid females were mature and the remainder had small but



Comparison of length and weight between triploid (open circles) and diploid (filled circles) chinook salmon from age four months to time of diploid maturity in year three. Dashed lines = weight, solid lines = length.

distinct ovaries. Ovarian development in the triploids was almost completely arrested.

... but more trials needed

This trial suggests that the growth rate of triploid chinook salmon may not be good enough for commercial culture though, in a different environment (e.g. in sea cages), better growth may be attainable. Also, in the trial, both ploidy types shared the same pond: rearing them separately might give different results if, for example, behavioural differences disadvantage triploids.

Springtime fasting and its effect on maturation – an experiment

A recent experiment carried out at Glenariffe tested the effectiveness of spring fasting to reduce the incidence of early maturation in male chinook salmon.

In August 1992, we stocked three batches of yearling fish into separate ponds. One batch acted as control. We fed these normal rations throughout the experiment. A second batch was given restricted rations for two months (September-October). We fed these only on alternate weeks. The third batch was treated like the second, but the feeding regime was continued

through November. The initial mean weight of all batches was about 100 g.

Growth in length and weight was monitored at intervals through the spring. The experiment ended in April 1993 when all fish were killed for sexing and measurement of gonad development.

Promising results

In the control batch, 60% of the males matured. There was little difference in maturation rate between the other two batches, one showing 21% maturing males and the other 24%. The difference in incidence of male maturation between these fasted fish and the controls was statistically significant. No females matured in any batch.

Growth of the test batches was depressed through the fasting period, but both batches grew faster than the controls when returned to full rations. This was possibly a compensation response after a period of reduced feeding opportunity. The characteristic has been recorded in similar trials with Atlantic salmon. By April, the batch starved for two months was not significantly different in average weight from the controls, though fish starved for three months were about 12% smaller.

We conclude that fasting, enforced at the right time of year, appears to offer a means of considerably reducing the incidence of early maturation in male salmon. Evidently, it need not result in reduced size as the fish enter their third year.

Ceri Hopkins was formerly a scientist (now retired) with NIWA, at Christchurch.

Database tops 10 000 records

Jody Richardson

NIWA'S FRESHWATER fish database is a comprehensive collection of site-specific fish records covering the whole of New Zealand, including Chatham and Stewart Islands. The database now contains more than 10 000 records, making it a formidable resource for fisheries research and management.

The database was established in 1977. The purpose of setting up a computer-based system was to ensure that information on the occurrence and distribution of freshwater fish species did not get lost in forgotten files and personal notebooks, was systematically recorded, and could be retrieved rapidly.

The foundation of the database was all

relevant information from MAF Fisheries records. This was then expanded to include major museum collections. These records make up the historical data.

Input from staff

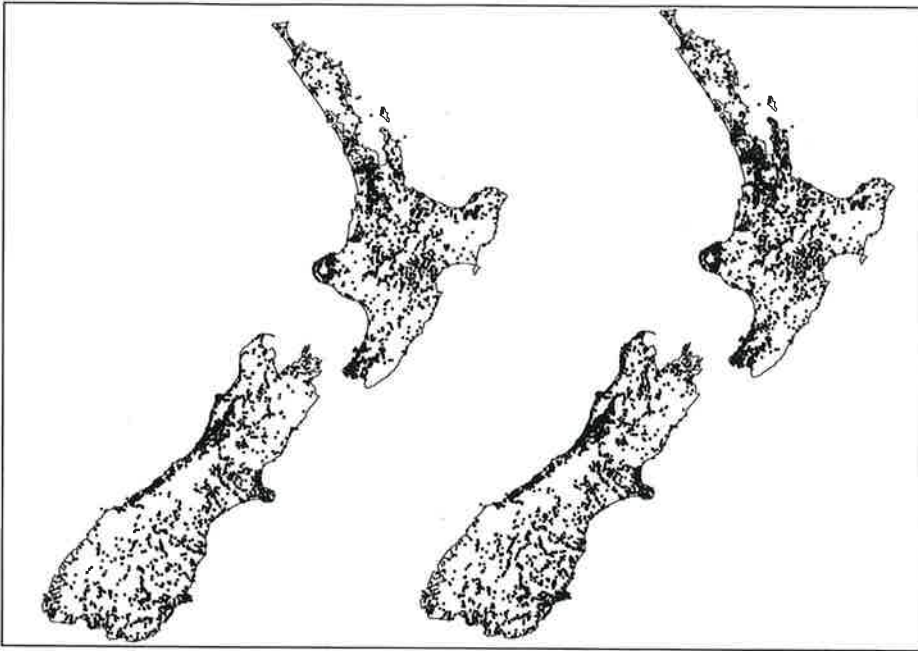
Beginning in 1978, all departmental staff engaged in field work were encouraged to fill out database cards so that recent information could be incorporated into the computer files. Booklets of cards were also distributed to fish and game councils, regional councils, government departments, and private consultants, many of whom elected to become active contributors to the database.

Initially, only a small proportion of the information recorded on the cards was transferred to computer. After a review of the database in 1987, new forms were designed. These facilitated the storage of

much more information, especially quantitative data. For example, information about the site has been expanded to include the percentage of each different habitat type (i.e., pool, run, riffle, etc.), the substrate composition, how much and what sort of cover for fish is present, and what vegetation/land use (e.g., native forest, pasture) comprises the catchment and riparian zone. Data about the species present now include the number caught, the life stage (adult or juvenile) and length, if available. As time allows, useful information from the old-style cards is being added.

Improved coverage

The past five years have been busy ones for data entry. About 3000 new records have been added and 1000 others upgraded. The new data fill in some sig-



The NIWA freshwater fish database coverage: left, up to 1985; right, up to April 1993.

Table 1. Comparison of selected habitat characteristics for five galaxiid species.

Species	% of sites where present (n = 3945)	Average altitude (m)	Average amount of native forest in catchment (%)	Average amount of coarse substrate (60 mm diameter) at site (%)	% of sites with flowing* or still* water	
					F	S
All sites	100	149	77	36	90	10
Inanga	15	16	72	17	91	9
Koaro	10	188	89	56	98	2
Banded kokopu	8	53	86	35	92	8
Giant kokopu	4	34	84	18	88	12
Shortjawed kokopu	2	93	85	56	100	0

* flowing water includes rivers, streams, drains, etc.; still water is lakes, ponds, swamps, etc.

nificant gaps in the nationwide coverage of the data, as shown in the diagrams. Parts of the Waikato, Coromandel, central Otago, northwest Nelson, and Chatham Island (not pictured) are now more fully represented. However, the east coast around Gisborne, Wairarapa, and Kaikoura is still lacking data, as are south Westland and Fiordland.

Since the database was upgraded in 1987, the amount of habitat data stored on the computer has gradually increased; 3945 records have complete data.

Using the data

As an example of how these data could be used, I thought it might be interesting to compare the habitat occupied by the five migratory galaxiid species: inanga, koaro, and the banded, giant, and shortjawed kokopu (Table 1).

This fairly simple analysis shows first, that none of these galaxiids are encountered very frequently. For example, the most common species, inanga, occurs at just 15% of the sites with complete records. Compare this with 48% for

longfinned eels. All the species except koaro inhabit sites with lower than average altitude, hardly surprising since they are diadromous (i.e. they spend part of their lives in sea water). All except inanga inhabit sites with more than average amounts of native forest in the catchment. Koaro and shortjawed kokopu prefer coarser than average substrate, inanga and giant kokopu prefer finer substrate, while banded kokopu have no preference. Shortjawed kokopu are never found in still water, but giant kokopu are slightly more likely than average to be found in still water.

Information available for analysis

While many fisheries biologists might say, "But, I already knew all that", being able to quantify this knowledge is an important step forward. These data could be exported to a statistical package for more rigorous analysis. For example, they could be used to test whether the mean substrate size occupied by a particular species was significantly greater than the mean of all the sites. From there, habitat

preferences could be identified, and in conjunction with more specific studies, habitat suitability curves could be developed.

Historically, the freshwater fish database has been used mainly to provide catchment-specific or species-specific distribution information. However, the addition of more habitat data has led to some innovative use of the database. For example, Colin Townsend and Neil Mitchell of Otago and Auckland Universities, respectively, used brown and rainbow trout distribution and habitat information to define the climatic range of these species in New Zealand. Their intention is to compare this with the ranges occupied by trout elsewhere in the world. Bob McDowall of NIWA, Christchurch, is using data from the Grey River catchment (over 450 records) to identify broad trends in fish distributions in relation to geography, environment, and life-history strategies of the fish.

We can be confident that these and other quantitative applications of the database will continue to expand our knowledge of New Zealand's freshwater fish. ■

Jody Richardson is a scientist with NIWA, at Ruakura.

Ecosystems modeller

ALEX ROSS recently joined NIWA, in Christchurch, as their new ecosystems modeller. Alex comes to Christchurch from the University of Strathclyde, Scotland, where he has worked as a research assistant for the past three years. His main research area has been development, testing and analysis of general ecosystem models of the fjords of the west coast of Scotland. This was also the subject of his PhD thesis.

Prior to this, Alex worked on individual mussel energetics, predicting rates of growth and reproduction from a consideration of food supply. This project led to an interest in ecology of mussels on rocky shores. In particular, he has developed models, in collaboration with other researchers, to investigate the differing roles of predation and hydrodynamic drag in influencing the spatial dynamics of mussel patches.

Since joining NIWA, Alex has begun developing general models, for a number of freshwater and marine systems, designed to address broad-scale questions of nutrient flow. In conjunction with this, he intends to model specific aspects of the dynamics of algae populations. He is looking forward to developing new areas of interest, one of which is modelling the distributions of native fish species in the Grey River.

Floods savage the Grey River fish fauna

Bob McDowall

THE WEST COAST is well known for its heavy rain and excessive flooding of its rivers. So it seems reasonable to assume that the fish faunas of West Coast rivers such as the Grey, would be well adapted to major floods. Yet data from sampling the fish faunas of tributaries of that river show that there may be large variations, both in the species to be found in the tributaries, and in their relative abundances.

For over ten years, NIWA, the West Coast Fish and Game Council, and the Westland Conservancy of the Department of Conservation have carried out systematic sampling of the fish fauna in Grey River and its tributaries. The programme aims to determine the faunas of these tributaries and factors affecting their abundance. In addition, some tributaries have been the target of more detailed studies that relate to specific land-use proposals for their catchments.

Evidence of flood

In July 1993 we sampled several tributaries of the mid and lower Grey River, as part of a programme involving reproductive strategies of bullies (genus *Gobiomorphus*). This was only a few weeks after a major flood. The flood was not, by Grey River standards, a huge one; it peaked at 3400 cubic metres per second (m^3s^{-1}) (measured at Dobson). Flow records for the Grey River show that there has been at least one flood larger than this in seven of the past 25 years. The largest was $5840 m^3s^{-1}$, on 13 September 1988. It was probably this flood which provoked construction of a costly flood retention wall between the main shopping centre of Greymouth and the river. Thus, the town now has some protection from inundation during flooding. Nevertheless, the 1993 flood was a substantial one, enough for the owner of the motel where we stayed, above the banks of the Grey River, to comment that it was the largest he had seen in his three years there.

We were unaware of this when we began sampling, but soon noticed that the streams looked as though the boulders had been scrubbed. Apart from in some sheltered areas below banks and in backwaters, the substrate was almost devoid of periphyton; it lacked the green, slimy coating typically present. The boulders and gravels had probably been extensively turned and shifted so recently that there had not been time for a new layer of periphyton to grow. The motelier's comments simply confirmed what we had already concluded: that there had been a substantial flood through the system not long before.

Table 1. Records of fish occurrences in Grey River tributaries.

Site and date	Lamprey	Longfinned eel	Giant kokopu	Shortjawed kokopu	Dwarf galaxias	Torrentfish	Redfinned bully	Common bully	Bluegilled bully	Upland bully	Brown trout
<i>Bray Creek</i>											
February 1988						p	c				a
November 1991		c				c	a		c		a
July 1993		o			o	o	c	p			a
<i>Woolley Creek</i>											
November 1986		a	p	p		o	a		o		c
October 1991		c		p			p				p
October 1991		c		o			p				
July 1993			p				p				o
<i>Blackball Creek</i>											
April 1986		p						o		a	a
February 1988						p	c		a		a
August 1984		a					a				a
August 1986						p	o				a
July 1993		p					o			o	o
<i>Redjacks Creek</i>											
December 1986		a				p		p	a	p	c
December 1986		a			o	o	c		c		o
December 1986		c				c	p		o	p	c
July 1993	p	o					o			o	p
<i>Big River (i)</i>											
August 1986						p			o		c
January 1992		c				c	c		a		c
July 1993		p				o	o		o	p	p
<i>Big River (ii)</i>											
January 1992	o	c				c			a		a
July 1993		p				o			p		

p = present; o = occasional; c = common; a = abundant (see text for full explanation).

Sparse fish fauna

The fish fauna in virtually all streams was very sparse. Needing some samples of female redfinned bullies, we searched all suitable habitats, but found very few - occasionally one or two from the most sheltered refuges, such as below steep banks and deep pools around bridge pilings, and in backwaters. Not surprisingly, fish often occurred where there was still some trace of periphyton left on the boulders, i.e., in places where the effects of the flood on the stream beds had been least.

Data available for the fish faunas of the streams we sampled are listed in Table 1. We have ranked fish abundances as: **p = present**: species observed, but usually only one or two fish; **o = occasional**: several of the species seen; **c = common**: species occurred quite often, here and there; and **a = abundant**: species abounded in suitable habitats. While these rankings are subjective, they give some measure of abundance. Numbers of species and the abundance of each have

varied from time to time over the years represented in these records. But what is noticeable is that the July 1993 sampling, in nearly all instances, showed the least number of fish present. Occasionally we found the same number of species, or even more, than in earlier records, and this probably reflects the intensive effort invested in attempting to obtain the needed number of redfinned bullies.

Earlier samplings

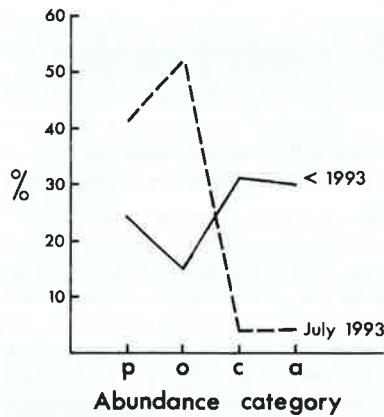
The distribution of abundances in earlier samplings show that the four abundance categories were fairly evenly represented, but that the rare categories greatly predominated in 1993 (24%, 15%, 31%, and 30% for **p**, **o**, **c** and **a** in the earlier years, compared with 41%, 52%, 4%, and 4% in 1993). So, well over 90% of the 1993 species/stream records were recorded as either **present** or **occurred**, compared with about 40% in earlier years.

Seasonal differences may, in part, explain the impoverished stream faunas in 1993 -

specifically, longfinned eels become very sluggish and tend to hibernate in the substrate during cold periods and become very difficult to catch. And it is clear that longfinned eels were caught less often in July 1993 than hitherto. But other native fish are not known to hibernate. We would expect to find them in consistent numbers, winter and summer.

Fish surveys and flood events

So, it seems clear that the June 1993 flood had a major impact on the fish faunas of the Grey River tributaries. We don't know what happened to the fish that seem to have been washed out of the tributaries, nor how long it will take for the native fish faunas of these streams to be fully restored. But an important lesson to be learned from this incident is that we



Abundance of fish species in Grey River tributaries prior to 1993 and during the July 1993 sampling. See text for explanation of abundance categories.

should not expect the fish faunas of our streams to carry the full richness of species diversity and abundance soon after major floods. Surveys to compare species diversities and fish abundances, both between streams, and across the years, should take account of the time elapsed since flood events. Although our fish have had millions of years to become adapted to the sorts of conditions that exist in our rivers, they are obviously still badly affected when the most violent floods take place.

"Where do fish go in floods?" We really don't know, other than, it seems: "Mostly somewhere else!"

Bob McDowall is a scientist with NIWA, at Christchurch.

1993 Salmon lottery results

A Dunedin angler, Mr A Johnston, has won the \$1000 first prize in this year's coded-wire tag lottery drawn by NIWA in Christchurch. Four anglers won second prizes of \$100 and 20 anglers collected consolation prizes of \$20. All winners are listed below.

This lottery is sponsored by NIWA to encourage salmon anglers to look for coded-wire tagged fish. Over 100,000 salmon are marked with coded wire tags each year and tag returns from anglers are an essential part of the tag/recovery programme.

The tags (1.25 mm long and 0.25 mm diameter) are injected into the nose of the young fish where they remain for the rest of its life. The tag cannot be seen once in place, so all tagged fish are marked externally by removal of the small, fleshy adipose fin, just in front of the tail. This fin does not regrow, so anglers can easily recognise a tagged adult salmon when it returns after up to three years at sea.

A total of 338 anglers were eligible for this year's lottery. Canterbury rivers, particularly the Waimakariri, Rangitata and Rakaita, accounted for 188 tagged fish. There were also 144 recoveries

from Otago Harbour. Mr Johnston's winning fish, a 4-year-old, came from a group of 13,000 juveniles reared at NIWA's Glenariffe hatchery and released into Otago Harbour in 1990.

Most fish caught this year were 3-year-olds, returning from releases in 1991. Survival rates for these releases have generally been higher than for these in the previous few seasons. One release from NIWA's Silverstream hatchery yielded a return of over 2%, the highest figure recorded since 1987.

NIWA thanks all anglers who supported the tag/recovery programme by looking for and returning tagged fish.

Winners	Tag no.	No. tagged	Released into:	Recovered from:
<i>1st prize of \$1000</i>				
Mr Andrew Johnston, Dunedin	63/40/58	13327	Inner harbour, Otago Harbour	Inner harbour
<i>2nd prizes of \$100</i>				
Mr F Naish, Dunedin	63/38/38	4931	Inner harbour, Otago Harbour	Location unknown
Mr M Pitcher, Christchurch	63/41/30	10234	Glenariffe Hatchery, Rakaita River	S.H.1 Bridge
Mr R Stuart, Christchurch	63/41/30	10234	Glenariffe Hatchery, Rakaita River	Acheron confluence
Mr D Weatherston, Dunedin	63/38/38	4931	Inner harbour, Otago Harbour	Inner harbour
<i>3rd prizes of \$20</i>				
Mr P Anthony, Ashburton	63/39/60	10940	Glenariffe Hatchery, Rakaita River	S.H.1 Bridge
Mr A Arps, Christchurch	63/39/10	3797	Rangitata Salmon Ranch, Rangitata River	Rangitata Mouth
Mr B Brockenshire, Oamaru	63/39/17	14129	Hakataramea River, Waitaki River	Location unknown
Mr F Carey, Port Chalmers	63/41/06	5069	Inner harbour, Otago Harbour	Harbour entrance
Mr J Chandra, Dunedin	63/38/38	4931	Inner harbour, Otago Harbour	Inner harbour
Mr R Chibnall, Ashburton	63/39/10	3797	Rangitata Salmon Ranch, Rangitata River	Rangitata Mouth
Mr A Crow, Christchurch	63/40/59	21000	Silverstream Hatchery, Waimakariri River	McIntosh's Rocks
Mr J Fitzgerald, Dunedin	63/41/06	5069	Inner harbour, Otago Harbour	Inner harbour
Mr J Fitzgerald, Dunedin	63/38/38	4931	Inner harbour, Otago Harbour	Inner harbour
Mr B Fridd, Temuka	63/39/11	5200	Ophi Mouth, Rangitata River	Rangitata Mouth
Mr R Hucklebridge, Mosgiel	63/41/06	5069	Inner harbour, Otago Harbour	Inner harbour
Mr B Ivey, Ashburton	63/36/52	16054	Glenariffe Hatchery, Rakaita River	Location unknown
Mr R Logan, Timaru	63/40/51	4985	Tent Burn Hatchery, Rangitata River	Rangitata Mouth
Mr J Meyer, Kaiapoi	63/40/59	21000	Silverstream Hatchery, Waimakariri River	Kaipoi River
Mr S Ovens, Dunedin	63/41/06	5069	Inner harbour, Otago Harbour	Location unknown
Mr D Randle, Dunedin	63/38/15	2069	Leith Stream, Otago Harbour	Location unknown
Mr L Reid, Dunedin	63/38/38	4931	Inner harbour, Otago Harbour	Location unknown
Mr L Reid, Dunedin	63/38/38	4931	Inner harbour, Otago Harbour	Location unknown
Mr A Robinson, Port Chalmers	63/38/38	4931	Inner harbour, Otago Harbour	Inner harbour
Mr E Waller, Kaiapoi	63/40/59	21000	Silverstream Hatchery, Waimakariri River	McIntosh's Rocks

Data retrieval and display: "made-to-order"

Barry Thomas and Guy Halliburton

DATA ON river levels and flows have numerous applications in New Zealand. For example, hydrological records are used in flood hazard estimation, the design of flood prevention structures, and water resource assessment for hydro-electricity generation. Over many years, an extensive network of recording sites has evolved to meet such needs. Many of the sites are operated by NIWA from offices at 15 locations, countrywide.

In the mid 1980s, the introduction of telemetry opened the door to new applications for hydrological information. Telemetry allows users to access "real time" data. Previously, information was often weeks old before becoming available. Therefore, it could not be used, for example, in flood warning systems. More up-to-date, or even instantaneously retrieved, hydrological data can have economic benefits for users of water resources, including many of NIWA's clients.

Elements of telemetry

Telemetry is a system for automatic transmission of data from a recorder to a "base". The elements of telemetry are: a sensor (the recording device) at the recording site; the "remote" a unit, connected to the sensor, which gathers the data on site, ready for transmission; a radio, for transmitting the data; a central computer unit, which controls the operation of a network of remotes; and software to control data collection and transmission, and to ensure its secure archiving.

Initially, the telemetry network now operated by NIWA was set up for:

- data retrieval from remote sites;
- management of data collection activities, such as the scheduling of flow gaugings.

Also, some catchment networks have been installed for flood warning systems.

NIWA's telemetry network is based on New Zealand-made data loggers, named Aquitel, and manufactured by Harding Signals Ltd, of Wellington. A specialised software package, Flosys, is used in conjunction with Aquitel. The program has been developed at NIWA in Christchurch. It is based on commercially-prepared software written to support Aquitel, and combined with selected features of NIWA's own program, Tideda (for archiving and processing time-dependent data). Flosys allows for alterations in the way data is handled at each site. For example, the system can be programmed to retrieve data at specified times. It can produce summaries of data, and run external flow prediction programs. It can also be programmed to transmit an alarm signal when certain river conditions are exceeded. Support and enhancements for Flosys are undertaken by NIWA staff in Christchurch.

NIWA staff throughout the country are responsible for operating the telemetry network. This includes field installation of units, day-to-day operation, and specialised functions for clients. All this work is carried out under a quality assurance system, certified by Telarc NZ against international ISO 9002.

Meeting special requests

A project initiated in late 1992 illustrates how the NIWA can "tailor" the telemetry system to meet special demands. ECNZ (the Electricity Corporation of New Zealand) required up-to-date information about lake levels and river flows from its Southern Lakes area, for display in its Dunedin office. Also required were flows and levels from the Upper Clutha area to be available at the Roxburgh Power Station control room. All data were to be retrieved and displayed automatically. A further requirement was that there

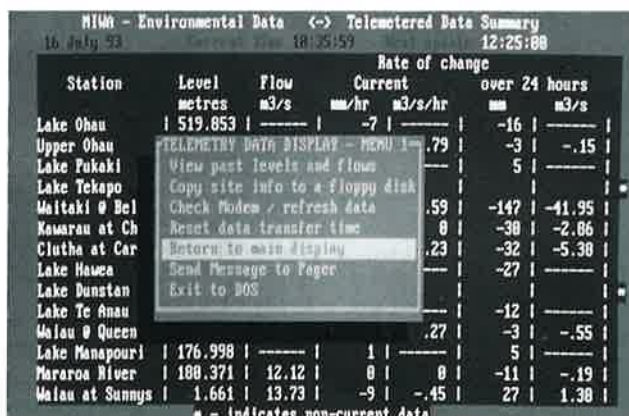
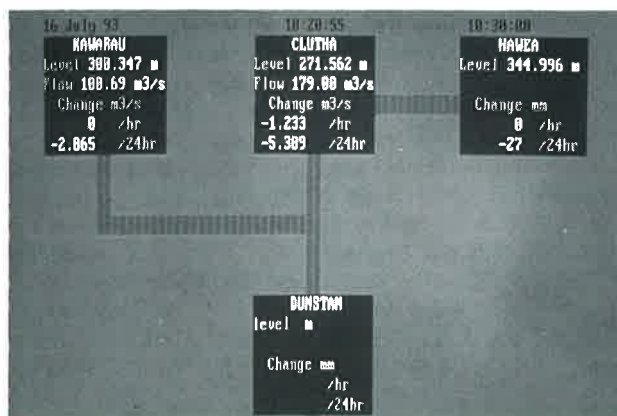
should be minimal operator involvement in running this system.

The first option considered was to install Flosys at both Dunedin and Roxburgh. However, a more appropriate choice was a computer-to-computer dial-in telephone link based on a commercial PC communication package - Norton's PCAnywhere. The latter option avoids installation of two new "base" stations, and associated radio/telephone communication links. Instead, it uses the existing Aquitel base stations at the NIWA offices in Dunedin, Alexandra and Tekapo. These bases automatically recall data from the remote sites, using Flosys's Advanced Programming facility. Flosys summarises the data on computer text files. PCAnywhere transfers these files to the ECNZ offices.

Custom-made display program

To deal with the final part of the data transfer - the display - staff at NIWA's Dunedin office provided a program specially "customised" for this assignment. The program runs continuously at the ECNZ offices, to control data transfer. ECNZ staff select times at which data needs to be transferred. At these times, PCAnywhere dials into the base computers at the three NIWA offices, and requests data on current river levels and flows. These are then displayed. Also displayed are the current rate of change in level (millimetres per hour) and flow (cubic-metres-per-second per hour), and the total change over the previous 24 hours.

Each time the information screen is updated, a summary of the flow and change information is transmitted, using NZ Telecom Communications facilities (Pacnet) to a pager carried by an ECNZ staff member. The level and flow data are also stored on files which can be copied, viewed or printed out, via a pop-up menu system. Other menu options include resetting the automatic data transfer time and



Left: An example of a teletyped data summary display for ECNZ, Dunedin, including a "pop-up" menu showing the options available. Right: Format for the data summary display provided for Roxburgh.

interval, testing the communications circuit, and sending messages to the pager. Such messages activate the pager alarm, whereas the data summary is updated silently.

Adaptability

The systems at both Roxburgh and Dunedin operate in the same way, but the screen display differs. At Roxburgh, only

the Upper Clutha information is required; data for the sites are displayed in boxes arranged to approximate their location in the catchment. ECNZ, Dunedin, requires, in addition, information on the levels and outflows of the Southern Lakes area. All three sets of data are displayed in a tabular format.

The system now operating for ECNZ provides information on river flows and

lake levels. However, it can be customised to transfer and display other data, such as rainfall intensity, air temperature, and water quality parameters. ■

Barry Thomas is Manager of NIWA's Dunedin office; Guy Halliburton is a scientist with NIWA, at Christchurch.

Solomon Islands Water Resources Project

Bob Curry

A HIGH-QUALITY, reliable, and locally-controlled water supply is something that most New Zealanders can take for granted. Inhabitants of the Solomon Islands are not quite so fortunate. However, with some help from NIWA and other New Zealand agencies, there are good prospects for improved water resources utilisation and management.

Since 1982, the Solomon Islands Water Resources Project has aimed to develop and strengthen the water resources assessment and management skills of the Water Resources Section of the Solomon Islands Ministry of Natural Resources through the support of New Zealand's Overseas Development Programme (ODA), administered by the Ministry of Foreign Affairs and Trade (MFAT). NIWA, and its predecessors, have provided technical advisers to MFAT since the project began.

Water resource problems

The Solomon Islands Government faces a number of important problems concerning the nation's water resources. For example, many remote villages must tolerate distant, silt-laden and polluted surface water supplies; the urban water supply to the capital, Honiara, is inadequate,

and the nation relies heavily on costly imported fuels for electricity generation.

The Solomon Islands Water Resources Project is tackling such problems by working with the local Water Resources Section. Its goals are to assist local hydrologists, hydrogeologists and drillers to:

- provide mainly groundwater supply systems to both rural and urban communities for agricultural and industrial development, and domestic purposes;
- assess the potential for developing water as an energy source, to reduce dependence on diesel fuel;
- assess and sustainably manage the nation's water resources.

NIWA: long involvement

NIWA's long-standing involvement with the project has been in a review and advisory capacity, with emphasis on training. Several NIWA staff have been involved. Paul Mosley provided project critique from 1982 to 1989. Bob Curry spent four years (1985-1989) in Honiara as Water Resources Adviser, seconded to MFAT. Brian Worboys undertook a two-week project progress review mission for MFAT during 1990.

Over the years, most of the hydrology/hydrogeology staff of the Solomon Islands Water Resources Section have attended 6-8 week work experience and training attachments with NIWA field teams throughout New Zealand.

Improved local handling of water resource problems

Since the Water Resources Project began, there has been notable progress in the Solomon Islands towards effective local utilisation and management of its water resources:

- A nationwide network of 11 rainfall intensity, 9 river flow and 32 groundwater recording stations is now operating. These sites provide data for use in water resource planning and



Solomon Islanders, Robert Rava and Michael Maehaka, eagerly explore, with assistance, the benefits of Tideda's newly introduced enhancements.

development. All data are archived using NIWA's programme Tideda.

- Provision of hydrological and hydrogeological data and advice sufficient to complete feasibility studies for urban water supplies for Honiara and the provincial centres; and hydro-electric power generation schemes for Honiara (6 MW) and several provincial centres (100-300 kW).
- Investigations and advice on the use of groundwater for a range of domestic, agricultural and industrial schemes particularly with respect to the maintenance of water quality and the avoidance of saltwater intrusion. Safe yields for many coastal wells have been recommended.
- Establishment of a groundwater drilling programme sufficient both to determine the necessary aquifer management requirements, and to satisfy the numerous requests for boreholes. Drilling rates have risen from 9 boreholes and 135 metres in 1985, to 31 boreholes and 789 metres in 1992. The Islands' drilling unit has achieved financial self-sufficiency through its operation.
- All the above achievements are being



Solomon Islands Water Resources Officer, Douglas Billy, and Bob Curry discuss the operation of the UK Didcot DDL004 rainfall intensity logger.

maintained through supporting local expertise and management.

“Continuing Links”

Full-time advisor assignments in the Solomon Islands were completed in 1991. That was not, however, the end of the project. MFAT retained NIWA to provide on-going advice and assistance to Solomon Islands staff. In 1992, Bob Curry accompanied a drilling expert on a training needs assessment consultancy in the Solomon Islands. This led to MFAT's “Continuing Links” programme, now proactively managed by NIWA. This is a five-year programme of training and technical advice with present indications that NIWA's management role is likely to continue through until 1996/97.

Over the last year the programme has in-

cluded: a three-week data processing and archiving mission to the Solomons, undertaken by Barry Waugh (NIWA, Wanganui); upgrading the Water Resources Section's version of Tideda to include recent enhancements to the program; backing-up the Solomon Islands' hydrological archive on NIWA's databank; subcontracting the Institute of Geological and Nuclear Sciences (IGNS) for a three-week training mission on geophysical groundwater techniques; arranging various drilling training assignments; organising customised correspondence courses with the Open Polytechnic of New Zealand; and work experience attachments for two hydrology staff with NIWA field teams throughout New Zealand.

Project monitoring

An important part of the Continuing

Links management is to undertake an annual liaison/training mission. This includes convening a meeting in Honiara of the Project Coordinating Committee, comprising Solomon Islands Government officials, hydrology/hydrogeology and drilling unit staff, and a representative from the New Zealand High Commission. Progress in the previous year is assessed, future training needs are determined, and the following year's programme is finalised. In addition, during these missions, staff are given training on a range of water resource topics. ■

Bob Curry is a Hydrologist and Client Services Manager with NIWA, at Kelburn, Wellington.

Honky nuts – sensitivity – salinity

Tony Robinson

In August and September 1993, Tony Robinson spent six weeks in Perth, undergoing training and “work experience”. This article describes some impressions gleaned during his time there.

MONITORING of river discharges in Western Australia involves a variety of methods – from calibrated velocity meters (OTTs) to “honky nuts”. Agencies throughout the state collect and archive water quantity/quality data, with varying degrees of accuracy. They include:

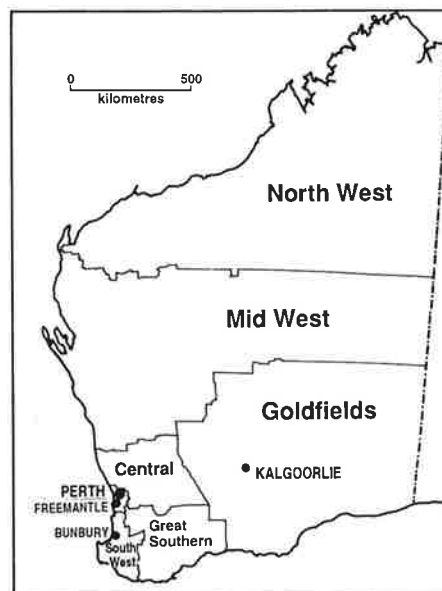
- Surface Water Branch of Water Authority of Western Australia
- Water Ways Commission of Western Australia
- Agriculture Department
- commercial entities (Aluminium Company of Australia – ALCOA)

Engineering and development

Engineering prowess arose in Western Australia during the development of the region's natural mineral resources – oil (north west shelf), bauxite (Darling Range), gold (Kalgoorlie). These commodities could only be fully utilized with major engineering expertise and exploits.

Consistent with this deeply engrained engineering tradition, strategic problems involving water supplies attract engineering projects as solutions. Problems include algal blooms, salinity, availability of potable water, and sensitivity of recording structures.

There are good reasons for considering that Western Australia's most valuable resource is fresh water. The exploitation



Regions of Western Australia.

of natural resources accelerated during the depression years, largely as a result of major engineering projects to improve water supplies. Water became readily accessible through reticulation schemes centred on the Darling Range catchments. This encouraged the clearing of vast areas of native forests including the majestic karri trees, reputedly amongst the tallest trees in the world, along with jarrah and marri. In addition, major engineering feats were required to supply water throughout the South West, Great Southern and Goldfields regions.

An illustration of the strength of public dependence on engineering is found in the fate of the engineer, C.Y. O'Conner. He was responsible for the water reticulation in the Perth area, and for upgrading of

the network feeding Kalgoorlie (a major town of the Goldfields region). He also designed the water supply scheme from Helena Dam to Fremantle. Mr O'Conner calculated that water from the newly commissioned pipeline should take three days to arrive in Fremantle, where festivities were underway. Unfortunately, at the appointed time, there was no water! Mr O'Conner's reputation was immediately in shatters. He never saw the results of his work come to fruition. He was found floating in Fremantle Bay two days later – only hours after the water had finally “spouted forth” into the town reservoir.

Salinity – a major problem

The water supply for the South West region comes from the Wellington catchment, which contains both the Harris and Wellington Dams.

The Wellington Dam is another example of an early engineering feat in the endless endeavour to develop the rich Western Australian land. Water from its catchment is used for both irrigation and “scheme” uses (potable water).

Since the turn of the century there has been evidence that clearing of native forests results in increasing saline runoff water. Unfortunately, this did not deter the profitable farming/forestry fraternities from their forest-clearing operations. Thus, the formerly potable water of the Wellington water supply scheme became saline and unusable.

The solution, naturally, involved an engineering project. The Harris dam was built in a sub-catchment that had not been cleared of the majestic native forests. Water from this reservoir now supplies the south west towns and is used to



Saline affected stream bed.

maintain the quality of the water in the Wellington reservoir.

During rainfall events the initial runoff is very saline. This "slug" of water slides beneath the fresher layers of the dammed water. The unwanted water can be "scoured out" by releasing water from the bottom of the dam. The timing of the release is determined by "real-time" monitoring of the salinity of inflows to the dam, via satellite, in conjunction with information regarding the saline profile against the dam face. Surplus fresh water from the Harris dam is then used to augment the discharged water from the Wellington dam.

A conservation order has now prohibited all tree-felling within the Wellington Dam catchment, but experts say the benefits will not be evident for at least 50 years.

Research confirms salinity problem

In the early 1970s, research was undertaken to confirm common knowledge that the clearing of forests was responsible for the increased salinity levels of surface water and rising ground water levels.

Groundwater levels and salinity were monitored from paired catchments. Within eight years of deforestation, the water table had risen 11 metres, absorbing salt that had been trapped in the soil for million of years. The saline levels of surface water rose to unacceptable levels, causing no end of headaches for the



Real-time monitoring salinity unit – South West region.

downstream users. Evidence of the damage being done to the land is clearly visible in the stream beds draining formerly usable land has been taken out of production due to increased saline levels.

Attempts to address this problem are fragmented and uncoordinated. The major driving force is the economy. Trees are once again becoming a valuable source of revenue to farmers, so huge areas are being replanted in fast growing Tasmanian blue gum, not only by the farming community but also by the Conservation and Land Management Department, and other forestry interests.

Sensitivity

One area in which the engineering ethos has been very dynamic is the construction of "sensitive" water level "control" structures. These are built in-stream, to allow very accurate measurement of water yield and saline levels.

Measuring of the surface water resource commenced in the early sixties and peaked in the early 1970s during which time the "sensitivity" god reigned. Control structures were being installed throughout the Perth and southwest regions as if there was not going to be any concrete for tomorrow! Sensitivity was the main criterion for meeting the quality assurance procedures of the day. Part of the guidelines stated: "The objective for design of sensitivity controls is to achieve a sensitivity measure of 1% as early as practicable and to keep the sensitivity at better than this value for the remainder of the rating curve. For small catchments, a



Sensitivity water level control structure.

sensitivity measure of 0.67% is achieved and maintained as early as possible."

To ensure that this objective was met, a large design infrastructure built up in the Public Works Department in the early to mid 1970s. It culminated in Bulletin 14: *Investigation and Design*. This sets out 16 types of sensitivity structures, to be used whenever installing a water level control structure. But the release of Bulletin 14 coincided with a move away from the installation of elaborate concrete structures.

The temporary structures now being installed follow the design guidelines in the Bulletin, but they are made of other materials – wood, fibreglass, sandbags – which might not meet the desired "sensitivity" objective.

Now – where do honky nuts come in? ...



Honky nuts (Western Australian name).

The Agriculture Department and other water recording agencies, in their quest for information and involvement of farmer and the community with the saline problem, have initiated a monitoring programme of water quantity and quality. Some "low-key" methods are recommended, such as using "honky nuts". You toss the nut into the water at a given point, and time how long it takes to travel a set distance. The Agriculture Department has also begun making portable "sensitivity structures".

The collection of data using such practices was discussed at a recent Water Quality Workshop in Bunbury. Also raised were matters involving the integrity and robustness of data collected using the "honky nut approach", and also of data collected by the Western Australian Water Authority.

The problem of salinity is immense, as is its effect on Western Australia. All approaches to solving it should be considered, but surely honky nuts are not the answer? ■

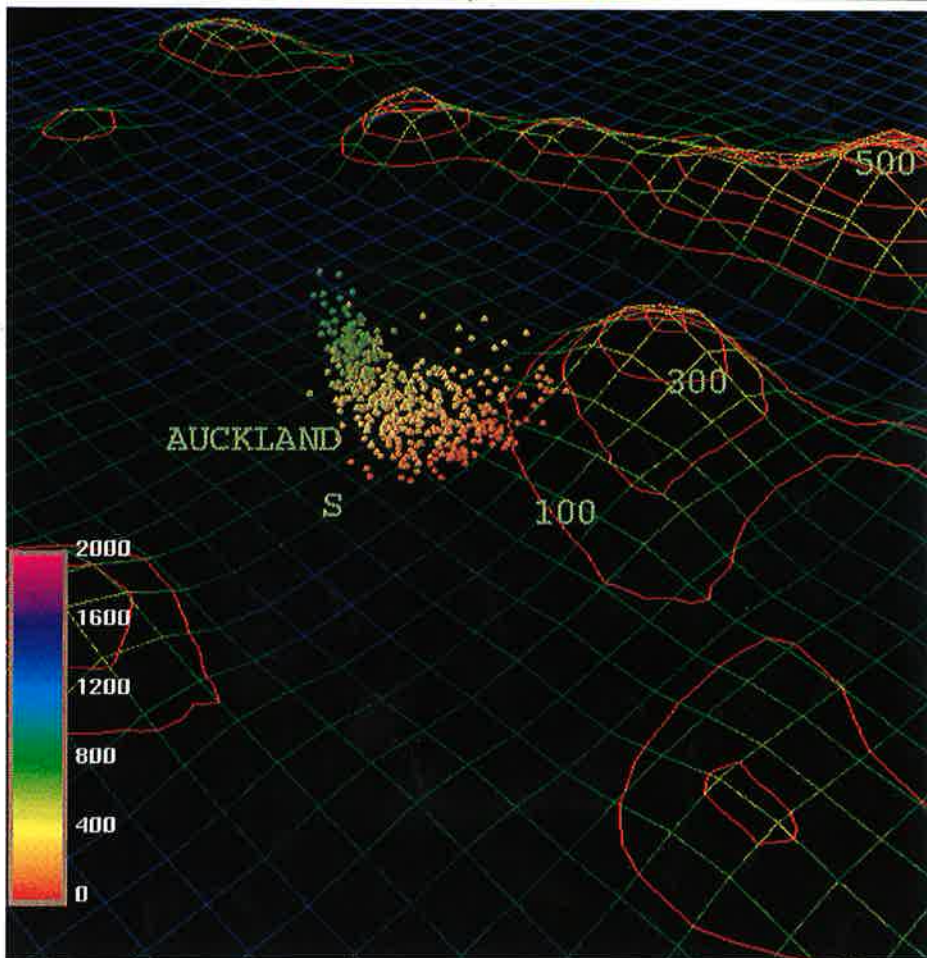
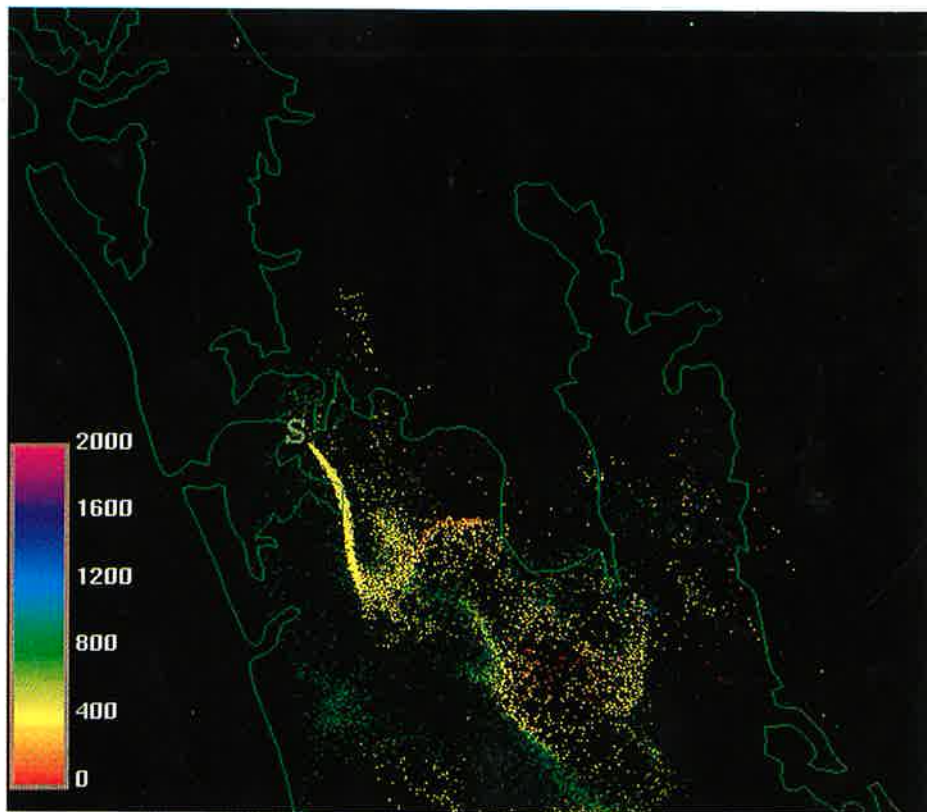
Tony Robinson is a Business Development Manager with NIWA, and Manager of NIWA's Nelson office.

New atmospheric modelling techniques

NIWA SCIENTIST, Dr Roger Ridley, has made exciting progress in implementing a new modelling system which has applications in weather forecasting, windflow studies, pollution dispersion, and climate research.

A Lagrangian Particle Dispersion Model is now running on a new high performance workstation after nearly a year of intensive development. The modelling system has two main components. Firstly, a detailed three-dimensional wind field is modelled, using a model developed by Dr Ridley at Monash University. Dr Ridley's Mesoscale Model (named RiMM) is based on mesoscale modelling systems used overseas but has been extensively adapted for New Zealand conditions. Secondly, once a realistic wind field has been established, particles are released within the model and tracked to show how material would be dispersed in the region.

The technique not only allows the study of weather and atmospheric processes in much greater detail than before, but is also a powerful visualisation tool, as shown in the figures reproduced here.



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Plan (upper) and perspective (lower) views of the dispersion of particles released from a hypothetical power station in south Auckland. The plan view shows the distribution of particles after a 24 hour simulation commencing at midnight. The perspective view shows the particles being mixed from their initial height down to the surface in the late morning. Different colours represent particles at different heights, as indicated in the scale, in metres. (Diagrams by Dr R.N. Ridley)