Fisheries resource knowledge, management, and opportunities: Has the Emperor got no clothes?

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session 2

Abstract

Fisheries in the ocean around New Zealand have become important industries. For the last 20 years the major tool used for the management of fisheries resources has been the quota management system. The extent to which our application of this system has been effective in meeting resource management objectives is questionable. The effective use of such tools requires a reasonable knowledge of the state of the resources being "managed" and of the ecological impacts of fishing activity. This paper explores the knowledge requirements of the management system and the role that science has been able to play in meeting those needs. Our success has been limited by a lack of definition of fisheries management objectives, ineffective processes for determining key research questions, and inadequate research funding. The delivery of useful research is also challenged by the large scale, complexity and variability of the systems which support the fisheries and by poor ecological and biological knowledge on which to develop the applied monitoring and assessment tools necessary. Future opportunities will be focused on maintaining healthy fisheries rather than developing new resources and will arise from recognition of major changes to some key fisheries, and an awareness that successful fisheries are dependent on the overall ecological resilience of the systems we are exploiting.

Introduction

Over the last 25 years we have made too many assumptions about the resources on which our fisheries depend, and their sustainability—to the point where some important elements of the industry are at serious risk, mainly through ignorance. We are at a point where our capacity to correct things has been undermined by a loss of capability and because we have cemented into our fisheries administration many attitudes, particularly relating to the implementation of property rights, which need to be changed. It is going to be hard because we have been doing things the way we have for so long.

When the Quota Management System (QMS) was introduced into New Zealand it was hailed as a "world leading" approach to fisheries management—and in some respects it was. That self-congratulation has evolved over the last two decades, especially when elements of the fisheries management system in New Zealand have been criticised, into an oft-repeated statement that we have the "best managed fisheries in the world".

There is also a strong perception among many stakeholders that the system is strongly based on science and that "resource sustainability is assured through the QMS and companies can securely invest in adding value to export products …" (Seafood Manifesto SEAFIC). In the Ministry of Fisheries 2000 Annual Report, the Chief Scientist was quoted (rather boldly) as saying "New Zealand is respected world wide as a leader in science-based fisheries management, so I believe we can all feel confident that our fishery will be there for future generations". I think the Emperor has no clothes; I think we have been fooling ourselves.

When the system was introduced in 1986 my perception was that most industry participants and investors thought that the initial Total Allowable Catches (TACs) for most fisheries were inherently conservative and that investment decisions could be confidently made on the basis that quotas were more likely to increase than decrease over time—particularly since our science effort would develop an improved understanding and confidence about the state of the resources.

The reality was that initial TACs were based on very little information other than catch histories. Our understanding at the time was not good enough to determine whether such levels of catch actually were conservative. On top of that, the science effort over the 20 years since has clearly not been adequate to improve that confidence greatly—certainly at the scale of the large number of fisheries "managed" within the QMS.

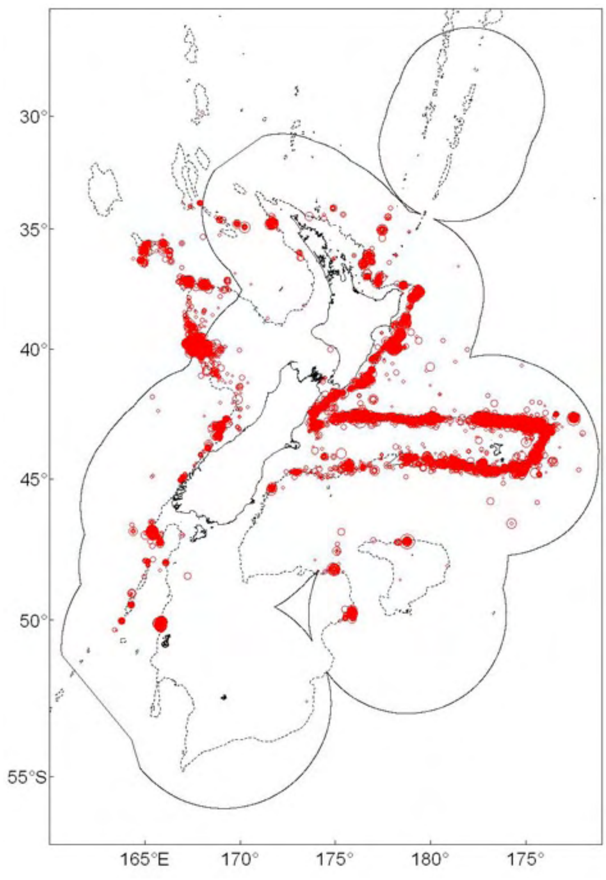

Fig. 1 Trawls which reported more than 1 tonne of orange roughy, 1979–2002.

Having said that, there do not appear to have been any spectacular "collapses" of fisheries in New Zealand as was seen, for example in the cod fishery in the NW Atlantic. However, one important element of the effects of fishing on orange roughy that can be clearly demonstrated is the major reduction which has taken place in the range of fish in "commercial" densities around New Zealand over time (Fig. 1 and 2).

I do not propose to debate the merits of the "world leading" arguments since they are not helpful (a **relative** lead does not ensure a **good** system) but I would like to explore the extent to which our fisheries management is *science-based* and whether the science on which it is based is appropriate and adequate.

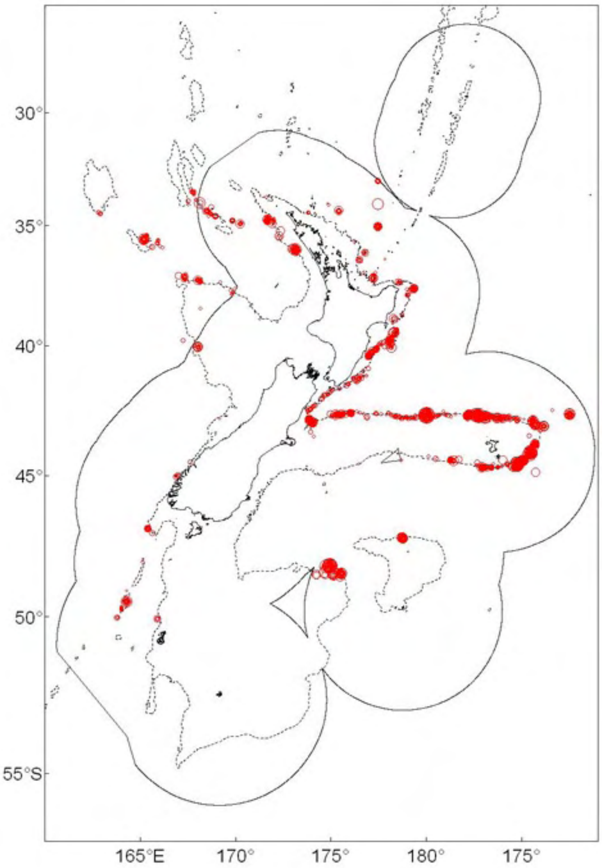

Fig. 2 Trawls which reported more than 1 tonne of orange roughy, 2003–2005.

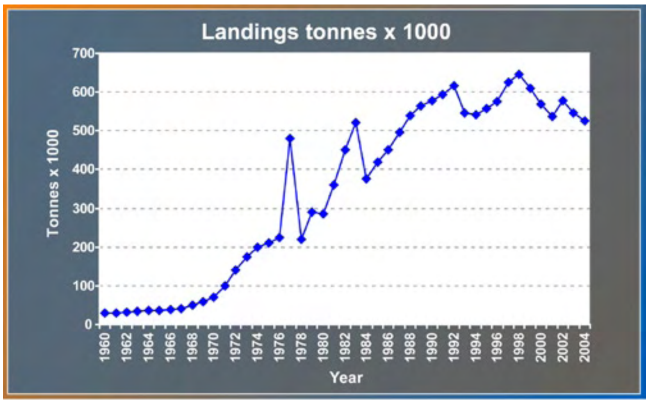

Fig. 3 Estimated landings of fish from the New Zealand area, including aquaculture production.

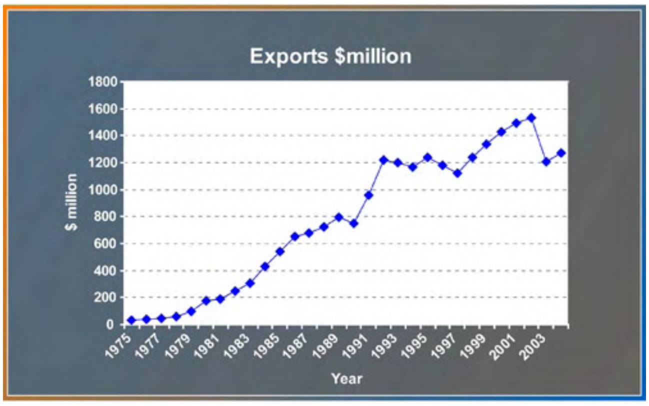

Fig. 4 Estimated export values for New Zealand 1975–2004.

Development of fisheries in New Zealand

Fisheries in New Zealand before about 1970 were based mainly on utilisation of inshore resources by locally owned and operated vessels. Activity offshore had until that time been confined to the well known exploits of Japanese snapper fishers and, further away, some "deepwater" activity by foreign vessels from countries such as the Soviet Union, Japan, Korea, and Poland. This activity picked up markedly in the mid 1970s just before the declaration of the New Zealand Exclusive Economic Zone (EEZ) in 1978.

After 1978 there was a brief period of consolidation and then a rapid expansion into middle depth and deepwater fisheries through to about 1990. Overall landings have fluctuated since then around a mean of about 550,000 tonnes per year.

Fisheries management

In 1986, New Zealand introduced a tool for the management of commercial fisheries based on Individual Transferable Quotas (ITQ)—generally known as the Quota Management System (QMS).

The system was introduced with the primary objectives of bringing economic rationality to commercial fishing and providing a better basis for the conservation and sustainability of fisheries resources. This was all done in an environment which was increasingly showing signs of "overfishing", rapid development of the new deepwater fisheries and a perception that a race for fish (too many fishermen chasing too few fish) was not rational (Sissenwine & Mace 1992).

An important misconception at the time was that the QMS was a **complete** fisheries management package. Although it was a hugely important tool, it did not address a number of key elements that you might expect to see in a coherent fisheries management system—at least as it was implemented:

- It did not handle mixed species fisheries.
- It was based on a statistical concept of sustainability—maximum sustainable yield (MSY).
- It assumed that we could reasonably determine what MSY was and the status of fisheries with respect to MSY.
- It was based on a fish **stock** concept that often bore little relationship to biology of fish.
- It was very inflexible with respect to area management questions mainly because of property right and value questions.

It did not address the ecological context in which fisheries operate—there were some later developments allowed for in the amendments to the Fisheries Act but there was still a huge emphasis on the "stock" idea which was a major barrier to managing multispecies /ecosystem relationships.

It was operated without a broader management planning context, with no management objectives other than the broad reference point of MSY.

An important concept introduced as part of the system was the concept of *output controls* (such as quota)—a clear departure from the previous *control of inputs*—such as the level of fishing effort. It is interesting to note that while some important input controls such as limited entry were taken away for ITQ species, many other input controls such as gear and area restrictions, seasonal closures, and size limits have remained largely unchanged to this day.

The other key concept that was introduced was the idea of "property rights". It is my contention that this concept then disproportionately dominated the administration, management and politics of commercial fisheries over the next 20 years, to the possible exclusion, or at least the cost, of other important objectives such as sustainability.

My proposition is that while some elements of the system we have developed ARE "world leading", many elements are not—because we largely have rested on our laurels since 1986 and in particular we have paid insufficient attention to the resource base on which our fisheries depend.

Put bluntly, the inevitable squabbling over allocation of access rights and some of the other systems that have been introduced—such as cost recovery from quota holders for management and research costs—have diverted attention away from the status of stocks and the research required to establish a useful understanding of that status. The processes have also provided active incentives for quota owners to argue against research to improve our understanding of those resources. Hall & Mainprize (2004) in an excellent review of the ecological elements of fisheries management succinctly noted that "the existence of perverse incentives for fishers that militate against environmentally desirable behaviours are ignored at our peril".

The rights-based approach has been accompanied by a call for rights holders to take on the main responsibility for management of "their" resources, with Government simply setting and monitoring appropriate standards. One of the important assumptions made by many supporters of this approach (including an active lobby group within the Ministry of Fisheries) is that right holders will act in a way which maintains the long-term value of their asset and that they will not act to undermine this, particularly in relation to sustainability questions.

While that is clearly an important incentive, my observation over the last 20 years of stock assessment discussions has been that there are clearly a lot of **other** pressures and incentives on quota owners, particularly economic ones, which are not focused on the long term. These often result in a high degree of risk-taking in uncertain situations and sometimes active resistance to research or interpretations of research which might result in reductions to TACs, or, of course, increases in costs to rights holders.

The cost recovery system and its effects on research

A particularly powerful perverse incentive is the **cost recovery** concept, or more particularly, the way it has been implemented. Put simply, many of the costs of managing fisheries are recovered by way of a levy system on quota owners. These costs include the costs of research. What more powerful incentive could one dream up for rights-holders to resist expenditure on uncertain activities such as research, especially as priority setting is likely to result in most work being done on stocks perceived as being most at risk, and for which TAC reductions are most likely. A similar dilemma exists where fisheries are small or have been reduced, perhaps through overfishing, to a low level. A particular feature of the system in such circumstances has been calls to stop research on the basis that the Quota owners cannot **afford** the costs.

The pressure on quota holders in this area has been heightened by continuing attempts by the Government to minimise government expenditure on fisheries research, largely on the grounds of attributable costs. That is, the costs should be borne by the beneficiaries of fisheries. As a result, most research costs have been paid through industry levies with little recognition of the benefits to the broader New Zealand economy or society from the presence of a fishing industry.

Further pressure and huge inefficiencies have also been introduced through an insistence by industry and government players on *contestable/market-based systems* for research delivery. In a small country with limited research resources, this made, and still makes, little sense, and it had the obvious effects of encouraging replication of expertise and facilities, reducing cooperation between competing providers, and reducing science communication. Moreover, science quality is not well handled by such systems. To cap it all off, there was no "market" with only one significant purchaser, and only one provider with any significant capability.

A further bad element to the system has been the focus on year-by-year contracting processes which have been a serious impediment to the establishment of suitable time series of measurements or longer-term studies more appropriate to the scale and temporal variation of the resources we are attempting to manage. Pressures to "focus" on direct research (monitoring) limit opportunities for more multidisciplinary or ecological studies. The lack of investment in research in New Zealand's oceans before1986 has not really changed much, we are living off our science capital. This is accompanied by a tendency in Public Good Science Funding processes to say "that's operational" and to not support attempts to understand our marine environment and its interaction with fisheries.

I believe that the way cost recovery has been implemented and become established in New Zealand is the single greatest risk to informed, sustainable management and development of our fisheries resources.

The need for science in fisheries management

Systems of fisheries management based on total allowable catches and oriented around the concept of **maximum sustainable yield** are hungry for information. In the absence of an adequate understanding of stock dynamics and sustainable yields, resource managers need to be sufficiently risk aware and averse and have adequate systems in place for monitoring changes in stocks.

As I noted earlier, when the QMS was introduced the initial TACs were based on a very limited knowledge of most of the resources being included—catch histories were the primary indicator of levels of catch which could be sustained. Those data were dodgy in accuracy and limited in scope, but there was a general perception that the TACs were "conservative" and that there was time to improve our knowledge and understanding through research.

As an aside I would note that it was a particular feature of the New Zealand experience that we introduced a record number of species into our QMS in one go, but while the number of species and stocks that were introduced was high (29 species groups and about 60 "stocks"), there was a large number of species which were not introduced but for which no management other than continuation of previous rules was available. The lack of any clearly stated criteria for what species would be included seemed to reflect a great degree of horse trading around the adjustment mechanisms proposed where catch histories exceeded TACs. This process was further distorted by an appeal process that effectively ignored TACs . This treatment of TACs as a kind of guideline only was made worse later by schemes to manage bycatch issues in multi-species fisheries that also led to TACs for some species being exceeded.

Fig. 5 (*below*) Estimated Government fisheries research expenditure 1981–2005.This includes a significant amount of "biodiversity" funding from about 2003.

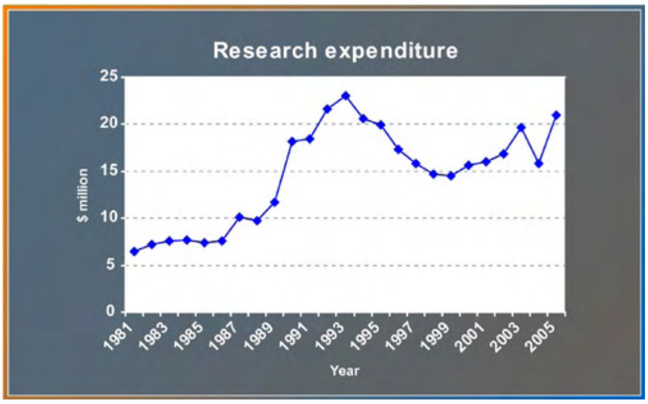

Fig. 6 (*above*) Research expenditure as a proportion of export dollars from fisheries.

Some important steps **were** taken over the next few years to improve our research capacity (such as funding for research vessels). However, the development of expertise and knowledge about our resources nowhere near kept up with the pressure on the resources and certainly did not deliver the progress that was assumed would be made when the QMS was launched.

I observe that even where relevant science is available, most decisions have been influenced by other factors, economic and political, associated with allocation concerns. The political reality is that the uncertainty associated with the science advice is not easily dealt with in the face of much more "certain" economic outcomes of decisions. There is a whole literature available about uncertainty in decision-making, and fisheries management is a particularly relevant and active field for discussion. The ongoing process of developing science advice for decision-making has been dominated by stakeholders who have tended to use the good consultative processes available to resist research efforts and/or to highlight the uncertainty in assessment and the inadequacy of our knowledge to effectively stall decisions.

Management where information is insufficient

It is hard to imagine that decision-makers will ever be presented with good quality, well-informed assessments for many fisheries based on a good understanding, well modelled, stock and fishery dynamics. It really is not affordable—and of course not likely.

There is therefore a need to have in place decision-making processes based on the best information available, and to develop workable applications of concepts such as *adaptive management* (Walters & Collie 1989) and the *precautionary approach*. This calls for science which seeks primarily to measure relative changes in stock size with reasonable precision and the attributes (where possible) such changes to fishery and non fishery cause, and which is responsive enough to provide timely advice to managers. The key to this approach is to move away from the expectation that we can measure absolute abundance as a basis for estimating MSY and related measures. Outcomes need to be monitored and management decisions need to be altered if the outcome falls short of what was intended—this may best be called proactive management (Hall & Mainprize 2004).

Uncertainty will still need to be dealt with. Hall & Mainprize (2004) noted that "the higher the uncertainties the higher the level of precaution needed in the harvest control rules or management procedures. If uncertainty is low harvest control rules can be more generous. It must be recognised…that in situations where data are limited, quantifying the uncertainty associated with reference points may not be possible at all. In reality it is very difficult to be precautionary when there is little or no data, unless one makes a decision not to fish at all."

The state of knowledge of stocks in 2006

It is not possible to determine precisely what knowledge or what quality is "enough" for decisions on the management of fisheries.

The information and analyses available on many fish stocks in New Zealand are very well documented by the Ministry of Fisheries in an annual document summarising the state of resources (Ministry of Fisheries Science Group 2006) in a format designed to be consistent with the requirements of the Fisheries Act. As such, the focus is on reporting the status of fish stocks in relation to the *biomass which will support the maximum sustainable yield* (B_{msy}). This somewhat static reference point has been the subject of much discussion but remains the primary marker—where information is available to determine it.

A review of the most recent Plenary document demonstrates the drought in our knowledge of even the most straightforward sustainability indicators. Of 84 "stocks" of demersal fish species where annual landings were greater than 500 tonnes, 24 were assessed as being above B_{msy}, 5 were assessed as being below B_{msy} and 55 were of uncertain status (Table 1). A recently reported analysis of a similar type shows that we are certainly not "world leading" in comparison with Australia (Table 2).

Table 1 Status of demersal New Zealand stocks with landings greater than 500 t per year (Source: Ministry of Fisheries Science Group 2006). B_{curr} is current biomass.

Stock status relative to B_{msy}	No. of stocks	% of stocks	2004–05 landings (t)
$B_{curr} > B_{msy}$	24	29	176,000
$B_{curr} < B_{msy}$	5	6	55,000
Uncertain	55	65	213,000
Total	84	100	444,000

Table 2 Status of Australian stocks in 2005 (Source: Caton & McLoughlin 2004).

Stock status	No of stocks	% of stocks
Over-fished	17	23
Not over-fished	17	23
Uncertain	40	54
Total	74	100

In general, I conclude that our science has not delivered a good service for the management and development of fisheries in New Zealand. Our system is NOT strongly science-based. That is a conclusion that can easily be reached even before considering the processes where science is incorporated (or not) into decision-making processes.

The reasons for this are complex but boil down to:

- insufficient research resources, people, equipment and funding;
- limitations on scientific method and theory to tackle many questions;
- an inadequate understanding of the dynamics of New Zealand marine ecosystems;
- a management system which provides very strong perverse incentives to keep research funding low; and
- a management system which treats the QMS as the **whole** of the system and which has not been able to develop any coherent management objectives on which to base decisions about the effectiveness of management or the allocation of scarce resources such as research resources.

In a recent review of fishery science, decision-making and sustainability, Garcia (2005) noted that "in the light of the irruption of the market economy and technological acceleration (compared to traditional fisheries management) the necessity to use science to assist in policy and management decisions was inescapable". He rightly noted that this necessity implies a high risk of manipulation of science and scientific results by all parties and the conduct of research in a socially and politically stormy environment.

Garcia also noted that various spectacular crashes of fisheries (Canadian cod stock, Peruvian anchoveta) led to arguments that more funds for research *per se* would not improve sustainability and that painful governance decisions were needed. Clearly relying on science was not enough.

In New Zealand we have not developed a system which includes management objectives which allow for effective targeting of limited science resources—at both a strategic and operational level. We are not alone. In a general review of the relationships between science and fisheries management Garcia (2005) noted that "scientists will probably never be fully aware of what all the objectives are (i.e., hidden agendas are part of the system)." He also pointed out that "it has been argued that in such a vacuum, scientists attempt to force a decision in a particular direction through the advice provided (and generally, according to the fishing industry, in an overly conservative direction)". In my view scientists in New Zealand have maintained an objective viewpoint, and have avoided being drawn into conservatism. I note, though, that this has not reduced fishing industry accusations that scientists are inherently biased towards conservation.

We need better defined management objectives that:

- take the biological/ecological situation more explicitly into account;
- allow for uncertainty and variation in the resources;

- are developed around a risk management framework;
- as far as possible PLAN for future events;
- are inclusive of all stakeholders;
- clearly identify knowledge needs and priorities, and limitations;
- are fairly resourced;
- incorporate measures of performance which are monitored, perhaps incorporating reference points as benchmarks.

In making such comments I am well aware that one should not underestimate the scale and complexity of the problem. The New Zealand EEZ is large and ecologically and environmentally complex and variable. We have developed important fisheries on a wide range of species. Many of our fishery resources have strong interactions with areas beyond our immediate jurisdiction and technological development in fisheries generally far outstrips our understanding or our capability to provide useful science input to decisions.

Where to from here?

I propose that we:

- urgently introduce good quality fisheries management **planning** systems based on the concept of co-management, with a clear definition of management objectives, and taking account of the great potential for conflicts of interest.
- urgently review some of the incentives in fisheries management processes, particularly cost recovery systems, risk assessment, and management performance arrangements.
- remove the restrictions imposed on research caused by the insistence on the great majority of research funding coming from quota holders.
- consolidate and improve the traditional analytical basis to assessing stock based around concepts such as MSY—and try and improve our information and understanding to support this. Key elements will be better understanding of recruitment processes and the factors influencing variability.
- invest seriously in improving our knowledge of resources as a basis for developing effective and efficient applied monitoring and assessment tools.
- continue to try and improve our ability to address fisheries assessment in an ecological context, including incorporating ecosystem production values, an understanding of functional biodiversity and interactions with fishery resource productivity.
- introduce systematic analysis of research and management performance.
- pay more attention to small-scale fisheries management.

Future opportunities

It is unlikely under present arrangements that significant new resource development will occur in New Zealand waters. Neither the industry nor the Government seems to be able to "afford" it. In any case, care is required, even if a development appears to be economically justifiable, because we need first to have a better understanding of the resources we are currently exploiting.

Some development of small-scale inshore resources is clearly possible but it needs to be based on a reasonable degree of understanding of sustainability, interactions with other fisheries, environmental impact, and cost benefit analysis. Fishing lower down food chains (e.g., myctophids) has been raised as a possibility but needs to be very carefully considered in the light of ecosystem effects. In both areas under current funding arrangements the likelihood of anyone being able to afford the necessary R and D is low.

The best future fisheries investments lie not in looking at the apparently greener grass over the hill but in fairly and squarely maintaining the healthy and productive fisheries that are available to us now.

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The 96% solution: resources on and beneath the ocean floor

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Abstract

New Zealand has jurisdiction over a vast marine territory that extends from the subtropics to the Antarctic. Known mineral occurrences suggest that this region almost certainly hosts extensive deposits of a variety of valuable resources. The location and extent of these resources is largely speculative, however, because only a small fraction of the region has been adequately surveyed. New Zealand's marine economy is currently worth about $3.3 billion a year in a GDP of US$80 billion, $750 million of which comes from the production of offshore minerals, primarily oil and gas (Statistics New Zealand 2006). Oil and gas production in 2002 contributed about 0.7% to the New Zealand economy. Utilisation of offshore resources in the deep ocean around New Zealand will become increasingly economically viable as demand increases and new technologies are developed. Environmentally responsible realisation of these benefits can be encouraged by reduction of investment risk through increased baseline knowledge of the region and growth of technical expertise, making non-government (probably foreign) investment attractive. We have the opportunity to gather these data now, while interest in offshore development is relatively low, and use them to guide resource management decisions to achieve economic growth and environmental conservation and minimise usage conflicts.

Non-living marine resources in the New Zealand region include oil and gas, and minerals formed or concentrated by physical, chemical and hydrothermal processes. Oil and gas are the most significant in terms of their present development, and in terms of recognised potential future value. Frontier petroleum basins cover an area of about 55,000 km^2, and may be capable of generating as much as 24 trillion barrels of oil (Uruski & Baille 2001). In addition to conventional oil and gas prospects, New Zealand has the most promising known gas hydrate resource potential in the Southwest Pacific. Gas hydrates are an enormous potential source of CO_2-efficient energy. Sea floor minerals that are known to occur in the New Zealand region include aggregate, ironsand, and gold in coastal areas, and manganese nodules, phosphorite nodules and hydrothermal minerals in the deep ocean. Ironsand and aggregate are currently being mined. Hydrothermal minerals such as gold, copper and zinc are of current economic interest—there is an exploration license that covers a prospective region for hydrothermal minerals along the Kermadec Arc. The other resources are not presently economically attractive.

Introduction

The islands of New Zealand are the emergent fragments of a vast submarine continent that stretches from Tonga, Fiji and the Coral Sea in the north to the subantarctic islands in the south (Fig. 1). New Zealand's maritime estate includes the exclusive economic zone (EEZ), continental shelf, and responsibility for the Ross Dependency.

New Zealand is quite isolated today, but it was once connected to Antarctica and Australia, part of the Gondwana super-continent. A plate tectonic boundary runs through New Zealand, and it is the compressive force across this boundary that keeps New Zealand elevated above sea level and the surrounding plateaus.

New Zealand has a land area of about 270,000 km^2, about the same as the United Kingdom. It has the 4th largest EEZ in the world, encompassing an area of about 3.8 million km^2. A 10-year project to determine the extent of the continental shelf has just been completed. After confirmation by the United Nations, New Zealand will have jurisdiction over resources on and beneath the seabed in an area covering up to 1.7 million km^2 beyond the EEZ. New Zealand also has a special interest in the oceans of the Ross Dependency, an area of about 1.5 million km^2. If we consider the land area, EEZ and legal continental shelf, then about 96% of New Zealand is under water.

This large area is certain to have resources that will contribute to New Zealand's future economic prosperity. Although some of the resources have been studied, we know so little about the offshore region that we cannot predict the full extent of their distribution and concentration. Knowledge of the ocean—the water column, the sea floor, what lives on it, and what lies beneath it—is essential for informed management of New Zealand's offshore mineral resources.

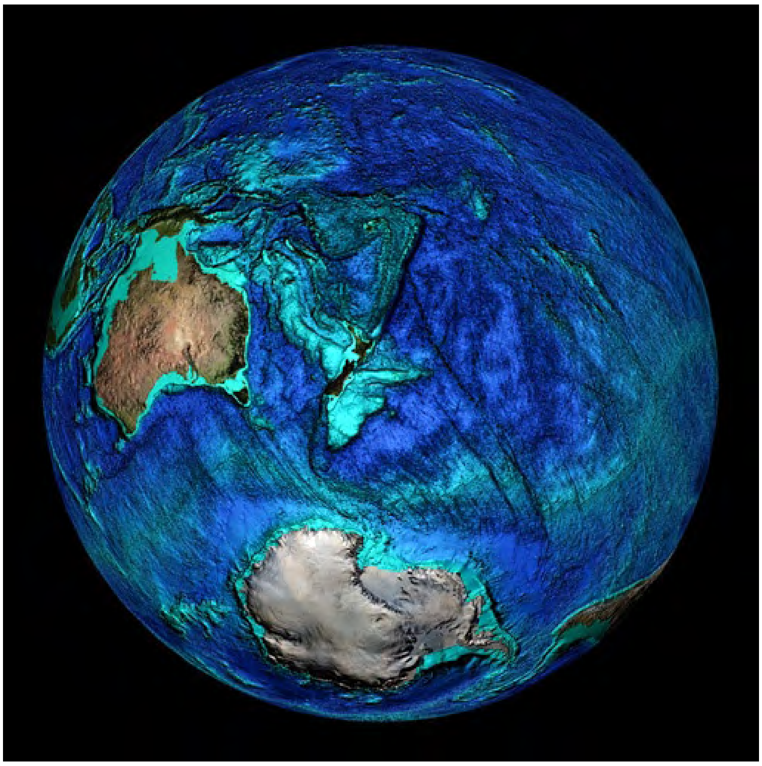


Fig. 1 Global bathymetry data showing New Zealand in the South Pacific. Image from the National Geophysical Data Center, National Oceanic and Atmospheric Administration, US Department of Commerce.

This paper addresses the question *Why are offshore mineral resources important?* But it considers this in the context of the underlying question *How can we best manage New Zealand's resources to promote continued economic growth and prosperity?* The purpose of the paper is to show that we can achieve this goal by recognising that New Zealand extends far beyond the coastline, and by including informed management of ocean resources in our economic future. Knowledge of the oceans is the key that will make this possible.

This paper focuses on what we know about New Zealand's mineral resources on and beneath the sea floor, and some of the factors affecting their development.

Economics of the ocean

New Zealand has a vast marine estate, but only about 3% of our GDP comes from the marine economy. The main reasons why this is so are the lack of knowledge about what is there, and lack of technology to make marine resources economically competitive. But this is changing rapidly. Bottom trawling, undersea cables and pipelines, aquaculture, tidal power generation—these are marine development issues that are frequently in the newspapers.

How much is New Zealand's offshore region worth? In 1998 the Department of Prime Minister and Cabinet published a report estimating the potential economic wealth of the oceans was tens of billions of dollars. Offshore research is expensive and it would be useful to demonstrate that it was leading towards a quantifiable goal and identify the rate of return on the research investment. However, deriving meaningful values for this analysis is very difficult.

In order to make an estimate of value, we need to consider what resources we know are there, how large they are, what they are worth, and what they will cost to produce.

With our present knowledge of offshore minerals it is impossible to make comprehensive estimates of their distribution and extent. We can make guesses based on our limited data and global statistics, but we really don't know how many more Maui gas fields there are, if any.

Value and cost are not only a matter of market price and production costs. There are societal and environmental costs that must also be considered. Our knowledge about the marine environment is as meagre as our knowledge of the resource distribution, yet any consideration of development must consider its environmental impact. If, for example, we find a giant gold deposit in the middle of a forest of coral, should we mine it? Is this the only coral forest of this type, or is it found in many places? We probably do not know. The New Zealand economy benefited greatly from cutting down kauri trees, but would we clear those forests to the same extent today?

Given this paucity of knowledge of resources we know exist, it is clear that we cannot begin to guess the possible value of unknown resources.

Consider an analogy. The United States purchased Alaska in 1867 for the equivalent of about US$1.7 billion in today's dollars. It was purchased for geopolitical, not economic reasons. It was called Seward's Folly at the time because the only known resource was furs, and these were thought to be largely gone. No-one imagined the enormous economic benefits that would one day come from Alaska. But 30 years after its purchase Alaska was part of a major gold rush. At today's prices, gold produced from Alaska would be worth about US$12 billion. A century after its purchase, in 1968, oil was discovered in Prudhoe Bay. So far that field has produced about 13 billion barrels of oil, worth about US$300 billion.

The point is that neither gold nor oil were known to exist in Alaska, and it is likely that new resources will be discovered in New Zealand's offshore. It would be a tremendous advantage to have sufficient knowledge already in place to manage them when they become important.

There are three broad phases to resource development:

1. discovery—recognition that a resource exists;
2. exploration—mapping and analysis of the resource; and
3. management—controlling utilisation of the resource.

The process is the same anywhere, whether it is New Zealand or the planet Neptune. Maori and other sailors discovered the islands of New Zealand, and were followed by surveyors, politicians and bureaucrats who mapped the land and managed its resources. Neptune was discovered by European astronomers in the mid 19th Century, and in 1989 the Voyager 2 spacecraft completed the only survey of the planet, including photographs of it and its moons. More exploration is required before politicians and bureaucrats can successfully manage either Neptune's resources or those in offshore New Zealand.

Successful progression from discovery to management requires a corresponding progression in knowledge. It is a cliché, but true, that we know more about the surface of the Moon than we know about the sea floor around New Zealand.

New Zealand's offshore data

Where is New Zealand in the spectrum of discovery, analysis and management of its offshore resources? In most cases we are still in the discovery phase because of the lack of data.

Fig. 2 New Zealand's topography sampled along main highways, an analogy to the data coverage in much of the offshore region.

In many areas the data have been collected along ships' tracks tens or even hundreds of kilometres apart. A rough analogy would be to drive the main highways of onshore New Zealand at night, trying to decipher the topography, ecology and resource potential from what you can see in the headlights. Figure 2 gives an impression of how much information this would provide. It would probably be possible to infer the presence of the Southern Alps, but it is unlikely that the location of Mt Cook could be predicted from this information.

Alternatively, our existing offshore knowledge can be compared to an early map of New Zealand, where a few areas, such as harbours, are quite well known, and the broad outline of the country's shape and morphology are known, but most details remain a mystery. On some early maps, features as large as Lake Taupo were "details" that were unknown.

Management of offshore mineral resources requires detailed knowledge of the sea floor and what lies beneath it. Modern technology has made it possible to much more efficiently collect these data. Multi-beam bathymetry data and high-quality seismic reflection data are the backbone that New Zealand needs to map its ocean territory. Multi-beam bathymetry data provide the equivalent of onshore topographic maps and aerial photographs, and seismic reflection data provide the third dimension—information about the rock layers beneath the sea floor.

Bathymetry data

There is quite an extensive coverage of single-beam bathymetry data around New Zealand (Fig. 3a). But even though these

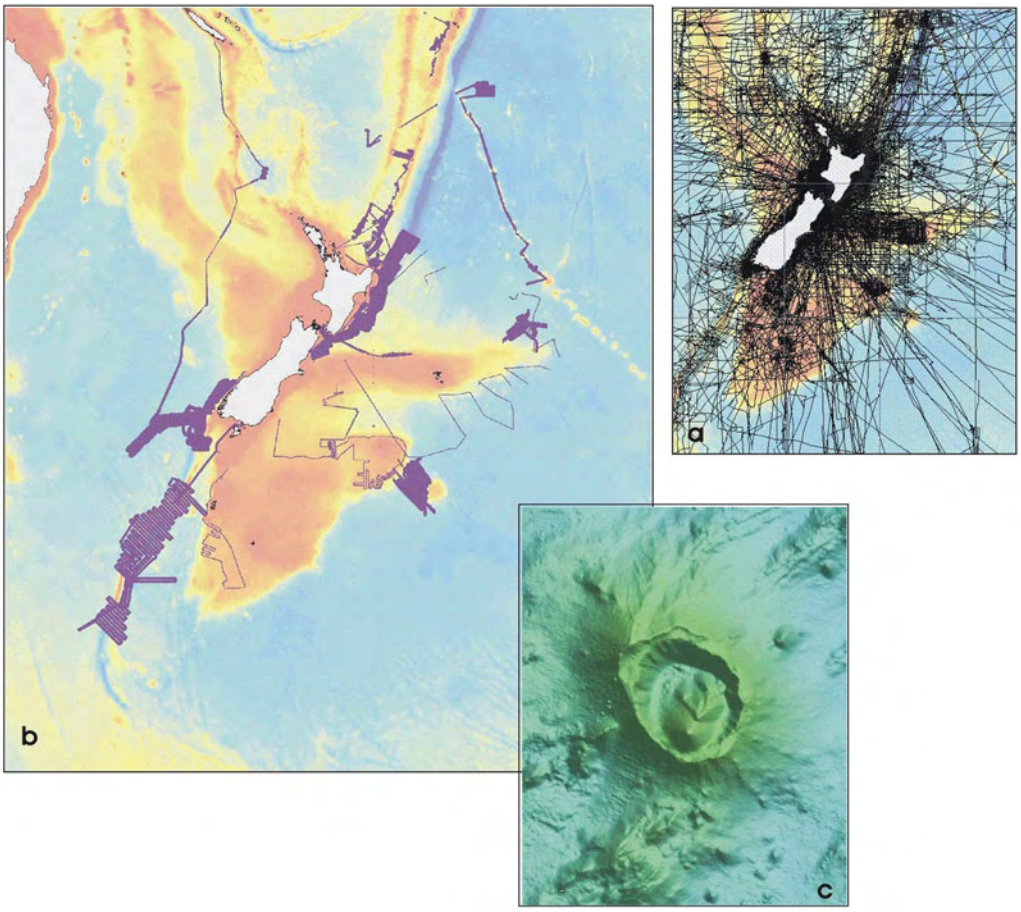


Fig. 3 **a**, distribution of single-beam bathymetry data, and **b**, multi-beam data. **c**, multi-beam data from a submarine volcano along the Kermadec Arc north of New Zealand showing individual lava flows and cones (de Ronde et al. 2005).

lines look closely spaced, in many areas they are actually quite far apart. Many Lake Taupo-sized features could fit between some of the bathymetry tracks.

Modern technology has given us the ability to fill in these gaps by inferring the general shape of the sea floor from satellite data. But these data image features at a scale of 3–5 km, a resolution too coarse to find and manage resources.

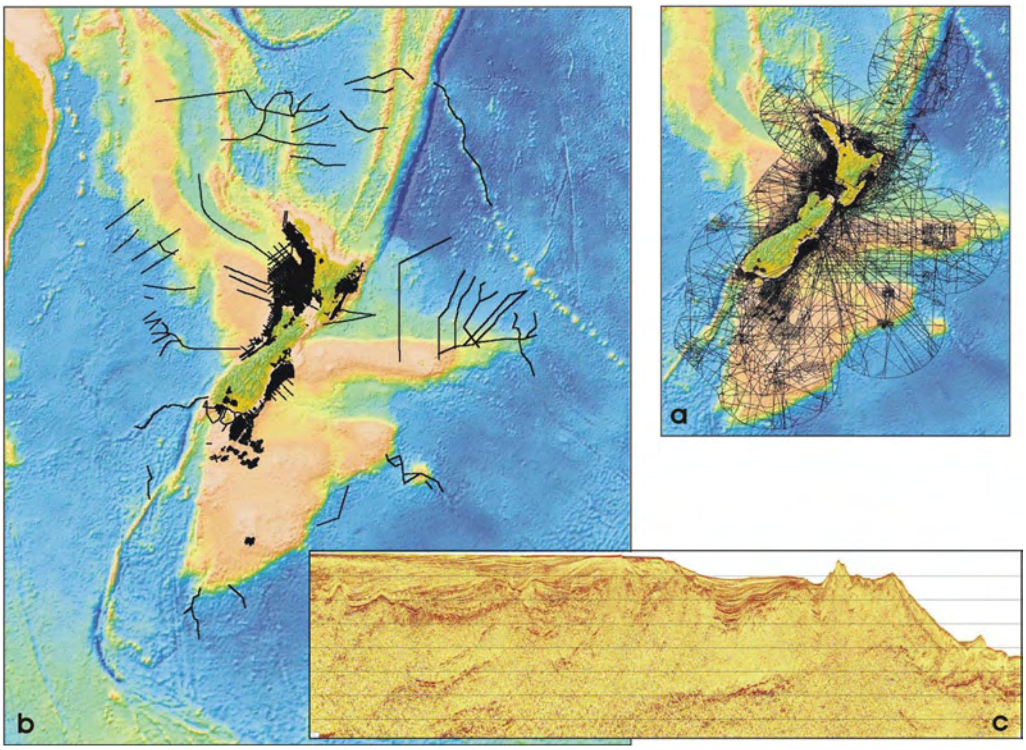
Multi-beam swath data are an essential component of the data required to manage ocean resources. They reveal the shape of the sea floor like an aerial photograph reveals the shape of the land, and provide information about whether the seabed is rock or sand or mud. Figure 3b shows that about 10% of the EEZ is covered with multi-beam bathymetry data. Figure 3c shows data collected over a submarine volcano on the Kermadec Arc north of New Zealand. These data have remarkable detail, and individual lava flows and cones are clearly apparent.

The cost of surveying the entire EEZ would be of the order of $200 million, about $50/km^2.

Seismic data

As for the bathymetry data, there is quite an extensive coverage of seismic reflection data that provide information about the rocks beneath the sea floor (Figure 4a). However, most of these data were collected decades ago with small systems and provide limited information about the subsurface.

Fig. 4 **a**, distribution of all seismic reflection data, and **b**, modern, high quality seismic data. **c**, modern data collected by the Ministry of Economic Development along the east coast of the North Island shows subsurface geological structure.



The distribution of modern, high-quality seismic data is much more limited (Fig. 4b). Most of these data were collected by oil exploration companies, and therefore are concentrated in near-shore sedimentary basins such as Taranaki and the east coast of the North and South islands. Over the last 10 years or so these data have been supplemented by data collected in other parts of the EEZ by research programmes and the Law of the Sea project. However, only about 15% of the EEZ has sufficient good quality, modern seismic data to provide even a hint of a Maui-sized oil or gas field.

Figure 4c shows an example of these data from a recent Ministry of Economic Development-funded survey on the East Coast. These modern data provide a detailed cross-section of the entire sedimentary sequence, and often show large-scale plate tectonic features such as, in this case, the Pacific Plate being subducted beneath the North Island.

Specialised vessels are required to collect these data. At current prices, the cost of reproducing the existing coverage of high-quality seismic data would be of the order of $240 million dollars. The cost of completing a regional seismic survey of the entire EEZ would be of the order of $100 million.

Other data

Other data, such as rock and sediment samples and gravity and magnetic field measurements, are also essential for discovering the distribution of marine mineral resources. These data complement the basic framework information obtained from multi-beam bathymetry and seismic reflection data.

New Zealand's offshore resources

Although offshore resources are still a small component of our economy, globally they are very important. Offshore oil and gas are a US$200 billion/year industry, and other offshore minerals are worth about US$2 billion/year.

Other offshore minerals are grouped on the basis of how they are formed—physical, chemical and hydrothermal. Globally none of these is as economically important as oil and gas, and some will require technological advances to be viable. But all of them are potentially important for New Zealand.

Oil and gas

Oil and gas are different from other offshore resources for a number of reasons:

- They are by far the biggest offshore resource sector.
- They are a relatively mature industry.
- New Zealand has an immediate need for a secure energy supply.
- They are likely to remain economically important for at least the next few decades.

When it was discovered in 1969 the Maui gas field was one of the global giant fields. It has provided secure, affordable energy for more than 30 years, and is still the major provider of New Zealand's natural gas. Compared with other oil and gas fields it covers a relatively large area, but in terms of New Zealand's offshore area it is tiny. If discovered today it would be worth of the order of $30 billion. Production is declining, and is expected to last for about another 10 years.

Even if New Zealand can somehow rapidly reduce its dependence on oil and gas, finding oil and gas fields would still be a huge benefit to the economy. Globally the demand for oil and gas is unlikely to decline for decades, and if New Zealand could become a net exporter of petroleum it would be an enormous supplement to our other export products.

Does New Zealand have another Maui? Can we find it in time to maintain our secure, affordable energy supply? The answers to questions like these have huge implications for our energy and economic future.

A large part of New Zealand's offshore area may have oil and gas, but after more than a century of exploration and production the oil and gas potential of New Zealand's offshore remains largely unknown. Figure 5 summarises our assessment of the region's prospectivity, showing areas where petroleum is known to have been or is likely to have been generated and areas where petroleum may have been generated.

Tararanki is the only offshore area currently producing hydrocarbons. The Ministry of Economic Development has recently been quite successful promoting New Zealand as an exploration target, and much of the red area on this map is licensed for exploration.

Given the large areas that may be prospective, a concerted exploration effort is likely to discover significant hydrocarbon reserves and ensure that offshore oil and gas production remain a significant part of New Zealand's economy.

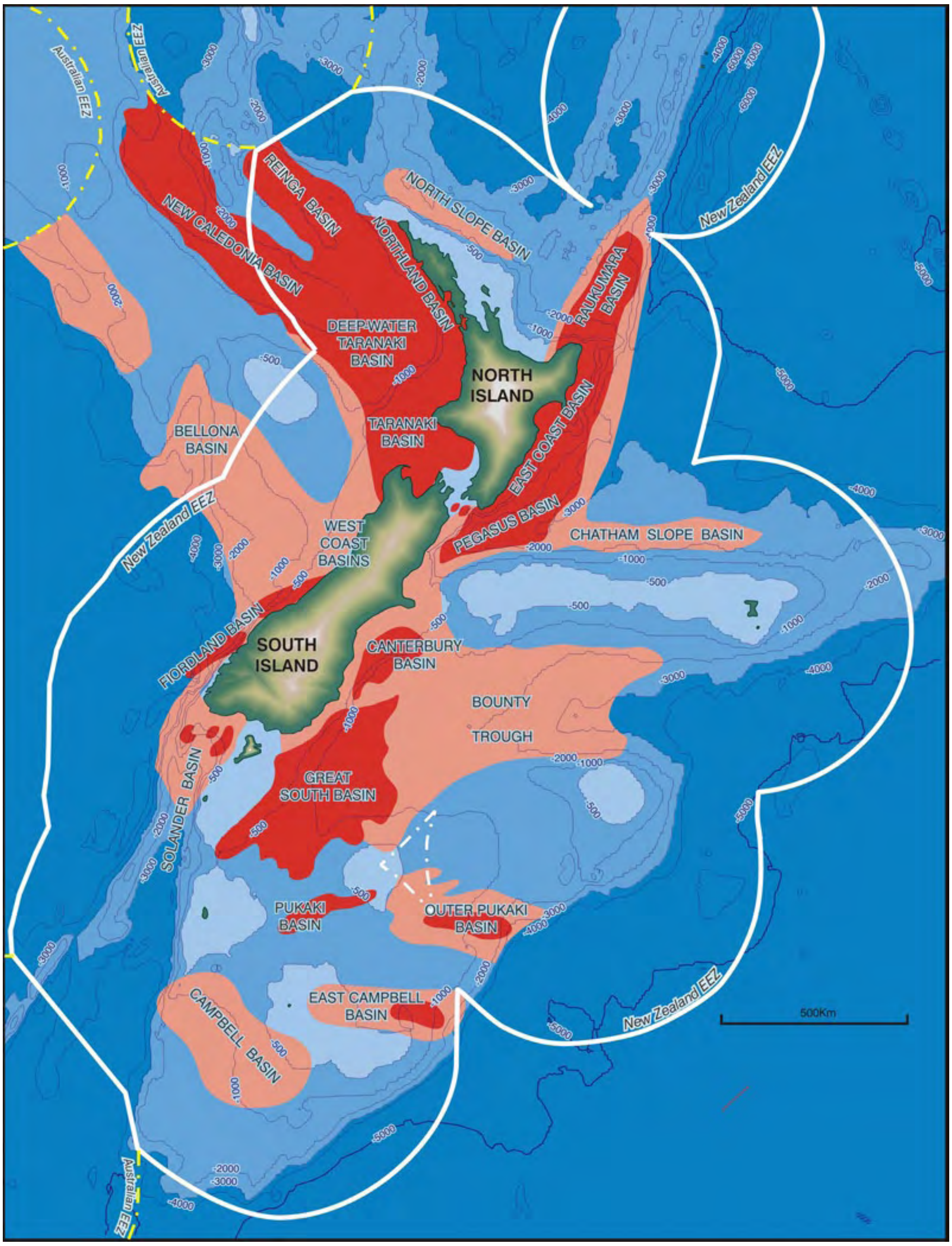


Fig. 5 Predicted distribution of New Zealand's offshore petroleum resources (Stagpoole et al. 2000). Red areas are those where petroleum generation has or is likely to have occurred, and the pink areas are where petroleum generation may have occurred.

Gas hydrates

There is another potential source of gas in the offshore—gas hydrates. According to some estimates, globally they contain energy reserves greater than all other hydrocarbon sources.

Gas hydrates are comprised of methane frozen in a water matrix. Their occurrence is controlled by pressure and temperature conditions in the rocks beneath the sea floor. Gas is formed in the earth and rises through cracks and pores until it reaches a point where it "freezes" due to the physical and chemical properties of the rocks and fluids. Onshore, gas hydrates are found in cold regions such as Canada and Siberia. Offshore, they are found in the top few hundred metres of sediment beneath the sea floor on many continental margins around the world.

As well as their energy potential, gas hydrates are important because of their possible effect on climate change, and their potential contribution to tsunami hazard. Because their formation is a function of temperature and pressure, changes in sea level or temperature could affect their stability. A rapid change in temperature or pressure could release massive amounts of methane into the atmosphere, potentially triggering or contributing to climate change. Instability arising from a rapid change in temperature or pressure could also result in massive submarine slides that could cause tsunamis.

Production from gas hydrates is not yet economic, but it is the subject of intense global interest. Japan is spending hundreds of millions of dollars on gas hydrate research, and in 2006 India spent US$36 million drilling holes along its continental shelf to evaluate potential gas hydrate resources. Scientists predict that economic development of gas hydrates could take place in the next 10–15 years. Pilot production from onshore deposits in Canada has demonstrated that it is feasible.

New Zealand's known gas hydrate deposits are along the continental shelf of the East Coast and Fiordland (Fig. 6). The East Coast gas hydrate province may contain more than 800 trillion cubic feet of gas (Pecher & Henrys 2003), about 160 times the amount of gas in the

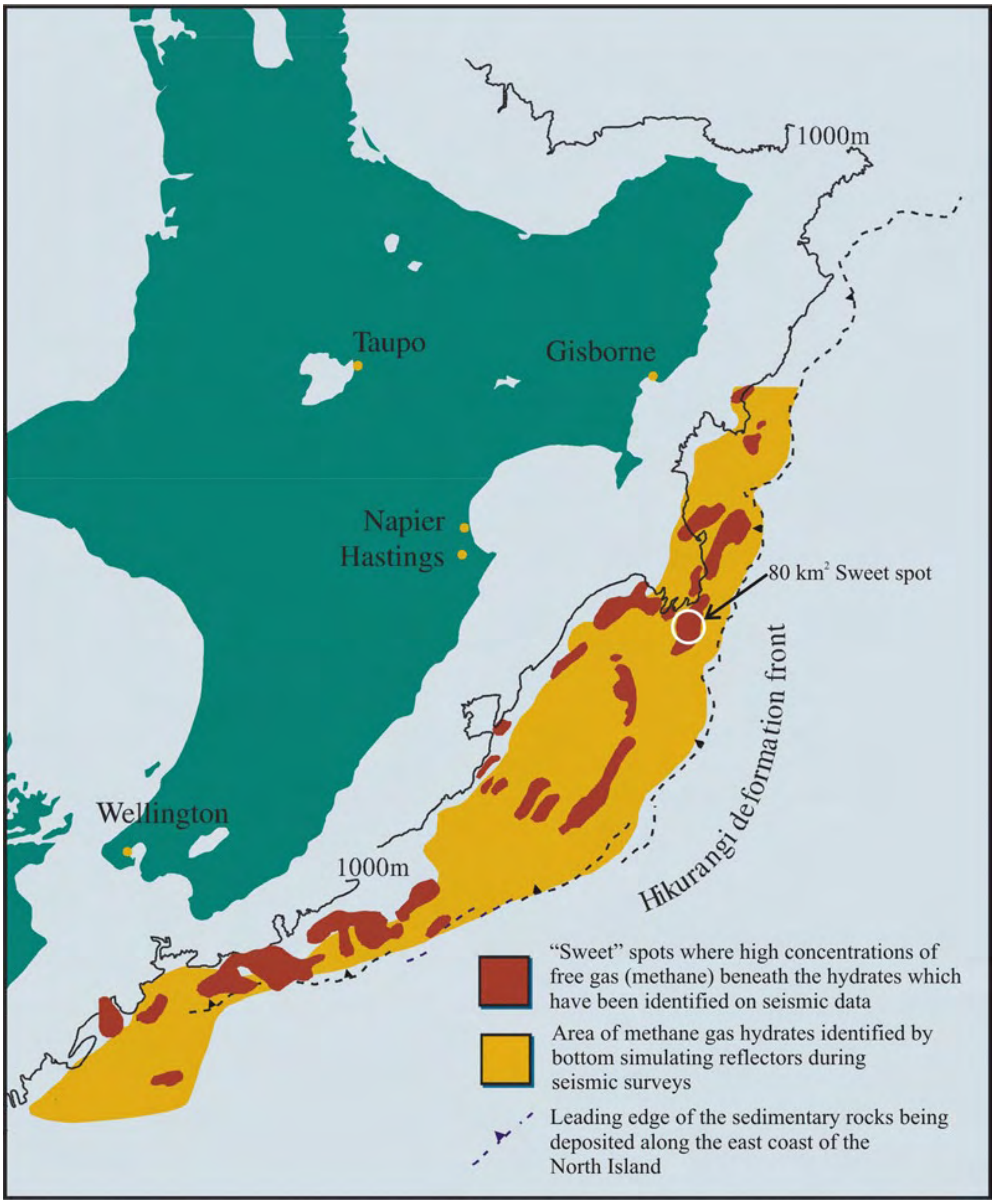


Fig. 6 Predicted distribution of gas hydrates along the east coast of the North Island (Pecher & Henrys 2003).

Maui field when it was discovered. The volume of recoverable gas could be more than 6 times that produced from the Maui field and 16 times more than current proven gas reserves.

Placer deposits

Placer deposits are concentrated by physical processes such as waves and currents. Globally, diamonds dominate this sector. Annual diamond production is worth about US$1 billion. Offshore tin mining is also a significant industry, with about 14% of global tin production coming from offshore Southeast Asia. Sand, gravel, coral, and shell are less valuable, but are locally very important. They are often used for beach replenishment, landfill and cement.

Offshore placer deposits are not currently a major resource in New Zealand, but they are likely to become more important.

For example, development of offshore aggregate sources for Auckland is becoming more attractive because:

- Urbanisation and conservation have led to more productive uses of onshore aggregate sources.
- Onshore mining activities are subject to increasingly stringent regulations.
- Land transport of aggregate puts a strain on already congested roads.

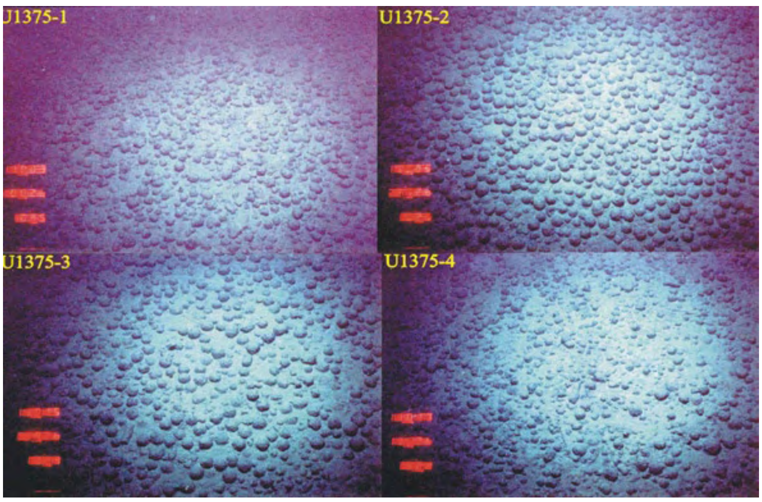
But this does not mean there will be unrestricted development of the offshore. It is instructive to remember that sand mining in Mangawhai Harbour was stopped in 2004 because of environmental concerns.

The offshore gold potential of Coromandel and the South Island's West Coast has historically attracted exploration interest, and there is currently a gold prospecting permit over much of the offshore West Coast. Another prospecting permit for gold, ironsand, titanium and other minerals covers parts of offshore Taranaki and Northland.

Nodules and crusts

Fig. 7 Manganese nodules from the deep ocean south of the Campbell Plateau (Chang et al. 2003).

Nodules and crusts are the result of chemical reactions between the sea floor and the sea water. Ferromanganese nodules, discovered in 1868, are the most well-known example of these deposits (Fig. 7). They form by direct precipitation of iron-manganese oxides from sea water. There are large deposits of ferromanganese nodules around New Zealand. The most well known of these is in the deep ocean area south of the Campbell Plateau (Graham & Wright 2006).



There was a flurry of commercial interest in ferromanganese nodules from the 1960s through the 1980s, but there has been little activity since. Ferromanganese nodules are not valuable because of their iron and manganese content, but rather because of the traces of cobalt, nickel and copper they contain. Record metal prices make mining of ferromanganese nodules more attractive, and the technology to extract them has been developed. But competition from large onshore mines, metallurgical difficulties, and concerns about environmental issues are significant barriers to development. The value of a tonne of polymetallic nodules in 2000 was about US$100, a figure that has showed no significant long-term change over the previous 40 years. The value of the cobalt, copper, and nickel contained in ferromanganese deposits within New Zealand's EEZ is estimated to be of the order of $1000 billion at current commodity prices (Graham & Wright 2006; I. Graham pers. comm. 2006).

There are currently seven areas in the deep ocean around the globe licensed for exploration for polymetallic nodules by the International Seabed Authority. These are not economically viable today, but are expected to become so as mineral costs rise and mining technology improves. This trend will also affect the prospectivity of New Zealand's resources.

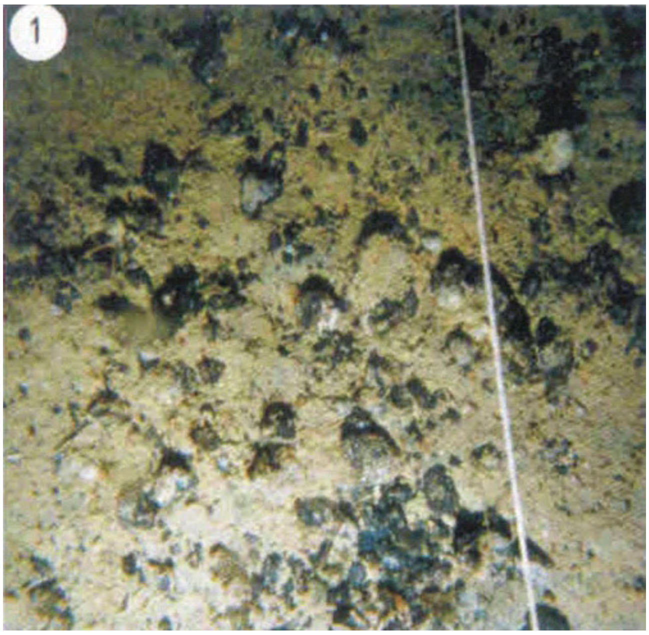


Fig. 8 Phosphorate deposits along the Chatham Rise (Kudrass & von Rad 1984).

New Zealand has large phosphorite deposits on the Chatham Rise, east of the South Island (Fig. 8). They were investigated by New Zealand and German scientists in the mid 1980s. The extent and grade of the resource are well documented (Kudrass & von Rad 1984), and the total value of the resource is estimated to be of the order of $3–4 billion. Production costs could be of the order of $2–3 billion and the environmental costs are unknown.

Phosphorite deposits on the Chatham Rise have similar properties to superphosphate, and could be used as a more long-lasting fertiliser. The resource may become viable as alternatives become more expensive.

Hydrothermal polymetallic sulfides

Finally, some resources are the product of submarine hydrothermal activity. These are the product of the movement of metal-rich fluids that are associated with volcanic activity. The most visually dramatic deposits are chimneys associated with hydrothermal vents. They are called "black smokers" because when the hot hydrothermal fluids meet the cold seawater the iron and manganese-rich particulates precipitate, forming chimneys and black "smoke".

The most valuable minerals are likely to be gold, silver, copper and zinc. The concentrations and value of these minerals vary, but typical assays and historic values indicate that the value of the copper and zinc will be as great as that of the gold and silver.

More widespread mineralisation can also produce large areas of high-grade ore. Each of the world's 21 giant lead-zinc deposits—those with geological reserves in excess of 100 million tonnes—was originally formed in a marine hydrothermal environment like those active today along the Pacific's volcanic arcs (C. de Ronde, pers. comm. 2006).

Hydrothermal mineral deposits are known to have been emplaced along volcanic arcs extending about 2,500 km north of New Zealand (Wright et al. 1998; de Ronde 2006; Fig. 9). Active volcanism is occurring along the Tonga-Kermadec arc, and the Colville and Three Kings ridges are fossil arcs. Offshore exploration licences searching for hydrothermal polymetallic sulfide deposits have been granted in New Zealand and Papua New Guinea.

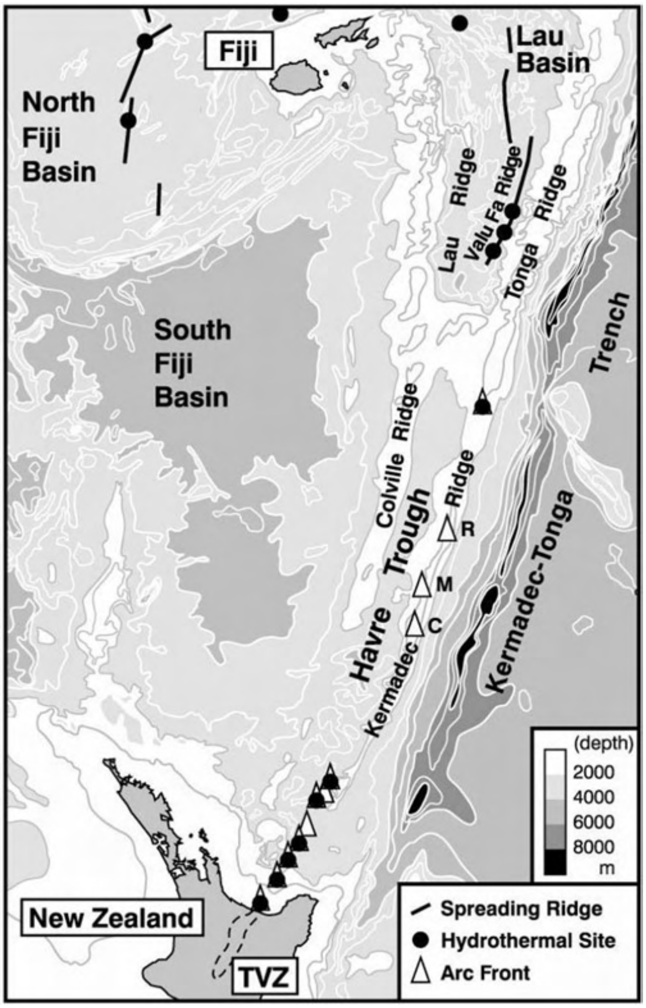


Fig. 9 Location of some of the active hydrothermal sites along the Tonga-Kermadec Arc (de Ronde et al. 2005).

Future of marine resources

There are significant technological challenges to overcome, but environmental, economic, and legal uncertainties will be major factors affecting the development of offshore resources. Lawyers and accountants, not scientists and engineers, make the final decisions about whether to develop a mining prospect.

Environmental uncertainties are potentially one of the largest factors affecting offshore development. The Resource Management Act 1990 regulates onshore development, and as the pressure to develop offshore resources increases it is likely that a similar framework will be put in place to manage them. There are already concerns about activities such as bottom trawling and aquaculture, and the Mangawhai sand mining precedent shows the power of public action.

This is not just a local phenomenon. Globally the petroleum industry, for example, has faced increasing regulation of the environmental impact of its offshore operations. This demonstrates that it is possible to put environmental regulations in place that still allow development, although there is always more that can be done as knowledge of the environment improves.

Economic uncertainties affect every resource development plan, both offshore and onshore. Offshore production of many minerals is still not viable because the value of the resource does not offset production costs, but this situation is changing.

Economic considerations include weighing the relative merits of offshore and onshore resources, and the merits of importing these resources. Factors that will influence these decisions include:

- There are still large onshore deposits with clearly understood economic and environmental risks.
- Everyone uses metals, but few people want to live near a mine. The choice of where development occurs will include societal costs as well as economic and environmental ones.
- Onshore costs are expected to rise because of alternative and more productive uses of the land, because of the effect of increasing regulations and accounting for externalities, and because of increases in the cost of labour, fuel, and other production inputs.
- Offshore costs are expected to decline as technology improves and perceived investment risk declines.
- Increasing global demand will raise resource prices and could impact on supply.

Factors that may influence decisions in favour of development of New Zealand's offshore mineral deposits include concerns about security of supply, providing a buffer against cost volatility, and improving the balance of payments.

Legal uncertainties have generally declined in recent years. Large areas of New Zealand's ocean estate have, or soon will have, clarity of sovereignty and a regulatory framework governing offshore resources (Fig. 10).

New Zealand completed negotiation of its maritime boundaries with Australia in 2004, and has begun similar discussions with Tonga and Fiji. Our Continental Shelf submission has been lodged with the United Nations and is being considered by the Commission on the Limits of the Continental Shelf, and the United Nations has issued guidelines for mineral development in the deep ocean. All of these factors reduce investment risk and make the development of offshore resources more attractive.

The challenge of managing competing uses will be at least as important as the other challenge. Fishing interests, wind turbines, tidal power stations, pipelines, cables, mines, spoil dumps, marine reserves—the list of potential uses is only going to increase. Onshore, the Resource Management Act considers the relative merits of alternative uses of the resources, deciding questions such as whether the land is more valuable as a mine or a park. Similar decisions will need to be made offshore.

Fig. 10 New Zealand's Exclusive Economic Zone, extended continental shelf, and negotiated boundaries with Australia (Government of New Zealand 2006).

Offshore, New Zealand doesn't have to end up with the equivalent of oil wells in suburban areas. We have a window of opportunity while demand for development of offshore resources is relatively low. With enough information it is possible to make informed decisions about alternative uses of the offshore, maximising the economic and social benefits for the country and minimising the environmental impacts.

The best thing New Zealand can do now is to undertake systematic, comprehensive surveys of its marine territory to provide maps and supporting data containing the same kind of fundamental, background information for resource management that onshore topographic, geologic, soil and vegetation maps provide. This is the way to be proactive rather than reactive, ahead of the proverbial bulldozers rather than trailing behind them. Successful utilisation of marine resources requires faith in the value of New Zealand's offshore; and commitment to invest large sums to make informed management possible.

Conclusions

New Zealand has a vast marine estate with huge resource potential. The challenge is to promote New Zealand's prosperity through informed management of increasing demands on those ocean resources. If there is anything our onshore experience tells us it is that it will not be easy.

If we discovered New Zealand today, with the knowledge and technology we have, would we develop it the same way? I would like to think that we would have a national park where moa still roamed, and another with vast stands of giant kauri trees. I would like to think that our largest population centre was located near our major sources of renewable energy and not in the middle of a field of volcanoes. And I would like to think that the capital city did not lie on top of one of the major fault lines that run through the country. If we plan ahead, if we invest in knowledge and find out where the fault lines and kauri forests are, then we should not make the same mistakes in the offshore.

Acknowledgements

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Developing the New Zealand marine infrastructure

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Introduction

The importance of New Zealand's oceans is not well understood in this country. New Zealand's oceans are the fifth largest of any country's in the world, thanks to our many small outlying islands and the continental shelf extensions (CAENZ 2001). In strategic terms these territorial rights present an immense one-off gift to our nation that will underpin future development and prosperity for our people.

New Zealand's coastal and marine resources and activities related to the ocean have long contributed to the New Zealand economy, but with this additional considerable endowment the potential exists for significantly increased contributions in the future. In addition, much of the infrastructure essential to the overall performance of New Zealand's economy and trade also impinges on the ocean. This includes our ports, the inter-island ferries and coastal shipping, offshore gas field development and production, the Cook Strait power cables and both our internal and international telecommunication networks. Increased demand for improved access to international markets and the demands of a growing economy and population will act to further expand economic activity within our ocean territories.

Simply put, to help sustain and grow the New Zealand economy, existing commercial activities in the oceans and the infrastructure services that support these endeavours will have to continue and further develop. In addition we will need to see the realisation of the many new opportunities that can be expected to emerge through technological advance and scientific discovery in future years. However from technological, environmental, economic and resource stewardship perspectives these same opportunities offer huge challenges to the ways we currently think about our oceans and our approaches to their management and potential exploitation.

Technological innovation is essential if New Zealand, as a small nation, expects to maintain a leading position in ocean development. Support of such innovation requires that we focus on knowledge gaps and maximise knowledge delivery to stakeholders. This will require imagination, ingenuity and the drive to develop our scientific knowledge and technological understanding to the forefront of international efforts in these areas.

Fostering technological development

Work by the New Zealand Centre for Advanced Engineering (CAENZ) on oceans opportunities has identified a substantial number of areas with potential for commercial development in addition to those sectors that are already contributing to economic activity (CAENZ 2003, 2006). While some existing sectors are currently growing there will be continuing need for further exploration and development of new opportunities, not all foreseeable, for which provision must be made.

Infrastructure development, including a strong knowledge and innovation system, is crucial if New Zealand is to take advantage of such opportunities and aspire to be at the forefront of oceans development internationally. In particular the acquisition, management and application of knowledge will be a vital component to transforming the ways in which we approach ocean development.

A common theme emerging from the work undertaken by CAENZ has been a recognition of the vital importance to oceans development of ensuring that there are policy frameworks in place that encourage both technology innovation and maximum knowledge transfer to stakeholders. For this to occur, the key principles identified by the different stakeholder groups who contributed to the CAENZ studies were that the ocean policy should be:

- based on explicit and sound principles that offer a balance across all sectors;
- supported by a well-developed and an efficient knowledge infrastructure;
- comprehensive in scope and provide for knowledge to be shared;
- sufficiently durable and robust to allow for technological change, new resource discovery, and/or emergent market opportunities.

Transparent and robust processes and systems for knowledge acquisition and management will need to be developed and continuously refined. In administrating future ocean activity careful consideration will need to be given to the form and allocation of property rights to foster knowledge sharing as well as providing the certainty needed for investment. There is also a question as to what point Government should be involved in providing for economic development, and in this regard what constitutes an optimal governance regime that maximises knowledge delivery to stakeholders?

Ocean governance

Over the last decade the New Zealand Government has taken more than a dozen key decisions on marine affairs (Beggs & Hooper 2005). Together, these initiatives have begun to change the ways in which we think about our oceans resource, but there is yet a long way to go before we have the comprehensive framework that will position this country as an effective maritime nation in the 21st Century.

Current policy and legal structures do not adequately meet the challenges of managing our ocean territories in a way that reflects the diverse challenges and opportunities that they offer. The reality is that only a relatively small part of New Zealand's GDP is presently derived from the ocean and our marine inventory is not managed in any sense that gives recognition to the immense strategic value of these resources to New Zealand's future prosperity.

In appraising the prospects for the development of our marine resources we have to address several important questions that have a significant economic content:

- Will New Zealand and overseas investors consider that New Zealand's marine resources compare favourably with other possibilities?

- Will governments, with constrained resources, be prepared to give high priority to marine research, education and capability building?
- Are we big enough as a nation to undertake the responsibilities involved, or to engage the active interest of others prepared to invest?
- How do we develop the institutional capacity and advanced technology solutions so as to reduce lead times and make New Zealand a preferred place to invest?

Whilst the current "Oceans Policy" (MfE 2003) round gives recognition to future economic well-being, the announced policy framework has yet to be fully developed beyond the Stage 2 working papers. Quite properly, oceans policy as currently presented seeks to ensure the ecological integrity and biodiversity of our oceans while also achieving a balance between the goals of sustainability, customary rights, and commercial activities. Recent history, however, suggests that we are in danger of seeing this strategic view of the oceans diluted by ad hoc fixes and special cases rather than offering the balanced outcome desired.

Barriers to the development of ocean-based industries in New Zealand thus are not related to a lack of vision, innovation, expertise or drive, but to a range of structural and knowledge constraints including:

- lack of knowledge about the oceans and their economic potential;
- lack of investment in marine and coastal sciences, marine engineering and the related sector development required to meet the needs of the future;
- uncertainty in respect of current resource allocation regimes and jurisdictional boundaries;
- risk-adverse policy and business settings that fail to deliver an internationally competitive risk and return investment offering which is attractive to international players;
- an unsatisfactory de facto regulatory framework unsuited to the requirements of an emergent marine industry;
- diversity of values and expectations held by the various stakeholders with an interest in our ocean resources.

What CAENZ argues is that we need to see a lift in the vision to offer an improved collective perception and understanding of the marine environment that is encouraging of pioneering efforts and the appropriate development of our oceans resources to the benefit of all New Zealanders. To capture this vision will require a strong commitment to develop our scientific knowledge and technological understandings into the forefront of international efforts.

Identifying and developing our ocean opportunities

As canvassed above, the precursor to successful marine development, setting aside the not inconsiderable technical risk factors that dominate investment in this sector, is a national attitude and policy climate conducive to the economic development of our marine resources. Technology investment is essential, but a small economy can only expect to maintain a cutting edge position in very few fields and, otherwise, await the availability of technology from overseas sources; just as the discovery of the Maui field followed on from international technological advances during the 1960s.

In its most recent report (CAENZ 2006) to the Ministry for the Environment on promoting the sustainable development of New Zealand's ocean resources, CAENZ undertook an analysis of the factors that might combine to lead or impede commercial development, especially in new industry sectors. This analysis was structured so as to inform the Ministry on the design of suitable interventions that could be used to catalyse such industry development were a suitable business case established.

The analysis covered a selection of case studies, all pertaining to the energy sector, and representing a temporal spectrum from historic (the discovery and development of the Maui gas and oil field) through contemporary (current oil and gas exploration and development) and near-term (wave and tidal electricity generation) to far-term (gas hydrate mining and conversion). These cases, in turn, spanned the full range of anticipated activities from fully commercial to future-focussed potential activity.

Case study	Resource opportunity	Relevance
Success story	Discovery, development and production of the Maui gas and oil field	When enabling technology became available, a governance framework already existed for a major discovery to be made. However, considerable intervention was necessary for its development.
Current opportunity	Oil and gas exploration	Considerable private sector investment in response to perceived opportunities. Are governance arrangements optimal to give best chance of restoring inventory and sustaining supply?
Emergent/undeveloped opportunity	Wave and tidal energy	Emerging technology being tested but as yet no viable business case identified; governance and/or economic interventions may catalyse development.
Future opportunity	Methane hydrates	Very large resource opportunity awaits technology development in first instance; governance deserves detailed consideration.

The key findings from this analysis are summarised below. It is clear that if New Zealand expects to maintain a leading position in ocean development, then this requires not only an effective statutory and regulatory framework, but also investment in education, facilities and people. Knowledge and understanding are the keys to wise decision-making and the successful application of technology for economic and social benefit.

Maui Gas Field

Maui was discovered by the Shell-BP-Todd (SBPT) consortium in 1969 and commenced production in 1979. With an estimated 3830 billion cubic feet (bcf)) of gas reserves, it was one of the largest offshore gas fields ever discovered at that time. Key factors underlying Maui's successful development include:

Exploration Technology—Acquisition of New Zealand's first seismic data by SBPT reduced their exploration risk and led to the discovery of Kapuni and then Maui; also, the discovery was drilled during the first deployment of an offshore drilling rig to New Zealand.

Policy—Continental Shelf Act 1964 vested offshore resources with New Zealand Government and allowed the issuing of permits; the Government's role as the major purchaser of Maui gas (through the Take-Or-Pay agreement) enabled the economic production of the field; the oil crisis in the 1970s led to the development of supportive policies, e.g., energy self-sufficiency and efficiency;

Energy Demand—The international oil crisis and attendant high prices and short supplies in the Pacific created a substitution opportunity for fuelling the thermal power stations then being built and meeting the country's needs for transport fuels;

Maui Joint Venture—provided for Government sharing of production risk, infrastructure development, cost overruns in platform construction and redesign, as well as the "upside".

Oil & gas exploration

New Zealand has an active exploration industry focused on the Taranaki Basin where it has been successful in the past. Expansion of the industry is primarily dependent on the capital and know-how of international exploration companies and their business decisions based on global market factors and their appreciation of resource prospectivity. New Zealand currently ranks 14th internationally in terms of attractiveness to exploration investment.

Reported barriers to expanding exploration activity include:

- the highly competitive international exploration "marketplace", including higher prospectivity in other parts of the world, closer proximity to markets, better access to equipment, availability of and access to high quality exploration data, etc;
- the relatively small New Zealand gas market, historically low prices for gas in New Zealand due to oversupply from Maui, and associated transportation and logistics issues related to New Zealand's distance to other markets;
- the infrequency in recent times of economically significant discoveries like Maui (2000 discovery of the 700PJ Pohokura field is an exception) that would stimulate exploration activity;
- no discoveries to date of a scale to justify development of new infrastructure and production outside the Taranaki Basin;
- the predominance of gas rather than the more desirable oil in the New Zealand Basin structures.

Wave and tidal energy

This is an emergent industry that, in the foreseeable future, will be strongly reliant on technology developed overseas. An industry grouping (AWATEA) has just been formed to promote interest in the sector and there are about 12 projects at various stages of assessment presently under way. However, none is expected to be deployed within at least a 24–36 month timeframe.

Reported barriers to the development of the wave and tidal energy industry in New Zealand are mainly related to uncertainty in respect of the operation of the RMA which is a de-facto "portal" for development, but is seen as inefficient in dealing with novel projects for which plans are almost always silent. Specific issues identified include:

- the NIMBY issue and the ease with which objections can be lodged under the Resource Management Act (RMA) and the potential for perceived vexatious objectors;
- the high perceived costs and complexities of consent applications relative to the small scale of the proof-of-concept or technology demonstration projects currently being planned;
- the absence of a specific protocol for offshore wave and tidal projects that would streamline and standardise the application process for both the industry and consenting regional authorities, thereby minimising inconsistent processing of applications across regions;

- perceived sovereign risk as a result of the ongoing Foreshore & Seabed debate, the Moratorium on Aquaculture and Minister of Conservation's veto powers over restricted coastal activities;
- perceived business risk in the allocation regime posed by the "first-in-first-served" policy and the potential for both "free riders" and speculators to secure occupancy and use rights ahead of industry trailblazers;
- reliance on predominantly overseas developed technology that is largely still pre-commercial and unproven, and which is expected to be relatively expensive to import to New Zealand;
- uncertainty over the cost of, and responsibility for, infrastructure development and access to the national grid as a result of the relatively poor risk/return profile of wave and tidal projects in the New Zealand electricity market;
- investment difficulties as a result of negative media reporting of deficiencies and failures of the RMA process.

Such uncertainties, compounded, impose a risk premium that severely dampens any business case already burdened with significant technology risk, with the effect that the required capital investment will not be forthcoming until greater clarity is achieved, or unless the risks are offset through tax concessions, revenue guarantees, or similar instruments.

Gas hydrates

New Zealand gas hydrate deposits discovered offshore in the Hikurangi (East Coast) and Fiordland margins are of major potential economic importance. There are additional indications of deposits in Canterbury, Great South and Taranaki Basins. However, these must be seen as a future opportunity, not immediately commercialisable, because of the technical complexities of extraction, transportation, environmental implications and a fundamental lack of scientific and engineering knowledge of the resource.

Despite the huge economic potential of gas hydrates to the country, New Zealand is not in a position to match the level of funding by Japan (US$50m per year funding), Canada and the United States who together lead gas hydrate research worldwide. On the other hand, New Zealand researchers from GNS Science and the University of Otago are implementing, and are continuing to develop, "smart" ways of leveraging their available contribution to these international efforts and, in doing so, sharing the results of the international R&D activities.

In one case cited in the study, participation by a New Zealand scientist at an international conference, which cost under NZ$5,000, has since led to an exchange programme and invitations to the host organisation to participate in a fully funded survey of one of the gas hydrate zones in New Zealand. (note—now commenced (GNS Science 2007) involving a 3-month study of New Zealand's ocean floor led by the German research institute IFM-GEOMAR from Kiel, and involving 27 scientists from 11 research organisations—five from New Zealand, five from Europe, and one from Australia). The opportunity cost of otherwise purchasing participation would have been in the order of hundreds of thousands of dollars.

Knowledge and technology—building opportunity

Development of our ocean opportunities will require New Zealand to compete internationally for investment and expertise. All the case studies presented above can be characterised as "frontier" activities through their dependence on the capital, resources and know-how of multinational companies. This dependence is the result, among other things, of New Zealand's small economy being unable to provide the high levels of R&D funding and investment required to develop these frontier opportunities, or support a permanent pool of indigenous expertise.

Unfortunately for New Zealand, multinational companies make their business decisions within a global context and, in many situations it is inevitable that opportunities in other parts of the world will prove more attractive for investment than particular opportunities in New Zealand. This typically occurs as the result of some combination of three key factors—acceptable returns on investment; acceptable levels of risk; and certainty of completion.

All three factors are within the scope of government intervention to reduce the risks to project sponsors. The appropriate mechanism to undertake requires policy frameworks that balance the risk return equation so as to provide pioneers with an acceptable rate of return without compromising competition from other potential participants. At the same time, it is also important that any policy intervention is seen to explicitly support and incentivise the identification and commercial development of new and novel economic opportunities.

Technology provides access to the oceans and, as well, the means to develop commercial enterprise and infrastructure. As has been stated above a systematic knowledge framework is fundamental to building understanding of our ocean opportunities and extending the potential of existing marine-based industries. As understanding grows and knowledge increases it is inevitable that new resource opportunities will present themselves.

There are many stakeholders with an interest in participating more fully in the exploration and development of future ocean opportunities. One of the identified barriers to participation in this future is that information generated and held by the different stakeholders is not generally accessible to other stakeholders, because of commercial confidentiality or as a consequence of the complexity of official reporting systems or intellectual property considerations.

In response, therefore, support of innovation requires that we focus on knowledge gaps and maximise knowledge delivery to all stakeholders. Investment in oceans research is critical if we are to enhance our understanding of the present and potential value of the marine estate. This, in turn, will require a significantly increased commitment from government to facilitate research and development at the "frontier" stage in order to build our knowledge and understanding as well as support the expertise and investment capability development required to establish these new industries.

In particular, there is a need to develop scientific, engineering and technical skills to enable rapid response to new frontier opportunities. Despite the significant economic potential, it is notable that none of the universities in New Zealand have programmes dedicated to addressing new opportunities like wave and tidal energy, or gas hydrates. In a wider context there is also the continuing need for better access to accurate and up-to-date resource and site data as a key driver to increasing industry activity. More intensive mapping of site, resource and reserve data should be considered a national priority due to the strategic and economic value of this data to New Zealand.

There is also the need for a closer alignment between science and engineering research to focus on developing potential solutions to specific opportunities rather than undertaking scientific research with limited or isolated application. Universities should be encouraged to expand their existing programmes to include relevant learning modules for near-term opportunities.

It has been suggested, for example, that New Zealand could capitalise on the opportunity to attract overseas wave and technology developers to New Zealand through the development of a "marine energy technology incubation park". This opportunity arises because overseas development companies cannot get access to suitable sites in their own countries and are interested in partnering with New Zealand companies to demonstrate and develop their technologies here. Such investment would help develop the local industry by expediting access to new technology and also capitalise on the potential international scientific and economic opportunity.

Finally, and as demonstrated by Maui and other projects internationally, some level of Government assistance at an early stage is critical to the successful development of new frontier industries. At its optimal level, Government interventions can do much to assist in the development of these frontier industries by providing certainty and confidence to pioneers by minimising completion risk i.e. the risk of a project failing because of the incapacity of the sponsor to complete the development stage or other factors outside the immediate control of the pioneer.

Conclusion

The concept of the ocean as a "frontier territory" is a fundamental theme emerging from CAENZ's investigations and various work streams over the last several years. We suggest that this theme should be considered a central tenet in the development of any new Oceans Policy framework.

The case studies examined above are all classic "frontier activities", which can be characterised by:

- significant technical risk;
- high start-up costs;
- gaps in policy, governance and management regimes (at least at the front-end stages of the industry establishment); and
- a long, convoluted, complex, uncertain path to market in the early stages of industry development.

While these points may seem obvious, it is an important contextual consideration that is often overlooked as policy development by Government too often lags economic development requirements. As we have established, pioneering efforts that have the potential to seed developments from which new sectors can emerge require some level of Government commitment to facilitate development at the "frontier" stage. Without such interventions development of the sector is unlikely to proceed in an optimal way because of the high establishment costs for new industries to develop such infrastructure.

As suggested, these interventions should embrace the development of scientific, engineering and technical skills to enable rapid response to new frontier opportunities. New Zealand's ocean territories are vitally important to our economy and, ultimately, have huge potential to contribute to New Zealand's future if we integrate our efforts. Successful governance of this new frontier will require an Oceans Policy framework that:

- is based on clear principles to provide continuity and consistency to pioneers and developers, and
- maximises the opportunity value to New Zealand of these resource opportunities.

This, in turn, will require that as a nation we actively encourage and support pioneering activity and, as well, learn to manage with risk rather than attempt to simply manage perceived risks.

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