Biotic Effects of Climate Change in the Bay of Plenty

Earthwise Consulting Limited Client Report

March 2006

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For
Environment Bay of Plenty

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Executive Summary

THE APPROACH

A qualitative approach has been adopted with this assessment, broadly following an approach presented in part by the Ministry for the Environment and being used widely around the world. The three broad steps taken are: assess effects; evaluate risk; consider adaptation options. In order to complete an assessment some background information is required. Thus, specific steps taken have been:

- Identify the main issues and relevant sources of information and data.
- Identify and draw together relevant climate and climate change information and data.
- Implement an initial assessment of effects using existing capacity.
- Complete a risk assessment.
- Consider adaptation options.
- Identify further steps that could be taken and how they might be achieved.

The focus has been to work with Environment Bay of Plenty staff and others to complete the above steps. It is intended that this will provide several benefits, including:

- Identifying and supporting the capacity of Environment Bay of Plenty to examine and consider effects of climate change.
- Highlighting what is known and what further work could be undertaken, and resources required for further work.
- Stimulating more in-depth consideration of appropriate adaptation measures and strategies for the region.
- Providing relevant information for communication to the general public in the Bay of Plenty.

KEY ISSUES

The principal issues of interest and concern to Environment Bay of Plenty relate to potential effects on biosecurity (pest plants and animals) and indigenous biodiversity. Of lesser concern, but still of vital importance to the region, are potential effects on economic land uses. Information is therefore provided on three principal areas: biosecurity, indigenous biodiversity, and economic land use.

CLIMATE VARIABILITY AND CHANGE

NIWA has previously completed a report for Environment Bay of Plenty on historical climate and climate change. Information has been drawn from this and other recent work completed by NIWA for Ministry for the Environment, along with work completed by Earthwise Consulting Ltd through the ‘Adapting to climate change in eastern New Zealand’ project. NIWA have also provided, at minimal cost, relevant spatial climate and climate change data used in this report. Some key summary points are:

- There has been a warming trend in mean annual air temperature across the Bay of Plenty of approximately 0.1˚C per decade over the last 100 years.
- In the last 30 to 40 years the Bay of Plenty has become generally drier, with fewer and less intense extreme rainfalls. There appears to have been a recent climate shift, with high intensity rainfall events experienced over the last few years that are comparable to events last experienced in the 1960s.
- With climate change temperature could increase on average by 0.5˚C to 3.8˚C over the next 70 to 100 years. Rainfall changes are uncertain but there could be drier average conditions, particularly in coastal areas.

- Changes in climate that might happen in the Bay of Plenty include:
    - Warmer winters, reduced frequency of frost inland and at higher elevations, and a longer growing season.
    - Drier average conditions will lead to increased drought risk.
    - More frequent and intense rainfall events could take place, with an increased risk of flooding and erosion.
    - It isn't clear if there could be more tropical cyclones and periods of intensive storminess, but it is possible that this could happen.

KEY BIOTIC EFFECTS OF CLIMATE CHANGE

Climate change has the potential to cause significant change to the biological melting pot in the Bay of Plenty. Key biotic effects are:

Biosecurity effects

- Wider establishment and spread of new and existing pest plants.
- Greater abundance of existing animal pests.
- Greater survival of a range of insect pests.

Indigenous biodiversity effects

- Shifts in suitable climate zones for species and communities.
- Strong impacts from increased weather extremes, particularly in areas already stressed such as smaller remnants of native vegetation.
- Changes to ecosystem productivity.
- Disruption to both coastal and fresh water ecosystems.

Agriculture and horticulture effects

- Direct and indirect changes to economic land uses through effects on water quality, drought risk, flood risk, and water availability.
- Southward spread of kikuyu and other subtropical grass species.
- Hayward kiwifruit production could become uneconomic in warmer parts of the region with a shift towards cooler, inland, sites.
- A range of other changes to agriculture and horticulture including changes in pests and diseases, effects on animal health, impacts on nutrient cycling, increased rural fire risk, and effects from sea-level rise in low-lying areas.

SUMMARY OF EFFECTS IN DIFFERENT PARTS OF THE REGION

There will clearly be different effects in different parts of the region with differences in the biological ingredients. These are influenced by climate, soils, topography, past and present land use, and urban development. To highlight these differences effects have been considered for Tauranga Harbour Catchment, Rotorua Lakes, and the Rangitaiki Plains.

Effects in the Tauranga Harbour Catchment

- Climate change, in combination with on-going pressures from urban expansion and land use change, will lead increasingly to a biosecurity situation comparable to Auckland and Northland.
- Warmer temperatures and sea-level rise will affect coastal vegetation, with the possibility of increased growth and spread of mangroves and favourable conditions for wetland ecosystems.
- Pressures on bush margins from invasive weeds are likely to increase.
- There will be on-going changes in agriculture and horticulture, with an increasingly sub-tropical environment in coastal areas.

Effects on the Rotorua Lakes

- There will be changes to both land and freshwater ecosystems.
- Sub-tropical weeds, such as woolly nightshade, could become more prevalent.
- Changes in temperature and rainfall patterns will have both direct and indirect effects on lake ecosystems.

Effects on the Rangitaiki Plains

- Coastal areas that are already below sea-level will be at increased risk from both river flooding and sea-level rise.

ASSESSMENT OF RISK

Overall, the level of risk to the Bay of Plenty environment is considered to be medium with high risk associated with more rapid establishment and spread of new pest plant species and effects on small remnants of indigenous vegetation. The overall picture of medium risk is consistent with the view, shared by most people spoken to during the course of this work, that climate change is one factor that is contributing to changes in the biota of the region.

Both the level of risk and upward trend of change provide good reason for adaptation to be implemented in a progressive manner from the present through to the next 20-50 years. Such an approach will ensure a minimisation of cost.

RECOMMENDED ADAPTATION ACTIONS

- The greatest challenge, in terms of effects on biota, is likely to be with biosecurity threats. However, this needs to be considered within the context of management of the whole environment of the Bay of Plenty.
- Education of people throughout the region is the key to successful implementation of adaptation. The wider community needs to be informed, on an on-going basis, about the risks, challenges, and opportunities that climate change will bring to an already dynamic and rapidly changing environment and what they can be doing about it.
- A number of actions could be taken to enhance the existing work of biosecurity staff:
    - Maintain and increase the contractor/work team approach.
    - Focus on control in low incidence areas and increase emphasis on biological controls, and increase ecological restoration of corridors (see below).
    - Strengthen regulation of internal borders, especially relating to garden plants, cleaning of machinery etc.
    - There is a need for clear guidance for local authorities, particularly relating to siting of new subdivisions and corridor plantings of natives, with clear information on both unsuitable and suitable plant species.
    - Explicitly consider climate change and adaptation when the Regional Pest Management Strategy comes up for review. This should include addressing the apparent gap between potential threats and resources to monitor them (highlighted by the difference in approach in Auckland). For example, an "Awareness" category could be incorporated with listing of all plants that could become threats in the future. This would help avoid surprises such as the recent proposal to ban two palm species in Auckland.
    - Implement a comprehensive plant species recording database. This is vital, not just for helping shape on-going management, but for documenting changes that may be attributed (at least in part) to climate change. This is a matter of both regional and national significance.
- Biodiversity changes that might occur are fairly speculative at present. With this in mind the principal actions needed are:

- Support and strengthen the role of ecological staff in the council and their linkages with other agencies in the region. Sharing of information and data of relevance to climate change is very important.
- Focus on ecological restoration in corridors, protected areas and smaller remnants of native vegetation. Such an approach will have multiple benefits, including helping control spread of biosecurity threats.

- There may be the need for some proactive approaches to land management in the region. Further education of, and engagement with, the public at large and rural communities is very important. In particular there ought to be:
  - Formal monitoring of changes in biota in economic land uses. For example, recording of changes in kikuyu. Development of kikuyu management plans, as in Northland, may be required over time.
  - Further consideration of the implications of changing land uses. For example, what are the biosecurity and biodiversity implications of inland spread of kiwifruit production? Land use changes (including urban spread) in sensitive catchment areas (especially Tauranga Harbour and the Rotorua Lakes) need to be managed with explicit consideration of climate change.
  - The situation in the Rangitaiki Plains is unique and needs more attention. The threats of both river flooding and inundation from sea-level rise are real, particularly for land areas that are currently below sea level. Serious consideration and discussion of future options is needed.

RECOMMENDATIONS FOR FURTHER STEPS

- A more in-depth understanding of risk would be beneficial. Some discussion within Environment Bay of Plenty is needed as to how best to focus this. Different approaches could be applied, including:
  - A process of review, consultation and public engagement to focus on key issues in different parts of the region and how they might be addressed. Such a process should be aimed at future visions that are positive, practical and achievable. The emphasis would need to be on different parts of the region because of unique combinations of issues that already exist and are likely to be faced in future. Ideally such an approach should take a broad view of climate change effects, not strictly focusing on biotic effects.
  - A formal, more in-depth, assessment of effects, with an associated risk assessment, on particular species or plant communities. This should be developed and implemented over time with a focus on: using the existing, considerable, knowledge of Environment Bay of Plenty staff; strengthening monitoring activities as discussed in the previous section; modelling effects of climate change at the species level (for example with the sort of work being done by Darren Kriticos at ENSIS).
- Incorporating proactive adaptation measures into policies and plans, including:
  - An overall emphasis on 'working with change' aimed at 'building regional resilience'.
  - Strengthening and enhancing the existing holistic management approach, with specific measures as recommended in the adaptation section of this report. Important actions include enhancing the present focus on catchment management, proactive management of corridors (especially roads and waterways) and at-risk ecological areas.
- Communication and education are paramount. The majority of people find change of any kind very difficult. Thus, it is of fundamental importance that the community at

large is engaged as much as possible in thinking about and acting on climate change. Some ideas for actions include:

- Create forums for public participation and engagement in identifying and discussing key issues and risks, and in developing positive, future, visions. This could be initiated through the process outlined above.
- Continue developing the climate change page on the Environment Bay of Plenty website.
- Consider using 'effects of climate change', on biota or more general effects, as a theme for the next environmental art awards.
- Develop climate change adaptation resource kits for schools and a delivery programme (see more discussion in the Communication and Education section below), and simple information packs for ratepayers, business and others.
- Create interactive displays, to visualise possible effects and positive future visions for the region. Engage artists in the region in helping create this.

* Develop linkages with other organisations in New Zealand and overseas, including:
    - Create a regional climate change partnership, involving public and private sector agencies within the Bay of Plenty.
    - Consider taking the initiative and host a regional council forum on 'biotic effects of climate change'.
    - Communicate with the Ministry for the Environment about the good work being done by Environment Bay of Plenty.
    - Make connections with overseas organisations and regional climate change partnerships. A good example is the ESPACE project in the United Kingdom (www.espace-project.org), but there are other partnerships in the UK and elsewhere.

Introduction

This report is based on an unequivocal view that climate change is happening. Thus, consideration of impacts and adaptation responses do not simply relate to some time in the future. Biotic changes are happening now, with an as yet unknown influence from climate change. Fundamental questions for Environment Bay of Plenty relate to what and how much needs to be known to develop and implement appropriate adaptation responses and over what time frames. The approach taken has been to work through a stepwise process of identifying key issues, assessing effects, evaluating risk, and considering adaptation options and further steps. Existing knowledge and expertise within Environment Bay of Plenty has been used as much as possible. This has enabled a clearer identification of issues, effects, knowledge gaps and needs for further actions than would otherwise have been achieved.

The word *biotic* means 'relating to life or to living things' (The Concise Oxford Dictionary). In its broadest sense the term 'biotic effects of climate change' can be interpreted to mean effects of climate change on life in the Bay of Plenty, encompassing all living things and their interactions. In a very narrow sense it can be interpreted to simply mean effects on plants and animals. Climate change will affect the whole of life in the Bay of Plenty. Thus, a more encompassing approach is taken with effects considered from the individual species level through to the catchment level. The integral role of people in the life of the region is taken into account when considering how the regional council and wider community might adapt to changes that could occur.

The climate and soils of the region provide ideal conditions for growing a diversity of plant and animal species for economic return. Development of the economic potential of the natural environment has come at a cost, with considerable resources expended on biosecurity control, biodiversity protection and enhancement, and flood and erosion protection. At present, in New Zealand, we are experiencing a culture shift from a pioneering phase of development, which focused on development of the economic potential of the land, to increased recognition of the interdependence of ecology and economy. This interplay between ecology and economy is of fundamental importance when considering the potential biotic effects of climate change and adaptive responses that might be needed.

The costs of managing the environment are increasing. This is evident with coastal protection work, lakes management, the unique challenges of managing the Rangitaiki Plains, along with increased pressure from introduced pest plants and animals. The present focus is addressing issues that have arisen from the rapid and intensive changes that have already taken place. However, there are emerging signs of an increasing influence from a warmer climate with changes and challenges emerging that are consistent with projected scenarios of climate change and their likely effects. Examples include the effect on kiwifruit of more frequent warmer winters, the spread and increased growth of mangroves, and the southward spread of weeds such as woolly nightshade and sub-tropical grasses in the North Island. Climate change poses significant challenges for present and future management of the biological resources of the region.

One way of viewing the present situation is of the region as a biological melting pot. Many ingredients have been mixed in and new ones are being introduced all the time. It is a dynamic, interactive, and changing mix. **Climate change can be seen as a warming of this biological melting pot.** The key ingredient is people, with their differing aspirations, attitudes and beliefs (see Appendix 1 for some of the differences that emerged through the early stages of this work). People are the cause of the issues and challenges being faced and have the potential to provide the solutions. This report highlights some serious issues and challenges that will have to be faced and which will challenge people. In its recommendations the report takes an optimistic view that Environment Bay of Plenty, in partnership with the wider community, has the capacity to take a positive and proactive approach in response to the biotic effects that may arise with climate change.

As a final note to this introduction it is important to highlight the fact that this report is the first of its kind in New Zealand to consider potential effects of climate change on biota at the regional level. In this context Environment Bay of Plenty are playing a very important role in highlighting issues that are not just of regional concern, but are of wider importance throughout New Zealand.

The Approach

In 2004 the Ministry for the Environment commissioned the development of a guide for local government on 'Preparing for climate change'. The principal focus of this guide was how to determine effects and impacts of climate change (see Ministry for the Environment, 2004). This report outlines an approach for assessing effects that is consistent with the risk assessment approach now adopted by the Intergovernmental Panel on Climate Change (IPCC) and increasingly used in countries such as the United Kingdom. In brief, there are three broad steps that need to be taken in a formal assessment approach:

1) Identification of issues and assessment of effects using available tools, expertise, and information;
2) Evaluation (quantification if possible) of the potential risk associated with projected effects;
3) Consideration of adaptation options.

It is important to note that in New Zealand we do not presently have as strong focus on adaptation to climate change as is increasingly emerging elsewhere in the world. Over the last decade international efforts have tended to focus on refining the science of climate change and developing mitigation measures (ie, reducing or offsetting greenhouse gas emissions). Adaptation work has tended to be focused more towards developing countries, many of which will likely experience the worst effects of climate change. However, it is increasingly acknowledged that despite efforts to reduce or offset emissions we will be committed to some level of anthropogenic (resulting from human activities) climate change and potentially severe effects may arise. Thus there is now an increased focus towards adaptation in developed countries, particularly in places such as Europe and Canada. A realistic view is that, in the absence of a global fossil fuel crisis (which isn't impossible) in the near future, significant levels of global greenhouse gas emissions will continue for some time. Developing and implementing sound adaptation policies is therefore a very sensible thing to be doing and, if done in the right way, could also provide on-going mitigation benefits.

Ideally adaptation should be founded on a sound knowledge of possible effects. However, there are two general problems with this in a New Zealand context. The first, which will be covered further in the Climate Variability and Change section, is the level of uncertainty in future projections of climate. This is a consequence of the uncertainty in the science and in the global politics surrounding mitigation measures, as well as some uncertainty in scaling global information down to the New Zealand scale. The second is the relatively low level of work in New Zealand aimed at quantifying effects, and the challenges and costs involved in doing such work.

In the absence of in-depth information on effects, it is therefore necessary to adopt a more qualitative approach. Such an approach has been adopted in this report, making the best use possible of available resources and expertise within the scope of this study.

Refining the approach

The focus is how to make best use of available information in providing an assessment of biotic effects of climate change in the Bay of Plenty. A qualitative approach has been adopted, following the three broad steps: assess effects; evaluate risk; consider adaptation options.

In order to complete an assessment some background information is required. Thus, specific steps needed to complete the assessment are:

1. Identify the main issues and relevant sources of information and data.
2. Identify and draw together relevant climate and climate change information and data.
3. Implement an initial assessment of effects using existing capacity.
4. Complete a risk assessment.
5. Consider adaptation options.
6. Identify further steps that could be taken and how they might be achieved.

The approach taken has been to work with Environment Bay of Plenty staff and others to complete the above steps. It is intended that this approach will provide several benefits, including:

1. Identifying and supporting the capacity of Environment Bay of Plenty to examine and consider effects of climate change;
2. Highlighting what is known and what further work could be undertaken, and resources required for further work;
3. Stimulating more in-depth consideration of appropriate adaptation measures and strategies for the region;
4. Providing relevant information for communication to the general public in the Bay of Plenty.

Identify the main issues and relevant sources of information and data

The principal issues of interest and concern to Environment Bay of Plenty relate to potential effects on biosecurity (plant and animal pests) and indigenous biodiversity. Of lesser concern, but still of vital importance to the region, are potential effects on economic land uses. Information is therefore provided on three principal areas: biosecurity, indigenous biodiversity, and economic land use.

Identify and draw together relevant climate and climate change information and data

NIWA has previously completed a report for Environment Bay of Plenty on historical climate and climate change. They have also prepared relevant information, in partnership with MWH Limited and Earthwise Consulting Limited, for the Ministry for the Environment guide on 'Preparing for climate change'. A summary is drawn from these source documents.

Landcare Research and NIWA have developed spatial climate datasets, for the periods 1951-80 and 1970-2000 respectively. Long-term monthly average temperature and monthly rainfall totals have been obtained from both sources for use by Environment Bay of Plenty staff. More detailed data are available, particularly from NIWA. NIWA have also created scenarios of future climate change. Relevant scenarios have been prepared for use by Environment Bay of Plenty staff.

Implement an initial assessment using existing capacity

The 'Preparing for climate change' guide outlines three main ways for assessing effects of climate change (see p 26 of Ministry for the Environment, 2004):

1) Modelling: computer-generated scenarios of climate change using either existing models and data or historical data such as past flood events to determine possible effects in the future.

2) Expert opinion: expert advice on plausible scenarios of climate change in a particular region.
3) Monitoring: the real effects of climate change will only emerge through ongoing monitoring and, in some cases, may be the only way that effects can be quantified over time.

In this report on biotic effects of climate change in Bay of Plenty the approach has been to:

1) Draw on expert opinion principally from Environment Bay of Plenty staff, Willie Shaw of Wildland Consultants (contributor to this report), Department of Conservation Rotorua, and Zespri. NIWA have provided relevant climate change information and Darren Kriticos (ENSIS) and Andrea Stephens (HortResearch) have provided background information on the CLIMEX model and their work with this tool (see Appendix 3). Informal interviews and published information provided the basis for an initial assessment, with subsequent input through a review and editing process. This approach clearly identifies what is known and what gaps in knowledge exist.

2) Work with Environment Bay of Plenty GIS staff to provide some first order maps using available data (ie, relevant land information data and NIWA climate and climate change data). These maps are not intended as definitive assessments of effects. They are presented to highlight both what can be done with existing information and what would be needed to develop more comprehensive assessments.

Complete a risk assessment

The qualitative and relatively broad scope of this report precludes an in-depth risk assessment. However, some evaluation of risk is warranted as this will help guide Environment Bay of Plenty in shaping further work and in developing and implementing adaptation measures. To this end a relatively simple risk assessment exercise was completed in conjunction with a workshop help with Environment Bay of Plenty staff on 27 January 2006.

Consider adaptation options

There is quite a lot of jargon on adaptation in the climate change literature, which is deliberately avoided here. The best way to address adaptation is to consider a positive, proactive, approach that builds on good work that is already happening. Given the considerable, and likely on-going, uncertainties with climate change and exactly what changes will manifest in future the best advice is to frame adaptation within the context of 'creating regional resilience'. This will be elaborated further in the adaptation section.

Identify further steps that could be taken and how they might be achieved

This final section explores further steps that could be undertaken by Environment Bay of Plenty drawing, in part, from information gathered from overseas (in particular from the UK). The focus here is on options for further work, education and communication, and strengthening interactions with other organisations.

Issues and Relevant Sources of Information

Issues of immediate relevance to the work of Environment Bay of Plenty relate to effects of climate change on biosecurity and indigenous biodiversity. These issues are, in reality, interdependent with economic land uses and the broader picture of catchment management. In addition, climate change will be an important, but not isolated, factor that influences and shapes the future of the Bay of Plenty. Thus, consideration of key issues needs to take into account a much broader picture. A useful starting point is to consider the level of change that has already occurred in the region.

Prior to human habitation the Bay of Plenty was predominantly in diverse indigenous forest cover with extensive freshwater wetlands on coastal plains and on lake margins. Aside from the effects of long-term climatic fluctuations, volcanic activity was a predominant modifying influence on soils and vegetation. The arrival of Māori in the region resulted in changes to vegetative cover, particularly in the more densely settled coastal areas. However, the most dramatic changes to the Bay of Plenty environment have taken place over the last 100-150 years, through clearing of native forest, introduction of exotic plants and animals, draining of wetlands, containment of rivers, and of course development of urban settlements and the infrastructure of a modern economy.

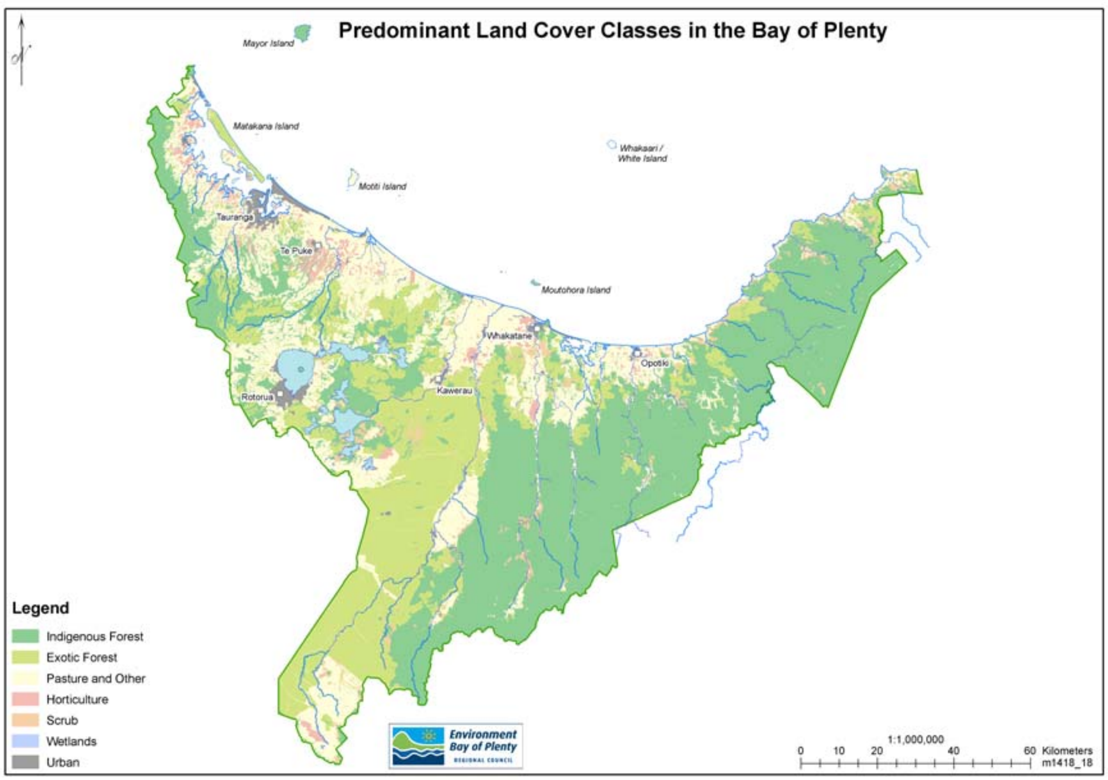


Figure 1: The Bay of Plenty can be viewed as a biological melting pot. Many ingredients have been mixed in and new ones are being introduced all the time. It is a dynamic, interactive, and changing mix. Climate change can be seen as a warming of this pot.

Biosecurity

Issues

Biosecurity is already a major issue for New Zealand and there could be considerable further challenges with climate change. The scale of the biosecurity threat is evident when considering the plant pest situation, as summarised on the Auckland Regional Council website (www.arc.govt.nz/arc/environment/biosecurity/pest-plants/). There are 35,000 introduced plant species in New Zealand compared to only 2,000 native species. Based on historical rates of acclimatisation plant species are going wild at the rate of 4 per year. Climate change is providing significant potential for acceleration of this rate. Surprisingly, given the scale of this threat, there has been relatively little attention paid towards potential effects of climate change on biosecurity in New Zealand.

Within the Bay of Plenty region there are differing areas of focus on biosecurity issues by different interest groups and organisations:

Environment Bay of Plenty – since coming into existence in 1990 Environment Bay of Plenty has shifted from a historical focus on pests affecting the management of production land towards a much more holistic focus that encompasses protection and enhancement of indigenous biodiversity, catchment protection, and removal of plant and animal pests in identified areas.

Farmers – farmers in the region have a historical and on-going focus on plant and animal pests that interfere with their land uses. In general they manage, and are expected to manage, what is on their own patch and look to other individuals and agencies to play their part. For example, it is a common concern amongst farmers about infestations of weeds such as blackberry in wildland areas, along roadway margins and railway corridors. There is also concern within the agriculture industry about potential spread of less productive pasture species and insect pests (such as the clover flea and tropical grass webworm).

Fruit growers – the principal concern in the fruit industry is with existing and potentially new insect pests.

Forestry – the main threat to forestry is the potential for damaging insect pests and plant pathogens. There have been many high profile cases of forestry pests arriving in New Zealand. Pest plants are also a concern, particularly during the forest establishment phase.

The public – it is difficult to gauge public concerns without a comprehensive survey, but a general view is that the public at large are principally concerned about aesthetics and their immediate patch. Some are very good at keeping their patch clean, others introduce and spread plants (and have historically done so, generally inadvertently) that have potential to become significant pests over time.

Department of Conservation – their principal focus is managing, within their resources, pest plants and animals that are a direct threat to indigenous biodiversity.

Public health agencies – there are potential threats to human health if important disease vectors become established, as illustrated by the discovery of the Southern salt-marsh mosquito in Napier in 1998.

The management of pest plants and animals provides significant challenges throughout New Zealand. For more than 150 years we have been actively bringing new species into the country and at the same time drastically modifying the environment. Kiwifruit are a good example of the benefits and costs that have resulted. They have become a crop of major economic significance to the Bay of Plenty region, and to New Zealand as a whole. There is also now recognition that wild kiwifruit plants have the potential to become a major threat in native forests, particularly small remnants and in forested gullies. This illustrates the fine line that can exist between economic benefit and ecological cost and the challenge that everyone faces in managing the environment for both present and future benefit.

Up until the 1990s there was a predominant focus on management of pests that were identified as threats to farming activity. Examples are gorse, blackberry, and rabbits. Since this time there has been increased recognition that the biological melting pot is far more complex. This complexity is a result of a diversity of factors including a growing number of pest species, a bigger and more diverse human community with a greater diversity of interests and values, increasing recognition of the importance of sound ecological management of indigenous biodiversity in sustaining economic activity, and greater recognition of Māori values and needs.

Environment Bay of Plenty has developed and implemented a pest management strategy (see Environment Bay of Plenty, 2003) that recognises this increasing complexity. The strategy will be discussed further in the adaptation section. Of immediate concern is to identify relevant information and how it might be used to more clearly identify and address threats that could arise with climate change.

Information

Different plant and animal species will respond to climate change in a complexity of ways. It isn't possible to understand in detail how this might unfold. However, there is information available on individual plant species that provides a starting point for understanding what sort of changes might happen and what sort of adaptation responses might be needed.

The Environment Bay of Plenty regional pest management strategy identifies different categories of pest plants and animals. A few are targeted for eradication. The majority require some form of control or are under surveillance as potential threats. For the last five years Environment Bay of Plenty staff have been recording site locations of all recognised plant pests. Records are kept mainly for sites where they are actively doing control work with landowners. Because of its historical importance there are very good records of woolly nightshade, a species of sub-tropical origin that thrives in the warmer coastal parts of the region.

There are a number of sources of information and expertise that can be drawn on. Some important ones, of direct relevance to understanding possible effects of climate change on plant and animal pests, are identified below.

Table 1: Biosecurity – relevant expertise and information

Source	Expertise	Data, information, tools
Environment Bay of Plenty	Pest management staff.	Pest plant databases have been developed over the last 5 years. Pest animal databases are less well developed.
Landcare Research	Biosecurity and pest management research.	Landcare Research has developed, and is developing, a range of useful databases and tools. See http://www.landcareresearch.co.nz/databases/index.asp and http://www.landcareresearch.co.nz/research/biosecurity/
Other Crown Research Institutes	ENSIS, HortResearch and others are presently working together on a national biosecurity research programme. Darren Kriticos at ENSIS, Rotorua has relevant expertise on pest ecology and climate change.	For some information about the collaborative project see www.improvedbiosecurity.org and Appendix 3. For information on CLIMEX, a useful tool for predicting distribution of plant and animal species, see www.ento.csiro.au/climex/climex.html and Appendix 3.
International Global Change Institute (IGCI), University of Waikato and partners	IGCI and the Ecology and Health Research Centre, University of Otago, Wellington have worked collaboratively to better quantify risks to New Zealand from exotic mosquitoes of public health significance.	Hotspots, a purpose-built integrated assessment model, developed to facilitate risk assessment. See www.waikato.ac.nz/igci/hotspots
Auckland Regional Council	Jack Craw, the Biosecurity Manager at Auckland Regional Council has been identified as a valuable source of information on potential pest threats for the Bay of Plenty.	The ARC website provides some valuable insight into potential challenges to the Bay of Plenty. For example they have a total of 78 plants under surveillance, compared to 23 in the Bay of Plenty. See www.arc.govt.nz/arc/environment/biosecurity/pest-plants/

Indigenous biodiversity

Issues

Indigenous vegetation accounts for 45% of land cover in the region. While there is a significant amount of indigenous forest, this is principally in the east and inland areas of the region. In coastal and lowland areas, in particular, there has been considerable loss and fragmentation of native vegetation over the last 150 years. As already noted, however, Māori burning had a very significant impact in these areas prior to European settlement, with the loss of primary indigenous forest and replacement with fernland, scrub and over time, secondary forest. Māori did not, however, drain wetlands. Environment Bay of Plenty has a map of likely vegetation cover *c.* 1840.

The biggest current and future threats to all remnant native vegetation are grazing by domestic stock and existing pest plants and animals. Climate change could cause significant further disruption, particularly of already fragile ecosystems and to species that are already under threat.

A very important issue is the serious challenge, and difficulty, of quantifying likely effects of climate change. At the very best informed guesses can be made based on present understanding of individual species, their interdependencies, and the disruptive influences of existing pest plants and animals. On-going urban spread and land use intensification will add to the challenges that are being faced.

A key issue, to be discussed further in the adaptation section, is how people can be further engaged in strengthening and enhancing existing indigenous biodiversity through strategic ecological restoration initiatives, including fencing, control of pest animals and plants, and restoration of "lost" or severely degraded ecosystems (including plantings of suitable species). Environment Bay of Plenty is very proactive in this regard.

Information

The Bay of Plenty is probably the most information rich region in New Zealand in terms of information on the location and composition of indigenous vegetation, habitats and species. Environment Bay of Plenty has commissioned numerous studies on regional biodiversity and there is considerable expertise in the region. Both regional and national databases exist.

Table 2: Indigenous biodiversity – relevant expertise and information

Source	Expertise	Data, information, tools
Environment Bay of Plenty	Pest plants and animals, soil and water conservation, freshwater ecosystems, estuarine and marine ecosystems, indigenous biodiversity, GIS mapping and databases.	
Department of Conservation	Indigenous biodiversity, threatened species, pest plant and animal control, including intensive predator management.	Threatened species, numerous reports, survey data, national and regional databases, technical expertise.
Wildland Consultants	Indigenous biodiversity, survey and monitoring, ecological restoration (planning and implementation), assessments of ecological effects. Terrestrial (coastal to sub-alpine), freshwater, and estuarine ecosystems.	Numerous survey reports and species lists, restoration plans, technical expertise.
Landcare Research	Matt McGlone has produced a report on climate change and	Report prepared by McGlone (2001) for Ministry for the Environment.

	biodiversity Expertise on indigenous biodiversity is being applied through a number of FRST research programmes.	See www.climatechange.govt.nz Information on relevant databases and tools can be found at www.landcareresearch.co.nz

Economic production land uses

Issues

Farming, forestry and horticulture are all significant contributors to the regional economy and collectively account for about 54% of land use in the Bay of Plenty. Historical development of these land-based industries has, in many areas of the region, been at the expense of indigenous vegetation and wetlands. The development of production potential has also provided opportunities for many of the pest plants and animals that are now widespread, and are continuing to expand (some species have considerable lag times in the environment).

Of principal concern to Environment Bay of Plenty is how production land is managed in relation to soil and water management, biodiversity protection and enhancement, and biosecurity management. Climate change will potentially impact on all of these in production land areas of the region. These impacts, on areas of concern to Environment Bay of Plenty, will arise both directly (eg, through effects on biodiversity) or indirectly. The latter may arise through changes in land use that result in response to climate change. For example, to realise potential benefits from increased atmospheric carbon dioxide (see the biotic effects section) would require increased input of N fertiliser, which could exacerbate existing problems with nutrient loading into sensitive environments. Relocation of kiwifruit to cooler, inland, sites could increase the threat posed by wild kiwifruit which have already been found well inland.

Of wider concern is how climate change might impact on the regional economy, of which land-based production is the mainstay. Issues of direct concern to farmers have been identified through the 'Adapting to climate change in eastern New Zealand' project (see Kenny, 2005). Key issues include:

- Water – water security and quality issues are key concerns.
- Biosecurity – potential effects on pastures, crops and livestock resulting from spread of existing and new pests.
- Social – changes in social structure of rural communities, relations with the urban population, the need for education about the good things farmers are doing.

Information

Table 3: Economic production land uses – relevant expertise and information

Source	Expertise	Data, information, tools
Earthwise Consulting Limited	Of direct relevance is the 'Adapting to climate change in eastern New Zealand' project, funded principally by the MAF	Copies of the 'Adapting to climate change in eastern New Zealand' publication (Kenny, 2005) have been disseminated by Environment Bay of Plenty. Further information can be

	Sustainable Farming Fund and other agencies including Environment Bay of Plenty.	found at www.earthlimited.org
International Global Change Institute, NIWA, AgResearch, HortResearch, Landcare Research	Collaboration through the CLIMPACTS research programme, funded by FRST.	The CLIMPACTS report (Warrick *et al.*, 2001) The CLIMPACTS model, available in demonstration form and now as a commercial product. See www.climsystems.com/site/home/
ENSIS, HortResearch and other CRIs	ENSIS, HortResearch and others are presently working together on a national biosecurity research programme.	CLIMEX, a useful tool for predicting distribution of plant and animal species. See Appendix 3 and www.ento.csiro.au/climex/climex.html
NIWA	Climate variability and change.	A recently completed report for Ministry for the Environment on changes in drought risk with climate change.
Ministry for the Environment	Advice on climate change.	A number of relevant publications (including the NIWA drought study) are available from their website www.climatechange.govt.nz

Climate Variability and Change

There are a number of recent publications that provide relevant information on climate variability and change for New Zealand as a whole and for the Bay of Plenty region. A useful national overview, with regional summaries, is provided in the local government guidance material (see Ministry for the Environment, 2004 and www.climatechange.govt.nz/resources/local-govt/guidance.html). A useful, reader friendly, summary is provided in the 'Adapting to Climate Change in Eastern New Zealand' publication (Kenny, 2005). Of most relevance is the NIWA study for Environment Bay of Plenty (see Griffiths *et al*, 2003) on the past and possible future climate of the Bay of Plenty.

It isn't the purpose of this report to reproduce all of this information. The following, therefore, is a brief summary of climate variability and change in New Zealand and the Bay of Plenty drawn from the publications cited above.

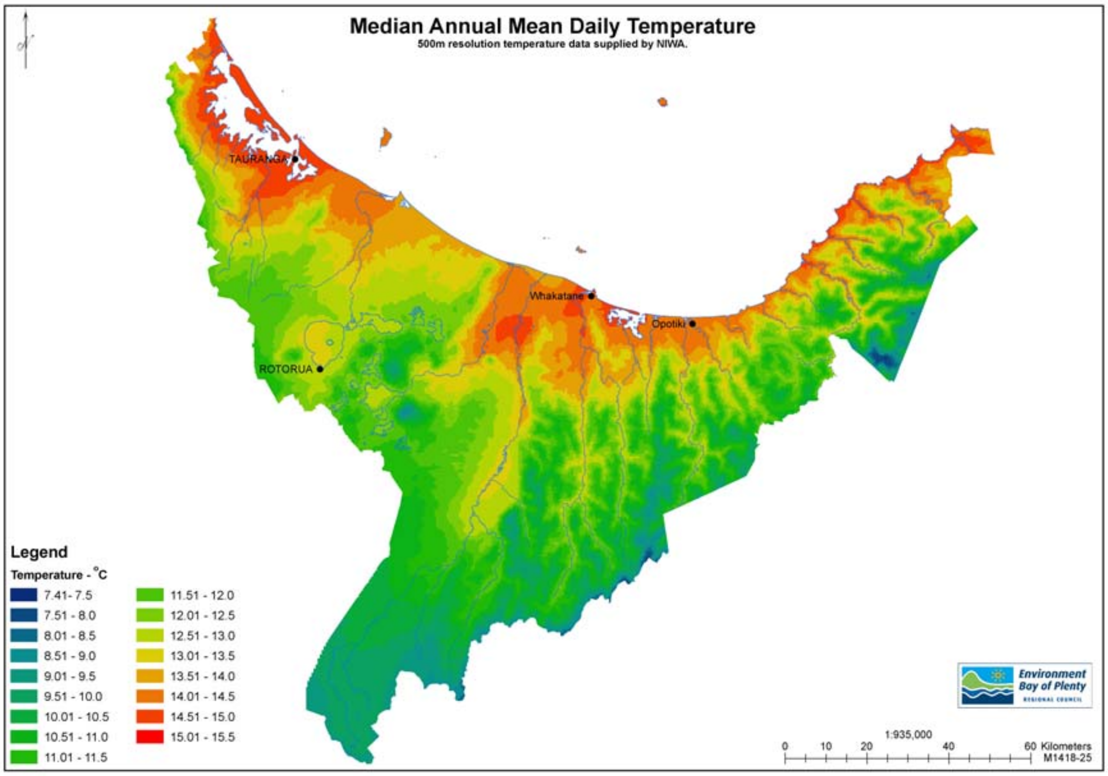
Climate variability

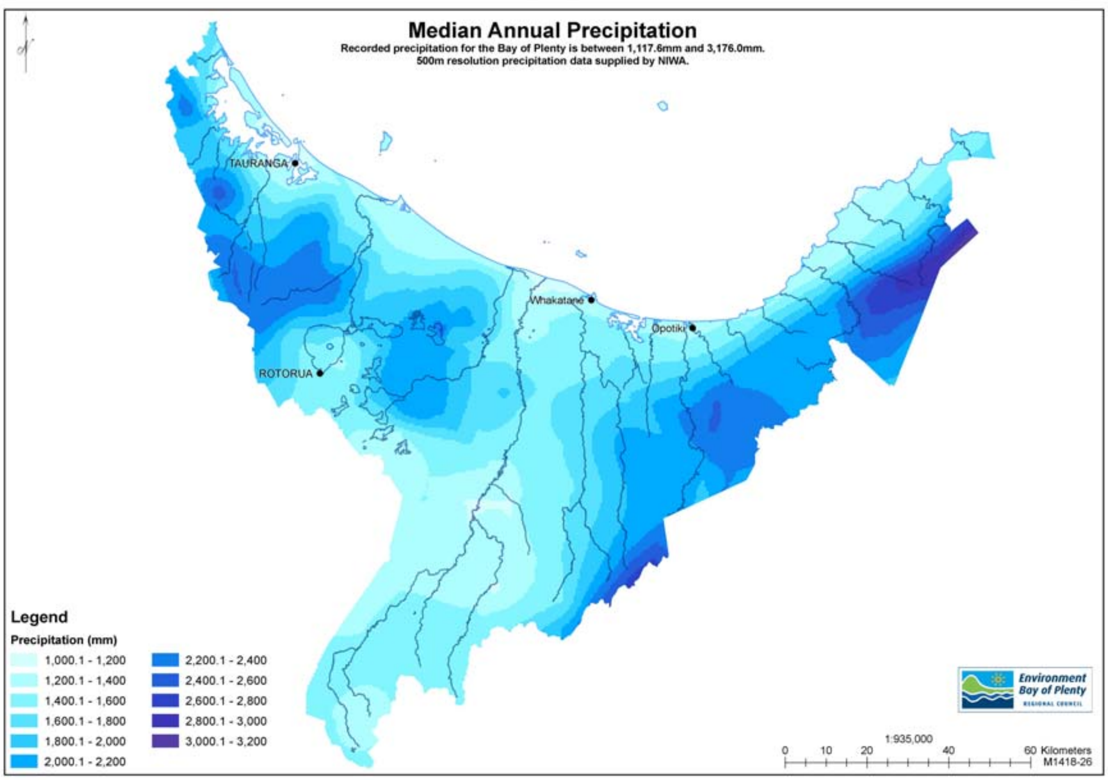
New Zealand's climate is sometimes considered to be predictably unpredictable, but there are noticeable patterns of change and variation. In individual years, annual New Zealand-wide temperatures can deviate from the long-term average by up to 1°C (plus or minus). Despite these fluctuations, there has been a long-term increase of about 0.6°C between 1920 and 2000. Annual rainfall, too, can deviate from its long-term average, by about plus or minus 20 percent. Sea levels have risen by an average of 16cm between 1900 and 2000, with similar plus or minus 20 percent year-to-year variations.

Some of the shortest-term temperature fluctuations arise simply because of the natural variability in the weather and its random fluctuations or 'chaos'. However, other changes are associated with large-scale climate patterns over the Southern Hemisphere or the Pacific Ocean. There are a number of key natural processes that operate over time-scales of seasons to decades, particularly the El Niño-Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO).

In the last 30 to 40 years the Bay of Plenty has become generally drier, with fewer and less intense extreme rainfalls. However, this has not resulted in an increase in the dry spell duration across the region. These observed changes are partly attributable to a positive IPO phase. A recent shift back to a negative IPO phase is likely to bring weaker westerlies and increased rainfall (although there is currently some uncertainty as to whether this shift has actually taken place (B. Mullan, pers comm.)). Evidence of this shift is found with recent intense rainfall events and subsequent flooding, which are comparable to events last experienced in the 1960s.

There has been a warming trend in mean annual air temperature across the Bay of Plenty of approximately 0.1˚C per decade over the last 100 years. Very high temperatures were recorded at Tauranga (the best temperature record in the region) in the 1990s. The 1990s were the warmest decade on record both nationally and globally. Coastal areas of the region have experienced an increased rate of warming over the last 50 years, with inland sites showing little warming or even slight cooling in some seasons. The number of frosts has decreased significantly in the region and the frequency of hot days has increased in areas such as Tauranga and Waihi.





Figures 2a, 2b: Maps of median mean annual daily temperature and median annual precipitation for the Bay of Plenty. Data courtesy of NIWA.

Climate change

There is now compelling evidence that climate change resulting from human activity is an underlying trend that is already happening and is with us as an influence on our seasonal climate and on climatic extremes. This influence may be relatively small at present, but it will become much greater in coming decades.

Natural variations will continue to impact on New Zealand climate in the future and will be superimposed on human-induced long-term climate change trends. Climate change is expected to shift the range of variability and, in some instances, to alter the patterns of variability. It will not remove this natural variability. Thus, the effects of climate change may be felt both through changes in long-term averages and in terms of the changed frequency and intensity of extreme events (such as tropical cyclones, heavy rainfall, storm surges, drought, wind storms, or very high temperatures). In many instances, it is the extreme events that will have the greatest impacts and for which we need to be prepared. A small shift in the average climate can cause significant changes in the occurrence of extremes.

Mid-range projections for New Zealand are for an increase in the annual average temperature of 0.5 to 0.7°C from 1990 to the 2030s, and 1.5 to 2.0°C from 1990 to the 2080s. There are likely to be greater increases in winter (meaning that the difference between winter and summer temperatures is expected to decrease) and in the north of the country (meaning the difference in temperature between the north and south is expected to increase).

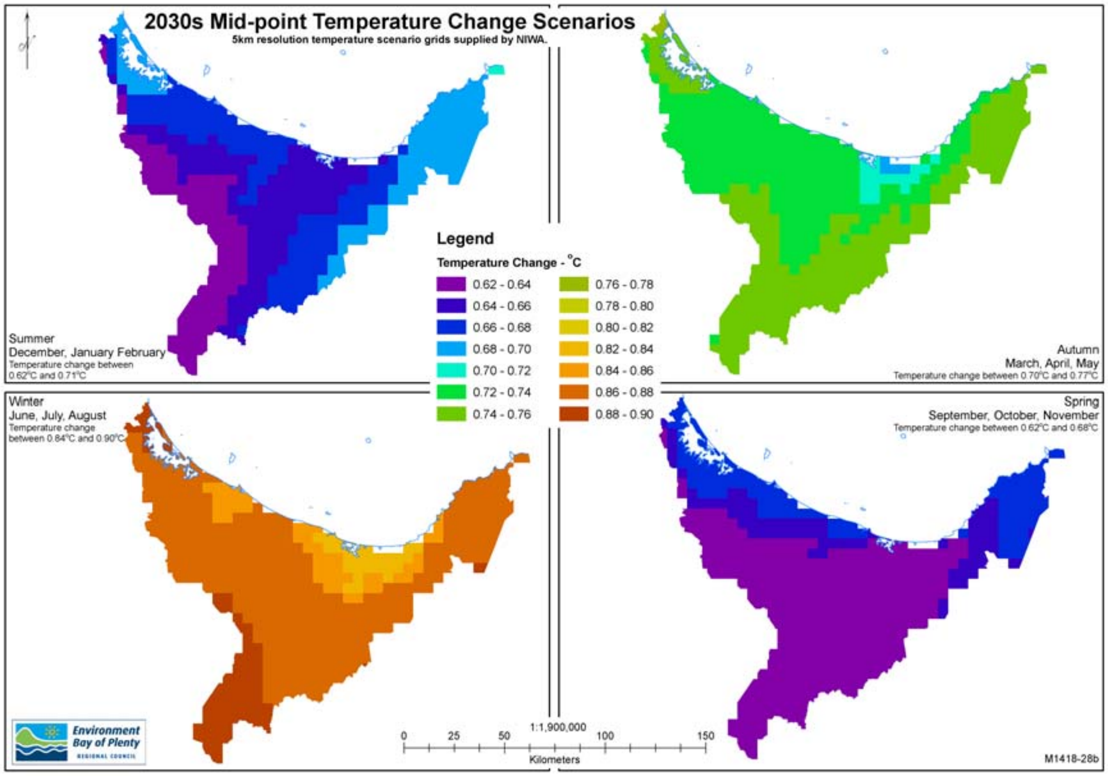
Generally, a trend to drier conditions in eastern regions and wetter conditions in the west is expected. This means that the difference in rainfall between western and eastern regions is likely to further increase. Drought and flood risk are likely to increase in many parts of the country, both as a result of climate change and as a result of increasingly intensive human activity. Even if average rainfall decreases in some areas there will still be extreme rainfall events, with research suggesting the possibility of more intense rainfall events.

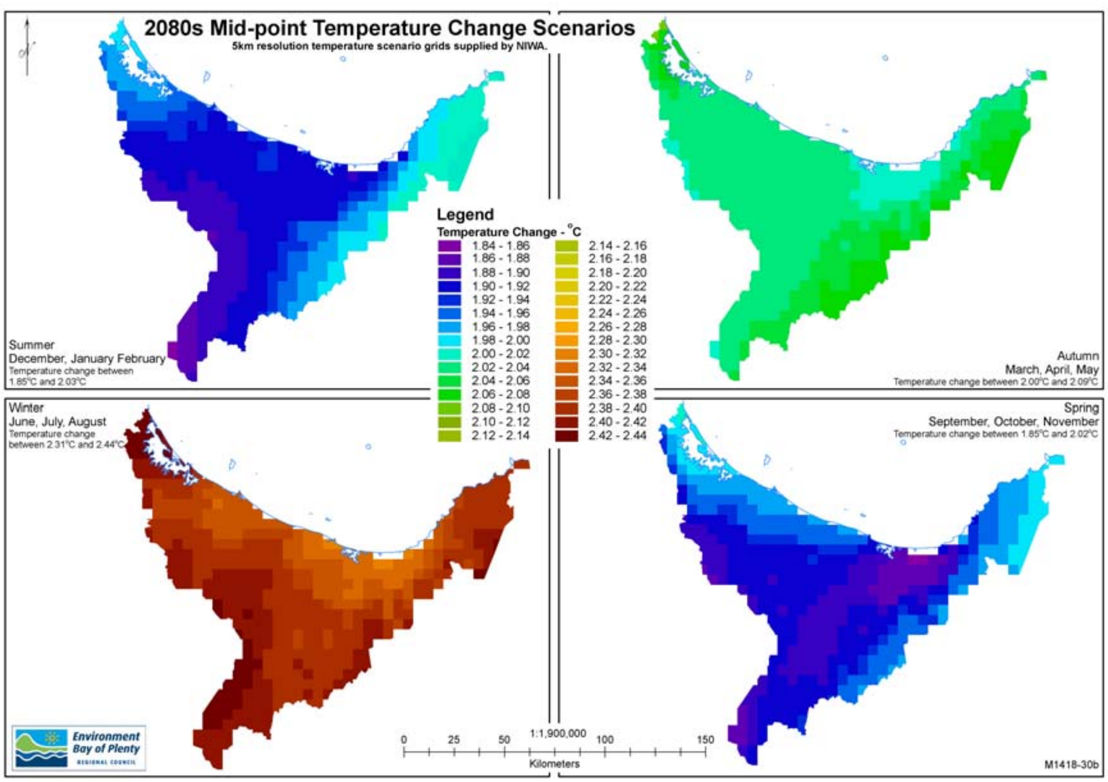
NIWA has recently completed a drought study, commissioned by the Climate Change Office/Ministry for the Environment and the Ministry of Agriculture and Forestry (Mullan *et al*, 2005, available from: www.climatechange.govt.nz/resources/reports/index.html). This study shows potential for a significant increase in drought risk in the Bay of Plenty, along with other eastern regions of New Zealand. By the 2080s severe drought (defined as the current one-in-twenty year drought) could occur at least twice as often and potentially more than four times as often, with a probable expansion of drought into the spring and autumn months.

Climate change in the Bay of Plenty

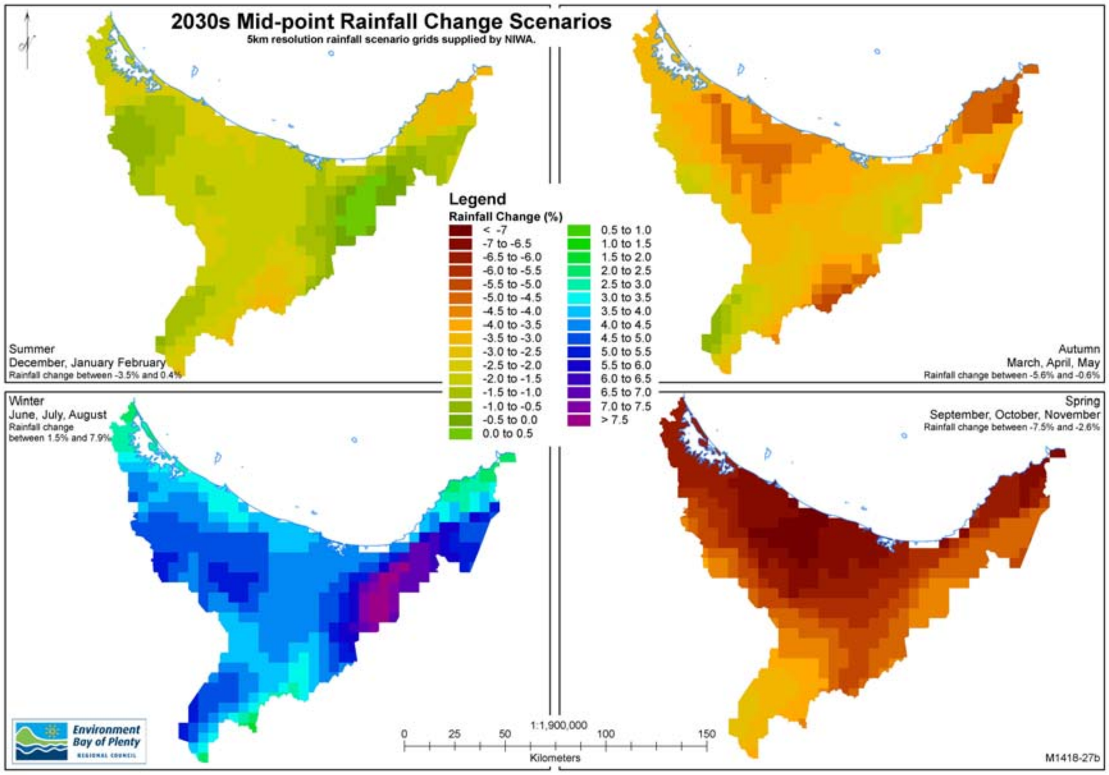
For the Bay of Plenty, recent model results indicate that temperatures will increase on average by 0.5° to 3.8°C over the next 70 to 100 years. Precipitation changes are more uncertain but there could be a trend towards an average decrease on an annual basis[1]. Evidence suggests a greater tendency towards drier conditions in coastal areas of the region.

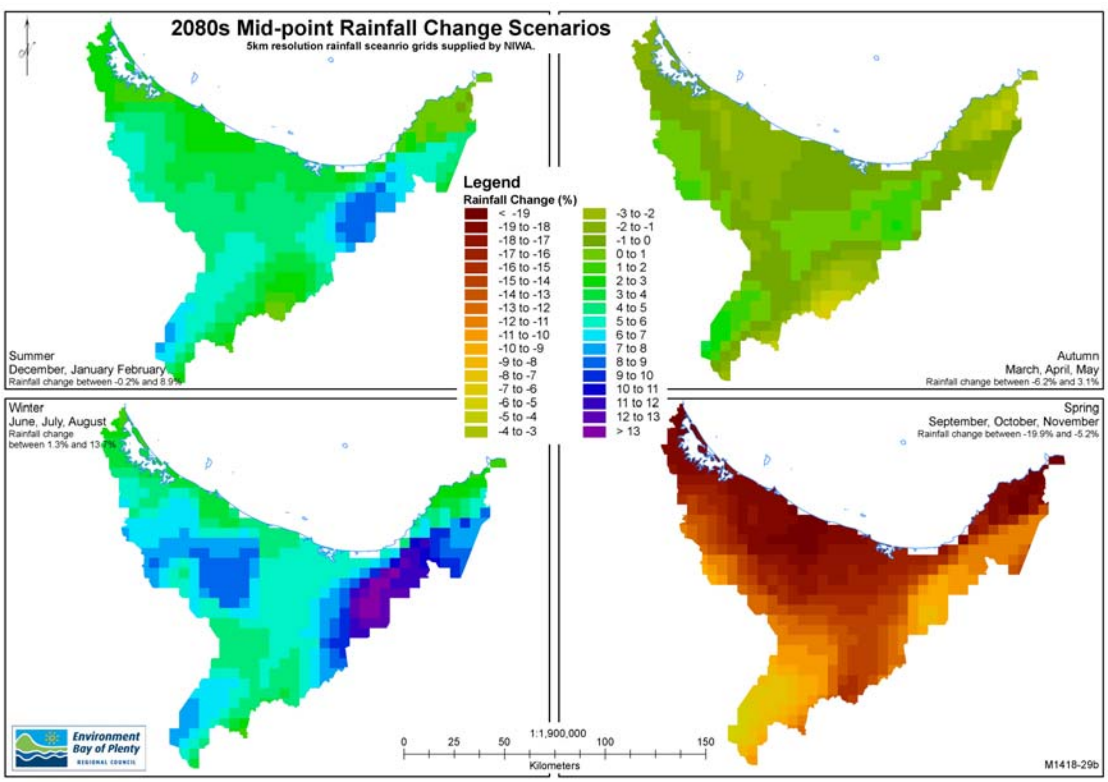
[1] Please note that climate data provided by NIWA are medians rather than means. There is some difference between these, more noticeably with rainfall, but they do not dramatically change the overall climate change picture. Strictly speaking median values shouldn't be used in future scenario assessments but subsequent analyses in this report are predominantly with temperature data for which differences are small.





Figures 3a, 3b: Projected mid-point changes in temperature for the Bay of Plenty, for the 2030s and 2080s. See Appendix 2 for temperature adjusted by these changes. Data courtesy of NIWA.





Figures 4a, 4b: Projected mid-point changes in rainfall for the Bay of Plenty, for the 2030s and 2080s. See Appendix 2 for rainfall adjusted by these changes. Data courtesy of NIWA.

Plausible changes in climate and hydrology that might be expected to occur in the Bay of Plenty include:

- Warmer winters, reduced frequency of frost inland and at higher elevations, and a longer growing season.

- Increased drought risk. As already stated the recent NIWA report shows that the frequency of severe drought (defined as the one-in-twenty year event) in the Bay of Plenty could increase up to four times, or possibly higher, by the 2080s.

- Wetter average conditions may prevail in the west which could possibly manifest as more frequent and intense rainfall events. The consequence could be increased risk of flooding and erosion.

- It isn't presently clear as to whether there could be increased numbers of tropical cyclones and periods of intensive storminess, but it is possible that such changes could happen.

Table 4: Summary of changes in temperature and precipitation for the Bay of Plenty (Graphic source: Kenny, 2005; Data source: Ministry for the Environment, 2004)

	Summer	Autumn	Winter	Spring	Annual
Temperature °C					
1990-2030s	0.0 to 1.2	0.0 to 1.3	0.4 to 1.6	0.2 to 1.2	0.2 to 1.3
1990-2080s	0.3 to 3.8	0.4 to 3.9	0.8 to 4.2	0.4 to 3.6	0.5 to 3.8
Precipitation % (Tauranga)					
2030s	-10 to +4	-16 to +4	-5 to +7	-20 to +8	-9 to +2
2080s	-7 to +19	-18 to +15	-2 to +9	-41 to -3	-15 to +2

Source: NIWA, from Wratt et al, 2004.

Biotic Effects

There will be gains and losses to the Bay of Plenty as a result of climate change. The greatest gains are likely to arise with the potential for increased pasture production in cooler (inland) areas and increased opportunities to grow a greater diversity of sub-tropical fruit crops. Greatest losses will result from increased biosecurity risks, impacts on indigenous biodiversity, and consequences of changes (in climate and land use/cover) for soil and water management. There will be a likelihood of increased incidence of lower quality pasture species over time, a decline in suitability of "Hayward' kiwifruit in warmer locations, and the potential for increased demand for water along with the consequences of increased drought risk.

Note: the following are either semi-quantitative or qualitative estimates/guesses only based on our current state of knowledge; there is a lot that we don't know and will only know with time. The challenge is to work with what we know, be honest about the uncertainties involved, and be smart in developing and implementing effective adaptation strategies.

Key biotic effects of climate change

Biosecurity effects

- Wider establishment and spread of new and existing pest plants.
- Greater abundance of existing animal pests.
- Greater survival of a range of insect pests.

Indigenous biodiversity effects

- Shifts in suitable climate zones for species and communities.
- Strong impacts from increased weather extremes, particularly in areas already stressed such as smaller remnants of native vegetation.
- Changes to ecosystem productivity.
- Disruption to both coastal and fresh water ecosystems.

Agriculture and horticulture effects

- Direct and indirect changes to economic land uses through effects on water quality, drought risk, flood risk, and water availability.
- Southward spread of kikuyu and other subtropical grass species.
- Hayward kiwifruit production could become uneconomic in warmer parts of the region with a shift towards cooler, inland, sites.
- A range of other changes to agriculture and horticulture including changes in pests and diseases, effects on animal health, impacts on nutrient cycling, increased rural fire risk, and effects from sea-level rise in low-lying areas.

Changes to biosecurity threats

This section provides a brief review and summary of existing knowledge, drawn from available literature and from interviews with Environment Bay of Plenty staff. It also includes a simple analysis of possible effects of climate change using climate data provided by NIWA and existing Environment Bay of Plenty data and GIS expertise. This approach will make apparent gaps in knowledge and expertise that need to be addressed.

There could be significant changes to pest plants and animals with climate change. At present:

- Temperature is the biggest climatic limitation to establishment and spread of new and existing pest plants and also influences habitats of key pest animals.
- Bay of Plenty soils are generally not limiting to pest plants, although soil moisture can be limiting in some areas (eg, peat soils). Soil moisture can also be a limitation to some pest animals (eg, rabbits).

Thus, projected changes in temperature and rainfall could potentially have significant effects on biosecurity in the region.

Pest animals

There will be potential for greater survival of a range of insect pests with climate change. Currently Environment Bay of Plenty animal pest officers are dealing with Argentine ants at Tauranga/Mount Maunganui. If the eastern Bay of Plenty becomes drier, there is a possibility that they will find establishment in that area easier than at present. Temperate habitats subject to climatic warming are likely to become more suitable to sub-tropical invertebrates and fungal pathogens.

All of the insects of concern at the moment are probably here as a consequence of border control failure[2]. The Environment Bay of Plenty animal pest coordinator states that he is 'terrified of fire ants outflanking border control because climate change as postulated could provide a better basis for initial establishment.' A range of mosquitoes, including the tiger mosquito, would also find an increase in temperature very much to their liking.

These concerns are reflected in recent published studies that have examined the potential for establishment and spread of a number of insect pest species under existing climatic conditions, including *Thrips palmi*, Argentine ants, fruit flies and mosquitoes (see Dentener *et al*, 2002; Charles *et al*, 2002; Stephens and Dentener, 2005; de Wet *et al*, 2005a,b,c, 2004, 2001, Woodward *et al*, 2001). A summary of recent HortResearch work, using the CLIMEX model, is provided in Appendix 3. HortResearch is involved in an on-going collaborative research programme to examine new biosecurity threats from pest animal and plant species. Consideration of climate change effects will be a part of this work. The Hotspots programme (see www.waikato.ac.nz/igci/hotspots/) has examined the potential risk posed by a number of mosquito species that are of potential significance to public health. A dedicated software tool was developed as an integral part of this work.

Environment Bay of Plenty staff suspect that future changes in pest animal populations (eg, possums, rabbits, wallabies) will be related to both direct and indirect effects of climate change, in particular to changes in temperature and rainfall and vegetation changes that may arise (eg, changes in species, phenology, fruit abundance). For instance if the Bay of Plenty does become drier, there is a possibility that rabbits will become more of a problem on free-draining pumice soils in the central part of the region, near Rotorua and on Kaingaroa Plateau, and on coastal sands, with a consequent increase in infestation levels and potential for damage. Warmer winters are known to favour possums. A continuation of the existing trend for warmer winters could therefore increase animal pest problems in cooler, inland sites.

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[2] Border control failure is a major concern for New Zealand and the Bay of Plenty. The most likely direct entry point is the Port of Tauranga with a local environment that is well suited to a wide range of sub-tropical invertebrates, vertebrates, and plants.

Pest plants

Many of the weeds in the Bay of Plenty have originated from South America and the majority prefer either the sub-tropical conditions of northern New Zealand or are tolerant of a wide range of conditions (see Appendix 4). As already mentioned, both existing and potentially new exotic species pose significant threats. Even without climate change, regional councils have significant challenges in dealing with existing weed infestations, continued spread of species into the wild (some of which may have been used ornamentally over the last 50-100 years), and the complexities of human activity, perception and behaviour. The scale of this challenge is highlighted by a current proposal by Auckland Regional Council to ban three palm tree species and public reaction to this (see 'Gardeners to fight ARC palm ban', New Zealand Herald, 12 January 2006).

Increasingly warmer conditions with climate change will favour establishment and spread of many existing and potentially new pest plants. There could be an acceleration of the rate of establishment of species in the wild and of southward and inland spread. This will be influenced also by on-going population changes and likely on-going increased pressure at air and sea ports. This will likely lead to further plant bans and public reactions to these, as illustrated above with the proposed palm tree ban in Auckland.

There is valuable information and knowledge available about many present and potential pest plant species, either from within the Bay of Plenty or from Auckland and Northland regional councils. This information has been drawn on in ecological reviews of individual pest plants, with consideration of climate influences. However, there has not been any systematic examination of potential threats with climate change. This ought to be considered when reviewing the regional pest management strategy.

Some relevant work is being undertaken through the Landcare Research 'Invasive Weeds Research Programme' and the 'Better Border Security' project, which is a collaborative venture between a number of CRIs. The former includes a component aimed at refining weed-risk assessment models and improving understanding of the dynamics of weed spread. Climate change is not an integral part of this work, but the research should provide a more robust foundation to facilitate future climate change assessments. While there is a climate change component to the latter work the principal focus is on potential new pests of economic significance with key stakeholders identified as Biosecurity NZ, Department of Conservation, Environmental Risk Management Authority and Forest Biosecurity Research Council.

While the CRI research programmes may offer some useful information, there is a clear need to develop an approach that builds on and enhances existing knowledge and capacity within Environment Bay of Plenty.

Pest plants – indications from other regions

Useful indicators of possible changes in pest plants for the Bay of Plenty are Northland, Rodney/Kaipara, the 'Hibiscus Coast', and Coromandel. The patterns of settlement, land use change and plant acclimatisation in these regions are different. However, Northland and Auckland regions do have distinctly warmer climates that support pest species that aren't presently prevalent in the Bay of Plenty. Many of these species are of sub-tropical origin and thus have the potential to become more established further south under a warmer climate. Land use intensification and urban growth, particularly in the western Bay of Plenty, is contributing to this potential, which is highlighted to some degree by comparing the numbers of classified weed pests in Auckland and the Bay of Plenty.

Table 5: Comparison of classified pest plants in Auckland and Bay of Plenty

RPMS Category	Auckland	Bay of Plenty
Total control/eradication	26	10
Progressive control/containment	11	15
Boundary control	4	3
Surveillance	78	23

Auckland has more than twice the number of plants it is seeking to eradicate and more than three times the number of plants under surveillance. However, it is important to note that the higher surveillance numbers in Auckland also reflect differences in approach between pest plant staff from the two councils. Environment Bay of Plenty's surveillance category is kept relatively small to enable monitoring objectives to be more realistically met. This in turn raises questions as to whether the Environment Bay of Plenty pest management strategy ought to be revised to provide a realistic assessment of the full scale of biosecurity threats.

The size of the urban environment in Auckland clearly gives greater potential for new weed pests. Climate change will add to the potential for this sort of situation in western Bay of Plenty, but the initial drivers are more likely to be the rapid changes in land use and population that are already happening.

An example of new problematic infestations that could arise is the coral tree, which is well established and forms dense infestations along the Hunua Coast, between Clevedon and Kaiaua. An increased occurrence of local naturalised trees was observed 6-7 years ago and reported to pest staff at Environment Bay of Plenty (W. Shaw, pers comm.). In this particular instance the tree was promptly controlled and recorded on the pest plant database. Another topical example is the palm tree situation in Auckland, with Environment Bay of Plenty staff already well aware of the potential threat that has resulted from increased use of palm trees in urban landscaping.

Biosecurity challenges in Northland

Warmer conditions in recent years have highlighted the sort of pest problems that are likely to arise with increased frequency in coming decades. The clover flea has become a significant pest in Northland in the past 20 years, with significant losses of clover, particularly on the lighter volcanic soils in the region. The tropical grass webworm, a windblown invader from Australia, has decimated all pasture species, in fact anything green, on the Aupouri Peninsula in the Far North of Northland in recent years. In Northland, kikuyu is a very important pasture component for sheep and beef farmers. The webworm is increasingly likely to persist in Northland with a trend towards warmer winters.

Note: *Tropical grass webworm is a non-selective feeder, eating almost anything green up to 1.0 metre above ground level. While it starts in kikuyu pastures, this may simply be that it is able to winter over in the warm, moist thatch of this species. Once it hatches and begins to spread, it takes everything in its patch. With up to 3000 caterpillars per square metre, it can clear over 100 hectares within a week, will eat avocado leaves up to a metre above the ground and will even take the green coating off rushes. Winter temperatures tend to affect its survival and it thrives in warm, moist summers. Predicted trends would make parts of Northland completely frost-free and warmer and damper in summer and autumn. This would definitely favour webworm. There is some evidence to suggest that warming to date has been* *part of the reason for webworm becoming established this time when it failed during previous incursions. That is, it has been recorded before but did not establish. It has established this time.*

There are several pest plants currently found in small or not very vigorous infestations in Northland that would become a serious pest, not only in Northland but also through other parts of northern New Zealand, if there were even a slight increase in temperature. Already wild ginger is a serious biodiversity weed in Northland, Auckland, and Coromandel, (and is well established in the eastern Bay of Plenty). Lantana is established and is spreading in Northland. This plant is reputed to be the worst weed of parts of New South Wales and Queensland and many Pacific Islands. Cape honeyflower is a serious problem on alluvial flats in the Far North and with fewer frosts its range could extend south of Auckland. Warming would not only increase the number of pest plants likely to threaten Northland, but would also shorten the time-span over which a plant becomes established and then begins to become a problem.

Mapping effects of climate change on weeds

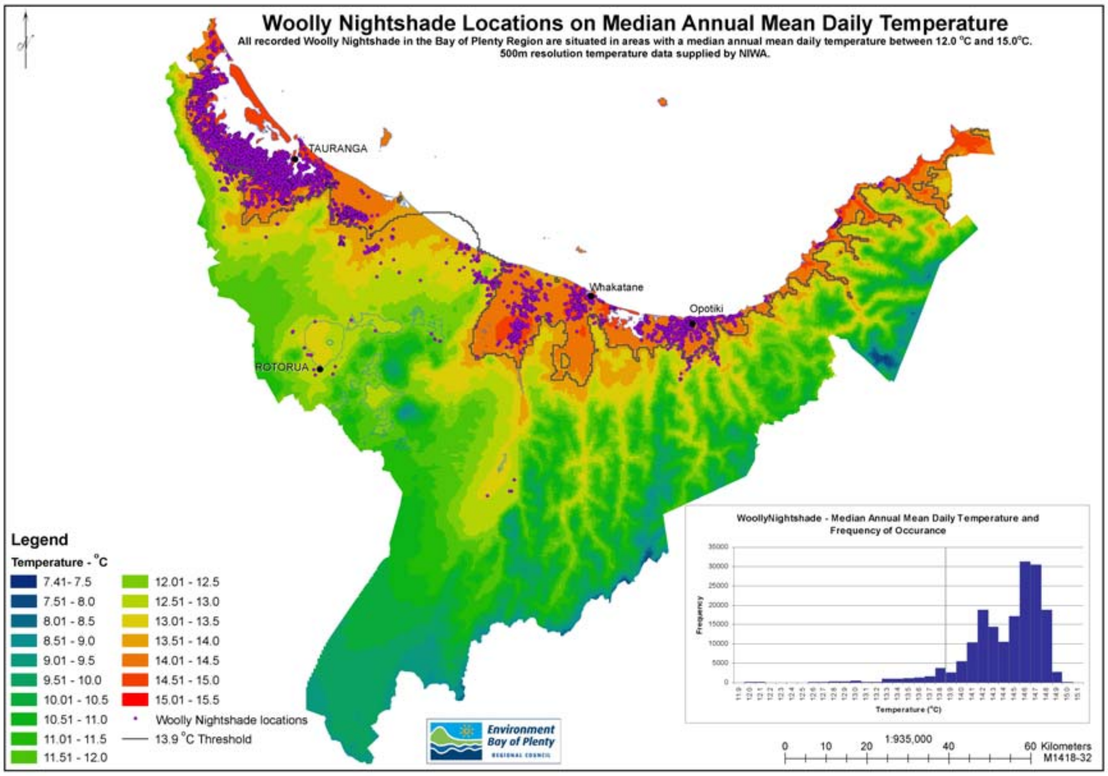
Where there is adequate distribution data and a clear sensitivity to a particular climate variable it is feasible to do some initial screening with relatively simple 'climate envelope' mapping. This initial screening approach has been applied to two plant pests that were identified as being temperature sensitive by Environment Bay of Plenty plant pest staff; woolly nightshade and blue morning glory.

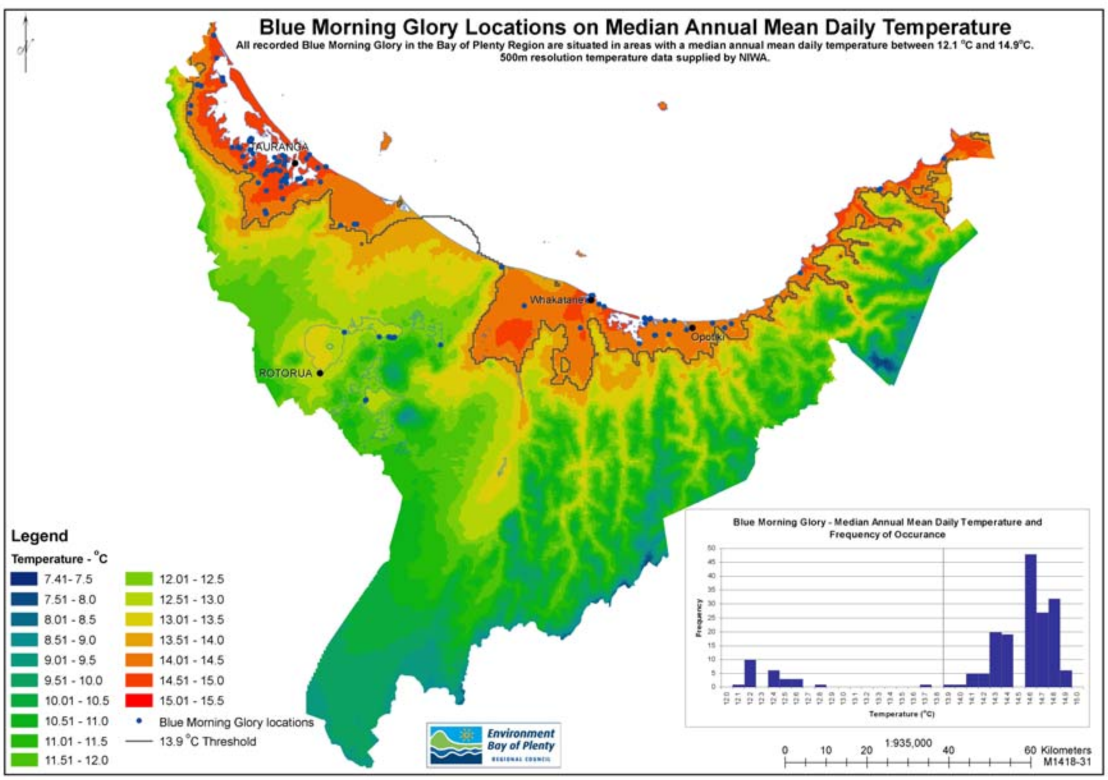
Woolly nightshade originates from South America and is presently a plant pest in tropical and sub-tropical areas of the world. It is widespread in coastal Bay of Plenty and is primarily a threat to pastoral farming. This weed has been an issue for quite a number of years with significant expenditure of resources on its control. It is presently classified as a 'progressive control' plant, with a focus on containment rather than eradication. Blue morning glory is widely spread in tropical areas, including the Pacific. It is presently under surveillance in both Auckland and Bay of Plenty regions, with potential to invade habitats such as scrubland communities.

Both species are presently found in warmer, coastal areas of the Bay of Plenty (see Figure 5). Most recorded observations of both are in locations where annual temperature is 13.9˚C or higher. Using this temperature threshold, a simple analysis could be made in the following way:

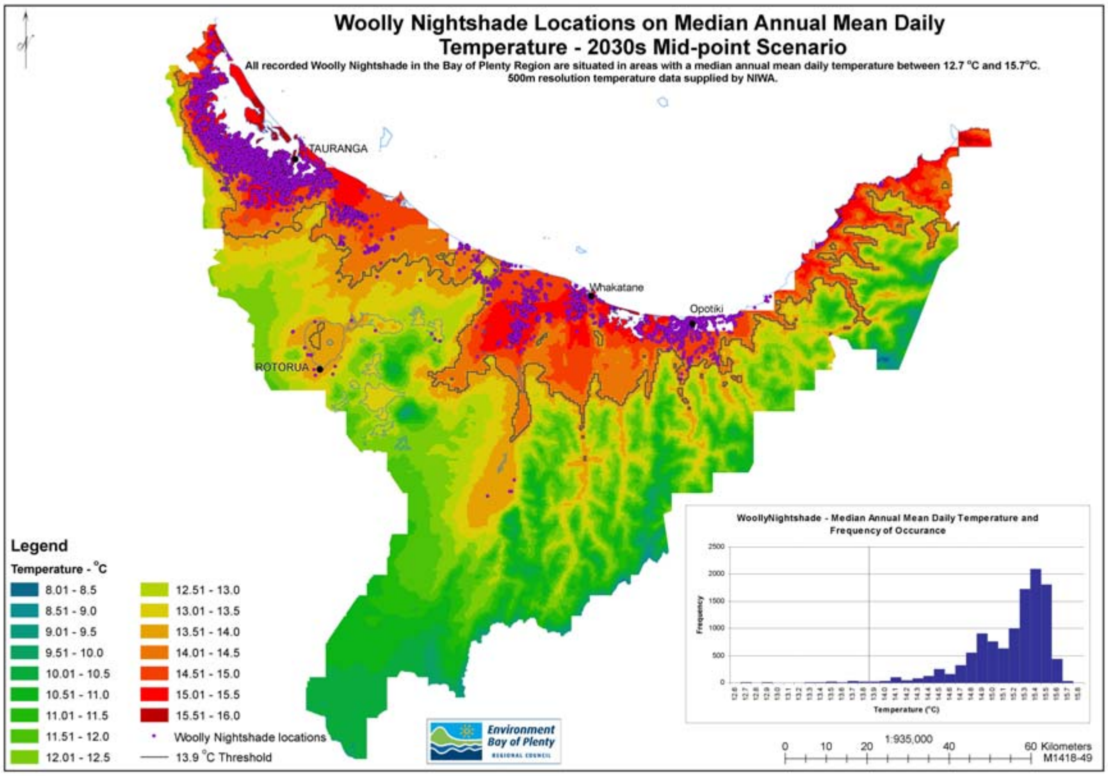
1) Use an annual temperature of 13.9˚C as a threshold to represent the primary distribution zone of woolly nightshade and blue morning glory.
2) Calculate the area (in km^2) of each land class from areas where annual temperature is 13.9˚C or higher using present climate data.
3) Repeat 2) using future climate data.

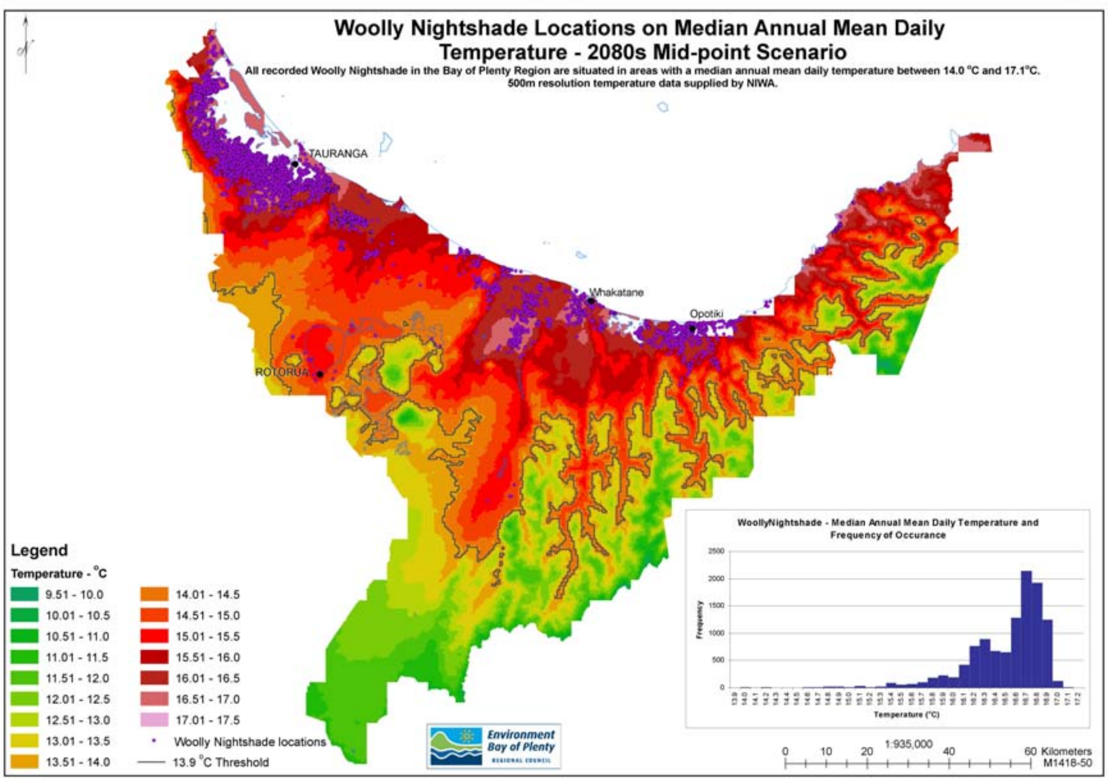
This information can then be combined with knowledge of preferred habitats, dispersal mechanisms, and present land cover classes in the region can be used to help evaluate the threat posed by climate change.





Figures 5a, 5b: Observed locations of woolly nightshade and blue morning glory, the majority of which are in areas where mean annual daily temperature is 13.9˚C or higher. Climate data courtesy of NIWA.





Figures 6a, 6b: Observed locations of woolly nightshade and shifts in the 13.9˚C threshold line for the 2030s and 2080s, highlighting the potential for increased spread of temperature sensitive plant pests. Climate data courtesy of NIWA.

The results of an analysis of effects on woolly nightshade are shown in Figure 6 and in Table 6 below (see Appendix 2 for similar results for blue morning glory). They show potential for spread to significant areas of inland pastoral land (2.5 times the present area by the 2080s) and possibly other areas. Southward spread of woolly nightshade is already happening in the North Island, with higher temperatures likely to accelerate the rate of spread over time. In the Bay of Plenty this increased potential for spread will challenge the policy of containment in present core infestation areas.

Table 6: Area of different land classes in zones of expanding suitability for woolly nightshade (using an annual temperature threshold of 13.9˚C)

	Area (square kilometres)		
Land class	**Present**	**2030s**	**2080s**
Exotic forest	200.40	582.75	1545.76
Horticulture	175.40	226.53	230.01
Indigenous forest	242.28	674.34	2527.87
Pasture and other	1044.63	1583.19	2468.61
Scrub	101.31	164.01	26.76
Urban	74.57	75.86	111.37
TOTAL	1838.60	3306.68	7151.37

Another very important piece of information from the above analysis is the increased percentage of indigenous forest cover that could be affected by temperature sensitive weeds. Impacts on indigenous forest areas from identified invasive weeds could accelerate rapidly between the 2030s and 2080s.

The same, or similar, analysis could be applied using a more robust approach (ie, that combines use of temperature and rainfall data, and possibly even soils data in some cases) to predict pest plant distribution for a much wider range of species. However, as a first step, the simple approach presented above provides some valuable insights into the likely threats posed by climate change for temperature sensitive species.

Biosecurity and indigenous biodiversity interactions

Invasion and disruption of indigenous ecosystems by plant and animal pests will be one of the strongest aspects of biotic change in the Bay of Plenty.

Effects on weeds

Weeds have a very high capacity to compete and colonise and will establish aggressively in the absence of natives. There are two general types of invasive weeds that pose a threat to indigenous biodiversity. Firstly there are those that are very aggressive invaders of exposed or open sites where there is often a low level of native seed present in the soil. Secondly, there are shade-tolerant species that have the capacity to establish and expand dramatically in forest understoreys.

There is much potential for further spread of existing weed species and some species have relatively long lag periods before they become more aggressive colonies along already established weed corridors. A proactive approach to addressing this potential problem is discussed in the Adaptation section. Warmer conditions could also lead to increased problems in inland native forest areas such as Whirinaki, the wider Te Urewera-Raukumara tract, and the Kaimai range. There are low weed problems in these areas at present.

Effects on pest animals
Warmer conditions would benefit pests such as possums and rats. Evidence shows that numbers are greater with warmer winters. Changes to fruiting and flowering of native plant species could support higher rodent numbers in winter with subsequent impacts on native birds. Exotic birds could benefit to the detriment of native species. There would be potential for increased disease risks.

Changes to indigenous biodiversity

This section provides a brief review and summary of existing knowledge, drawn from available literature and from interviews with Environment Bay of Plenty and regional Department of Conservation staff.

Native forest

Four main types of change to indigenous biodiversity could occur (see McGlone, 2001): i) a southward and altitudinal shift in suitable climate zones for species and communities, ii) strong impacts from increased weather extremes, particular where there is already stress, iii) changes to ecosystem productivity and nutrient cycling, iv) disruption of fresh water ecosystems. Changes in exotic pests and weeds will also have impacts.

Animal pest problems in native forest presently overshadow climate influences. Possums, deer, feral goats, and wallabies have induced widespread fundamental changes in forest structure, regeneration, and successional sequences. The identification of climate-driven changes in vegetation will be difficult, problematical, and debatable. After all, we still have only a limited grasp of what is “normal” in terms of episodic events, and the capacity of vegetation communities to respond and adjust to change.

Keeping the above in mind, the following are some possible changes that could arise, identified by staff from Environment Bay of Plenty and Department of Conservation.

- Seeding behaviour of some species could be affected.
- The northern extent of a number of native bird species, invertebrates, and plants is found in the Kaimais. This could change.
- Some native plants have their ecological limits in the Bay of Plenty. Climate change could result in changes to their altitudinal and latitudinal range. Such changes would not be clear cut given the great many competitive and mutualistic interactions that occur in plant communities, including the roles of invasive pests.
- Distribution patterns of migratory birds could change, potentially affected by seasonal climate and habitat changes at both a global and local scale.
- Amphibians (eg, native frogs) are very sensitive to climate, and are already experiencing disease problems.
- A big problem is the fragmented landscape. Fragmentation has led to a dramatic increase in vulnerabilities, particularly to invasive pests.
- Changes in frequency[3] of ‘mast’ years in the extensive area of indigenous forest in the region could be a problem in terms of effects on rat populations and bird life. How pest populations change in native forest will be dependent on changes to their food supply. To add to the complexity of understanding effects, there is presently

[3] There is presently relatively little understanding of what is the ‘normal’ frequency of ‘mast’ years in Bay of Plenty beech forests which makes it very difficult to quantify any effects of climate change.

conflicting evidence as to whether 'mast' years are linked to colder or warmer conditions. Increased beech seed production would result in increased mice, rats and mustelids with negative impacts on native fauna.

- A warmer climate could create opportunities for invertebrate pests.
- Mangroves could spread and show increased growth with on-going changes in sediment and nutrient loads and with effects of higher temperatures. Rising sea levels would also influence growth and spread of mangroves.
- With the possibility of a higher frequency of intense rainfall events with climate change effects on indigenous biodiversity could be very significant. Recent historical examples are the Wahine Storm (1968) and Cyclone Bernie (see Shaw, 1983). More recently there has been the impact on Matata Lagoon from an intense rainfall event.
- Extreme summer droughts have occasionally triggered dieback events in Bay of Plenty forests. Any increase in drought frequency and severity could trigger more such events. Ephemeral wetlands could be at higher risk from any increase in summer drought.
- Increased fire risk would be a problem. Extreme historical drought events have predisposed even wet montane forests to fire and increased frequency of drought events would lead to increased risk of uncontrolled fire in forests on the upland ranges.
- With the possibility of increased weather extremes there could also be increased risk of sequences of extreme events with climate change. Sequences of extreme events (eg, summer drought followed by storms) already affect indigenous vegetation and have done so for centuries. An increased incidence of such sequences could impact on natives, for example with increased dieback of some species or species collapse. This could lead to greater erosion and flooding downstream.

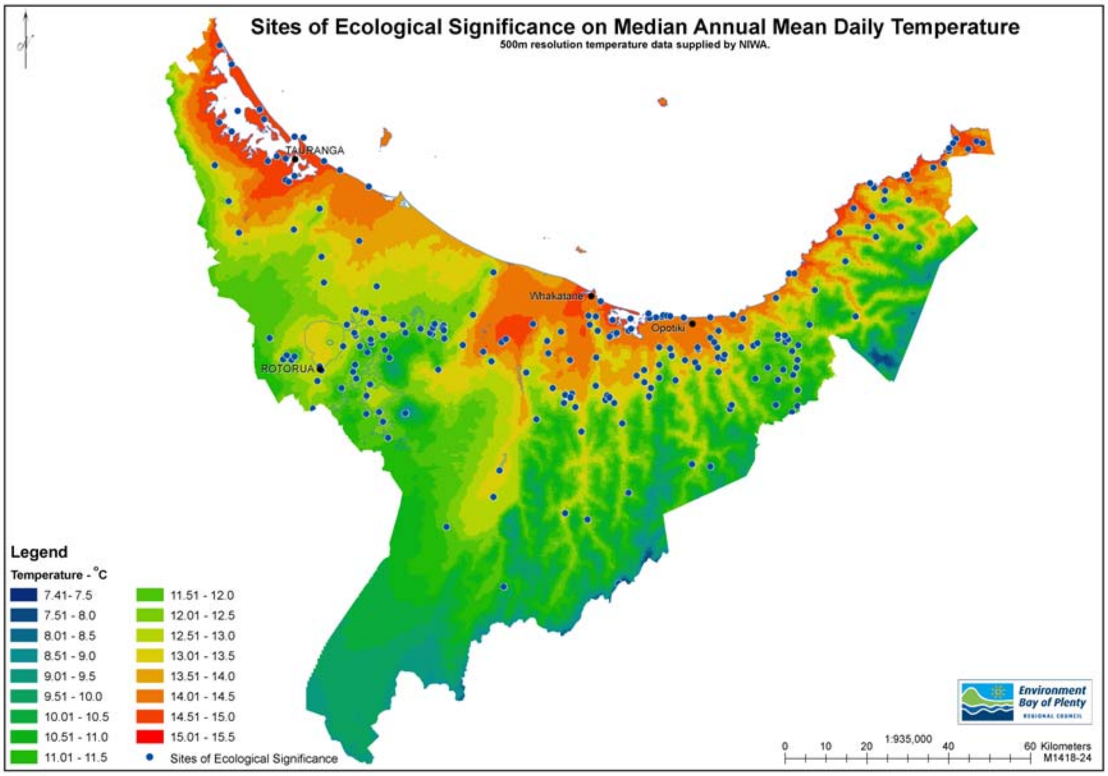
The potential effects of higher temperatures on indigenous biodiversity are highlighted through Figure 7. Comparable maps for future rainfall scenarios show relatively little change in annual average rainfall (see Appendix 2). This tends to reinforce the view, given through the summary points above, that the greatest effects will arise from changes in average temperature in combination with changes in climate variability and extreme events.

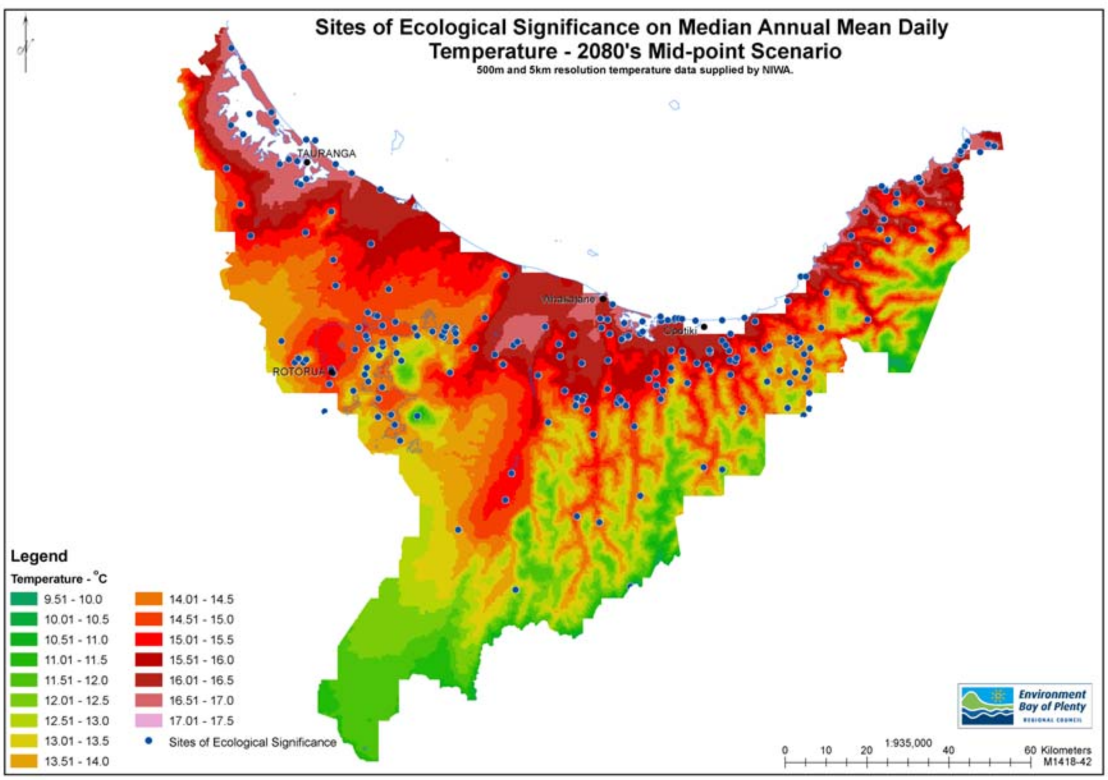
Estuaries, lakes and wetlands[4]

Estuaries

Estuarine vegetation is also potentially at risk from sea-level rise (and associated changes, for example in sediment dynamics and salinity) as a result of climate change (Burns *et al.*, 1990; Titus, 1990; Nicholls et al., 1997; Nicholls, 1999). A rise in mean sea-level may be the most important factor influencing the long-term future spatial extent and distribution of estuarine vegetation, but the effect will vary dramatically depending on the local rate of sea-level rise and the input of sediments into estuarine systems. Estuarine vegetation has some capacity to respond to sea-level rise by vertical accretion through sediment trapping and organic matter input. If this rise keeps pace with sea-level rise, estuarine vegetation will grow upwards; if it does not, the vegetation will sink relative to sea-level. Areas of intertidal estuarine vegetation will be submerged for progressively longer periods during a tidal cycle, and may die due to water-logging, causing a change to non-vegetated intertidal areas, or even open water. Direct losses of estuarine vegetation due to sea-level rise can be offset by inland wetland migration into newly flooded areas of low-lying terrestrial vegetation (i.e., coastal lowland conversion

[4] The material in this section was prepared by Environment Bay of Plenty staff in 2002.





Figures 7a, 7b: Changes in temperature in relation to identified sites of ecological significance. See Appendix 2 for the 2030 result and for rainfall changes. Climate data courtesy of NIWA.

to coastal wetland as sea-level rises). In areas without low-lying coastal lowlands, or in areas where the adjacent land has been developed or protected to stop coastal flooding, wetland migration cannot occur.

- Episodes of increased algal growth (sea lettuce) in Tauranga Harbour have been observed to correlate with climatic factors (El Nino/La Nina). If climate change is demonstrated to affect the Southern Oscillation Index (this is currently uncertain), then it is likely to have effects on growth of sea lettuce, and possibly other algal species.

- The recent Didemnid 'explosion' in Tauranga, Whangamata, Nelson, and Picton Harbours may be an example of what may occur if previously little known and understood native species 'bloom and dominate' under more suitable conditions. The result may be complete ecosystem changes, with dramatic a loss of biodiversity in these marine communities.

- Mangrove spread and growth has become a significant issue in Tauranga Harbour (and in other areas) to the point where community groups have formed to actively work on controlling its spread, alongside restoration of other coastal vegetation. The argument put forward is that mangroves are spreading because of sediment loading from local rivers, but this is not known with certainty. While this may be a factor there is also the possibility that temperature increases in recent decades are encouraging both spread and increased growth. Temperature clearly has an influence with mangroves reaching heights of 15m in the far north, 5m around Whangarei, and historically only 0.3-0.5m in Kawhia and Ohiwa harbours (see Salmon, 1980).

Lakes

- An increased likelihood of eutrophication for lakes in the Rotorua district. Five of these lakes already exceed specific trophic level indices, and algal blooms are a frequent and troublesome occurrence in several. Extended periods of hot, still, weather is a prerequisite for triggering algal blooms in eutrophic lakes. Higher temperatures resulting from climate change are likely to increase the degree of eutrophication and frequency of algal blooms in Rotorua and other lakes, particularly for shallow lakes (e.g. Rotorua and Rotoehu, in which nutrient levels and algal blooms are already problematic), although deeper lakes such as Rotoiti are now also badly affected.

- Changes in rainfall may lead to rises or falls in lake levels[5], altering lake margin habitats including wetlands. The habitat loss consequences of lake level decline could be particularly marked for lakes with steeply sloping shores.

- Declining lake levels, with drier average conditions, may have a significant impact on the aquatic macrophytes, especially the deeper native communities. The bottom depth limit of these would decline as light penetration is reduced due to increased algal production. The possibility of exotic species expanding and, destroying native plant communities, is also likely to be triggered by climate change.

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[5] The levels of some of the lakes (e.g. Rotoiti and Rotorua) are controlled closely within tight ranges. Most of the others are uncontrolled and have widely varying levels, responding to long term rainfall patterns. Some (e.g. Rotorua, Rotoehu, Okataina) have natural ranges of several metres but high levels only occur relatively infrequently.

- Warmer water temperatures could favour more sub-tropical species, although cool winters will always be likely to provide a major limiting factor.

- The range of trout may decrease as water temperatures warm. This could have adverse effects on tourism due to a decline in sport fishing. To provide a context, Auckland is marginal for trout because of its warmth. The difference in average daily summer temperature between Auckland and Rotorua is in the order of 2ºC. Therefore warming of 2ºC could impact severely on Rotorua's highly valued rainbow trout fishery, especially in shallow lakes. Brown trout prefer slightly cooler water so would be affected by smaller temperature increases.

- There are presently few pest fish species in the Bay of Plenty, but they have the potential to become a problem. Studies in the US suggest that carp may become more widespread under warmer temperature scenarios (Le Roy Poff *et al.* 2002), although these are very different to koi carp or catfish in terms of the types of effects they produce in lakes and wetlands. Increases in the distribution and abundance of pest species would obviously further stress aquatic ecosystems.

Wetlands
Both coastal and inland freshwater wetlands are already under threat in the Bay of Plenty. Some of these are the last remaining examples of formerly extensive systems. Climate change and sea level rise would place further pressure on these remnant ecosystems.

- Coastal wetlands are threatened by inundation resulting from sea level rise due to climate change. The Bay of Plenty has a number of important coastal wetlands, including those at Tauranga, Ohiwa Harbour, Matata, Kaituna, and Little Waihi, which may encounter additional stress in the event of sea level rise.

- Any marked, prolonged changes in precipitation are likely to have adverse effects on wetlands subject to inflows, outflows and the hydrology of each site. Both prolonged periods of inundation, and of water scarcity, adversely affect the survival of many wetland species. Decreases in rainfall may lead to an increase in demand for groundwater abstraction[6]. This could have adverse effects on wetlands and other aquatic ecosystems that are groundwater-fed.

- As noted for lakes above, climate change may lead to an increase in abundance, distribution and diversity of invasive plant and animal pests in all aquatic ecosystems.

Changes to production land uses

This section provides a brief review and summary of existing knowledge, drawn from available literature, previous work by the author and discussions with Zespri staff.

Water

Water is already a key issue, particularly for agriculture and horticulture. Any changes in land use, land cover, or management could have subsequent impacts on water quality, flood potential, and drought risk. Water isn't the focus of this report but it is very important to be

[6] A big issue here is the levels of abstraction from streams and rivers for irrigation in relation to base flows. If base flows were to decrease then there could be significant effects even from current levels of abstraction.

mindful that biotic changes in the region, whether in unmanaged or managed ecosystems, could have significant impacts on water resources. Possible increases in drought risk, resulting directly from projected climate change, will have serious implications for water resource management and future land use options. This will result in both direct and indirect effects on the biotic changes summarised below. The potential for flooding, as experienced over the last two years, also remains high.

Changes to pasture production

New Zealand and some overseas research suggests that higher temperatures and carbon dioxide concentrations expected over the next few decades will lead to a 10-20% increase in annual pasture yields in New Zealand. The extent to which these gains occur in the Bay of Plenty will depend strongly on changes in pasture composition.

A big issue for pasture production will be an increased incidence of lower feed quality sub-tropical grasses such as paspalum and kikuyu. Farmers south of Auckland are already observing spread of these species, as documented for example in a recent issue of Rural Waikato (October 25, 2005). Other invasive sub-tropical grass species could also become a much greater problem.

Kikuyu is already a challenge to farmers in coastal areas of the region and where it isn't yet totally dominating the approach is to spray it off and then re-sow. With the potential to spread, particularly on free-draining sandy and volcanic soils, spraying and re-sowing may become less of an option over time.

The possibility of increased drought risk in the region could contribute to the spread of sub-tropical pasture species and weeds. Other effects that may occur include:

- Effects on animal production and health. Warmer wetter conditions in some areas and/or years could lead to increase incidence of diseases such as facial eczema, plus much greater problems with internal parasites.
- Implications for soil fertility and fertiliser requirements.
- Changes to the range, identity and incidence of pest, weed and disease problems.
- Impacts of sea-level rise and river flooding in low-lying areas such as the Rangitaiki Plains.

Changes to arable cropping

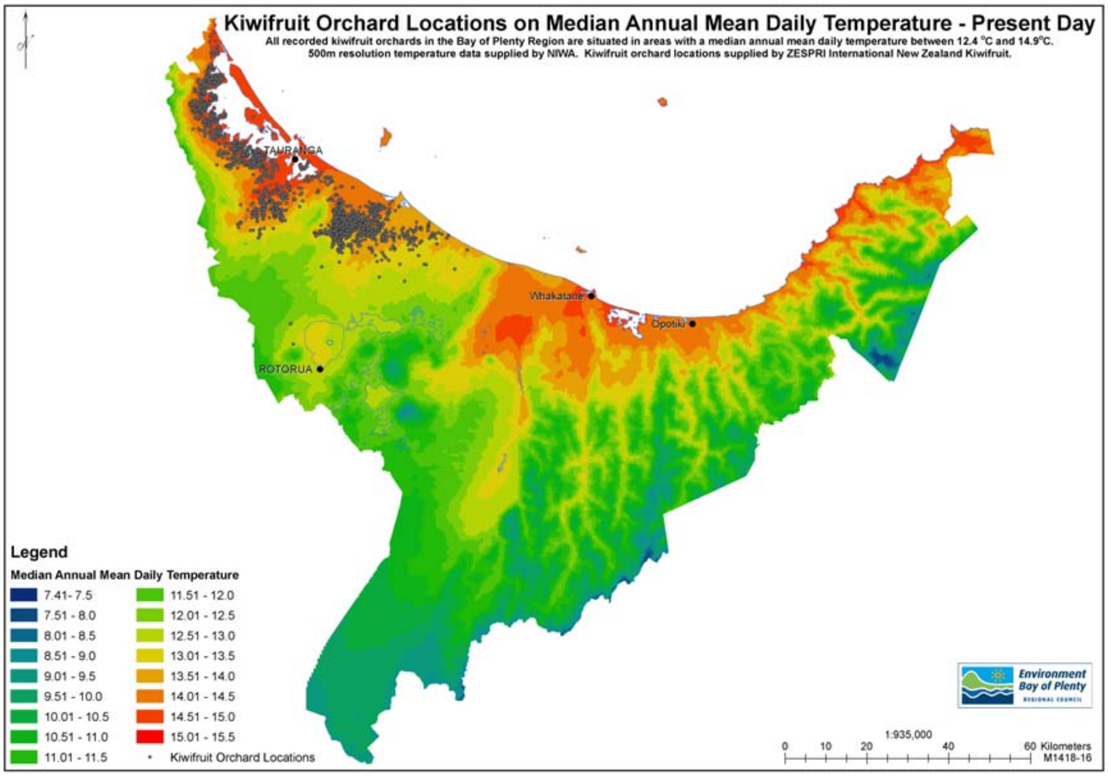
Maize is the principal arable crop in the Bay of Plenty. Higher temperatures would be of benefit, but changes in rainfall patterns will be very important. Risks of summer drought could be offset over time with earlier sowing of faster maturing varieties.

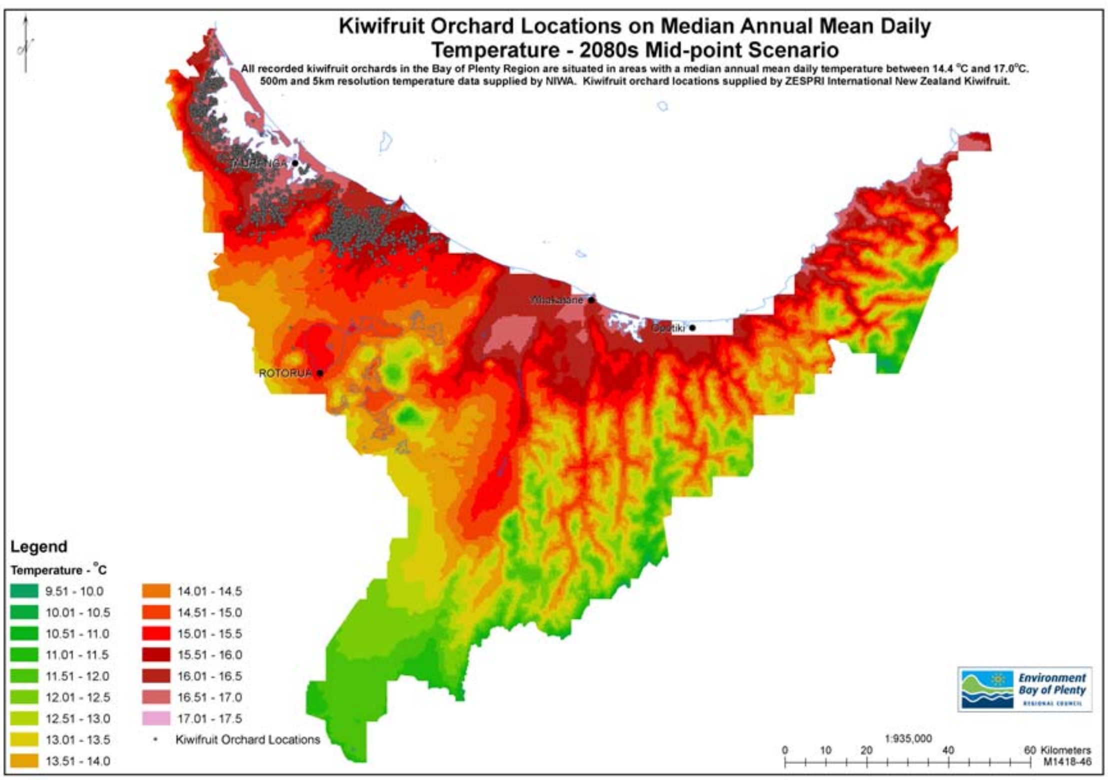
There could be increased problems with weeds, pests and diseases, possibly requiring new pest management approaches.

Changes to fruit production

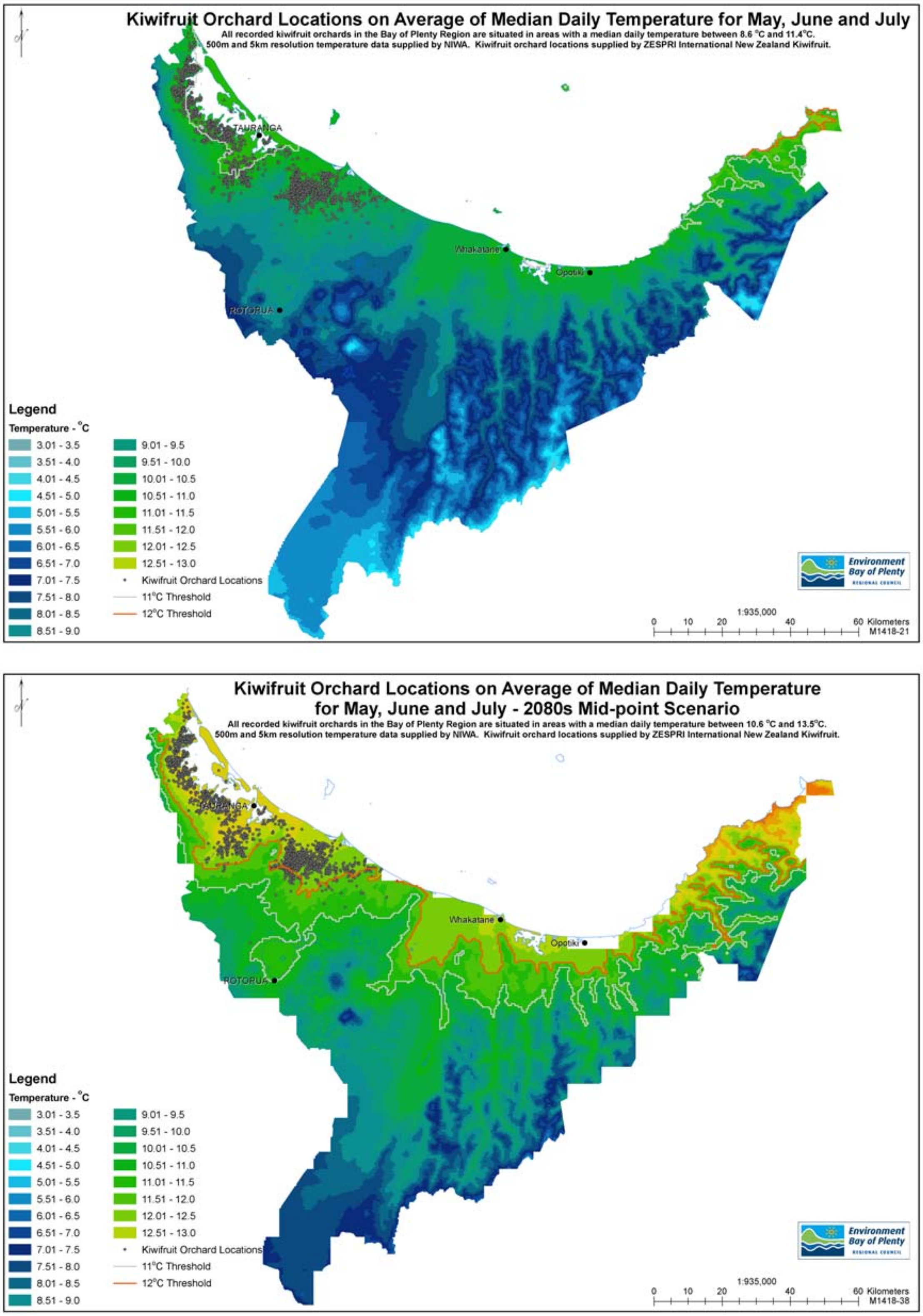
Higher temperatures will have mixed effects on fruit crops.

With kiwifruit the two main impacts could be on crop suitability (bud break) and higher pruning costs with more summer vigour. Increased pests and diseases could also be an issue. Greater extremes would also have impacts, such as the late spring frosts of a few years ago.





Figures 8a, 8b: Changes in median annual mean daily temperature in relation to present kiwifruit orchard locations. Climate data courtesy of NIWA. Kiwifruit orchard locations courtesy of ZESPRI International. See Appendix 2 for the 2030s result.



Figures 9a, 9b: Potential shifts in areas suitable for Hayward kiwifruit are highlighted by the 11˚C and 12˚C (May-July averages) threshold lines. Climate data courtesy of NIWA. Kiwifruit orchard locations courtesy of ZESPRI International. See Appendix 2 for the 2030s result.

The present focus is to push the production envelope which can increase vulnerability of the crop. There is a shift to a greater emphasis on quality. Another issue is the present expansion into higher risk areas as a result of urbanisation pressures and returns to growers stimulating further investment. Climate is also a factor in this expansion. The ideal climate is a cool winter, warm spring, cool dry summer, warm dry autumn. Kiwifruit already require regular application of HiCane to manage the amount of flowering. There is increasing pressure to discontinue with use of this product, with a pending review by ERMA because of health effects from spray drift. Without a viable alternative, Hayward kiwifruit could become uneconomic in warmer parts of the Bay of Plenty in 40-50 years time, and researchers are at least 10 years away from finding viable alternatives. Newer varieties are very bird-friendly which could be an issue in terms of plant dispersal and potential weed problems. Potentially the biggest impact could be on organic Hayward growers. Impacts on water use for irrigation (and frost protection) would also be critical for growers located on shallower soils.

The potential effects of climate change on the kiwifruit industry are highlighted through Figures 8 and 9 (see Appendix 2 for the 2030s results). A clear illustration of the potential impact of higher average temperatures is shown in Figure 8. It suggests the possibility of either a significant shift in production areas and/or changes in varieties. This possibility is made even clearer in Figure 9 where temperature thresholds used by Kenny *et al.* (2000) for the May-July period are applied. Areas on the coastal side of the red line (the 12˚C threshold) are considered unsuitable while those between the red and white lines (the 11˚C threshold) are considered suitable so long as there is some management of bud break. If an upper limit of 12˚C is applied (which matches the 1951-80 average for Kerikeri, for the May-July period) then a complete displacement of areas suitable for Hayward kiwifruit could happen by the 2080s. This would have significant implications in terms of changes in land use and increased pressure on indigenous vegetation.

The avocado industry would benefit from higher average temperatures although there will be on-going problems with diseases such as phytophthora. The citrus industry could also benefit from higher temperatures and other sub-tropical crops could become increasingly viable.

Changes to forestry

The mainstay of the New Zealand forestry industry, and a key component of the Bay of Plenty economy and environment, is plantation production of *Pinus radiata.* With a rotation period of 25-30 years there is the possibility of significant climate change within the lifespan of newly-planted trees. However, there is no indication at present that climate change would have significant adverse effects on pine production in the Bay of Plenty. The greatest threat to pines is from invasive pests and diseases which could cause significant damage. It is possible that climate change, combined with existing pressure on our borders, could add to this risk. Land use change is another potentially significant factor. For example, large scale conversion of areas presently in pine forest to pasture production will lead to further changes in biota, hydrology, and nutrient outputs (nutrient losses from pine forests are on a level similar to indigenous forest).

Three Case Studies

The biological ingredients are different in different parts of the Bay of Plenty. These are influenced by climate, soils, topography, past and present land use, and urban development. Thus the biotic effects of climate change, and necessary responses, will differ. Three brief case studies are presented to highlight these differences.

Summary of effects in different parts of the region

Effects in the Tauranga Harbour Catchment

- Climate change, in combination with on-going pressures from urban expansion and land use change, will lead increasingly to a biosecurity situation comparable to Auckland and Northland.
- Warmer temperatures and sea-level rise will affect coastal vegetation, with the possibility of increased growth and spread of mangroves and favourable conditions for wetland ecosystems.
- Pressures on bush margins from invasive weeds are likely to increase.
- There will be on-going changes in agriculture and horticulture, with an increasingly sub-tropical environment in coastal areas.

Effects on the Rotorua Lakes

- There will be changes to both land and freshwater ecosystems.
- Sub-tropical weeds, such as woolly nightshade, could become more prevalent.
- Changes in temperature and rainfall patterns will have both direct and indirect effects on lake ecosystems.

Effects on the Rangitaiki Plains

- Coastal areas that are already below sea-level will be at increased risk from both river flooding and sea-level rise.

Tauranga Harbour catchment

The Tauranga harbour catchment has experienced significant change over the last 150 years. The topography and climate of the area originally provided rich habitat for a diverse range of sub-tropical and temperate native plant species and associated fauna. Indigenous forest remnants, much of which is regenerating and secondary, presently occupy 24% of the land cover. These remnants are mostly confined to the flanks of the Kaimai ranges. Areas that were originally in coastal and semi-coastal vegetation are now primarily used for pastoral farming, horticulture, urban, and exotic forestry.

This is a dynamically changed and changing environment with on-going changes resulting from rapid population increase and urbanisation, coastal development, land use intensification, and spread of lifestyle blocks.

These ingredients provide a potentially volatile biological melting point which needs to be managed very carefully when considering the possible consequences of climate change.

Issues

Biosecurity is a major issue in the area. Historically, weeds such as woolly nightshade have been a high priority with core areas of infestation located in this catchment. The Port of Tauranga, combined with rapid influxes of people, new plants and rapid land use changes over the last 20 years, provides high and increasing potential for new pest incursions.

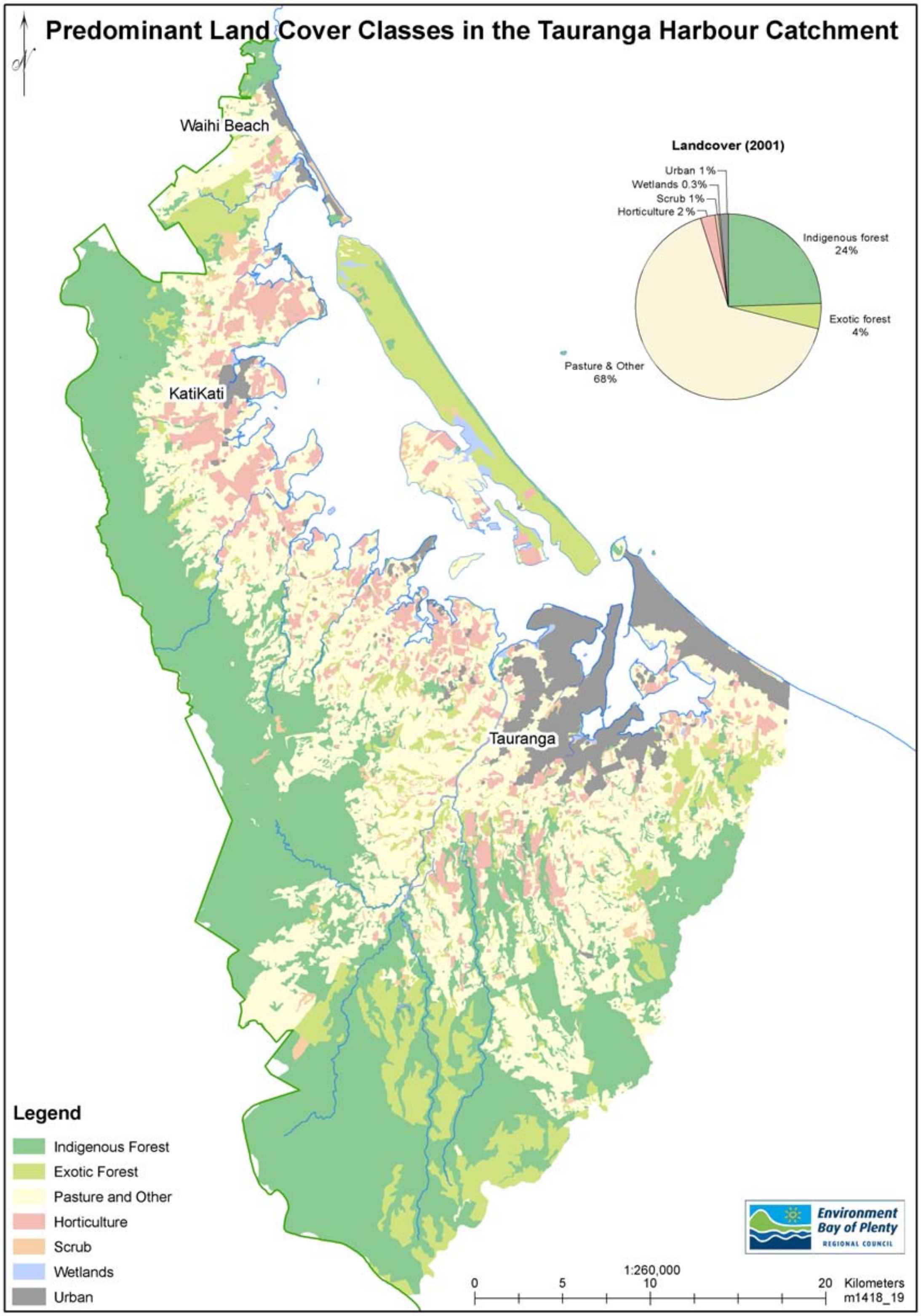


Figure 10: Predominant land cover classes in the Tauranga Harbour catchment.

The effects of silt loading into Tauranga Harbour are raising awareness of the importance of appropriate land cover and land use in the wider catchment area. How this wider area is managed will be critical in terms of the potential effects of climate change.

The spread and increased growth of mangroves is likely a result of a complexity of factors, including silt loading, warmer temperatures, more people, and increased pressure on the environment in terms of aesthetics, land development, recreational needs and so on.

Rapid development of a coastal environment with very little remnant native coastal vegetation is another issue, particularly when considering the potential consequences of sea-level rise.

Effects in the Tauranga Harbour catchment

Climate change, in combination with pressures from on-going population increase, urban expansion and land use change will lead increasingly to a biosecurity situation that is comparable to Auckland and Northland. A warmer climate will favour established weeds such as woolly nightshade and will most likely encourage increased spread. There could be increased pressure on coastal areas from weed pests such as lantana and Italian buckthorn and a very diverse range of pest plant species already present on coastal dunes.

Warmer temperatures will favour further growth and spread of mangroves. This will further challenge people's attitudes.

Pressures on bush margins from invasive weeds is likely to increase, especially when combined with ongoing subdivision and greater numbers of houses located immediately adjacent to (and even in) indigenous forest remnants.

There will be on-going changes in production ecosystems with the potential for subtropical grasses to increasingly prevail in coastal and semi-coastal areas, and even in more inland sites. It is quite likely that a Northland type situation could prevail over time, requiring significant changes in pasture management.

The fruit industry in the area will undoubtedly experience further change. There has already been significant change over the last 30-40 years from an area that historically grew citrus and some apples to the growth of kiwifruit and the more recent development of the avocado industry. With warmer temperatures there will likely be further intensive land development further inland and at higher altitude (and closer to the bush margins).

As suggested earlier, these changes, in combination with an already dynamic and rapidly changing environment, provides potential for a very volatile biological melting pot that will have to be managed very carefully.

Rotorua Lakes

The lakes are nestled in a volcanic landscape where various eruptive events have had a major influence on landform and soil development. Active geothermal sites are still present and Rotorua is a regional and national centre for geothermal features. The lakes catchments have experienced significant land use changes since human occupation. This has occurred in two main phases, with initial Māori burning of primary forests, which was replaced with extensive areas of fernland and shrubland. This phase was followed by conversion of much of the catchments to pasture, plantation forestry, and urban development over the last century.

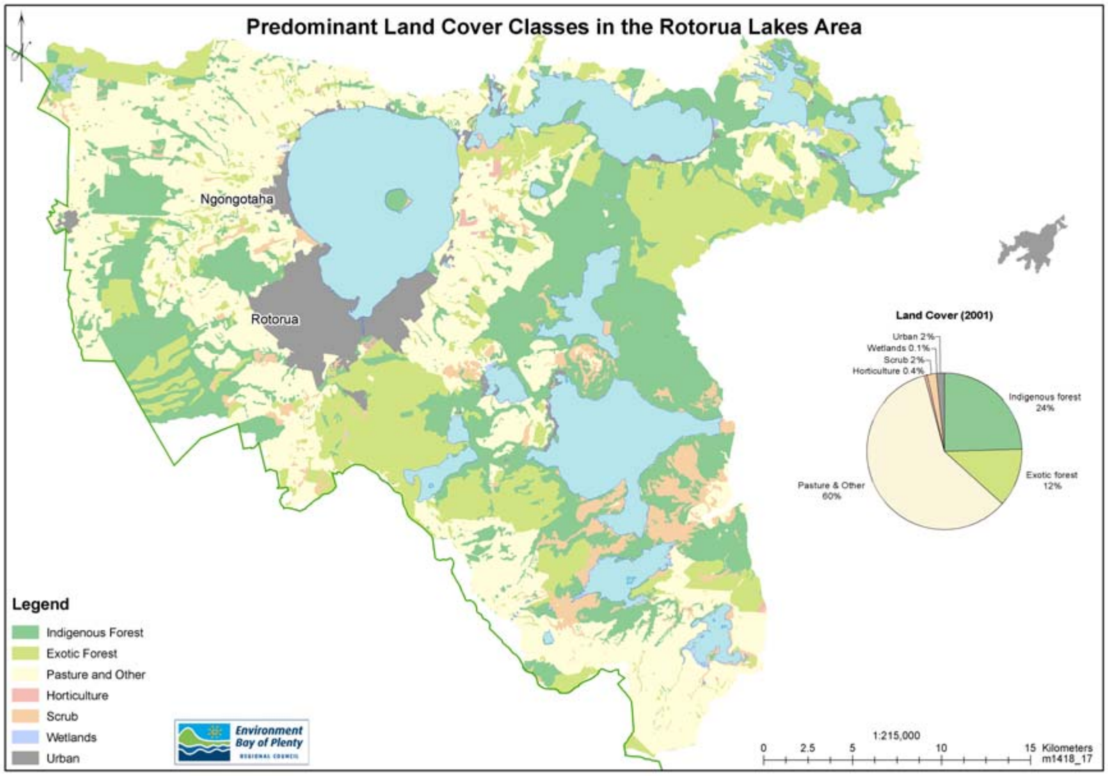


Figure 11: Predominant land cover classes in the Rotorua Lakes area.

Flatter land in particular has been most heavily affected, with only 2% of relatively unmodified primary forest remaining on flat to undulating land. There are, however, still extensive areas of indigenous vegetation on steeper land.

Some of the most significant changes, in terms of effects on the lakes, have been the increase in pastoral farming, particularly dairy farming, the loss of wetlands (nutrient filters) on wetland margins, and nutrient inputs from urban settlements.

Issues

The history of land use, and associated nutrient losses to the lakes, has created a legacy of nutrient-enriched receiving waters that have deteriorated dramatically in quality. This had lead to major community concern and a relatively rapid response from the management agencies. To date, these responses have included lake management plans, fencing of lake margins, major investment in sewerage reticulation from lake settlements, and the planning of a diversion structure to direct flow from the Ohau Channel (70% of the nutrient inflows into Lake Rotoiti) into the Okere arm of Lake Rotoiti and thence into the Kaituna River. It is projected that $190 million will be spent on lakes protection and enhancement over the next 20 years.

Effects on the Rotorua Lakes

There is potential for both terrestrial and aquatic effects. The former could include the potential spread of weeds that are more prevalent in warmer, coastal areas, such as woolly nightshade and ginger (which is already locally common).

There is already strong pressure for more development of land uses that result in less nutrient losses to receiving waters and options are being explored for wetland restoration on lake margins.

There is still, nevertheless, potential for further deterioration of lakes due to arrivals of new pest plants and animals, such as pest fish species. New arrivals could have dramatic effects, as occurred, previous with waternet in the 1980's (which then disappeared), and the recent arrival of didymo in the South Island.

Rangitaiki Plains

The Rangitaiki Plains is a low-lying coastal and semi-coastal area of 342 km^2 that were formed principally from volcanic deposits, with subsequent aggradation from river flooding. There is evidence from inland dunes of podocarp forest before the Taupo pumice eruption 1800 years ago. At the time of European settlement, large areas were in wetland, with associated vegetation (flax, raupo, rushes, cabbage tree, manuka, some areas in kahikatea). River flooding is a feature of the area with significant flooding from the Rangitaiki River in 1916 (twice), 1925, 1937, 1944, and 1964, and 2004. Drainage of the plains began in the early 1900s, with the principal canal and drains dug by 1916 with diversion of the Rangitaiki River (which previously fed the Tarawera and Whakatane Rivers) to the sea. Land drainage was accompanied by the development of dairy farming which remains the predominant land use. Peat underlies an extensive area of the plains, with drainage resulting in significant shrinkage (a total of 2.5m in Whakatane west over the 30-year period 1928 to 1958). The Edgecumbe earthquake (1987) resulted in further decreases of land levels in some areas.

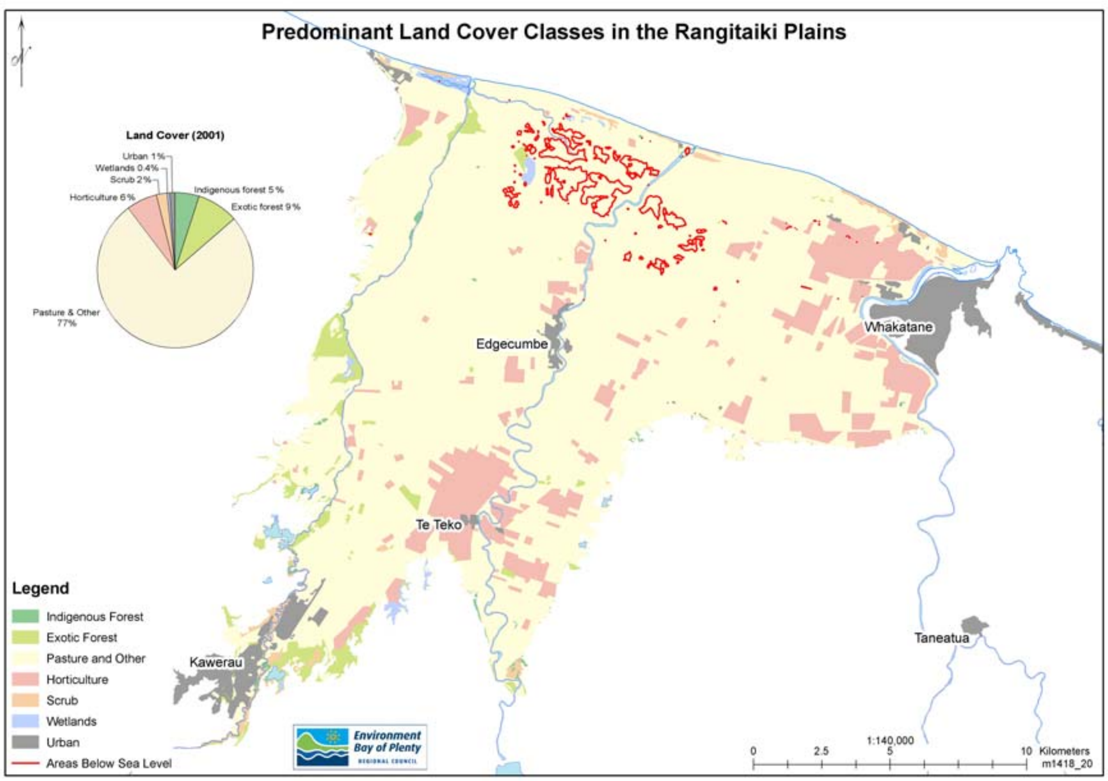


Figure 12: Predominant land cover classes in the Rangitaiki Plains with areas below sea level identified (based on available data).

Issues

The Rangitaiki Plains is an environment radically-modified from what it was barely 100 years ago. Further change is inevitable. This is a very dynamic environment with earthquakes, long-term influences from volcanoes, effects of river flooding, and a changing social situation. With climate change there could increased flood risk from the combined effects of river flooding and rising sea levels. This would particularly affect coastal areas that are presently below sea level.

Effects on the Rangitaiki Plains

Climate change, in combination with projected sea-level rise, will accelerate changes in land use and cover on the Rangitaiki Plains. Using available land elevation data, areas that are currently below sea level have been identified (see Figure 12). This land is at continued, and increasing, risk of both flooding and inundation from the sea and is currently subject to ongoing drainage pumping.

The greatest biotic effect of climate change in the Rangitaiki Plains is therefore likely to be reversion of part of the plains to wetland, in particular those areas that are presently below sea level. If climate change projections are taken seriously then it is inevitable that change will need to happen.

Assessment of Risk

As already indicated only a simple risk assessment has been completed within the context of this study. This was completed through circulation of a risk assessment table ahead of a workshop held with Environment Bay of Plenty staff on 27 January 2006. Brett Mullan (NIWA) and Darren Kriticos (ENSIS) provided useful presentations to participants. Numbers were relatively low for the workshop session, but some valuable general discussion developed, particularly around adaptation measures that could be adopted by Environment Bay of Plenty. John Mather (Plant Pest Coordinator) had completed a draft of the risk assessment table, which was subsequently circulated for further comment. The completed table is given below.

Overall, the level of risk to the Bay of Plenty environment is considered to be medium with high risk associated with more rapid establishment and spread of new pest plant species and effects on small remnants of indigenous vegetation. The overall picture of medium risk is consistent with the view, shared by most people spoken to during the course of this work, that climate change is one factor that is contributing to changes in the biota of the region. Thus the required responses, in most cases, will be refinement of existing policies, plans and practices rather than radical change.

The likely trend for impacts, and the probability of them happening, is upward. Thus, both the level of risk and upward trend of change provide good reason for adaptation to be implemented in a progressive manner from the present through to the next 20-50 years. Such an approach will ensure a minimisation of cost.

This broad evaluation ideally needs to be extended to provide a more in-depth risk evaluation of the principal threats identified. A framework for this already exists within Environment Bay of Plenty. For example, the current pest classification is based on level of risk to the environment and the capacity of the regional council to manage this risk. Consideration of climate change effects, along with effects arising from other on-going changes, and associated risk ought to be considered when the current classification is next reviewed. Likewise consideration of climate change risk and adaptation responses ought to be actively incorporated in other relevant plans and policies as they are reviewed and revised.

A risk minimisation approach is to adopt a positive, proactive, approach to adaptation. The key component of this is to focus on creation of regional resilience, identifying strengths and supporting and building on these and also identifying areas of weakness that need to be addressed.

Table 7: Biotic effects of climate change in the Bay of Plenty – risks and adaptation responses

	Biotic effects	Degree of risk to the Bay of Plenty environment (L/M/H)	Probability (L/M/H)	Geographic scale (specify part of region)	Urgency	Costs to Environment Bay of Plenty of adaptation (L/M/H) And timescale for least cost (Now, next 10-20 years, 20-50 years, 50+ years)
1.	Threat of more rapid spread of existing pest plant species	M	H	Coastal areas, Rotorua lakes, settlements, ports and airports	M	M 0 to 15 yrs
2.	Threat of more rapid establishment and spread of new pest plant species	M to M/H	H	Similar to above, especially settlements	M	M 0 to 30 years
3.	Increased threats from existing pest animal species	M	M	Coastal, thermal areas, volcanic plateau	M	L to M 0 to 5 yrs (ants) 0 to 20 yrs (rabbits)
4.	Potential threats from new pest animal species	M	M, H (ants)	As above	M	0 to 10 yrs (fish) 0 to 25 yrs (other threats)
5.	Increased growth and spread of mangroves	L	M/H	Tauranga and Ohiwa Harbours, Maketu and Little Waihi estuaries	L	0 to 50 yrs
6.	Effects on small remnants of indigenous vegetation	H	H	Near any settlements	M/H	0 to 20 yrs
7.	Effects on native forest	M	M	Te Puke, Tauranga, Rotorua Lakes, East Cape	M	0 to 20 yrs
8.	Changes in pasture composition in production land areas	L/M	M	Especially northern and coastal areas	L/M	0 to 30 years
9.	Impacts on the kiwifruit industry	L/M	L/M		L/M	0- to 25 yrs

Adaptation

The best approach to adaptation is to focus on building regional resilience. With this in mind a number of recommendations are made for adaptation actions, followed by more in-depth discussion of these.

Recommended adaptation actions

1) The greatest challenge, in terms of effects on biota, is likely to be with biosecurity threats. However, this needs to be considered within the context of management of the whole environment of the Bay of Plenty.
2) Education of people throughout the region is the key to successful implementation of adaptation. The wider community needs to be informed, on an on-going basis, about the risks, challenges, and opportunities that climate change will bring to an already dynamic and rapidly changing environment and what they can be doing about it.
3) A number of actions could be taken to enhance the existing work of biosecurity staff:
    a. Maintain and increase the contractor/work team approach
    b. Focus on control in low incidence areas and increase emphasis on biological controls, and increase ecological restoration of corridors (see below).
    c. Strengthen regulation of internal borders, especially relating to garden plants, cleaning of machinery etc.
    d. There is a need for clear guidance for local authorities, particularly relating to siting of new subdivisions and corridor plantings of natives, with clear information on both unsuitable and suitable plant species.
    e. Explicitly consider climate change and adaptation when the Regional Pest Management Strategy comes up for review. This should include addressing the apparent gap between potential threats and resources to monitor them (highlighted by the difference in approach in Auckland). For example, an "Awareness" category could be incorporated with listing of all plants that could become threats in the future. This would help avoid surprises such as the recent proposal to ban two palm species in Auckland.
    f. Implement a comprehensive plant species recording database. This is vital, not just for helping shape on-going management, but for documenting changes that may be attributed (at least in part) to climate change. This is a matter of both regional and national significance.
4) Biodiversity changes that might occur are fairly speculative at present. With this in mind the principal actions needed are:
    a. Support and strengthen the role of ecological staff in the council and their linkages with other agencies in the region. Sharing of information and data of relevance to climate change is very important.
    b. Focus on ecological restoration in corridors, protected areas and smaller remnants of native vegetation. Such an approach will have multiple benefits, including helping control the spread of biosecurity threats.
5) There may be the need for some proactive approaches to land management in the region. Further education of, and engagement with, the public at large and rural communities is very important. In particular there ought to be:
    a. Formal monitoring of changes in biota in economic land uses. For example, recording of changes in kikuyu. Development of kikuyu management plans, as in Northland, may be required over time.

b. Further consideration of the implications of changing land uses. For example, what are the biosecurity and biodiversity implications of inland spread of kiwifruit production? Land use changes (including urban spread) in sensitive catchment areas (especially Tauranga Harbour and the Rotorua Lakes) need to be managed with explicit consideration of climate change.
c. The situation in the Rangitaiki Plains is unique and needs more attention. The threats of both river flooding and inundation from sea-level rise are real, particularly for land areas that are currently below sea level. Serious consideration and discussion of future options is needed.

An overview of adaptation to biotic effects of climate change

It is evident from this review that the greatest biotic challenge that will arise with climate change will be through biosecurity threats. Other issues will also create further challenges in the future, including, the role and importance of catchment protection and management, and management of coastal environments, (including the management of change with mangroves) lakes and wetlands. Production land uses will change, along with further urban development and spread of lifestyle blocks.

The key ingredient in the mix is people. Environment Bay of Plenty has the responsibility of balancing the diverse needs and interests of people with the need for protecting and enhancing the regional environment. How Environment Bay of Plenty shapes and modifies its work in the face of climate change will be critical in terms of shaping wider community responses to challenges and threats that will arise.

At the core to effective adaptation are two things:
1) The community management approach;
2) The environmental management approach.

The approach to working with people involves activity on individual properties, support for community initiatives (eg, Care groups), and education. There is an underpinning regulatory framework, but the principal thrust of work by Environment Bay of Plenty is to bring about positive outcomes through education of the public.

Environment Bay of Plenty has adopted a holistic environmental management approach, as documented for example in their Regional Pest Management Strategy. The focus is a site-based approach to the management of invasive pests which is integrated with indigenous biodiversity protection and enhancement, and soil and water conservation. This approach has a sound ecological basis.

Environment Bay of Plenty, therefore, has a sound basis for developing effective, proactive, adaptations to climate change. The overall focus needs to be on developing a resilient region. How the likely biotic changes are managed by people (individually and as communities) will determine the future resilience of the Bay of Plenty.

How much does the community care about these issues? More work is needed to fully gauge this. Clearly they care when something becomes a problem in their back yard. For example, people in the eastern and western parts of the region are very concerned about the impacts of recent storms and harbour-side residents are concerned about the spread and growth of mangroves. This spread and increased growth may actually be happening for their long-term benefit, eg, by providing improved coastal protection. Spread of mangroves has motivated people to do something. But do they care about the spread of weeds such as woolly nightshade? Are they concerned about the increased threat to indigenous biodiversity that could result with climate change? With more people in the Bay of Plenty environment there is much greater potential for people to affect the environment and be impacted by it. An outcome of this, as with storm damage and the mangrove situation, is heightened awareness of issues. This situation provides excellent opportunities for informing and educating the public.

The process of engaging the public should be built around issues that are presently engaging their interest but geared towards identification of potential areas of weakness where threats posed by climate change may be the greatest.

Biosecurity approach

At present there is a mix of approaches taken by Environment Bay of Plenty, but the main focus is educative and advisory. This approach should be continued but at the same time careful thought should be given to desirable outcomes in terms of building wider resilience and whether these can be achieved within timeframes that match with climate change.

A key issue here is the management of ecological linkages and corridors (eg, along streams), some of which are currently regarded as 'wasteland' (road margins and railways). Even without climate change these are avenues for spread of existing and new pest species. Should there be a more proactive approach to revegetation of such areas with natives? Such an approach would, over time, reduce opportunities for spread of invasive weeds and develop corridors for indigenous plants and fauna. In this context, the selection of species for soil conservation and roadside plantings is very important. Appropriate species for planting roadsides are not always being used at present, with an emphasis on what is cost-effective in the short-term. However, appropriate species are increasingly being planted by district councils and roading authorities.

At present we don't necessarily value these areas of unproductive land and perhaps this view needs some re-evaluation. They do present some level of potential threat (biosecurity), but also opportunities (biodiversity enhancement) in more developed parts of the region. There is evidence that this view is changing. For example, Environment Bay of Plenty has recently assisted the Western Bay of Plenty District Council produce a long-term strategy for pest plant control and revegetation on local and State highway road margins.

The threat posed by different types of weeds also needs to be carefully considered. In general, there are three main areas of concern with respect to weeds:

1) those that threaten indigenous biodiversity;
2) those that threaten production land uses;
3) those that affect people's enjoyment, or appreciation, of the environment.

Woolly nightshade for example, poses little threat to intact indigenous vegetation. Eradication of this particular weed would take 50 years or more (W. Shaw, pers comm.) and there would still be residual seed and the threat of re-invasion from outside the region. It is well established north of the Bay of Plenty and is spreading southwards (based on a review of its pest status from Regional Council websites in the North Island). So the pressure is there and will increase with warmer temperatures. A similar time frame (50+ years) will also be required for species such as contorta pine in southern Kaingaroa.

If containment is continued as the principal strategy, should novel approaches be explored? For example, some weedy species have potential to be developed economically for their medicinal value. In Brazil, its country of origin, woolly nightshade has been recognised as a plant with medicinal potential (see articles by Stepp (2004) and Stepp and Moermann (2000) for a discussion of medicinal values of weeds. These and other articles can be found at: www.clas.ufl.edu/users/stepp/pubs.html). In Australia a pharmaceutical company has recently made commercial plantings of Apple of Sodom (*Solanum linnaeanum* and is using extracts from this in the development of treatments for skin cancer (see www.solbec.com.au under Coramsine™). So there is realistic potential to get some positive return from weeds that are unlikely to be eradicated. Such 'out of the square' thinking may increasingly be required to meet the challenges of climate change.

Another approach is biological control. Environment Bay of Plenty is currently providing funding to Landcare Research to progress the biological control of woolly nightshade and many other pest plant species.

Pest plant information

Information on potential threats from Northland and Auckland is gained through occasional trips by Environment Bay of Plenty pest plant staff, who have both informal and formal contacts with staff in these regions. This process of information sharing could be formalised more and strengthened with a more systematic documentation of potential threats to the Bay of Plenty that may arise with climate change.

Pest plant staff have been recording information on pest plants for the last five years. The most comprehensive information held is on woolly nightshade. However, a more comprehensive plant species recording database would be valuable. At present the focus is on recording information on plants that are in the regional pest management strategy (RPMS). In general staff only record information from sites where they are doing work (eg, this is why woolly nightshade presence isn't recorded in Environment Bay of Plenty databases for Matakana Island where it is quite prolific).

A fundamental starting point for a control programme should be to document the full extent of a species and to record new infestations as they come to hand. This is essential for the development of a strategic approach that enables consideration of effects from climate change and other influences over time.

Thoughts from Walter Stahel, Environment Bay of Plenty Biosecurity:
I feel it is extremely important that we know as much as possible about what grows in the region as naturalised exotic plants as well as native plants. A Plant Inventory Database is an essential tool for long term planning in pest plant management and monitoring of Environmental Programmes. It would also be a useful tool for monitoring plants should there be a significant change in our climate.

What we would want from the database:

- The database should be linked to the existing land management database Map Info and VNZ. Links should also be strengthened with Department of Conservation who hold fairly detailed locational records of native plant species.

- Individual land parcels be accessed through VNZ Val. No.
- Plants of significance or important pest plants, or new invaders can be recorded via GPS on maps.
- All plants can be recorded by the botanical and common name incl. short comment.
- Species lists can be printed off for any land parcel and used as check lists for monitoring.
- Report all species recorded in the region, separated into natives and exotics.
- Report on all the locations of individual species.

Indigenous biodiversity

This is a particularly significant issue that needs careful consideration and a planned approach to the following elements:

- retain what we still have;
- develop strategies to protect and enhance what we have;
- ensure that there is good monitoring and reporting;
- have a (relatively) rapid response capability to deal with new problems as they arrive;
- develop opportunities for ecological restoration;
- ensure that there is good information sharing.

Climate change will increase pressure on indigenous biodiversity, from the combined effects of increased threats from pest plants and animals and climatic disturbance events (an example is the 2004 infilling of the Matata Lagoon with storm debris – a previously high value site for indigenous waterbirds). Should we be protecting our streams more? There cannot be any doubt that there needs to be better protection for streams. There have been, in recent decades, major “slugs” of sediment introduced to Bay of Plenty estuaries in single storm events. These effects are occurring along with on-going incremental introductions of sediment.

The most vulnerable features are smaller remnants and narrow ribbons of indigenous vegetation along waterways, and these are typically often the only remaining examples of indigenous biota in the most developed landscapes.

There needs to be a much greater focus on the retention of these features, in good condition. Intensification of land use, especially urbanisation, needs careful management to prevent invasion of additional exotic plant species and additional domestic pets – there are already significant issues and will exacerbate climate change effects.

Potential changes in the suite of invasive species means that there is increased need for systematic monitoring and recording of potentially invasive species and for rapid response mechanisms for potentially-damaging species while they are still in the early stages of establishment.

Ecological restoration is now an ongoing and long term requirement, of heightened importance because of climate warming and the need to retain and enhance the resilience of indigenous ecosystems and the need to minimise or remove invasive pathways for new pest plants and animals. Ecological restoration of large tracts of indigenous vegetation is perhaps best undertaken under single management agency leadership but restoration of small remnants will always require a strong community and landowner focus and Environment Bay of Plenty has a major role to play in this area.

Production land uses

Management changes will be needed to cope with increased presence of kikuyu pasture, as is now happening in Northland. The Northland experience provides ample information that could benefit Bay of Plenty farmers who increasingly have to manage kikuyu rather than spraying and resowing infested areas as presently occurs on some farms.

It is feasible that proactive kiwifruit growers will move inland to cooler sites over time. Some are already doing this. This will lead to on-going land use change and would require a re-evaluation of land management approaches in different parts of the region, and consideration of biosecurity and biodiversity implications. Land use change in sensitive catchment areas, such as Tauranga Harbour and Rotorua Lakes, will need to be carefully managed with explicit consideration of climate change effects in these areas.

There are unique issues in the Rangitaiki Plains, particularly in areas that are already below sea level, with the existing flood risk and real threat of inundation arising from sea-level rise. There needs to be careful thought about the relative costs and benefits of proactive adaptation vs adopting a 'wait and see' approach. A proactive approach would involve identifying land at greatest risk from flooding and inundation and considering the costs and benefits of increased protection against the potential costs and benefits of re-converting this to wetland. Creation of 'new' wetland zones on low-lying parts of the plains could be accompanied by planned changes in economic land use. For example, possibilities such as aquaculture or commercial flax cultivation could be considered. The latter is a realistic possibility given the strong interest at present in developing a modern flax industry in New Zealand. While the short-term cost would be significant, there could equally be significant long-term benefits with planned, proactive change. Enforced change could come at significant cost. At the very least these issues need to be raised and discussed with the local community.

Further Steps

An overall view, shaped through the course of this study, is that Environment Bay of Plenty is presently well placed to address the potential effects of climate change on biota in the region. Many things are already in place that will simply require further refinement to enable explicit consideration of, and action on, climate change. However, this is not to suggest that effects will be minimal and won't result in costs to the region. The key is to be smart and forward thinking and acting, and to ensure that the public are informed and engaged as much as possible. To this end the following recommendations are made for further steps:

Recommendations for further steps

1) A more in-depth understanding of risk would be beneficial. Some discussion within Environment Bay of Plenty is needed as to how best to focus this. Different approaches could be applied, including:
    a. A process of review, consultation and public engagement to focus on key issues in different parts of the region and how they might be addressed. Such a process should be aimed at future visions that are positive, practical and achievable. The emphasis would need to be on different parts of the region because of unique combinations of issues that already exist and are likely to be faced in future. Ideally such an approach should take a broad view of climate change effects, not strictly focusing on biotic effects.
    b. A formal, more in-depth, assessment of effects, with an associated risk assessment, on particular species or plant communities. This should be developed and implemented over time with a focus on: using the existing, considerable, knowledge of Environment Bay of Plenty staff[7]; strengthening monitoring activities as discussed in the previous section; modelling effects of climate change at the species level (for example with the sort of work being done by Darren Kriticos at ENSIS).
2) Incorporating proactive adaptation measures into policies and plans, including:
    a. An overall emphasis on 'working with change' aimed at 'building regional resilience'.
    b. Strengthening and enhancing the existing holistic management approach, with specific measures as recommended in the adaptation section of this report. Important actions include enhancing the present focus on catchment management, proactive management of corridors (especially roads and waterways) and at-risk ecological areas
3) Communication and education are paramount. The majority of people find change of any kind very difficult. Thus, it is of fundamental importance that the community at large is engaged as much as possible in thinking about and acting on climate change. Some ideas for actions include:

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[7] **Some Environment Bay of Plenty staff have indicated that they are already *implicitly* considering climate change. However, consideration of climate change needs to be both implicit and *explicit*. Explicit consideration of climate change effects and adaptation responses is very important as such information needs to be visible and accessible. If Environment Bay of Plenty staff are aware of climate change this needs to be communicated more effectively and widely to others. To this end there is a need for systematic consideration of climate change effects on biota, using the considerable expertise within Environment Bay of Plenty, and wide discussion of appropriate adaptation response measures.**

a. Create forums for public participation and engagement in identifying and discussing key issues and risks, and in developing positive, future, visions. This could be initiated through the process outlined in 1a) above.
b. Continue developing the climate change page on the Environment Bay of Plenty website.
c. Consider using 'effects of climate change', on biota or more general effects, as a theme for the next environmental art awards.
d. Develop climate change adaptation resource kits for schools and a delivery programme (see more discussion in the Communication and Education section below), and simple information packs for ratepayers, business and others.
e. Create interactive displays, to visualise possible effects and positive future visions for the region. Engage artists in the region in helping create this.

4) Develop linkages with other organisations in New Zealand and overseas, including:
a. Create a regional climate change partnership, involving public and private sector agencies within the Bay of Plenty.
b. Consider taking the initiative and host a regional council forum on 'biotic effects of climate change'.
c. Communicate with the Ministry for the Environment about the good work being done by Environment Bay of Plenty.
d. Make connections with overseas organisations and regional climate change partnerships. A good example is the ESPACE project in the United Kingdom (www.espace-project.org), but there are other partnerships in the UK and elsewhere.

Assessing risk

One of the key weaknesses identified through this work has been the lack of sufficient knowledge on effects to give an in-depth risk assessment. This needs to be addressed. A combination of approaches ought to be adopted, as outlined in the first recommendation above. At the workshop held at Environment Bay of Plenty on 27 January, 2006 there was some discussion of expert knowledge and modelling approaches. John Mather presented the view that there is a lot of knowledge on present and potential biosecurity threats among Environment Bay of Plenty staff. John reiterated their awareness of potential threats from more northern regions and also talked about their awareness of potential threats from overseas. There was some discussion as to how this knowledge could be formalised, for example through developing an 'Awareness' category for potential threats that staff don't currently have resources to monitor. Walter Stahel's thoughts for more comprehensive documentation of observed plants also need serious consideration. However, there is possibly also some value in exploring the potential contribution that could be made through the sort of modelling approach outlined by Darren Kriticos of ENSIS at the January workshop. Darren's estimate is that it would presently take 5 days to complete an analysis, including consideration of climate change, for one pest plant species. He believes that this could possibly be reduced to 2-3 days. It could be of value to explore this approach on a trial basis for a few selected species. Such work would require close interaction with the pest plant staff.

Quantifying effects on biosecurity

Climate change is likely to contribute to significant biosecurity challenges in the future. To develop a thorough understanding of the likely threats would require:

1) A comprehensive database of all pest species that are likely to be a threat in the future, including information on their climatic limits.
2) Evaluation of the type and extent of habitat that individual species are likely to invade.
3) Evaluation of likely changes in species distribution in relation to potential habitat.

To achieve this would involve:

1) Documenting all current and potential pest threats. This would require a more systematic approach to pest recording in the region as well as drawing together information on potential threats from Northland and Auckland regions and overseas.
2) Mapping potential spread of current and potential pest threats with climate change and drawing on local knowledge and expertise to evaluate this information.

Quantifying risk in relation to indigenous biodiversity is much more problematic. We are talking about complex, dynamic, and in some cases fragmented, ecosystems that are already experiencing pressure from introduced pests. A more realistic approach is to draw together the considerable knowledge and expertise in the region and provide a qualitative risk evaluation for identified areas of indigenous vegetation.

Engaging the public in this work, through public forums, is also very important. This should be done in conjunction with the work outlined above.

Incorporating proactive adaptation measures into polices and plans

As already explained, it is important that in-house awareness of climate change be made explicit. The most obvious way for this to happen is for climate change to be considered in an overarching manner when policies and plans are reviewed and revised. At the recent ESPACE conference in the UK (held on 29 November 2005) one speaker commented that 'if we can get it right for climate change we can get it right for everything else'. With this comment in mind the key recommendation is that the council adopt an overall focus on 'working with change' and 'building regional resilience' (see Appendix 5 for a recent article on 'Adaptation, change management and the psychology of change' prepared by Dr Kenny for a special climate change issue of the Journal of Primary Industry Management). Environment Bay of Plenty has the potential and resources to be providing leadership, both within the region and as an example to other regions in New Zealand. There is evidence that this is already happening, with Environment Bay of Plenty already one of the most proactive councils in New Zealand in terms of considering effects of, and responses to, climate change.

Communication and education

Effective communication and education on climate change effects and adaptation is of fundamental importance. The public need to be made aware of issues as much as possible and engaged in finding positive solutions that will benefit the region as a whole. There are many ways in which this can be achieved, with some key ideas recommended in 3) above.

Environment Bay of Plenty has already taken an initiative in this regard, through the development of a climate change page on their website and the very well organised dissemination of the 'Adapting to climate change in eastern New Zealand' information.

Some useful ideas for further communication and education activities might be gleaned from the following:

i) The New England Science Center Collaborative (www.sciencecentercollaborative.org/nescc/) is a well organised and resourced partnership in the north-eastern US. For example, they have developed the Climate Change Backpack® as a resource for schools and other groups.

ii) There are now regional climate change partnerships throughout the UK most of whom have, at the very least, websites for sharing of information. The South East Climate Change Partnership www.climatesoutheast.org.uk/ are a particularly well organised group. Take note, for example of their recent response to a consultation on a national Adaptation Policy Framework. Within this document they emphasise the importance of doing more than just 'awareness raising'. A sense of urgency needs to be communicated widely and the public engaged in active responses. For example, as part of their contribution to the ESPACE programme (www.espace-project.org) they carried out a 'future vision' process with a coastal community.

iii) Art has a very important role to play in engaging people. Such an approach was successfully integrated into the 'Adapting to climate change in eastern New Zealand' work. There is scope with the Environment Bay of Plenty environmental art awards, for holding art/science workshops on climate change in the region, and for developing interactive displays.

In the early stages of this work Graham Woodhead, a primary teacher from Tauranga, responded to the media release seeking feedback from the public on observed biotic changes. In a subsequent meeting Graham outlined his thoughts on how climate change might be effectively delivered to schools. His view is that the age groups to target are Years 5 and 6 (10/11 year olds) onwards. A very small number of primary school teachers might pick up on climate change as an issue, but the majority would need someone to come into their classroom. This would need to be a dedicated person with dedicated resources. It won't happen otherwise, unless an individual teacher is interested. Simply developing resources for schools, particularly senior primary school level and possibly for intermediate schools, isn't enough. It is likely to be a different situation in high schools.

Developing linkages

It is important to be aware that Environment Bay of Plenty is one of an increasing number of agencies around the world that are seeking to address climate change. As mentioned above, there is a particularly strong focus on regional climate change partnerships in the UK. This regional partnership approach ought to be explored by Environment Bay of Plenty, along with strengthened linkages within New Zealand and connections with regional partnerships overseas. Such a partnership approach should embrace the full range of issues, not just relating to biotic effects, that the Bay of Plenty will have to face with climate change. In countries such as the UK the specific issues, and mechanisms for addressing them, may be different. But there are still fundamental similarities in approach (ie, the risk assessment and adaptation frameworks developed by the UK Climate Impacts Programme, UKCIP, see www.ukcip.org.uk) and the same challenges in terms of engaging communities (public and private sector) in thinking about, and acting on, climate change. An example of this is given below.

An immediate step would be to seriously consider the idea of a regional climate change partnership, using as a model the partnerships in the UK and also the New England Science Center Collaborative in the United States (see the Communication and Education section above). Accessing relevant information from the internet and providing relevant links on the Environment Bay of Plenty climate change web page is a good way of making this information more widely available. It is very important for Environment Bay of Plenty and the community to be made aware that climate change really is a global issue, and there are local and regional groups around the world increasingly focused on finding solutions. Another option to consider is for Environment Bay of Plenty to become an extended partner in the ESPACE programme. There is no cost involved in this and it could help promote information exchange and sharing. It is not immediately evident from a first look at the ESPACE website, but they are doing some work that could be of value to Environment Bay of Plenty, particularly in terms of approaches to engage the wider community.

An example of the benefits of linkages

As an example of the benefits of linkages and information sharing, the results of a recent study on 'Business Risks of Climate Change to the Public Sector in Scotland' (published in November 2005) have been shared by a colleague of the author, who works with the Environmental Change Institute at Oxford University. This study has made a set of recommendations that have a lot of similarity to the recommendations made in this report:

1) That climate change be added to the corporate risk register, with explicit consideration of climate change in plans and risk management strategies.
2) There should be an initial focus on raising awareness of climate change and adaptation as the first stage in building adaptive capacity.
3) There should be further analysis of adaptation options identified for key impacts, with a focus on 'no regrets options' in the first instance and more in-depth analysis of actions that may involve higher costs.
4) Work with other organisations for mutual benefit.

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Appendix 1 – Emergent challenges between people and their interactions with the environment

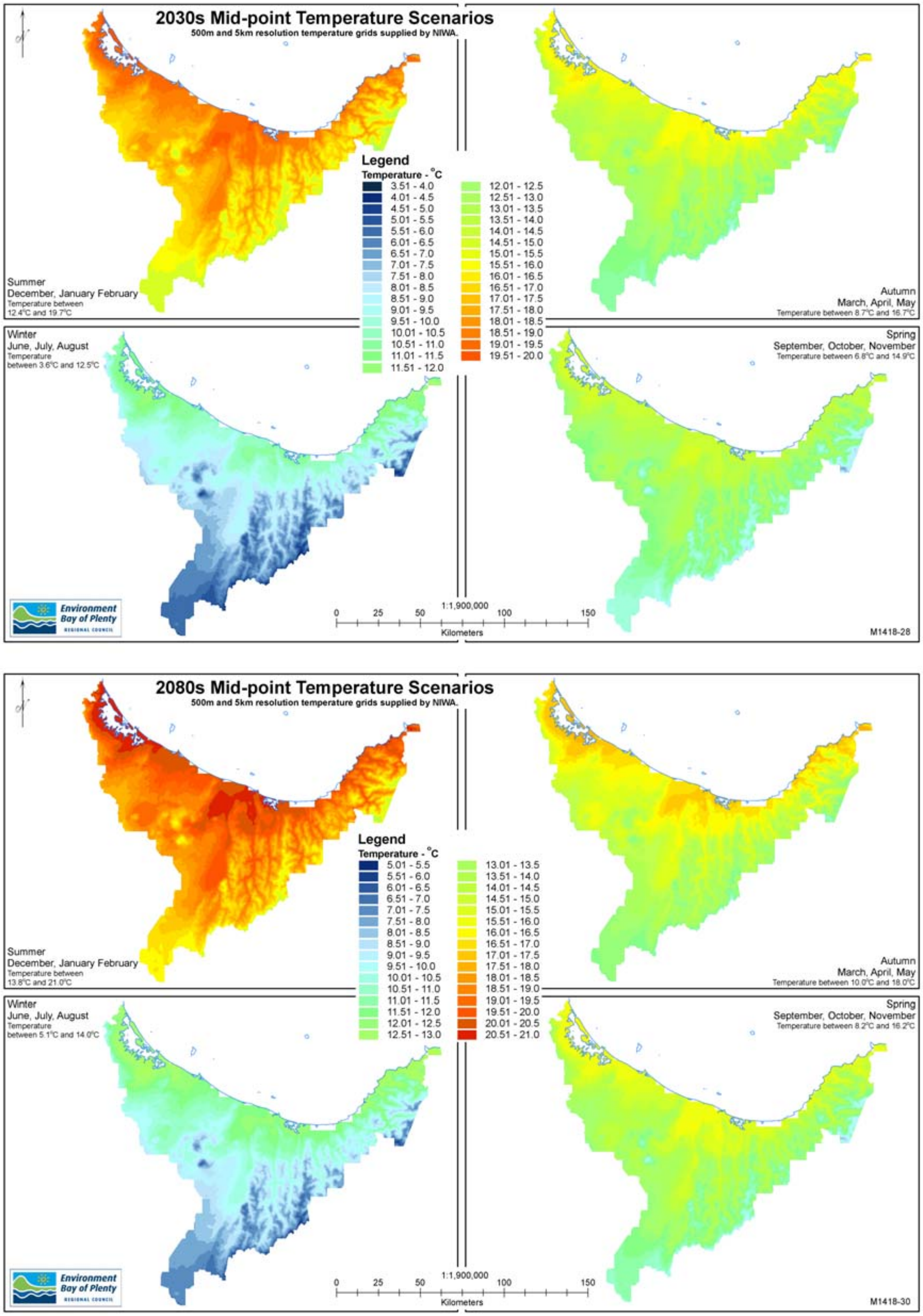
Some challenges relating to different points of view that were identified from early discussions and interviews are summarised below.

1) Does there need to be a shift in approach for the management of weeds, with the potential for climate change, along with other pressures (population increase and spread), to considerably exacerbate existing problems? The Environment Bay of Plenty approach to weed control has created tensions in some areas, particularly with farmers. While this tension appears, superficially, to relate to the proliferation of certain weed species it is actually related more to the management of weeds in general along roadsides, railway corridors and other 'wasteland' areas. Along with waterways, these will be avenues for rapid spread of existing and potentially new plant pests. This is not to forget the role of people as many new infestations originate from urban and rural residences.

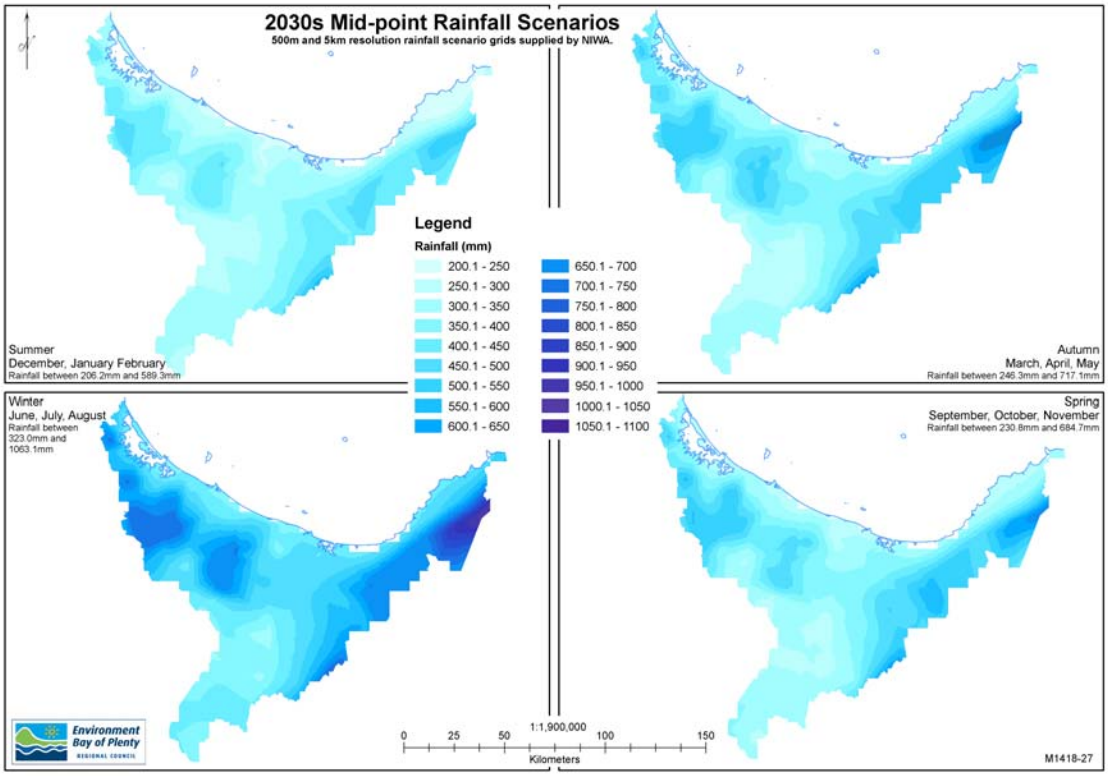
2) There are tensions between the natural workings of nature and people. A good example is the spread and growth of mangroves. Both Māori and Pakeha see potential losses with these and are working to remove mangroves and contain their spread. But do we understand enough about what nature may be providing us with as long-term gains, particularly when considering the potential for sea-level rise? There is increasing awareness, at least locally, that increases in mangroves are simply an indicator of sediment (and nutrient) outputs from the relevant catchment(s). Changes in mangroves are also related to climate change so it is an increasingly complex picture.

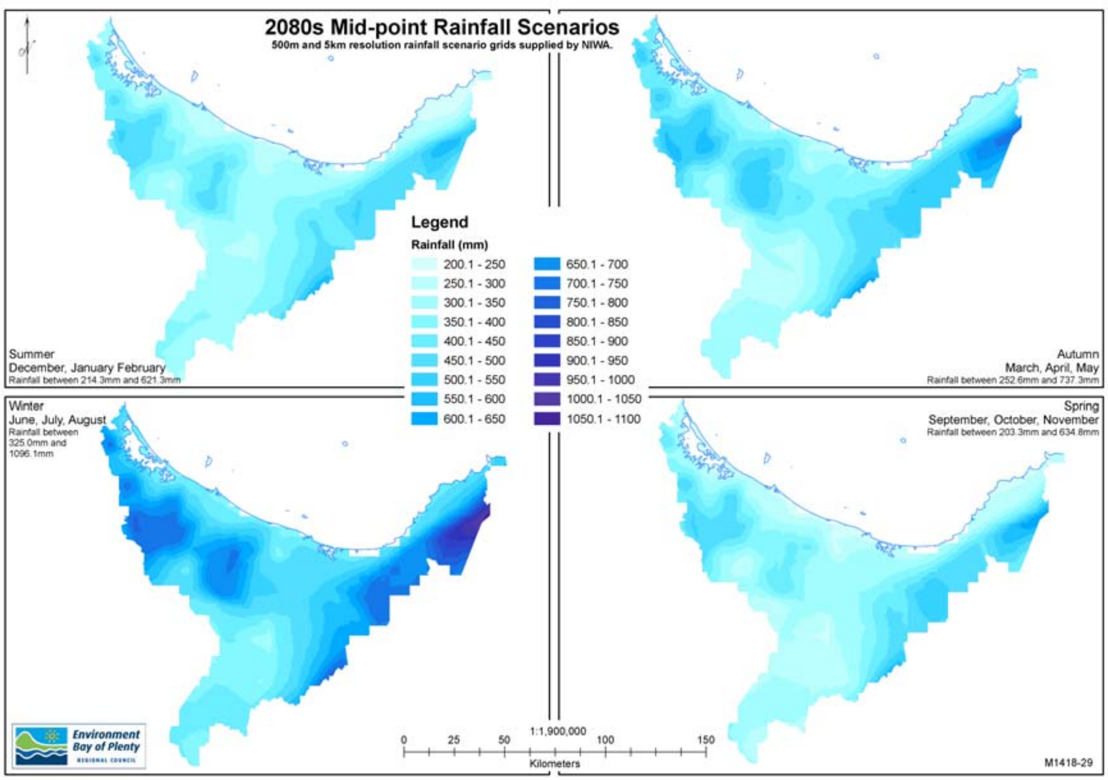
3) There are tensions and challenges with intensive land uses in some areas, the need to protect native forest and the aggressive nature of many introduced plants and animals. These tensions and challenges will increase, potentially quite rapidly, over coming decades. This will arise from the potential for climate change to increase pressure from certain introduced weeds, to bring about unknown changes to native plants and animals, and to lead to changes in the coastal environment as well as to lakes and rivers (will parts of the Rangitaiki Plain become wetland again?).

Appendix 2 – Additional maps

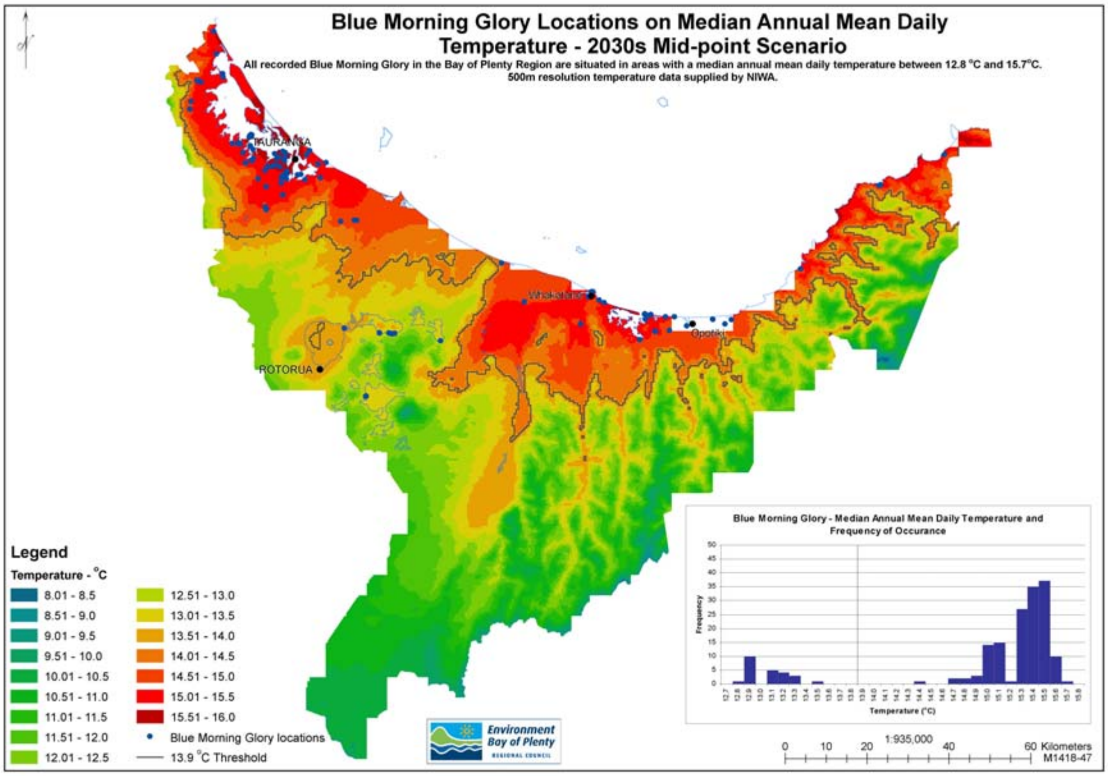


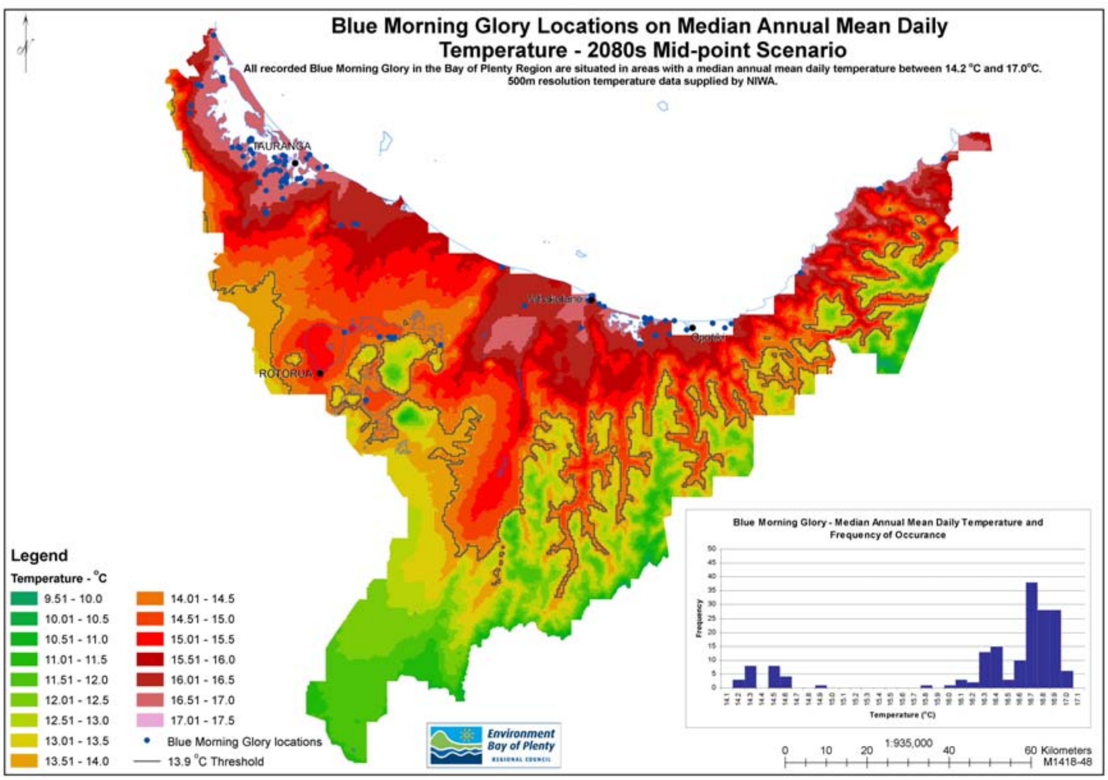
Figures A2-1: Seasonal temperatures, adjusted by future scenario values, for the 2030s and 2080s. Climate data courtesy of NIWA.



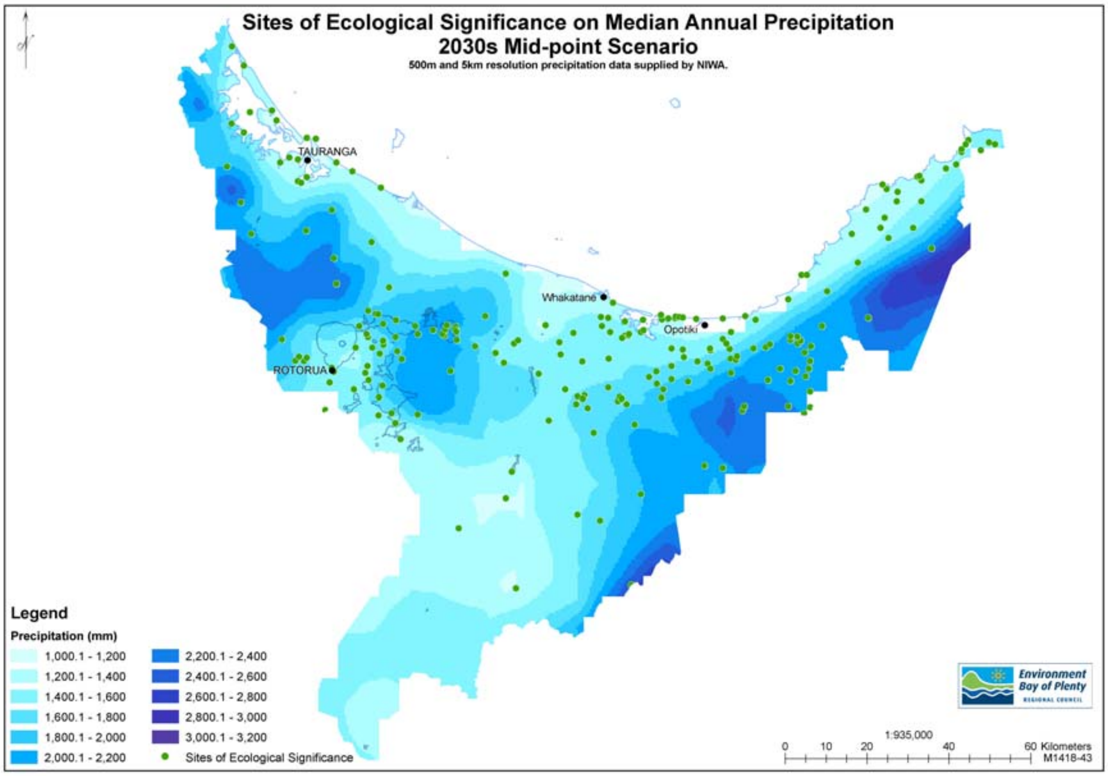


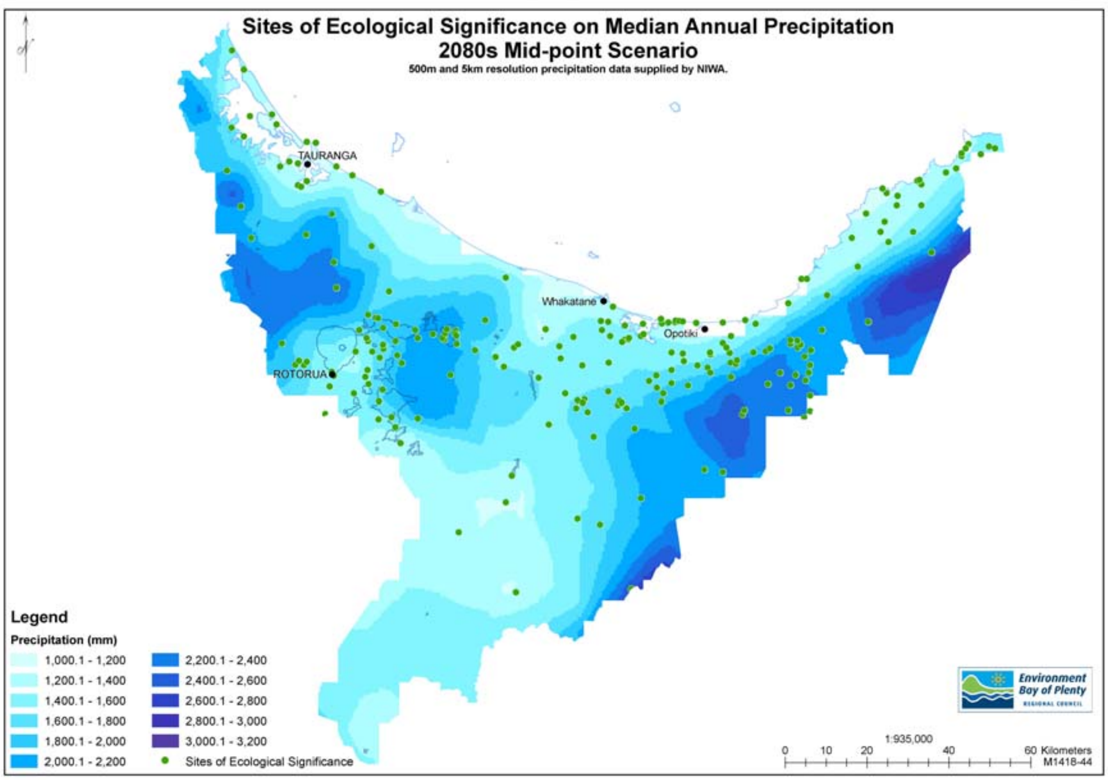
Figures A2-2: Seasonal rainfall, adjusted by future scenario values, for the 2030s and 2080s. Climate data courtesy of NIWA.



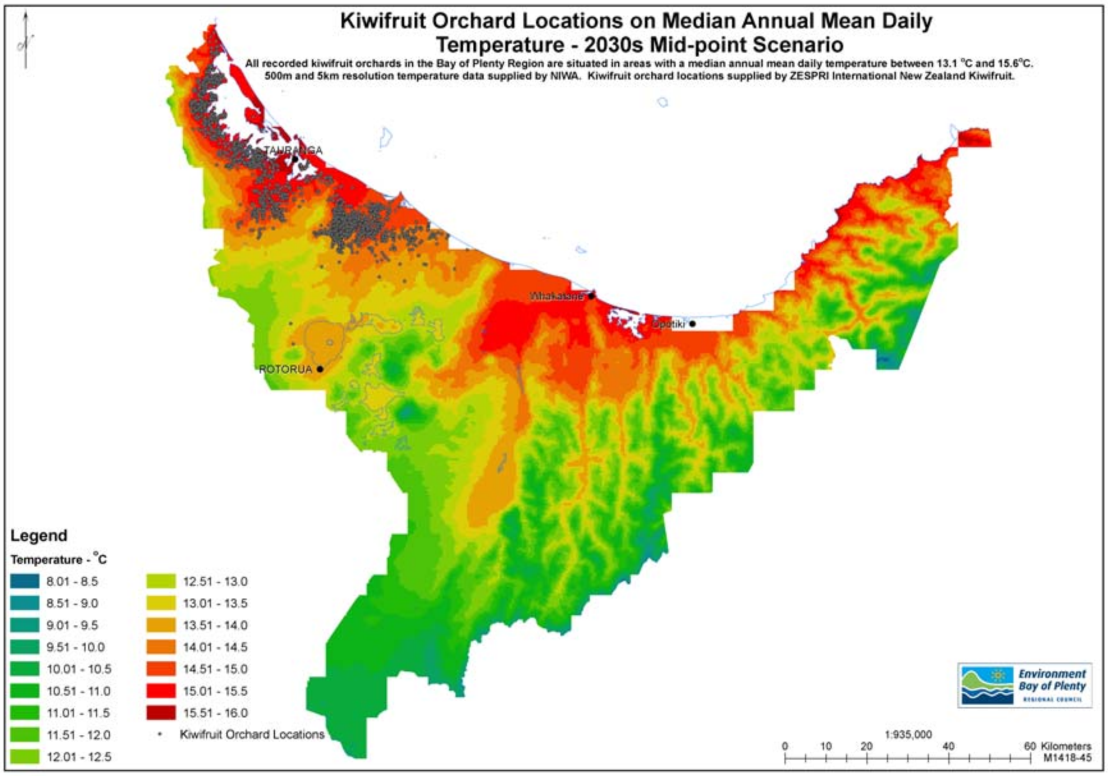


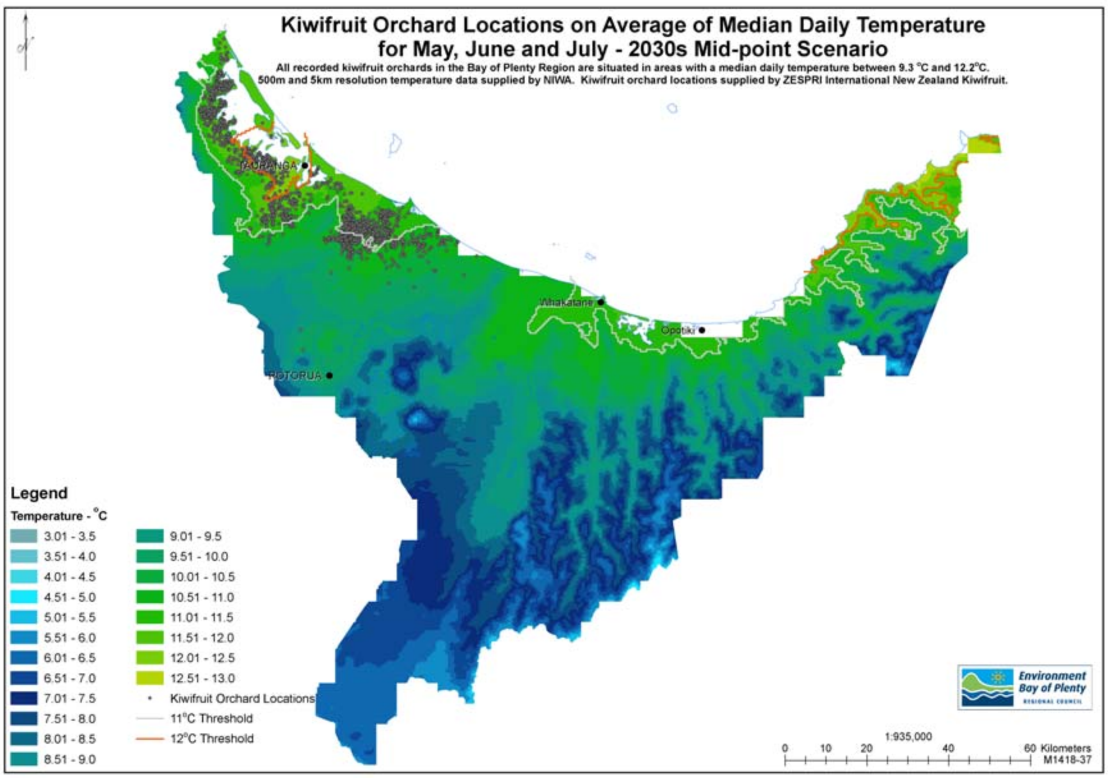
Figures A2-3: Observed locations of blue morning glory and shifts in the 13.9˚C threshold line for the 2030s and 2080s. Climate data courtesy of NIWA.



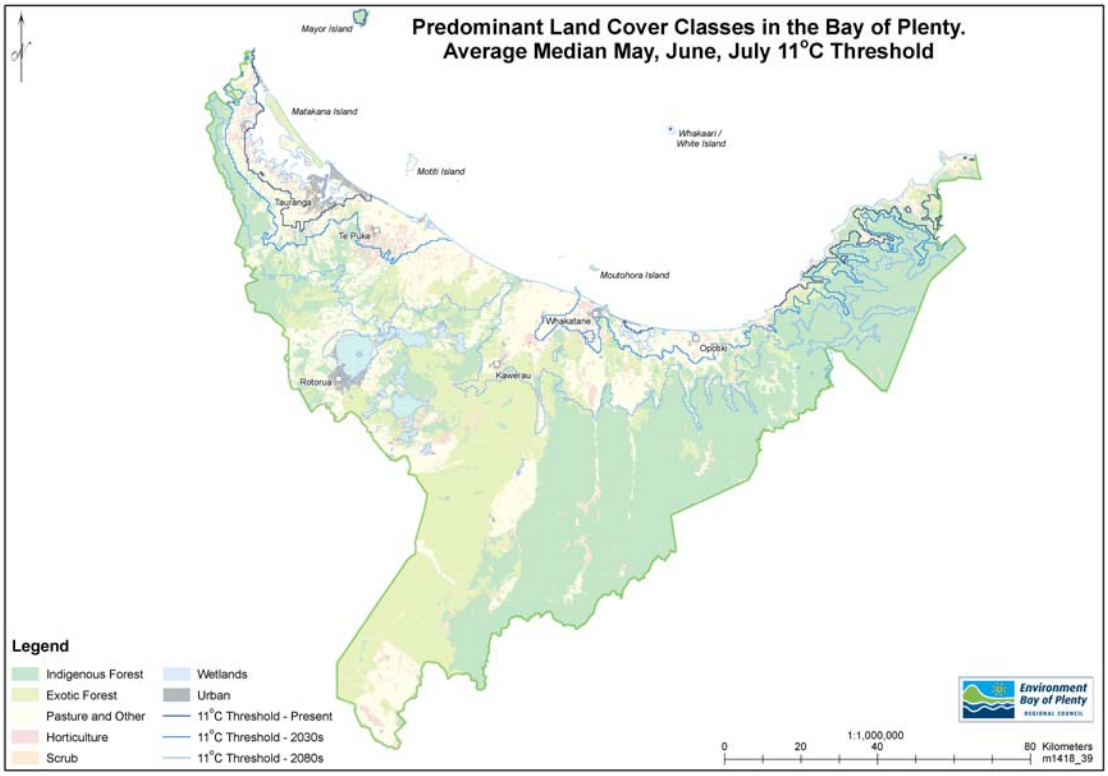


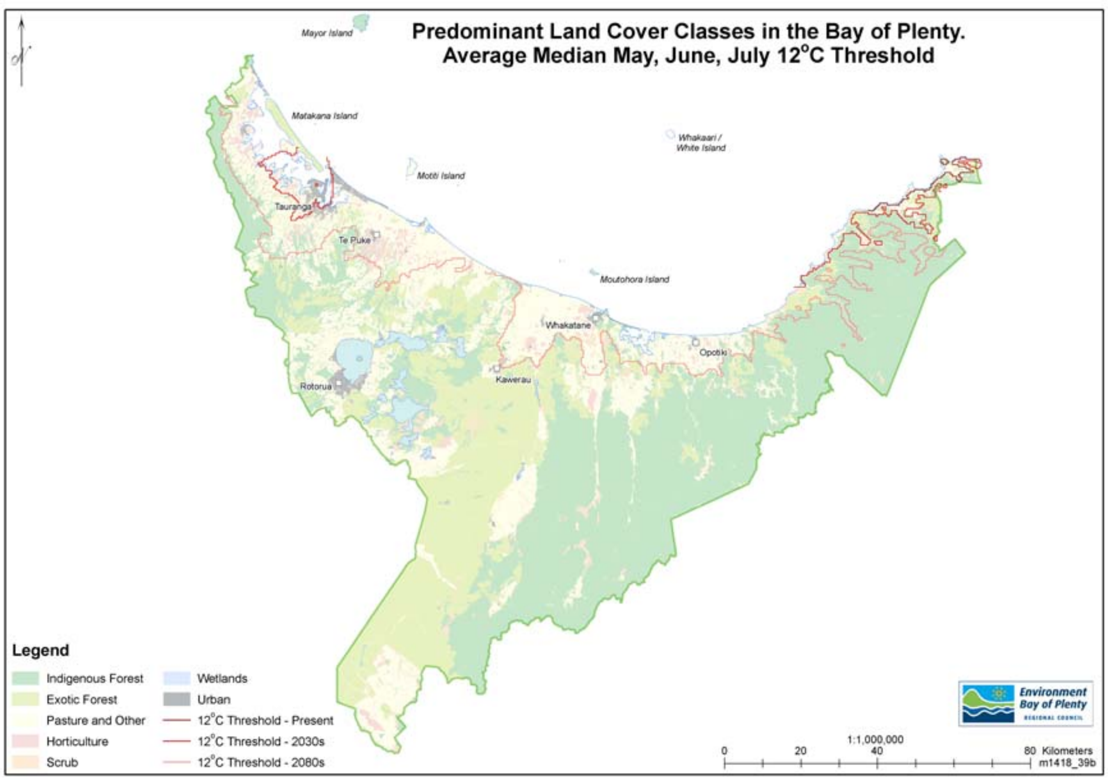
Figures A2-4: Changes in rainfall in relation to identified sites of ecological significance. Climate data courtesy of NIWA.





Figures A2-5: Changes in annual and May-July temperature and potential shifts in areas suitable for Hayward kiwifruit, 2030s. Climate data courtesy of NIWA. Kiwifruit orchard locations courtesy of ZESPRI International.





Figures A2-6: Shifts in 11˚C and 12˚C threshold lines for Hayward kiwifruit in relation to present predominant land cover classes.

Appendix 3 – CLIMEX

The following is summary information about CLIMEX obtained from the CSIRO website (www.ento.csiro.au/climex/climex.html). CLIMEX is a software tool for predicting the potential distribution and relative abundance of species in relation to climate. It is used widely to examine the distribution of insects, plants, pathogens and vertebrates for a variety of purposes, including biogeography, quarantine, biological control and impacts of changes in climate and climate variability. This program was developed by CSIRO Entomology in 1985 and has had numerous successful applications under practical conditions.

Further information on CLIMEX, including a comprehensive bibliography, can be found at the website given above. Within New Zealand there are a few people who have expertise with this tool. Two people identified through this project are Darren Kriticos from ENSIS and Andrea Stephens from HortResearch, who are both involved in the Better Border Biosecurity research programme, funded by FRST.

Thoughts from Darren Kriticos, ENSIS

CLIMEX ideally needs someone with ecological skill/knowledge to interpret information. It takes one week to generate output for a species, although this could be reduced to a few days. If you took a more national approach you could cover many of the principal species of interest and concern in one hit.

The process of generating output from CLIMEX for a particular species involves:

- Engaging a research assistant to collate relevant literature, principally from web sources.
- Using a technical person to run CLIMEX and generate results.
- Using ecological expertise to interpret results.

Through a combination of expert knowledge, reviewing literature, and applying CLIMEX the main biosecurity threats to the Bay of Plenty region, with climate change, could be identified more clearly. This would involve identification and mapping of:

- Presently marginal species that could become more prevalent
- Present problems that could become worse
- Species that are likely to diminish
- Species that are insensitive to changing conditions

Climate data required to run CLIMEX are long-term monthly averages of Tmin, Tmax, Precip, Relative Humidity 9am and 3pm.

HortResearch's CLIMEX work, a summary provided by Andrea Stephens

HortResearch has been developing expertise in CLIMEX and the sister CSIRO population modelling package, DYMEX, for approximately five years. HortResearch's interest is primarily biosecurity driven, with an entomological focus. We would like to better understand the likelihood of establishment of insect pests in New Zealand, particularly the horticultural regions (eg, Bay of Plenty, Hawke's Bay).

Current research focuses on fruit flies (Diptera: Tephritidae), which are major pests of a variety of fruit crops throughout the world. We would like to have a better understanding of which of the fruit fly species have the greatest likelihood of establishment so that biosecurity systems can be better focussed onto the species which represent the greatest threat. A paper outlining the threat of Oriental fruit fly is in preparation with Darren Kriticos (ENSIS).

Previous research has focussed on a wide range of potential and actual pests. Three papers have been produced exploring the likelihood of establishment and potential population dynamics of *Thrips palmi* and the potential distribution of Argentine ants (see publication list below). In addition, a number of internal reports have been produced, developing skills and expertise.

Publication list:

Charles J.G., D.M. Suckling, D.J. Allan, K.J. Froud, P.R. Dentener, P.G. Connolly and H. Verberne 2002: The distribution of Argentine ants in New Zealand: can a ten year old decision not to eradicate be revisited? *In* Defending the Green Oasis: New Zealand biosecurity and science, S.L. Goldson and D.M. Suckling (eds). New Zealand Plant Protection Society Inc.

Dentener P.R., D.C. Whiting and P.G. Connolly 2002: *Thrips palmi* Karny (Thysanoptera: Thripidae): could it survive in New Zealand? New Zealand Plant Protection 55:18-24.

Stephens, A.E.A. and P.R. Dentener, 2005: *Thrips palmi:* population growth & survival in New Zealand. New Zealand Plant Protection 58: 24-30

Appendix 4 – Current pest plants

The following is a brief summary of origin, preferred habitat and threat for some of the classified pest plants in the Bay of Plenty. This information was mostly drawn from information found on the Auckland Regional Council website.

Total control pest plants

Weed	Country of origin	Habitat	Threat	Year introduced or first recorded in the wild
African feather grass	Southern Africa	Prefers damp situations but infestations may also occur on dry and sandy banks, with established plants being drought resistant.	A threat to pasture production and has the potential to become a major weed of roadsides, wasteland and urban amenity areas.	1890s
Senegal tea	Central and southern America (Mexico to Argentina)	Found in warm temperate regions, although it appears to be tolerant of frost in New Zealand conditions.	A semi-aquatic plant that is a threat to waterways.	Introduced in 1970s, first recorded as a naturalised plant in late 1990.
White-edged nightshade	North Africa	Mostly found in warm, sunny situations in higher rainfall areas.	A threat to pasture production on marginal land and also has the potential to become a problem on forest margins	Introduced in the 1880s and report wild by 1883.

Progressive control pests

Weed	Country of origin	Habitat	Threat	Year introduced or first recorded in the wild
Banana passionfruit	Tropical South America		Native forest, forest margins, horticultural	First recorded in the wild in 1958.

			areas, shelter belts.	
Bushy asparagus	South Africa	A shade loving species. Prefers sandy or poorly structured, low fertility, soils.	A threat to native forest and coastal areas.	First recorded in the wild in 1976.
Cathedral bells	Central and South America	Susceptible to frost and heavy shade, but flourishes in Bay of Plenty.	Has the potential to become a major weed in native forests and a wide range of other habitats.	First recorded in the wild in 1946.
Climbing spindle berry	Japan, Korea and northern China		A serious threat to native forest and forestry plantations.	First recorded in the wild in 1981.
Lantana	Tropical America	Moderately tolerant of frost, wet and shade, but prefers drier conditions.	Extremely competitive in a wide variety of habitats, including forest margins, coastal areas, shrublands, wasteland, exotic plantations, gardens and on offshore islands.	First recorded in the wild in 1912.
Old man's beard	Europe	Widespread in New Zealand.	A serious threat to native bush.	First recorded in the wild in the mid 1930s.
Wild ginger	Kahili ginger is a native of India, found on the lower slopes of the Himilayas. Yellow ginger is a native of eastern India and Madagascar.	Prefer open, well lit sites with good moisture and warmth. Will show under forest canopies.	Primarily a threat to native forest.	Officially recorded as growing wild in the 1940s

Woolly nightshade	Brazil and Uruguay	Frost sensitive. Prefers a sub-tropical climate.	An invader of pastoral, wasteland and forest margins. Short-lived in regenerating bush areas.	Recorded growing wild as far back as 1883

Surveillance pests

Weed	Country of origin	Habitat	Threat	Year introduced or first recorded in the wild
Blue morning glory	Tropical Pacific and the Americas	Grows well in subtropical and temperate areas, but frost sensitive.	Highly invasive of forest areas and wasteland.	First recorded in the wild in 1950.
Climbing asparagus	South Africa	Tolerant of shade but dislikes dry and poorly drained soils.	A threat to all types of forest.	First recorded in the wild in 1959.
Houttuynia	Eastern Asia.	Preferred habitats are moist, loamy forest soils, wetlands and stream margins.	A threat to native forest and wetland areas.	A recent introduction.
Italian buckthorn	Mediterranean	Prefers a Mediterranean type climate, and thrives in coastal areas.	A threat to coastal areas and all types of forest.	First recorded in the wild in 1930.
Mignonette vine	South America	Generally prefers fertile soils in warm, moist climates.	A potential threat to disturbed forest, forest margins, open areas, amenity areas, gardens, orchards	First recorded in the wild in 1940.
Mist flower	Mexico and the West Indies	Prefers warm, wet conditions and semi-shaded areas.	Found in forest margins, stream banks, wetland areas and poorly managed pasture.	First recorded in the Waitakere Ranges in 1913 and urban Auckland in

				1945.
Moth plant	Argentina and Brazil	Prefers loose, fertile soils in moderate to high rainfall areas.	A threat to disturbed or low native forest, forest margins, coastal areas and urban areas.	First introduced in the 1880s
Pampas	South America (Argentina, Brazil, Ecuador, Peru)	A versatile plant that is tolerant of shade, frosts, poor drainage and wet soils.	Invasive in exotic pine plantations. A threat to coastal ecosystems and wetland areas.	First introduced in the late 19th century and well established north of Wellington by 1925.
Parrots feather	South America, now widespread around the world	Prefers nitrogen rich water and temperatures from 8 to 30˚C	Waterways.	First recorded in the wild in 1929.

Appendix 5 – An article prepared for the March 2006 issue of the Journal of Primary Industry Management

Adaptation, change management and the psychology of change
Dr Gavin Kenny, Earthwise Consulting Ltd

What do you know about climate change impacts and adaptation? You'll have heard and read a lot recently about measures to reduce greenhouse gas emissions (mitigation). But what about the effects climate change might have on you and your livelihood and what you do to deal with this? As a very brief summary, over the next 100 years we can expect average temperature to increase throughout New Zealand, with a trend to decreased rainfall in the east and increased rainfall in the west. Extreme weather events could possibly become more common over time. Higher winter temperatures could extend growing seasons and reduce frost risk but also encourage spread and increased incidence of pests and diseases. Drought risk is likely to increase considerably in the east, based on a recent study by NIWA, with increased pressure on increasingly limited water supplies and challenges to sustainable land management. There will continue to be good and bad years. However, the signs are that we are faced with increasingly rapid change (not just climate change). It makes good business sense to be smart and proactive in addressing change so that we can deal with the multiple challenges that are ahead in ways that are beneficial to our economy, society and to the environment. What we do to deal with climate change and how we go about it is called adaptation. This article focuses mostly on how we might go about getting people thinking about and acting on adaptation and the very important role that our forward-acting farmers and the rural community in general have to play.

Climate change doesn't mean 'Change or die', the title of an article referred to later in this discussion, although some well-respected commentators believe that this is exactly what it means. However, we do need to change our thinking and what we are doing if we are going to deal effectively with the multiple challenges and changes that the future will provide. The following is a presentation of my evolving thinking on how we might positively and proactively adapt to a future with climate change. We all need to be thinking, discussing and acting on this a lot more than we presently are.

I've been working as a climate change scientist since the beginning of the 1990s, with an interest in this topic and agricultural ecology extending back another decade to my early years at Massey University. For much of that time I've had my own struggles with the climate change issue. Often my work seemed to be removed from the reality of people's daily lives. This was brought home to me in 1991. I was working with the newly formed Environmental Change Institute at Oxford University, managing a European Union project on the impacts of climate change on agriculture. One day a local farmer walked through the door, curious to learn what sort of work we were doing. I took the time to show him the nice colourful maps we were producing, showing where maize might be growing in future and where water may be a limiting factor to its production. It was interesting work, but I struggled to bridge the gap between the science and the day to day life of this farmer.

This encounter challenged me to strive to bridge this gap. I'm still working on it. Despite the enormous amount of work done by scientists around the world there is still scepticism among many, or at the very least a general attitude that there are more immediate issues for concern and we'll deal with climate change when it comes.

How long do we wait before we act? Yes, we're talking a lot about our obligations under the Kyoto protocol and what we need to be doing to address them, and considerable funding is going in this direction. But have we got it right? I don't believe we have. It concerns me that we appear to be fixated on discussions about mitigation activities while we completely lack a clear, well coordinated, focus on how we prepare ourselves for a future with climate change. We need to be acting a lot more on adaptation. In fact I believe that adaptation ought to be our principal priority with a broadened focus that encompasses mitigation measures. My argument for this is simple. Climate variability already has a huge impact on our environment, our lives and our livelihoods. These costs could increase significantly if we are not smart and proactive in preparing for climate change. Even if you're sceptical, let's be smart anyway and do things that will be beneficial even if the worst effects don't arise. Along the way let's build in sensible and workable mitigation solutions. For example, we need to be planting trees for catchment protection and other multiple benefits, with carbon sinks as a mitigation outcome (creation of carbon sinks) not the other way around.

Learning from farmers

This need for a stronger focus on adaptation, at a practical grassroots level, was one of my motivations for resigning from a secure research position five years ago and becoming independent. I got myself out on the ground and started talking to farmers, initially in Hawke's Bay and subsequently also in Bay of Plenty, Marlborough and Canterbury. I owe a great deal to the farmers I've met over the last five years. They have helped shape my thinking and work on climate change in a way that would never have happened sitting in front of a computer screen or going to conferences. My focus was to bring together the thinking and wisdom shared with me by farmers and to weave this together with my own evolving thoughts on adaptation. This work culminated in the publication of 'Adapting to climate change in eastern New Zealand' in July 2005 (hard copies can be obtained from the author, email gavinkenny@clear.net.nz, or go to www.earthlimited.org). It was supported principally by the Sustainable Farming Fund with additional support from six other agencies – Environment Bay of Plenty, Hawke's Bay Regional Council, Environment Canterbury, Ministry for the Environment, Merino NZ Inc and AGMARDT.

Some very important messages have come out of this work. Three key ones are:

1. Smart farmers are adapting to multiple changes and challenges. They recognise that we are in a world of rapid change and that they need to be ahead of the game. Increasingly these farmers see, partly influenced by overseas markets and the changing regulatory environment, that they need to be constantly changing and adapting. Into this mix are the ever present impacts on farming of weather extremes, such as droughts and floods. Then come challenges from biosecurity threats, trends toward biodiversity protection and enhancement, pressures from spreading urban areas, increased demands for increasingly limited water. Climate change will impact on all of the above, and possibly is already beginning to have impacts. So, what do we need to be doing? **We need to be working a lot more with our smart, forward thinking and acting farmers towards shaping positive visions for the future.**

2. Despite the good work of forward-acting farmers we lack a coordinated approach to extend their work more widely and engage wider communities. There is a greater

sense of disconnection between urban and rural communities than existed in the past. I heard this from farmers during the course of my work over the last few years and then saw it reflected in the outcome of our last election. We have some huge challenges ahead of us and it is vital that we are working together to build resilient farming systems, resilient catchments, resilient communities. There are good examples around of successful interactions. As much as we need to be supporting and celebrating our forward-acting farmers we also need to be celebrating our community successes as much as possible. **We need to shift our approach from what is essentially a crisis management approach to a change management approach that engages whole communities.**

3. Adaptation to climate change should be given the highest possible priority at all levels of decision making in both the public and private sectors. As I heard someone say recently, 'if we get it right for climate change, we'll get it right for everything else'. Our primary focus needs to be to protect and enhance our environment for the benefit of all, to create resilience in the face of climate change and the multiple other forces of change that we are already having to address. If we think and plan carefully we will gain multiple benefits from such an approach, including mitigation benefits. At present we aren't making the connections and perhaps because of this we don't have an effective process for engaging people. Good communication and education are paramount. **We need a coherent, focused, and well-coordinated approach to adaptation, with well thought out mitigation measures that fit together with this. Alongside this we need to be focusing on good communication and wider education of the public.**

Are you a pessimist or an optimist?

One of our major problems at present is that we have the luxury of choice. In the words of one farmer who came to one of the adaptation workshops I ran, 'so long as we have the luxury of choice we will continue to disagree on solutions'. This can become an excuse for paralysis, along with a belief that climate change is too big an issue, or too fuzzy and far away, to deal with now. The luxury of choice offers us an opportunity to act positively and proactively. It's smart business to work in this way. But do we have the collective wisdom and will to act?

The founder of the Gaia hypothesis, James Lovelock, has a very pessimistic view about the ability of humanity to respond quickly enough to address climate change. He believes that the world has already passed the point of no return with climate change and that civilisation as we know it is unlikely to survive (see 'Humanity faces "revenge of Gaia"', The New Zealand Herald, 17/1/06). In a talk given in 2004, Lovelock presented a view that we need to make a 'well-planned sustainable retreat' from nature. He believes that agriculture is the cause of many of the problems we are facing at the global scale. I agree, we can't keep destroying the world's forests for farmland, we do have serious soil degradation and water resource problems around the world and significant losses of genetic diversity. However, I disagree on the solutions he proposes. Rather than solve problems through agriculture, Lovelock suggests that we turn our creative energies towards synthetic means of producing food and that we give nature a rest. I've seen and learnt enough from forward acting New Zealand farmers, and am aware enough of good things being done by farmers elsewhere in the world, to be encouraged that we can find solutions through agriculture. In fact, I strongly believe that our collective future is strongly dependent on our farmers and their actions. But, to go back to the key messages to emerge from the adaptation work I've done, I don't believe that these are simply physical, biological or technical solutions. And this is, perhaps, where Lovelock falls into the trap of pessimism. His Gaia hypothesis is founded on a very compelling and profound physiological view of the earth as a self-regulating organism. Lovelock has talked in great depth about the physical and biological make-up and interconnections of the earth organism. However, what is lacking is a psychological perspective. When we consider the role of people, in finding solutions to the problems we have created, this is of fundamental importance. It's what we think that matters, and then it matters a lot how we act on what we think and how we interact with others.

If we take a psychological view then we can find much greater cause for optimism. Another influential and important writer, Theodore Roszak, puts forward a view that innate in every human is what he calls an 'ecological sub-conscious', and that we need to find positive ways to awaken this in people. This might sound a bit woolly, but what it essentially means is a connection with the land. The vast majority of farmers will tell you that they care very much for the land and want to leave things in a better state for future generations. This care of the land is increasingly reflected in the number of land care, coast care and water care groups that have developed in New Zealand.

Change management and the psychology of change

So, how do we go about developing a psychological approach to addressing climate change, in particular in shaping individual and collective adaptation responses?

Through the course of my adaptation work with farmers I have used terms such as, proactive adaptation, creating resilience, change management, the psychology of change. These terms evolved out of my own thinking and the farmers I was working with. It shouldn't be a surprise to learn that the adaptation work I did with farmers is strongly mirrored in much more theoretical work being done by some climate change researchers elsewhere in the world. More recently I've found a report from a Dutch researcher who has worked with small farmers in Africa. His findings, on the adaptive capacity of the small farmers he worked with, have some strong parallels with the key messages I have learnt here in New Zealand. This has affirmed my strong belief that the way forward is to work alongside our farmers as much as we can. But how might we formalise this? The theoretical frameworks I've found lack a practical focus from my point of view, and we desperately need a practical focus to climate change.

A formal, and practical, approach to adaptation needs to draw from the three key messages identified earlier in this discussion:

1) We need to support the good work of our smart, innovative, farmers. In my work I've operated on a "5%" rule. I expect no more than 5%, possibly even less, of farmers to actively engage in discussions and workshops relating to climate change and adaptation. These are the leaders of change and we need to work with them.
2) We need to question the role that crisis has in stimulating change. Do we need crisis to change, or can we actively promote and manage change?
3) We need to be listening to each other a lot more. Everyone, meaning farmers and urban communities, needs to respect other points of view and work together for the future.

Searching the internet for information on 'change management' and the 'psychology of change' provides further valuable insights to this discussion. An on-line search under 'change management' reveals the following from Wikipedia (see http://en.wikipedia.org/wiki/Change_management):

'Change management is the process of developing a planned approach to change in an organization. Typically the objective is to maximize the collective efforts of all people involved in the change and minimize the risk of failure in implementing the change. The discipline of change management deals primarily with the human aspect of change, and is therefore related to pure and industrial psychology.'

This article further identifies two types of change management: reactive change which is in response to changes in the macroenvironment, and proactive change in which case the source of change is internal. With climate change we presently have choice as to whether we 'wait and see' and adapt reactively or begin acting now and adapt proactively. We may not have such luxury of choice in the future. The key to proactive adaptation is that internal change is needed. We all need to change how we think if we're going to be serious about addressing climate change. That's a big challenge.

Further exploration led to a recent issue of an on-line business journal called FastCompany (see www.fastcompany.com, Issue 94), with two relevant articles titled 'Change or Die' and 'The Case for Change'.

In his editorial letter on 'The Case for Change', John Byrne comments that *'the odds of making lasting changes are almost always against us -- even when our very lives are at stake. That troubling fact only underscores the difficulty of altering the culture or direction of an enterprise populated by thousands of different people with different agendas.'*

If we extrapolate these views to the scale of a global issue such as climate change it is not hard to imagine why adaptation has tended to sit on the sidelines. If making lasting change is such a challenge for an enterprise of thousands, how can we bring it about for whole communities (rural and urban) in New Zealand and elsewhere in the world? Byrne's letter and the related article on 'Change or Die' by Alan Deutschman, don't leave us without hope. In answering his own question 'so how do we shift the odds in our favour?' Byrne summarises the important insights shared by Deutschman, as follows:

- *'Real change isn't motivated by either crisis or fear. The best inspiration comes from leaders who can create compelling and positive visions of the future.*
- *Small, gradual changes rarely lead to transformation. Radical, sweeping changes are riskier but often more effective, because they quickly yield benefits visible to everyone.*
- *Narratives, not facts, guide our thinking. Data on declining market share or quality problems won't get employees to change what they do. Rather, appeals rooted in emotion are what best inspire people to alter course.'*

Deutschman also provides evidence, through a narrative on treatment of heart disease patients, that the most effective change comes about when people are actively supported in the change process.

So, there is some good information out there that we can draw on. The challenge we have is to do something about the future in the sense of adopting a 'future is now' approach. For that to happen, we need to be prepared for change and to make change management a constant in our lives and work.

By way of conclusion
I'm very grateful to the Oxford farmer who challenged me 15 years ago, and to the New Zealand farmers who have challenged me even more in recent years. Thinking about climate change and communicating it to others is not easy work. However, despite the current lack of attention to adaptation, I have an optimistic view. This view has been shaped through my interactions with forward-thinking and acting farmers. These people are providing leadership. We simply need to give wider acknowledgement to them and their work and put in place a well thought out programme for adaptation that is integrated with sensible mitigation measures. It is of fundamental importance that at the heart of such a programme is a clear and strong acknowledgement that change of any kind isn't easy for the vast majority of people. Change has to be managed, with as many people as possible engaged in shaping future visions. We have the knowledge to deal with climate change. Our present challenge is to recognise and acknowledge the importance of adaptation, and to act.

About the author
Dr Gavin Kenny has degrees in horticultural science and a PhD in agricultural meteorology. He has been involved in climate change research for the last 15 years and has worked on climate change projects in New Zealand, Europe, the Pacific Islands and Bangladesh. For the last five years he has worked independently to bring a practical focus to climate change and adaptation.