Geospatial Threat Measurement: An analysis of the threat the diatom *Didymosphenia geminata* poses to Canterbury New Zealand

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Frontispiece

In a few hundred years the natural biogeographical barriers provided by oceans, mountains, rivers and deserts, which provided the isolation essential for unique species to evolve have lost their effectiveness, the movement of organisms from one part of the world to another through trade, transport, travel and tourism has been the one critical factor (DePoorter, 2003).

Abstract

This thesis provides analysis of the threat *Didymosphenia geminata* poses to the Canterbury Conservancy of the Department of Conservation. More specifically, it examines the relationship between Values, Risk and Hazard to measure the degree of threat posed by the diatom. This is the first time this type of Threat Analysis has been applied to such a problem in this region; and so will provide an important insight into the validity of the application of this methodology to an alien invasive threat. Moreover, it is the first time Values, Risk and Hazard have been modelled together to give an over all threat classification in this context. Risk mitigation is one of the variables that can be measured, managed and priced; factoring this into the model is also discussed.

Qualitative and quantitative Values and Risk information is provided by Department of Conservation staff; some from their local knowledge and some from biodiversity datasets which have been collected over time. The Risk data is supplemented by fishing access data supplied by the two local Fish and Game Council Offices. Where available, further Values and Risk data is been gleaned from existing datasets in order to supplement the existing data. The Hazard data is taken from the work done by NIWA in 2005 and 2007; the latter being generated after field surveys were conducted on *D. geminata* infected sites in the South Island.

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List of Abbreviations

AHP	Analytical Hierarchy Process
AOG	All of Government
AWL	American Wildlands
BNZ	Biosecurity of New Zealand
BPI	Biodiversity Probability Index
DOC	Department of Conservation
DNA	Deoxyribonucleic acid
DPM	*Didymosphenia geminata* Predictive Model
ERA	Ecosystem Restoration Analysis
ERI	Ecological Risk Index
ES	Expert Systems
ESRI	Environmental Systems Research Institute
GAP	Gap Analysis Project
GARP	Genetic Algorithm for Rule-Set Prediction
GIS	Geographic Information Systems
EGW	Erythrina Gall Wasp
FWENZ	Freshwater Environments New Zealand
IRA	Integrated Risk Assessment
LCDB	Land Cover Data Base
LCDB2	Land Cover Data Base 2
LEM	Likely Environment Model
LENZ	Land Environments New Zealand
LINZ	Land Information New Zealand
LRI	Land Resource Inventory
MAF	Ministry of Agricultural and Forestry
MCA	Multi Criteria Analysis
MCV	Multispecies Conservation Values
NIWA	National Institute of Water and Atmospheric Research
QEII	Queen Elizabeth the Second
REC	River Environment Classification

ROS	Recreation Opportunity Spectrum
SDSS	Spatial Decision Support System
SSWI	Sites of Significant Wildlife Interest
TA	Territorial Authority
TIM	Threat Identification Model
USA	United States of America
WERI	Wetlands of Ecological and Representative Importance
WONI	Waters of National Importance
WTA	Wildfire Threat Analysis

Chapter One: Introduction

1.1: Context

For many years the focus of protecting representative habitats in New Zealand has been on terrestrial environments. With the advent of an alien invasion of fresh waterways, it has become obvious that not only do we not know which rivers are more important than others; we do not know what the likelihood is that the current invasive threat will be able to invade these important areas. In short, we do not have our rivers classified or ranked for importance nor do we have any way of analysing the threat to them.

The purpose of this Thesis is to research and develop a Geographic Information System (GIS) based Threat Analysis Model. This Model will identify values including biological, recreational, and cultural Values. This Thesis will also identify sites at risk from *Didymosphenia geminata* invasion and sites able to sustain *D. geminata*, and thus analyse the threat *D. geminata* poses in the Department of Conservation (DOC) Canterbury Conservancy. If this Threat Analysis proves successful then the question of whether a system of threat mitigation is able to be factored in and analysed in this context will also be examined.

D. geminata is a diatom; a type of single celled algae which we have little understanding of in terms of its biological and ecological roles. The diatom was first described from the Faroe Islands north of Scotland by Cleve between 1894 and 1896 and is common in Scotland, Sweden and Finland (Spaulding & Elwell, 2007).

GIS offers so much in terms of analysis and predictive modelling. Provided appropriate spatial data can be obtained, the use of GIS should enable rivers to be classified and their susceptibility to threats like *D. geminata* invasion to be quantified. Unless the true extent and value of these areas is known, then a part or all of them could potentially be lost. Without a classification there can be no strategy to combat the potential loss of uncontaminated waterways to future generations. Hoban (2007) talks of death (of waterways) by *D. geminata* with the movement of the diatom being largely systematic but also in some cases disturbingly unpredictable; working its way through neighbouring rivers in Southland then appearing in the Buller River far from its initial site. Hayes (2006) claims *D. geminata,* without control, threatens to impact on New Zealand's $145-230 million angling industry.

This Thesis involves developing and running a series of GIS models designed to rank river Values, Risk and Hazard. Values are determined by ranking all the aspects of a waterway that make it important. Risk is measured by factoring in the activities which are likely to introduce the diatom *D. geminata* to a waterway. The Hazard component is about how well the diatom will survive should it get to a waterway, the Hazard component of this Threat Analysis Model is filled by Kilroy et al. (2007) and their habitat suitability prediction as this was developed for *D. geminata*. These three components or Models; Values, Risk and Hazard, are then combined to quantify Threat in relation to a site, factor in Threat mitigation and project the overall effect.

Within a few hundred years the natural biogeographical barriers provided by oceans, mountains, rivers, and deserts have lost their effectiveness in providing the isolation essential for unique species to evolve. The movement of organisms from one part of the world to another through trade, transport, travel, and tourism has been the one critical factor in loss of effectiveness of these barriers (DePoorter, 2003). In the case of *D. geminata* the most likely reason for its initial introduction into New Zealand was foreign recreational fishers. There are other theories as to its introduction, though, Henzell (2007) cites MAF Biosecurity New Zealand as stating that *D. geminata* DNA analysis results point to the North American population as the likely source of the introduction of *D. geminata* into New Zealand.

1.2: The International Experience with *Didymosphenia geminata*

Over the past twenty years, the distribution of *D. geminata* has been gradually expanding outside its native range; and the diatom's growth rates have increased in its native range where previously it had been in low concentrations (Spaulding & Elwell, 2007).

In August 2007, an international workshop on *D. geminata* was held in Montreal and participants came from Europe, North America, Iceland and New Zealand to share experiences of the impact of the *D. geminata* incursion.

Kawecka and Sanecki (2003), who discuss *D. geminata* in Poland have found the diatom to have changed habitat; with it disappearing from one river system and establishing in another system of a different type. This has lead to the conclusion that *D. geminata* has a wider capacity for adaptation than previously thought.

In the United States of America (USA) climatic factors (seasonal mean temperature, precipitation) and hydrological factors (river flows) largely explain current distributions of the diatom. With climate change the expectation is that warmer climate and increased drought conditions in the western USA will cause the diatoms range to expand; the expansion will be aided by humans through physical transport of it (Spaulding & Elwell, 2007).

Vancouver Island in British Columbia, Canada has been infected with *D. Geminata.* There is discussion in British Columbia on the impact that raising nutrient levels has on the density of the infestation, and the observation that low nutrient levels are correlated with high density of *D. geminata* (Elwell, 2007). Kirkwood et al. (2007) discusses *D. geminata* distribution and bloom formation along the south-eastern slopes of the Canadian Rockies. They have found, in relation to river flow rates, the diatom have a preference for lower more regulated flow rates.

Australia has imposed fishing equipment cleaning regulations at their international borders with Tasmania. They are also watching closely across the Tasman Sea for potential ramifications of mass infections in New Zealand (MAF BNZ, 2008). This is because Tasmania is a well recognised fishing destination with similar fresh water habitats to South Island New Zealand.When *D. geminata* was first reported in New Zealand in 2004 very little work had been done on its biology, ecology, impacts, surveillance methods and control methods internationally. This has meant that the work being done in New Zealand has made us a world authority on this diatom.

The worldwide distribution of *D. geminata* was presented in Spalding and Elwell's (2007) White Paper on the spread of the diatom in 2007 (Figure 1.1). In their paper New Zealand was the only Southern hemisphere country confirmed as having *D. geminata* present.

Figure 1.1: Confirmed presence and published records of *D. geminata* from around the world. Dots do not represent number of reports, but show rough geographic area of populations (Spaulding & Elwell, 2007, p9).

Spaulding and Elwell (2007) also modelled suitable stream habitats based on the environmental conditions of known occurrences of the diatom. Figure 1.2 demonstrates that there is reason for concern in the Southern Hemisphere. The modelled results in Figure 1.2 present a very different picture from the historical accounts of *D. geminata* in the United States of America.

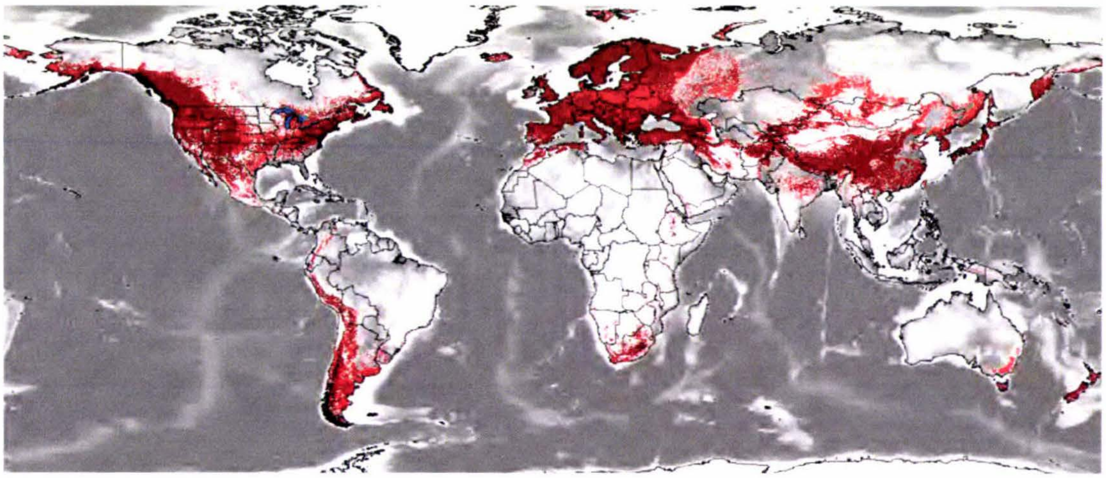

Figure 1.2: Map of the world showing regions where suitable stream habitats for *D. geminata* are located. Results for Australia are preliminary. (Spaulding & Elwell, 2007, p11).

Note the appearance of most of New Zealand as having suitable stream habitats for the diatom (Figure 1.2). However, international experience with *D. geminata* is that it is found in the cool temperate regions of the Northern Hemisphere, which includes the rivers of northern forests and alpine regions of Europe, Asia, and parts of North America.

1.3: The Study Area

The study area of this Thesis is the New Zealand DOC's Canterbury Conservancy which lies within the zone of mid-latitudes, extending from about 42 degrees 04 minutes North to 44 degrees 55 minutes South. It covers an area from the Southern Alps in the West to the Pacific Ocean in the East and from the Conway River in the North to the Waitaki River in the South (Figure 1.3).

Figure 1.3: Canterbury Conservancy in relation to New Zealand.

The total Canterbury Conservancy land area encompasses approximately 4.2 million hectares and around 77,000 kilometres of water courses. The Canterbury Conservancy is split into five administrative areas (Figure 1.4). These administrative areas are the operational arm of the department.

The key study area authorities include regional Fish and Game Councils (both North Canterbury and Central South Island), ECan, and MAF Biosecurity New Zealand, Territorial Local Authorities, local IWI as well as the Department of Conservation.

The Canterbury Conservancy includes some of New Zealand's premier fishing rivers as well as some of its least modified freshwater systems. The Canterbury rivers are currently under threat from dairy farming as well as potentially from *D. geminata.*

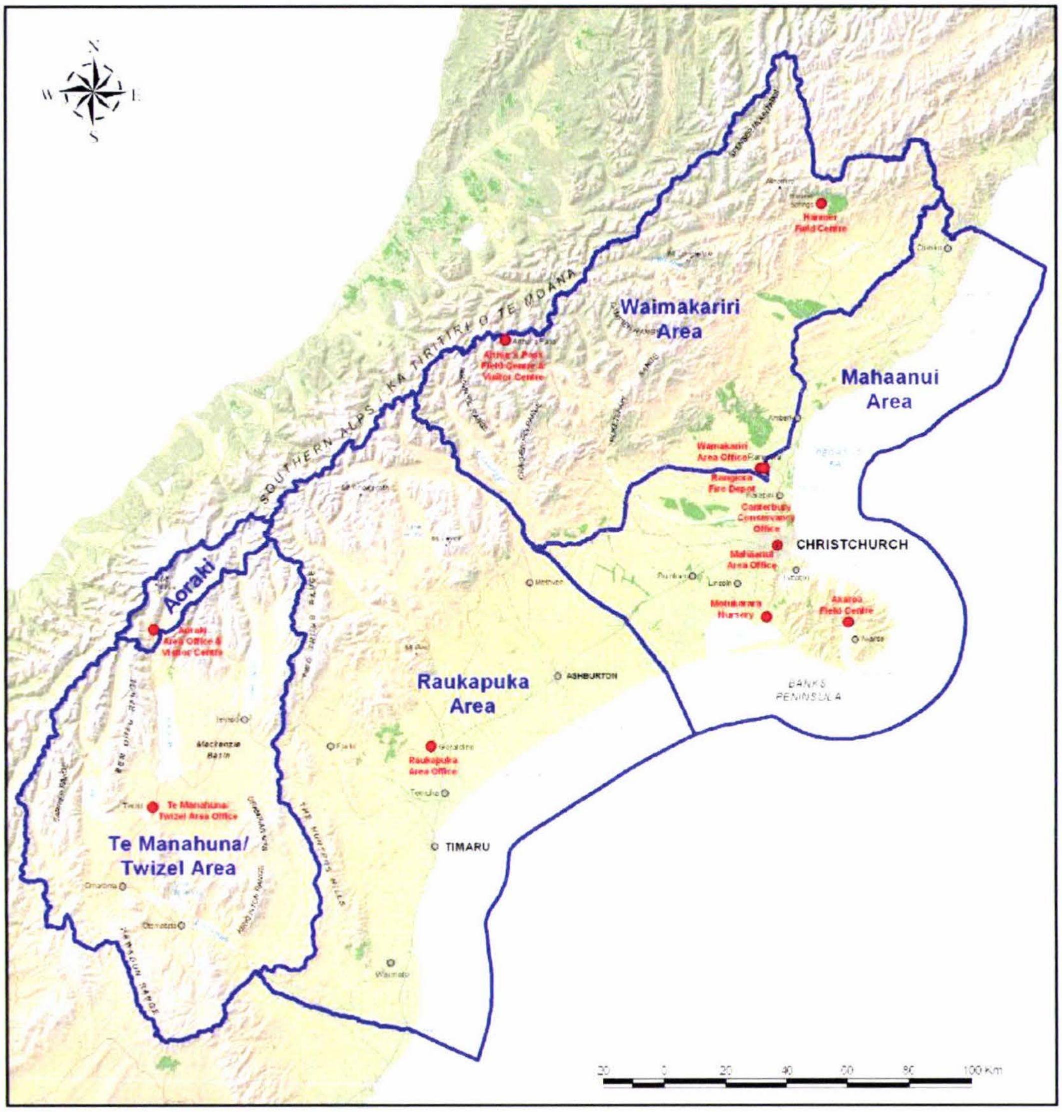

Figure 1.4: Map of the study area showing the boundary of the Canterbury Conservancy and the area boundaries that fall within that.

These rivers cover a wide variety of types; spring fed, lake fed, and general catchment fed which rely on precipitation or snow melt for flow. They flow through landscapes as diverse as alpine through to the Canterbury plains and coastal lands, so offer a wide range of freshwater habitats.

These rivers provide a wide range of recreation activities including fishing, rafting, kayaking, tramping, mountain biking, four wheel driving, horse trekking, sail boarding, and boating, to mention the more popular ones. This degree of activity and usage increases the potential risk of *D. geminata* dramatically. This is particularly the case for activities where the equipment may be exposed to *D. geminata* in one river system and it is then transported to an uninfected river system with viable cells still attached. Although *D. geminata* is a microscopic organism a single drop of water has the potential to spread it and therefore recreational activities have the potential to increase the spread of the diatom which is why the 'Check, Clean, Dry' message is being promoted by the agencies charged with *D. geminata* management. Canterbury already has several catchments where *D. geminata* is present.

1.4: Research Objectives

The following are the research objectives of this Thesis:

1. Investigate the practicality of producing a GIS Model to: identify site Values; identify sites at Risk from *D. geminata* invasion; identify sites able to sustain *D. geminata*; and thus analyse the threat *D. geminata* poses in the DOC Canterbury Conservancy.
2. If it is practical to produce such a Model, then investigate if this Model could be adapted to allow threat mitigation activities to be factored in to identify the likely outcome of those activities (i.e. will it make site prioritisation and invasion control operations more timely and successful?).

3. Identify the factors that would need to be taken into account and what data sets are likely to be available for this mitigation to be taken into the analysis.

1.5: Structure of Thesis

This Thesis consists of eight chapters that are structured around the research objectives. After the introduction in Chapter One, Chapter Two will review the literature relating to modelling approaches to Values, Risk, and Hazard assessment, more specifically in relation to their impact on overall Threat Analysis.

Chapter Three will discuss the methodology used in this Thesis. It will cover how the research objectives will be achieved, the data sources used, how these data were obtained and what other data should be assessed for its contribution to identifying overall Threat. The relationship between the Values, Risk, and Hazard Models, and their impact on the Threat Analysis Model will also be discussed.

Chapter Four will highlight the many permutations to the weighting and calibrations of the factors contributing to Values, Risk, and Hazard, and the assessment of Threat arising from this. This chapter will also look at how these factors are exhibited in rivers known to be infected with *D. geminata.* It will look at what Risk factors would be the most cost effective to manage.

Chapter Five will graphically compare various factors of the Threat Analysis Model and their relationship to overall Threat, both in the Model and in reality.

Chapter Six will present the results of the Threat Analysis Model in its component parts and then as a whole.

Chapter Seven will discuss the components of the modelling exercise in relation to some of the approaches to biological threat measurement outlined in Chapter Two.

Chapter Eight will present the conclusions that can be made from the research. This chapter will also provide a critique of the research in this Thesis and discuss what other research possibilities could follow.