Protecting toad populations in agricultural areas

Constance Browne
PhD student
Department of Biological Sciences

The western toad (Bufo boreas) is one of the many amphibian species that has experienced population declines. It is the only amphibian species in Canada red listed by IUCN; this is due to dramatic declines in the USA. Suggested threats include habitat degradation, stocking of fish, species introductions, disease/pathogens, and UV radiation. Research on the status, threats, and habitat use of the western toad in Canada is necessary because currently there is not enough information to assess its vulnerability.

Toads live in agricultural areas if the essential habitat features for breeding, foraging, and hibernation are met, however, often this is not the case. If we could manage agricultural land in a manner that maintains toad populations, then potentially, huge areas of habitat could be protected/restored for this species.

Protecting toad populations has benefits for both farmers and the ecosystem. Farmers benefit because toads eat insects, such as grasshoppers; therefore, protecting toad populations may lessen dependence on chemical sprays used for insect control.

The western toad could also be used as an umbrella species for protecting biodiversity in agricultural lands. Typically, umbrella species are large mammals that often cannot survive within agricultural landscapes. The toad is an ideal species because, it requires relatively large areas (approximately 2 km) for a home range, it is sensitive to declines in ecosystem health, and requires both aquatic and terrestrial habitats.

continued page 2
What are the challenges the western toads face in agricultural landscapes? The three main challenges I see are: having suitable breeding, foraging, and hibernation sites available and within a distance they can easily travel to; being close enough to other toad populations that the site could be re-colonized in the event of a local extinction; and, increased mortality due to crop harvesting.

Two objectives of my research are to examine: habitat use of western toads throughout the breeding, foraging, and hibernation seasons; and, how toads respond to an approaching tractor.

My research from 2004/2005 has shown that western toads use relatively large areas (up to 2 km) to meet their habitat needs. Suitable breeding sites are often the limiting feature for many amphibian species; however, for western toads in Alberta, suitable hibernation sites may be the most limiting factor. Toads are not freeze tolerant like the sympatric anurans that live in the Aspen Parkland and Boreal regions of Alberta; therefore, they must find suitable hibernation sites that do not fall below zero degrees Celsius.

My results to date support this idea. In 2005 in the Boreal Forest, over half of the 17 toads I tracked from the breeding pond to hibernation site moved over 1 km to reach this site, and 13 of the 21 toads tracked to hibernation were found hibernating communally.

Agricultural areas may be particularly challenging for toads because large uniform areas do not provide the features required for all life periods. However, with the right mix of land use types, agricultural areas can support toad populations. In 2004, I radio-tracked western toads in an agricultural setting near Elk Island National Park in the Aspen Parkland region of Alberta. I captured seven toads at a breeding pond in a pasture and found that after breeding, five of the toads moved 200 to 800 m in a two day period out of the pasture site into adjacent crop fields. They remained in these crop fields for most of the summer then the remaining two (I lost five) moved into an adjacent forest and selected red squirrel tunnels for hibernation.

In 2006, I will continue my research at this agricultural site with an increased sample size of 30 to 40 toads to see if the majority of toads follow the same pattern of breeding in pasture ponds, foraging in crop fields, and hibernating in red squirrel tunnels.

Crop fields appear to be an important foraging area for western toads at the agricultural site. Toads likely select fields because the tall grasses provide more shelter than open pasture, are warmer than the forest, and possibly have more insects. However, use of crop fields does not come without risks. Two of five toads living in the crop fields were killed during harvest. Increased mortality to adult toads could be especially harmful to the population because toads are relatively long lived (approximately 10 years) and naturally have high mortality rates as young but relatively low mortality rates as adults. Therefore, even a small increase in adult mortality could greatly affect the population.

I will investigate the timing of crop field use and toad behaviour when approached by a tractor in order to make suggestions for potential modifications to harvesting to reduce toad mortalities. For example, if toads only use crop fields during certain periods of the year, then perhaps crops that are not harvested during this period could be planted at toad sites. If the harvest must be conducted during periods when toads use the fields then perhaps the methods of harvest could be adjusted to reduce mortalities. For example, if toads run from approaching vehicles then perhaps farmers could cut their fields in parallel lines chasing toads out of the field rather than in circles starting from the perimeter moving inward which might chase toads towards the center. If toads lie flat to hide from the tractor, then perhaps farmers could keep their blades set at a distance high enough from the surface to avoid hitting toads.

Western toad populations are still widespread across Alberta. If we can identify the essential habitat features and threats to this species, then we will have a unique opportunity to develop a proactive conservation strategy to protect this species in Alberta.
While exploration and production of coalbed methane accounts for close to 10% of all natural gas produced in the United States during the past 10 years, in Canada, coalbed methane (CBM) production is in its infancy.

The Canadian Association of Petroleum Producers (CAPP) estimates that over 60% of Canada's CBM resource is in Alberta. According to the Alberta Energy and Utilities Board (EUB) by 2014, 12% of Alberta's gas will be from CBM. Furthermore, according to the Canadian Association of Petroleum Producers, Canada's proven reserves of conventional gas are sitting at 56.5 trillion cubic feet.

CBM development, however, raises a number of environmental issues. Waste water is one of them. The U.S. Geological Survey (USGS) states that, “the amount of water produced from most CBM wells is relatively high compared to conventional natural gas wells because coal beds contain many fractures and pores that can contain and transmit large volumes of water.” For example, in the United States, CBM wells generate approximately 10 to 100 times more produced water than a conventional gas well. This is not completely true in Alberta, since most of the CBM developments have taken place where the wells are mainly dry. However, it is expected that the Ardley area (Scollard Formation) that will be the major focus of development in the next few years contains non-saline water. (See map)

My goal is twofold: to explain the mechanisms that the government uses to deal with the large volumes of wastewater associated with gas production; and to provide a recommendation in order to help inform AB residents about the potential water implications in the development of CBM.

Coalbed Methane is natural gas in coal. According to the Energy Utilities Board, “It consists primarily of methane; the gas we use for home heating, gas-fired electrical generation, and industrial fuel.” A more technical definition provided by the Canadian Society Unconventional Gas is: “CBM is created during coalification, the natural process that converts organic matter into coal over time. A seal created by overlying rock and/or water within the fractures of the coal seam keeps the methane ‘adsorbed’ or attached to the coal.”

CBM is similar to conventional natural gas, and is more environmentally friendly than oil, power plants, and coal.

CBM is mainly found in central and southern Alberta where there are major oil and gas development projects. The three main regions are: the Horseshoe Canyon (Mainly Dry Coals), Belly River coals (Mainly Dry Coals), the Mannville Coals and the Ard-
Partners in Stewardship

ley Coals (Coals with saline or non-saline water).

In Alberta, CBM is regulated in the same way as conventional natural gas. The main difference is that if a company wants to remove non-saline water, it must obtain a permit from Alberta Environment. According to the Energy Resources Conservation Board, (ERCB) and Alberta Energy, coalbed methane is a form of natural gas. As a result, all acts and regulations administered by the ERCB and Alberta Energy that pertain to natural gas also pertain to coalbed methane. Overall, the handling and disposal of the water is by far the most significant environmental issue that a CBM developer needs to face.

In addition to the EUB regulations, a company must follow the regulations set out in the Canada Water Act. The Canada Water Act states that “the producer must be authorized by the Department of the Environment to use, divert, or dispose of any non-saline water before the wells are drilled. Before authorization is granted, adjacent property owners, who would be impacted by the development, must be informed of plans to handle the water.”

According to Alberta Environment, before a permit is issued, the developer must produce a detailed report making sure that the proposed water diversion follows these guidelines:

• Will not adversely affect the water supply of other users
• Will not cause adverse effects on any aquifer.

After reading many regulations and studies, I came to the conclusion that the CBM developers are ultimately responsible for deciding whether the water was good to dispose on the surface or re-injected into an aquifer. Why? – Because CBM companies are mainly the ones that run the extensive water quality analysis, hydrological studies and ultimately monitor the water.

Re-injection technology has been in used in Alberta for a long time. Conventional oil and gas usually produces saline water. Deep well disposal of oilfield and industrial wastewaters are considered by the Alberta Government to be a safe and viable disposal option, as long as the wells are properly constructed, operated and monitored. However, CBM has the potential of producing large quantities of non-saline water (as mentioned above) and the province does not have yet the experience in dealing with those issues.

Overall, it is known that CBM development is at an early stage in Alberta and that there are many things in relation to the environment that need to be learned. The CBM consultation process initiated by Alberta government in 2003 is a step forward towards the ideal legal framework of CBM development.

My recommendation is that in areas where many CBM wells are being planned, such as Ardley, it will be better to do an Environmental Impact Assessment (EIA) before any new project is allowed to proceed. CBM wells are currently classed as conventional natural gas wells, so are on the exempted list and are not required to have Environmental Impact Assessment (EIA). An EIA will assess the project’s potential impact on the environment and give stakeholders an opportunity to review and evaluate potential impacts. This process also allows for full public participation and ensures economic development occurs in an environmentally responsible manner.
An investigation into the death of trees

Juha Metsaranta  
PhD student  
Department of Renewable Resources

The next time that you walk into a forest, take a closer look at what you see around you. Despite the outward simplicity of forests in Canada, with their relatively low species diversity, the complexity of their dynamics can often be surprising. If you are in the boreal forest near Edmonton, then perhaps the forest that you are standing in is an aspen-white spruce mixedwood. Or, perhaps if you are standing on what looks like perfect beach sand in northern Saskatchewan or Manitoba, you might be in a fire-origin jack pine forest. If you ever end up in a forest like that, then after spending some time admiring its nearly perfect aesthetic qualities, you might start to observe it with a more scientific gaze.

Even in a forest that contains only a single species of trees, you will still see that there are a variety of sizes of trees. Some are larger, and some are smaller. You will also notice that there are numerous dead trees, including both standing dead (snags), and fallen dead (coarse woody debris) trees. If you are like me, you might wonder how the forest got to look the way that it looks today. Why did this tree die and this other one live? Did they die all at once, or was it a slow, steady attrition? Why did this tree become large and dominant, while this other one is small and suppressed?

As a result of my curiosity, I am exploring these questions. More specifically, I am studying the impact of weather variation and disturbance on growth and competitive relationships in forests. I am undertaking this research because I believe it will provide insight into how we might adapt forest management...
policies and practices to climatic changes that are likely to occur in the near future.

My studies are focused on jack pine forests in the Canadian prairie provinces, and I am using a combination of techniques from dendrochronology, forest growth and yield studies, and spatial analysis. I am trying to determine how competition interacts with weather variation and disturbances to produce the structure that we see in these forests today.

Unfortunately, trees remind me of both my mortality, and the lack of time most I have to finish my graduate research! I’ll be lucky if I end up reaching eighty years, which is not very long in arboreal time (and it would certainly be considered unproductive to wait my whole life just to see what happens to one particular forest). I know if I measured the size of some trees this year, then chances are, if I went back each year for the next two or three years, I probably won’t see a lot of change (while my parents were smart enough to save money for my tuition, they weren’t smart enough to establish and re-measure a network of permanent sample plots that I might study for my PhD).

Fortunately, for people like me who want to study the dynamics of populations of long-lived woody perennials, trees in temperate regions like Canada leave a record of their past size in their annual rings. The branch of science concerned with the study of the pattern of tree rings is called dendrochronology.

Most of us know that we can estimate the age of a tree by counting the number of rings in the cross section of a log or in a tree stump. If we don’t want to kill the tree, we can do this by using an instrument known as an increment borer to extract a core sample from a tree, the same way that we might extract a sediment core from a lake or an ice core from a glacier (except that it can be done easily by hand). However, dendrochronological techniques are not just about counting rings to estimate tree ages. By measuring their widths, it is also possible to reconstruct the growth history of a tree. Using allometric relationships developed in forest growth and yield studies, one can express ring widths in a wide variety of growth metrics, including height, biomass, and volume, on an annual basis.

As a result, we can see periods of both above and below average growth, and perhaps determine if these periods are related to stresses such as drought and insect defoliation.

Also, by matching patterns of wide and narrow rings in a number of trees, one can assign exact calendar years to each annual ring in each tree by a process called cross-dating. By combining many of these individual growth histories together, one can reconstruct the past dynamics of whole populations of trees (population, in this case, defined as those trees growing, or having at some time grown, in 900 m² square plots). These reconstructed dynamics can then be used to gain some very interesting insights into why forests look the way they do today, and these insights can then be used to make forecasts of how they might look in the future.

Generally, we think that competition for light is the most important competitive process in many forests. Competition for light is usually called “size-asymmetric”. That is, by being taller and being able to intercept more light, large trees tend to obtain more than their fair share of the light resource, and therefore will grow disproportionately more than smaller trees, which will tend to become more and more suppressed over time and eventually die. This is essentially the basis for the self-thinning relationships in plant population ecology. However, given recent discoveries about the importance and prevalence of root grafting in many forests, it may be that trees are really “symmetric” competitors. That is, they essentially obtain resources and grow in proportion to their size.

What, then, causes the self-thinning and size structured nature of many forests?

My hypothesis is that the importance of density-independent (but perhaps size dependent) factors like weather variation and insect defoliation actually mediate what we interpret to be the results of competition in many forests. It remains to be seen whether or not the testimony of the trees themselves supports this hypothesis.
Subtle crayfish invasions with dramatic ecological impacts

Iain D. Phillips
MSc candidate
Department of Biological Sciences

Lurking beneath Canadian water lays a juggernaut of environmental change. As one drives a highway or grid road across the prairies many may notice bison re-establishing in Elk Island National Park, and purple-loosestrife strangling some poor sucker of a wetland. Ringneck Pheasants launch across grassland shrubs, and a bold flock of Hungarian Partridge scoot in front of our pickup.

Be it the academic descending into the area, the rancher who has lived that section through his life, or the Cree whose ancestral tales pre-date all but the land itself — they all perceive the change. However, overlooked by most, virulent crayfish are colonizing Alberta on the coat-tails of human activity, and re-colonizing eastern Canada in the absence of it.

Crayfish have taken up homes in the Battle River along highway 14, in the North Saskatchewan sliding by Edmonton, the South Saskatchewan under the Trans-Canada, and even in the Oldman River. These channels drain Alberta, but to crayfish they are thoroughfares into yet unexploited frontiers. Occasionally crayfish get a lift to lakes and ponds by a curious kid exploring nature or a sport fisherman with a bucket full of bait, but it is unknown what the main mechanism is for the recent crayfish range expansion. Further, it is difficult to observe the range they now occupy, or the impact they may be having when they hide beneath the mirror surface of Alberta's water bodies.

The recent range expansion of this non-indigenous species presented me with a unique situation where a species was on its way by the university quite literally. A friend, Mike Clark, and I set up an enclosure experiment in the river just beyond the front of the crayfish invasion in an attempt to determine how these new guests could potentially change the biota of the river. We found that not only do the crayfish decrease the amount of invertebrate biomass in the river; they also consume leaf matter quite handily. The potential loss of insects and other invertebrates in rivers here may have negative impacts for the fish community if there are no fish large enough to eat the crayfish themselves. By acting as a "shredder," and consuming the leaf matter, crayfish will conceivably compete with river insects that would otherwise fill that niche, thereby further reducing the amount of prey for forage fish in the river too. This particular species of crayfish has also been shown to consume young fish and eggs, and may directly impact fish stocks here that are unfamiliar with this competition/predation.

No one has yet studied whether there are fish large enough to be significant predators to the crayfish that are arriving. Heavy sport fishing in Alberta has reduced the average size of many fish species, and this may compromise their ability to eat adult crayfish that typically grow to be about 8 cm long.

Several European studies have shown that amphibians too are victims of crayfish predation, especially in their larval forms. As many populations of frogs, toads, and salamanders continue page 8

The species currently invading Alberta typically grows to approximately 8 cm long and live 3 years. This species of crayfish is distributed across Canada, but has been absent from Alberta since the retreat of the last glaciers.
Partners in Stewardship

are already compromised by habitat disturbance, crayfish may further threaten these organisms in Alberta. Unfortunately no studies have been done that specifically looking at the crayfish species’ interaction with these amphibians, and only incidental reports of crayfish predation have been collected. I believe this is a conservation concern that requires attention before crayfish dominate the shallow ponds and lakes amphibians use.

Over the past few decades many lakes in eastern Canada have experienced extirpation of the crayfish as acid rain rendered boreal water-bodies inhospitable. However, as we decrease acid rain causing emissions, and the lakes return to a normal pH, little is known about the impact returning species will have on the new environment. Thus I conducted another component of my research on one such boreal lake that had experienced acidification, and has remained without crayfish for nearly two decades. Through a controlled reintroduction I have determined that the crayfish reduces the aquatic insects by about 70%, and the bottom dwelling algae by nearly 90%.

It may not be possible, or feasible to contain the crayfish invasion as it passes into Alberta. However, we need not think the end of our natural aquatic ecosystems is imminent, merely that they are changing. Although my field experiments clearly demonstrate this species of crayfish has a dramatic impact on its environment and the availability of prey for forage and sport fish, Saskatchewan, Manitoba, and northwestern Ontario have had this crayfish species for as long as anyone can account. These provinces still have fish, amphibians, and certainly have aquatic insects.

The concern for Alberta may be how many multiple disturbances its aquatic environment can handle. Our eastern neighbors do not have the same amount of resource development and landscape-level habitat disturbance as Alberta. The aforementioned compromised fish and amphibian populations may not be able to handle another stress. In the absence of research on these problems I do hope the keen young child playing in the ponds near his house, the weekend angler out on the river, or those who live on the land and know it well keep an eye out. We have a new guest, and it does not have a polite demeanor.
Environmental health risk management research

Daniel I. Jalba
MSc student
Department of Public Health Sciences

How safe is our tap water? In the city? At my summer cottage? In motels, national parks, restaurants, remote communities, holiday resorts? What do public health agencies do to assure that drinking water is consistently safe? Do current safeguards assure that every Canadian is provided with safe drinking water? Is another Walkerton still possible in Canada?

Five years after Walkerton, I have undertaken descriptive qualitative research to address these questions which are relevant for the safety and security of every Canadian. This represented my MSc thesis under the supervision of Dr. Steve Hrudey (Environmental Health Sciences, Department of Public Health Sciences). To maximize our knowledge, I interviewed medical officers, environmental health managers and environmental health officers (EHOs) experienced in water safety, from 15 public health agencies in Alberta, BC, Saskatchewan, Ontario and Quebec. Data collected during the one-hour semi structured interviews was supplemented by a questionnaire survey sent to all practising EHOs in Western Canada (Alberta, Saskatchewan and BC). For comparison purposes, I also interviewed their Australian counterparts from four public health agencies in Victoria and New South Wales. Australia, a country with a long established record in drinking water safety, has avoided a fatal waterborne outbreak similar to Walkerton.

The complete findings of the study will be published with Canadian Water Network funding (Spring 2006). In summary, events like Walkerton and the subsequent North Battleford outbreak stimulated water providers, regulatory agencies and public health agencies to assure more safeguards are in place. While drinking water can never be 100% safe, it approaches this limit in virtually all large Canadian cities and in most medium and small size cities. In general, municipal water providers benefit from good funding and expertise and provide quality water at a low cost per capita. There are regional differences, however, and it is important to note that in certain cities the lack of a source to tap approach to drinking water safety and robust multiple barriers to contamination leave the water supply with few redundancies to cope with a major challenge (e.g. storm, massive contamination, drastic changes in source water quantity or quality).

However, it is the assurance of safety of drinking water in small communities, in

continued page 10
the “unregulated” public water systems (i.e. water systems under a certain size that are not required to be licensed and have certified trained operators, for example under 15 connections), and in the “unregulated” non-residential systems (e.g. motels, parks, campgrounds, trailer parks) that varies greatly, with numerous small systems still left without effective safeguards under either normal or emergency situations.

Such systems generally fall “by default” under public health agency responsibility, as primary guardians of public health. Public health agencies with good funding have taken important steps to catalogue and address deficiencies in these systems in an integrated raw water source to consumer tap approach. Generally, their more rural counterparts are resource limited and are more likely to adopt a reactive approach largely based on periodic water testing for fecal contamination indicators or consumer complaints. In addition, our research also indicates that some professionals are unclear about where the critical priorities lie for assuring drinking water safety.

A common constraint facing public health agencies in affluent countries like Canada is that it is often difficult to prove the true effectiveness of their actions in terms of maintaining and improving population health. We would only know when they are failing to do so, because of the occurrence of otherwise preventable diseases, something that may not be evident except for major disasters. Drinking water safety faces the same challenge. A simple numerical compliance approach in relation to water quality standards cannot be sensitive and specific enough for these needs, and is inherently reactive. In most realistic cases by the time adverse results are recognized and communicated, contaminated water has already been distributed to the public.

In recent years there has been increasing international recognition that treated water monitoring has limited value to indicate or exclude hazard presence and that sole reliance on end-product monitoring provides inadequate assurance of drinking water safety. This recognition has been integrated in the 2004 World Health Organization drinking water guidelines and in several national frameworks (e.g. Australia), and is also formally recommended by Health Canada since 2004. Based on international high-level water safety expertise, these documents indicate a will to do things differently by moving monitoring attention upstream to be proactive rather than reactive. Such an approach is in line with the public health scope, which by definition is preventive. To be truly proactive we need a preventive, risk-based approach to understanding water systems, managing drinking water safety, regulating and maintaining public health surveillance.

The basic causes for waterborne disease will always be present, in particular human and animal fecal contamination. However, in the last 150 years we have become increasingly adept at controlling human disease spread by drinking water exposure. We are now faced with a new frontier — we have to assure that we provide this control consistently and for every Canadian. The international trend is now to move beyond narrow numerical compliance and towards a preventive, risk-based approach to drinking water management. Public health and other agencies involved need to promote risk management policies and training for staff and water operators as part of a population health based strategy for safe drinking water.

To cite from the participating environmental health inspectors: “There is still a surprising amount [sic] of Canadians consuming unsafe water (biological contaminants) either at home or through exposure to small water systems at lodges, resorts, small communities. There is a concerning lack of treatment/filtration for even large systems in [respondent’s home province]. In rural areas many residents still consume surface water with no treatment whatsoever. If the public was more aware of drinking water safety issues, they would ask more questions for both public and private systems”.

10 Partners in Stewardship
Water stress brought about by salt, drought, cold and heat stress is one of the major problems facing agriculture worldwide. The cost of these stresses, collectively known as abiotic stresses, is estimated to be in billions of US dollars per year, and is expected to increase. Salinity alone is one of the most severe among the abiotic stresses and it is estimated that increased salinization of arable land will have devastating global effects, resulting in the loss of 30% of arable land within the next 25 years, and up to 50% by the year 2050. As the world’s population continues to rise, their increased need for food has to be met by an increase in yield per land area due to the loss of agricultural land. Classical breeding approaches to enhance plant tolerance to salinity have been largely unsuccessful due to the complex nature of plant responses to this stress. Over the last two decades, scientists have unraveled the genetic code of several different organisms including a number of plants. However, our understanding of the proteins specified by the genome, which perform all cellular functions including mediating plant responses to stresses, and their exquisitely coordinated cellular activities, is far from being complete. In this post-genomic era, proteomics- and genomics-based discovery approaches may help in the identification of those proteins (and genes) that may play crucial roles in mediating plant responses to stresses and aid in the rational engineering of crop plants capable of performing better under conditions of abiotic stress.

Genes are contained in all living cells. They provide instructions on cell function, and are passed from generation to generation to enable a species to survive. A 19th century monk, Gregor Mendel through the selective cross-breeding of common pea plants over many generations deduced that plants inherit factors (now called genes) from each parent, and his heredity laws became the basis of our present understanding of heredity and genetics. The latter half of the 20th century witnessed significant developments that led to the elucidation of complete genome sequences for a number of plants. Genome (an organism’s total genetic material) is virtually
static and can be well defined for an organism while the proteome (complete set of proteins expressed by the genetic material of an organism) changes in response to external and internal conditions; so knowledge of proteins, the mature products of genes, is very important.

In our research, we have investigated the responses of the legume pea to salinity stress using two-dimensional electrophoresis and Mass Spectrometry. Two-dimensional electrophoresis enables us to compare hundreds of proteins simultaneously and Mass Spectrometry permits successful identification of proteins.

The objective of our study was to identify as many proteins whose levels were affected by salinity as possible. In addition to the identities of the proteins themselves this approach also provides us with a glimpse into the various cellular processes that may be affected by the salinity (or for that matter any stress) which may form the basis for detailed investigation. Our investigation into the salinity responses of pea roots identified several proteins, including the PR10 (pathogenesis-related) proteins.

We hypothesized a crucial role for PR10 genes in abiotic stress responses and tested our hypothesis by transferring the pea PR10 gene in canola (Brassica napus) and model plant Arabidopsis thaliana using modern biotechnology techniques. The transgenic plants (Arabidopsis and Canola) exhibited enhanced germination and growth under saline conditions as well as tolerance to a number of stresses during germination and subsequent growth. Our studies demonstrated for the first time that they may have utilities in enhancing germination as well as conferring multiple stress tolerance in a number of plant species. In addition to the potential application of our research we continue to investigate the biological role of PR10 proteins in plants and our results may contribute to an enhanced understanding of the biology of these proteins.

World food grain production must double by the year 2050 to meet the demands of a growing global population and we have to achieve this food production in the face of decreased land area for cropping, diminishing water resources and worsening environmental constraints, such as salinity, drought and cold. The amount of arable land cannot be increased, so we must find ways to produce more. Biotechnology together with proteomics and genomics gives us an important additional tool towards meeting these needs. There is an urgent need to identify additional novel genes both from a crop improvement perspective and, to enhance our understanding of plant responses to stresses. As indicated before, the sustainability of life on this planet depends on our ability to increase food production which, in our opinion, can only be achieved through rational crop improvement. The mid 20th century saw many countries increase their agricultural productivity in what is referred to as the “Green Revolution” which was characterized by the modernization of agriculture and the introduction of chemical crop protection agents including pesticides and herbicides. It is time for a second revolution, the biotechnology revolution, which has the potential to further increase agricultural productivity, worldwide.

We hope as a new and final thought that our own research in this area will contribute by identifying proteins that respond to various stresses and understanding their function in order to accelerate the development of hardier, higher-yielding crops.