RMA

The Resource Modeling Association is an international association of scientists working at the intersection of mathematical modeling, environmental science, and natural resource management. We formulate and analyze models to understand and inform the management of renewable and exhaustible resources. We are particularly concerned with the sustainable utilization of renewable resources and their vulnerability to anthropogenic and other disturbances.

RMA Newsletter Fall 2017

Introduction to the

2018 Guangzhou Conference

by Yiming Liu and Krishna Paudel

The 2018 World Conference on Natural Resource Modeling will be held on 9-13th June 2018 in Guangzhou, China. This year the #WCNRM 2018 is co-organized by South China Agricultural University. For a hundred years, South China Agricultural University has developed into a multi-disciplinary, comprehensive university comprised of the disciplines of agriculture, engineering, liberal arts, basic sciences, economics, management, law, education, history and philosophy. Through its 2 900 faculty and staff as well as 43000 students among which 5500 are masters and doctoral students, SCAU has always been contributing to the development of agriculture and society in China. The theme of the #WCNRM 2018 conference focuses on biodiversity conservation and sustainable development, which aims at balancing social, economic and ecological dimensions especially in developing countries where the severe environmental problems affect the economic growth. Thus, the conference will pay special attentions on forest biodiversity, agricultural development, water resources management, and rural livelihood issues to promote

Inside

(continued from front page)

a harmonious and sustainable development.

Four outstanding keynote speakers will be invited to give talks on ocean environmental restoration, forest and ecology, economic modeling and water use in agriculture. Georges Zaccour is working in Department of Decision Sciences, HEC Montréal, Canada. Professor Zaccour's fields of expertise include Energy/Environment, Marketing, Game Theory, and Control Theory. Jeffrey Peterson is the Director of the University of Minnesota's Water Resources Center, a partnership of University Extension and the College of Food, Agricultural, and Natural Resource Sciences. His research area is environmental policy analysis, focusing on water use and water quality impacts from agriculture. Jun Wang is professor in College of Marines of South China Agricultural University. Professor Wang's research focuses on Marine Pollution and Ecotoxicology; Agricultural and Food Chemistry are also field of his scientific expertise. Junchang Liu is a Forest Economist at the School of Economics & Management, Beijing Forestry University, China. Professor Liu's research focuses on the forest statistics and evaluation of forest resource.

Guangzhou is located in southern China, north of the Pearl River Delta. As the capital of Guangdong Province, Guangzhou is the center of its politics, economy, science, education and culture, with nearly 13 million of inhabitants. Guangzhou enjoys a mild sub-tropical climate with plentiful rainfall all year round, which makes it a beautiful city with evergreen scenery and flowers blooming all the year round, hence reputed as "Flower City".

Guangzhou is one of the most famous historical cities in China with over a 2,200-year history. As an ancient but dynamic city, Guangzhou impresses visitors with both its vivid modern ambience and unique traditional Lingnan indigenous culture. In addition, Canton cuisine is highly recommended as it is one of the four major food styles of China.

As first social event of the #WCNRM 2018 conference, on Sunday, June 10, there will be excursions to Nansha Wetland Park and Tin Hau(Matsu) Temple in Nansha District, Guangzhou. Nansha Wetland Park is located on the west bank of estuary of Pearl River, and the whole area constitutes a beautiful rural picture with pure water, blue sky and verdant trees. In the 200-square-meter core region of the tourist area, grows varieties of mangrove and reed. Many kinds of birds come here for perch and reproduction, making here a place of a rare paradise for birds in Pearl River Delta.

Tin Hau Temple locates at the mouth of the Pearl River just southeast of Guangzhou's Dajiao Mountain, and it is the largest Matsu Temples in Southeast Asia. We will visit these two places to sight the wetland biodiversity and mangrove, meanwhile to experience the unique indigenous culture in Guangzhou.

Looking forward to seeing you in Guangzhou on 9-13th June 2018.

PRESIDENT'S COLUMN

by Luc DOYEN

Every year, the RMA fall newsletter is an important moment for the President of the Resource Modeling Association because it is the key period to both evaluate the work achieved during the past year and to launch the activities of the upcoming year. Again a matter of tipping point and regime shift …

First, examining the recent RMA outcomes, my view is that 2017 has been a very fruitful and positive year for the association. We are well progressing towards the objectives stated last year. RMA indeed strengthened his influence and affirmed his pivotal role for interdisciplinary researches at the interface of ecology, economics, mathematics and computer sciences and devoted to the sustainable management of natural resource and ecosystems.

As major results, I first want to point out the great success of the Barcelona conference WCNRM 2017. It has indeed been very successful from the scientific viewpoint with more than 140 submissions, 110 talks during 3 days of scientists from all around the world with a very satisfying balance between young and senior researchers. I am convinced that the central theme of the conference namely "Vulnerability and Resilience of Socio-ecological Systems" as well as the quality and diversity of keynote speakers including Linda Nøstbakken (Norway, Resource Economics), Mark Finney (US, Research Forester), Marc Castellnou (Spain, Research Forester) and Frank van Langevelde (Netherlands, Ecology) have strongly contributed to the attractiveness of the conference. The awarding of both the Rollie Lamberson Medal and the prize of best student presentation during the conference also reinforces this interest of our annual conferences. Bill Reed from the University of Victoria in Canada was also honored as RMA Fellow 2017 by the Resource Modeling Association in recognition to his scientific work in natural resource modeling and for his sustained leadership regarding the resource conservation, management and economics. The Barcelona conference has also been successful as regard social events. In particular the gala dinner friendly organized on a nice terrace along the Barcelona port was a very pleasant moment that every participants strongly enjoyed. Many attendees had difficulties to leave this wonderful place of the Catalan city.

More globally, let me emphasize that the choice of a very big, tourist and appealing city such as Barcelona participated to the success of the conference.

Moreover, key to the success of any conference is the unseen work behind the scenes, with tireless efforts from local scientists, administrative staff and organization. In that respect, Nuria Prat Guitart, Elsa Pastor, Oriol, Mariona and all Spanish colleagues in particular from the Pau Costa Foundation and the Universitat Politècnica de Catalunya did a great job and deserve warm acknowledgements for the organization of WCNRM 2017. Some nice pictures are scattered within this newsletter.

More are accessible online at:

https://www.flickr.com/photos/paucostafoundation/albums/72157685806245335/page2.

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Let me also mention that another fruitful output of the Barcelona conference relates to the preparation of a special issue in journal NRM dedicated to 'Vulnerability' and led by Elsa Pastor. This a good transition to speak of RMA's journal entitled 'Natural Resource Modeling'. Our interdisciplinary and international journal, published by Wiley since 2008, is also developing well thanks to Shandelle Henson, the new Editor-in-Chief. In particular, Shandelle created in 2017 new categories of submissions and appointed a new editorial board. She details the new NRM dynamics within this newsletter.

Among the other good news for RMA, I want to point out that our communication through electronic networking is also progressing well. In particular, the use of Facebook, ResearchGate or LinkedIn networks is now more intensive and systematic. In that respect, the young scientists engaged on the board including Vanessa Trijoulet for ResearchGate and LinkedIn, Yi-Hsiu Chen for Facebook and Twitter play a crucial role. Accordingly, the dissemination activities of Yi-Hsiu Chen is detailed in another columns of this newsletter. Do not hesitate to send and circulate scientific information on these networks.

Another strength of RMA relies on the publication of the bi-annual RMA newsletters. Regarding the content of this newsletter, I am convinced that we need to enhance its scientific content. In that perspective, this fall newsletter contains an executive summary of the paper which won the Lamberson award in 2017. This 2017 Lamberson Medal was awarded to RMA members Guillermo Herrera (Professor and Chair, Department of Economics, Bowdoin College), Holly Mueller (Assistant Professor, Department of Ecology, Evolution, and Marine Biology, University of California Santa Barbara) and Michael Neubert (Woods Hole Oceanographic Institution) for their paper "High seas fish wars generate marine reserves'. This outstanding paper published in PNAS exemplifies the interest of spatially explicit and dynamic game models to deal with renewable resources management. This Fall newsletter also welcomes new RMA board members: Vanessa Trijoulet from NOAA (Woods Hole, USA) will now be Director in charge of electronic communication for RMA. Leif Kristoffer Sandal (Professor of Applied Mathematics and Management Science at the Norwegian School of Economic), Frank Vandevelde (Professor of Ecology at Wageningen University, The Netherlands) and Martin Quaas (Professor of Economics at the University of Kiel) also join the RMA board and will reinforce its scientific credibility while still contributing to friendliness of the association. All three are presented with more details within this newsletter. Frank Vandevelde also provides in this newsletter an executive summary of his outstanding presentation as Keynote speaker during the Barcelona conference. His scientific contribution deals with the 'Social resilience in honeybee colonies".

Now let me speak of the future and launch the RMA activities of the upcoming year 2018. The conference #WCNRM 2018, to be held on 9-13th June 2018 in Guangzhou, China, is progressing well under the leadership of Paudel Krishna, Yiming Liu and the support of South China Agricultural University. The theme of the conference focuses on biodiversity conservation and sustainable development with special attentions paid on forest biodiversity, agricultural development, water resources management, and rural livelihood issues. Four outstanding keynote speakers are invited: Georges Zaccour (HEC Montréal, Canada), Jeffrey Peterson (Director of the University of Minnesota's Water Resources Center, USA), Jun Wang (professor of South China Agricultural University) and Junchang Liu (Forest Economist in the School of Economics & Management, Beijing University). The quality and complementarity of these keynotes speakers combined with the effectiveness and scientific skills of the South China Agricultural University in Guangzhou as well as the interest of China regarding biodiversity conservation and sustainable development will all strongly contribute to the success of our next international and interdisciplinary conference WCNRM. This is the first annual RMA conference organized in Asia and consequently it will actively expand the influence of our association. Please send your abstract online by January 2018.

This president's column is also an opportunity for me to send a warm welcome to all new RMA members, in particular those that have joined from the last conference in Barcelona. On behalf of RMA, I wish you all a happy holiday season and a prosperous new year.

Luc Doyen

President RMA,

Senior Scientist CNRS,

University of Bordeaux

Introducting the RMA Board new members

Frank van Langevelde

Associate professor in the Resource Ecology group of Wageningen University, The Netherlands. His research interest focuses broadly on the effects of environmental stress on animal populations and how animals adapt to stress. Environmental stresses can be diverse, such as infection with parasites, threats from predators, and exposure to extreme ambient temperatures or periods of drought. When stressful environmental conditions lead to a reduction in survival or reproductive output of individuals, and when these conditions maintain, they can lead to population extinction. Organisms are known to adapt to environmental stress and animals, in contrast to plants, can move to avoid stressful conditions and search for more favourable conditions. However, animal movement is often limited, especially in human-dominated landscapes where habitat is fragmented. He studied and published about local population dynamics of animals with movement constraints in a variety of organisms and ecosystems ranging from springtail, honeybees, butterflies up to elephant. See for more information:

https://frankvanlangevelde.com/

Martin Quaas

Professor of Economics at Kiel University, Germany. He has graduated in Physics and received a PhD in Economics in 2004 from the University of Heidelberg. His main scientific expertise is in natural resource economics, doing interdisciplinary research at the interface between economics and ecology. The main natural resources Martin is studying are fisheries, focusing in the effect of market interactions in multi-species fisheries, the effects of taking the age structure of fish populations into account on optimal management, and the distributive effects of fisheries reform, rangelands, with a particular interest in the effects of uncertainty and biodiversity, and conceptual questions. Martin's further fields of research include climate economics (questions of climate engineering), and urban/regional economics.

Research results have been published in some 66 articles both in economic (e.g. Ecological Economics, Journal of Environmental Economics and Management) and natural science journals. Martin Quaas has extensive experience as Principal Investigator in the Kiel Cluster of Excellence Future Ocean, and numerous externally funded projects. He serves in the editorial boards of Natural Resource Modeling and Environment and Development Economics.

Leif Kristoffer Sandal

Professor of Applied Mathematics and Management Science in the Norwegian School of Economics (NHH). He received his Dr. Scientarium degree in applied mathematics and theoretical plasma physics. He has published numerous papers. His research interests are in stochastic and deterministic continuous-time optimization, including theory, algorithmic analysis, and applications.

He founded the international master and doctorial programs at NHH in Energy, Natural Resources and the Environment (ENE) and is presently the director of the ENE Research Centre at NHH.

Leif has published widely in the field of fishery economics and was pioneering the introduction of stochastic modeling in bioeconomics. His international network is extensive with many joint publications with researchers in Europe, China, Australia and North America. He has been the principal investigator in numerous international projects. His present research interests include real-world applications of dynamic modeling and stochastic optimization in Managing Natural Resources, Pollution Problems and Corrective Taxes and Sustainable Feedback Policies in Bioeconomics.

Spatial Fish Wars

by Holly V. Moeller [a], Guillermo E. Herrera, and Michael G. Neubert [a]

Laureates 2017 of the Lamberson Award

Effective and sustainable management of resources is enhanced by property rights: giving an individual (e.g., a sole owner, or a cooperative group of owners) exclusive harvest rights alleviates the tragedy of the commons, with both economic and ecological benefits. For example, profitability is enhanced, biological stocks are maintained at higher (and therefore healthier) levels, and employment levels may even be higher than in open access settings.

However, access to natural resources cannot always be controlled; high-seas fisheries are emblematic of this fact: fish may be harvested by any vessel with the technological capacity to reach the open ocean fishing grounds. Attempts to establish international accords that regulate fishing beyond the exclusive economic zones of individual countries are fraught with socio-political conflict, and have been successful only in a few cases (e.g., restricting the harvest of marine mammals). Despite the bleak prognosis (depleted stocks and complete erosion of economic net benefits) for truly "open-access" high seas fisheries, our analysis (Herrera et al. 2016) suggests that some shared fishery systems may be able to escape the " tragedy of the commons,"(Hardin 1968) – at least while the number of countries with fishing access is relatively small.

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Our results are based on a bioeconomic model of a fish stock that reproduces and diffuses freely through a linear habitat, with "hostile boundary conditions" that give rise to spatial heterogeneity. A finite number of countries have access to this fishery, and are able to control the location and fishing intensity of their fleets. The countries also have full knowledge of one another's activity, including both fishing intensity and spatial distribution of fishing fleets. Given this knowledge, each country "strategically" manages its individual fishing fleet in order to maximize its own profit (i.e., the difference between the value of the catch and the cost of fishing effort) subject to the behavior of the other fleets.

The simultaneous solution to this non-cooperative optimization problem is a Cournot-Nash equilibrium, i.e., a set of strategies in which no player can unilaterally change strategy and improve its payoff. Because our players (nations with fishing fleets) are all identical, the solution is symmetrical: each utilizes the same strategy in distributing its fishing effort across the habitat. In essence the solution to our problem is a spatial extension of Levhari and Mirman's (1980) classic "fish war" equilibrium. The shape, or spatial distribution, of these strategic equilibria surprised us: In particular, the fact that as part of a non-cooperative profit-maximizing strategy, competing nations often independently establish marine reserves.

Marine reserves are places within a fish stock's habitat that are closed to fishing. Designed as spatial refuges for exploited stocks, reserves have generally

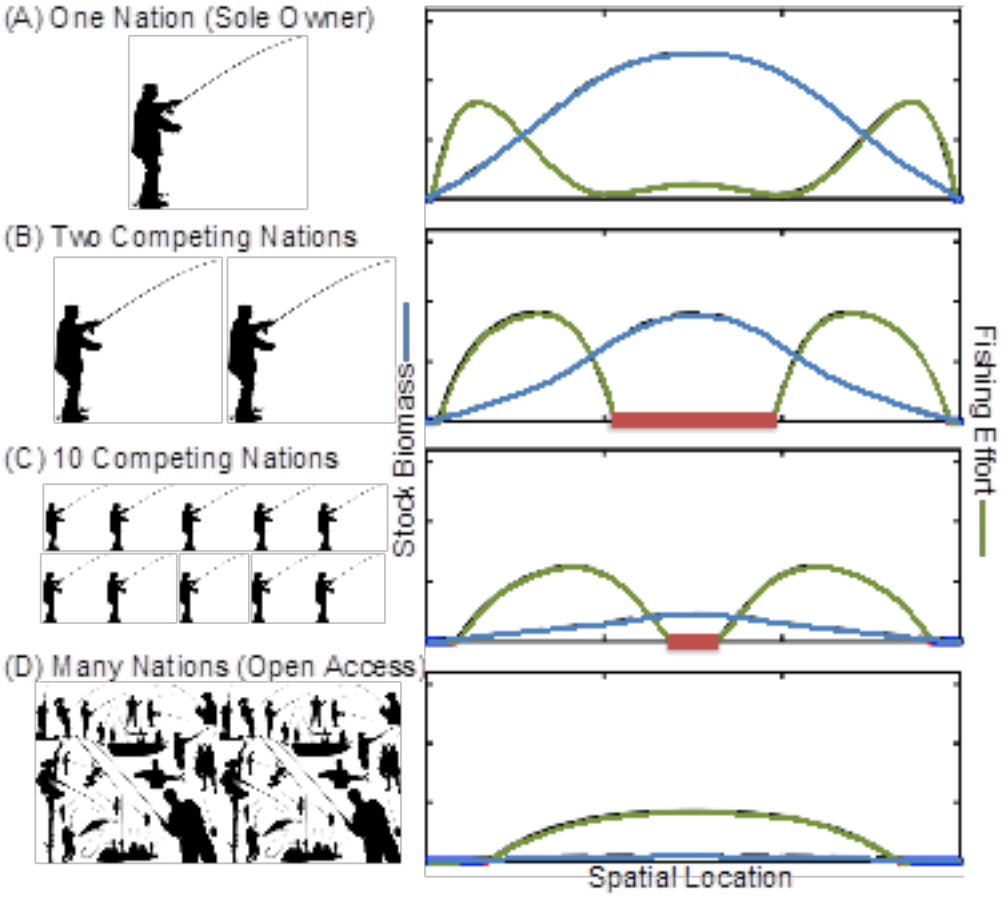


Figure 1. Spatial distribution of fishing effort (green) and resultant fish stock biomass distribution (blue) for an increasing number of non-cooperative nations (panels A-D). Thick red lines highlight central reserves established independently by each of the competing nations; note that the size of these reserves shrinks with increasing numbers of nations until, for the open access case, the central reserve has been completely eliminated. Stock biomass also declines as nation participation increases.

Box 1: The Mathematical Model

Our model considers a fish stock of density *N(x,t)* that lives within a one-dimensional habitat of length *L*. The population grows logistically, with a maximum per capita growth rate *r* and carrying capacity *K*. We approximate movement of individuals as diffusion, with a diffusion coefficient *D*.

Fish are harvested by fleets from *h* independent, non-cooperative, and identical states. Each state *i* manages its own fishing fleet, leading to an effort distribution in space and time $E_i(x,t)$; We assume that the capture of fish is the product of this effort, the local stock density, and the catchability coefficient *q*. Thus we obtain:

$$\frac{\partial N}{\partial t} = rN\left(1 - \frac{N}{K}\right) + D\frac{\partial^2 N}{\partial x^2} - qN\sum_{i=1}^{h} E_i(x,t).$$

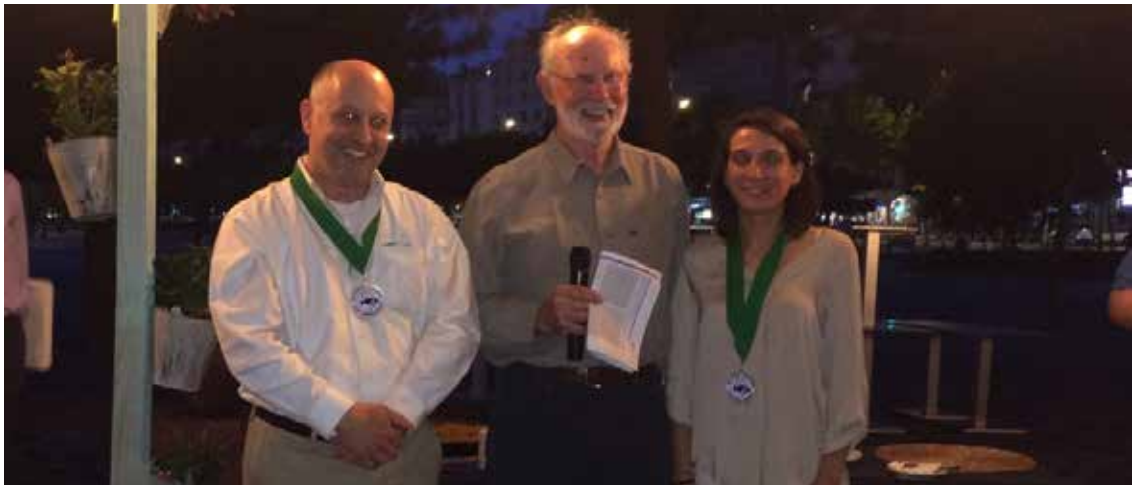
Given a fixed price per unit stock biomass *p*, a cost per unit effort of w_0, and an additional cost per unit effort w_1 which represents costs associated with interference between fleets trying to fish the same location, we can then compute the rent density for state *i* as:

$$\rho_i\left(\mathbf{E}, N\right) = pqE_iN - \left(w_0 + w_1||\mathbf{E}||_1\right)E_i.$$

Each state's goal, then, is to maximize the present value of its private rent Π_i, i.e., the integral of its rent density over all habitat space from *0* to *L*, and over an infinite time horizon, subject to a discounting rate *a*:

$$\Pi_i(E,N) = \int_0^{\infty}\int_0^{L} \rho_i\left(\mathbf{E}(x,t), N(x,t)\right)e^{-at}dx\ dt.$$

Assuming each state has full knowledge of the distribution of stock and every other state's effort, the outcome is a Cournot-Nash equilibrium. We apply Pontryagin's maximum principle and numerically compute the solution, which is identical for each state.



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been found to positively impact stock sizes, habitat quality, and the health of other members of the aquatic community. However, because these closures involve setting aside parts of the ocean that might otherwise be profitably fished, they are often viewed as economically costly. This opportunity cost can be a major impediment to reserve establishment.

As a result, a number of researchers have studied scenarios under which marine reserves may be economically optimal (i.e., part of a profit-maximizing management strategy). This may occur when, for example, the designated reserve is in an area that would be costly to fish, protects a population "source" such as spawning grounds, or protects habitat from damage by fishing. These closures are economically beneficial because their elevated populations of motile stock "spill over" into fishable areas where they are profitably harvested.

Because marine reserves contain large amounts of stock biomass, one might expect that, when a competing nation not subject to the closures and regulations established by other owners enters a fishery, the first place that it would fish would be this resource-rich reserve. Thus we hypothesized that, while sole owners maintained reserves as part of a profit-maximizing strategy, once multiple nations were competing non-cooperatively for the same fish stock, these reserves would disappear.

However, for a wide range of parameter values, reserves persist when the number of competing nations is finite. As the number of competing nations increases, however, the reserves become smaller and more centralized; eventually, they disappear altogether as the non-cooperative solution converges on the open access result. It is important to note that our results depend upon each nation having complete knowledge of all other nations' strategies. Such a high degree of knowledge is, at present, unrealistic; however, our ability to obtain this information is increasing as new satellite methods of tracking fishing vessels are coming online (Mills et al. 2007).

Our work is important because of its surprising conclusion that reserves may help even multiple competing nations maximize their individual profits (though of course they can achieve even better results if they cooperate, i.e., jointly optimize behavior). This result provides further evidence for the economic efficacy of closed areas. The fate of high seas fisheries is hotly contested; recently, some economists have argued that the high seas should be closed to fishing altogether, protecting vulnerable migratory stocks from overexploitation by confining individual nations to their Exclusive Economic Zones (Sumaila et al. 2015). While international accords achieving such an aim are subject to complex sociopolitical forces, our results suggest that such closures may be easier to implement in the international policy arena than previously thought. Our bioeconomic modeling efforts inform the policy process from a theoretical perspective.

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Science communication in conservation process is thought to involve three major sectors of society–scientists, the public and policy makers. In the interactions among these sectors, the information delivery from the researchers to publics is particularly important as it helps to raise public awareness on environmental issues and encourage supports for relevant policies. As we move into the Internet Age, social networking sites have become new platforms for public engagement and provided a great opportunity for researchers to reach wider audiences than before. To facilitating science communication and interactions, the Resource Modeling Association is now active on the two most popular social networking platforms–Facebook and Twitter.

The overall aim of the Resource Modeling Association Facebook page (fb.me/ResourceModelingAssociation) is to deliver the latest updates on research findings and academic opportunities in mathematical modeling, environmental science and natural resource management. It also provides an ideal space to interact with both researchers and the public informally. The RMA Facebook page was created in June 2013, and, to date, it has been followed by more than 200 Facebook users. In the past year, the updates on conference news and new publications on the Natural Resource Modeling Journal were posted from weekly to monthly basis. The most popular post so far about the World Conference on Natural Resource Modeling in 2017 has been viewed nearly 400 times and reached more than 1200 users.

Following up the encouraging attempt with Facebook, we recently have expanded our effort to another popular social networking platform–Twitter. Young compared to all other RMA social networking groups, the RMA Twitter page (@ResModelAsso) was created in June 2017. Although it has only been five months since the Twitter page was created, the RMA Twitter page has had more than fifty tweets and the followers are continuing growing.

After a fruitful year of social networking, we will continue to share scientific news on the RMA Facebook page, and we encourage both the RMA and non-RMA members to follow our Facebook and Twitter page to keep up with the latest updates on science and from the association. We also welcome all the RMA members to send messages to us if there are any research findings and academic opportunities to be shared.

Our dedicated Community Manager on Facebook and Twitter:

Yi-Hsiu Chen,

PhD at National Centers for Coastal Ocena Science,
NOAA'S Beaufort Lab, NC USA.

Editor's Column

by Shandelle M. Henson

Editor -in-Chief of Natural Resource Modeling

Your Thoughts about Natural Resources:

A Call for Perspectives, Letters, and Editorials

We are interested in your expert insights, thoughts, and opinions! Do you have comments on some area of natural resources? Would you like to write a non-technical review of some aspect of management? Do you wish to comment on a paper in the Journal? Are you willing to put forth a controversial hypothesis to which others can respond? Can you write a survey of a particular need in resource management or about the effects of a recent natural disaster on a natural resource system?

The journal of the Resource Modeling Association is Natural Resource Modeling. In order for our journal to be an influential leader in the academic conversation on the management of natural resources, we need more than research articles. We need opinion pieces, commentaries, book reviews, letters, and guest editorials.

Early-career researchers understandably might not spend much time writing such articles, which are not always peer-reviewed and may not "count" in promotion and tenure. Established researchers, however, have the luxury of sharing their broad perspectives and expertise through these channels. Perhaps we even have an ethical obligation to produce non-technical writing that is accessible to resource managers, policy makers, and the general public.

One way in which you can do this is by submitting Perspectives, Letters, and Editorials to the Journal.

Perspectives are, in fact, peer reviewed. They are opinion articles that present evidence. They may deal with opposing views and debates, and the editor may invite a response by someone holding an opposing view.

Letters usually are not peer-reviewed. They comment on a paper or a letter in this or another journal, or they review a book.

Editorials often introduce thematic and special issues, but guest editorials also may address general or specific items of interest in natural resource management. Editorials are not peer-reviewed. They sometimes are written by members of the editorial board, by guest editors of special issues, or by invited guest editors. However, I am interested in editorial submissions from anyone who would like to address some aspect of natural resources in an accessible way.

I hope you will share your expertise by submitting an article for consideration in one of these venues. If you have any questions, please contact me at:

editor@resourcemodeling.org.

Best wishes,

Shandelle.

Shandelle M Henson

Editor-in-Chief, Natural Resource Modeling

Professor of Mathematics, Professor of Ecology

Andrews University

Selected presentation from Barcelona conference:

Social resilience in honeybee colonies

by Frank Vandevelde [1] and Coby van Dooremalen [2]

Honeybees are social animals that interact with each other to support colony growth and reproduction. Colonies face many disturbances, such as low amount of food during a wet summer or due to human land use, severe winters, parasites and pesticides used to protect crops. Although many studies have shown negative effects of these stressors on individual bees, effects of colony level are only rarely studied. Understanding the effects of stressors on colonies may help to explain and predict the vulnerability and resilience of socio-ecological systems. During the presentation at the 2017 RMA World Conference in Barcelona, I illustrated the effects of stressors on the resilience of honeybee colonies during winter.

Since several decades, alarming winter losses in honeybee colonies have been reported in many countries, especially in the temperate regions of the Northern Hemisphere (Neumann & Carreck 2010). Although not much is known about the development of honeybee colonies during winter as hives remain closed, the ability to regulate temperature in honeybee colonies seems to be crucial, especially in the temperate regions with low temperatures during winter, because generating and preserving heat are the key processes to survive a cold period.

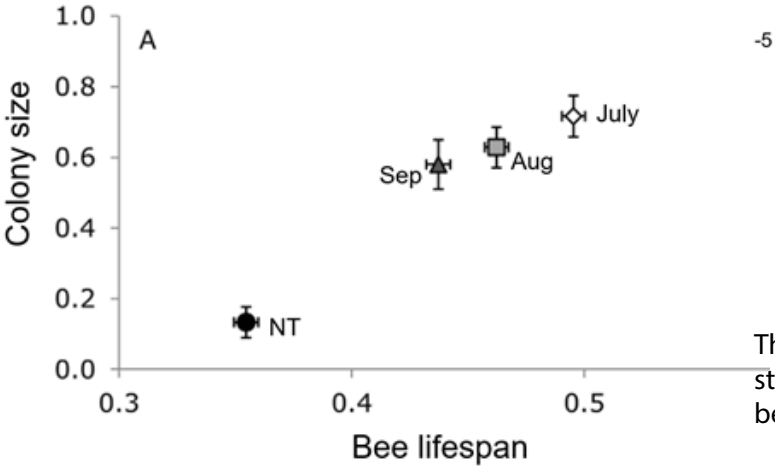

Figure 1. *Winter survival as a function of bee survival in November 2005. Fraction of frames occupied with bees in a colony in April in relation to bee survival at 100 days for the cohorts marked in November 2005 (Van Dooremalen et al. 2012)*

We earlier illustrated the effect of the parasitic mite Varroa destructor on the longevity of honeybees during winter (Van Dooremalen et al. 2012). Individual bees from a colony that had low mite infestation (treated against this mite) had longer life span, and these colonies had lower probability of extinction (Figure 1). We also measured the ability of individual bees to keep themselves warm, and we found that bees from colonies that were infected with the microsporidium Nosema ceranae (not treated against this parasite) lost heat more quickly than healthy bees when put on ice (Figure 2).

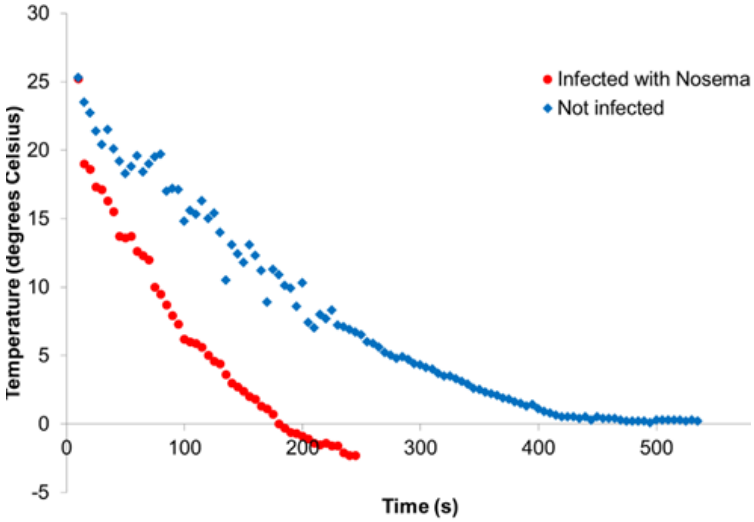

Figure 2. *Decrease in temperature of individual bees (one from a colony infected with the microsporidium Nosema ceranae and one from a healthy colony) over time from the moment that they are put on ice. The temperature was measured using an infrared camera (Van Langevelde et al. in prep.).*

These results suggest that bees from colonies exposed to stressors may have a lower probability to survive winter because of failing thermoregulation.

To further explore this hypothesis, we modelled the dynamics in local bee density (ρ) and local temperature (T) in a colony, using the thermotaxis-diffusion model of Wat-

mough and Camazine (1995) and we added mortality of individual bees:

$$c\frac{\partial T}{\partial t} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\lambda(\rho)\frac{\partial T}{\partial r}\right) + \rho f(T)$$

$$\frac{\partial \rho}{\partial t} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\mu(\rho)\frac{\partial \rho}{\partial r}\right) - \theta(\rho) + \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\chi(T)\rho\frac{\partial T}{\partial r}\right)$$

The assumptions are that :

(1) each bee bases her behaviour exclusively on the temperature she experiences in her local environment,

(2) she moves in the direction to higher temperatures when she is too cold and to lower temperatures when she is too warm.

In the first equation, c is the heat capacity of the cluster (=1 J K^{-1} cm^{-3}), λ(ρ) is the coefficient of heat conduction, and f(T) is the metabolic output per bee.

The first term represents the heat energy per unit time gained by the bees a distance r from the centre of the cluster due to conduction from their neighbours. The second term is the change in the local temperature due to the heat produced by the bees' metabolism. In the second equation, μ(ρ) is the motility of the bees, θ(ρ) represents the specific mortality rate (t-1), and χ(T) is the thermotactic velocity, which is a measure of the net motion of the bees in the direction of increasing temperature.

Simulations of this model show that the outside temperature determines that size of the colony in the hive (Figure 3) and that mortality of individual bees, due to the stressors that were mentioned earlier, result in a rapid collapse of the colony (data not shown). During the presentation, we argued that inadequate regulation of nest temperature might cause winter losses in honeybees.

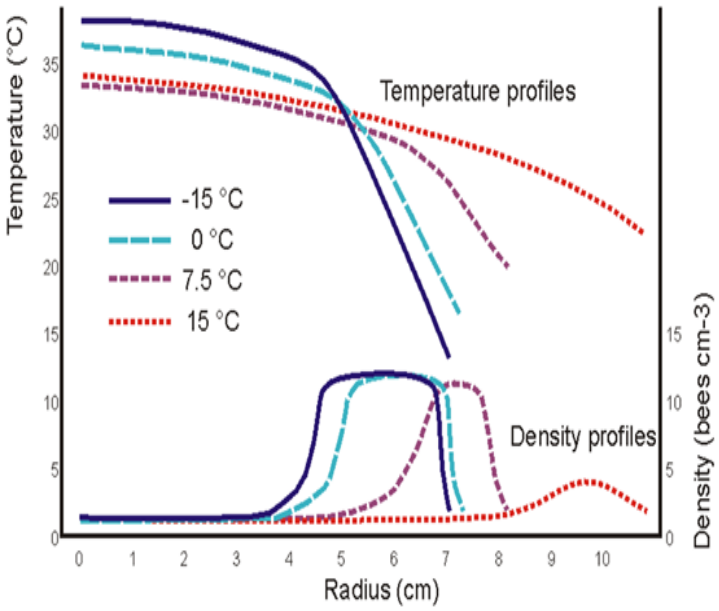

Figure 3. *Profiles of local temperature and bee density predicted by the model as function of the ambient temperature (from -15 °C to 15°C). See text for model description.*

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From WCNRM 2017

Best Student presentation: Jody Mc Kerral

Winner of the student prize WCNRM 2017 for the best presentation in Barcelona as PhD student, Jody McKerral is currently undertaking a PhD at Flinders University, South Australia, supervised by Prof. Jim Mitchell and Prof. Jerzy Filar. She is the recipient of the Fulbright South Australia Postgraduate Scholarship, for which she will undertake a 2018 placement in Albert-László Barabási's laboratory at Northeastern University, Boston. Her research examines universal laws in ecology from the perspective of dynamical and complex systems, aiming to uncover mechanistic processes and develop network models of ecological systems. Other areas of interest include biophysics and fluid mechanics, including microfluidics, diatom nutrient uptake, and energy efficiency of swimming. Jody also collaborates on applications of evolutionary game theory within microbial systems. She is the recipient of the 2017 Australia and New Zealand Industrial and Applied Mathematics Society's AF Pillow Scholarship for "exceptional ability and potential future contribution to the field of Applied Mathematics in Australia". Jody is also a Playford Trust PhD Scholar, University medallist and recipient of the 2015 School of Biological Sciences Honours Scholarship, the Max Clark prize from the Faculty of Science and Engineering for the highest ranked undergraduate academic performance, a Department of Environment, Water and Natural Resources Honours Scholarship, and the Soroptomist International Southern Districts of Adelaide prize for high achieving women. Outside of mathematics, she is a highly awarded classical guitarist, a world champion freediver, and holds a volunteer position as Technical Officer and Director on the board of the Australian Freediving Association.

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