

RMA

The Resource Modeling Association is an international association of scientists working at the intersection of mathematical modeling, environmental sciences, 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 2019



#WCNRM 2020 Valparaiso-Chile

For the first time in South America, the 2020 World Conference on Natural Resource Modeling will be held on January 8-10, 2020 in Valparaíso, Chile, hosted by Universidad Técnica Federico Santa María. The 3-days conference focuses on methods for operationalizing sustainability in the context of natural resource management. Thus, the conference will pay special attention to the main Chilean economical activities: mining, forestry, agriculture, and fishery, as well as to the pollution mitigation, con-

trol of epidemics, and wildfires, among other topics. Chile, as many emerging countries, has an economy strongly depending on its natural resources. A sustainable development based on their exploitation is a major challenge that must reconcile the development of communities and the conservation of the resources. Moreover, this challenge should be addressed under an uncertain future related to climate change. Indeed, Chile is one of the most affected countries by this phenomenon. Although it is responsible only of 0.25% of the world

global emissions, Chile fulfills 7 over the 9 vulnerability conditions defined by the United Nations. This places it among the 10 nations most affected by the climate change, according to the 2017 Climate Risk Index report, presented by Germanwatch agency in the COP22. For instance, drier winters and hotter

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summers are strongly impacting its agriculture and causing an increasing number of wildfires.

Our country, as many others in the world, is truly a natural system at risk, and it is now a hotspot for natural resource modeling!



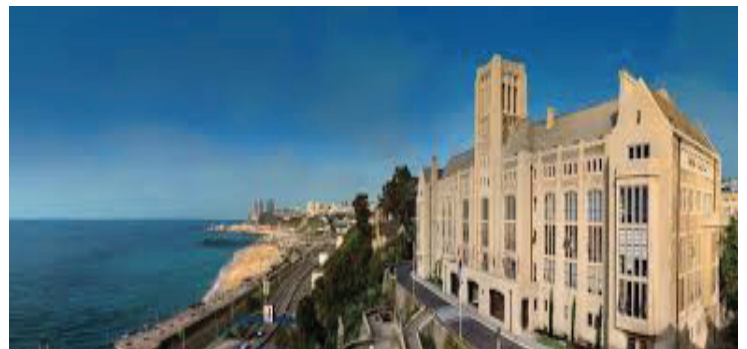
This #WCNRM 2020 conference will be a stimulating opportunity to address the points above in one of the most captivating cities in South America; namely Valparaíso. The Chilean principal port and its second-largest city, Valparaíso is Chile's most distinctive city and one of South America's most intriguing. Occupying a narrow strip of land between the waterfront and the nearby hills, its convoluted center has distinctive, sinuous cobbled streets, and is overlooked by precipitous cliffs and hilltop suburbs, which are accessed by funicular railways and stairway footpaths. Nearby Valparaíso there are excellent spots to appreciate local biodiversity, such as the National Park La Campana and the beaches of Quintay. Casablanca Valley, in the way from Santiago, is also an interesting place to visit, famous for its vineyards. The city of Viña del Mar, known as the "Garden City", is part of the same urban area than Valparaíso and is one of Chile's premier beach resorts. In the (museum) Palacio Rioja of Viña del Mar will be held the second plenary talk (Wednesday January 8; 17h00) followed by a cocktail in its gardens.



The 3-days scientific program features four outstanding keynote speakers:

- Prof. Suzanne Lenhart, Chancellor's Professor in the Mathematics Department at the University of Tennessee, Knoxville (US), will present the talk "Optimal control for management of aquatic population models";
- Prof. Alejandro Maass, Director of the Center for Mathematical Modeling (Chile), Full Professor at the University of Chile, and Associate Researcher of the Center for Genome Regulation (Chile), will present "What optimize communities of microorganisms to configure its dynamical networks?";
- Dr. Eva Plaganyi-Lloyd, Senior Research Scientist at CSIRO CMAR (Australia) will introduce "Methods to model and manage risk in marine natural systems".
- Prof. José L. Torero, Head of the Department of Civil, Environmental and Geomatic Engineering at University College London (UK), will share with us his expertise on major environmental problems such as wildfires, oil-spills or large underground coal fires for which he has developed unique approaches towards impact mitigation.

The WCNRM2020 conference will be held in the main UTFSM campus located in Valparaíso, covering most of the front area of Los Placeres hill. Its magnificent location faces the Pacific coast and is visible from a vast part of the bay of Valparaíso.



We look forward to welcoming the RMA community next January, and we invite you not to miss the opportunity to enjoy the Chilean summer in a stimulating and friendly scientific forum.

For more information, visit the conference website at : <http://www.am2v.cl/wcnrm2020/>

Pedro Gajardo and Héctor Ramírez C.

PRESIDENT'S COLUMN

by Frank VAN LANGEVELDE



In this 'fall' RMA newsletter, I would like to take the opportunity to introduce myself as the new president of the association. I am professor of Resource Ecology at the Wageningen University in The Netherlands. My interest focuses on ecological and evolutionary adaptations of animals to stress (for example predation, human activity). My work is mainly related to large herbivores in African savannas, and I like the combination of statistical and mathematical modelling together with experiments and field studies. Probably not a typical RMA member, as economics is not directly part of my work. However, as being a modeller of biological systems, I feel at home in the RMA. I would like to promote the RMA a bit more among biologists as they can learn a lot from the knowledge and skills present in the RMA.

I would like to express my sincere thanks to Luc Doyen for being the former president of the RMA. Luc, during your period as president, well-attended conferences were organized, the new agreement with our partner Wiley was signed, information sharing by social media was established, and many more mile stones. The new agreement with Wiley will strengthen the sustainability of both the association and our journal NRM (Natural Resource Modeling). It will make possible new activities to enlarge our membership and our scientific influence worldwide regarding the management of natural resources.

We just had our successful annual World Conference on Natural Resource Modeling in Montréal, Canada. The conference had many presentations from all around the world, arising from many disciplines and with a fruitful mix of senior and junior scientists. I would like to sincerely thank Michèle Breton, Baris Vardar, Georges Zaccour together with the GERAD at HEC Montréal as the conveners of the conference! I would like to send a warm welcome to all new RMA members, especially those

that have joined us after the last conference.

A bit earlier than we are used to, our next annual World Conference is about to start January 8-10 2020 in Valparaíso, Chile, hosted by the Universidad Técnica Federico Santa María. The theme of the conference is "Decision support methods for natural systems at risk". At the moment of writing this column, the situation in Chile has stabilized significantly. I would like to welcome you all in this beautiful country on behalf of the conveners Pedro Gajardo (Universidad Técnica Federico Santa María) and Héctor Ramírez (Universidad de Chile). I am convinced that the outstanding keynote lecturers combined with the skills of the organizing team as well as the attractive location will contribute to the success of our next conference.

The communication of the RMA through social media such as ResearchGate, LinkedIn and Twitter is doing well. Do not hesitate to use these media to circulate information in line with the objective of the RMA, such as new academic positions, conferences, workshops, books, papers. It would be great if these media can also be used for topics related to the focus of the RMA to be discussed among the members and others.

The objective of the RMA is to foster research and teaching at the interface of ecology, economics, mathematics and computer sciences and devote to the sustainable management of natural resource and ecosystems. As members of the RMA we have the possibility to promote the global interest in sustainability and environmental issues and help to find solutions. I hope that the upcoming conference, the NRM journal, the RMA newsletter and social media will help us with this.

Looking forward to meet in Chile!

Frank van Langevelde
President RMA,
Professor Resource Ecology
Wageningen University
The Netherlands

Recovery time for a population subjected to an environmental disturbance

by Azmy S. Ackleh, Hal Caswell, Ross Chiquet, Tingting Tang, Amy Veprauskas

Laureates 2019 of the Lamberson Award



On January 1, 2014 a new consortium was formed and funded by the Gulf of Mexico Research Initiative (GoMRI). The consortium was named Littoral Acoustic Demonstration Center-Gulf Ecological Monitoring and Modeling (LADC-GEMM). The researchers in this consortium have multidisciplinary expertise including acoustic physics, oceanography and mathematical modeling. The overarching project that the consortium has been focused on since its initiation is to understand the impact of the 2010 BP oil spill incidence on the dynamics of marine mammals that inhabit the Gulf of Mexico.

This paper is inspired by the overarching project of the consortium. In particular, for a slow growing population, such as Gulf Marine Mammals (Chiquet et al., 2013), an environmental disturbance may affect the vital rates of the individuals in that population and may result in a declining population. In this paper, we examine the recovery time, the time it takes for a population to return back to pre-disturbance total density or biomass, and how different factors (e.g., changes in vital rates, disturbance magnitude and duration) affect the recovery process. Understanding the recovery process of a population subjected to manmade or natural disturbance can aid in management decisions including establishing regulations on harvesting or habitat quality. Clearly, there are many factors affecting the

recovery time. For example, the vital rates (fecundity and survivorship) during the recovery process are particularly important to the length of the recovery time since the impact of many other factors are realized through them. By estimating the recovery time for different values of vital rates or disturbance properties, one can better understand the recovery process and subsequently choose reasonable intervention strategies.

In this work, we derive new formulas for the sensitivity of the recovery time to changes in the initial population structure, vital rates, and environmental factors. This sensitivity analysis pinpoints which factors contribute the most to the recovery process. The techniques used in the sensitivity derivations are general enough to be applied to various models. They can also be used to obtain the mean recovery time and upper and lower estimates of the recovery time for a population experiencing demographic stochasticity provided that the recovery probability is equal to or near one. Thus, these formulas provide an alternative to stochastic simulations that has the advantage of being computationally efficient and does not require solving the stochastic model thousands of times to generate a mean recovery time.

MODELING FRAMEWORK

We desire to create a general framework that can apply to different populations to identify key compo-

nents in the recovery process. Thus, we use a general matrix modeling approach to study the recovery process of a population given an environmental disturbance. In particular, we consider a population described by a discrete-time, stage-structured matrix model. We divide the female population at time t into m stages described by the vector $n(t) := [n_1(t); n_2(t); \dots; n_m(t)]^T$, where T denotes the transpose of a vector.

Given the population at time t , the population at time $t + 1$ is determined by the projection matrix $A[\theta(\epsilon(t)), \epsilon(t)]$. Here, $\epsilon(t)$ describes the environment at time t and $\theta(\epsilon(t))$ represents the environment dependent vital rates. This leads to the non-autonomous matrix model

$$(1) \quad n(t + 1) = A[\theta(\epsilon(t)); \epsilon(t)]n(t);$$

where $t = 0; 1; 2, \dots$

In our developed theory we assume that the time when an environmental disturbance occurs is $t = 0$, the population experiences proportional reductions in vital rates following a disturbance given by ϵ_0 , and the population before the disturbance was growing in numbers even if growth is slow. The latter assumptions means the dominant eigenvalue of $A_0 := A(\theta(0); 0)$ is greater than one, that is $\rho[A_0] > 1$. We also assume that over time the impact of the disturbance vanishes and the vital rates begin to recover until they reach their predisturbance level. In general, such a recovery of the vital rates approximately follows a sigmoid curve, but as shown in Ackleh et al. (2017), a constant reduction followed by the complete recovery of the vital rates provides lower and upper bound estimates for such sigmoid functions. Thus, to model the process of environment recovery after an event, we consider the following step recovery function:

$$(2) \quad \epsilon(t) := \begin{cases} \epsilon_0, & 0 \leq t < T_C \\ 0, & t \geq T_C, \end{cases}$$

where $0 < \epsilon_0 < 1$. For instance, ϵ_0 could represent reductions caused by abnormally high toxicant levels due to an oil spill or low food sources due to flooding. Here, T_C is the time when the negative effect caused by the environmental event disappears. To examine the recovery process, we focus on the recovery time which we define to be the first time after T_C at which the population has recovered to its pre-event size.

Using equations (1) and (2), the matrix model solution can be written as

$$(3) \quad n(t + 1) = A_0^{t-T_C} A_{\epsilon_0}^{T_C} n(0).$$

Let $N(t) := \mathbf{1}_m^T n(t)$ denote the total population size at time t , where $\mathbf{1}_m$ is a $m \times 1$ vector of ones. Then the recovery time, denoted by T_{rec} , is the first integer $t + 1 > T_C$ that satisfies $N(t + 1) \geq N(0)$ or, from equation (3),

$$(4) \quad \mathbf{1}_m^T A_0^{t-T_C} A_{\epsilon_0}^{T_C} n(0) \geq N(0).$$

We define the $m \times 1$ vector $p(t)$ to be the population distribution of individuals from all stages at time t so that $n(t) = N(t)p(t)$. For notational simplicity, we use N_t and p_t to denote the total population and population distribution at time t , respectively. Using this notation, equation (4) is equivalent to

$$(5) \quad \mathbf{1}_m^T A_0^{t-T_C} A_{\epsilon_0}^{T_C} p_0 \geq 1,$$

where p_0 is the population distribution at time $t = 0$. The assumption that $\rho[A_0] > 1$ guarantees that a solution to equation (5) exists.

Therefore, in order to understand the sensitivity of the recovery time T_{rec} to various parameters, we can study the recovery equation

$$(6) \quad 1 = \mathbf{1}_m^T A_0^{t-T_C} A_{\epsilon_0}^{T_C} p_0$$

The recovery time T_{rec} , as defined by equation (5), can be obtained by solving equation (6) and rounding the solution up to the next integer value. Meanwhile, the sensitivity of T_{rec} with respect to a perturbation in a variable θ , $dT_{rec}/d\theta$, can be obtained by implicitly differentiating equation (6), solving for $dt/d\theta$, and evaluating this quantity at a solution pair (θ, t) of equation (6).

RESULTS ILLUSTRATING THE UTILITY OF THIS FRAMEWORK
General sensitivity formula. By differentiating both sides of (6) with respect to the magnitude of impact of the disturbance and solving for the sensitivity of the recovery time, we obtain the following new formula:

$$(7) \quad \frac{dT_{rec}}{d\epsilon_0} = - \frac{\mathbf{1}_m^T A_0^{T_{rec}-T_C} (p_0^T \otimes \mathbf{I}_m) \frac{d(A_{\epsilon_0}^{T_C})}{d\epsilon_0} \frac{d\text{vec}[A_{\epsilon_0}]}{d\epsilon_0}}{(A_{\epsilon_0}^{T_C} p_0)^T (\mathbf{I}_m \otimes \mathbf{1}_m^T A_0^{-T_C}) \frac{d\text{vec}[A_0^{T_{rec}}]}{dT_{rec}}}$$

Here, the \otimes operator denotes the Kronecker product and the vec operator stacks the columns of a matrix to make a column vector.

In a similar manner we can use (6) to derive sensitivity formulas of the recovery time to the vital rates θ or the initial population distribution p_0 (see, Ackleh et al., (2019)).

APPLICATION TO A SPERM WHALE MATRIX MODEL.

We next present an application of the sensitivity formula (7) to a sperm whale model that was developed in Chiquet et al. (2013). In this model the population of sperm whales is divided into five stages: calves, juveniles, mature females, mothers and post-breeding females. Here we assume that the disturbance causes reductions in survival rates.

In Figure 1 (left), we present the solution of (7) when the duration of impact of a disturbance is fixed at $T_C = 10$ years. From this figure, we observe that, if a disturbance causes a 5% reduction in survival rates, that is $\epsilon_0 = 0.05$, then $dT_{\text{rec}}/d\epsilon_0 = 1089$. This means that a 20% increase in this reduction, that is increasing ϵ_0 to $\epsilon_0 = 0.06$, would increase the recovery time by approximately 11 years. Since this graph is increasing, increases in larger values of ϵ_0 will result in even larger increases in the recovery time. For instance, if the reduction is increased from 20% to 24% (also a 20% increase), then the recovery time is increased by approximately 53 years.

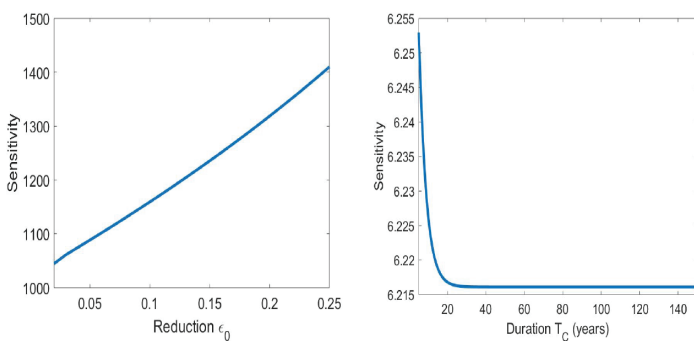


FIGURE 1. The sensitivity of recovery time to changes in (left) ϵ_0 and (right) T_C

For comparison, in Figure 1 (right) we give the sensitivity of the recovery time with respect to changes in the duration of impact T_C when ϵ_0 is fixed at $\epsilon_0 = 0.05$. In this graph, we observe that, as T_C increases, the sensitivity approaches a value close to six. Thus, each additional year of impact results in approximately six additional years of recovery. From these figures, we may conclude that the re-

covery time for sperm whales is more sensitive to changes in the magnitude of impact than the duration of impact. This suggests that management strategies aimed to mitigating the impact of a disturbance should focus on reducing this magnitude.

In the case of an oil spill, this might include strategies such as removing oil from the water. Similar calculations also reveal that the recovery time is more sensitive to changes in the survival of the adult class than changes in survival of the juvenile classes, suggesting that directed management strategies should focus on improving survival rates of mature individuals.

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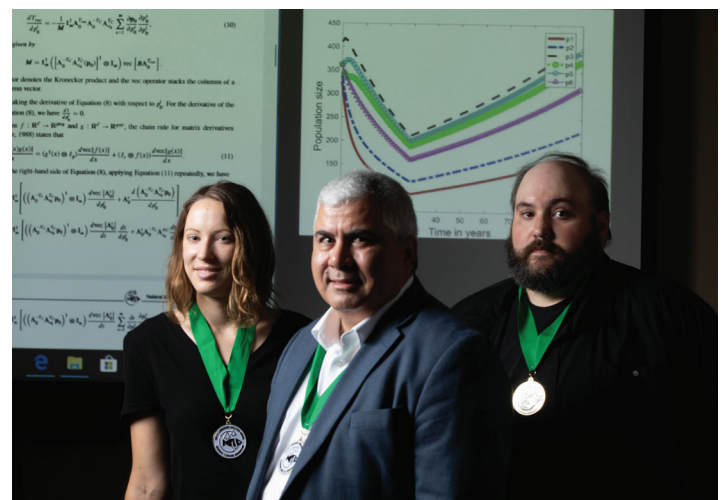


Figure 2. Left to right: Dr. Amy Veprauskas. Dr. Azmy S. Ackleh. Dr. Ross Chiquet.

Estimating the economic damages of United States invasive forest pests

by Emma Hudgins, McGill University, Montreal, Canada

Accurate economic assessments of the impacts of non-native species are needed to effectively inform policy controlling management practices, as well as to incentivize cost-effective spending to control invasions. Urban trees are the main target of economic damages due to invasive forest pests in the United States (Aukema et al. 2011). Estimates of damages due to pest species are frequently cited and used in policy recommendations, but are currently out of date.

In spite of existing data limitations, subcomponent models relying on partial information can be combined to produce higher resolution estimates. This project combines three existing frameworks to more accurately estimate future damages to US urban trees due to invasive forest pests: an existing economic approach, a recent modelling framework for US urban tree distributions, and forecasts of forest pest spread derived from earlier work.



Figure 1. A selection of highly damaging invasive US forest pests.

Images from Kewaunecomet.com, Bugguide.net, iNaturalist.

Using these frameworks, we combine estimates of the tree population in roughly 30,000 US communities, estimates of future tree exposure due to pest spread, estimates of tree death due to pest exposure, and a simple model of human behaviour in response to tree death. This approach modifies the existing damage estimates to incorporate species-

specific spread predictions and spatial models of host distributions.

We chose to focus only on damages to street trees, because they have been surveyed the most thoroughly across the US and they are likely to be managed the most consistently. Koch et al. (2018) created a database of urban trees in the Eastern US from the amalgamation of multiple community inventories, which we used to model the number and size class trees in each community. We modelled the genus-specific street trees in a community using a combination of poisson GAMs and Boosted Regression Trees relating the trees within a DBH size class to environmental variables and community characteristics.

We derived host mortality estimates from Potter et al. (2019), who created a database that categorized pest threats to each host species by severity. Some of these categories were very broad (e.g. 25-95% mortality). We expect that deadly pests are more rare than innocuous ones. Based on this logic, we chose to model the host mortality frequency distribution with a Bayesian approach. We fit a Beta distribution to the frequency distribution of pests in each mortality category (Fig. 2). Simultaneously, we fit parameters for the upper limit of the two lowest mortality categories and the lower limit of the highest category, which had imprecise values (e.g. >95%), but could be ranked relative to others.

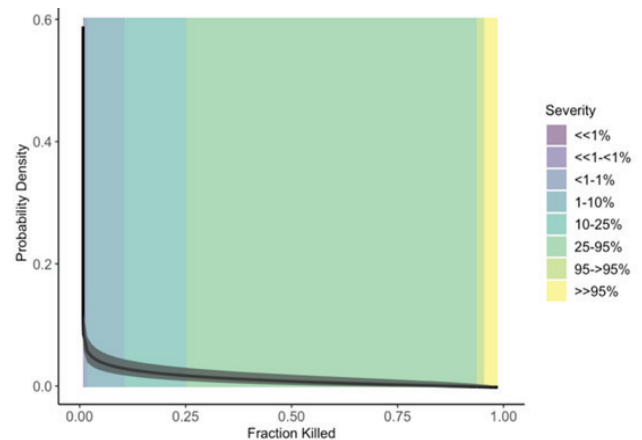


Figure 2. Curve from Bayesian host mortality analysis (95% Bayesian Credible Intervals in Grey) overlaid on mortality categories from Potter et al. (2019).

The expected mortality for a pest in each category is the point along the x axis within each bin where 50% of the area under the curve lies.

To convert estimates of invisable urban hosts into cost estimates of host damage, we modelled spread using the Semi-Generalized Dispersal Kernel (SDK, Hudgins et al. 2019). This is a spatially explicit, negative exponential dispersal kernel model that can account for additional spatial predictors in source and recipient sites. As a final, simple layer that allows us to move from mortality estimates to cost estimates, we made several assumptions about the human response to tree mortality. Because preventative behaviour is much harder to estimate, we estimated what we believe is the minimal management response required: only dead trees are managed, and that they are managed by removal and replacement.

Once all subcomponent models had been appropriately parameterized, we could combine the urban tree estimates, pest spread estimates, host mortality estimates, and management responses to obtain cost estimates. We explored uncertainty in many modelling phases, most importantly in the dynamics of what we dub ‘mortality debt’, which we define as the time period between a pest initiating damage within a community and it reaching its maximum possible host mortality within that community. Previous estimates have ranged from 10-100 years (Aukema et al. 2011) so we tested this range. We summed the damages from 2020-2050 to get a total discounted cost for this 30-year window. We then obtained annual costs by calculating an annuity over the 30-year time horizon.

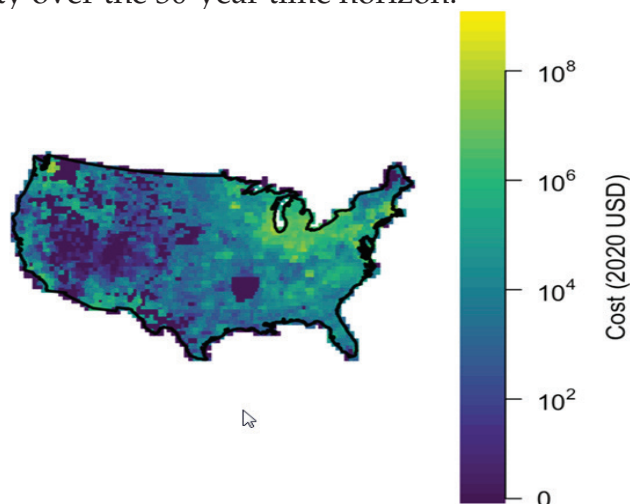


Figure 3. Spatial distribution of total estimated economic damage to street trees due to US invasive forest pests from 2020-2050.

We estimate up to 10% of street tree losses by 2050. Street tree damages vary by an order of magnitude based on mortality debt scenario, with shorter debts leading to lower costs. We estimate annualized costs between \$22-170M USD. Over time, street tree damages vary by an order of magnitude based on mortality debt scenario, with shorter debts leading to lower costs. Spatially, future damages will be primarily borne in the northeast (Fig. 3). These patterns are driven primarily by emerald ash borer spread. This cost estimate is arguably a lower bound, at least for street trees. In cities such as Montreal, trees are being preventatively sprayed for emerald ash borer, and similar schemes exist in many US cities. As such, preventative behaviour is a key additional cost that merits future study. Secondly, given the strong sensitivity of cost estimates to mortality debt, any information that could narrow its range across species would substantially decrease uncertainty, and should be the focus of future work.

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New RMA Officer: Oceania Representative

Dr Matthew Holden



Dr. Matthew Holden is an applied mathematician using dynamic models and decision theory to improve conservation planning when conservation benefits depend on how humans modify their behaviour in response to policy. Some of his projects include illegal use and trade of natural resources, fisheries management, and invasive species management. He earned his PhD in Applied Mathematics at Cornell University, and is currently Lecturer & ARC DECRA Fellow at the School of Mathematics & Physics of The University Of Queensland, and the Centre for Biodiversity and Conservation Science in Brisbane, Australia.

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Recycling opportunity under environmental impacts

by Etienne Lorang, Gilles Laforgue,

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The concept of “circular economy” emerged at the end of the 20th century and is often presented as a key pillar toward a sustainable economic model. Leaving the “produce, consume, throw away” linear model, recycling is viewed as a key element of this new approach, such as closed-loop supply chains, services economy and eco-design. With development difficulties of specific markets and industries, recycling struggles to compete with regular production, especially when approaching high recycling rates. For instance, France shows a rate of 40% for household solid waste (Eurostat 2015) with especially low rates for plastic packaging (26%, PlasticsEurope, 2016).

Material	Paper	PET	Aluminum	Glass ^a
δ_v (kg CO ₂ e/t)	297	3 270	9 827	923
δ_r (kg CO ₂ e/t)	317	202	513	409

Table 1: Emissions rates in France (Federec and ADEME)

The economic literature has been addressing the topic of recycling since the 1970's, with development levers such as delaying the exhaustion of natural resources and mitigating private and social costs of waste accumulation, [5][4] leading to policy implications. [3] However, a more recent approach also involves pollution and climate externalities linked to resources extraction and consumption. [2][1]. Moreover, recent approaches of the circular economy encourage the use of a holistic approach, thus evaluating different interactions between human activity and natural environment, when recycling is considered. In addition, to considering resource exhaustion and waste accumulation, we also introduce greenhouse gas emissions.

For this analysis we model an industrial sector with a recycling loop available and externalities coming from stocks: resources exhaustion, waste accumulation, free access to waste for the recycler and cu-

mulative greenhouse gas emissions, as modeled in Figure 1.

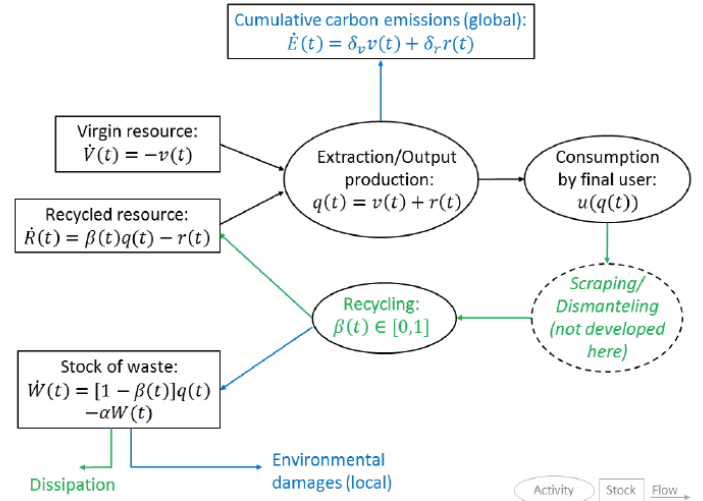


Figure 1: Global structure of the model, with stocks and flows.

The social planner chooses resource quantities v , r and the recovery rate β to maximize the discounted social welfare. We use constant marginal costs of resource use $c_v < c_r$, convex recycling costs $qf(\beta)$, a damage from waste accumulation, a carbon budget E and a finite planning horizon. This model introduces a competition between the use of the two resources, virgin and recycled, the outcome of which is determined by the least cost principle. We also assume that the virgin resource is relatively abundant (coherent with a carbon budget properly set to meet climate objectives) and a scarce recycled resource. We use λ_i for the social cost of i , all positive $\forall i \in \{v, r\}$. The analysis of the full marginal costs of resources

$FMC_v = c_v - \beta\lambda_r + \delta_v\lambda_E + (1-\beta)\lambda_W + f(\beta)$ and $FMC_r = c_r + (1-\beta)\lambda_r + \delta_r\lambda_E + (1-\beta)\lambda_W + f(\beta)$ shows an arbitration including private costs $c_{v,r}$, social costs of resources $\lambda_{v,r}$ and emissions $\delta_{v,r}\lambda_E$. However recycling social and private costs ($f(\beta)$) and waste accumulation do not intervene. This arbitration leads to at most one switch of input, from virgin to recycled, on the condition that extracting polluted more than recycling, and the associated

social cost difference $[(\delta_v - \delta_r)\lambda_{E0} - \lambda_{R0}]e^{\rho t}$ weighs more than the private costs difference $c_r - c_v$, as Figure 2 shows.

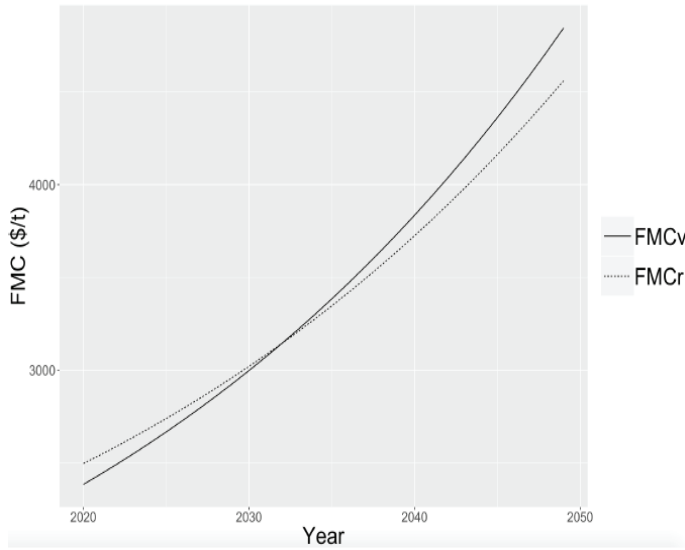


Figure 2: Full marginal costs with a switch of inputs

Regarding the optimal recycling path, the first-order condition on waste stream recovery gives the marginal social benefit of recycling $\Phi_\beta(t) = \lambda_R(t) + \lambda_w(t)$. It shows the motivations for waste recovery: reducing the waste impact and providing a future input for production (a speculative activity). This social benefit must be equal to the marginal cost of recycling, $\Phi_\beta = f'(\beta)$. Cost function $f(\beta)$ being convex, the shape of Φ_β shows (Figure 3) increasing or decreasing recycling rates, with possible saturation when recovering is not beneficial enough.

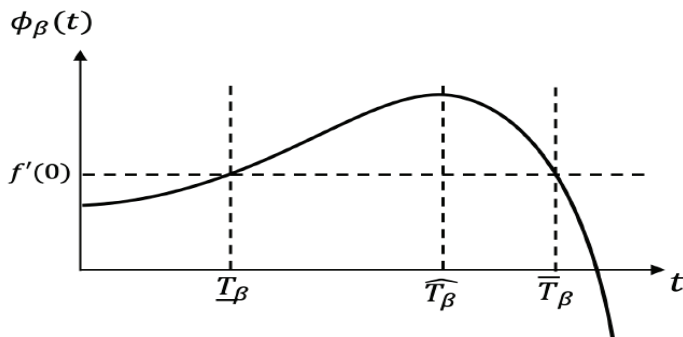


Figure 3: Saturation of β

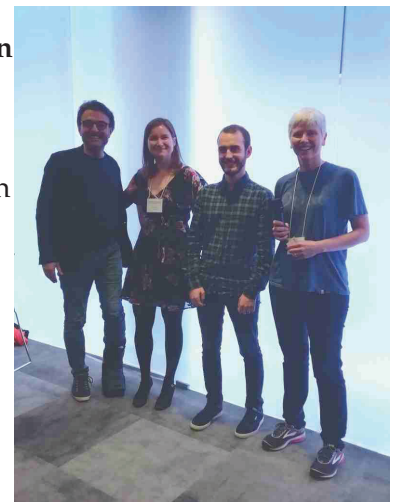
Finally, this model allows us to describe the different trade-offs in place when considering an industrial sector with a recycling technology and different constraints. We show that with a high enough difference in greenhouse gas emission rates, there is a switch from the use of virgin to recycled input. Otherwise, high private costs for recycling fosters extraction, raising concerns for sectors like paper or cardboard when the climate constraint is taken into account (Table 1). Besides, numerical sensitivity analysis show that strengthening the carbon policy (lowering the carbon target) fosters the use of the recycled input, while lowering total production, as the use of both are polluting activities.

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Best Student presentation laureates:

Emma Hudgins and Etienne Lorang, kindly surrounded by Luc Doyen and Shandelle Henson.



In Memoriam, Terrance J. Quinn II



On May 3, 2019, Prof. Terrance J. Quinn II passed away in Rancho Cucamonga, California, surrounded by friends and family. After receiving his PhD in biomathematics from the University of Washington in 1980, Terry was recruited

in 1985 to join what was then the School of Fisheries and Science as part of the University of Alaska Juneau. Terry was granted tenure in 1991 and promoted to full professor in 1998. He retired and became professor emeritus in 2018. Terry's class on fisheries population dynamics became a core part of a graduate-level fisheries degree at UAF. This course was taken by an entire generation of Alaskan graduate students who went on to be leaders in fisheries management in Alaska and elsewhere. That course became the basis of his book, *Quantitative Fish Dynamics*, which was published in 1999, coauthored with his friend Rick Deriso and that remains a widely used reference for graduate courses in fish population dynamics.. Terry was an internationally recognized expert in fishery population dy-

namics, with over 100 peer-reviewed scientific publications. He collaborated with colleagues all over the world, especially in Chile, New Zealand, South Africa, and Canada. Among the many awards and honors he received, he was most proud of the Wally Noerenberg award from the Alaska Chapter of the American Fisheries Society in 2009 and an Award of Recognition and Appreciation he received from the North Pacific Fishery Management Council in 2016. He was a member of Ocean Studies Board of the National Research Council from 1995 to 1998. He served on five NRC committees and chaired two of those, all leading to NRC publications. He was an associate editor of the *Canadian Journal of Fisheries and Aquatic Sciences* for over 15 years.

In addition to attending many WCNRM meetings, Terry helped organize both WCNRM meetings held in Juneau, Alaska (1995, 2009) and was a keynote speaker at the WCNRM meeting in 2001 (Logan, Utah). His keynote remarks were published in *NRM* (Quinn II, T.J., 2003. Ruminations on the development and future of population dynamics models in fisheries. *Natural Resource Modeling*, 16(4), pp.341-392.).

Terrance has been designated RMA fellow in 2019.

WCNRM 2021, Leipzig

In 2021, World Conference on Natural Resources and Management will be held *at German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig and University of Leipzig.*

Prof. Martin Quaas will be the main convenor of WCNRM, more details to come in the spring newsletter!



Editor's Column

WCNRM 2018 : Special Issue on Economic Modeling of Natural Resources for Sustainable Development

by Shandelle M. Henson,
Editor-in-Chief



The third issue of Natural Resource Modeling in 2019 (Volume 32, Issue 3) is a special issue devoted to papers delivered at WCNRM 2018 in Guangzhou,

China. The papers center on the economic modeling of natural resources for sustainable development. Professor Krishna Paudel, who holds the Gilbert Durbin Endowed Professorship in the Department of Agricultural Economics & Agribusiness at Louisiana State University, Baton Rouge, Louisiana, USA, edited the special issue. You can find the issue at

<https://onlinelibrary.wiley.com/toc/19397445/2019/32/3>.

Papers in the issue center on the areas of water, fisheries, forestry, and agriculture. Here I mention very briefly the topics of the papers; for more descriptive summaries, see Professor Paudel's editorial :

<https://onlinelibrary.wiley.com/doi/epdf/10.1111/nrm.12238> and the abstracts.

In "Innovation as a policy strategy for natural resource protection" Jeffrey Peterson explores how investments in eco-innovation can benefit both the environment and agricultural producers, leading to solutions better than those achieved by environmental policy alone.

Susaeta and Gong, in "Optimal harvest strategy for even-aged stands with price uncertainty and risk of natural disturbances", show that forestry investment should consider two risks: uncertainty in future timber prices as well as risk of catastrophic events.

Dahmouni et al. ("A fair and time-consistent sharing of the joint exploitation payoff of a fishery") demonstrate that a cooperative solution can provide higher payoff than a noncooperative solution in the presence of pollution.

In "Transboundary extraction of groundwater in the presence of hydraulic fracturing", Poudel and Paudel consider groundwater management in the presence of hydraulic fracturing. Their work suggests that a tax on fracking may reduce economic damage

and that policy makers should consider the total cost and benefit of fracking.

Chen et al. ("Farm households' rice production behavior in China under a separability assumption: A metaheuristic optimization approach") consider optimal production strategies under the assumption of separability of consumption and production in Chinese households.

In "The impact of environmental regulations on forest product trade in China", Zhang et al. look at the effects of environmental regulations on forest products trade in China.

I hope you enjoy the special issue dedicated to WCNRM 2018 Guangzhou. I warmly thank Professor Krishna Paudel for his excellent work and collegial interactions in editing this issue. I also am grateful to the authors who submitted their work for the issue. Finally, a big thanks goes to the organizers of the Guangzhou meeting and all those who supported it.

Would you like to guest edit a special issue from a conference, from a particular area of natural resource modeling, or in honor of a mentor? I welcome your ideas! Please write to me at: henson@andrews.edu.

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*The official newsletter of the
Resource Modeling Association*

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