

RMA

The Resource Modeling Association is an international association of scientists working at the intersection of mathematical modeling, environmental sciences, sustainability sciences, and resource management. We formulate and analyze models to understand the dynamics of natural resources and promote their sustainable management.

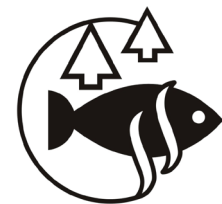
RMA newsletter | Spring 2023



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PRESIDENT'S COLUMN

by Frank VAN LANGEVELDE



Under the 2015 Paris agreement, countries agreed to pursue efforts to limit global temperature rises to 1.5C. At the current rate, however, people are burning fossil fuels, so that only seven to eight years remain before this 1.5C limit is passed. The predictions are that sea level will rise, putting many people at risk from coastal storms and flooding, and that heat waves will continue to get worse, exposing a large part of the world population to extreme heat frequently. We already see many examples of these events happening around us. At the same time, biodiversity is declining with an alarming rate. I believe that the Resource Modelling Association (RMA) can help to prevent global temperature rise, mitigate negative effects of this increase, and protect the rich biodiversity and natural resources. 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 resources and ecosystems. As members of the RMA, we have the possibility to promote the global interest in sustainability and environmental issues such as climate change and biodiversity loss. Let's discuss these issues when we meet during the next World Conference on Natural Resource Modeling WCNRM23.

The WCNRM23 will be organized from 20-23 June in Amsterdam. I hope to meet all of you in person again. We will enjoy the rich culture of Amsterdam, which is an old city with many attractions. In the 12th century, Amsterdam was founded at the mouth of the Amstel River. Amsterdam's main attractions include its historic canals, the Rijksmuseum, the state museum with a vast collection Dutch Gold Age art, the Van Gogh

Museum. Takes some extra days before or after the conference to have a look in Amsterdam. The theme of the conference will be "Biodiversity loss and climate change as challenges for natural resource management" and four well-known keynote speakers will give their view on this topic: Anne-Sophie Crépin (Beijer Institute, Sweden), Robert Holt (University of Florida, USA), Martin Quaas (Universität Leipzig, Germany) and Max Rietkerk (Utrecht University, The Netherlands). These keynote speakers will set the stage for our thinking about modelling natural resources that are heavily exploited. Many scientists from all around the world will present their work during the conference. The journal Natural Resource Modeling prepares a special issue resulting from the conference, we will provide more information during the conference. I am looking forward to meet you all again and enjoy a wonderful conference.

The board of the RMA proposes dr. Krishna P. Paudel as nominee for the next RMA president. Krishna is deputy director for research and communications in the Resource and Rural Economics Division at the USDA's Economic Research Service. In his research, he focuses on water quality and quantity, technology adoption, and international development economics. He will be appointed during the next WCNRM23. Let me know if someone else also wants to be nominated.

The RMA frequently communicates through social media such as ResearchGate, LinkedIn and Twitter, which are also open for your input. We 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.

Looking forward to meet in Amsterdam and I want to send my very best wishes to everyone in the RMA community!

Frank van Langevelde, President RMA
Professor Wildlife Ecology and Conservation
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Laureates 2022 Lamberson Award

Optimal control of harvest timing in discrete population models

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When managers employ harvesting as an intervention, such as in fisheries and pest control, they take into consideration a broad variety of factors including expected yield, expected next season population size, expected cost, and harvest timing. Until now, models of harvest timing have been continuous in time with the exception of the Seno model (Seno, 2008). We mechanistically derived two discrete-time models with explicit harvest time and yield and performed optimal control analysis on these models.

To derive our models we assumed that seasons were of unit length, and considered the events taking place within one season. Such events would vary widely depending on the ecology of the application and our models serve as examples only. We assumed that within each season the population undergoes a sequence of three events: density-dependent mortality throughought the season; proportional harvest at rate γ at time θ_t within the season; and a density-independent recruitment pulse which occurs immediately before census.

By solving an ODE for the mortality process in each of the two models, we arrive at a difference equation to represent the population dynamics. The next-generation population size for our Beverton-Holt type model is determined by

$$N_{t+1} = \frac{b(1 - \gamma)N_t}{1 + N_t\beta(1 - \gamma(1 - \theta_t))},$$

with yield given by $Y_t = \frac{\gamma N_t}{1 + N_t\beta\theta_t}$.

Our second model we refer to as the Ricker-type model reads:

$$N_{t+1} = b(1 - \gamma)N_t e^{-\mu N_t},$$

which is interestingly independent of the harvest time and whose yield is given by: $Y_t = \gamma N_t e^{-\mu N_t \theta_t}$.

For our mechanistic models, we consider possible components of a management goal and some simple ways of incorporating them into our objective functional. The objective functional we wish to maximize as a function of harvest timing and intensity is given by

$$J(\theta, \gamma) = A_T N_T + \sum_{t=0}^{T-1} \left(\delta^t \left(A_t N_t + B_t Y_t - C_1 \left(\frac{1}{2} - \theta_t \right)^2 - C_2 \gamma_t - C_3 \gamma_t^2 \right) \right),$$

where $\delta \in (0, 1]$ is a discount factor. We assume $A_t, B_t \geq 0$, indicating weights on how important it is to managers to maximize population at time t and yield at time t respectively. The term $C_2 \gamma_t + C_3 \gamma_t^2$ represents the non-linear cost of harvest. The cost of harvesting may vary depending on the time of the year, due to ease of harvest or labor seasonality. Here, we consider the term $C_1 \left(\frac{1}{2} - \theta_t \right)^2$, which indicates that the cost of harvest is minimized in the middle of the season. Qualitatively similar results can be obtained with harvest cost having a minimum at other intermediate points in the season.

We perform optimal control of our Beverton-Holt type model and of our Ricker type model with two controls (θ, γ) , by direct optimization of the objective functional in MATLAB with MultiStart choosing start points to employ in fmincon. In Figure 1, the optimal state is shown in the left in blue circles while the optimal harvest timing is shown on the horizontal axis in black squares, with its position marking the time of optimal harvest. The optimal harvesting intensity is shown in the right in pink diamonds.

While performing optimal control of our Beverton-Holt type model, we discovered that some choices of parameters give rise to cycles. These cycles might be in the optimal control and/or state, a phenomenon not present in the dynamics in the absence of optimal control. Figure 1 shows an example of cycles in the optimal control and state. Cycles also occur in the Ricker-type model where they don't exist in the absence of harvesting.

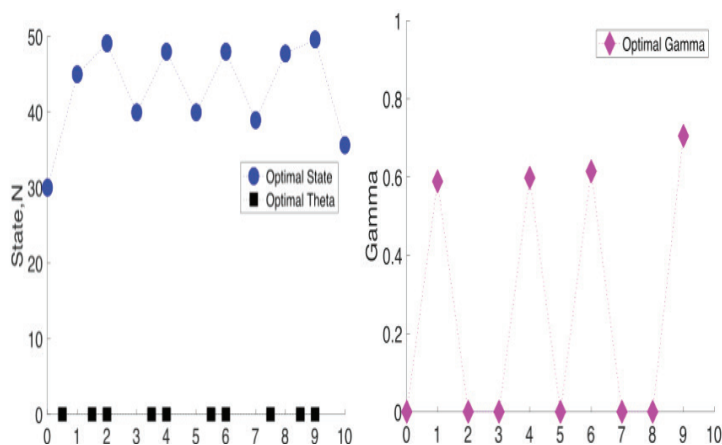


Figure 1: Parameter values are given in the paper <https://doi.org/10.1111/nrm.12321>

We observed cycles in two kinds of scenarios, both with high cost placed on harvest timing. We hypothesize that the cycles are caused by an alternating focus on maximizing yield (via a high harvest intensity early in the season when the population size is large) in one season and on minimizing harvest-related costs in another season (via harvesting close to mid-season and as little as possible). As the latter allows the population to recover, there is sufficient stock again in the next season to generate revenue from intense harvesting, and the cycle repeats. Hence, the oscillations may be based on the fact that yield, population size, and harvest-related costs contribute to the objective functional, which can be maximized by a rotational pattern in time. This suggests that a key ingredient for the cycles to occur is the possibility that both the harvest intensity and harvest timing can vary from season to season, i.e. that both controls are time-varying. The oscillations are remarkable because we do not know of another harvesting model that is able to destabilize Beverton-Holt population dynamics (except for a harvest control rule inducing a discontinuity in the dynamical system; (Lois-Prados & Hilker, 2022)). Here, we have demonstrated for the first time that cycles can emerge as the optimal strategy when harvest timing is taken into account.

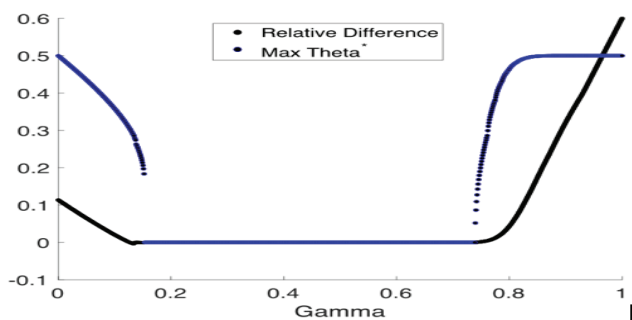


Figure 2: Optimal control of harvest timing only for fixed values of harvest intensity. In black we have the relative difference of the objective functional compared to harvesting at the beginning of the season. In blue we have the maximum value of the harvest timing vector θ^* for each value of γ .

We found that there are some cases where mid-season harvest is preferable to beginning- or end-of-season harvest. Figure 2 shows some of these cases. This is a novel result, based on taking into account harvesting costs. If time-dependent harvesting costs are ignored, existing theory predicts largest population sizes at the beginning of the season (Kokko & Lindström, 1998). A strong Allee effect population size has been reported to lead to non-monotonic relationships between equilibrium population size and harvest timing, with population size initially decreasing and later increasing - but it is unclear whether they could grow larger than at the beginning of the season (Cid et al., 2014). In general, whether controlling only harvest timing or both harvest timing and harvest intensity, mid-season harvest tends to occur when yield and harvest intensity are low, or when cost associated with harvest timing is high. Low yield might result from low intensity harvesting, or from depletion of stock due to high intensity harvesting, or as an intermediate season (or two) in a cycle between a high intensity and high yield season. Indeed, under some circumstances mid-season harvest is not only preferable to beginning- or end-of-season harvest, but the only option that will result in a profit rather than a loss.

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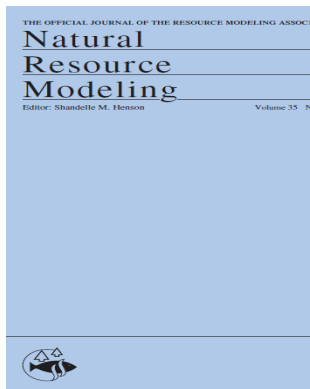
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Natural Resource Modeling

The official journal of the RMA

EDITOR IN CHIEF REPORT BY JOHN HEARNE

Shandelle Henson resigned as Editor in Chief at the end of last year. Shandelle was responsible for producing six volumes (30-35) of the journal. Under Shandelle's leadership the cites per article increased every year bar one. Shandelle introduced changes to the categories of articles published. An important innovation was the introduction of a requirement for authors to highlight a paper's recommendations to resource managers. She also successfully saw the transition of the journal to Gold Open Access. Thank you Shandelle for your work in maintaining and improving the journal over the six years you served as EIC.

New Editor In Chief: From this year I have been appointed as the new EIC for NRM. I have been actively involved with the RMA for three decades, serving as President twice, and as conference organiser three times (Pietermaritzburg, Melbourne, Barcelona). You can find more details about me at <https://hearne.online/>.

Relationship between RMA and NRM: The journal was originally started by members of the RMA in the 1980's and for a couple of decades was published by the Rocky Mountains Mathematics Consortium. It is now a Wiley Online journal. The journal provides an opportunity for authors to present to the RMA community new ideas and concepts in more rigorous detail than is possible at conferences. There is a symbiotic relationship between the RMA and the NRM journal. Wiley provides funds to the RMA which is used to subsidise the annual RMA conference. The conferences provide an opportunity to solicit articles for a special issue of the NRM. The Wiley contribution to RMA is dependent on the success of the journal so please submit your research papers to NRM.

Gold Open Access: A couple of years ago NRM became a Gold Open Access journal. Articles published in NRM are freely available to everyone to download and read. OA journals on average have seen cites increase by more than 50%. There is an Article Publication Charge (APC) but this should not discourage you from submitting to NRM. Authors from various countries get automatic fee waivers and numerous other

countries and university groups have signed agreements with Wiley so that there is no personal cost to the author. More details can be found on the link given below: <https://onlinelibrary.wiley.com/page/journal/19397445/homepage/fundedaccess.html> If any RMA member does not fall under any of these waivers or agreements, please contact me before submitting your manuscript. There are a limited number of additional waivers that we might be able to award to you subject to certain conditions.

Scope of NRM: The scope of the journal has recently been broadened. (See <https://onlinelibrary.wiley.com/journal/19397445>). I believe this more accurately reflects the scope of talks presented at the RMA conferences and hence the interests of members. It is hoped that this will also lead to an increase in submissions. Submissions declined sharply after the journal introduced an APC. They are picking up again with more institutions signing agreements with Wiley but we would still like to see more manuscripts coming in.

Editorial Board: With the broadening of the scope there has already been a shift in the distribution of submissions by field. This has led to a heavy workload for some Associate Editors (AEs) and some manuscripts that don't fit well with any AE. To mitigate this we are expanding and strengthening the editorial board and have already made the following four new appointments.

- Stephen Davis (Complex Systems, Zoonotic Diseases, and Biocontrol), RMIT University, Australia
- Yue Dou (Agent-based Modeling and Land System Modelling), University of Twente, The Netherlands
- Kevin Jan Duffy (Disease and Ecological Systems), Durban University of Technology, Durban, South Africa
- Nevil Quinn (Hydrology), University of the West of England, Bristol, UK

All four of the above have substantial research achievements in their fields.

Latest issues of NRM: The February and May issues of NRM provide an excellent example of the diversity of problem-solving, methodology and application location of our RMA community. Have a look at the following link: <https://onlinelibrary.wiley.com/journal/19397445>

In conclusion, I look forward to a close collaboration between NRM and RMA for our mutual benefit. I hope to see many of you next month at the conference in Amsterdam.

New officer: John Hearne NRM EDITOR IN CHIEF

John Hearne is an Applied Mathematician and Operations Researcher who has worked mainly on problems related to natural resources. These include the conservation and also the sustainable utilisation of wildlife, freshwater requirements in estuarine ecosystems, effects of riparian vegetation on river flows and water quality, agricultural pest management, and mitigation of wildfire hazards to property and wildlife.

He has had an involvement with the Resource Modeling Association (RMA) over three decades serving as its President twice. Earlier this year he took over the role as Editor in Chief of Natural Resource Modeling. The journal is closely linked to the RMA having been established in the 1980's by its members. John was born and grew up in South Africa where he spent most of his career. He was a professor in Applied Mathematics at the University of KwaZulu-Natal when he left in 2003 to take up a position in Australia, where for fifteen years he served as Head of Mathematical and Geospatial Sciences at RMIT University in Melbourne. Currently, he is an Honorary Professor at this institution.



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