

2021

World Conference on Natural Resource Modeling

June 1 - 4, 2021
fully virtual

Welcome to WCNRM2021 on

Tipping ecological-economic systems towards sustainability

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Resource Modeling Association



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Practical Information

Conference Venue: Zoom

Links:

- Room A:

<https://zoom.us/j/99290030166?pwd=YVIYaHY4RnFhU0hsMGN3b29lZGZqUT09>

- Room B:

<https://uni-leipzig.zoom.us/j/69400506204?pwd=MkpBTEJzUHJWeE11bVpzRW1HVlBMZz09>

- Main room:

<https://zoom.us/j/96199232695?pwd=b1cybkxsZHFTanM0dEFPRGJBSIRlQT09>

Technical Information:

- Presenters: Please arrive 15min early to your session. You can share your presentation via the **Share Screen** button in the tool bar.
- Participants: Please use your full name in Zoom. Please turn your video on and your microphone off unless you are speaking.
- All talks will be recorded (based on consent) and can be streamed here:

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Plenary Talks

Keynote 1: Tuesday, June 1, 2021: 17:00 - 18:00 CEST

- **Steve Carpenter** (University of Wisconsin-Madison, USA)
Safe Operating Space for Walleye Fisheries: Experimental Tests

Keynote 2: Wednesday, June 2, 2021: 8:30 - 9:30 CEST

- **Marie Riekhof** (Kiel University, Germany)
To tip or not to tip - Reflections on tipping points in ecological-economic systems

Keynote 3: Thursday, June 3, 2021: 18:30 - 19:30 CEST

- **Camilla Sguotti** (University of Hamburg, Germany)
Approaches to understand the resilience of marine resources

Keynote 4: Friday, June 4, 2021: 10:00 - 11:00 CEST

- **Yunne Shin** (IRD, France)
Uncertainty in scenarios and models of biodiversity

	Time (CEST)	Time (UTC)	Main room	Room A	Room B
Tuesday, 01/June/2021					
Session 2	16:30 - 17:00	14:30 - 15:00	Opening Ceremony		
	17:00 - 18:00	15:00 - 16:00	Keynote 1: Steve Carpenter		
	18:00 - 18:30	16:00 - 16:30	Coffee Break		
	18:30 - 20:00	16:30 - 18:00		Wildlife	Forestry
Wednesday, 02/June/2021					
Session 1	08:30 - 09:30	06:30 - 07:30	Keynote 2: Marie Riekhof		
	09:30 - 10:00	07:30 - 08:00	Coffee Break		
	10:00 - 11:30	08:00 - 09:30		PhD session 1.I	Fisheries I
Session 2	16:30 - 18:00	14:30 - 16:00		Methods	Fisheries II
	18:00 - 18:30	16:00 - 16:30	Coffee Break		
	18:30 - 20:00	16:30 - 18:00		PhD session 2.I	Fisheries III
Thursday, 03/June/2021					
Session 1	08:00 - 09:30	06:00 - 07:30		PhD session 1.II	Fisheries IV
	09:30 - 10:00	07:30 - 08:00	Coffee Break		
	10:00 - 12:00	08:00 - 10:00		Social ecological systems	Bioeconomic systems
Session 2	16:30 - 18:00	14:30 - 16:00		PhD session 2.II	Society and Climate Change 2.I
	18:00 - 18:30	16:00 - 16:30	Coffee Break		
	18:30 - 19:30	16:30 - 17:30	Keynote 3: Camilla Sguotti		
Friday, 04/June/2021					
Session 1	08:00 - 09:30	06:00 - 07:30		Society and Climate Change 1.I	Water and Pollution
	09:30 - 10:00	07:30 - 08:00	Coffee Break		
	10:00 - 11:00	08:00 - 09:00	Keynote 4: Yunne Shin		
	11:00 - 11:30	09:00 - 09:30	Closing Ceremony		
2	16:30 - 18:00	14:30 - 16:00		Renewable Resources	Policy, resilience and climate change

Abstracts (time is in CEST)

Wildlife

Tuesday June 01: (6:30pm - 8:00pm) • Room A

Session Chair: Frank Jensen

6:30pm - 7:00pm • Balancing conservation and commerce

Pierce Donovan, Michael Springborn

Abstract: The losses from extinction events are not well-known, making an expected net benefits approach to conservation problems difficult to justify. A viable control strategy instead focuses on limiting the risk of extinction to some acceptably low level at the least possible cost. Here we extend a recently developed shadow value viability approach for solving conservation problems with irreversible thresholds with dynamic programming. In a social planner context, the method involves identifying the loss from extinction that drives enough conservation effort to ensure survival with a given level of confidence. We demonstrate the method in a numerical application to the conservation of the Pacific leatherback turtle population, which co-mingles with the Pacific swordfish fishery. We show how the efficient outcome can be achieved among decentralized fishers by using the planner's shadow value to set market-based instruments for managing turtle bycatch. This approach translates the species viability objective into economic terms so conservation and commercial harvest can be rationally integrated.

7:00pm - 7:30pm • Modeling wildlife coexistence: a case of study and future directions in Central Chile

William Campillay-Llanos, Christian Osorio

Abstract: The mechanisms allowing the coexistence of species with similar ecological niches are very relevant from a community ecology perspective, given the theory predicts that the subordinate competitor should go extinct, unless the species partition their ecological niches over (at least) one of its dimensions.

Space, time, and trophic resources are regarded as the principal axes upon which species segregate. Here, we investigated segregation along these niche axes to determine mechanisms underlying coexistence between the two main predators, puma (*Puma concolor*) and culpeo foxes (*Lycalopex culpaeus*) --the largest wild felid and the largest wild canid inhabiting Chile, respectively-- in the Andes of Central Chile. We used mathematical and statistical methods over field collected data: (i) occupancy modeling to examine space (i.e.: habitat) use; (ii) overlap, Kernel Density Estimation to determine model activity patterns and estimate overlap, and (iii) analysis of prey remains in scats to compute diet breadth and similarity. We found high spatial overlap and positive associations between detection of the carnivores lending little support for spatial segregation. Similarly, we found high nocturnal, temporal overlap between pumas and foxes that matched peaks in activity of prey. In contrast, dietary overlap between pumas and foxes was low, suggesting that niche

segregation likely occurs along the dietary axis. The puma diet was dominated by introduced, exotic hares and foxes appeared to shift away from hares to rabbits, small mammals, and seeds. We discuss that, given lagomorphs are the main dietary resource for pumas, management decisions regarding the control or eradication of such exotic species could negatively affect puma survival.

We also present preliminary results of a community ecology study, focused on coexistence between native wild mammals and the impact of exotic wild mammals, that we are currently conducting in the coastal mountain ranges and coastal plains of the Province of Talca, Maule Region, Chile; and discuss future research directions in this area.

7:30pm - 8:00pm · Joint Management of Populations of Marine Mammals and Fish Species: The Case of Grey Seals in the Baltic Sea

Frank Jensen, Johan Blomquist, Staffan Waldo, Ola Flaaten, Maija Holma

Abstract: In this paper, we present a steady-state equilibrium predator-prey model for joint management of grey seals and fish species (cod and herring) where a broad set of benefits and costs associated with seals is taken into account. The model is used to investigate a number of practical policy scenarios including optimal joint management of grey seals and fish species. The model is parametrized for the Baltic Sea and one conclusion is that the optimal population of grey seals is much lower than the actual population under optimal joint management for both cod and herring. This result is robust to changes in relevant parameter values and the conclusion can be explained by the fact that the profit from fisheries is much larger than the net benefits from grey seals.

Forestry

Tuesday June 01: (6:30pm - 8:00pm) · Room B

Session Chair: Brooke Anne Williams

6:30pm - 7:00pm · Composition diversification vs. structure diversification: How to conciliate timber production and carbon sequestration objectives under drought and windstorm risks in forest ecosystems

Sandrine Brèteau-Amores, Rasoul Yousefpour, Marc Hanewinkel, Mathieu Fortin

Abstract: Forests provide ecosystem services such as timber production and carbon sequestration. However, forests are sensitive to climate change. As the pace of climate change continues to accelerate, climate-induced damages are expected to cause substantial amenity losses for the society, in addition to financial losses for forest owners. Forests in the Grand-Est region, France, are dominated by European beech, for which a decline in productivity is anticipated due to repeated drought events induced by climate change. These forest ecosystems are also threatened by windstorm events. Tree species diversification is one of the many forest management strategies that can help beech forests to adapt to increased risks of severe drought and windstorm events. This article presents the results of a study that compared different forest adaptation strategies from an economic perspective

with the objective to reduce drought- and windstorm-induced risks of dieback. In this study, two types of diversification strategies were analysed, first separately then jointly. These are: mixing beech with oak (composition diversification) and shifting from an even-aged to an uneven-aged forest (structure diversification). We also considered two types of loss associated with different recurrences of drought and windstorm risks, namely financial loss and reduction of carbon sequestration capacity. We combined a forest growth simulator with a forest economic approach through the computation of land expectation value (LEV). The maximisation of the LEV criterion made it possible to identify the most economically effective adaptation strategies. Results show that diversification increases timber production and LEV, but reduces carbon storage. The two risks as well as the adaptation strategies show some synergies. Finally, trade-offs between the financial balance and the carbon balance (*i.e.*, adaptation vs. mitigation) are achievable.

7:00pm - 7:30pm · Index insurance for coping with drought-induced risk of production losses in French forests

Sandrine Brèteau-Amores, Marielle Brunette, Christophe François, Antoine Leblois, Nicolas MartinSt-Paul

Abstract: Drought-induced risk of forest dieback is increasing due to climate change. Insurance can be a good option to compensate potential financial losses associated with forest production losses. In this context, we developed an *ex ante* index-based insurance model to cope with drought-induced risk of forest dieback. We applied this model to beech and oak forests in France. We defined and then compared different indices from simple ones relying on rainfall indices to more complex ones relying on the functional modelling of forest sensitivity to water stress. After the calibration of the contract parameters, an insurance scheme was optimized and tested. We showed that optimal insurance contracts generate low gain of certain equivalent income, high compensation, and a high basis risk. The best contract was not proportional to the complexity of the index. There was no clear advantage to differentiate contracts based on species. Results highlighting the various perspectives of this first approach are discussed at the end of this paper.

7:30pm - 8:00pm · WePlan – Forests: A decision support platform for spatial planning of forest ecosystem restoration

Brooke Williams, Hawthorne Beyer, Renato Crouzeilles, Marina Schmoeller

Abstract: Forests are home to 80% of the world's biodiversity and stock high amounts of carbon relative to other ecosystems. However, substantial areas of forest have been cleared and, of the remaining forests, as much as 82% are now degraded to some extent as a result of human actions such as industrial logging, urbanization, agriculture and infrastructure. Tropical forest restoration has the potential to counteract some of these negative impacts and deliver multiple benefits, such as climate change mitigation, biodiversity conservation, and provide sustainable livelihoods for people. In response to the need thus identified, the "WePlan – Forests" was developed.

WePlan – Forests is a decision support platform for spatial optimisation planning of forest ecosystem restoration that can significantly enhance the outcomes of policies, programs and

projects for biodiversity conservation, sustainable development, and climate change mitigation. The platform consists of a user-friendly web-based interface that automates the technical and computing requirements of complex spatial analyses and allows users without GIS and spatial modelling know-how to explore a broad range of results and scenarios. The WePlan - Forests platform can help governments and other stakeholders to plan and implement forest restoration to cost-effectively achieve biodiversity conservation and climate mitigation benefits. WePlan - Forests also enables users to explore the potential of certain areas to sustain natural forest regrowth, a restoration intervention that is often the most cost-effective and provides substantial benefits for biodiversity and climate.

In this talk I will present the WePlan - Forests methodology, underlying data, and near future advancements with the aim of inviting feedback and discussion. This project was developed by the International Institute for Sustainability Australia and International Institute for Sustainability Rio, in partnership with the Convention on Biological Diversity (CBD) Secretariat as part of the implementation of the Forest Ecosystem Restoration Initiative with the financial assistance of the Korea Forest Service of the Government of the Republic of Korea and the European Union.

PhD session 1.I

Wednesday June 02: (10:00am - 11:30am) • Room A

Session Chair: Michael Stecher

10:00am - 10:30am • Parameter Allocation of MIKE SHE model for flow simulation of Ziarat River in Iran

Abolfazl Zarghi, Abdolreza Bahremand, Vahedberdi Sheikh

Abstract: Parameter estimation is one of the major steps in hydrologic modeling. Parameter values can either be calibrated or logic-based specified. In distributed physics-based models, it is arguably possible to specify parameters using catchment characteristics, hydrologic knowledge, and understanding parameters and model behavior. Such logic-based parameter specification is called as parameter allocation. This study tried to practice this modeling approach using the MIKE SHE model and simulate the daily hydrograph of the Ziarat watershed located in the North of Iran. The model was performed using both allocation and calibration approaches for a certain period from 01.23.2013 to 09.21.2014, and for the period from 04.15.2016 to 09.21.2017 as validation. The results of the simulation based on each of the approaches were evaluated by the Nash-Sutcliffe and Kling-Gupta efficiency criteria. Based on these criteria, the model in the parameter allocation approach had a good performance, and showed consistency in the validation period. Regarding the water balance, the results of the allocation approach were more reasonable and meaningful. Therefore, it can be concluded that spending more time for knowing the watershed characteristics and parameters of the model and understanding the model behavior leads to more acceptable and consistent results that reduces the need for calibration, significantly.

10:30am - 11:00am · Socio-economic determinants and adaptation role of mixed cropping against untimely rainfall

Hardeep Singh

Abstract: In the developing countries, problems like water and soil pollution, intensive use of agricultural practices, and weather uncertainties have given rise to concerns about the sustainability of agricultural production in the plausible future. Mixed cropping has been considered as an ex-ante risk management strategy, which besides protecting production losses from climate uncertainties, also protects soil and water losses. However, in the literature, there is a lack of evidences of what socio-economic factors determine the adoption of this type of cropping system. Further, the literature does not provide any evidences of the adaptation role played by mixed cropping against untimely rainfall. Therefore, this paper focuses on two interrelated issues: First, what socio-economic factors determine the adoption of mixed cropping regardless of the crop combinations followed by the farmers across different cropping seasons; secondly, it examines the adaptation role of mixed cropping against weather uncertainties. We find that age and education of the household head, dependency ratio, crop losses in the past, ownership of land, access to extension services, income from off-farm activities, and ownership of livestock are significantly and positively correlated with the adoption of mixed cropping. Most of the variables are significant and of expected sign in the Kharif season. Besides this, we find that mixed cropping reduces the crop losses accruing due to delayed monsoon arrival.

11:00am - 11:30am · A composite model of bistable stochastic ecosystems

Michael Stecher, Stefan Baumgärtner

Abstract: Many ecosystems appear inherently stable over long periods of time, but then suddenly undergo dramatic shifts in species composition and provision of ecosystem services seemingly without warning. The notion that ecosystems may exhibit two or more alternative stable states under the same set of environmental conditions has been the leading theoretical explanation for this phenomenon. The success of multi-stability theory is at least partially due to its intuitive way of explaining the mechanisms behind these shifts by the use of simple graphs like the ball-in-cup diagram as heuristic devices. However, the appealing simplicity with which the theory is often propagated has led to confusion about the gap between static, deterministic theory and complex, dynamic, stochastic reality.

In this paper, we narrow this gap by connecting simplistic heuristics with solid mathematical modelling. First, we review the key concepts of multi-stability theory and the heuristics commonly employed to illustrate them. We then define these concepts rigorously in a simple dynamic model which is able to reproduce the stylised cases illustrated in the heuristic graphs. Adding stochasticity to the model, we study the impact of continuous fluctuations as well as rare events on the behaviour of ecosystems. In particular, we use a mean-reverting jump-diffusion process taken from the finance literature to model the evolution of the ecosystem state over time.

This innovative specification has the advantage of being tractable enough to enable a number of different applications. For instance, we are able to derive objective probabilities

of regime shifts over arbitrarily long time intervals and analyse how they change depending on ecosystem characteristics. Another possibility is to analyse the consequences of different types of stylised management actions. We show that seemingly similar management actions entail substantially different outcomes depending on ecosystem dynamics, highlighting timing as a crucial aspect of ecosystem management. Finally, our generic ecosystem model may serve as a foundation for alternative approaches of ecosystem management based on probabilistic measures that incorporate stochastic ecosystem dynamics.

We contribute to the literature on multi-stable ecosystems and their management by providing clear mathematical definitions for concepts like regime shifts, resilience, and basins of attraction for the first time. This enables a better understanding of these concepts and facilitates communication about them.

Fisheries I

Wednesday June 02: (10:00am - 11:30am) • Room B

Session Chair: Pamela Katic

10:00am - 10:30am • Heterogeneity in behavior and tipping points in a coupled human-natural model

Thang Dao, Robert Arlinghaus, Josh Abbott, Eli Finichel, Martin Quaas

Abstract: Diversity, e.g. diversity in species or functional traits, is usually associated with increasing resilience of natural and coupled human-natural systems. Yet, we believe heterogeneity in human behaviors may also predispose a coupled human-natural systems to cross tipping points, caused by the feedback among ecological and social system. We develop a bio-economic harvest model with heterogeneous participants to characterize the necessary and sufficient conditions for the emergence of multiple steady state equilibria and an anthropogenic tipping point, below that the population of an exploited natural resource will collapse to undesired state characterized by low resource abundance. To outline our case, we use a recreational fishing model with heterogeneous anglers that vary in fishing skill. We show that the necessary condition for the emergence of a tipping point is the presence

of a fish population level at which the elasticity of aggregate fish landing with respect to fish population, that measures the responsiveness of fish landing to a change in fish population, is less than that of fish population growth. Under the necessary condition and given a certain fishing skill distribution, the sufficient holds when the angler population size is big enough but not too big to rule out the case only one undesired steady state prevails. We provide a two-stage strategy of fishing fees to help a system initially locked below the tipping point level

escape such the low regime during the first stage of fishing fee program. During the second stage, the fishing fee trajectory enables the fish population to trace the optimal path towards the first best steady state equilibrium in the long run. Finally, we provide a discussion on the complex effect of heterogeneity in fishing skill on supporting the necessary condition. We argue that the fat tail of the distribution, rather than the degree of heterogeneity, may play a role on the emergence of an anthropogenic tipping point.

However, this effect becomes weak and even disappears when recreational fishing activities are too essential for (almost) all anglers.

10:30am - 11:00am · Optimal harvest of North Sea Cod under Evolution along a maturation-growth trade-off

Hanna Schenk, Fabian Zimmermann, Martin Quaas

Abstract: A side effect of targeting large fish is a strong selection pressure on a smaller size at maturation. This has resulted in fisheries-induced evolution of earlier maturation in several fish species. Due to life-history trade-offs fish that mature at a younger age also grow more slowly. The fisheries-induced evolution thus reduces the economic benefits for fisheries, especially as large fish are proportionally more valuable than small fish. We include these processes in an economic-ecological-evolutionary demographic fishery model to study economic implications of fisheries-induced evolution and to derive optimised fishing management strategies. Economic benefits of fishing depend on the size structure of catches, as prices depend on the size of the fish caught. Economic costs of fishing depend on the size of the accessible fish population, which depends on the gear used. We apply the model to the North Sea cod fishery and find that the optimal fishing strategy is to stop fishing for a number of years until the population has rebuilt its productivity. Harvesting can subsequently be increased to a higher level. Although the original population composition is more valuable, reversing the Evolutionary change is not beneficial, even without discounting.

11:00am - 11:30am · Bioeconomic modelling for resilience management of aquaculture systems

Pamela Katic

Abstract: Change is integral to aquaculture ecological-economic systems, and its consideration in aquaculture management is key to ensure resilience. Diversifying seafood consumption and production, through sustainable approaches such as Integrated multi-trophic aquaculture (IMTA), could improve resilience of aquaculture systems to changes and derive sustainable benefits. We define resilience in aquaculture systems and present a framework to investigate the role of IMTA in increasing systems' resilience. We develop a bioeconomic model for resilience management of aquaculture systems and propose steps as a base to operationalise resilience in ecological-economic aquaculture systems from an interdisciplinary perspective, and to understand the role of IMTA in resilience management. The model is illustrated using a case study of salmon farming in Scotland.

Social and economic considerations related to the resilience of aquaculture systems have been largely studied in a static and ad-hoc manner around questions of economic feasibility or financial profitability based on exogenous assumptions of harvest, feed and species choices or in global discussion pieces. While a conceptual bioeconomic model of IMTA has been produced that integrates biological/ecological with economic/societal dynamics, to the best of our knowledge, no model has analysed the impacts of IMTA on the resilience of ecological-economic systems.

We aim to operationalise resilience in ecological-economic aquaculture systems from an interdisciplinary perspective and to understand the role of IMTA on resilience management. To achieve this, we define the steps needed to achieve resilience management of ecological-economic aquaculture systems and contextualise these using a bioeconomic model of aquaculture species' growth and harvest for two specifications: (i) monoculture salmon farm and (ii) IMTA farm.

We develop two simplified systems of differential equations to capture complex population and nutritional (fatty acids) profile dynamics in a salmon monoculture and an IMTA farm. We couple each of these systems with an economic value or objective function. The biological variables enter and influence this value function.

The IMTA system is compared to a monoculture farm under several contrasted fishing scenarios given by deterministic and stochastic (continuous and discontinuous) changes in exogenous variables. Economic and viable strategies are then simulated and resilience measurements quantified. In the first stage of the analysis, we solve a full deterministic maximisation problem using dynamic programming. In the second stage of the analysis, we analyse the sensitivity of the results of the first stage to different scenarios given by variations in economic, biological and environmental parameters. In a third phase, we modify the model to analyse the effects of stochastic stresses and unpredictable shocks in the structure of the model's constraints.

Methods

Wednesday June 02: (4:30pm - 6:00pm) • Room A

Session Chair: *Ronny O Vallejos*

4:30pm - 5:00pm • Efficient synthetic generation of ecological data with preset spatial association of individuals

Bogdan Strimbu, Andrei Paun, Alexandru Amarioarei, Mihaela Paun, Victor Strimbu

Abstract: Many experiments are not feasible to be conducted as large factorials. The feasible alternative are simulations using synthetically generated data. The main objective of the present research is to develop a methodology and a platform to synthetically generate spatially explicit forest ecosystem data represented by points with a predefined spatial pattern. Using algorithms with polynomial complexity and parameters that control the number of clusters, the degree of clusterization, and the proportion of nonrandom trees, we show that large spatially explicit forest ecosystem data can be generated time efficiently, to enable large factorial simulations. The proposed method was tested on 1200 25 ha generated forest stands using 10 spatial indices: Clark-Evans aggregation index, Ripley's K, Besag's L, Morisita's dispersion index, Greig-Smith index, the size dominance index of Hui, index of nonrandomness of Pielou, directional index and mean directional index of Corral-Rivas, and size differentiation index of Kint. To ensure generality replicability of the study we have provided a free fully functional software, with GUI and help, to execute the stated tasks.

5:00pm - 5:30pm · Estimation of Nearly Singular Covariance Matrices for Modelling Georeferenced Variables

Javier Pérez, Jonathan Acosta, Ronny O Vallejos

Abstract: Spatial analysis commonly relies on the estimation of a covariance matrix associated with a random field. The estimation strongly impact the variogram estimation, prediction where the process has not been observed, and therefore the construction of more sophisticated models. If some of the distances between all the possible pairs of observations in the plane are small, then we may have an ill-conditioned problem, resulting in a nearly singular covariance matrix. In this work, we suggest a covariance matrix estimation method that works well even when there are very close locations in the plane. The method is based on the estimation of eigenvalues of the unitary matrix decomposition of the covariance matrix. Several numerical examples are conducted to provide evidence of a good performance of the suggested method, specially in the context of covariance estimation and kriging. An application to a macroalgae estimation in a restricted area in the pacific ocean is developed to determine a suitable estimation of the effective sample size associated with the transect sampling scheme.

5:30pm - 6:00pm · Straight forward methods for parameter allocation of WetSpa-Python model

Abdolreza Bahremand, Sajad Ahmadyousefi, Vahedberdi Sheikh, Chooghi Bairam Komaki

Abstract: A recent paper (Bahremand, 2016) advocates process modeling and de-emphasizes numerical optimization used for parameter estimation in hydrological modelling. The paper discusses how to limit calibration and describes how model parameters should be specified in a physically-valid fashion in lieu of numerical optimization procedures that do not fully capture the physics of hydrological processes within a given model domain. Here, in the current paper, we present an example of how the WetSpa-Python model parameters can be allocated as per the conceptual framework introduced by Bahremand (2016). We propose what can be construed as straightforward methods to perform this allocation: an initial sensitivity analysis is conducted, model parameters are allocated, and only a few parameters are adjusted for calibration. As an example of parameter determination, the mass-curve technique for dam reservoir sizing via the Rippl Diagram is applied to obtain the maximum active groundwater storage in a watershed. We also explain how numerical methods of calibration involving optimization can be avoided by adjustment of only two parameters over a limited range of numerical values. Numerical calibration often masks underlying inconsistencies in the physics of process representation. Therefore this research demonstrates how model parameters can be selected in an efficient and accurate fashion, thereby contributing to the corpus of research on accurate model representation of hydrological processes.

Fisheries II

Wednesday June 02: (4:30pm - 6:00pm) • Room B

Session Chair: Kanae Tokunaga

4:30pm - 5:00pm • Fishing as a disruptor of habitat matching in fish populations

Darren M Gillis, Elmer Wade

Abstract: Fish distributions often follow the distributions of their resources. However, fishing activities that focus on high densities of fish could disrupt the relationship. This implies that growth or recruitment in fished populations will differ from unfished populations of the same size. However, the impact will be fishery specific due to differences in the habitat landscape. The impact of fishing will also vary with the ability of the fleet to respond to local changes in fish availability. I will present an agent based model (ABM) of fishing activity that explores how changes in information exchange among vessels and fish habitat distributions could influence the level of disruption that occurs between fish and their resources. The results of the ABM will be compared to impact of fishing on local (10' square) abundance observed across the Gulf of St. Lawrence snow crab (*Chionoecetes opilio*) fishery. This additional source of variability will not be captured by simple metrics such as spawning stock biomass but may impact population productivity. Metrics presented in the model and the fishery comparison provide a starting point to considered fleet disruptions of the fish-habitat match in the assessment of exploited fish populations.

5:00pm - 5:30pm • Bioeconomics of technological interdependencies in a sequential shrimp fishery: optimal size of the industrial fleet in southern Gulf of California

Fernando Aranceta-Garza, Francisco Vergara-Solana, Juan Carlos Seijo

Abstract: The bioeconomic sequential externalities in the white shrimp (*Litopenaeus vannamei*) fishery during 2014-2015 season in southern Sinaloa, Mexico, were analyzed by calculating the optimal size of the industrial fleet (trawlers) given the current oversized small-scale fleet (SSF: cayucos). For this purpose, we constructed a dynamic multi-fleet age-structured bioeconomic model with natural mortality-at-age and catchability-at-age. The distributed delay model was applied to simulate recruitment seasonality. The reproductive effect of seasonal sea surface temperature (SST) was also considered. The constant size of SSF was represented in *status quo* while reducing industrial fleet by -25%, -50% and -70%. Maximizing net present value "NPV" of industrial fleet. The model showed the technological interdependencies of two fleets competing for one species and their respective externalities. The *status quo* fishery showed a deteriorated biomass (0.27, below MSY); overcapitalized fleet (especially for the SSF); fleets low NPV of resource rent, especially for the cayucos (\$761 USD per season). The access limitation of trawlers presented a progressive improvement in all bioeconomic variables, mainly on biomass (+27%) and NPV resource rent for trawlers (+700%). The SSF presented positive marginal externalities (4%). However, biomass was still below MSY (0.34) and the fishery trade-off showed a 70% industrial fleet loss to overcome the negative externalities of the actual SSF status. Given the current conditions of the sequential shrimp fishery (i.e., overcapitalized, overexploited, difficulty to

control SSF) the limitation of industrial effort to the area could be a viable strategy to improve the fishery bioeconomic performance. However, it is necessary to explore more management strategies that include the small-scale fishery to attained sustainable levels and higher profitability for users.

5:30pm - 6:00pm · Fleet heterogeneity and economic performance in American Lobster fishery

Kanae Tokunaga, Alexa Dayton

Abstract: American lobster fishery is the most valuable fishery in the United States. After several decades of steadily increased landings, the American Lobster fishery now dominates Maine's marine economy. The center of the fishery, the Gulf of Maine, is one of the fastest-warming water in the world, and there is uncertainty about the future robustness of the stock and the economic value, and profitability of the fleet appear vulnerable. This research characterizes heterogeneity in Maine's fishing fleet using latent profile analysis and then quantifies the technical efficiency of Maine's lobster industry for each profile to benchmark diversity of fishing styles and associated economic performance in Maine's lobster fishery in the pre-warming period. The study uses a unique dataset obtained from the firm-level economic survey of the American lobster fishery operators (Dayton et al. 2010) conducted in 2010, the year before the reported environmental change in the Gulf of Maine. In total, firm-level economic and operational data were collected from 1,007 harvesters. First, the latent profile analysis was performed, identifying four fishing styles representative of the fisher's experience, fleet's technical capacity, and technology, and fishing ground characteristics. For each identified fishing style, we conduct the Cobb-Douglas and trans-log stochastic profit frontier analysis. Our findings indicate economic efficiencies differ based on their choice of fishing styles and found technical upgrades generally contribute to improved economic performance in the pre-warming period. Reported societal benefits associated with employment levels have characterized the lobster production environment over firm-level efficiency. This research establishes a critically important baseline for future comparison and quantification of policy reforms within the U.S. lobster fishery.

PhD session 2.1

Wednesday June 02: (6:30pm - 8:00pm) · Room A

Session Chair: *Celine Audrey Huber*

6:30pm - 7:00pm · Climate Justice in an Intergenerational Sustainability Framework: A Stochastic OLG Model

Gianluigi Cisco, Andrea Gatto

Abstract: Climate justice is conceived as the intertemporal climate equity and equality exchange amongst generations. Sustainability – intended as the interplay amongst the economy, the society, the environment, and the governance – is essential to forge the climate justice theoretical framework. On this base, the study attempts to model the

intertemporal choice of the status quo amongst generations in these four domains, making use of an overlapping generations (OLG) model making use of an intertemporal choice framework. The proxies detected are GDP growth (economy), environmental quality (environment), and labor growth, and environmental investment (society) as assumptions. The governance dimension is captured by the difference in wealth between young and old generations. The work aims at replying to the following research question: *Which are the conditions for sustainable development such that climate justice holds?* The intra-intergenerational exchange is defined in two periods, while the individual provides their preferred economic and environmental choice mix as consumption-saving. This study shows that keeping the business-as-usual scenario, young generations will have to bear the brunt of sustainable development. Also, reduced emissions are only achievable with increased efforts by the youth by reducing their leisure and consumption. These facts call for enhanced intergenerational sustainability and climate justice policies.

7:00pm - 7:30pm · Institutional arrangements and the impact on natural resource governance in the Bulgarian Black Sea

Nona Nenovska

Abstract: The more complex and interdependent natural resources are the greater the challenge of their economic and ecological sustainability is in the long-term. When we examine the concept of sustainability: economic sustainability, ecologic sustainability, we can look into what are the institutional arrangements that manage to reconcile these two objectives over time. The study of the governance of common pool natural resources could represent an important tool to understand the complexity of interactions between ecological and socio-economic spheres. This paper aims to achieve several goals. Firstly, is to contribute to natural resource governance literature from the perspective of institutional environmental economics. More specifically, it will contribute to the common pool resources (CPR) theories by broadening the scope to the context in which they are embedded. Secondly it will focus specifically on marine natural resources governance, via two spatial interconnected case studies: the marine protected areas and the harvesting of the invasive species *Rapana Venosa* in the Bulgarian Black Sea. Thus, trying to determinate the institutional level challenges and explore the potential path of institutional arrangements for the governance of those resources leading to long-term sustainability or short-term profits.

7:30pm - 8:00pm · When profitability and sustainability coincide. Biodiversity offsets, ecosystem services and economic development: a viability approach

Celine Audrey Huber

Abstract: Numerous scientists advocate for the use of Biodiversity Offsets (BO) as economic instruments to manage biodiversity and ecosystem services in the context of economic development. This study investigates the conditions for the sustainability of BO, in the sense of the reconciliation between ecological and economic objectives. It especially focuses on the role of time in development-offsets projects.

To address this issue, an ecoviability model is proposed, allowing to adopt a dynamic, multicriteria approach, through ecological and economic constraints. We here rely on a No

Net Loss (NNL) and a positive Net Present Value (NPV) constraints. In particular, we compute the difference between the time necessary to achieve the NNL and the payback time (a positive NPV) that we name offsets sustainability duration.

We show analytically that this offsets sustainability duration can be very long, in particular when the biodiversity intrinsic growth rate is too small as compared to the discount rate. By contrast, there exist sustainable situations, in the sense that offsets sustainability duration is low when the intrinsic growth rate is high enough. We point that this result is in line with the Green Golden Rule (Clark, 1973). More globally, a sensitivity analysis shows that economic parameters (such as the marginal revenue and the offsets cost) impact more the offsets sustainability duration than biodiversity parameters.

Finally, a numerical application related to mangroves in Madagascar illustrates the analytical findings.

Fisheries III

Wednesday June 02: (6:30pm - 8:00pm) • Room B

Session Chair: *Andrés Vargas*

6:30pm - 7:00pm • Subsidies, temporary laying-up, and efficiency in the commercial fishery of Mecklenburg-Vorpommern, Germany

Dieter Koemle, Thang Dao, Xiaohua Yu, Robert Arlinghaus

Abstract: Fisheries subsidies are controversial, as they have contributed to overcapacity and resource degradation in the past. While attempts to reduce “harmful” subsidies have been made, countries such as the European Union have provided support mechanisms for fishermen in times of crises. One of these measures is the temporary cessation of fishing, or temporary laying-up (TLU), that requires fishers to seize their entire fishing activity for a limited number of days in return for financial compensation. The literature has suggested that subsidies related to laying-up may be related to fishers not exiting the industry, i.e. delaying capacity reduction.

Nevertheless, the effect of temporary laying-up policies on fisher performance is poorly understood. In the quest for capacity or effort reduction pursued in many (coastal) fisheries, the effect of a temporary reduction of fishing days on the whole fishery may be ambiguous. First, compensation payments may help fishers to adapt, invest in better fishing gear and other equipment. Second, laying-up days will decrease the total effort a fisher can exert and therefore likely reduce revenues. Third, pre-determined laying-up will also reduce the capacity to optimally allocate fishing days, therefore reduce efficiency. Fourth, in limited space, the effect of other’s laying-up may encourage other fishers to fish more, or in more profitable places.

We use a recent TLU policy in the state of Mecklenburg-Vorpommern, Germany, as a case study to better understand how these three components may affect fisher performance. Using monthly observations, we estimate the stochastic revenue frontier as well as inefficiency by the multiplicative generalized error model. Our results suggest that additional subsidies are associated with outward shifts in the revenue frontier. On the other hand, own laying-up days shift the revenue frontier inward, particularly for larger vessels. However, we

only find limited evidence of spillover-effects between fishers participating in the TLU and those who do not. Robustness checks on spatially separated subsamples support these results.

Outward shifts in the revenue frontier may indicate that vessels become more profitable with increased subsidies. This, in turn, may decrease the probability of these vessels to exit the industry. Given structural changes in the fishery in response to the policy may have important implications for approaching or moving away from biological tipping points of the exploited resources.

7:00pm - 7:30pm · Navigating conservation and social objectives through adaptive harvest management in the coupled social-ecological system of freshwater recreational fisheries: a modelling approach

Robert Arlinghaus, Shuichi Matsumura

Abstract: Recreational fisheries constitute strongly coupled social-ecological systems. Many recreational fisheries are also spatially structured, where regionally mobile anglers link a set of spatially segregated lakes, ponds and rivers in freshwater landscape. Understanding the dynamics and outcomes of management interventions at landscape scales demand the construction of social-ecological models that encompass spatial variation in fish productivity and response to harvesting and angler behavioral responses to local management initiatives. We present the construction of a freshwater social-ecological model of a regionally mobile pool of anglers exploiting a set of pike (*Esox lucius*) populations striving in 121 lakes. We use this model to test the performance of a range of harvest management policies that are either unresponsive to local ecological states or adaptive depending on resource status. We show that adaptive harvest policies outperform one-size-fits all policies in both social and ecological dimensions. We further show that local closures (i.e., input controls) are unnecessary and do not help social and conservation objectives for fishes as long as managers adaptively strengthen output regulations in response to local resource states. Finally, we show that a stratified assessment scheme that periodically samples a set of lakes and uses the information of these lakes to inform policy adaptation in unassessed fisheries can produce reasonably good outcomes. Hence, implementing active management of recreational fishing harvest using simple harvest regulation prototypes is feasible and can strongly improve outcomes compared to current practice.

7:30pm - 8:00pm · Functional diversity and the portfolio effect in an artisanal fishery in Colombia

Andrés Vargas, Sebastián Restrepo, David Diaz

Abstract: It is an increasingly accepted idea that biological diversity contributes to the stabilization of ecosystem functions and the services they provide to society. If the resources people depend on for their livelihoods have a heterogeneous response changes in environmental conditions, then a diversified portfolio of resources has the potential to stabilize their income. This is particularly important for households exposed to environmental variability. From this effect, which is analogous to the risk spreading function

of financial portfolios, arises the insurance value of biodiversity. That is, the value of reducing the uncertainty of ecosystem services provision to risk-averse households. On this light, this paper explores the relationship between catch and income, and changing environmental conditions in an open-access small-scale fishery context, in which fishermen manage the impacts of ecological changes through a diversified fishing portfolio. Our case study takes place in a estuarine system in the Colombian Caribbean characterized by interannual changes in salinity closely related to El Niño-Southern oscillation cycle. Fishermen in the area catch species that have differences in their tolerance to salinity. Our results show the stabilizing role of biodiversity under normal and high salinity conditions.

PhD session 1.II

Thursday June 03: (8:00am - 9:30am) • Room A

Session Chair: *Julide Ceren Ahi*

8:00am - 8:30am · Reviewing sustainability of Marine Fisheries of Odisha, India:
A Bioeconomic Approach

Pritam Tripathy, Neha W. Qureshi, Suraj Kumar Pradhan, Swadesh Prakash

Abstract: Odisha is one of the well-known coastal states of India for its species richness diversity. The state has a coastline of 480 km, which constitutes 6% of the Indian coastlines. The state marine fisheries are small-scale enterprises in nature and the catch is mostly from traditional crafts and gears. The high-value varieties of fishes and prawns are supplied to inter-states directly or export to foreign countries through available processing industries in Odisha. Although, the marine fisheries in the Indian states are multispecies and multi-fleet, which are characterized by regulated open access. Over the period of time, the state has faced a serious issue of depletion in the fish stocks due to incessant growth in the fishing capacity. The excessive fishing capacity has not only disturbed the natural resources in terms of ecosystem overfishing but also arise resource users' conflicts and intractable disputes among fishermen deployed with different types of gears. Because of its profitability, the industry has been commercialized and the sustainability of fisheries has been compromised. Thus, the sustainability study of marine fisheries resources of the state is undertaken with the help of bioeconomic analysis. The time-series data on species wise catch and effort for the period of 1980-2018 were obtained from various published secondary sources as well as with a hybrid approach, using Fuzzy Cognitive Map (FCM). While the Fuzzy Cognitive Map (FCM) is used to understand the concepts and connections of various heterogeneous factors that have an influence over the marine fisheries resource sustainability. The Surplus Production Model developed by Fox (1970), has been used to analyze the Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY) in consideration of three different cost scenarios. The results depicted that MSY found to be 96985 MT at an effort level of 38.934×10^6 kW days. The MEY found in model I, model II, and model III are 77264 MT, 80779 MT, and 87671 MT with a fishing effort of 18.220×10^6 kW days, 19.877×10^6 kW days, and 23.955×10^6 kW days, respectively. It is revealed from the Fuzzy Cognitive Maps that the government's intervention is an important driver to achieve the sustainability of marine fisheries resources through various concepts and their connections. The hierarchy index of the FCM is 0.001, which is highly democratic. Currently, overfishing is persisting in

the state with an effort level of more than twice of f_{MEY} i.e., far beyond the level that maximizes economic rent and existing fisheries are operating at a biologically and economically unsustainable level. The study concluded that the fishing efforts need to be reduced because of depleting stock and poor economic efficiency in this sector. With the existing regulations of seasonal and conservational closure, there is an urgent need for effective marine fisheries management, conservation, and policy formulation for the economically efficient harvest of resources in the state.

8:30am - 9:00am · Labour in the Circular Economy: a catalyst towards sustainable development

Julie Metta

Abstract: This study analyses the circular economy as an alternative to cope with both the exhaustibility of resource, and the pollution induced by improper waste management. I shape a two-sector growth model in a simple closed economy. The waste stock is assumed to negatively affect labour productivity. (e.g. January 2019, in Rome, Italy, a landfill burned forcing workers to stay home for several days - The Independent, 2019). I investigate the optimal allocation of labour between the production and the circular sector to sustain development while limiting environmental impact caused by waste on labour. I model changes in economies due to an endogenous choice of labour in the supply and I analyse under which conditions the circular economy can generate endogenous growth. My approach is innovative as I emphasise the role of the labour in the circular economy, illustrating the important role of the circular sector to sustain economic development. The results lead to a full circular economy model for the management of resources. The model offers a new approach for substitutable development of supply chains.

9:00am - 9:30am · Management of coastal cod stocks in Arctic Norway: incorporating society's preferences regarding distribution

Julide Ceren Ahi, Claire Armstrong

Abstract: Coastal cod harvest has a long history in Arctic Norwegian culture and tradition, where it remains a vital commercial and recreational activity for coastal communities. However, due to increased pressure, coastal cod stocks in the region are in severe decline in recent decades, which calls for more informed management options.

In this study, we estimate the socially optimal amount of coastal cod biomass in Arctic Norway by employing a dynamic bio-economic fisheries framework. In addition to the monetary benefits of the primary users of coastal commercial fishermen and the recreational anglers, we also incorporate non-use values deriving from a discrete choice experiment (DCE) conducted on the regional population. The experiment not only informs on the willingness-to-pay (WTP) for improving the coastal cod stocks for future generations, it also provides the locals' position regarding the distribution of coastal cod among different users and conservation. While this approach enables us to feed the often neglected non-use values into the system, it also expands the former studies combining bio-economic models

and stated preferences by comparing the optimal biomass based on society's standpoint and the current situation regarding distribution of stocks.

The preliminary results indicate that if the management of stocks matches the society's distribution of use and conservation, the socially optimal coastal cod biomass level rises from 290153 tons to 518057 tons, with a 10000-ton decrease in the harvest. As the average annual coastal cod harvest is approximately 44000 tons, this is a significant decline. The non-harvested stocks for improving the biomass condition generates a non-use benefit of around EUR 270 million, while resource rent from the commercial harvest is around EUR 31.5 million. However, optimizing on the current situation, and therefore not adjusting the share of stocks toward regional population's preferences, the optimal stock level is 508716 tons, with around 5000-ton decline in harvest levels from the current situation. In line with the reduced optimal stock level, conserved biomass produces a much lower monetary benefit of EUR 93 million in this case, whereas the resource rent from the commercial harvest rises to EUR 43.4 million. In both cases, the recreational fishermen are on the losing side in monetary terms. Nonetheless, when the regional population's views on the sharing of stock are taken into consideration, the overall monetary gains compensate for the loss of recreational fishermen, while the system generates a monetary loss deriving from the large drop in conservation value in status quo.

Overall, the results demonstrate the considerable gap between the present condition of coastal cod biomass and socially optimized management options, while pointing out the differences between the current regulatory framework and regional population's standpoint regarding a vital public resource.

Fisheries IV

Thursday June 03: (8:00am - 9:30am) • Room B

Session Chair: *Hanna Schenk*

8:00am - 8:30am · On the fisheries benefits of protecting large fish from harvest assessed using age-structured models

Robert Arlinghaus, Robert Ahrens, Mike Allen, Carl Walters

Abstract: We address the problem of optimal size-selective exploitation in an age-structured fish population model by systematically examining how density- and size-dependency in growth, mortality and fecundity affect optimal harvesting patterns when judged against a set of fisheries objectives. The study offers five key insights. First, while minimum-length limits often maximize the biomass yield, exploitation using harvest slots (i.e., regulations that protect both immature and very large individuals) can generate within 95% of maximum yield; harvest slots also generally maximize the number of fish that are harvested. Second, density-dependence in growth and size-dependent mortality predict more liberal optimal size-limits than those derived under assumptions of no density and size-dependence. Third, strong density-dependence in growth maximizes the catch of trophy fish only when modest harvest is introduced; the same holds for numbers harvested, when the stock-recruitment function follows the Ricker-type. Fourth, the inclusion of size-dependent maternal effects on

fecundity or egg viability has only limited effects on optimal size limits, unless the increase in fecundity with mass (“hyperallometry”) is very large. However, large hyperallometry in fecundity shifts the optimal size-limit for biomass yield from the traditional minimum-length limit to a harvest slot. Fifth, harvest slots generally provide the best compromises among multiple objectives. We conclude that harvest slots, or more generally dome-shaped selectivity to harvest, can outperform the standard minimum-length selectivity. The exact configuration of optimal size limits crucially depends on objectives, local fishing pressure, the stock-recruitment function, and the density and size-dependency of growth, mortality and fecundity.

8:30am - 9:00am · Consumers' love for marine biodiversity

Kira Lancker, Julia Bronnmann

Abstract: In a marine multi-species environment, consumers' decisions may introduce interactions between species beyond biological ecosystem links. The theoretical literature shows that consumer preferences for variety can trigger a sequential collapse of fish stocks. However, consumer preferences are not yet fully understood empirically: It is uncertain how variety-loving consumers are.

In this article, we present an aggregation procedure to study consumer preferences in a highly diverse marine system. In a first step, we use co-integration analysis to find groups of species that consumers find substitutable. In a second step, we use a quadratic almost ideal demand system (QUAIDS) to estimate price elasticities between these groups. We use these to quantify and compare welfare losses and spillovers from species-specific price shocks that may for example result from restoration efforts. Our case study from Senegal across 28 species reveals evidence that consumers value the ocean as a source of diversity on their plates. Thus, efforts to maintain biodiversity are justified by economic reasons in addition to ethical ones.

9:00am - 9:30am · Tipping points in the pelagic Northern Humboldt Current Ecosystem: coping strategies and consequences for the Peruvian Anchoveta fishery

Giovanni Romagnoni, Jorge Tam, Matthias Wolff

Abstract: The Humboldt Current Ecosystem is among the most productive upwelling ecosystems worldwide, hosting the Peruvian Anchovy (*Anchoveta*, *Engraulis ringens*) fishery, the largest fisheries in the world. The system is subject to strong fluctuations related to the El Niño Southern Oscillation and other short and long term cyclic patterns. These affect the food chain, leading to changes across components of the system from plankton to megafauna, and influence the anchovy target fishery, with dire repercussions on the socio-economic system. These cyclic events interact with global climate change in unpredictable ways. The adaptive management strategies in place allowed so far a sustainable management of the anchovy fishery, however the future implications of ENSO and climate change interactions may lead to a tipping point, at which the system may turn to a different, less (fishery) productive state. To prevent this eventuality, or to be prepared for its arrival,

the identification of fishing management measures that can cope with an ecological tipping point are needed.

We apply here an ecosystem model for the Northern Humboldt Current ecosystem using the Ecopath with Ecosim framework. We design climate and fishing scenarios with the goal of identifying tipping points on the pelagic component of the system, dominated by anchovy. The purpose of this exercise is to determine to what extent fishing can influence the position of a tipping point, and how alternative fisheries management measures can permit to avoid a tipping point, while maintaining a lively fishery. The capability of the ecosystem model to account for multi-species dynamics allows the inclusion of predator-prey dynamics and predation mortality, moving away from single species perspective.

Additional considerations on the potential alternatives for fisheries, such as diversification of the fishery and change of target species, are discussed. These measures, when properly planned, may allow avoiding that an ecological tipping point automatically leads to a collapse of the fishery sector, and to a socio-economic tipping point for a system that relies heavily on fisheries for income and food security.

Social ecological systems

Thursday June 03: (10:00am - 12:00pm) • Room A

Session Chair: *Muniyandi Balasubramanian*

10:00am - 10:30am • Building Socio-Ecological resilience to promote sustainability: The case study of Dal Lake, Jammu and Kashmir, India
Ishfaq Ahmad Sheergoiri, Aadil Farooq War, Subzar Ahmad Nanda

Abstract: Lake ecosystems are considered sustainable when they have the ability to cope with and recover from stresses and shocks, which allows them to maintain or improve their capabilities in the future. Resilience theory offers a vision of sustainability. It is related to the magnitude of disturbance that a social-ecological system can absorb and still retain essential structures and functions of the coupled human and natural systems by updating the self-organization capability through learning and adapting. The social-ecological resilience to future challenges of these ecosystems and the communities which depend on them is directly intertwined and is continuously being challenged by rapid urbanization, population growth and the impacts of land degradation and climate change. Resilience theory offers a vision of sustainability. The drivers leading to land transformation are broadly categorized as biophysical, institutional, technological and economic factors which are often interwoven and therefore cannot be understood independently. Thus, a sustainable lake ecosystem would mean nurturing social institutions that can dynamically evolve adequate solutions in both social and ecological sense. Dal Lake, an important water reserve for Srinagar City of Kashmir valley provide suitable settings for developing measures of social-ecological resilience as it is geographically bounded and readily identifiable as a coupled system where human activity is often an integral part of Lake ecology. The case for building resilience of this system is urgent, given the trends in human settlement, resource use, eutrophication and climate change. Therefore, we tried to develop a measurement model for resilience of

Dal Lake based on selected surrogates or indicators as proxies to assess resilience in this closely intertwined social-ecological system. The indicators for examining the social-ecological resilience of Dal Lake were

1. Use of local indigenous knowledge
2. Diversity of institutions to respond to change
3. Demography
4. Socioeconomic status (income, political power, livelihood)
5. Land use decisions (how these are taken?)
6. Changes in Land cover, land surface, and biodiversity

Our analysis revealed that measurement and formulation of social-ecological resilience is required to strengthen and sustain the desired social-ecological state of Dal Lake and make it resilient to future change and unpredictable events.

10:30am - 11:00am · Henna (*Lawsonia inermis* L.) dynamics in socio-ecological system of arid zone of Pali Marwar, India

Dheeraj Singh, M K Chaudhary, Chandan Kumar, A Dudi

Abstract: Henna (*Lawsonia inermis* L.), is a perennial shrub dominating the agro-ecosystem of Pali district of Rajasthan, India which is priced for its leaves which have natural dyeing properties. From ancient times, henna has been employed as a cosmetic dye for hair, skin and nails and it has acquired a particular significance in Islamic culture. It is dryland shrub which can tolerate extreme dry and high temperature conditions and survives well on problematic soils with high pH and saline water where other crops cannot be grown. The development of henna cultivation and processing in Pali, Rajasthan is a blend of indigenous knowledge and people's innovations. It has led to overall development of the region through new avenues in trading, processing and marketing. Presently henna cultivation in the region is under 40,000 hectares which is the largest area under this crop at single location and it is purely rainfed with no use of fertilizers or pesticides. The value of henna from this region is because of this pattern of cultivation being followed by the farmers since decades. In this crop generally, no fertilizers and plant protection measures are used and a single leaf cutting is taken every year under the rainfed conditions and two cuttings where water is available. Under rainfed conditions for dense planting the dried leaf yield in the first year is about 250 kg/ha while over the second, third and fourth years the yield normally ranges from 500 to 2,500 kg/ha. Traditionally the farmers adopt summer ploughing to control weeds, insect pests and water retention during rains. The crop starts giving returns from second year onwards which continues for 20 years with incurring of only maintenance cost in the form of hoeing, weeding and harvesting. By following these measures, on an average they produce 15-20 quintal dry henna leaves per hectare from their barren fields. After drying, the twigs and woody portion is separated from the bulk and the seeds and leaves are collected. The leaves are carried to processing units where the leaves are processed and then powdered for packing in different sizes packets. The seeds are used for nursery raising which are in great demand for their ornamental garden value and as seedling for further extension of henna fields in new areas. The woody portion is also sold at premium price for brick industry. The village women and young girls are employed throughout the year for making and filling of henna cones which is semiliquid form of henna

used for tattooing. The financial analysis indicated that henna farming due to its high quality at Pali is a profitable and attractive option for farmers livelihoods. The occurrence of frequent drought also encouraged farmers to divert area in henna as farmers hardly get any income from arable crops during drought situation while henna gives at least some returns during this agriculturally harsh condition. Sustainable income from henna benefits the farmers of the district as it can tolerate high salinity, drought and incidences of pest and diseases.

11:00am - 11:30am · Valuing ecosystem services evidences from the global biological diversity the Western Ghats, India

Muniyandi Balasubramanian

Abstract: The study examines the economic value of ecosystem services in the Western Ghats in Karnataka, India. There are a number of studies have been investigated in this region but the lack of economic assessment of ecosystem services still remains scarce. Therefore, this study has estimated the value of provisioning services through the market price method of non-timber forest products and the value of water ecosystem services through the 253 households; regulating ecosystem services has been estimated based on secondary data of the different protected areas, and the value of recreational ecosystem services through the travel cost method of 725 tourist visitors are visiting to the protected areas. The total economic value of ecosystem services has estimated at Rs 391.1 billion for 2019-20. The regulating ecosystem services such as carbon sequestration and soil erosion prevention has the highest value among the other ecosystems services in the study area. The main policy implication of the study is useful to design entry fee for the various protected areas and sustainable natural resources management for the socio, economic and ecological sustainability at the local level.

Bioeconomic systems

Thursday June 03: (10:00am - 12:00pm) · Room B

Session Chair: *Matthew H Holden*

10:00am - 10:30am · Sustainability of grazing land management in northern Australia's tropical savanna under global change

Rebecca K Runting, Martin Nolan, Darran King, Javier Navarro, Raymundo Marcos-Martínez, Jonathan R Rhodes, Jeff Connor, Lei Gao, April Reside, Jorge Alvarez-Romero, Euan Richie, Ian Watson, Andrew Ash, Timothy Doherty, Michalis Hadjikakou, Don Driscoll, Brett A Bryan

Abstract: Livestock is an increasingly important part of the global food system and the livelihoods of local people, but concerns have been raised about the future sustainability of livestock production including greenhouse gas (GHG) emissions, biodiversity, and water resource use. Extensively grazed cattle generally have a relatively high methane output per animal due to poor quality pasture and limited options for intensification, but significant

potential for emissions reductions exists. At the same time, the capacity of tropical savanna to maintain livestock production is likely to be impacted by climate change, primarily through the impact of changes in temperature, rainfall, and fire regimes on pasture and water requirements. In addition, external economic drivers, such as changing prices for livestock and carbon, could affect the viability of these production systems and abatement actions. We used an integrated, spatio-temporal modelling approach to assess the impact of climate change, fire, and global economic drivers on the effectiveness of different management actions across northern Australia's rangelands. The outcomes we assessed spanned a range of sustainability indicators, including landholder profit, beef cattle production, water intake, land degradation, GHG emissions, and biodiversity. Without changing grazing management or undertaking GHG emissions abatement actions, the future of northern Australia is heavily skewed towards production outcomes at the expense of all environmental outcomes. Continuing with the current level of grazing is not sustainable due to the accelerated land degradation and increasing water intake arising from a changing climate. Alternatively, planned early dry season burning resulted in substantial emissions reductions, and became economically profitable independent from grazing under all global change scenarios that included a carbon price. Although there were no perfect win-wins, production and environmental outcomes could be balanced by combining safe stocking rates and emissions abatement actions. Vast areas of extensively grazed savannas have relatively low levels of livestock production, so the opportunity to diversify income streams through income from emissions abatement actions may prove vital in a changing climate.

10:30am - 11:00am · Organic Leakage in the Beef Sector and its Impacts on the Value Chain

Yan Jin, Kevin Kilcline, Mary Ryan, Cathal O'Donoghue

Abstract: Organic farming is an agricultural method that encourages the responsible use of energy and natural resources, the maintenance of biodiversity, preservation of regional ecological balances, enhancement of soil fertility, and maintenance of water quality. Various organic supports have been offered worldwide to encourage farmers to respond to the market demand for organic foods and stimulate organic conversion, which is a process that has to be undergone by all conventional farms that wish to convert to organic ones.

However, with the potential leakage of organic products to the conventional (non-organic) value chain, the policy support may result in less than effective policy incentives and as a result have the potential of auditors questioning the schemes. Analyzing the general impacts while presuming no leakage across the value chain in previous studies would overestimate the impacts of organic conversion. The study contributes to the literature in three aspects. 1. Illustrating the leakage of animals from the organic to the conventional value chain and its mechanism from a theoretical perspective; 2. Quantifying the level of organic leakage and its impacts on the value chain based on a Bio-Economy Input-Output model; 3. Providing policy implications on the viability and potential improvement of the incentive schemes based on the implementation and effectiveness of the current policy support.

To analyze the value generation across the value chain and the interdependencies between various inputs and outputs among segments of production, we adopt a Bio-Economy Input Output model (BIO). To assess the change of value added at various stages of the beef

industry, we further disaggregate the BIO model to include additional 26 sectors for cattle at various age groups, as well as additional processing and retailing sectors. The disaggregation enables us to analyze the interdependencies that exist at the farm gate of the beef industry in detail, differentiate the production costs between conventional and organic sectors, and quantify the value added across the value chain.

By mapping the progression of animals through the organic value chain, results show that the leakage of animals from the organic to the conventional beef sector in Ireland equals to around 17%. We quantify the impacts of organic leakage for farmer, processor, and retailer across the value chain to be around 18.4 million euros. Inefficient schemes without getting the impacts that those schemes are targeting at may be a source for public fund loss. To stimulate organic conversion, it is crucial to take into consideration of the potential leakage across the value chain and its impacts. In other words, it is necessary that policy measures go beyond production to include processing and retail, as well as developing the demand side. Our study provides insights for stakeholders, especially for policy makers in policy design and improvement in the future. The results also have important implications for the discussion on effective and efficient policy schemes on organic conversion worldwide.

11:00am - 11:30am · Evaluate the conservation value of leopard cat's habitat in Taiwan

Yawen Chiueh, Yi-Chin Lai

Abstract: Leopard cats, a top-level carnivore, are the key-stone species in the ecosystem and also the flagship species in Taiwan. Leopard cats is facing the threat of human development such as habitat loss and fragmentation, in Taiwan. Leopard cat's habitat should be developed or that to conservation? The value of land development and the value of habitat conservation is need to be estimated. This study uses the contingent valuation method (CVM) to evaluate the Miaoli (residents in the leopard cat's habitat) and the Hsinchu (non-residents of the leopard cat's habitat) people's willingness to pay (WTP) for the conservation of the leopard cats and compare the difference between the adult's WTP and child's WTP. We create a hypothetical market and use payment cards method to estimate the residents' and non-residents' (in the leopard cat's habitat) WTP. The adult of personal per year WTP is NT 929.05 at Miaoli area, that is NT 1,181.48 at Hsinchu area and all adult is NT 1,064.94 at Miaoli area and Hsinchu area. The non-use value of the conservation of the leopard cats is NT 199.1715billion one year.

11:30am - 12:00pm · Lions, tigers, and bears, oh my! - how do we save them from poaching?

Matthew H Holden

Abstract: Illegal harvest of wildlife (poaching) is one of the greatest threats to biodiversity. Most countries try to reduce poaching by increasing law enforcement to catch and punish poachers. But despite best efforts from police, poaching is still pervasive. In this talk, we present ordinary differential equation models of poachers and wildlife, to explore why law-enforcement has failed to stem the poaching problem. We then use these models to project

the performance of controversial, alternative, management actions, such as campaigns to reduce consumer demand for illegal wildlife products and legalizing the trade of these products.

PhD session 2.II

Thursday June 03: (4:30pm - 6:00pm) • Room A

Session Chair: *Suvangi Rath*

4:30pm - 5:00pm • Ecosystem dynamics and fishing management scenarios for the coastal fishery in French Guiana under climate change constraints

Hélène Gomes

Abstract: Marine ecosystems, biodiversity, and fisheries are under strain worldwide due to global changes including climate warming and demographic pressure. To address this issue, many scientists and stakeholders advocate the use of an ecosystem approach for fisheries that integrates the numerous ecological and economic complexities at play rather than focusing on the management of individual target species. However, the operationalization of such an ecosystem approach remains challenging, especially from a bio-economic standpoint. Here, we propose a model of intermediate complexity (MICE) relying on multi-species, multi-fleet, and resource-based dynamics. Climate change effects are incorporated through an envelope model for the biological growth of fish species as a function of sea surface temperature. The model is calibrated for the small-scale fishery in French Guiana using a time series of fish landings and fishing effort from 2006 to 2018. From the calibrated model along with climate scenarios derived from IPCC, we contrast different fishing management strategies at the horizon 2070 including Multispecies Maximum Sustainable Yield (MMSY), Multispecies Maximum Economic Yield (MMEY) and viability, in order to explore the impact of these fishing management strategies and climate change on the ecosystem dynamics and on the fishery production.

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Abstract: Lake Poyang is China's largest freshwater lake. The lake provides important winter habitat for numerous endangered and threatened species of cranes and other waterfowl. Lake Poyang has provided multiple market and non-market ecosystem services in an uncoordinated fashion to local users for centuries. Conflict among users has been shaped and moderated by various traditional systems of rights and customs. Over the recent past, changing environmental and economic conditions have magnified some of those conflicts. This paper develops and calibrates a model of one important conflict where long-standing local fisheries operations have increasingly impinged on winter habitat for endangered and threatened waterfowl.

Lake Poyang is a seasonal lake whereby a vast region floods under subtropical monsoon weather, and then recedes as the dry Autumn-Winter season unfolds. For centuries, local villages have constructed and maintained dikes that trap water and fish in sub-lakes as the surrounding lake recedes. Local villages auction temporary user rights to individual contractors to extract fish from adjacent sub-lakes. Contractors execute a slow draining of the sub-lakes that allows low cost harvesting of escaping fish, generating proceeds partly returned to the village. Draining the lakes also exposes tubers, which are prime feed for critically endangered Siberian cranes and other species. The conflict emerges because the sub-lake drawdown that is dynamically optimal for within-season fisheries production is not optimal for tuber foraging for the wintering wildfowl populations. As China's wealth has grown, the market value of tourism services associated with crane viewing and photography has grown, leading to conflicts within the various lake-side villages over how to trade off multiple users of near-shore lake uses. In addition, the central government is promoting preservation of unique habitat and endangered species, actions that signal growing recognition of non-market ecosystem values.

To understand the interaction between local fishery practices, water level change, tuber growth and crane populations, this paper constructs a structural model that begins with a model of the inter-annual hydrology of Lake Poyang coupled to a model of lake-bottom vegetation and intra-annual crane population biology. Without local sub-lake fisheries, crane populations would be determined by the influence of intra- and inter-annual water fluctuations on vegetation critical to over-wintering feeding. The lake-vegetation-crane model is parameterized and then coupled to a model of the local sub-lake fisheries. We determine optimal sub-lake drawdown under various bioeconomic conditions and examine the impact of profit maximizing fisheries decisions on crane populations. We find that the fisheries begin drawdown sooner and drain the lake earlier than desirable for crane population habitat provision.

We also discuss how this complicated system may evolve under climate change. Climate change is projected to alter inter- and intra-annual rainfall at Lake Poyang, and conditions in the Siberia where birds breed after wintering in Lake Poyang. We find that more rainfall in Lake Poyang during the Autumn-Winter season shortens the fishing season and escalates the conflict between fishery and crane conserving. This in turn suggests mitigation strategies that might counter adverse climate impacts on survival of endangered species dependent upon Lake Poyang.

5:30pm - 6:00pm · Drivers of Ecosystem Changes and Human Wellbeing A Case Study of Jamujhari Village

Suvangi Rath, Amarendra Das, R K Mishra, Khitish Kumar Sarangi

Abstract: In this paper we have tried to understand the drivers of ecosystem changes and its implications for human wellbeing. For this purpose, we have done the mapping of the ecosystem of a village located near a Sanctuary and a state capital. We have assessed the changes in the ecosystem over last three decades. We have mapped the drivers of changes to the ecosystem. Using FGDs and Expert Interviews local perceptions on the ecosystems and their services have been taken into account to assess the implications of the change in the ecosystems overtime. It has been found that the village being close to the capital city is highly influenced by urbanisation that has led to a negative shift in the prime occupation of the village, i.e. agriculture. However, owing to less human intervention, the natural environment has seen a positive shift.

Society and Climate Change 2.1

Thursday June 03: (4:30pm - 6:00pm) · Room B

Session Chair: *Jorge Marco Renau*

4:30pm - 5:00pm · Health Interventions in a Poor Region and Resilience in the Presence of a Pandemic

Amitrajeet A Batabyal, Hamid Beladi

Abstract: We focus on a poor region and analyze the connections between health interventions undertaken by a regional authority (RA) and this region's resilience in the presence of a pandemic such as Covid-19. First, we show how a health intervention by the RA stochastically impacts an appropriately defined health indicator for this region. Second, we compute the probability that the health status of this region's population falls below a minimum acceptable level in the presence of the health intervention. Third we solve an optimization problem in which the RA maximizes the likelihood that the health status of this region's population stays above a minimum acceptable level at a given economic cost. Finally, we discuss the nexus between a health intervention, our region's health status, and its resilience by presenting two applications of our theoretical framework.

5:00pm - 5:30pm · Sustainability trajectories of socio-ecological system.
Modeling environmental policy and climate change scenarios in a tropical
Andes basin.

Linda Ivette Berrio-Giraldo, Clara Inés Villegas-Palacio, Santiago Arango-Aramburo

Abstract: Formulation and implementation of land-use strategies for sustainable territory management require an understanding of the complexity of the socio-ecological system in the territory. This calls for a systemic analysis the socio-ecological system which allows us to understand the trade-offs and synergies between different ecosystem services and the effects on the socio-economic factors resulting from the different land management practices. The above can promote the design of sustainable landscape strategies that meet human need while maintaining the ecosystem's capacity to preserve key ecosystem services.

This research analyzes the dynamic effect of different policy and climate change scenarios on the sustainability of a basin using a simulation model in system dynamics. The applied model allows understanding the dynamics of land use and land cover change, and its incidence on the provision of ecosystem services related to water and soil resources. Also, the effects on the net benefits perceived by the economic activities related to each land cover are analyzed. For the conceptualization of the model, this research was based on the conceptual framework proposed by IPBES, and five modules were defined: natural, ecosystem services, economic, socio-cultural, and institutional.

The case study is the Riogrande basin, which is located in the northern region of the department of Antioquia - Colombia. The ecosystem services selected were erosion control and surface water supply. The scenarios and policies analyzed include assessment of institutional capacity, climate change, and two types of policies: (i) endogenous types such as Payments for Environmental Services and (ii) exogenous type such as Free Trade Agreement. Each scenario and policy were contrasted with the BAU case to 2040.

It was found that a combination of restrictive policies and conservation incentives can improve the sustainability of the socio-ecological system. The above is due to guarantee the provision of ecosystem services and generate economic income that positively contributes to the economy of landholders in the basin at the same time. The importance of socio-cultural characteristics in the design and effectiveness of policies was also highlighted. This research demonstrates the advantages of the application of integrated simulation models since it allows to evaluate the aggregate effect of these policies on the socio-ecological systems, and evidence counter-intuitive effects or trade-offs between environmental objectives.

5:30pm - 6:00pm · Optimal policy design under time-varying social and
environmental conditions

Jorge Marco Renau, Renan Goetz

Abstract: This paper analyzes the influence social networks and the state of a common property resource have on compliance with social norms in relation to a social dilemma. We find that interior equilibria can be stable and their stability is augmented when informal enforcement (social pressure) entails costs. The area of network influence allows to identify under which conditions legal (e.g., fines or subsidies) and informal enforcement policies are

available to policymakers and design optimal policies to achieve full cooperation. In relation to the resource, we show that cooperativeness is unlikely to prevail if social dilemmas are perceived as not severe.

Society and Climate Change 1.I

Friday June 04: (8:00am - 9:30am) • Room A

Session Chair: *Felix Meier*

8:00am - 8:30am • The Commons Problem under Uncertainty and Precaution

Björn Bos, Moritz Drupp, Jasper Meya, Martin Quaas

Abstract: We study a commons problem under uncertainty, where individual actions affect the a risk of a future damage event. We show that for risk-averse agents, an extra risk on the amount of the damage induces more precautionary actions in Nash equilibrium. Similarly, for prudent agents an extra risk in all states of the world induces more precautionary actions in Nash equilibrium. We show that this may lead to the result that small extra risks may increase welfare in Nash equilibrium and derive a condition on the relationship between actions and damage probability and the opportunity costs of precaution for this result to occur.

The model applies to climate change, where the actions are the countries' carbon dioxide emissions causing the threat of climate damage, as well as to the COVID 19 pandemic, where physical social contacts cause the risk of an infection with the coronavirus. Data from a representative survey in Germany shows that the theoretical results are in line with the theoretical predictions.

8:30am - 9:00am • On the cost-effective temporal allocation of credits in conservation offsets when habitat restoration is uncertain

Martin Drechsler

Abstract: Tradable permits or offsetting schemes are increasingly used as an instrument for the conservation of biodiversity on private lands. Since the restoration of degraded land often involves uncertainties and time lags, conservation biologists have strongly recommended that credits in conservation offset schemes should awarded only with the completion of the restoration process. Otherwise, as is claimed, is the instrument likely to fail on the objective of no net loss in species habitat and biodiversity. What is ignored in these arguments, however, is that such a scheme design may incur higher economic costs than a design in which credits are already awarded at the initiation of the restoration process. In the present paper a general agent-based ecological-economic simulation model is developed to explore different pros and cons of the two scheme designs, in particular their cost-effectiveness. The model considers spatially heterogeneous and dynamic conservation costs, risk aversion and time preferences in the landowners, as well as uncertainty in the duration and the success of restoration process. It turns out that, especially under fast

change of the conservation costs, awarding credits at the initiation of restoration can be more cost-effective than awarding them with completion of restoration.

9:00am - 9:30am · Carbon dioxide removal in a global analytic climate economy
Felix Meier

Abstract: This paper investigates the option of carbon dioxide removal (CDR) and storage in different reservoir types in an analytic climate-economy model, and derives implications for optimal mitigation efforts, and CDR deployment. I show that the introduction of CDR lowers net energy input and net emissions over the entire time path. Furthermore, CDR affects the Social Cost of Carbon (SCC) via changes in total economic output but leaves the analytic structure of the SCC unchanged. In the first years after CDR becomes available the SCC is lower and in later years it is higher compared to a standard climate-economy model. Carbon dioxide emissions are first higher and then lower relative to a world without CDR. The quantitative analysis shows that the effect of CDR on the SCC is minor and only accounts for an increase of 3 USD/tCO₂ by the year 2100.

Water and Pollution

Friday June 04: (8:00am - 9:30am) · Room B

Session Chair: *Emmanuelle Augeraud-Veron*

8:00am - 8:30am · On optimal clean-up of polluted sites under limited funds
Pauli Lappi

Abstract: How should a given budget be used to clean-up N number of polluted sites, when the sites' pollution stocks cause damages and the clean-up is costly? A problem policy makers often face is the prioritisation of polluted site clean-ups under limited budgets. The aim is to answer how should a given initial budget be used to finance site clean-ups when the budget is initially low enough so that all the sites cannot be cleaned simultaneously at the outset. In particular, given the sites' properties related to the time evolution and hazardousness of the pollutions stock and given the available clean-up technologies, in what order should the sites be cleaned to minimize the total damages from the sites' pollution stocks?

The developed model is as follows. Each polluted site has a pollution stock that causes damages and which diminishes through natural processes. At each instant the decision maker can either invest into a costly abatement capacity of the site to speed up the abatement process or wait and save the funds. The investment costs must be covered by the available funds whose evolution in time is described by an initial value problem with jump conditions. These downward jumps in the budget occur at clean-up dates and the sizes of the jumps are determined by the investment cost. The problem for the decision maker is to use the available budget to minimize the total present value of pollution damages over an infinite time horizon by choosing the clean-up dates and the clean-up investment capacities. To answer the research questions, it is first shown that all of the remaining budget is used to clean-up the last site. Then it is argued that every site is cleaned and after this it is shown

that a solution to the problem is a solution to a simplified problem. This problem is used to characterize the optimal solution and the relevant trade-offs in the form of waiting rules. Simplified problem formulation will be used to investigate the optimal order to clean the sites (note: this last part is work in progress).

The model can also be used to answer a similar question related biodiversity conservation: How should a given budget be used to restore N number of ecosystems, when sites' habitats are valuable and restoration is costly? Instead of thinking the model as polluted site clean-up, the model can be interpreted as describing the order to restore weakened habitats or ecosystems when the conservation budget is limited. In this interpretation the deteriorated ecosystem produces some benefits (instead of damages as with polluted sites), but once restored, the benefits increase. Restoration is costly, and each restoration cuts the available budget.

8:30am - 9:00am · Partial Equilibrium Modelling for Estimating Trade-offs of Economic Enterprises in Lake Dal, Kashmir, India
Neha Wajahat Qureshi, M Krishnan, N Sivaramane

Abstract: Lake Dal, Srinagar, Kashmir, India plays host to major economic activities relating to tourism, sightseeing, recreational activities, fisheries, harvesting of food and fodder plants, irrigation of vegetable crops. The Lake Dal is the fountainhead of three lead economic activities, namely 1) fishery 2) tourism and 3) vegetable farming. During the second half of the 20th century, this previously undisturbed water body became the worst victim of anthropogenic pressures and has undergone tremendous ecological changes. It has also suffered in terms of skewed growth in the composition of fish populations in the lake. This study thus aimed to establish a trade-off between the three main economic enterprises on Lake Dal and achieve the optimum levels of returns for the enterprises that it supports, using a decision support system. This study is a pioneering study and was severely challenged by a lack of time-series data for various parameters. For estimating trade-offs among the economic enterprises in Lake Dal, a custom made excel template was developed to achieve partial equilibrium. Partial equilibrium analysis was used to estimate trade-offs among the 3 economic enterprises by optimizing the amount of pollution abatement investment to maximize the total welfare of all the stakeholders. The total lake welfare was estimated by taking the summation of total net returns annually from all the three sectors and the employment generated by them (José- María Da-Rocha, 2020). A linear programming model was used to maximize the total welfare from the lake. The welfare optimization exercise, therefore, yielded a total optimal welfare value of INR 5684.85 million over INR 3144.02 million (present value), with a pollution abating investment of INR 13.21 million, which indicated an 81 percent increase in total welfare generated from the three enterprises operating on the Lake Dal. The optimization matrix does not recommend any change in pollution abatement cost with respect to dredging and de-weeding.

9:00am - 9:30am · Sustainable groundwater management in a two-cell aquifer model

Emmanuelle Augeraud-Veron, Jean-Christophe Pereau

Abstract: The design of optimal water policies between farmers, municipalities and groundwater-dependent ecosystem is analysed in a hydro-economic model with physical interactions between a confined aquifer and a shallow aquifer having a natural drainage. The non cooperative open loop equilibrium and the social optimum implemented through a water market are derived in this multi-use and multi-cell model. Based on the Pecos Basin case study, we analyse the trajectories of the water tables and the water allocation between users and the environment. We also explore the consequences for the water manager to use a one-cell model instead of the two-cell model. Our results show the importance to consider hydraulic conductivities for the preservation of groundwater-dependent ecosystem.

Renewable Resources

Friday June 04: (4:30pm - 6:00pm) · Room A

Session Chair: *Stefan Baumgärtner*

4:30pm - 5:00pm · Time-consistent renewable resource management with present bias and regime shifts

maria arvaniti, Chandra Kiran B. Krishnamurthy, Anne-Sophie Crepin

Abstract: We investigate the extraction plan of present-biased decision makers managing a renewable resource stock, whose growth is uncertain and which could undergo an abrupt and significant change when stock falls below a threshold. We show that the Markov-Nash equilibrium extraction policy is unique, time consistent, and increasing in resource stock. Increases in the threshold or in the degree of present bias trigger greater resource extraction, rather than the precautionary reduction in extraction often observed with exponential discounting. Our analysis suggests that accounting for and appropriately dealing with resource managers' present bias may be important to ensure sustainability of resource use.

5:00pm - 5:30pm · Impacts of human behaviour in agri-environmental policies: how adequate is homo oeconomicus in the design of market-based conservation instruments?

Martin Drechsler

Abstract: Models of human-environment systems frequently employ the model of rational behaviour in which a rational, perfectly informed and self-interested *homo oeconomicus* maximises individual utility. This model has been criticised with regard to its adequacy in models of social-ecological systems, because other motives exist beyond profit maximisation

that affect land-use decisions. The question arises what consequences do these other motives have on the design and performance of environmental policy instruments. For this, two existing generic models of agri-environmental schemes are expanded to consider alternative landowner behaviours: agents make mistakes in their search for the profit-maximising land-use decision, are inequity-averse and care about the profits of their neighbours, and are influenced by their neighbours' decisions. In the analyses even large deviations from the model of *homo oeconomicus* have generally only a small or moderate effect on the cost-effective design and the level of cost-effectiveness of the two agri-environmental schemes. With the models being rather simplistic, the results should not be used for specific policy advice but to point out and argue that the model of *homo oeconomicus* should not be abandoned prematurely, but its scope in environmental policy advice needs to be assessed more thoroughly both empirically and theoretically.

5:30pm - 6:00pm · Responsibility for regime shifts in managed ecosystems

Stefan Baumgärtner

Abstract: I develop a quantitative measure of a manager's responsibility for a regime shift in a managed ecosystem with stochastic dynamics. I build on the well-established concept of responsibility, which I operationalize in a simple generic model. Causal responsibility is the degree of causation of an outcome due to the manager's action, which is in contrast to chance influences that may also have caused the outcome ("good luck" or "bad luck"). Normative responsibility is the manager's obligation to see to it that the system is in, or shifts to, a specified desired state. It implies a particular management action. Virtuous responsibility is the degree to which the manager lives up to her normative responsibility when taking a management action. The quantitative measurement of responsibility is relevant to judge management actions, to reward or punish the manager based on the extent of her (ir)responsibility, and to design institutions that enable and encourage responsible management of ecosystems with potential regime shifts.

Policy, resilience and climate change

Friday June 04: (4:30pm - 6:00pm) · Room B

Session Chair: *Luc Doyen*

4:30pm - 5:00pm · Environmental Policy Stringency and Economic Growth: New Evidence from OECD and BRIICS Countries

Mahmoud Hassan

Abstract: This paper makes three contributions to the literature of environmental economics. First, a new environmental policy stringency index (EPS) provided by the OECD, is employed as an indicator for the stringency of environmental regulations. Second, this study explores the nature of the relationship between EPS and GDP per capita. Third, we examine whether this relationship differs between BRIICS and OECD countries. Using data from 27 OECD countries and 6 BRRICS countries over the period 1990 - 2015, we find that a more

strict environmental policy is associated with an increase in the GDP per capita in the short-and-long-term. This positive relationship appears to be more important in emerging economies than developed. Finally, market-based environmental policy instruments are more effective to promote GDP per capita growth than non-market instruments. Therefore, a more stringent environmental law is a desirable policy not only to protect the environment but also to promote economic growth at the same time. In addition, the designers of environmental policy should focus on the use of market-based instruments.

5:00pm - 5:30pm · Climate change impact assessment on the coastal district of west Bengal, India

Sandip Pal, Vinod kumar Yadav

Abstract: Climate change and global warming has been given to top priority in recent days. To understand the socio-economic vulnerability and resilience of coastal village population of South 24 Parganas district of West Bengal, India with respect to climate change, the current research was taken. The socio-economic vulnerability index (SEVI), socio-economic sensitivity index (SI) and socio-economic adaptive capacity index (ACI) were calculated using standard methodologies. Exposure index was developed through multi hazard vulnerability map (MHVM) using GIS tools and finally the CVI for individual village, talukas and district levels were calculated. Socio-economic sensitivity index for villages in South 24 Parganas district ranging between 0.20-0.52 with median 0.37, which indicate less socio-economic sensitivity. There was a moderate economic sensitivity (ranging from 0.12-0.60, median 0.41) but low social sensitivity (ranging from 0.23-0.54, median 0.34) with significant difference between these two dimensions ($\chi^2=1059.30$; $p < 0.05$). Adaptive capacity of South 24 Parganas district was moderate (ranging from 0.22-0.62; median 0.41) besides CVI (ranged-0.10-1.0, median-0.40). SEVI calculated from rescaled SI and ACI was rated as low (0.47). Based on SEVI three villages were selected and Fisheries Livelihood Resilience (FLIRES) were calculated using RAPFISH-3.0, Multidimensional scaling. Among three selected villages, Abad Gangadharpur was found to be more vulnerable with low resilience at various dimensions. Geographical isolation, less financial and infrastructural supports were the main cause identified for vulnerability of the village. The different vulnerability index are further spatially represented using GIS tools for better understanding and management strategies. Exposure components were found to be a greater influencer in assessment of cumulative vulnerability status. It was also noted that village level study provides more insight on climate change impact assessment within district perspective. Key finding of this study shows lack of infrastructure facilities, institutional support, availability of markets, literacy rate, alternative job opportunities are the key factors influencing the vulnerability. The study also reveals that more financial, infrastructural and institutional supports are needed for the coastal population of the studies area.

5:30pm - 6:00pm · Operationalize the Three Rs of Resilience through
Ecoviability

Luc Doyen

Abstract: Scientists and decision-makers lack a shared understanding of resilience, and practical applications in renewable resources management including biodiversity management are rare. Here, we define ecological-economic resilience as a property of ecological-economic systems that includes three main characteristics — resistance, recovery and robustness (the ‘three Rs’). We define ecological-economic resilience management as planning, adaptation and transformational actions that may foster these three Rs characteristics. We show to what extent ecoviability modeling provides a relevant framework to operationalize such ecological-economic resilience management. Applications to fisheries and land-use illustrate the general approach.