THE UNIVERSITY OF MICHIGAN
DEPARTMENT OF ECOLOGY AND EVOLUTIONARY BIOLOGY

# NATURAL SELECTIONS

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## Five million Museum of Zoology specimens find new home

Over the past year some five million specimens from the U-M Museum of Zoology's "wet" research collection – animals preserved in alcohol inside various containers – moved from the Ruthven Museums Building on central campus to an impressive new off-campus facility.

"The move was designed to update the infrastructure of all ethanol collections. Basic standards and safety codes for storage of flammable material have changed comprehensively," said Diarmaid Ó Foighil, EEB professor and director and curator of the UMMZ. "The 1920s-era ethanol collection infrastructure in Ruthven no longer met code. The university has invested very heavily in providing a new state-of-the-art research collection facility on Varsity Drive."

The new facility, adjoining the U-M Herbarium in Ann Arbor, was designed and built to safely store the ethanol collections and to provide modern facilities for collection-based research activity. The budget for the project, which included building the new storage facility, moving the collection and other selected renovations, was $17.6 million. The move was completed five weeks ahead of schedule from December 2011 to July 2012, under budget, and with only a miniscule number of jars broken.

The U-M News Service filmed two videos about the "epic move" featuring an interview with Ó Foighil that appeared on the U-M Gateway.

According to Ó Foighil, highlights of the ethanol collections include an extraordinary assemblage of freshwater fish

credit: Mark O'Brien

biodiversity and an amphibian and reptile collection that is "easily one of the best in the world." In the video, Greg Schneider, collections manager for the Amphibian and Reptile Division, shows some examples of this global richness, including a goliath frog from Cameroon, the smallest known chameleon, and an Indian cobra with spread hood.

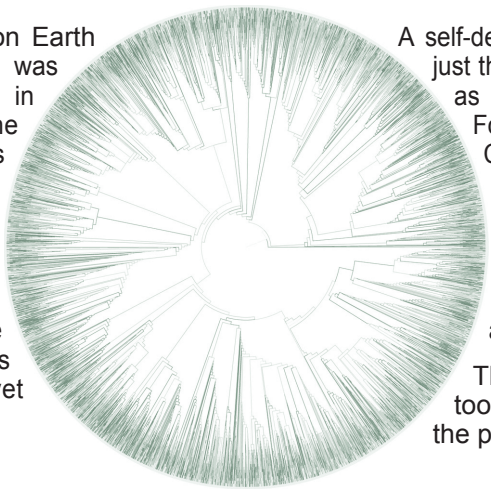
"We are looking forward to an equally first-class facility adjoining the U-M Herbarium for the dry collections, which are slated to move next," said Deborah Goldberg, professor and chair of EEB. "The co-location of the collections will bring about even greater integration of research between the Herbarium and the Museum of Zoology, including our ongoing efforts to make information available online through international databases."

"Two years of detailed planning and design paid off in a smooth problem-free move," Ó Foighil said. "The challenge is now to replicate this process for the dry collections and the entire UMMZ program, which is also relocating to Varsity Drive."

***View the video: http://bit.ly/ummz_move_video***

## Smith to tackle first ever draft of the tree of life

The realization that all organisms on Earth are related by common descent was one of the most profound insights in scientific history. The goal of elucidating the phylogenetic relationships of all species – building the complete tree of life – has since emerged as one of the grandest and most daunting scientific challenges ever undertaken. Imagine a tree of life that synthesizes all living and extinct creatures ever to grace the face of the planet – more than two million species named to date and millions more as yet unnamed.



A self-described computer nerd, Stephen Smith, is just the person to embark on this enormous task as part of a $5.76 million National Science Foundation three-year grant called OpenTree. Collaborators from the National Evolutionary Synthesis Center (NESCent) at Duke University, and seven other institutions will work together to grow this revolutionary draft tree. OpenTree is part of a larger NSF-funded effort called Assembling, Visualizing and Analyzing the Tree of Life (AVAToL).

This tree is expected to be a powerful tool that will enable scientists to interpret the patterns and processes of evolution

**see tree of life, page 6**

# chair's notes

**Deborah E. Goldberg**
**Elzada U. Clover Collegiate Professor and Chair, Ecology and Evolutionary Biology**

Dear Friends,

I returned to active duty in late April after a refreshing, although too short, sabbatical at the University of Arizona. I want to thank Professor Mark Hunter for doing a stellar job shepherding the department during the last semester and leaving me free to think about science and to enjoy the desert. Besides Tucson, I spent some time in France, Prague, Mexico, Nebraska, New York, and Florida, and even made one trip back to Ann Arbor. I refreshed my desert botany (it was a good bloom of winter annuals), spent time learning about trait-based macroecological patterns and analytical approaches with colleagues at the University of Arizona, got involved in analysis of data from several different long-term studies of desert vegetation, and worked through a considerable backlog of manuscripts with colleagues so that I was no longer the rate-limiting step.

As you'll see, we've dedicated this issue of *Natural Selections* to introducing our fantastic new assistant professors: Vincent Denef, Meghan Duffy, Daniel Rabosky and Stephen Smith. In these pages, you'll read about the interesting and ground-breaking research they conduct.

In addition, I'd like to extend a warm welcome to our new Michigan Fellow and assistant professor, Lauren Sallan, and research scientists Alison Davis Rabosky and Melissa Duhaime. Dr. Sallan's research interests include early vertebrate evolution, macroevolution, paleobiology, paleoecology, ichthyology and systematics. Dr. Davis Rabosky's research interests are the evolution of behavior, evolutionary genomics, character evolution and phylogenetics, and herpetology. Dr. Duhaime studies marine viral community genomics, phage-host model systems, and plastic-microbe associations in aquatic systems.

Unfortunately, I also have some sad news to share with you from over the past year. On November 24, 2011, Professor George Estabrook died after a courageous battle with cancer. George had been on the faculty at U-M since 1970 and taught numerous courses including computer-aided inference in ecology, practical botany and human nutrition for non-biology majors. On Feb. 13, 2012, Professor and Curator Emeritus Ed Voss died. Many of you will remember Ed from using his three-volume work, *Michigan Flora*, the bible for Michigan botanists. He continued his work on this project well after retirement and, in fact, three days after his death, the U-M Press released *Field Manual of Michigan Flora*, co-authored by Ed and Dr. Anton A. Reznicek. Ed was also a legendary teacher at the U-M Biological Station, again continuing to lead short courses well after his retirement.

Since this issue focuses on new faculty, I would be remiss not to mention the many accomplishments and activities of our wonderful graduate students. Kevin Bakker recently published his findings on vast differences in microbial communities in the polar oceans in *PNAS* and the story was featured on U-M's Gateway and in the media. Katherine Crocker is a volunteer ambassador with the Rackham Graduate School's International Connect Welcome Program to help give new international students a friendly introduction to U-M and life in Ann Arbor. One of our new master's students, Benjamin Miller, has been awarded the prestigious National Science Foundation Graduate Research Fellowship. This award has a long history of recipients who achieve high levels of success in their future academic and professional careers. You can stay in the loop with our regularly updated news about our graduate students and more on our website. http://www.lsa.umich.edu/eeb.

I look forward to hearing from you in the year ahead. Wishing you a joyful and peaceful holiday season and a happy new year 2013!

My warmest wishes always,



**Editors**: Deborah Goldberg, Nancy Smith
**Writer, editor**: Gail Kuhnlein
**Production, illustration**: John Megahan
**Photographer**: Dale Austin

faculty profile

# Investigating multi-faceted multi-host/multi-parasite systems

How many people have been asked by the President of the United States to help with his child's science homework? Duffy is a new assistant professor in U-M's EEB department and she was at the White House recently with a group of her colleagues receiving the prestigious Presidential Early Career Award for Scientists and Engineers.

She describes how they were lined up with a stand in for President Obama to set up the group photo to make sure he wouldn't block anyone. When Obama entered the room for the photo, he asked for help with Malia's science homework, gave a talk, and shook hands. "Everyone was so excited," she said.

Duffy was a biology major at Cornell University. When faced with a genetics exam that covered population genetics she realized her passion and began working in an evolutionary ecology lab shortly afterward. Most recently, she was an assistant professor in the School of Biology at Georgia Institute of Technology.

Duffy currently researches multi-host parasites, which can infect humans and other animals. "One of the big questions is how do parasites go between different host species? Presumably they need to do slightly different things to end up in each host species. How hard is it for them to do that? Do you end up with different strains that specialize on each of the different species or do you end up with a generalist?"

"If you think of HIV's initial jump into a novel host species, researchers have ideas of when and maybe how it happened but it was such a long time ago, we can't observe it very easily," Duffy said.

She works on different species of *Daphnia*, water fleas, an ecologically important group that's easy to work with. *Daphnia* eat algae in lakes and fish eat *Daphnia* so they are key components in the food chain. At one to two millimeters wide, *Daphnia* are a crustacean, a tiny cousin to lobsters, crabs and shrimp.

With *Daphnia*, the researchers don't have to worry about the feasibility of manipulating host communities in the lab. "A handy aspect of the system is that the *Daphnia* makes resting eggs, they're like seeds that go into the sediment of the lake. Parasites make spores that go into the lake sediment. We can go back in the lake sediment and pull out the *Daphnia* that were there when the parasite first appeared, expose them to each other and see how the parasite and *Daphnia* evolve through experiments in the lab." Additionally, *Daphnia* are transparent. "We can just look at them under a microscope and tell if they're infected and what they're infected by."

**Dr. Meghan Duffy (center) with Dr. Cora Marrett, Deputy Director of NSF and Dr. John Holdren, Assistant to the President for Science and Technology, receiving PECASE.**

The parasites Duffy's lab works on are a yeast, *Metschnikowia*, and a bacterium, *Pasteuria*. Several parasites, including these two, were described in 1880s by Eli Metchnikoff, a Russian who is considered the father of modern immunology. He won a Nobel Prize in part for his work on *Daphnia*, although he's more widely known for his work on starfish.

Duffy was first author of the cover story in the March 30, 2012 issue of the journal *Science*. This research seeks to understand the environmental determinant of the severity of parasite epidemics and whether the severity influences how the host population evolves.

For this study, they looked at seven lakes in Indiana that unexpectedly fell into two categories. Some of the lakes had high nutrients, (nitrogen and phosphorus), not many fish and therefore, not much predation. Other lakes were the opposite with few nutrients and many fish, meaning high predation.

Predators preferentially eat infected *Daphnia*, which are more opaque and therefore easier to see. As it turned out, the first group of lakes, without many fish, had large epidemics. The lakes with many fish had smaller epidemics. The fish unintentionally cull the disease.

Their findings demonstrate that the ecological context determines the size of the epidemic that happens. And, the size of the epidemic determined how the population evolved in response to it.

"As someone who works on evolutionary ecology, what's really fascinating is that there is no perfect strategy, so the *Daphnia* face tradeoffs. It's a little hard to intuit ahead of time which strategy would make more sense but you just let it play out in nature and you end up seeing what is the right strategy.

***"It's a little hard to intuit ahead of time which strategy would make more sense but you just let it play out in nature and you end up seeing what is the right strategy."***

see multi-host/multi-parasite, page 7

# Exploring the "wild wild west" of microbes

**Vincent Denef**
credit: Joann Cavaletto (NOAA GLERL)

Terra incognita. The wild wild west. This is how Vincent Denef, one of the newest members of EEB's faculty, describes his research into the vast and barely explored microbial world.

Denef joined EEB as an assistant professor from the University of California, Berkeley in January 2012. Originally from Belgium, he towers at six feet seven inches and is one of the friendliest people you'll ever meet.

"Microorganisms were the first form of life and have been around for billions of years," Denef said. "This incredible diversity has coevolved with the geological history of this planet, and they are a crucial cog in the machinery to keep the planet running and sustaining life. All microbial life, the bacteria, archaea and eukaryotes are the unseen majority of life. At the same time, we have limited understanding about the most basic questions: What is the spatial and temporal distribution of these organisms? What are the identities of these organisms?"

However, breakthroughs in molecular methods (genomics and metagenomics, which uses DNA extracted from environmental communities) in the last decade have enabled meaningful molecular studies that are providing new insights in the microbial world.

***"The Great Lakes comprise 95 percent of surface freshwater in the United States and 20 percent of the world's surface freshwater."***

"We have to look at genes, how genes are expressed, and how the abundance of the microbial populations that carry them changes over time relative to other organisms in complex and different environmental conditions. That's our way of doing natural history, and even there, we are just scratching the surface."

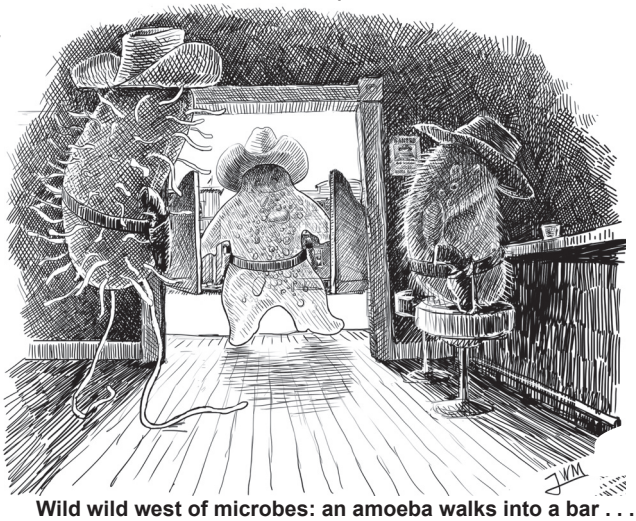
As a doctoral student in Belgium, Denef was eager to use tools of microbial ecology and evolutionary biology in the environment. He got his chance as a postdoctoral fellow at UC Berkeley, working in an acid mine drainage system. The extreme environment pushes the limits of human endurance – reaching temperatures over 118 degrees Farenheit, 100 percent humidity, low oxygen levels and the most acidic water on the planet. But, since a low diversity microbial system with strong coupling between geochemical processes and biology exists in the abandoned mines, it allowed the researchers to study the impact of population level evolutionary processes on the ecology of these organisms within a community setting.

Although Denef changed systems at U-M, he's still exploring the fundamental connections between microbial genome evolution and altered ecological behavior of microbes, especially as a result of human disturbance. Denef is primarily studying the effect of invasive species on fresh water lake systems, particularly the invasion of zebra mussels on inland Michigan lakes.

Denef is interested in how existing lake balances change as a result of invasions. Freshwater systems, (lakes, rivers, reservoirs) are only three percent of terrestrial environment, but they're disproportionately active sites of carbon processing. The Great Lakes comprise 95 percent of surface freshwater in the United States and 20 percent of the world's surface freshwater. "It's a strategic resource for lots of reasons," said Denef. However, he notes that in addition to the different stressors already affecting the lakes, over the next century, the lakes are threatened due to climate change.

While the ocean is generally a sink of $C0_2$, where it is collected and stored, freshwater systems can be net sources of $C0_2$ to the atmosphere, because they are heavily impacted by terrestrial inputs of carbon, which runs off into rivers and lakes where it is processed by microbes, mainly heterotrophic bacteria.

"There is still very little known about environmental constraints determining both the identity and activities of microbial populations," said Denef. Some of the questions that remain unanswered include: How dynamic are the microbes by season, type of lake and location? Which exact carbon gets converted by which organisms? What are the effects of: invasions? land use changes? other stressors?"



**Wild wild west of microbes: an amoeba walks into a bar . . .**

see wild wild west, page 7

faculty profile

# Never having to outgrow the dinosaur phase

From the moment five-year-old Danny Rabosky captured his first snake he recalls, "I was pretty sure I was going to be catching things for the rest of my life."

"I had a dinosaur phase as a very young kid but I never really outgrew it. I was always into reptiles and amphibians," said Rabosky, a new assistant professor in EEB who was previously a Miller postdoctoral fellow at the University of California, Berkeley.

As a young boy growing up in northern Ohio, Rabosky curated a museum in the basement displaying skulls, fossils, birds' nests, and even some pinned insects. While his parents were not excited about snakes, they were enthusiastic about their son's interests.

Nowadays, the herpetologist and evolutionary ecologist is interested in biological diversity in its broadest sense and the processes that generate it. Specifically, he investigates differences in diversity in the natural world, such as why some groups of animals have more species than others. "We don't have a satisfactory answer for why there are only four species of great apes on the planet versus arguably a million species of beetles."

"It's not just that groups that have been around longer diversify more. There are lots of very old groups that are not diverse," he explained.

In addition to species diversity, Rabosky considers diversity of organismal form or function, anatomy and ecology. Consider the famous groups demonstrating adaptive radiations like Darwin's finches or African cichlid fishes. Not only do they diversify rapidly in taxonomic terms but furthermore, they develop an incredibly diverse array of morphologies. Some 500 or more species of cichlids in Africa's Lake Malawi look very different and find food in radically different ways: eating other fish, crushing snails, scraping algae off rocks, eating microscopic plankton, and several even specialize on biting fin chunks off of other cichlids.

"This is a bizarre level of specialization that you don't see in many other organisms. In the same lake, there are catfishes, eels and electric fishes that have one or five or 10 species max. What is special about being a cichlid that results in species diversity?"

Rabosky seeks to answer these questions taking a variety of perspectives from empirical field work collecting data to theoretical musings figuring out how to ask big questions about differences in species diversity. Questions he ponders deal with things like diversity through time and space, geography and why some organisms undergo mass extinction while others survived. People have been musing on these differences in diversity since before Darwin in 1859.

"It's a great time to be an evolutionary biologist, we are just now starting to get the tools and data to the scale where we can test big questions," said Rabosky. "I think we'll make a lot of progress in the next 10 years or so."

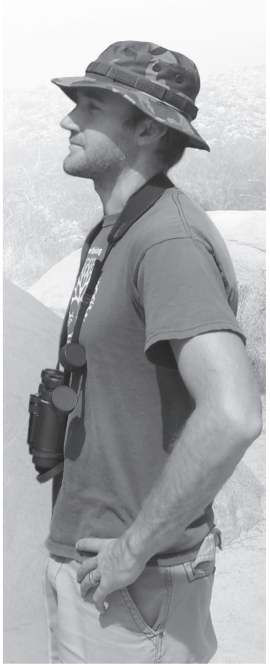
He is currently researching groups of reptiles that dispersed to Australia, which he considers one big evolutionary theater where the ongoing performance stars snakes and lizards. "The diversity of reptiles in Australia is so far off the charts relative to most other places in the world, it's mind blowing."

"Within Australian lizards, there are three groups of skinks that have diversified independently. I spend a lot of time studying one group of skinks that has diversified into about 250 species. We don't know all the species yet but that's already the most diverse group of reptiles in Australia." He'd like to find out what has caused that group to diversify and contrast that to smaller groups.

In the field, Rabosky collects ecological data, such as whether different species use different habitats. He also takes DNA samples from the lizards back to his lab in Ann Arbor in order to better understand how new species evolve and how different species are related to one another. Using ecological information about species' habitat or diet along with their genetic information helps scientists determine what's affecting a group of animals.

*"It's a great time to be an evolutionary biologist, we are just now starting to get the tools and data to the scale where we can test big questions."*

Rabosky said science is really in its infancy of understanding the evolutionary processes and theories about what makes some groups more diverse or understanding the rate at which new species develop through time. He's immersed in figuring out the theoretical aspects of species diversity through the development of computer and mathematical models and statistical tools to gain insights into how various processes can generate diversity differences. The models give predictions that Rabosky tests against data from real organisms.

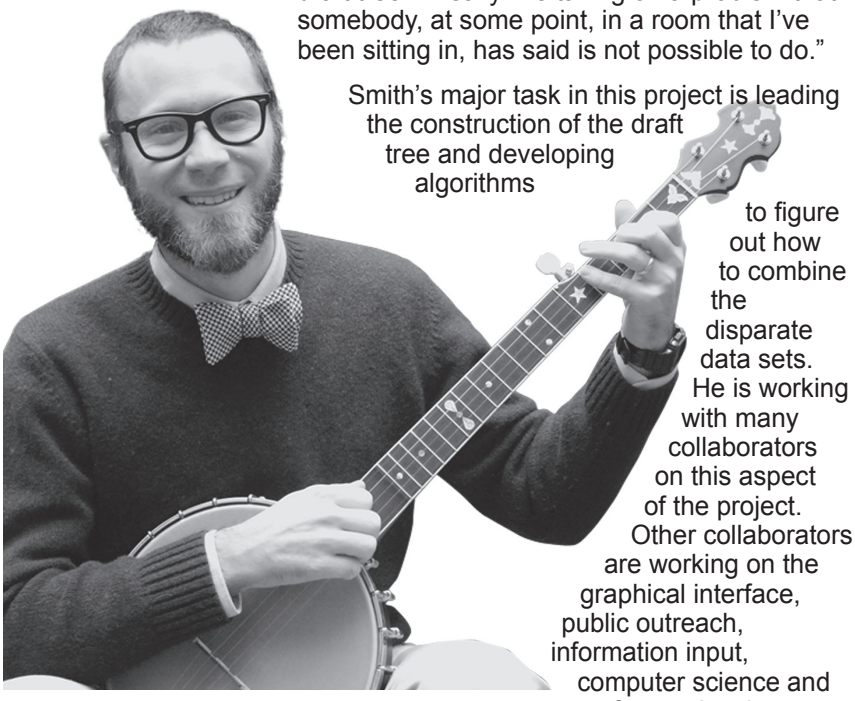


**Dan Rabosky**
credit:
Alison Davis Rabosky

see dinosaur phase, page 7

tree of life from page 1

and to predict the responses of life to rapid environmental change. “This is a very complicated beast, and I’m really looking forward to the challenge,” Smith said of the draft tree. “I really like taking on a problem that somebody, at some point, in a room that I’ve been sitting in, has said is not possible to do.”



**Stephen Smith**
credit: Dale Austin

Smith’s major task in this project is leading the construction of the draft tree and developing algorithms to figure out how to combine the disparate data sets. He is working with many collaborators on this aspect of the project. Other collaborators are working on the graphical interface, public outreach, information input, computer science and software development.

Smith joined EEB as an assistant professor in January 2012 from Brown University where he was an iPlant postdoctoral researcher.

Smith has been working on increasing the size of phylogenetic trees for a while. As a graduate student at Yale, he stunned his professor and advisor Dr. Michael Donoghue, a world expert on a group of plants called Dipscales (which includes the common shrub honeysuckles and Viburnums). Dipsacales had 300 species sampled and Donoghue thought larger wouldn’t be possible as the largest trees to date had some 2,000 species and took enormous computational resources. Smith created the phylogenetic tree of over 5,000 species within a few weeks. The computational tools Smith needed didn’t exist so he simply created them. As a result, Smith discovered evidence for woody plants evolving at a much slower rate than herbaceous plants.

“He has streamlined the making of phylogenies,” said Donoghue, a Yale botanist, in a 2010 article, “The Botanist Hacker” in *The Scientist* when Smith was named a scientist to watch. “It’s revolutionary.”

Smith and collaborators were the first scientists to exponentially increase the size of the datasets for trees that can be created, up to 100,000 species and counting. He has created numerous open source software programs, some with self-deprecating names such as PHLAWD (pronounced flawed) and phyutility (pronounced fyoo-til-i-tee).

Just as the Human Genome Project provided numerous, largely unanticipated new insights about the genetic underpinnings of life, constructing the full phylogenetic tree of life is expected to fuel fundamental research on the nature of biological diversity and its relationship to human well-being. The new information is expected to help enhance agriculture, identify and combat diseases (of humans and crops), conserve biodiversity, and predict responses to global climate change and to biological invasions.

“Imagine you have a bacterial infection that doesn’t have a cure but your bacteria is closely related to one that does and let’s say that the antibiotic is produced from compounds in a fungus. We can look at that fungus and its relatives for potentially interesting compounds that might help with our bacterial infection or have other uses. The tree of life can give us a more directed way to ask questions about useful plants, fungi and animals.”

“This is similar to when astronauts went to the moon and looked back at the Earth for the first time,” Smith said. “It will be our first opportunity to see all of the organisms that we know on Earth. This is our moon shot.”

***“The new information is expected to help enhance agriculture, identify and combat diseases (of humans and crops), conserve biodiversity, and predict responses to global climate change and to biological invasions.”***

During the fall 2012 semester, Smith will teach the evolution course for undergrads. He’s developing a new graduate level course on phylogenetic methods and theory that he’ll teach starting in winter 2013.

“I really enjoy teaching and the ability to freely think about questions that are not only interesting to me but are stepping stones that are important to furthering our understanding of life on Earth. It’s fun to be in discussions with scientists – coming up with interesting questions – and answers, hopefully.”

He bikes pretty seriously, about 100 miles a week when the season starts. In his younger days, Smith played in punk and hard core bands. Nowadays, to relax from his mind-bending research exploits, he plays bluegrass banjo, classical guitar and drums.

**With excerpts from a U-M News Service press release by Jim Erickson.**

faculty profile

**dinosaur phase from page 5**

His breadth of experience expands far beyond reptiles. A recent paper Rabosky published in *PLoS* was about what controls species diversity in all multicellular organisms including plants, ferns, fish, insects, and more.

"Who else gets paid to think about exciting problems in the world and what shapes the universe around us? If I was sitting on a billion dollars, which I'm not [laughter], I would do exactly what I do now." Rabosky is co-advising and mentoring two Ph.D. students and is teaching a graduate level class on computer programming oriented to ecologists and evolutionary biologists this fall. Beginning next fall, he'll teach an undergraduate class on vertebrate diversity and evolution.

Rabosky married another evolutionary biologist, Alison Davis Rabosky, a research scientist in U-M's EEB department who appreciates reptiles as much as he does. Rabosky is into distance sports such as cycling and running. He and his wife enjoy being out in nature looking at birds, rocks, and of course, reptiles.

**A western blue-tongued skink, Western Australia,** credit: D. Rabosky

**wild wild west from page 4**

Denef's big question is how can humans live sustainably on this planet and what are the impacts of our behavior on the natural balances? Getting a better understanding of this can help us mitigate the effects of our activities, especially in the realm of climate change. Denef had a paper published in *Science* in April 2012, which determined evolutionary rates of free-living microbes in the environment for the first time.

Denef is on board with the National Oceanic and Atmospheric Administration's Great Lakes Ecological Research Laboratory, complementing their long-term studies of the dynamics of phytoplankton, zooplankton, and fish communities as well as the impact of invasive species within the Great Lakes. He's embarking on a series of research cruises on Lake Huron with NOAA collecting samples in a variety of conditions to help discover the role of the tiniest creatures in the freshwater system food web.

"A privilege I have as a scientist is that I'm able to explore these vast unknowns of our diverse surroundings," he said. "Microbes might be really tiny but just look at the major oxygenation events and innumerable other activities that they are responsible for. Look at our own bodies, we are 10 times more microbial than we are human."

***"Microbes might be really tiny but just look at the major oxygenation events and innumerable other activities that they are responsible for."***

Denef taught Microbial Ecology 400 during the winter 2012 semester and is currently developing a new course for non-majors called Life Decoded: Genomics in Society.

Denef and his wife, Melissa Duhaime, who joined EEB as a research scientist, are avid mountain bikers. He commutes to work by bike year round to add some adventure to each day. Speaking of adventure, they are the delighted (and exhausted) new parents of twin girls!

**multi-host/multi-parasite from page 3**

"If you're resistant to the parasite, you don't make as many babies. The lakes with large epidemics were more resistant but had fewer babies, while the lakes that had small epidemics became less resistant, because being less resistant to the parasite meant they had more babies."

Duffy is currently teaching introductory biology, setting up her lab, conducting research, mentoring students, writing publications and writing grant proposals, "the usual mix of things," she said. She especially likes having a career that allows her a wide variety of activities, including going out on lakes rowing a boat around.

Her husband, Silas Alben, is an associate professor in the Department of Mathematics at U-M. Their daughter, Ruthie, who is 20 months old, is adept at saying "no," "mine," and, most recently "no want it!" Duffy is a runner but is on hiatus while she's pregnant. But she walks about four miles a day at her treadmill desk. Staying on the move makes her feel much more alert when she works.

A friend of hers said, "nothing says assistant professor – mom of a toddler as much as a treadmill desk."

**Meghan Duffy**
credit: Rachel Penczykowski

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# Picture perfect

Congratulations to our Honorary Photographer at Large, Susanna Messinger, who came in first place with “A fleet of dragonflies.” Second place: Alison Gould “Gorgonian.” Third place” Kevin Bakker “Sunset on the Okavango Delta, Botswana.”

Honorable mentions:
Rachel Cable “Geladas in flight.”
Jason Dobkowski “Sleepy kit.”
Kevin Bakker “Lilac breasted-Roller, Kalahari Desert.”

The honorary title “Photographer at Large” is in memory of David Bay who was the self-described “photographer at large” for EEB and its predecessor departments for 34 years. He touched the lives of hundreds of faculty, students and staff with his humor, good nature and expertise.

All of the photos can be viewed here in color: http://bit.ly/eebphotos2011

A fleet of dragonflies

Gorgonian

Sunset on the Okavango Delta, Botswana

Geladas in flight

Sleepy kit

Lilac breasted-Roller