

Modeling Forum

Results of the 2001 Interdisciplinary Contest in Modeling

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Introduction

A total of 83 teams of undergraduates, from 58 institutions in 5 countries, spent the second weekend in February working on an applied mathematics problem in the 3rd Interdisciplinary Contest in Modeling (ICM).

The 2001 ICM began at 12:01 A.M. on Friday, Feb. 9 and officially ended at 11:59 P.M. on Monday, Feb. 12. During that time, teams of up to three undergraduates were to research and submit an optimal solution for an open-ended modeling problem. The 2001 ICM marked the inaugural year for the new online administration contest, and it was a great success. Students were able to register, obtain contest materials, download the problems at the appropriate time, and enter data through COMAP’S ICM website.

After a weekend of hard work, solution papers were sent to COMAP on Monday. Three of the top papers appear in this issue of *The UMAP Journal*.

Results and winning papers from the first two contests were published in special issues of *The UMAP Journal* in 1999 and 2000.

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COMAP's Mathematical Contest in Modeling and Interdisciplinary Contest in Modeling are unique among modeling competitions in that they are the only international contests in which students work in teams to find a solution. Centering its educational philosophy on mathematical modeling, COMAP uses mathematical tools to explore real-world problems. It serves the educational community as well as the world of work by preparing students to become better informed—and prepared—citizens.

This year's problem was about limiting or preventing the spread of zebra mussels in the Great Lakes and inland waterways of the United States and Canada.

Problem: The Zebra Mussel Problem

Our Waterways—An Uncertain Future

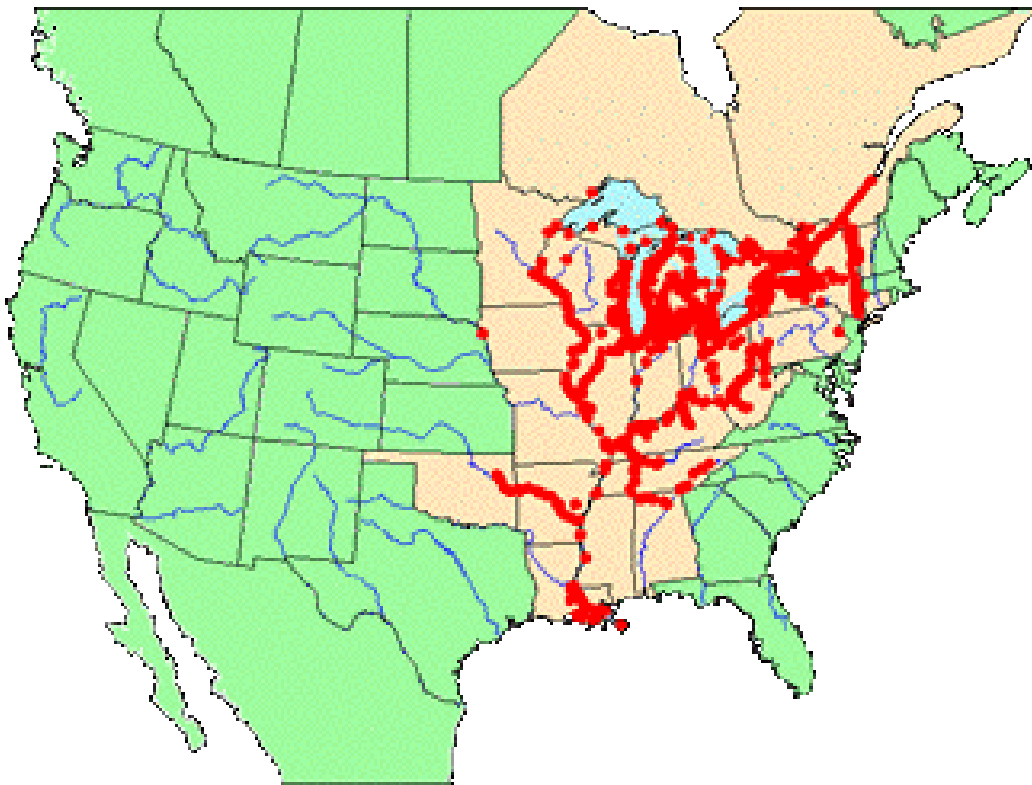


Figure 1. Map showing U.S. states and Canadian provinces with zebra mussels in inland and adjacent waters in July 2000.

Zebra mussels (*Dreissena polymorpha*) are small, fingernail-sized, freshwater mollusks unintentionally introduced to North America via ballast water from a transoceanic vessel. Since their introduction in the mid-1980s, they have spread through all of the Great Lakes and to an increasing number of inland

waterways in the United States and Canada. Zebra mussels colonize on various surfaces, such as docks, boat hulls, commercial fishing nets, water intake pipes and valves, native mollusks, and other zebra mussels. Their only known predators—some diving ducks, freshwater drum, carp, and sturgeon—are not numerous enough to have a significant effect on them. Zebra mussels have significantly impacted the Great Lakes ecosystem and economy. Many communities are trying to control or eliminate these aquatic pests. (Source: Great Lakes Sea Grant Network <http://www.sgnis.org/>.)

Researchers are attempting to identify the environmental variables related to the zebra mussel infestation in North American waterways. The relevant factors that may limit or prevent the spread of the zebra mussel are uncertain. You will have access to some reference data to include listings of several chemicals and substances in the water system that may affect the spread of the zebra mussel throughout waterways. Additionally, you can assume individual zebra mussels grow at a rate of 15 mm per year with a life span between 4–6 years. The typical mussel can filter 1 liter of water each day.

Requirement A

Discuss environmental factors that could influence the spread of zebra mussels.

Requirement B

Utilizing the chemical data provided at <http://www.comap.com/undergraduate/contests/icm/imagesdata/LakeAChem1.xls> and the mussel population data provided at <http://www.comap.com/undergraduate/contests/icm/imagesdata/LakeAPopulation1.xls>, model the population growth of zebra mussels in Lake A. Be sure to review the information below about the collection of the zebra mussel data.

Requirement C

Utilizing additional data on Lake A from another scientist provided at <http://www.comap.com/undergraduate/contests/icm/imagesdata/LakeAChem2.xls> and additional mussel population data provided at <http://www.comap.com/undergraduate/contests/icm/imagesdata/LakeAPopulation2.xls>, corroborate the reasonableness of your model from Requirement B. As a result of this additional data, adjust your earlier model. Analyze the performance of your model. Discuss the sensitivity of your model.

Requirement D

Utilizing the chemical data from two lakes (Lake B and Lake C) in the United States provided at

<http://www.comap.com/undergraduate/contests/icm/imagesdata/LakeB.xls>
and

<http://www.comap.com/undergraduate/contests/icm/imagesdata/LakeC.xls>,
determine if these lakes are vulnerable to the spread of zebra mussels. Discuss your prediction.

Requirement E

The community in the vicinity of Lake B (in Requirement D) is considering specific policies for the de-icing of roadways near the lake during the winter season. Provide guidance to the local government officials regarding a policy on “de-icing agents.” In your guidance, include predictions on the long-term impact of de-icing on the zebra mussel population.

Requirement F

It has been recommended by a local community in the United States to introduce round goby fish. Zebra mussels are not often eaten by native fish species, so those fish represent a dead-end ecologically. However, round gobies greater than 100 mm feed almost exclusively on zebra mussels. Ironically, because of habitat destruction, the goby is endangered in its native habitat of the Black and Caspian Seas in Russia. In addition to your technical report, include a carefully crafted report (3-page maximum) written explicitly for the local community leaders that responds to their recommendation to introduce the round goby. Also, suggest ways to help reduce the growth of the mussel within and among waterways.

Collection of the Zebra Mussel Data

The developmental state of the zebra mussel is categorized by three stages: veligers (larvae), settling juveniles, and adults. Veligers (microscopic zebra mussel larvae) are free-swimming, suspended in the water for one to three weeks, after which they begin searching for a hard surface to attach to and begin their adult life. Looking for zebra mussel veligers is difficult because they are not easily visible by the naked eye. Settled juvenile zebra mussels can be felt on smooth surfaces like boats and motors. An advanced zebra mussel infestation can cover a surface, even forming thick mats sometimes reaching very high densities. The density of juveniles was determined along the lake using three 15 × 15 cm settling plates. The top plate remained in the water for the entire sampling season (S—seasonal) to estimate seasonal accumulation. The middle

and bottom plates are collected after specific periods (A—alternating) of time denoted by “Lake Days” in the data files.

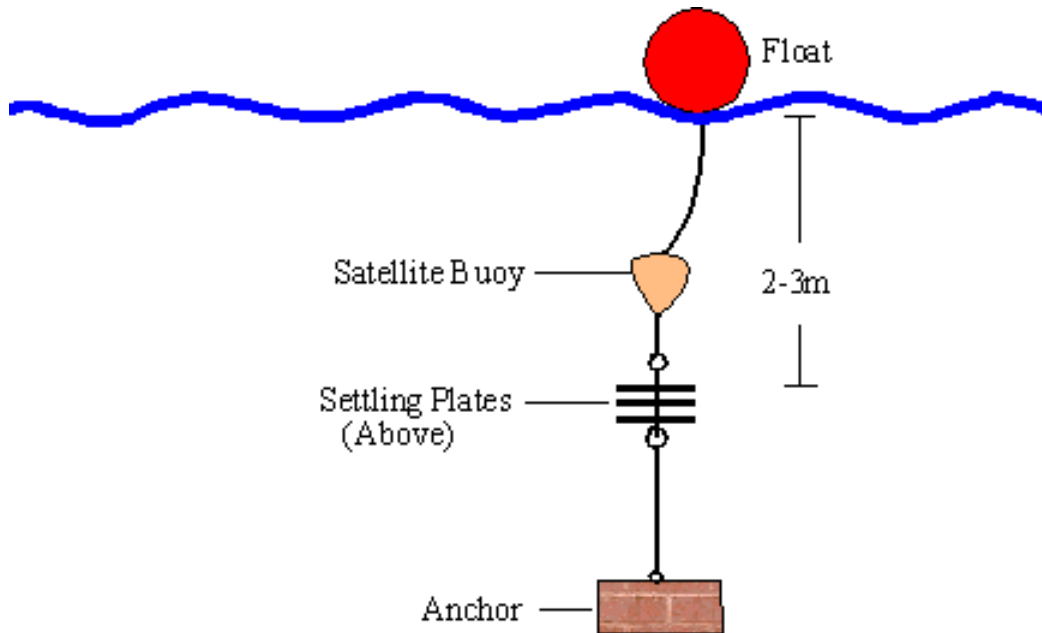


Figure 2. Diagram of collection apparatus.

The settling plates are placed under the microscope, all juveniles on the undersides of the plate are counted, and densities are reported as juveniles/m².

The Results

The solution papers were coded at COMAP headquarters so that names and affiliations of the authors would be unknown to the judges. Each paper was then read preliminarily by two “triage” judges at the U.S. Military Academy at West Point, NY. At the triage stage, the summary and overall organization are the basis for judging a paper. If the judges’ scores diverged for a paper, the judges conferred; if they still did not agree on a score, a third judge evaluated the paper.

Final judging took place at the College of St. Rose, Albany, NY. The judges classified the papers as follows:

	Outstanding	Meritorious	Honorable Mention	Successful Participation	Total
Zebra Mussel	3	14	28	38	83

The three papers that the judges designated as Outstanding appear in this special issue of *The UMAP Journal*, together with commentaries. We list those



Figure 3. A settling plate after collection.

teams and the Meritorious teams (and advisors) below; the list of all participating schools, advisors, and results is in the **Appendix**.

Outstanding Teams

Institution and Advisor

Team Members

“A Multiple Regression Model to Predict Zebra Mussel Population”

Harvey Mudd College
Claremont, CA
Michael E. Moody

Michael Schubmehl
Marcy LaViolette
Deborah Chun

“Identifying Potential Zebra Mussel Colonization”

Humboldt State University
Arcata, CA
Eileen M. Cashman and Jeffrey B. Haag

David E. Stier
Mark Alan Leisenring
Matthew Glen Kennedy

“Waging War Against the Zebra Mussel”

Lewis and Clark College
Portland, OR
Robert W. Owens

Nasreen A. Ilias
Marie C. Spong
James F. Tucker

Meritorious Teams (14 teams)

Beijing University of Posts & Telecommunications, Beijing, China
(He Zuguo and Luo Shoushan) (two teams)

Dickinson College, Carlisle, PA (Brian S. Pedersen)

East China University of Science & Technology, Shanghai, China
(Xiwen Lu and Yan Qin)

Harvey Mudd College, Claremont, CA (Michael E. Moody)

North Carolina School of Science and Mathematics, Durham, NC
(Dot Doyle and Dan Teague)

Northwestern Polytechnical University, Xian, China (Yong Xiao Hua and Yi Lu Quan)

South China University of Technology, Guangzhou, China
(He Chunxiong and Tao Zhisui)

Southeast University, Nanjing, China (Sun Zhi-zhong)

University College Dublin, Dublin, Ireland (Ted Cox)

University of Science and Technology of China, Hefei, China
(Tao Dacheng and Ma Jianxin)

Villa Julie College, Stevenson, MD (Eileen C. McGraw)

Zhejiang University, Hangzhou, China (Yang Qifang and He Yong) (two teams)

Awards and Contributions

Each participating ICM advisor and team member received a certificate signed by the Contest Directors and the Head Judge.

Judging

Director

David C. "Chris" Arney, Dean of the School of Mathematics and Sciences,
The College of Saint Rose, Albany, NY

Associate Directors

Michael Kelley, Dept. of Mathematical Sciences, U.S. Military Academy,
West Point, NY

Gary W. Krahn, Dept. of Mathematical Sciences, U.S. Military Academy,
West Point, NY

Judges

Richard Cassidy, Dept. of Industrial Engineering, University of Arkansas,
Fayetteville, AR

Wayne Jerzak, Dept. of Mathematical Sciences, Rensselaer Polytechnic
Institute, Troy, NY

Sandra Nierzwicki-Bauer, Dept. of Biology and Darrin Fresh Water Institute,
Rensselaer Polytechnic Institute, Troy, NY

Triage Judges

Darryl Ahner, Mike Corson, Alex Heidenberg, Jerry Kobylski, Gary Krahn, Joe Myers, Mike Phillips, Kathi Snook, Gideon Weinstein, and Brian Winkel, all of the U.S. Military Academy, West Point, NY

Source of the Problem

The Zebra Mussel Problem was contributed by Sandra Nierzwicki-Bauer, Dept. of Biology and Darrin Fresh Water Institute, Rensselaer Polytechnic Institute.

Acknowledgments

Major funding for the ICM is provided by a grant from the National Science Foundation through COMAP. Additional support is provided by the Institute for Operations Research and the Management Sciences (INFORMS).

We thank:

- the ICM judges and ICM Board members for their valuable and unflagging efforts;
- the staff of the Dept. of Mathematical Sciences, U.S. Military Academy, West Point, NY, for hosting the triage judging; and
- the staff of the School of Mathematics and Sciences, The College of Saint Rose, Albany, NY, for hosting the final judging.

Cautions

To the reader of research journals:

Usually a published paper has been presented to an audience, shown to colleagues, rewritten, checked by referees, revised, and edited by a journal editor. Each of the student papers here is the result of undergraduates working on a problem over a weekend; allowing substantial revision by the authors could give a false impression of accomplishment. So these papers are essentially *au naturel*. Light editing has taken place: minor errors have been corrected, wording has been altered for clarity or economy, and style has been adjusted to that of *The UMAP Journal*. Please peruse these student efforts in that context.

To the potential ICM Advisor:

It might be overpowering to encounter such output from a weekend of work by a small team of undergraduates, but these solution papers are highly atypical. A team that prepares and participates will have an enriching learning experience, independent of what any other team does.

Appendix: Successful Participants

KEY:

P = Successful Participation

H = Honorable Mention

M = Meritorious

O = Outstanding (published in this special issue)

INSTITUTION	CITY	ADVISOR	I
CALIFORNIA			
Harvey Mudd College	Claremont	Michael E. Moody	O,M
Humboldt State University	Arcata	Eileen M. Cashman and Jeffery B. Haag	O
COLORADO			
Colorado Northwestern Comm. College	Rangely	Richard S. Knaub	P,P
University of Southern Colorado	Pueblo	Bruce N. Lundberg	P
FLORIDA			
Florida A&M University	Tallahassee	Bruno Guerrieri	P
ILLINOIS			
Monmouth College	Monmouth	Christopher Gerard Fasano	H
IOWA			
Luther College	Decorah	Reginald D. Laursen	H
Simpson College	Indianola	Steve Emerman and Jeff Parmelee	P
KENTUCKY			
Asbury College	Wilmore	David L. Coulliette	H,H
MARYLAND			
Villa Julie College	Stevenson	Eileen C. McGraw	M,P
MASSACHUSETTS			
Gordon College	Wenham	Dorothy F. Boorse and Mike Veatch	H
MIT	Cambridge	Michael P. Brenner and L. Mahadevan	H
MINNESOTA			
Macalester College	St. Paul	Peter W. Vaughan and A. Romero	P P
MONTANA			
Carroll College	Helena	Kyl Strode	H
NEVADA			
Sierra Nevada College	Incline Village	Steven D. Ellsworth	P

INSTITUTION	CITY	ADVISOR	I
NEW JERSEY			
Rowan University	Glassboro	Hieu D. Nguyen	P
NEW YORK			
Roberts Wesleyan College	Rochester	Carlos A. Pereira	H
SUNY Geneseo	Geneseo	Christopher C. Leary and Gregg Hartvigsen	P
U.S. Military Academy	West Point	Scott Nestler and Suzanne DeLong	H
		Michael Jaye and Michael Huber	H
NORTH CAROLINA			
Elon College	Elon College	Crista L. Coles and and J. Todd Lee	H,P
N.C. School of Science & Mathematics	Durham	Dot Doyle and Dan Teague	M
OHIO			
Youngstown State University	Youngstown	Thomas Smotzer Scott Martin	H H
OKLAHOMA			
University of Central Oklahoma	Edmond	Jesse W. Byrne and Charlotte K. Simmons	P
OREGON			
Clatsop Community College	Astoria	Michael C. Vorwerk	H
Eastern Oregon University	La Grande	Richard A. Hermens	P
Lewis and Clark College	Portland	Robert W. Owens	O
Rogue Community College	Grants Pass	John T. Salinas	P
PENNSYLVANIA			
Clarion University	Clarion	Andy M. Turner and Sharon L. Challener	H
Dickinson College	Carlisle	Brian S. Pedersen	M
SOUTH DAKOTA			
Mount Marty College	Yankton	Bonita L. Gacnik	P,P
TENNESSEE			
Austin Peay State University	Clarksville	Nell K. Rayburn and James Bateman	P
VIRGINIA			
Chesterfield County Math & Science H.S.	Midlothian	Diane C. Leighty	P

INSTITUTION	CITY	ADVISOR	I
CANADA			
University of Saskatchewan	Saskatoon	Tom G. Steele	P
CHINA			
Anhui University	Heife	Wang Hai-xian and Cheng Jun-sheng	P
Beijing Univ. of Posts & Telecommunications	Beijing	He Zuguo and Luo Shoushan	M,M
Beijing University of Aero. & Astronautics	Beijing	Lin Guiping and Peng Linping	P
Chongqing University	Chongqing	He Renbin and Shi Junmin	H,H
Dalian University of Technology	Dalian	Zhao Lizhong	H
East China University of Science & Technology	Shanghai	Lu Xiwen and Qin Yan	M
		Lu Yuanhong and Su Chunjie	P
Experimental High School of Beijing Normal University	Beijing	Wang Jiangci	P
Fudan University	Shanghai	Cai Zhijie	H,P
Harbin Institute of Technology	Harbin	Shang Shouting and Zheng Tong	P,P
Hefei University of Technology	Hefei	Su Huaming	H,P
Mathematics School of Nankai University	Tianjin	Fu Lei and Ruan Jishou	H
Northeastern University	Shenyang	Xue Dingyu	P
Northwestern Polytechnical University	Xian	Xiao Hua Yong and Lu Quan Yi	M
		Nie Yu Feng and Sun Hao	P
Peking University	Beijing	Ma Ping and Chen Xin	P
School of Math'l Sciences, Peking University	Beijing	Zhang Tao and Yang Xingwen	P
Shanghai Jiaotong University	Shanghai	Gong Peimin and Bo	P,P
South China University of Technology	Guangzhou	He Chunxiong and Tao Zhisui	M
		Xie Lejun and Hong Yi	H
Southeast University	Nanjing	Sun Zhi-zhon	M,H
University of Science and Technology of China	Hefei	Tao Dacheng and Ma Jianxin	M
		Sun Guangzhong and Song Zhiwei	H

INSTITUTION	CITY	ADVISOR	I
Xian Jiaotong University	Xian	He Xiaoliang	P,P
Xian University of Technology	Xian	Xie Xing Long	P
Zhejiang University	Hangzhou	Yang Qifanand He Yong	M,M
Zhongshan University	Guangzhou	Yuan Zhuojian Tang Mengxi	H H
FINLAND			
Päivölä College	Tarttila	Merikki Lappi and Esa I. Lappi	H,P
HONG KONG			
Hong Kong Baptist University	Kowloon	Tong Chong Sze	P
IRELAND			
University College Dublin	Dublin	Ted Cox	M,H

Editor's Note

For team advisors from China, we have endeavored to list family name first, with the help of Susanna Chang '03.