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UMASS MARINE
The University of Massachusetts Graduate School of Marine Sciences and Technology

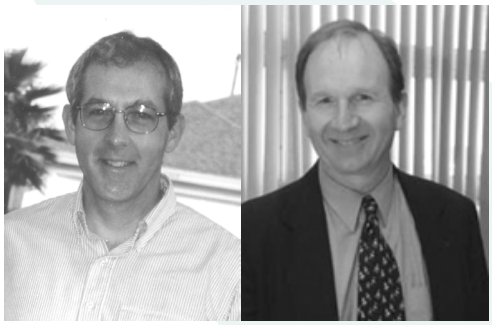
Rogue waves challenge ocean theorists

Long thought to exist only in seafarers' "fish stories," rogue waves on the order of one hundred feet tall have been detected in recent years by radars mounted on North Sea oil platforms. Now, a global census by the European Space Agency has established these monster waves as a relatively common phenomenon.

In a project dubbed MaxWave, European scientists recently assembled some 30,000 satellite radar "imagettes" to get an image of the world ocean over a period of about three weeks in early 2001. Within that short period, they identified at least ten rogue waves with heights of 25 meters or more.

More than 100 ships are sunk every year, and up to 10% of those are supertankers and container ships more than 200 meters in length. It's impossible to investigate such accidents to the same extent as, say, airline disasters, and most have been chalked up to "severe weather." Rogue waves are now implicated in many of those sinkings.

To better understand the phenomenon of rogue waves and its implications, we talked to two scientists on the faculty of the UMass Marine Graduate School. Steve Pennell is Professor of Mathematical Sciences at UMass Lowell. His related work includes modeling wave-wave interactions and investigating the surface expressions of internal ocean waves. Wendell Brown is Professor of Oceanography and Faculty Chair at SMAST/UMassD. An observational oceanographer, his research has ranged over a number of ocean basins in the Western Hemisphere, but has focused particularly on the regional Gulf of Maine, where studies of the internal tide have been one of his continuing interests.



Wave modeler Steve Pennell, UMass Lowell, and oceanographer Wendell Brown, UMass Dartmouth.

UMM: *How are these rogue waves similar to or different from the solitary waves you have studied and modeled?*

Pennell: Rogue waves are similar to solitary waves in that both are isolated mounds of water rather than wave trains, both can be huge, and both are described by nonlinear equations. The main difference is that rogue waves are surface waves, whereas oceanic solitary waves are internal waves. The generation mechanisms also appear to be different. Oceanic internal solitary waves are usually generated by tidal flow over an underwater sill, as at the Strait of Gibraltar. Sea floor topography may play some role in the generation of rogue waves, but it appears that near-surface currents and wind play more important roles.

Brown: Some internal solitary waves, or ISWs, result from highly nonlinear distortion of much smaller internal tidal waves, which in turn are generated by tidal currents flowing over steep bottom topography. The resulting internal solitary waves can have underwater amplitudes of 200 meters (in the South China Sea, for example). While these ISWs are not nearly as energetic as

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A message from the Dean . . .

Dear Friends of the Ocean,

I am pleased to announce that we have been granted an opportunity to expand our research in critical areas of fisheries science and oceanography and to support the training of a new cohort of graduate students through the University of Massachusetts Graduate School of Marine Sciences and Technology. We have, working with the Massachusetts Marine Fisheries Institute, received funds to embark on an ambitious program of fishery and related oceanographic research. About $300,000 will be used to fund graduate student stipends to conduct research relevant to the program. The program focuses its research on scallops, groundfish, lobsters, and oceanographic modeling of Georges Bank and the Gulf of Maine.

Our very successful video surveys of the spatial and size-specific abundance of scallops on the continental shelf will continue under the new program. The video surveys will be used as a baseline to calculate the fishing power and catchability of various types of scallop gear, and the effect of fishing gear on habitat and on benthic fauna. We will also continue our studies of tagged scallops on the continental shelf to estimate growth, migration, and mortality rates. Finally, laboratory studies of scallop biology—using specimens contributed by the commercial fleet—will be conducted to enhance stock assessment estimates.

In the groundfish arena, an innovative Fishery Management Decision Support System is already under development.

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Introducing ...

Students

It was more than 20 years ago that **Deborah Cobb** finished her bachelor's degree in Biology at East Carolina University. She had already started graduate school when love intervened. She got married, moved to New England, and started a family. As Deborah puts it, "I put graduate school on hold for a few years; a few years turned out to be a couple of decades."

In 2002, with one child in a doctoral program, one in college, one in high school, and one in middle school, Deborah picked up where she left off. While still teaching part-time at Concord Academy, she enrolled part-time in the UMass Marine Graduate School on the Boston campus, studying under Professor Robert Chen.

At left, Deborah Cobb. Below: Deborah immersed in her work.

Deborah's thesis research centers on monitoring bacterial levels in the Pine Tree Brook in Milton before, during, and after a water quality improvement project by the Neponset River Watershed Association. The Pine Tree Brook borders Milton High School, a convenience for the school's Environmental Science students who are involved in Deborah's sample collection, processing, and data interpretation.

"Ultimately, I would like people to be more educated about coastal processes and their effects upon our quality of life," Deborah says. "Hopefully, with education, change will come and our coastal areas will start to rebound."

A part-time student for her first three semesters at UMass, Deborah will be a fulltime student this fall and part of the Watershed-Integrated Sciences Partnership (WISP) at the Dedham Middle School. "The important thing is that I finally made it back to grad school," she says. "I am having the best time, and I wish there were more hours in each day to fit in everything."

• • •

Adrienne Pappal has always known what she wanted to do. "I never dreamed to be an astronaut or superstar. I still keep the pictures from childhood that I drew of myself in a vast Crayola sea. There is something so compelling about that great expanse of water."

Her continuing fascination with the ocean eventually led Adrienne to enroll at the University of New Hampshire (UNH) in 1997 to study Marine and Freshwater Biology. "As an undergraduate," she says, "I jumped at any opportunity to expand my exposure to the field of marine science."

Such opportunities appeared first in the form of summer field marine science programs at the Shoals Marine Lab, jointly operated by UNH and Cornell University. "These were my first real field experiences," says Adrienne, "and I was hooked."

From that point, Adrienne moved into teaching, sharing her enthusiasm for marine science with fellow college students as teaching assistant, with the public at the NH Seacoast Science Center, and with school children aboard the NH Sea Grant Floating Lab, a series of mini-research cruises, whereon the children become the researchers.

Adrienne's final semester as an undergraduate was spent in New Zealand through the EcoQuest program, where she studied marine sciences and conducted independent research. "There, I was challenged in every way," she reports, "from scaling mountains to spending hours sorting samples. But the rewards were great."

At SMAST, Adrienne is pursuing her master's degree in Living Marine Resources Science and Management through the UMass Intercampus Marine Graduate School. With advisor Dan MacDonald, she is researching the community structure of fishes in varied intertidal habitats.

"I am particularly interested in the distribution patterns of juvenile winter flounder, as this species is in decline in New England estuaries. I hope to continue my research this fall with laboratory study of habitat preferences of juvenile winter flounder."

Characteristically, Adrienne also has plans for the longer term. "I think the most important goal of studying the ocean is conservation and the spread of knowledge," she says. "I hope one day to become a professor so I can teach others about the wonders of the ocean. If I can touch one life to get involved and excited about the ocean, then I'll have reached my goal." §

Adrienne Pappal collects samples on the shore of Mt. Hope Bay.

Dean's Message, *continued from page 1*

Operations research theory will be incorporated into the system to enable formulation of decision rules that take into account multiple species interactions. We are also developing an acousto-optic fish assessment array for Georges Bank. The array will be used to enumerate size and species-specific fish abundance on the Bank. Fishing-gear engineering studies will modify trawls to improve their selectivity to separate target and non-target species to minimize waste and reduce unwanted bycatch.

The lobster fishery will be the focus of a three-part research effort. Lobster stock assessment will be enhanced by calibrating ventless traps using scuba observation, and migrations will be studied to better identify stock structure. The lobster disease problem will also be defined and evaluated, and studies of Buzzards Bay water will help determine the role of water chemistry in declines in lobster abundance.

Finally, the new program will also bolster our Georges Bank/Gulf of Maine oceanographic modeling research. The Georges Bank/Gulf of Maine region is the breadbasket for coastal New England, and we are bringing more and more model products into near real time.

Stay tuned to the *UMass Marine* newsletter and to our website **www.umassmarine.net** to follow the progress of these exciting research efforts.

- Brian Rothschild, Dean

Rogue Waves, *continued from page 1*

the 30m surface rogue waves, they can compromise submarine stabilty and may have led to the sinking, implosion and loss of more than one U.S. submarine.

UMM: *Could a geographical concentration of sinkings, as is claimed for the Bermuda Triangle, be related to the prevalence of rogue waves?*

Pennell: I don't know about the Bermuda Triangle, but yes, I would certainly think so in general. Rogue waves seem to be more prevalent in regions where wind-generated surface waves meet a current running in the opposite direction (for example, off the east coast of South Africa and in the North Atlantic). The effect of this wave/current interaction is analogous to what happens when a wave hits a solid wall: the wave runs up the wall, leading to a substantial increase in wave height. Certainly an increased risk of rogue waves would correlate with an increased risk of ships sinking.

"The picture [at left] was taken on the oil freighter Esso Languedoc *outside the coast of Durban (1980). The man who took it, Philippe Lijour, estimated the mean wave height when this occurred to be about 5-10 m. The mast on the starboard side is 25 m above the mean sea level. The wave approached from behind and broke over deck, but caused only minor damage."* www.math.uio.no/~karstent/waves/index_en.html, 14 Sept. 2004

UMM: *From your work, can you say anything about the likely persistence of such waves? For example, in 2001 two cruise ships — the* Bremen *and the* Caledonian Star *— were hit by 30-meter waves in the same week at locations less than 1000 km apart. Any chance they were hit by the same wave?*

Brown: I strongly doubt it.

UMM: *Granted, that would require a rogue wave traveling on the order of 10 kilometers per hour, but the alternative would be two rogue waves in the same ocean basin in the same week.*

Pennell: I can't say whether the *Bremen* and the *Caledonian Star* were hit by the same wave, but it wouldn't surprise me if rogue waves were found to be long-lived. Solitary wave solutions of many nonlinear wave equations turn out to be remarkably stable.

UMM: *The European Space Agency, sponsor of the MaxWave project, says that prior to the confirmation that rogue waves are relatively common, scientists' statistics predicted that such large deviations from the surrounding sea state should occur only once every 10,000 years.*

Brown: These probabilities of occurrence (like those that predict the 100-year storm, for example) are based on observation statistics. But with very few realizations—in other words, very few observations of extreme storms—the uncertainties in the statistics are large.

UMM: *What kind of assumptions must have been embedded in those statistics?*

Brown: That the background environment is not changing in any basic way so that the statistical estimators (in this case, the probability of encountering a rogue wave) can be considered stationary. However, we know that there is long-term climate variability: El Nino, the North Atlantic Oscillation, global warming. So, I would be skeptical of statistics based on a stationarity.

Pennell: As Wendell says, there was an assumption of stationarity, and it was assumed that the distribution of wave heights was Gaussian, or, as a social scientist might say: distributed on a bell curve. That would make a wave height several standard deviations away from the mean extremely unlikely, and rogue wave heights are certainly several standard deviations above the mean.

UMM: *The MaxWave Project has inspired follow-up research on ship design and on the geographical distribution of rogue waves over the longer term. The latter project seeks insight into the generation mechanisms of rogue waves; could it lead to a start at predicting rogue waves?*

Pennell: Modelers will have a field day with the study of rogue waves. Preliminary numerical studies indicate that several model nonlinear wave equations can give rise to solutions that look like rogue waves. Once we have more data and a better physical understanding of rogue waves, we can find out which, if any, of these nonlinear wave equations is a good model.

Brown: Such highly nonlinear processes are wildly difficult to predict. However, I suspect the rogue waves arise out of particular oceanic conditions that are favorable to their generation. So a rogue wave forecasting center would probably be running data-assimilation ocean models with explicit surface wave-generation physics. They would issue warnings with probabilities of encountering a rogue wave—akin to what tornado forecasters do. §

Scramble for eggs, *continued from page 4*

out of Gloucester and Newburyport. This season, samples will be collected through these same sources, but also through collaboration with Canadian trawl surveys and independent Cape Cod hook fishermen. The goal is to collect samples throughout the study area over the course of the entire spawning season, which runs approximately from October to May.

Measuring fecundity and egg size has traditionally been done by counting and measuring one egg at a time under a dissecting microscope, making the process time-consuming and cumbersome. This may explain the dearth of published fecundity data for northwest Atlantic cod. All samples in the current study will be analyzed using digital imaging software, which is faster and more accurate than traditional methods, and can still be accomplished quite inexpensively.

It is the aim of this research not only to develop fecundity data, but also to simplify laboratory methods while maintaining the quality of the data. It is hoped that accomplishing this latter goal will lead to more frequent fecundity studies on Atlantic cod and other fisheries species, providing managers with better materials for building sustainable fisheries in the Northeast. §

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Inside . . .

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student research

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UMass Researchers Scramble for Eggs

In an ongoing study at UMass Amherst, researchers are working to estimate relative fecundity, or the number of eggs produced per gram of body weight, of Atlantic cod in the Georges Bank and Gulf of Maine regions. Fecundity information is used along with estimates of spawning stock biomass of egg-producing females to predict how many eggs the stock will produce as a whole. This information is then used to predict how many adult fish can be expected to grow from these eggs.

One might assume that such basic life history information on a species as important as cod would be abundant. On the contrary, according to Prof. Francis Juanes, principal investigator for the project, little current fecundity information exists for Georges Bank cod and none exists for Gulf of Maine stocks. In fact, says Juanes, "Other than an outdated [1880] estimate for Gulf of Maine cod, which was based on six individuals, no published fecundity estimate exists for any of the cod stocks from Cape Breton, Nova Scotia to Georges Bank until last year."

More recent estimates do exist for fecundity of cod in the North Sea and Arcto-Norwegian waters; however, cod fecundity is known to vary between stocks over a relatively small spatial scale, so these figures would be inaccurate for northwest Atlantic fish. Last year, in the only recent cod fecundity study of northwest Atlantic stocks, Canadian researchers showed that cod fecundity in adjacent management areas varied by as much as 50% within the same spawning season.

In the present study, funded by the Cooperative Marine Education and Research Program (CMER), ovary samples from developing female cod have been collected by National Marine Fisheries Service personnel aboard NOAA research vessels out of Woods Hole, and by research assistant Nikolai Klibansky aboard commercial fishing vessels participating in state-run trawl surveys

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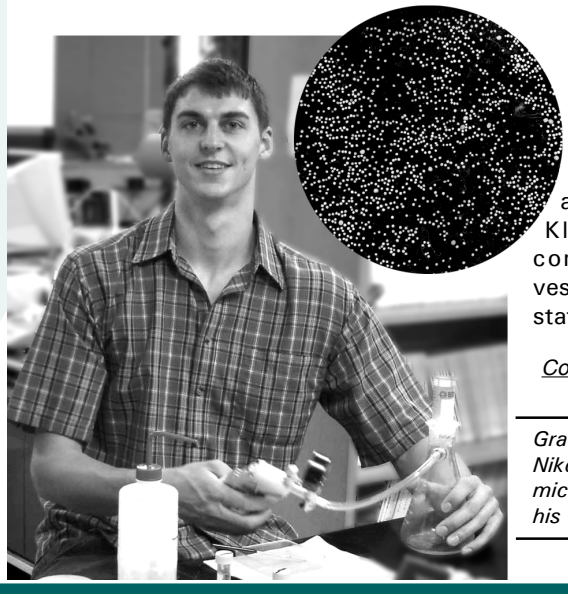

Graduate student Nikolai Klibansky and a microscopic view of his cod eggs.