Judges' Commentary: The Outstanding Coral Reef Papers

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Introduction

The Interdisciplinary Contest in Modeling (ICM)® is an opportunity for teams of students to tackle challenging real-world problems that require a wide breadth of understanding in multiple academic subjects. This year's problem required a particularly deep understanding of ecology to model a solution effectively. Due to the rapid growth of aquaculture facilities currently being installed in or adjacent to many sensitive coastal ecosystems, research into sustainable culturing methods is an active area of investigation. Seven judges gathered in late March to select the most successful entries of this challenging competition out of an impressive set of submissions.

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The Problem

The primary goal of this year's ICM was to develop an aquaculture scenario that incorporated species from multiple trophic levels to reduce the level of effluent leaving the fish pens for a specific case study in the Philippines. These fish farms are adjacent to coral reefs, thus the target was to improve water quality such that corals could thrive in the area while an economically viable aquaculture industry could also be maintained. The main tasks expected of the teams were as follows:

1. Model the original Bolinao coral reef ecosystem before the introduction of fish farms.
2. Model the current Bolinao milkfish monoculture.
3. Observe the remediation of Bolinao via aquaculture.
4. Maximize the value of the total harvest.
5. Call to action.

Overall, the judges were impressed by both the strength of many of the submissions of individual teams and the variety of approaches that teams used to address the questions posed by the ICM problem.

Judges' Criteria

In order to ensure that the individual judges assessed submissions on the same criteria, we developed a rubric. The framework used to evaluate submissions is described below.

- **Executive Summary:** It was important that teams succinctly and clearly explained the highlights of their submissions. These executive summaries needed to include modeling approach(es) used for both the current monoculture and in remediation using polyculture. Further, the summary needed to answer the most pressing questions posed in the problem statement, namely recommendations for remediation and the impact on water quality and optimizing the harvest. Truly Outstanding papers were those that communicated their approach and recommendations in well-connected and concise prose.
- **Domain Knowledge and Science:** The problem this year was particularly challenging for teams in terms of the science.
  - To address the requirements effectively, teams needed first to *establish an ecological frame of reference*. Many teams were able to do this reasonably well; teams that excelled clearly did a great deal of research. Often, what distinguished the top teams was the ability not just to describe the

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ecosystem in a single section of the paper, but to integrate this domain knowledge throughout the modeling process.

  - A second important facet of the problem was the ability to *understand issues that impact water quality*. Many teams created reasonable models of the species and their interactions but very few effectively modeled the water quality.

- **Modeling and Assumptions:** The most popular models used were differential equations—usually linear for the simple cases and then expanding to include nonlinear terms. Simulation was also a popular approach to the problem. Often the models appeared appropriate but neglected any discussion of important assumptions. Additionally, many papers lacked a reasonable discussion of model development, instead presenting a series of equations and parameter values without support. Finally, the very best papers not only formulated the models well, but were able to use the models to produce meaningful results to address the problem and to make recommendations.

- **Solution (Optimization):** Perhaps the most distinct difference between the best papers and others was the ability to utilize their models to develop an actual solution to the problems. Many teams failed to address the most important portions of the problem in any substantive way—what should be done to remediate Bolinao and how to balance the water quality while maximizing harvesting. As a result, the judges put additional emphasis on the actual solution presented, in addition to the modeling approach.

- **Analysis/Reflection:** Successful papers utilized the models developed in early sections of the paper to draw conclusions about the important issues in addressing problems with the Bolinao ecosystem. For example, the important parameters were identified in terms of their impact on the water quality and the harvest available. In the best papers, trade-offs were discussed and, in truly exceptional cases, some sensitivity analysis conducted to identify potential issues with the solutions presented.

- **Communication:** The challenges of the modeling in this problem may have contributed to the difficulty many teams had in clearly explaining their solutions. Papers that were clearly exposited distinguished themselves significantly, emphasizing that it is not only good science that is important, but also the presentation of the ideas.

Discussion of the Outstanding Papers

The two Outstanding papers each had features that distinguished them from the other submissions. Working under the time constraint, both teams were impressive in their ability to research the ecological issues, propose reasonable models, and to present their work in a clear and readable manner. This year, in

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particular, the judges felt that the Outstanding papers each demonstrated particular strengths in one of the important dimensions discussed in the previous section. No submission was able to dominate every area, but these two teams were clearly superior in different ways.

China University of Mining and Technology

The China University of Mining and Technology submission was notable for the impressive array of modeling techniques utilized in attacking the problems. There were other papers with a similar level of modeling, but this group not only described the modeling process clearly but connected the models coherently to the problem at hand. As with many of the teams, the principal models used were differential equations (Volterra models). The team also used the Analytical Hierarchy Process (AHP), as well as nonlinear optimization to improve their models and to address the later requirements of the problem. They propose strengthening the "middle strata of the foodweb" by introducing herbivorous species to the polyculture. They also propose a strategy for harvesting various species while still satisfying the constraint to maintain good water quality in Bolinao. While extremely strong on the modeling, the paper could have been further improved with more depth on the ecological issues and the overall quality of the writing.

U.S. Military Academy

The paper from the U.S. Military Academy included perhaps the clearest understanding and presentation of the ecological problem and issues among all submissions. The paper was extremely well written and researched. Unlike many teams, the group chose discrete models (difference equations) as the primary tool for their analysis and then employed simulations to help with the optimization tasks. The team did an exceptional job of showing how their model output support the move from a mono- to poly-culture—they added blue mussel mollusks to the system to show the positive effects of such a change. They also proposed an optimal harvesting strategy involving multiple species. This paper could have been strengthened by adding detail about the models and modeling process.

Why Some Other Teams Weren't Outstanding

In addition to the two Outstanding papers, the judges noted several other papers of equal merit in terms of the modeling effort but excluded from award due to issues with proper documentation. The issue was not the fact that material from Websites or books was included—within reason, quotations properly cited are appropriate. Rather, some teams used material taken directly from such sources (sometimes as much as one or more pages of text) in place of their own ideas, failed to document a quoted passage as a quotation, or both.

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Conclusion

The judges extend their congratulations to all who participated in the contest. It is a pleasure to see the variety of approaches taken by the different teams; some of these were novel and interesting. The number of excellent papers made the judging both enjoyable and difficult. The problem this year was extremely challenging and the ability to both research and then model in a short period of time was impressive.

Two facets of this year's ICM are worth noting:

- The importance of understanding the underlying science in formulating mathematical models. In the practice of modeling, assumptions should be carefully thought out and checked and, whenever possible, experts should be consulted.
- How critical communication skills are to the analyst. A great mathematical model is not likely to be used if not clearly and concisely explained.

Recommendations for Future Participants

- Not even ingenious solutions are a substitute for clear exposition.
- Ensure that the assumptions you make are clear to the reader, and address them in your conclusions and recommendations.
- Address all aspects of the problem that are asked.
- Between two equally-clear explanations, the shorter one is better.
- Properly citing sources is critical. Judges notice plagiarized material and disqualify papers that contain it; cite as you go, not at the end.
- The recommendations and sensitivity analysis are often as important as the model itself. Frequently, it is better to have a well-analyzed model that accounts for slightly less than a comprehensive but untested one.
- Team members should work to integrate their final submissions. Your paper should read as though it has only one author.

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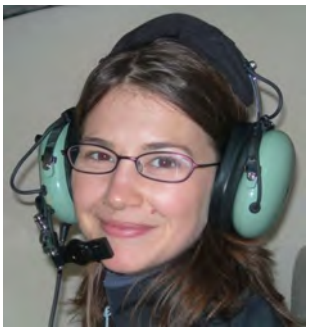
About the Authors



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