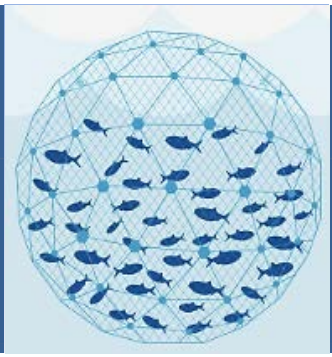

Modeling the Environmental Effects of Marine Fish Cage Culture

Summary of a Workshop to Assess Model Application, Capacity, and Validation Needs

20 - 21 March 2012
Silver Spring, Maryland

Sponsored by the NOAA Office of Aquaculture

Modeling the Environmental Effects of Marine Fish Cage Aquaculture

A Workshop to Assess Application, Capacity, and Validation Needs

20 - 21 March 2012
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Goals

1. Review current state of knowledge regarding environmental impacts of marine cage culture
2. Evaluate models as tools for regulators, researchers, and industry to support sustainable industry growth in the U.S
3. Assess capacity of existing models to predict environmental impacts, optimize farm siting and inform BMPs
4. Identify barriers to model development (*e.g.*, environmental effects), model sensitivity and field validation needs

Outcomes

1. Review of draft NOAA Technical Memorandum, *Marine Cage Culture and the Environment: Twenty-first Century Science Informing a Sustainable Industry*
2. List of modeling parameters
3. List of validation needs for models and barriers to validation
4. Outline next steps to bring models into operational status in the United States

Planning Team

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WORKSHOP SUMMARY

DAY ONE Tuesday, March 20

Welcome

Michael Rubino welcomed participants and provided the framework for the workshop. He said that NOAA needs to know the current scientific information about environmental effects of cage culture and must be able to share and communicate this information. NOAA will use this information in partnership with the Army Corps of Engineers, EPA and state regulatory agencies to make decisions about where to site fish farms in U.S. coastal waters. James Morris followed with an overview of the workshop goals and objectives.

Session 1

Aligning Models with Manager Needs: ***How Are Models Currently Being Used by Managers to Site & Manage Marine Cage Culture?***

Objective: Increase understanding of managers' information needs in order to better inform tool development.

Four presenters provided perspectives of resource managers on the use of models for informing aquaculture stakeholders in their current regulatory role.

1. **Marine Salmon Net Pen Aquaculture in WA**
   Paula Ehlers, Washington Department of Ecology

Paula Ehlers provided a brief history of salmon farming in WA since the 1960's and described the regulatory framework. The permitting process involves the WA Department of Ecology, Department of Agriculture, Department of Fish and Wildlife, Native American Tribes, the Army Corps of Engineers, the Food and Drug Administration, the National Marine Fisheries Service and local government. NPDES permits are required, as are pollution prevention and accidental fish release plans. Many of the regulations and policies are due to be revised and updated by 2015. About 5 of the 12 counties potentially impacted by aquaculture are concerned about environmental and disease issues. One county passed a full prohibition and is trying to encourage other local governments to ban aquaculture. NOAA can support local communities by providing technical information, such as modeling, and scientific guidance.
QA: How much is the issue over local land use patterns versus overall regulatory constraints? A lot of industry wants to site in Puget Sound, but they are concerned about the regulatory requirements. In local communities, landowners and commercial fisherman that are most

opposed. Current statutes require no net loss to ecological function for permitting, but this is hard to define. The agency tends to lean on the side of protecting the natural resources.

2. Aquaculture in Maine
Jon Lewis, Maine Department of Marine Resources

In Maine, the industry is primarily growing salmon and cod, with halibut production likely to increase soon. Currently, 20 million pounds of salmon are harvested each year. There has been a monitoring program since 1988 to track environmental impacts. The results so far suggest environmental impacts have been minimal, especially outside of the immediate farm perimeters. Farms are monitored twice a year. If there are problems at a farm, there is increased monitoring and further production may be halted until there is benthic recovery. Generally feed management is thought to drive enrichment, not fish waste. There must be site-specific evaluation and sociological considerations incorporated into the permitting process, which may be impossible to include in models. For example, eastern Maine welcomes the aquaculture industry as it needs jobs. Here, social issues drive aquaculture development. Additional concerns for the industry are disease and health issues such as sea lice and infectious salmon anemia (ISA).

QA: Modeling does not replace monitoring. Similar to Washington, farms in Maine started in backwaters and had some environmental issues, but were eventually relocated to less nutrient sensitive areas. In Washington, farms were also moved into deeper water, but this was less common in Maine, possibly to avoid having to go through regulatory process again. Even minor changes in farm siting or management may require new permitting. Dale Kiefer noted that modeling may be a useful tool for examining a selection of minor potential farm changes to help decide on specific changes. Currently, Maine adjusts farm siting and management by trial and error. Jon noted that modeling may be useful, but the agency will continue to rely on monitoring for most regulatory purposes.

3. Siting Marine Cage Culture in Scotland
Jeremy Spurway, Scottish EPA

There are about 400 sites in Scotland, mostly on the west coast and the western and northern Isles (Orkney and Shetland Isles). They predominantly raise Atlantic salmon, but also trout and halibut. These fish are considered a high quality product. Permitting is done as a seabed lease from the Crown Estate, siting permitted by Local Authority in consultation with navigation and conservation regulators, and discharges licensed by SEPA. Modeling is used to achieve goals of sustainable operations, site optimization and monitoring strategy. DEPOMOD is a dispersion model used by the farm operator to assess site specific organic loading. The Scottish EPA is moving toward permitting by feed load rather than by farm size to encourage more efficient feed management. Other improvements to the impact modeling suite would be adding robust solute models, validation and incorporation of probabilistic models. The dream model would

be a GIS plug in, be platform independent, have default and configurable parameters, make probabilistic predictions, configure optimization constraints/targets, use local hydrodynamic data, assess far-field impact, include risk screening to highlight need for audit, link to monitoring database, and generate license conditions.

QA: Jack Rensel asked if there has been an evolution of site placement and how many are depositional. About one quarter of sites are over coarser bottoms, and overall farms are now in more energetic (*i.e.*, high current) areas than before. Dr. Hargrave asked if DEPOMOD differentiates between food and feces. Yes, it differentiates between feed and feces as they descend, then tracks them concurrently if the re-suspension module is turned on. Jeremy noted there are some out of date parameters in those models.

4. Aquaculture in Canada

Fred Page, Fisheries and Oceans Canada

There are 500+ farms equal distributed between the east and west coasts. The managers' needs are driven by socioeconomics, the need to eliminate environmental impacts, market demand and perception, and the government's desire to balance it all. Managers must develop ways to make proactive decisions, approve site applications, ensure industry stability, define disease management zones, and estimate influence on environment. Operational issues include stocking licenses, oversight and monitoring, diagnose monitoring results, cull orders, implement quarantine sites, and enforcement actions. Models need to be credible, understood, predict spatial and temporal scale and intensity of effects, digestible and sufficient, and predict decision criteria. Canada uses several models such as DEPOMOD, FVCOM (circulation model), and others. Future model improvements should involve improved benthic dynamics models, including cumulative and dispersal effects, forecasting disease and pest spread and zonation, assessing climate change impacts and including integrated multi-trophic aquaculture (IMTA).

QA: Dale Kiefer asked if they use models in legal cases? Fred said this is a dangerous route to go, but it is possible. The value for models is to help educate the public and users about the nuances of the problem.

Aligning Models with Manager Needs: ***Assessing Manager Needs***
Mike Rust and Facilitators

Objective: To develop shared understanding of managers' needs for models and ways that models are useful in siting and managing cage culture.

Mike Rust introduced this part of the session. We don't want to reinvent the wheel and it is not necessary to have only a single model. We do want to know how accurate a model's predictions are in a variety of sites and farm conditions. Another approach might be to use several models, as the weather service does for hurricane predictions, which are complimentary rather than competitive.

The following questions were used to prompt participant discussion during this session:

> What are the needs for models by managers?
> How well do current models address those needs?
> What are the limitations to you using the models?

<u>What are the needs for models by managers?</u>

There is a difference between research and operational models. Each has different uses and applications. There needs to be good collaboration between the modelers and managers to make a product that is operational for the end user – farm operators. They need models that are reliable and accurate, site-specific and relatively simple to use. There is a lot of data collection, development and validation that must be done to build trust in the reliability of modeling approaches.

There may be some misconceptions that managers are not capable of using models so there needs to be good communication between all the stakeholders. Some people do not trust models and in some cases, it is social perceptions rather than scientific ones that drive decision making. It needs to be clear that models are just one tool available for resource managers to use. Many resource managers (in other agencies and not necessarily aquaculture regulators) already use numerical and conceptual models extensively to make decisions. Environmental models used for aquaculture should be acceptable to and useable by them as well in implementing a cooperative/joint permitting processes. At the same time, managers must be able to explain the modeling process to the public and condense the technical aspects to make them understandable.

In addition to complex physical models, Barry Hargrave suggested that the "traffic light" decision support system can be useful for doing initial triage for. Variables considered can be adjusted to meet local priorities and can quickly result in simple yes or no answers for preliminary screening that are based on a combination of science and social or economic

priorities. For a site that gets a "maybe" rating, more complex models can then be done to follow up at finer scales.

The biggest question for farmers and managers is how much fish biomass can be produced without environmental damage. To answer this question across all regions, the models must be site-specific and allow for local and regional calibration flexibility (i.e., differential parameterization).

Dale Kiefer stressed that models must be as good, technically, as we can make them. There is always room for improvement, tweaking and more science. For example, far-field effects modeling is more complex than near-field and must incorporate information at different scales. We need to maintain the complexity of the models to make them robust, but also need to be able to condense their output and make it understandable and believable. In other countries, modeling has been used as a basis to deny farm permits applications for concerns of environmental impacts. Therefore, we must have confidence in model reliability and models must be field validated (not just simulated) in a variety of locations.

Paul Sandifer noted that in addition to numerical models it is also important to consider social and economic factors.

<u>How well do current models address those needs?</u>

Jon Lewis wondered what parameters are in current models. Models currently include a wide range of chemical, biological, hydrodynamic and farm management parameters including production, feed input and waste, feces output, number of fish and cages, size of farm, location of cages, temperature, biomass, sediment grain size, background nutrient levels, baseline organic matter, and many more.

Kenny Black said that in Scotland the models have been validated and are accepted. Now they are moving to expand the models to be able assess risk at different scales (far-field, regional) and in other habitats (hard bottom).

James asked for the managers' perspective on what the knowledge gaps are and what they need to make models applicable to their daily responsibilities.

Fred Page said that model use is moving on the right direction. They need to have confidence that the predictions are site-specific and valid. The models don't have to be perfect, but they do need to work well most of the time. Jeremy added that using the models correctly is important. They can be useful for an overall assessment of risk. One approach is to begin with simpler risk triage processes and then follow up by using the more complex models to determine more detailed site-specific impact potential and to fine tune or adjust farm management. Kenny Black added that managers need the ability to do adaptive management so that small adjustments to farm operations can be done without re-permitting.

Lee Carrubba said that some models that are not aquaculture specific (from EPA NPDES process, for example) could be used to help with siting or defining regions that would be conducive to aquaculture. NOAA should look into and build on the existing framework for siting. Also, it is important to get buy in from local stakeholders about where to put cages and supporting the industry.

Paul Sandifer added that models must be validated by third party review and they must stand up to public opinion and legal scrutiny.

<u>What are the limitations facing managers to using the models?</u>

Limitations include a lack of technical capability to run complex models, limited funding, and uncertainty about the framework for regulatory application. Also, training to use the models takes time and can be difficult since each model is unique. Most models are too technical for most coastal managers to incorporate into routine decision making; therefore, we need to make modeling a well-coordinated and centralized working group made up of government, academics, and NGOs that can provide modeling services to managers. Ideally models would be GIS-compatible with other marine spatial planning activities.

Model improvement needs include resuspension parameters and probabilistic outputs. Models need to accurately measure resuspension and transport of waste materials across the sea bottom to accurately predict benthic effects. Ideally, models can be used to better educate the public about net pen aquaculture and can be used within a larger coastal zone management context.

Session 2

Whitepaper Review ***Marine Cage Culture and the Environment: Twenty-first Century Science Informing a Sustainable Industry***
Carol Price and Facilitators

Objective: Complete review of white paper and develop list of environmental effects parameters for modeling to be used for building or reviewing models.

Carol Price began by reviewing the session objective which was to gather feedback from experts about how well the report captured the current state of knowledge about the environmental impacts included in the analysis. The authors want to make sure the report adequately reflects the range of potential impacts and identifies which environmental effects are most important for inclusion in modeling and monitoring. An overview of each chapter was provided followed by a general discussion among the participants.

Chapter 1 **Water Quality**

Several topics were identified for potential inclusion in the report. Barry Hargrave suggested adding information about the sea surface microlayer as a place where trace metals can be concentrated and transported away from a farm site. Kenny Black said that additional information about dissolved oxygen impacts in fjords is available for inclusion and that he had sent Carol the relative papers. Jack Rensel noted that far field effects may be significant, but are not easily measurable. Mike Shane suggested including information about using stable isotope analysis to track nutrients from aquaculture facilities. Jon Lewis asked about definitive links between HABs and aquaculture. Daniel Bennetti added that site selection criteria were not addressed in the paper, and that offshore siting in high energy environments is where farms are likely to be located in the U.S. Also, he suggested considering farms as sources of fertilization, rather than pollution, which may enhance marine productivity. Paul Sandifer said that all the nutrients need to be considered together, not as separate inputs, to take into account additive/interactive effects. He also added that scale of space and time must be considered and long-term monitoring is important. Dale Kiefer added that nutrient inputs are of most concern in areas where nutrients are limiting. Models must account for phosphorus as well as nitrogen limitation. Jack Rensel said that nutrient criteria can be set up by ecoregion, with no farms being allowed in nutrient sensitive areas. This was successfully used in Puget Sound. The biggest gap for models is having quantitative information regarding the resuspension and transport of waste particles across the sea bottom. Mike Tlusty suggested restructuring the report section so that the studies finding no impact should be included after those that do show impacts, and that there should be discussion about why there may or may not be impacts in each study area. Lee Carrubba suggested not lumping all the study regions together, but to separate by tropical or temperate waters. She stated that monitoring needs to include sampling at different points in the water column and to take into account the potential effects to sensitive environments distant from the farms (*e.g.*, corals).

Chapter 2 **Benthic Effects**

Jon Lewis commented that loading, not siting per se, is the key to decreasing benthic impacts. Lee Carrubba suggested that having the benthic impacts considered here and then in the Marine Life chapter might be confusing, and should perhaps be combined. There needs to be narrative which ties everything together. More information should be included on farm site characteristics and husbandry techniques. She also noted that sediment deposition and resuspension need to be considered at locations down current of the farms. Fallowing needs to be included. Jon Lewis asked about harrowing as a benthic recovery technique. Mike Rust said it has been tried by the Japanese, but that it is not considered a viable management tool. Barry Hargrave suggested adding illustrations to link together the chemical and biological sediment processes. He suggested starting with the classic conceptual models (Pearson and Rosenburg 1978) and then adding sediment depth, loading rates, biodiversity, geochemistry, etc. Kenny Black said it is important to know what functions you are trying to protect and use those in the monitoring standards.

Chapter 3 **Marine Life**

Paul Sandifer asked for clarity on effectiveness of fallowing. Kenny Black noted that the use of fallowing may be perceived as a measure of farm management failure. He clarified by saying that if you farm sustainably, then you don't have benthic impacts and don't need to fallow. Barry Hargrave stated that there is very little known about hard bottom impacts, as nearly all work has been done in soft sediments. Mike Tlusty mentioned a recent paper in *Science* that compared share (spread impacts over larger areas) versus spare (concentrate impacts in less areas, but with higher localized effects) approaches to terrestrial agriculture. He suggested this should be examined for aquaculture too. Carol noted that there are few studies on marine aquaculture impacts to marine mammals and other pelagic marine life.

Daniel Benetti said that marine mammals and sharks around cages can cause problems, especially with public perception. Jack Rensel said that NOAA is conflicted about permitting farming in some areas due to potential interactions with marine mammals, and that risk assessments were needed. Diane Windham added that there are many issues to think about with protecting marine mammals including hazards to navigation, predation by pinnipeds, ship strikes, cross-jurisdictional issues. Jack Rensel noted that food web diversity and abundance may be enhanced by net pen wastes when siting and sizing of the farms are optimized, a process that has been done by trial and error in the past. Jon Lewis added that waste feed from farms likely supplements the diet of many species around farms. Lee Carrubba said that the behavioral changes to animals that aggregate to fish farms should be considered as a potential negative effect. She also agreed to send Carol several papers about nutrient effects to some sensitive habitats. Daniel Benetti said that proper site selection should avoid impacts to most sensitive habitats, especially if farms are offshore. Fred Page noted that in coastal nearshore areas there may be siltation impacts.

Chapter 4 **Chemicals**

Some countries are better at reporting chemical use. Jon Lewis (?) noted there are implications for illegal use of non-approved chemicals. These should be included in the report. Other participants noted this could include too many chemicals to include in the report, but maybe some of the most likely could be listed. Lee Carrubba noted that you need to account for chemical/metals that may already be present at background levels. Barry Hargrave noted that heavy metal concentration values need to be normalized using lithium. Fred Page suggested that his dye plume work illustrates how important it is to sample where therapeutants are present in the water column.

Chapter 5 **Management Tools**

Fred Page said that while IMTA is popular, it is not currently efficient or practical. It does not help with most benthic impacts. It looks "green" but is difficult to implement. Daniel Benetti agreed adding that it is difficult to get farmers to invest in IMTA. Paul Sandifer and Jack Rensel added that IMTA technology development is a long-term research effort that is worth pursuing. Some species are better at assimilating nutrients than others. Jon Lewis said that there have been problems with mussel growing in proximity to salmon farms in Maine. Jeremy Spurway suggested taking the entire chapter out of the report. It was noted that site selection was not included in this section, but could be. Barry Hargrave supported the idea, implemented in Norway and elsewhere, where aquaculture management is based on hydrographic regions rather than an individual farm basis. Carol added that feeds management was handled in a different recent report, so was not covered in this analysis. Paul Sandifer pointed out that genetic and disease impacts were omitted from this analysis, but are important to consider. Mike Rust explained that another group is working on a genetics review.

James Morris concluded this session by thanking everyone for their review and input. The analysis will be revised to include the feedback and the final product will help NOAA to provide information to guide sustainable growth of this industry in the U.S.

DAY TWO Wednesday, March 21

Session 3

Current Status of Modeling Capacity in the U.S.
James Morris & Facilitators

Objective: Increase understanding of current state of aquaculture modeling in the U.S.

Four presenters described cage culture related models that they have developed. They were asked to give an overview of their model, including the theoretical background used for original development. They provide information about what the input and response variables are and what the next steps are in model development or improvement.

Karan Venayagamoorthy Stanford SUNTANS Model

The Stanford SUNTANS Model is a fluid mechanics model which was designed as a research model to look at the physics of the flow around cages and its effect on plume dynamics. This is a very complex mathematical model which was used to look at factors affecting the flow

patterns and turbulence at various scales. Such models can be used in conjunction with laboratory and field experiments to inform siting and cage spacing, and for model parameterization. This model compared outflow patterns from net pens in various locations inside a modeled bay and was capable of varying factors including cage position, Earth's rotation and water depth. The results highlighted that physical processes at many scales can influence flow dynamics around fish cages.

QA: Jack Rensel noted that the model was used in a publication that showed plumes hitting the coastline but that it was misleading because the images used a log scale and the concentration near the coast was orders of magnitude less than at the source. Also he noted that the wastes were treated as conservative materials, not subject to biological uptake and degradation that occurs in reality. He added that the media seemed to have misrepresented this work and Karan agreed. Karan said the model was still being adapted as part of the larger SUNTANS project. One potential for expansion of the model was to include vertical mixing and stratification.

Ralf Riedel GoMex Carbon Sedimentation Model

This model was developed several years ago when Ralf worked with the Mississippi Offshore Aquaculture Consortium. Because funding was discontinued, further model development was not possible. This is a relatively simple operational model constructed with the end user (farm operator) in mind. It uses fish and feeding data to predict carbon sedimentation in the sediment immediately around fish cages. The model is still applicable, but would need updating and validation to be used in the future. It is easy to use for running site specific simulations.

QA: There were several questions about the hydrodynamics data used in the model. Ralf replied that he used daily means from nearby field monitoring data. He used literature values for settling rates. The model needs to better incorporate waste decay rates. During general conversation among the group, it was noted that there is need for both simple and complex models.

Jeremy Spurway DEPOMOD

This model has been in use for over a decade by many users in Europe and elsewhere in the world. This particle tracking model is based upon Gaussian dispersion equations. It is driven by

current data or external hydrodynamic files and is used to predict the deposition of fish farm solids to the seafloor and the resulting benthic biodiversity response.

DEPOMOD needs to be updated to update the prameterization of resuspension, thresholds for sheer stress, bottom roughness variability and sediment density, and tackling the ranges of these values found in the environment. There is also some interest in moving away from ITI for faunal impact analysis and incorporating a sulfide impact model.

DEPOMOD is a standard part of the regulatory toolbox used by the farm operators and SEPA to establish license limits, configure farm sites and set farm loading.

QA: Jon Lewis asked if the waste feed input is a constant. It is a constant proportion but can be tweaked. Jack Rensel asked how you know what is labile. Kenny Black replied that most of it is and the value can be adjusted accordingly, but that labile carbon tends not to matter anyway in recovery rate. It is background C levels that are more important. Jack pointed out that a past criticism of the model was the inability to separate feed from fecal inputs. Jeremy said that is still the same, but you can model with fecal at 0% and account for the difference that way. Jeremy also talked more about including sediment sulfide as a model output to assess benthic impacts as well as recovery.

Jack Rensel & Dale Kiefer AquaModel

AquaModel is a comprehensive, GIS-integrated tool that models many water column and benthic effects at near and far-field scales. It includes a fish physiology component and can use various water current and bathymetry data. It accounts for benthic deposition and resuspension, can include a mixed layer, and tracks feed and feces separately. A plankton model can predict the response of phytoplanktonand zooplankton to dissolved nutrients. Microbial biomass (aerobic and anaerobic) is also calculated. AquaModel can be interfaced with various regional circulation models such as the Finite Volume Coastal Ocean Model (FVCOM) data. This model has been calibrated and tested in several different ecoregions, from tropical to temperate, using several discrete fish species physiology submodels. Some validation has been conducted using salmon farm data. Model development will include better consolidation rates, resuspension and improved mesofield circulation data (input from multiple current meters around a farm site).

QA: Jeremy Spurway asked if the water column portion of the model used vertical water column profile data. Jack indicated that it operates with a mixed (surface layer) and separate deep layer or with no layering, as the user chooses. Jack said it does, but can run with point estimates too. Jon Lewis asked if you can manipulate feed rates. Feed rate is assigned by the user or more commonly optimized by the program with user settings for percent waste feed. James asked for information about how their end user partners (operational farms) are using the model for siting or management. Dale said the application has been minimal, aside from simulation work. The model has been run for use in permitting processes in Puerto Rico (cobia) and by Hubbs-SeaWorld Research Institute, but those projects were put on hold. It is also being applied at an operational farm in the Gulf of Maine, but needs additional validation there. James asked how many parameters are in the model and which are most sensitive. Dale said there are about 30 input parameters. Water circulation data, fish biomass, temperature, and the physiological parameters in the model are most sensitive. Karan Venayagamorthy asked if they were imposing a numerical grid. The model runs on a Cartesian grid. It takes several days to run a year-long simulation, and that the time step intervals are important because scale effects are different. Dale noted that as you add farms to an area, farm management practices become increasingly important, not just the physics. There are many spatial and temporal dynamics to consider. Fred Page asked if you can adjust vertical and horizontal mixing, and Jack said you can. Carol asked if the benthic geochemistry module was still being developed and Dale said it is.

Model Development & Validation Needs
Carol Price and Facilitators

Objective: Identify best use, barriers to application, and validation needs for models.

At the end of this session, the workshop participants were asked to help fill out the following comparative matrix for the four models that were presented. This information will be used to assess how different types of models can be applied to marine aquaculture issues, the needs and visions for model development, and opportunities to validate and apply the model. This matrix will be useful in comparing research versus operational models and guiding the use of modeling by different stakeholders. The complete matrix is on the following pages.

Matrix Comparing the Four Models

	SUNTANS	GoMex	DEPOMOD	AquaModel
Niche/Best Use	• Not designed for aquaculture management decisions • Coastal ocean model • Process • Research • Parameter investigation • Hydrodynamic data processes. • High expertise • High resolution • Input to other models • FVCOM boundary conditions78 • Far field	• Sediment model • Near field • Threshold model • First cut, screening • Sensitivity tools • Benthic	• Near field • Operational • Widely used • Field monitoring • Benthic only	• Near (single farm) and far fields (multiple farms) • Comprehensive, integrates physics and biology • Versatile • GIS integrated • Water column and benthic • Built in contouring package to display results • Good visual graphic output
Users	Research, academic, possibly management	Managers (end user)	Regulators, farms	Regulators, farms
Road Blocks to Application	• Availability, Cost, Training • Couple to biology and ecology • Funding • Open source	• Availability, Cost, Training • Free • Maintenance lag time • No resuspension or assimilation capacity for waste particles • Out dated	• Availability, Cost, Training • Fee of £250to track users and ensure distribution of updates • Acceptance by regulators? • Access to code	• Availability, Cost, Training • U.S. Industry, small staff • Need little training • Need to understand fish farms • Lack of validation and peer reviewed applications

	SUNTANS	GoMex	DEPOMOD	AquaModel
Field and Other Validation Needs and Opportunities (partners & locations)	• Wants more partners and validation. • Resuspension • Share datasets across all	• Needs support/funding /partners • Resuspension • Share datasets across all	• Resuspension • Needs refresh • Share datasets across all • Compared with Delft3D in SARF035 project to evaluate far field impacts • Way ahead of others • Compared with 3 other models	• Resuspension • Share datasets across all • Use Maine data • More links to biology
Vision for Model	• To Improve understanding of physics and processes • Support role for other aquaculture models • Understand physics and biology	• Farm siting and management fine tuning • Understand physics and biology	• See Jeremy's dream slide • Improve biogeochemistry • Bring code up-to-date • Rewrite in different language and remove dependence on ancillary software • Offshore • Hard bottom • Understand physics and biology	• See Jack and Dale's vision slide • Become operational to help build U.S. aquaculture industry • Work with NOAA to become sustainable • Tool to understand physics and biology
Peer-review Status	• Yes, 5 years. Quite a bit in prominent journals. No validation in aquaculture	• No	• Yes, in several papers since 2002 • 2 agency evaluations	• 1 peer-reviewed journal for AquaModel and other journals for the 4D GIS • On-line technical reports • 2 draft papers

Closing Comments

Each participant was asked to say a few words about the workshop. Most said they thought it had been a worthwhile meeting, that they learned a lot, and had made valuable connections with colleagues. The outlook for the development of environmental impact models was quite positive and several collaborations to further develop and validate models have already been initiated. It was suggested that a follow up workshop be held in a year to continue the momentum and encourage cooperation across the scientific, regulatory and industry stakeholders. Michael Rubino said that this workshop will help NOAA fulfill its responsibility to permit and regulate the marine aquaculture industry as it develops in U.S. waters and to communicate to the public about the environmental effects. James Morris concluded by thanking everyone for their participation and highlighted the importance of this work to developing sustainable marine cage culture in the United States. He also discussed several next steps including publication of the whitepaper and efforts to develop a network of modelers to foster collaboration and build NOAAs capacity on this issue.

This summary was prepared by Carol Price in April 2012 from meeting minutes provided by April Bagwill, Alison Hammer and Stephanie Kavanaugh. Please direct any questions about this workshop to James.Morris@noaa.gov.

MEETING PARTICIPANTS

Participant	Affiliation
Jack Rensel	Rensel Associates Aquatic Sciences
Dale Kiefer	University of Southern California
Karan Venayagamorthy	Colorado State University
Ralf Riedel	University of Southern Mississippi
Jeremy Spurway	Scottish Environment Protection Agency
Mike Shane	Hubbs-SeaWorld Research Institute
Paula Ehlers	Washington Department of Ecology
Jon Lewis	Maine Department of Marine Resources
David Rivas	CICESE Oceanografia Biologica
Thomas Valdemarsen	Syddansk Universitet, Biologisk Institut
Barry Hargrave	Fisheries and Oceans Canada, retired
Kenneth Black	Scottish Association for Marine Science
Michael Tlusty	New England Aquarium
Carol Price	NOAA National Ocean Service
Fred Page	Fisheries and Oceans Canada
Paul Sandifer	NOAA National Ocean Service
Daniel Benetti	University of Miami
David Fredriksson	US Naval Academy
Michael Rubino	NOAA National Marine Fisheries Service
Lorenzo Juarez	NOAA National Marine Fisheries Service
David O'Brien	NOAA National Marine Fisheries Service
Mike Rust	NOAA National Marine Fisheries Service
Suzzane Bricker	NOAA National Ocean Service
Lisa Marie Carruba	NOAA National Marine Fisheries Service
James Morris	NOAA National Ocean Service
Jess Beck	NOAA National Marine Fisheries Service
David Alves	NOAA National Marine Fisheries Service
Diane Windham	NOAA National Marine Fisheries Service
Laura Hoberecht	NOAA National Marine Fisheries Service
Alan Everson	NOAA National Marine Fisheries Service
Robert Bastian	US Environmental Protection Agency
Allison Hammer	NOAA National Ocean Service
Stephanie Kavanaugh	NOAA National Ocean Service
Susan Bunsick	NOAA National Marine Fisheries Service
Brian Fredieu	NOAA National Marine Fisheries Service
Chris Botnick	NOAA National Marine Fisheries Service