Scope of work for a food web model to characterize the seasonal abundance for important prey species of endangered species in Massachusetts and Cape Cod Bays

Massachusetts Water Resources Authority

Environmental Quality Department
Report ENQUAD 99-09

Scope of work for a food web model to characterize the seasonal abundance for important prey species of endangered species in Massachusetts and Cape Cod Bays

submitted to

U.S. Environmental Protection Agency, Region 1
Massachusetts Department of Environmental Protection
Outfall Monitoring Science Advisory Panel
Inter-Agency Advisory Committee
Public Interest Advisory Committee

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prepared by

Carlton D. Hunt
Roy K. Kropp
Battelle
Duxbury, MA

and

James J. Fitzpatrick
HydroQual
Mawah, NJ

for

Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Boston, MA 02129

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BACKGROUND

The draft NPDES permit for the future outfall (outfall T01) calls for development of a scope of work for a food web model by December 31, 1998. The draft NPDES permit (page 9) specifies that as part of ambient monitoring:

> "The MWRA shall: … by December 31, 1998, develop a scope of work for a food web model to characterize the seasonal abundance for important prey species of endangered species in Massachusetts and Cape Cod Bays. The food web model shall: (a) include phytoplankton, zooplankton, planktivorous fish and marine mammals, (b) allow an evaluation of the strength and likelihood of potential stressors that may alter the food web, (c) be based on results of ongoing monitoring, special studies of plankton (phytoplankton and zooplankton) dynamics and any other current or historical research in Cape Cod Bay, and (d) be reviewed by the science panel described under section 7d below. The MWRA may choose to fulfill the obligations described in this paragraph by ensuring that these items are performed by another entity.
>
> On or after December 31, 1998, EPA will review all available information, including the results of all on-going monitoring and special studies, and models, and develop any appropriate requirements for additional monitoring and modeling in Massachusetts and Cape Cod Bays. The monitoring plan described in Attachment N shall be modified to reflect these additional requirements."

EPA's Overview of the permit (http://www.epa.gov/region01/reginit/overview.html) indicates:

> "Concerns have been raised about the potential impact of the outfall on plankton species in Massachusetts and Cape Cod Bays, especially the formation and composition of zooplankton patches which are a key food source for right whales. The permit requires the MWRA to develop a scope of work for a study that would evaluate and model the food web for endangered species in Massachusetts and Cape Cod Bays. When that scope of work is completed (required by the end of 1998), EPA will develop appropriate additional requirements for monitoring and modeling activities. These additional requirements will be incorporated into the monitoring plan."

The Overview above, plus verbal clarification from EPA (see minutes of the 10/27/98 meeting of the Outfall Monitoring Science Advisory Panel), document that the intended focus of the effort is on right whales rather than on other endangered species.

The required scope of work is included in the subsequent sections. It addresses the key concerns listed in the permit: (a) to include phytoplankton, zooplankton, planktivorous fish and marine mammals, (b) to allow an evaluation of the strength and likelihood of potential stressors that may alter the food web, (c) to be based on results of ongoing monitoring, special studies of plankton (phytoplankton and zooplankton) dynamics and any other current or historical research in Cape Cod Bay. Towards this end, this scope of work focuses on the key factors that affect the seasonal abundance for important prey species of the endangered species that inhabit Cape Cod Bay but focuses on the food web of the right whale as it is of greatest concern in Cape Cod Bay. A food web model can also form the basis for evaluating transfer of toxic chemicals through the food web to endangered species, but is not required under the permit language, thus this aspect of the potential impact is not specifically developed in the scope of work.

The scope of work presented in this document specifically addresses nutrient loadings to the Massachusetts/Cape Cod Bay system, potential effect(s) of major alteration of nutrient loading and transport on the right whale food chain, nutrient effects on phytoplankton abundance and species

composition, linkages between phytoplankton species and abundance and zooplankton species and abundance including the seasonality of both, the factors affecting the composition and formation of zooplankton patches in the Bays, and the interactions of other zooplankton predators that compete for this right whale food. Because visits to the Bays may be a small part of the overall food web of these whales, and other factors may be more important to the survival of this species than food limitation, this scope of work also incorporates an assessment of large scale issues (external forcing functions) affecting the survival of right whale. These include the annual range and visitation frequency to the Bays, contribution of the Bays system to the annual food requirements of the whales, and other factors important to the survival of this species. The development of the appropriate modeling approach to address prediction of impact is listed as a separate task, as are the tasks required to formulate, calibrate, and validate the model prior to making predictions.

Iterative development process

The model development is expected to require an iterative effort and continuous interactions among researchers, modelers, the OMSAP, regulators, other interested parties, and MWRA monitoring program to be successful. At any stage in the modeling, any or all of the tasks included in the scope of work below may need to be revisited and modifications to the approach or data needs made. Such interactions require that appropriate stopping points be defined for agency and peer reviews. MWRA will work with EPA, MADEP, and the OMSAP, regulators, and other interested parties to develop an appropriate review process and schedule.

In addition, a modeling effort may be affected by specific issues or questions raised during the course of the development. Several of the Tasks described in this scope of work thus contain examples of questions that may need to be addressed to complete the Task successfully. While these are representative of the types of questions that would need to be addressed under particular tasks, they are not intended to be exhaustive compilations of all relevant questions. Such compilations would be developed during execution of the tasks themselves.

SCOPE OF WORK

Ecological assessments of potential impact from the relocation of the Massachusetts Water Resource Authority's treated sewage outfall into Massachusetts Bay were completed in the late 1980's and early 1990's (EPA 1988, EPA 1993, NMFS 1993). The assessments were completed with the best available environmental data. Since completion of these assessments, MWRA and others have developed a substantial database and understanding of the ecological functioning and transport mechanisms of Massachusetts and Cape Cod Bays (the Bays). In addition, more sophisticated modeling of the ecosystem and effluent plume dynamics have been undertaken (HydroQual and Normandeau 1995; Signell et al. 1996). In spite of the consistent findings that impact on the ecosystem will be limited and confined to an area very near the outfall, and that the relocated discharge will have no jeopardy to continued existence of endangered species from outfall relocation (EPA 1993, NMFS 1993), concerns remain over the potential impact of the outfall relocation to endangered species. These concerns focus primarily on effects that the discharge may have on the food web of endangered species, specifically the northern right whale that visits the Bays seasonally. Despite the lack of direct evidence or quantitative predictions of impact to the food web of endangered species, the suggestion has been made that food web modeling could provide predictions of impact to these animals from the relocated MWRA outfall.

However, it is clear that a food web model that provides confident predictions of nutrient or toxics effects on a highly mobile top consumer from a discharge tens of kilometers away from the major area inhabited requires a highly detailed fate and transport model that incorporates the key cause and effect links within the food web. While a detailed review of the relevant literature is a separate task defined in this scope of work, neither MWRA nor the authors are aware of any such modeling structure that has been successfully applied to a marine ecosystem. Because of the challenge presented, development of an effective, reliable food web model for this species requires a systematic approach and framework to ensure that reliable predictions can be made.

This scope of work provides such a model development framework, and identifies the tasks required to complete a food web model, by which the potential effects of the MWRA discharge on the prey species and, thus, right whales that visit Massachusetts and Cape Cod Bays, can be developed. A fundamental underlying premise of this scope of work is that unless the best currently available information suggests the discharge from MWRA's outfall in Massachusetts Bay has an appreciable potential to harm the Bays ecosystem in such a manner that endangered species would be affected, model development is unwarranted at this time. A second fundamental premise is that unless a model can be constructed, calibrated, and verified such that its predictions of impact from the relocated outfall would be quantitative and can be made with high certainty, proceeding with model development in advance of the basic research that would produce such confidence is premature.

The process that will be followed to guide model development is shown in Figure 1. The framework would be implemented in an incremental manner with decision points for process review, including recommended decision criteria for stopping or and continuing, suggested end points, and definition or redefinition of subsequent steps. This incremental approach is required to ensure the relevance of the model effort, to consider its predictive skill, and to define the appropriate modeling framework.

The first activity to be conducted under this scope of work would revisit the major impact evaluations in the SEIS and in the later EPA/NMFS endangered species consultation. Three major Federal technical reviews of the MWRA project determined that upgrading treatment and relocating the effluent discharge would have no unacceptable consequences for Massachusetts and Cape Cod Bays (EPA 1998), and would not jeopardize endangered marine mammals within the Bays (EPA 1993, NMFS 1993). This would

include review of the assumptions used in the assessments and new data that has become available since the assessments were completed. Data updates will be developed from more recent data and information (e.g., ongoing MWRA monitoring, other research, evaluations of historical information or data of plankton communities (phytoplankton or zooplankton or both). This assessment will address the following questions: "Will environmental conditions worsen as a result of the outfall relocation?" and if so "Is such change likely to harm whales?"

If the answer to the first question is no, then the value of additional modeling is questionable, but continued monitoring in its present form would be indicated. An evaluation of whether to modify the present monitoring program could be made as long as specific questions addressable by a monitoring program can be defined relative to the endangered species. If the evidence addressing the first question indicates that adverse impacts are likely, then an evaluation of the potential harm to the endangered species should be made to further understand potential for impact. If the answer to this question is no, then continued monitoring or conduct of additional research would be indicated. Moreover, if available information is equivocal, further research to define significant linkages must be conducted as part of basic research on the endangered species and should proceed as part of a larger effort to understand man's impact to these species.

If these assessments lead to the conclusion that impacts of relocating the outfall discharge are greater than predicted in previous reviews, and that whales are likely to be impacted by the change, development of the food web model would proceed. This effort could require substantial research into fundamental processes that control the various linkages between the nutrients, phytoplankton, prey, and whales. The steps required to complete the modeling are described in the subsequent sections of the process (Figure 2). This scope of work is developed around these various tasks. Depending on data needs, and type of modeling algorithms required, optional field or laboratory studies may be required. Examples of areas potentially requiring additional research and study are indicated in Figure 2. Specific questions that may need to be addressed are provided in the relevant tasks. Areas where data are inadequate would be subject to research proposals or Quality Assurance Plans (QAPs). The specific activities necessary to address the tasks identified in this scope of work are also subject to development of study and QAPs before any activities would be authorized.

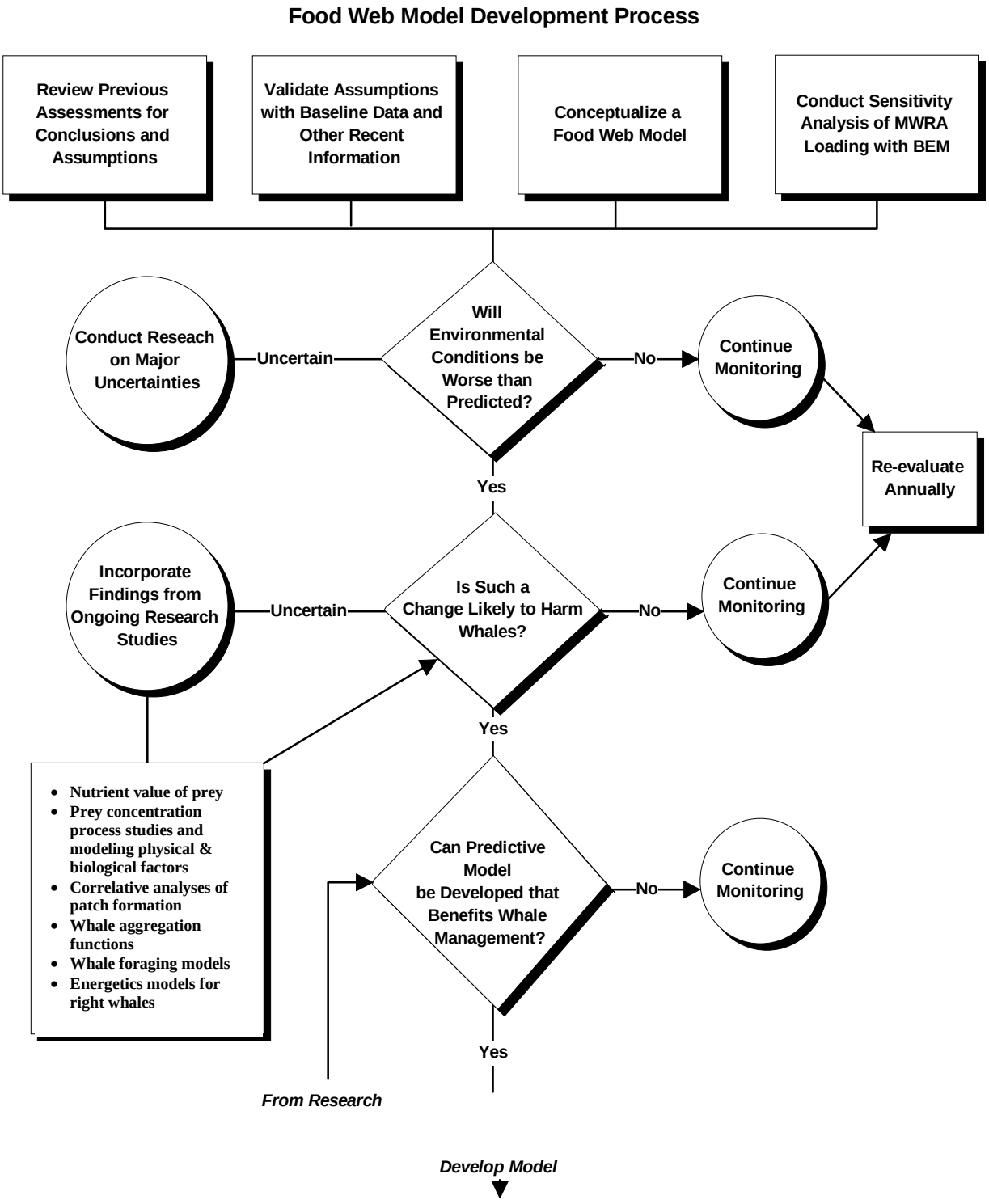

Figure 1. Food Web Model Development Process – Initial Assessments. Examples of research questions that are likely to arise during the development of the model are listed under ongoing research studies. These are not considered all inclusive as other research activities may be identified during any model development.

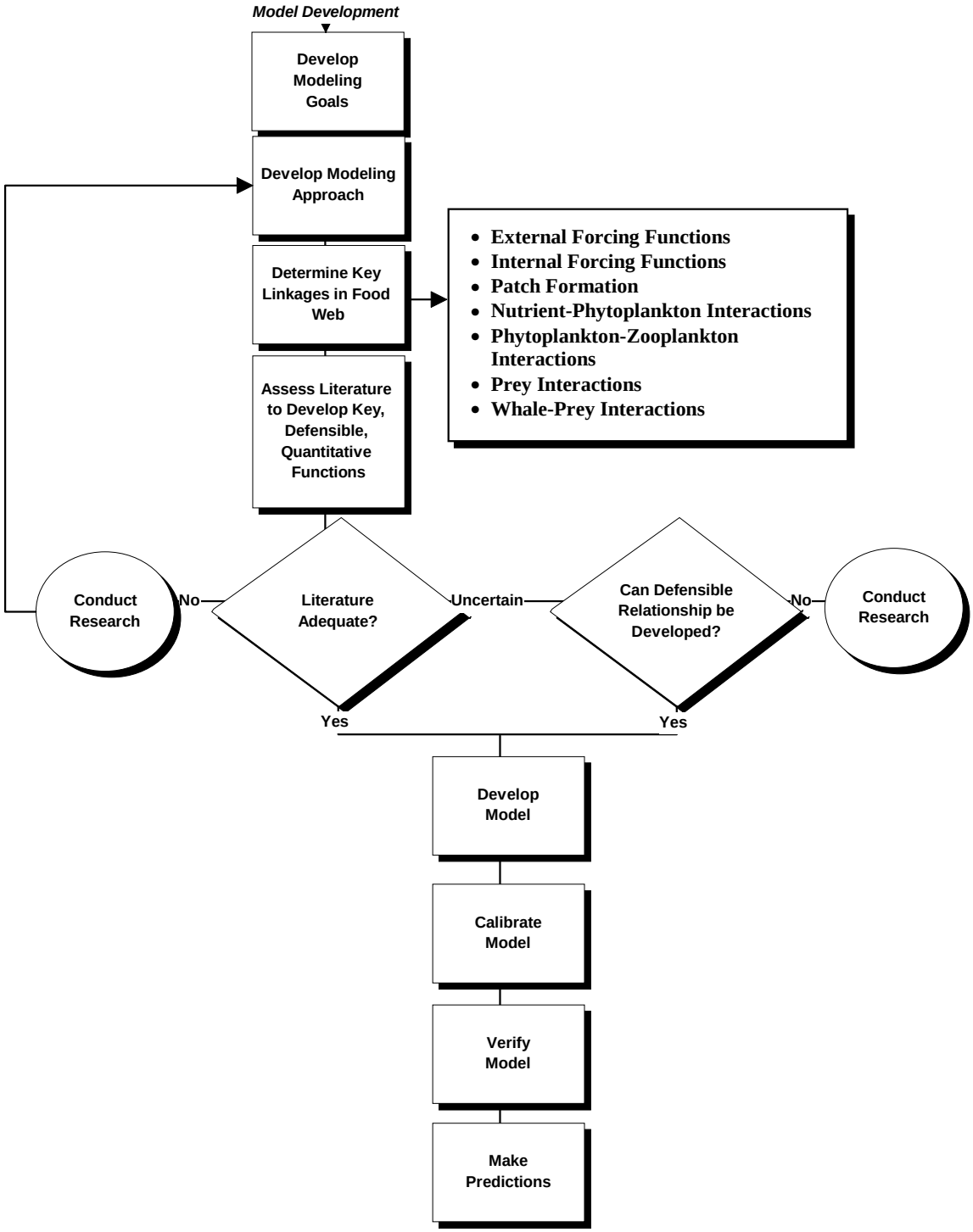

Figure 2. Food Web Model Development Process - Model Development. Examples of research areas that are likely to arise during the development of the model are listed under key linkages in the food web model. These are not necessarily all inclusive as other research activities may be identified during any model development.

Task 1: Review of Previous Assessments and New Information

Three major Federal technical reviews of the MWRA project determined that upgrading treatment and relocating the effluent discharge would have no unacceptable consequences for Massachusetts and Cape Cod Bays (EPA 1988), and not jeopardize endangered marine mammals within the Bays (EPA 1993, NMFS 1993). All of these reviews were based upon the best information available when they were prepared. However, only the earliest results of MWRA's comprehensive Baseline Monitoring Program were available when the 1993 reviews were conducted, and the Bays Eutrophication Model (HydroQual and Normandeau 1995) was in an early stage of development. Today, more than five years worth of baseline monitoring and other research are available to supplement those evaluations, along with a developed and calibrated BEM.

This task will revisit the major impact evaluations in the SEIS and in the later EPA/DMF endangered species consultation, other relevant reports (e.g., updates to the effluent plume dilution transport modeling (Signell et al. 1996); zooplankton historical perspective, etc), the MWRA conceptual endangered species food web model (Kelly et al 1998), and evaluate the results of sensitivity analyses using the BEM model to evaluate the significance of the MWRA effluent to nutrient impacts in the Bays. The information in these documents will be used to address the questions such as:

- Does the information gathered since 1993 support or weaken the findings of these documents?
- Are the uncertainties noted in these reports increased or decreased by recent findings?
- Do sufficient uncertainties remain to warrant proceeding to a model development?
- Will the effluent from the new outfall cause chemical, physical, or biological changes in the receiving waters of sufficient magnitude to adversely affect populations of endangered whales foraging seasonally in Cape Cod Bay and Stellwagen Bank, tens of miles from the new outfall?
- If population size or biomass of preferred whale food items were substantially reduced as a result of effluent from the new outfall, would right, humpback, and fin whale populations in the western North Atlantic Ocean be adversely affected, or would the whales move to other foraging areas?

The Task will be conducted as four subtasks:

Subtask 1.1: Summarize the previous impact evaluations and key assumptions
Subtask 1.2: Evaluate recent data relative to Subtask 1.1 assumptions
Identify any significant changes
Subtask 1.3: Develop a conceptual food web model
Subtask 1.4: Conduct sensitivity analysis to constrain role of outfall relative to nutrient dynamics of the Bays

The results of this Task will be presented to the OMSAP, regulators, and other interested parties for review and direction regarding the modeling effort. If the OMSAP recommends continued development of the model the following Tasks would be conducted incrementally. At any point in the process, research studies could be recommended to ensure the model is properly formulated and that predictions can be made confidently.

Task 2: Model Goals

Under this task, key questions that will be asked of the model, including hypotheses and modeling goals, will be developed. This effort will occur in conjunction with the OMSAP, regulators, and other interested parties to ensure the purpose and goals of the model are clearly articulated and understood. In the event that model development is pursued, MWRA and the authors strongly recommend that OMSAP or the

regulators or both establish a Model Evaluation Group (MEG), perhaps as a subcommittee of the OMSAP itself. This committee would be made up of experts in the fields of numerical and ecological modeling, to assist OMSAP in its task of overseeing and guiding MWRA's implementation of the scope of work. Since developing a model that meets the requirements in the draft NPDES permit would at least stretch and might well exceed the current state of the science of numerical and ecological modeling in the marine environment, such a MEG would likely require expertise from outside the Massachusetts Bay region.

Task 3: Modeling Approach

Under this task, the type of model and approach that will be used to meet the goals developed under Task 2 will be prepared. Two subtasks are required and will address questions such as: "Can the model framework selected be populated given the existing state of knowledge? If not, what outstanding questions remain to be addressed? What research would be required to address these questions? What are the appropriate funding mechanisms for the research? What time frame is required to complete the research?

Also under this task, it should be determined, based on a careful review of the literature and the available data, whether a single model or a series of phased models should be developed to address the needs and concerns of the environmental community and regulators with respect to the potential effects of nutrient loading and transport on the right whale food chain. For example, one approach would be to implement the food web modeling framework proposed by Kelly et al. (1998). A second approach might be to follow a phased approach in developing the food web model. A first step using this approach might be to expand the BEM to include two functional zooplankton groups, calanoid copepods (Calanus and Pseudocalanus) and non-calanoid copepods (Acartia, Oithona, etc.). If a successful model of these two functional zooplankton groups can be developed, it could be used to determine whether outfall relocation would have an impact on zooplankton biomass and community structure. If no impact is observed then no additional food web model development need be performed. If on the other hand, the model computes significant changes in zooplankton biomass or community structure, then the next phase in the food web model development would be required. A phased approach would enable researchers to build a food web model from the "ground up". A "ground up" approach would enable the construction and calibration of a food web model using the parts of the ecosystem which are best understood and for which sufficient data are available for model calibration. At the end of each phase an evaluation could be made, using model outputs, whether the model computations suggest that additional development of the food web is required. A phased approach would also permit researchers to conduct appropriate field monitoring or laboratory experiments or both as necessary to better understand food web dynamics and to provide information with respect to the various rates and transfer coefficients required to calibrate a detailed food web model. To conduct this work two subtask will be implemented.

Subtask 3.1: Review of modeling literature

An exhaustive review of the published literature on ecological and food web modeling will be conducted. This review will address questions such as: What extant modeling approaches show the most promise in addressing the model goals and requirements? If developed for non-marine systems, can they be adapted to the marine environment and to New England waters?

Subtask 3.2: Determination of key links in food web.

The key linkages require to develop the model will be assessed under this subtask. The linkages will be based on the conceptual model of Kelly et al. (1998), but will add specificity relative to phytoplankton, zooplankton (either species or species groups), prey species and prey interactions, and physical and biological forcing functions. Boundary conditions and other major forcing functions will be identified under this task.

The present monitoring program and data will be evaluated for data relevancy. Recommendations for additions or modifications to the monitoring program may be made to ensure the data appropriate to the models goals and approach are collected.

The Task will result in a recommended modeling approach for approval by the OMSAP or other oversight group (e.g., MEG), as appropriate.

Task 4: Literature Assessment of Key Functional Relationships

This task will review the available literature on food web modeling to identify the key formulations required to link the relevant food web compartments identified under subtask 3.2 or from the research topics (e.g., nutrients to phytoplankton species composition and abundance; phytoplankton-zooplankton , linkages, patch formation and dynamics, prey interactions, prey biomass and distribution, etc.). The information developed under this subtask will be used to recommend whether information in the literature is adequate to develop appropriate mathematical expressions of the linkages or whether defensible algorithms can be developed in lieu of clear functional relationships. If such linkages can not be made with confidence, then additional studies that will enable the linkages to be defined could be recommended. An evaluation of the confidence that can be placed in the model predictions will also be developed under this subtask.

Key questions that must be addressed include:

- How do physical, chemical, and biological factors interact to control the species composition and primary production of phytoplankton communities?
- What physical or chemical parameters in the effluent or receiving waters are most likely to cause changes in phytoplankton community structure and production?
- What are the causes of blooms of desirable (e.g., diatoms) and nuisance (e.g., *Phaeocystis, Alexandrium*) phytoplankton and nanoplankton?
- What physical, chemical, and biological factors control distribution and production of desirable (as food for right whales) zooplankton (primarily the copepods *Calanus finmarchicus* and *Pseudocalanus* spp.)?

  How does phytoplankton community structure affect composition and production of zooplankton communities in the bays? Does this relationship vary seasonally? Does this relationship vary yearly?
- Does the presence of nuisance/toxic phytoplankton adversely affect the abundance and production of desirable zooplankton species? Are there different effects on desirable and less desirable zooplankton species?
- What is the role of predation in controlling the production and population size of desirable zooplankton in the bays? What are the effects of short- and long-term changes in predator (e.g., sand lance, herring, mackerel) abundance on zooplankton production?
- What are the factors that control or cause the formation of dense patches or aggregates of calanoid copepods upon which right whales selectively feed?

An evaluation of present monitoring data will be included and recommendations for inclusion or modification of the outfall monitoring program made to ensure the appropriate data are collected.

The results and recommendations will be conveyed to the OMSAP, regulators, and other interested parties for review and direction.

Task 5: Model Formulation and Construction

The actual model (or models if, as a result of Task 2, a phased sequential modeling approach is determined to be the preferred approach) will be developed under this Task. Formulation and construction of the model(s) require two major steps.

Subtask 5.1: Theoretical Construct

The first step in this process is to develop a theoretical construct. This step requires the development of a series of differential equations (or energy flow diagrams) which describe the various state-variables incorporated in the model and their coupling to one another and to environmental forcings (e.g., lights, tides, winds, etc.). Once developed, these differential equations must be coded into the appropriate modeling language (e.g., FORTRAN for the BEM or STELLA for a non-spatially detailed food web model similar to Kelly et al. (1998).

Two key model inputs to be evaluated under this subtask are the specification of model boundary conditions and predation pressures at various levels of the food web. Based on an analysis of BEM computations it was found that the import of nutrients from the Gulf of Maine was the major source of nutrients to the Massachusetts Bays system. This boundary may also be important source of zooplankton and predator fish species to the Bays ecosystem. If planktivore and pecivore species are not directly modeled as state-variables in the food web model sufficient data will be required to specify their seasonal and yearly variability, since they may be an important exogenous or forcing function of the model.

Subtask 5.2: Numerical Specification

The next step in this process is the numerical specification of the model coefficients, rates and inputs. This latter step is equally as important and difficult as the specification of the model's mathematical basis. Once these three steps are completed a series of numerical checks will be performed to ensure that the model is properly coded and debugged. The product will be a fully debugged functional food web model.

The MEG, OMSAP, regulators, and other interested parties would review the model as part of this task. OMSAP and MEG review of the model is key to the successful development and acceptance of the model. First, it provides an early "peer review" of the model framework to ensure that the model has been constructed properly and meets the needs of the project. It also provides an opportunity to review model coefficients, rates and inputs to ensure that they are reasonable, given the available literature and field and laboratory studies. Secondly, it provides model credibility when presented to regulators and the concerned public.

Task 6: Model calibration

Calibration runs against known data sets will be performed under this Task. One aim of the calibration effort is to achieve a reasonable calibration of the observed data, using a consistent and rational set of theoretically defensible coefficients, rates and inputs. Data appropriate to the calibration runs will include the MWRA outfall monitoring program and other available data. Specific data requirements for the model calibrations will be developed under the Task 3 and 4. Implementation of the data gathering efforts or modifications to the present outfall monitoring program will be reviewed with the OMSAP, regulators, and other interested parties.

Task 7: Model Verification

Additional model evaluations using additional field data should be performed using the calibrated model(s). Preferably these data should encompass different external conditions or forcings or both. This analysis would provide additional verification of the model(s). To the extent possible, changes in model coefficients, rates and inputs (except for justified exogenous inputs such as loadings, boundary inputs, sunlight, wind, etc.) should be minimized between the calibration and the verification. Models that have

widely varying coefficients to merely "fit" the observed data should not be considered calibrated and validated and would have limited predictive powers.

Task 8: Model Projections

The calibrated model(s) can then be used to make projections of water quality and environmental response to system perturbations. Ultimately the goal of this effort is to determine the impacts of nutrient inputs and outfall relocation on the seasonal abundance of important prey species for right whales. Model projections should be judged relative to some baseline condition (e.g. computations determined from the calibration period or some pre-determined baseline water quality year for which the calibrated model was exercised) and should not be considered absolute predictions of future ecosystem response. Since only a small portion of the domain of the right whale would be modeled and since their growth and survival are dependent on other factors outside of the Massachusetts Bay ecosystem, the model projections would be limited to changes in right whale prey biomass and species composition.

Task 9: Reports

This task includes preparation of reports that describe the modeling activities. Draft and final summary reports will be prepared upon completion of each task. In addition, a draft and final report describing the model development, calibration, verification, and predictions will be prepared.

One report from this task has been prepared by MWRA (Kelly et al. 1998, at http://www.mwra.state.ma.us/harbor/enquad/pdf/98-04_enquad_report.pdf). This report partly addresses the reporting requirements from the first task and develops a conceptual food web model for the right whale prey in Massachusetts Bay. The major pathways and linkages in the food web were identified. The report contains as attachments the comments of one expert reviewer on the efficacy of the conceptual model and requirement to develop a model, and clarifications from EPA on the intent of the draft permit language. This conceptual model was presented and discussed by the OMTF on April 29, 1998.

Task 10: Research Topics

This task captures areas that may require conduct of additional research before the model development can be completed. Specific research topics and activities (field or laboratory, or both) that would be required to develop data to support the modeling effort would be defined under the preceding tasks. Activities conducted under this task would be identified during the implementation of the modeling scope of work. For each area, a specific research question must be identified and clearly articulated. Research (laboratory and field) proposals would then be requested and evaluated. Depending on data needs, specific research efforts could require several years to complete. Depending on the magnitude and focus of the questions, funding by federal and state agencies may be more appropriate that MWRA monitoring funds. For examples, studies of the following type may be required to complete the food web model:

- Nutrient-Phytoplankton Interactions
- Phytoplankton-Zooplankton Interactions
- Predator-Prey Interactions (Whale and other prey)
- Nutrient value of prey
- Patch Formation factors
- Prey concentration process studies and modeling physical & biological factors
- Correlative analyses of patch formation
- Whale aggregation functions
- Whale foraging models
- Energetics research and models for right whales
- External Forcing Functions
- Internal Forcing Functions

SCHEDULE

To develop this scope of work, MWRA has assembled a team of experts in the fields involved. However, these experts, including the authors, find it difficult to suggest a realistic timeline for model development, given the many uncertainties and open scientific questions that might require major, multi-year research efforts. It is instructive, however, to note the 2.5 year development time required for the Bays Eutrophication Model (HydroQual and Normandeau 1995) as an illustrative example. This state of the science model was developed with the close interaction of and input from a Model Evaluation Group, and so that development process itself forms a model of the process suggested for the development of the FWM.

However, even that 2.5 year process can not provide a confident estimate of the time that might be required for FWM development. The BEM represents an adaptation to the Massachusetts Bays system of a eutrophication model already successfully developed for the Chesapeake Bay system and further developed for Long Island Sound. Therefore, BEM development began with the equivalent of Tasks 2 and 3 complete, and with substantial portions of Tasks 4 and 5 already completed. As noted above, the authors are unaware of any extant FWM that could be adapted to the Massachusetts Bay ecosystem, so FWM development, if required, would start with Task 2.

The schedule of milestones and deliverables for Task 1 are indicated below.

Task 1: Review of Previous Assessments and New Information.

Most of the review tasks and sensitivity analyses detailed under this scope of work (Task 1) have already been carried out, at least in a preliminary way. The timeline below shows some of the milestones in this process. If full execution of Task 1 were to be required by OMSAP or regulators, a synthesis report containing completed Task 1 reviews could be prepared by Spring 1999.

Milestone	Due Date
Review of previous assessment	November and December 1998
Update prior assumptions in assessments	November and December 1998
Perform BEM sensitivity analysis	December 1998
Conceptualization of food web model	Complete (Kelly et al. 1998)
Presentation to OMSAP	December 18, 1998
Summary report for Task 1	MWRA Nutrients Issues Review (August 1999)

Tasks 2 through 10

The schedules for the Tasks 2 through 10 would be developed as part of the Task specific Quality Assurance Plan development.

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Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Boston, MA 02129
(617) 242-6000