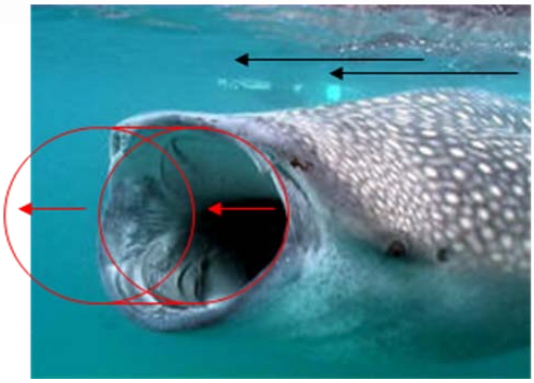
System-Wide Water SWWRP Resources Program

Coupling Eutrophication and Fisheries Bioenergetics Models



Volume = f(speed, mouth area)

Description: Corps of Engineers Integrated Compartment Water Quality Model (CE-QUAL-ICM or simply ICM) is a finite-volume water quality model which has seen wide application to rivers, lakes, and estuaries. ICM models the aquatic carbon, nitrogen, phosphorus, and oxygen cycles and is commonly used in studies aimed at controlling eutrophication. Phytoplankton are universally included in ICM applications because of their recognized role in the eutrophication process. Recently, attention has focused on higher-trophic-level organisms which consume phytoplankton. Studies have been conducted aimed at examining the role of these organisms in limiting phytoplankton concentrations. These studies consider the possibility that enhancement of populations of planktivores may augment controls on nutrient discharges to receiving waters. Multiple approaches to coupling higher-trophic levels into ICM have been taken. Bivalve filter feeders have been installed directly in ICM (Cerco and Noel 2007) and ICM has been linked to the ECOPATH network model (Cerco et al. 2010). Most recently, ICM has been coupled to a fisheries bioenergetics model (Dalyander and Cerco 2010).

Application: Atlantic menhaden (*Brevoortia tyrannus*) is a small, highly-exploited, planktivorous fish that is abundant in Chesapeake Bay. Stakeholders have speculated about the importance of menhaden in consuming phytoplankton in the Bay and whether excessive phytoplankton concentrations might be reduced by enhancing menhaden population. These questions were explored by coupling the ICM eutrophication model with a fisheries bioenergetics model. Fish are modeled as discrete “super individuals” which represent schools moving through the model computational grid. Movement is determined through a combination of known migration patterns and random movement. The bioenergetics model allows for fish growth to be quantified based on food intake and energy losses to life processes such as respiration. Fish biomass and nutrient accumulation/ recycling are explicitly accounted for, allowing for a realistic estimate of the impact of fish on the water column. Initial model runs have qualitatively replicated observed effects on water quality, including significant algal consumption, oxygen depletion, and ammonium excretion.

Benefits: Management of eutrophication in inland and coastal waters is an issue of national importance. Eutrophication control is commonly addressed through reduction of external nutrient loads with the intention of limiting excess phytoplankton production and associated effects (low dissolved oxygen, reduced water clarity, species shifts). Guidance for nutrient control programs is frequently obtained from eutrophication models such as CE-QUAL-ICM. Management of fisheries is likewise a national concern. Fisheries are commonly managed through controls on harvests with guidance

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potentially provided by an appropriate model. Management of eutrophication and of fisheries cannot be entirely separated, however. Management of both must be considered in order to answer questions such as:

- How does nutrient management in a watershed affect fisheries harvest in adjacent water bodies?
- How does fisheries management affect eutrophication effects such as low dissolved oxygen?

The coupling of ICM with a bioenergetics model provides a rigorous, defensible mechanism to address environmental issues in which both eutrophication and fisheries are a concern.

Data Requirements: The data requirements for application of the fisheries model are extensive. Initially, a eutrophication model of the system must be created which requires the observations necessary to create hydrodynamic and water quality models of the system. For fish bioenergetics, the major data requirements are information on fish population, migration patterns, and age structure. Site-specific information on fish bioenergetics is desirable but this information can be obtained from published tables in the absence of site-specific data.

Future Capabilities: The menhaden bioenergetics model is presently being incorporated into the latest 50,000-cell Chesapeake Bay model. The existing model will be used to examine management scenarios that couple menhaden enhancement with nutrient controls in the bay watershed. These scenarios will contribute to the formulation of a Total Maximum Daily Load (TMDL) for the estuary. At the same time, the model is being modified to incorporate menhaden behavior. Menhaden motion will be determined by the availability of prey and to avoid undesirable conditions. A long-term goal is to combine the bioenergetics model with one of the Corps agent-based fish models such as the Numerical Fish Surrogate (NFS).

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References:

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