Ferreira, Joao G. 2016. Application of the EcoWin model to shellfish culture in South Puget Sound. Prepared for Pacific Shellfish Institute, Olympia, WA by Longline Environment Ltd. 3 p.

Introduction and Discussion

The implementation of EcoWin (see e.g. Ferreira et al., 2008; Nobre et al., 2010; Nunes et al., 2011; Ferreira et al., 2014, for application in various parts of the world) involves a set of stages, which include (i) adaptation and if necessary development of biogeochemical and physiological process equations; (ii) spatial definition of the modeling domain; and (iii) coupling to hydrological and hydrodynamic models.

The first stage led to the implementation of computer code to simulate the growth and environmental effects of the key shellfish species cultivated in Puget Sound. The various individual models were successfully developed as AquaShell models, tested in WinShell, and implemented in EcoWin. The same functions, for geoduck, Manila clam, Pacific oysters, and Mediterranean mussels, were implemented in the local-scale FARM model (see elsewhere in this report). Whereas FARM does not support multiple shellfish species in combination (although it supports multiple trophic levels in IMTA), EcoWin does.

A specific 'object' (see Ferreira, 1995 for the core EcoWin concept paper) was developed to allow seeding and harvesting of several shellfish species, taking advantage of the multiple inheritance property of C++.

The second stage requires multiple datasets and a substantial level of analysis and stakeholder consultation. This is required for definition of both the spatial boundaries and the internal divisions. A typical EcoWin spatial framework uses two vertical layers and a set of boxes defined according to the criteria shown in **Table 1**.

Table 1 – Methodology for definition of a spatial framework in EcoWin

Criterion	Observations and examples
Bathymetry	Separation of deep channels from shallower areas, separation of areas with clearly different hydrodynamics, etc
Water quality	Salinity gradients, nutrient dynamics, food availability (phytoplankton, detrital organics) for shellfish, hypoxia hotspots, etc
Aquaculture	Distinction of areas used for different types of aquaculture, separation of farms where possible
Administrative	Inclusion of county line and other administrative divisions, to enable the model to address management units
Hydrodynamics	Subsequent analysis of a first-stage box division to flag model boxes that may be too small for accurate simulation of circulation at the time-step required (typically 15-120 minutes) to allow decadal scale modeling of commercially relevant shellfish populations.

An exhaustive multi-criteria analysis using Geographic Information Systems (ArcGIS) was performed, draft proposals were discussed with stakeholders (8 from industry, including Taylor Shellfish, Dept. Ecology, and PSI itself) and a subsequent final division was made.

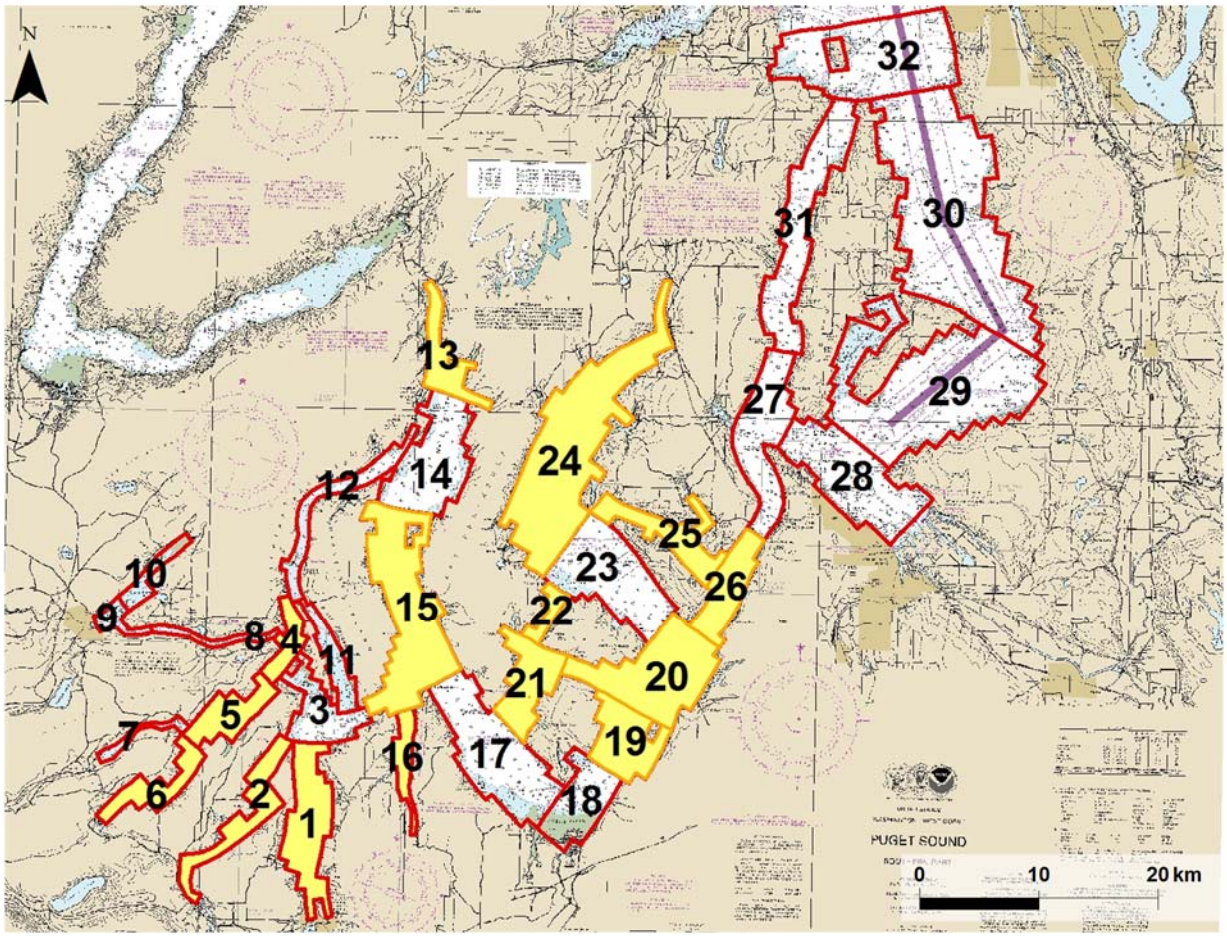

Figure 1. Summary of stakeholder proposals for the EcoWin.NET model boxes. In yellow are the boxes where boundary changes were implemented.

The output of this intermediate stage of analysis is shown in **Figure 1**. An analysis of potential numerical instabilities of this spatial framework was then executed. We concluded in Vazquez, et al (2014) that: "After the numerical analysis the shallower boxes where identified (shown in red) These boxes could pose a problem but **Error! Reference source not found.** indicates that the residence time is higher than the timestep normally used to run the EcoWin ecological model. On that basis we propose 38 horizontal boxes for South Puget Sound, with a two vertical layer scheme for a total of 76 boxes."

EcoWin typically relies on other models to deal with both the hydrology and hydrodynamics. These models are run for the system to be simulated, and the exchanges of water and (where appropriate) other variables are provided to the ecosystem model. For catchment hydrology and nutrient loading, models such as SWAT (Soil and Water Assessment Tool – Texas A&M) are typically applied (see Ferreira et al. 2008, Nobre et al. 2010), but in PESCA only the hydrodynamic component was considered.

The third stage of model implementation required that Stage 2 supply the hydrodynamic modelers with the appropriate GIS files. These are then used to aggregate the outputs of a finer-scale circulation model in time and space. Those outputs, appropriately upscaled and verified for consistency, in particular with

respect to mass conservation, are then supplied to the ecosystem modelers. This proved to be a challenge for the current effort (**Attachment A**), so the full implementation of EcoWin for SPS is dependent on the completion of this final stage.

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