ONLINE SUPPLEMENT 16.8

LOOP ANALYSIS – GULF MENHADEN (*BREVOORTIA PATRONUS*) EXAMPLE

The simplest stable system in loop analysis is a single node with a self-loop. For example, a microbial colony maintained in a Petri dish. The negative self-loop then represents the care that a microbiologist administers to that colony. In addition to a species, a node in a signed digraph may represent an interactive system of cells, tissues, or organs at a given level of biological organization. In an explicit stream context, a signed digraph may include riparian, upland, fluvial and hyporheic sub-systems, each represented by a node with explicit links describing exchanges among them. Likewise, a node can be decomposed into constituent pieces at lower levels of organization. Below, we present an example using management of the Gulf Menhaden (*Brevoortia patronus*) as an empirical case study.

Donald Baltz from Louisiana State University is interested in the effects of commercial fishing on different Menhaden age-classes. In particular, he wants to know if fishing imposes age-class suppression and/or competitive release among age-classes. These interactions are important because they may influence fishable stocks in the future. Currently, Donald has at his disposal the following information: (1) the average Menhaden lifespan is ~4 years; (2) the Menhaden reaches sexual maturity and begins reproduction at 2 years of age; and (3) all age-classes are subjected to fishing pressure because harvested fishes are indiscriminately ground into meal for resale.

Clearly, a signed digraph with a single Menhaden node does not provide much insight. So Donald contacts Jeffrey Dambacher of the Commonwealth Scientific and Industrial Research Organisation (CSIRO, Australia), seeking advice on how to incorporate multiple age-classes in a loop analysis model. Together, they create a basic age-class model with distinct nodes and connections between five life stages: the egg stage and ages 1–4 (Figure S16.8A). In this model, three specific points should be noted. First, each successive life stage receives positive input from the prior stage. Second, returns to the egg stage from age-classes 2, 3, and 4 are all positive (and age-class 1 is sexually immature). Third, each life stage has a negative self-loop; the selfloops account for the fact that unidentified ecological forces (e.g., self-thinning within resource limited populations) impose limits on the abundances of each life stage.

Modifications can now be made to the basic five-compartment model (Figure S16.8A), simulating 'thought experiments' of increasing complexity and biological realism. The models shown in Figures S16.8B and C now incorporate the effect of a new predator – Menhaden fisheries – with differing levels of selectivity. In Figure S16.8B, we see a model of selective predation on Age-4 fishes. In Figure S16.8C, we see a model of indiscriminate predation (i.e., harvest).

In a fourth model (Figure S16.8D), we have removed the predator node and added new nodes for plankton and zooplankton. This model depicts competition for zooplankton among Age-2, Age-3, and Age-4 Menhaden. However, Age-1 fishes partition the resource by feeding on smaller planktonic species. Note that all Menhaden age-classes have negative effects upon their prey, while plankton and zooplankton have positive effects on their predators (i.e., classic predator-prey dynamic).

What then is the next step? We run the loop analysis models to explore the potential effects of different harvest regulations and predation scenarios. To do so, we may use one of several free software applications, including the R package 'LoopAnalyst' (https://cran.r-project.org/web/packages/LoopAnalyst/index.html) or Mark Novak's (Oregon State University) Mathematica code (http://people.oregonstate.edu/~novakm/2012/11/27/loop-analysis-in-mathematica/). Alternatively, we may use the online model building tool, with its intuitive symbols palette and graphic user interface, posted on the 'Loop Group' website at Oregon State University (www.ipmnet.org). This particular tool will determine whether a system-level model is stable and if not, it will help the investigator to understand why. If the system is stable, the graphical output will determine which nodes are likely to increase or decrease over time, pursuant to 'experimental' conditions that the investigator imposes. Numerical results are also presented in matrix format. (The Loop Group website also includes a primer with demonstrations, a library of published food-webs that can be modeled and a list of related publications for further reading.) In the end, loop analysis has great heuristic value and can help to identify system components that warrant closer examination via experimental manipulations.

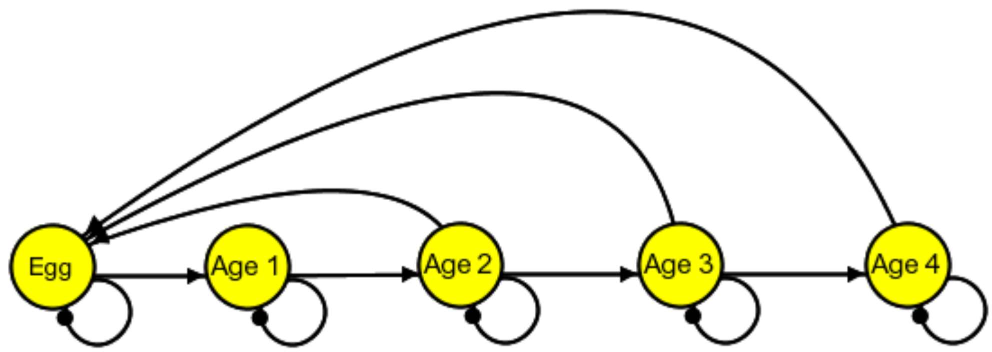

Figure S16.8A A basic, five-node model (signed digraph) of Gulf Menhaden life stages. Positive interactions are shown as directed arrows (→) while negative interactions are shown as black circles (⊸●).

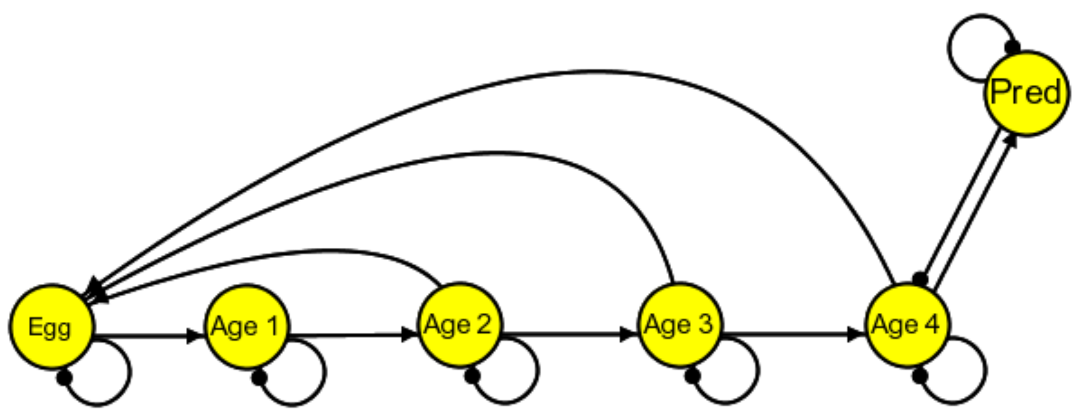

Figure S16.8B A Gulf Menhaden model that includes selective predation (i.e., fish harvest) on Age-4 fishes. Symbols are as shown in Figure S16.8A (positive interactions →; negative interactions ⊸●).

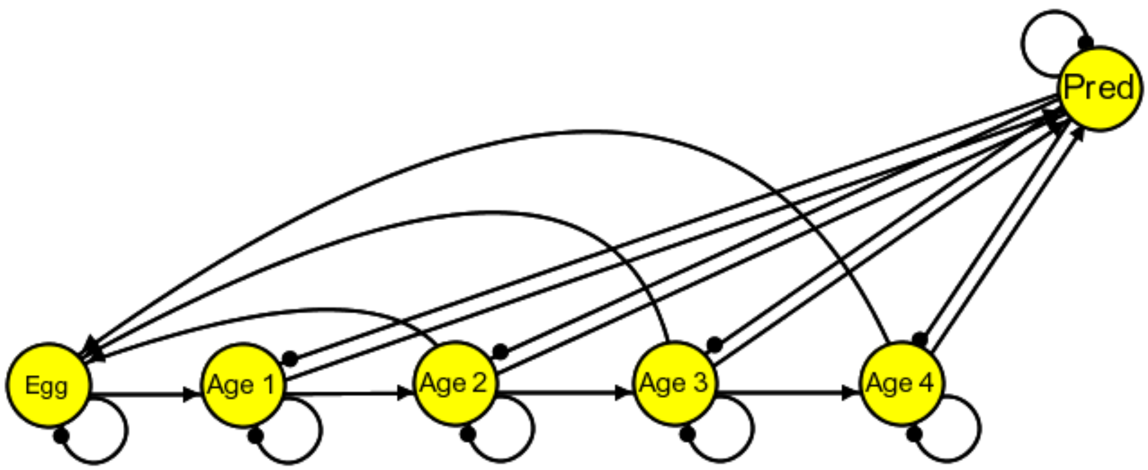

Figure S16.8C A Gulf Menhaden model that includes indiscrimiate predation (i.e., fish harvest) on all free-swimming age-classes. Symbols are as shown in Figure S16.8A (positive interactions →; negative interactions ━●).

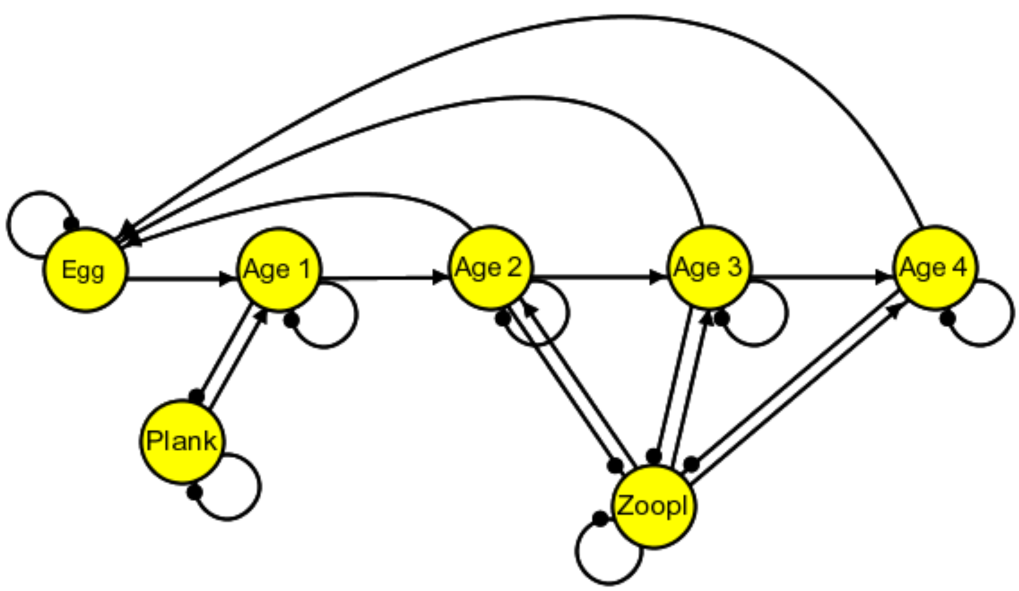

Figure S16.8D A Gulf Menhaden model of intra-specific (Ages 2–4) competition for zooplankton ('Zoopl') and Age-1 predation on plankton ('Plank'). Symbols are as shown in Figure S16.8A (positive interactions →; negative interactions ━●).