Salmon Escapement Goals: Models, Development and Applications

Fishery Models and Applications

Introduction

The purpose of this short paper is to discuss the conditions under which fishery-related models can be applied. Fishery models, if used appropriately, can be used to solve specific problems, but not all fishery management issues require a model. It is therefore necessary to have an idea and necessary application controls before any model can solve a fishery management question. Technical knowledge and appropriate application of fishery models are presented and discussed to give the reader a better understanding concerning the development and utility of models.

The development of escapement goals, as required by Federal law, must utilize the best available science to achieve Maximum Sustained Yield (MSY) or Optimum Yield (OY). These yields, or harvests, secure food supplies and food security for the nation, not just Alaska, while creating and benefiting the national economy. Alaska has a sustainable fishery policy that can be defined as food harvests, as well as social or economic wants, which are often defined as a parochial want.

Federal law mandates require stakeholder and public input opportunities throughout the entire Salmon Fishery Management Plan (SFMP) development process. However, the current State escapement goal process entirely precludes any stakeholder or public process.

Models

An ecosystem (fishery) model is an abstract, usually a mathematical representation of an ecological system (ranging in scale from an individual, population, community, or even an entire biome), which is studied to better understand the real system.

Using data gathered from the field, ecological relationships, such as the relation of spawners to rates of yield, or that between predator and prey populations—are derived, and these are mathematically combined to form fishery models. These model systems are then studied in order to make predictions about the dynamics of the real system. Often, the study of the inaccuracies in models (when compared to empirical observations) will lead to the generation of hypotheses about possible fishery relations that are not yet known or well understood.

Models enable researchers to simulate large-scale experiments that would be too costly or unethical to perform on a real ecosystem. They also enable the simulation of fishery management measures over very long periods of time (i.e. simulating a process that takes centuries in reality, can be done in a matter of minutes in a computer model).

Fishery management models are mathematical representations of ecosystems. Typically, they simplify complex food webs down to their major components or trophic levels and quantify these as either numbers of organisms or biomass. Sustainable Ecosystem (fishery) Management Modeling can assist in the implementation of sustainable developments. Systems analysis that describe how fishery resources can support the sustainable management of natural capital and resources is an increasingly used term for a guide for future development. Sustainability can be considered in terms of three aspects: environmental, economic and social domains.

Modelers Should be Conscious of the Following

1. Modelers and the models they create, or use, are observer-defined abstractions that may or may not reflect reality, but only in the framework of the observers viewpoint. Some models created can leave the arena of science and enter the realm of beliefs.
   Example #1: A belief that overescapement does not occur
   Example #2: Overharvesting and underharvesting beliefs
   Example #3: Every model has errors and estimates of realities

2. There is an optimal degree of model complexity as models become complex and difficult to manage. There is often an increased level of uncertainty. Model complexity increases as variables are added, therefore the level of predictable accuracy declines.

3. Fishery model(s) outputs comprise specific uncertainties. To overcome uncertainties, extensive information is required, collected or generated using Bayesian Methodologies in order to address a precise question or hypothesis.
   Example: Do Bayesian techniques add data that never existed in the real world?

4. Fishery-related models require a clear and precise specification of the focus of the outcomes of the effort. Models must have a clear purpose and outcome prior to constructing any fishery management-related models.

5. Fishery models need intellectually chosen criteria, data inputs and data outcomes with clear distinctions of important and unimportant components. What is relevant to the outcome and what is ‘white noise’ or irrelevant information.
   Example: The use of aerial surveys compared to weir counts.

6. Fishery models can be developed, if necessary or advisable, at individual, population, ecosystem, landscape or biome levels. What is the appropriate level at which any fishery model is to be developed?

7. Fishery management models can illustrate interactive and feedback processes. These are often referred to as density-dependent issues.

8. Fishery models can and may support the decision-making process. Models such as spawner-recruit relationships, number of spawners needed to achieve Maximum Sustained Yield (MSY) or Optimum Yield (OY).

There Are Major Limitations on What Fishery Models Can Do

1. Fishery modeling is not a new form or alchemy. You cannot put in data concerning cohos, pinks, chums along with your hopes and beliefs and expect that the computer model will do magic and produce Chinooks and sockeyes. Thus, the old saying 'garbage in - garbage out' principle holds, regardless of the strength in any belief system.
   Example: This often comes into fishery management discussions by one or more participants saying: 'More fish beget more fish' or 'I don't believe in underharvests, overescapement or surplus escapement.' It is not a matter of belief, but rather a scientific inquiry when constructing fishery management models.

2. Fishery management models cannot function in a vacuum without an appropriate, underlying theoretical framework or problem statement.
   Example: One does not build a fishery management model and then look for an application.

3. Fishery management models cannot function without an empirical database used for development and model testing. Models that rely heavily of Bayesian methodologies are always suspect.
   Example: Especially when Bayesian methodologies use randomly generated data to describe non-random consequences.

4. Fishery management models must be treated skeptically. When they are applied outside of the pre-established validation parameters, most models are developed to show potential future events. However, we can never fully know the current and future forcing functions (rate of climate changes, ocean acidification, ocean thermal refugia and optimal ranges) are having on any model variable (data set) until these have occurred.
   Example #1: In a retrospective look in the rear-view mirror, we often try to retrospectively adjust fishery management models to fit the present-day conditions.

5. Fishery management models rarely produce reliable prognoses that can be used with caution in discussion of future scenarios. Models should not be used for a specific

prognosis. Models are useful in organizing applied outcomes; however, we need to realize that a model's output may never be realized.
Example: No current model for the Kenai River Late-Run Sockeye Salmon predicted or foresaw that within the past 6-7 years, these fish would be, on average, one or more pounds less in weight at the same age. See Issues Paper by UCIDA. That is partly understandable because all current models do not include forcing function of climate change. In this case, the fishery management models are based on data sets that are incomplete or inaccurate.

Bibliography

Numerous articles, books and other documents were reviewed in the writing of this paper. These include:

Box, G. E. P. (1976), "Science and statistics" (PDF), Journal of the American Statistical Association, 71 (356): 791–799, doi:10.1080/01621459.1976.10480949.
Box, G. E. P. (1979), "Robustness in the strategy of scientific model building", in Launer, R. L.; Wilkinson, G. N. (eds.), Robustness in Statistics, Academic Press, pp. 201–236, doi:10.1016/B978-0-12-438150-6.50018-2, ISBN 9781483263366.
Box, G. E. P.; Draper, N. R. (1987), Empirical Model-Building and Response Surfaces, John Wiley & Sons.
Box, G. E. P.; Draper, N. R. (2007), Response Surfaces, Mixtures, and Ridge Analyses, John Wiley & Sons.
Box, G. E. P.; Luceño, A.; del Carmen Paniagua-Quiñones, M. (2009), Statistical Control By Monitoring and Adjustment, John Wiley & Sons.
McCullagh, P.; Nelder, J. A. (1983), Generalized Linear Models, Chapman & Hall, §1.1.4.
McCullagh, P.; Nelder, J. A. (1989), Generalized Linear Models (second ed.), Chapman & Hall, §1.1.4.
Cox, D. R. (1995), "Comment on "Model uncertainty, data mining and statistical inference"", Journal of the Royal Statistical Society, Series A, 158: 455–456.
Steele, J. M., "Models: Masterpieces and Lame Excuses".
Gelman, A. (12 June 2008), "Some thoughts on the saying, "All models are wrong, but some are useful"".
Fasham, M. J. R.; Ducklow, H. W.; McKelvie, S. M. (1990). "A nitrogen-based model of plankton dynamics in the oceanic mixed layer". Journal of Marine Research. 48 (3): 591–639. doi:10.1357/002224090784984678.
Hall, Charles A.S. & Day, John W. (1990). Ecosystem Modeling in Theory and Practice: An Introduction with Case Histories. University Press of Colorado. pp. 7–8. ISBN 978-0-87081-216-3.

Dale, Virginia H. (2003). "Opportunities for Using Ecological Models for Resource Management". Ecological Modeling for Resource Management. pp. 3–19. doi:10.1007/0-387-21563-8_1. ISBN 978-0-387-95493-6.
Forbes, Valery E. (2009). "The Role of Ecological Modeling in Risk Assessments Seen From an Academic's Point of View". In Thorbek, Pernille (ed.). Ecological Models for Regulatory Risk Assessments of Pesticides: Developing a Strategy for the Future. CRC Press. p. 89. ISBN 978-1-4398-0511-4.
Millspaugh, Joshua J.; et al. (2008). "General Principles for Developing Landscape Models for Wildlife Conservation". Models for planning wildlife conservation in large landscapes. Academic Press. p. 1. ISBN 978-0-12-373631-4.
Jørgensen, Sven Erik (1996). Handbook of environmental and ecological modeling. CRC Press. pp. 403–404. ISBN 978-1-56670-202-7.
Grant, William Edward & Swannack, Todd M. (2008). Ecological modeling: a common-sense approach to theory and practice. John Wiley & Sons. p. 74. ISBN 978-1-4051-6168-8.
Odum, H.T. (1971). Environment, Power, and Society. Wiley-Interscience New York, N.Y.
Reuter, Hauke; et al. (2011). "How Valid Are Model Results? Assumptions, Validity Range and Documentation". In Jopp, Fred; et al. (eds.). Modeling Complex Ecological Dynamics. Springer. p. 325. ISBN 978-3-642-05028-2.
Arditi, Roger; Ginzburg, Lev R. (1989). "Coupling in predator-prey dynamics: Ratio-Dependence". Journal of Theoretical Biology. 139 (3): 311–326. doi:10.1016/S0022-5193(89)80211-5.
Arditi, R. and Ginzburg, L.R. (2012) How Species Interact: Altering the Standard View on Trophic Ecology Oxford University Press. ISBN 9780199913831.
Antmann, S. S.; Marsden, J. E.; Sirovich, L., eds. (2009). Mathematical Physiology (2nd ed.). New York, New York: Springer. ISBN 978-0-387-75846-6.
Barnes, D.J.; Chu, D. (2010), Introduction to Modelling for Biosciences, Springer Verlag
Palsson, Bernhard (2006). Systems biology* properties of reconstructed networks. Cambridge: Cambridge University Press. ISBN 978-0-521-85903-5.
Young-Seuk Park, Sovan Lek, in Developments in Environmental Modelling, 2015
Sven E. Jørgensen, Todd M. Swannack, in Encyclopedia of Ecology (Second Edition), 2019