PROGRESS REPORT: November 2004

GLOBEC; Physical Influences on California Current Salmon

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I. Key Objectives:

A. Retrospective: How do variability on regime, annual and event time scales interact to influence CCS salmon populations at various latitudes?

B. Individuals: To understand how physical and biological conditions in the local coastal ocean, and ocean entry conditions of the fish (size and time of entry), influence juvenile salmon in ways that are important to population dynamics. To accomplish this develop a bioenergetic, individual-based model and perform experiments tracking particles with various swimming behaviors in the GLOBEC circulation model.

C. Populations: To understand the population dynamic effects of a varying environment in the early juvenile stage and at the age of returning to spawn.

D. Metapopulations: To understand how the metapopulation structure due to straying influences the population responses of salmon to changing environment.

II. Which papers were associated with each of these?

A. To answer the question in A., we performed a retrospective analysis of population variability of chinook salmon, coho salmon and Dungeness crab, along with physical conditions in the CCS, upwelling, sea surface temperature and sea level height (Botsford and Lawrence 2002, Botsford, et al. 2003). We noted that these three species covaried with "warm/cool" conditions in the CCS, but that they responded on different temporal and spatial scales. The differences in temporal scales of response were explained by showing how age structure and density dependence interact with environmental forcing (McCann, et al. 2003).

B. To address the questions regarding individual juveniles, we first formulated a model that described how changes in growth (possibly due to changes in abundance and composition of prey) and mortality patterns (possibly due to changes in predators) during the early juvenile stage would lead to differences in both survival to spawning and age at spawning. This bioenergetic model was used in conjunction with release/return data. The next step was to implement this description of individuals in the GLOBEC models of circulation in the coastal ocean to assess the effects of swimming behaviors possible at each size and age. Completion of this step awaits the availability of the GLOBEC circulation model. We have examined the effects of swimming particles in preliminary versions of the GLOBEC circulation model (and in CODAR fields, see Botsford, et al. 2004 presentation), but realistic model current fields are not yet available. We have two related publications on oceanographic considerations in tracking other biological particles in current fields (Largier 2003, 2004). While parts of our juvenile model have been presented at various conferences (see Presentations: Lawrence and Botsford 2001, Lawrence and Botsford 2000, Lawrence and Botsford 1999, Rhodes and Botsford 1999a, b), no publications have resulted because of the lack of availability of circulation fields from the physical models.

C. One of the differences between coho and chinook salmon identified in our retrospective analysis was that coho salmon declined dramatically in the mid-1970s while chinook salmon did not. Our first population paper addressed the question of how salmon populations responded to variability in ocean survival with a focus on the importance of differences in spawning age distributions, a major difference between coho and chinook salmon (Hill, et al. 2003, Botsford, et al. in press). A second way that conditions during the early juvenile period can effect adults is through their spawning age; the fraction spawning at each age and the mean age of spawning vary from year to year. Our current efforts focus on that mechanism, and a publication is in preparation.
D. To examine the effects of metapopulation structure on dynamics, we first addressed the proposition that the straying rates were in most Pacific salmon populations too small to have much effect on population persistence. A two -patch metapopulation model was used to show that even very small straying rates had a significant effect on time to extinction (Hill, et al. 2002).

Which papers addressed the 3 core hypotheses of the GLOBEC NEP program?
Our analysis of variability in coho and chinook salmon in the CCS addresses core hypothesis I, and and refuted it by showing that while inverse covariability between coho salmon populations in the Gulf of Alaska and the CCS was evident in their opposite shifts in abundance, similar shifts were not observed in GOA and CCS chinook salmon (Botsford and Lawrence 2002, Botsford, et al. 2003). Our examination of the differences between responses to time varying mortality of populations with different spawning age structure (Hill, et al. 2003, Botsford, et al. in press) attempt to explain that difference, hence also address core hypothesis I. These identify a difference in environmental response between populations with environmental variability at the age of ocean entry and the age of return for spawning, hence they address core hypothesis III. Our examination of the effects of straying and metapopulation structure on salmon populations (Hill, et al. 2002) is also relevant to differences in response to the environment, hence addresses core hypothesis I.

III. Online status of data and model products
This has not been applicable to us thus far.

IV. What papers will emerge by the end of the project?
A. An analysis of the population dynamic effect of time variability in age of maturation, with authors Worden, Hastings and Botsford.
B. An analysis of the way in which changes in juvenile growth and mortality rates lead to various survivals and ages of maturity using our bioenergetic IBM, with authors Lawrence and Botsford.
C. A study of the effects of swimming behavior and size and growth on horizontal distribution of juveniles. This depends on the availability of useful current fields. Authors will probably be Kaplan, Lawrence, Largier and Botsford.
D. Further analysis of metapopulation dynamics, with authors Worden, Botsford and Hastings.

Publications

Botsford, L.W. and C. A. Lawrence. 2002. Patterns of co-variability among California current chinook salmon, coho salmon, Dungeness crab, and physical oceanographic conditions. Progress in Oceanography 53: 283-305.

Botsford, L.W. and C. A. Lawrence. Differences in dynamic response of California Current salmon species to changes in ocean conditions. Deep-Sea Res. II (GLOBEC Special Issue) To appear in January, 2005.

Botsford, L.W., C.A. Lawrence, M.F. Hill, A. Hastings and K.S. McCann. 2002. Dynamic response of California Current populations to environmental variability. Pp 215-226 in N.A. McGinn, editor. Fisheries in a Changing Climate. American Fisheries Society Symposium 32, Betheseda, Maryland.

Hill, M.F., A. Hastings and L.W. Botsford. 2002. The effects of small dispersal rates on extinction times in structured metapopulation models. American Naturalist 160: 389-402.

Hill, M.F., L.W. Botsford and A. Hastings. 2003. The effects of spawning age distribution on salmon persistence in fluctuating environments. Journal of Animal Ecology 72: 736-744.

Largier, J.L. 2004. The importance of retention zones in the dispersal of larvae. American Fisheries Society Symposium 42:105-122.

Largier, J.L. 2003. Considerations in estimating larval dispersal distances from oceanographic data. Ecol Applications, 13(1) Supplement, S71-S89.

McCann, K.S., L.W. Botsford and A. Hastings. 2003. Differential response of marine populations to climate forcing. Canadian Journal of Fisheries and Aquatic Sciences 60: 971-985.

Presentations

Botsford, L. W., C. A. Lawrence and A. Hastings. 2004. Differential Response of Coho and Chinook salmon to the Regime Shift in the Mid-1970s. 51st Annual Eastern Pacific Ocean Conference (EPOC), Dunsmuir Lodge, Victoria, Canada.

Botsford, L. W, C. A. Lawrence, M. F. Hill and A. Hastings. 2004. Comparative analyses of the response of California Current chinook and coho salmon to the regime shift of the mid-1970s. 2004 Ocean Sciences Meeting, AGU, Portland, OR.

Botsford, L. W., J. L. Largier, D. M. Kaplan and C. A. Lawrence. 2003. Simulating juvenile salmon growth and swimming in a near shore flow field. Joint Cal-Neva Meeting of the American Fisheries Society. San Diego, CA, April 2003.

Lawrence, C. A., L. W. Botsford, M. F. Hill and A. Hastings. 2002. Responses of California Current populations to environmental variability. 2002 Ocean Sciences Meeting, ASLO/AGU, Honolulu, HI.

Lawrence, C. A. and L. W. Botsford. 2001. Influence of size and time of ocean entry on survival and precocious maturation of CCS coho salmon. 3rd Salmon Ocean Ecology Meeting, Seattle, WA.

Botsford, L. W. and C. A. Lawrence, A. Hastings and M. Hill. 2001. Large-scale ecosystem forcing of California Current salmon populations. 48th Annual Eastern Pacific Ocean Conference (EPOC), Stanford Sierra Camp.

Botsford, L. W. , C. A. Lawrence, K. S. McCann, and A. Hastings. 2000. Variability in California Current catch of Dungeness crabs, coho salmon and chinook salmon: population analysis of ecosystem forcing. 2000 Ocean Sciences Meeting, ASLO/AGU, San Antonio, TX.

Lawrence, C. A. and L. W. Botsford. 2000. Size and time of ocean entry as determanints of survival and precocious maturation in CCS coho salmon: a modeling and retrospective analysis. 2000 Ocean Sciences Meeting, ASLO/AGU, San Antonio, TX.

Lawrence, C. A. and L. W. Botsford. 2000. Salmon Population Dynamics: US GLOBEC retrospective and modeling studies in the California Current ecosystem. PICES IX Annual Meeting, Hakodate, Japan.

Botsford, L. W. and C. Lawrence. 2000. Retrospective and modeling studies of California Current salmon. 47th Annual Eastern Pacific Ocean Conference (EPOC), Dunsmuir Lodge, Vancouver Island, Canada.

Lawrence, C. A. and L. W. Botsford. 1999. Growth and mortality of coho salmon during initial ocean entry: an individual-based modeling study. Gordon Research Conference: Coastal Ocean Modelling. New London, NH.

Rhodes, C. L. and L. W. Botsford. 1998a. Individual-based models of coho salmon during initial ocean entry. 45th Annual Eastern Pacific Ocean Conference (EPOC), Timberline Lodge, Mt. Hood, OR.

Rhodes, C. L. and L. W. Botsford. 1998b. Survival of coho salmon during initial ocean entry: dynamical consequences of size-dependent mortality and environment dependent growth rate. Annual Meeting, Ecological Society of America, Baltimore, MD.