Climate, Growth, and Fisheries Production of the Gulf Corvina *(Cynoscion othonopterus)*

Clima, Crecimiento y Producción Pesquera en el Golfo Corvina *(Cynoscion othonopterus)*

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EXTENDED ABSTRACT

Climate variability can affect fish populations and fisheries in numerous ways, including inducing measurable fluctuations in fish recruitment, growth, condition, and fisheries production. Fisheries production in the Eastern Pacific (EP) is strongly affected by climate forcing (Beamish 1993). For example, El Niño Southern Oscillation (ENSO) events are associated with significant increases in Sea Surface Temperature (SST), increased precipitation, and decreases in primary productivity in marine environments (Fiedler 2002). Known biological effects of the warm phase of ENSO, El Niño, have included decreases in growth rate in some fishes in the EP (Woodbury 1999). However, warm SSTs during El Niño years have been linked to an increase in growth rate or condition (i.e., weight-length relationships) in some salmonid, lutjanid, and epinephelid fishes (Mcfarlane et al 2005, Williams et al. 2007, Aburto-Oropeza et al. 2010).

Gulf Corvina (*Cynoscion othonopterus*) is an intensely harvested sciaenid fish that is endemic to the Gulf of California, Mexico, where ENSO is arguably the main climatic driver (Lluch-Cota et al. 2010, Aburto-Oropeza et al. 2010). This species has a well-documented life history making it a suitable model species for researching relationships between climate, growth, and fisheries production (Gherard et al. 2013, Erisman et al. 2012). The purpose of this study was to investigate the relationship between the Multivariate ENSO Index (MEI) and adult fish condition, fish growth rate, and fisheries production.

The Multivariate ENSO Index (MEI) was used as a proxy of the strength of ENSO events. To assess annual fish condition we used total weight and total length data from 9,588 fish sampled from 1997 to 2015. Annual weight- length relationships were estimated by using both logarithmic and exponential models for adult fish (Cone 1989, Froese 2006). The slope (b) of the weight-length relationship for each survey year was compared to MEI to investigate annual variations in fish conditions in response to ENSO. To measure growth rate, a total of 440 otoliths were collected and aged according to the methods of Gherard et al. (2013). Two chronologies were created to assess differences in juvenile (years 0-2) and total growth rate (years 2 - 10) with MEI. A range of 20 to 30 otoliths per collection year were processed. Chronologies were standardized to remove age effects according to the detrending methods of Black et al. (2005). Average growth anomalies per each year of the twenty-five years of formation observed (1990 to 2015) were then correlated with MEI. Lastly, annual catch data from 1998 to 2014 were compared to MEI to assess relationships between climate and fisheries production.

Fish condition showed a moderate positive relationship with mean annual MEI using the logarithmic model ($r = 0.36$), whereas the relationship was stronger using the exponential model ($r = 0.55$). Juvenile fish growth rate had a weak correlation with mean annual MEI ($r = 0.28$) but a stronger relationship with MEI bi-monthly averages during winter and spring months (January-June), peaking in March/April ($r = 0.48$). Total fish growth rate (years 2 - 10) when correlated with annual average MEI had a moderate relationship ($r = 0.42$). When bi-monthly MEI averages were correlated with total fish growth rate, the January-June months ranged ($r = 0.38 – 0.54$). When landings data were lagged five years to simulate the relationship between the birth year of fish and the age at which most fish are harvested, a strong positive relationship was found (Figure 1) ($r = 0.60$).

The results of our study indicate that El Niño conditions are favorable for adult condition, growth rate of both juveniles and adults, and future fisheries production of the Gulf Corvina. Increases in the condition and growth rate of adult fish may be due to increases in metabolism associated with elevated SSTs (O'Conner et al. 2007). Likewise, known increases in the abundance of the main prey item of adult Gulf Corvina, the Pacific Anchoveta *(Centengraulis mysticetus)* (Mellink 2001, Román-Rodríguez et al. 2000) during El Niño years may also the positive relationships found between condition, growth, and MEI.

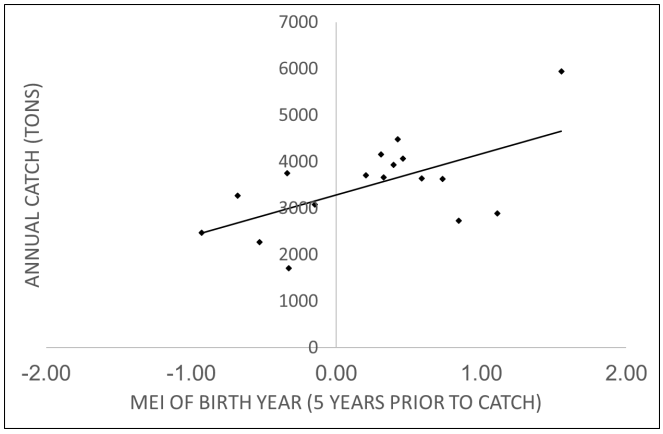

Figure 1. Positive relationship between MEI at birth and fisheries production lagged five years (r = 0.60) 1998 - 2014 based on the peak age of selectivity of the fishery (i.e. age 5). Results indicate potential predictability of a Gulf Corvina *(Cynoscion othonopterus)* with increasing strengths in El Niño events in the Gulf of California, Mexico.

Growth rate in juvenile Corvina is highest during the period of January to June, commensurate with the timing of spring floods in the primary nursery grounds of the Colorado River Delta. Previous studies have shown that juvenile Gulf Corvina use the brackish habitats created by the follow of the Colorado River, and increased flow into the Delta enhances juvenile habitat quality and benefits juvenile survivorship and recruitment (Rowell et al. 2005). Our results showing a positive relationship between juvenile growth rate and MEI support this hypothesis, since El Niño years are associated increased river flow during the spring months. Our results on the relationship between MEI and future fisheries production provide further support on the positive relationship between ENSO and the Gulf Corvina. Specifically, they indicate that favorable environmental conditions created during El Niño years (e.g. more brackish habitat) enhances growth, and potentially recruitment, of juvenile Gulf Corvina and is associated with higher landings five years later when they fish are large enough to be harvested by the commercial fishery. Most climate models predict that El Niño events are likely to become more frequent and intense over the next century (Fiedler 2002), which is likely to result in serious impacts on the world's fisheries (Brander 2007). The results found in this study highlight the potential for predictability of an important commercial fishery in the midst of a rapidly changing climate, such that climatic and environmental conditions at birth can be used to predict future stock condition and set appropriate harvest limits.

KEYWORDS: Fisheries, climate variability, fish growth, fisheries production

LITERATURE CITED

Aburto-Oropeza, O. E. Sala, G. Paredes, A. Mendoza, and E. Ballesteros. 2007. Predictability of reef fish recruitment in a highly variable nursery habitat. *Ecology* **88**(9):2220-2228.

Beamish, R.J. 1993. Climate and exceptional fish production off the West-Coast of North America. *Canadian Journal of Fisheries Aquatic Sciences* **50**:2270-2291.

Black, B.A., G.W. Boehlert, and M.M. Yoklavich. 2005. Using tree-ring crossdating techniques to validate annual growth increments in long-lived fishes. *Canadian Journal of Fisheries Aquatic Sciences* **62** (10):2277-2284.

Brander, K.M. 2007. Global fish production and climate change. *Proceedings of the National Academy of Sciences* **104**(50):19709-19714.

Cone, S.R. 1989. The need to reconsider the use of condition indices in fishery science. *Transactions of the American Fisheries Society* **118**:510-514.

Erisman, B.E., O. Aburto-Oropeza, C. Gonzalez-Abraham, C. Mascareñas -Osorio, M. Moreno-Báez, and P.A. Hastings. 2012. Spatio-temporal dynamics of a fish spawning aggregation and its fishery in the Gulf of California. *Scientific Reports* **2**(284)**:**1-11.

Fiedler, P.C. 2002. Review: Environmental change in the eastern tropical Pacific Ocean: review of ENSO and decadal variability. *Marine Ecology Progress Series* **244**:265-283.

Froese, R. 2006. Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. *Journal Application Ichthyology* **22**:241-253.

Gherard, K.E., B.E. Erisman, O. Aburto-Oropeza, K. Rowell, and L.G. Allen. 2013. Fishery-dependent estimates of growth, development, and reproduction in Gulf Corvina *(Cynoscion othopterus). Bulletin of the Southern California Academy of Sciences* **112**(1):1-19.

Holmgren, M., M. Scheffer, and E. Ezcurra, E. Gutiérrez, and G.M.J. Mohren. 2001. El Niño effects on the dynamics of terrestrial systems. *Trends in Ecology and Evolution* **16**(2):89-94.

Lluch-Cota, S., A. Parés-Sierra, V.O. Magaña-Rueda, F. Arreguín-Sánchez, G. Bazzio, H. Herrera-Cervantes, and D. Lluch-Belda. 2010. Changing climate in the Gulf of California. *Progress in Oceanography* **87:**114-126.

Macfarlane, R.B., S. Ralston, C. Royer, and E.. Norton. 2005. Juvenile chinook salmon *(Oncorhynchus tshawytscha)* growth on the central California coast during the 1998 El Niño and 1999 La Niña. *Fisheries Oceanography* **14**(5):321-332.

Mellink, E., J. Domínguez, and J. Luévano. 2001. Diet of Eastern Pacific Brown Boobies *Sula leucogaster* on Isla san Jorge, north-eastern Gulf of California, and an April comparison with diets in the middle Gulf of California. *Marine Ornithology* **29**:23-28.

O'Conner, M.I., J.F. Bruno, S.D. Gaines, B.S. Halpren, S.E. Lester, B.P. Kinlan, and J.M. Weiss. 2007. Temperature control of larval dispersal and the implications for marine ecology, evolution and conservation. *Proceedings of the National Academy of Sciences* **104**(4):1266 -1271.

Román- Rodríguez, M.J., 2000. Estudio pobacional del chano norteno, *Micropogonias megalops* y la curvina Golfina *Cynoscion othonopterus* (Gilbert) (Pisces: Sciaenidae), especies endemicas del alto Golfo California, Mexico. Instituto del Medio Ambiente y Desarrollo sustentable del Estado de Sonora. Informe final SNIB-CONABIO Proyecto No. L298. Mexico D.F. 143 pp.

Rowell, K., K.W. Flessa, D.L. Dettman, and M. Román. 2005. The importance of Colorado river flow to a nursery habitat of the Gulf corvina *(Cynoscion othonopterus. Canadian Journal of Fisheries and Aquatic Sciences* **62**(12):2874-2885.

Williams, J.P., L.G. Allen, M.A. Steele, and D.J. Pondella II. 2007. El Niño periods increase growth of juvenile white seabass *(Atractoscion nobilis)* in the Southern California Bight. *Marine Biology* **152**:193-200.

Woodbury. D., 1999. Reduction of growth in otoliths widow and yellow-tail rockfish (*Sebastes entomelas* and *S. flavidus* during the 1983 El Niño. *Fisheries Bulletin* **97**:680-689.