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# Letter to the editor – environmental development – comment on Arreguín et al. 2017

Dear Editor,

In their recent contribution to Environmental Development, (Arreguín-Sánchez et al., 2017) describe anomalies in sea surface temperature (SST) and the discharge of the Colorado river in relation to fisheries catches in the Gulf of California (GoC), Mexico. They imply that the observed changes in fisheries in the region are due more to climate variation than to fishing pressure. The authors argue that scientific studies and conservation strategies in the region have produced erroneous conclusions, "*motivating the limitation of fishing activities, ending fishing activities or establishing marine protected areas*".

We agree that the aforementioned physical parameters have important consequences for different fisheries resources in the Gulf, and our own work over the past 20 years has shown that El Niño Southern Oscillation (ENSO) and freshwater inputs to marine ecosystems can affect fishery landings for both coastal and pelagic fishes (Velarde et al., 2004, 2013; Aburto-Oropeza et al., 2007, 2010). The new article by Arreguín-Sánchez et al. (2017) however, contains significant methodological flaws, does not provide evidence to support their conclusions, and we disagree with their interpretation of complex ecological processes and the implications for fisheries management.

The authors suggest that "climate regimes" have overarching importance for the sardine populations in the GoC, which ultimately affect other fishery species through food chain linkages. However, their results (1) are not supported by statistical analyses; (2) do not incorporate climatic indices such as the Multivariate ENSO Index (MEI) and the Pacific Decadal Oscillation (PDO), even though they acknowledge the importance of such phenomena in regulating ecosystem processes within the GoC, (3) ignore published works that set out to address exactly the hypothesis they are exploring, (4) present data that has unknown origin when compared to other published work and government data, and (5) only include data up until 2010 in their manuscript.

One of the main questions that Arreguín-Sánchez et al. (2017) set out to answer is whether observed changes in abundance of forage fish stocks come from high fishing efforts or from natural environmental variability. In order to tackle this problem they present a time series plot (Fig. 3 in Arreguín-Sánchez et al., 2017) of SST anomalies and total catches as well as sardine landings in the GoC. They then claim that based on the results of Bakun et al. (2009) "*the changes expressed by the SST anomaly explain 38% of the catch variation ($p < 0.05$)*". This is by no means grounds to conclude that climate regulates catches of these species. First, there is extensive scientific literature that demonstrates that correlation does not imply causation (Sugihara et al., 2012; Glaser et al., 2013; Clark et al., 2015), and the authors did not even consider the possibility of exploring further methodologies to prove their point. Second, even if the correlation implied causation, what about the remaining 62–85%? Stock abundances often only explain similar amounts of annual variation in recruitment and problems with stock-recruitment models are well noted (Cury et al., 2014; Lowerre-Barbieri et al., 2016). Simply using catch as a surrogate for population abundance has also been heavily cautioned within the scientific literature (Hilborn et al., 2013).

Looking at the figure presented (Fig. 3 in Arreguín-Sánchez et al., 2017), the suggested relationship between SST and catch is not obvious at all, and the authors do not present any calculation or any accessible data set where this assertion might be corroborated. Furthermore, the data series they present does not coincide with the data presented in Bakun et al. (2009), who in turn, obtained their data series from Lluch-Cota et al. (2007). The official sardine and pelagic fisheries catch and effort statistics are available from a special INAPESCA-managed website (http://www.sardinagolfodecalifornia.org/informes-tecnicos/), and again, the official statistics do not coincide with the data presented by Arreguín-Sánchez et al. Reading their paper with detail, it is unclear where they got their 38% value for association between SST and sardine catches, and what statistical method was used to reach this unfounded conclusion. Using an open access, corrected database of the official CONAPESCA landings (Ramirez-Valdez et al., 2014), we again found that the numbers presented by the authors in their introductory text are inaccurate. Total landings in 2012 in the GoC were in fact 1,054,972 t (not 1.2 million), which corresponded to a total revenue of 502 million U.S. dollars (not 600 million) at that time.

Furthermore, the authors are blatantly ignoring published work in rigorous scientific journals that has addressed exactly the point they are exploring - the complex, two-way relationship between fishing effort and environmental anomalies on sardine landings. For example, among many articles tackling this issue, Velarde et al. (2015a), (2015b) have demonstrated that both oceanographic anomalies and high fishing pressure jointly produce collapses in sardine catches in the GoC and force nesting seabirds to emigrate. Through path analysis, a form of Structural Equation Modeling used to establish the importance of different factors as predictors of a

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given effect, the authors showed that, combined, fishing effort and total landings in the previous fishing season were as important predictors of sardine declines as were the seasonal SST values in the GoC, and that both combined (overfishing and high-temperature anomalies) can provide a serious blow to the fish populations. The authors fail to note that predictions of total catch and the catch per unit effort in the sardine fishery improve greatly when incorporating additional biological covariates such as the clutch size and diet composition of local seabird populations feeding on the sardines (Velarde et al., 2004, 2013). Neglecting to mention such advances in marine science in the GoC ignores the fact that the sardine fishery could be better managed by predicting catches using methods that look at more than climatic variables, particularly single variables in isolation such as SST. It is noteworthy that several management methods in different parts of the world are now integrating the use of biological parameters related to trophic web information. In these cases, this ecological information is not only accepted as reliable but even required for fisheries management decisions (Furness, 1990; Cairns, 1992; Davoren et al., 2007).

Although Arreguín-Sánchez et al. suggest that climate is the main driver of fluctuations in fisheries catches, and that it should be given more weight than actual fisheries exploitation levels, they do not include any measures of access to the fishery, technological advances in catch methods, consistency in reporting or fishing effort, making their conclusions invalid. The authors fail to acknowledge the steadily growing artisanal fleet size in the GoC, which has gone from approximately 17,000 fishing vessels in 2006 (Johnson et al., 2017) to an estimated 25,000 in 2010, and it is likely to have grown considerably since then (Cisneros-Mata, 2010). The fisheries reports referenced in their article are not up to date (the latest reference being 2012), and the landings data collated within these summary reports undergoes no formal peer-review and is known to contain significant errors (Cisneros-Montemayor et al., 2016).

The argument of Arreguín-Sánchez et al. that climate drives fisheries production in the GoC ignores the known influence of life history strategies on population fluctuations in response to climate and ocean changes. They focus entirely on the life history and population dynamics of fast-growing, short-lived forage fishes, such as sardines, while completely ignoring long-lived, slow-growing species that have long supported the most important and valuable commercial fisheries in the GoC. Life history traits are the underlying determinants for population responses to both environmental variations and fishing pressure (King and McFarlane, 2003). Forage fishes like sardines are best described as "opportunistic strategists" that exhibit cyclical population patterns with high-interannual variability in response to environmental and climatic conditions. Thus, for these species, the influence of climate on fisheries production could exceed the impacts of fishing in some years. However, this is not the case for groupers, seabasses, snappers, and other large-bodied, slow-growing, long-lived fishes with a periodic life history strategy that has evolved to maintain a stable population over long periods of unfavorable environmental conditions (King and McFarlane, 2003). For these species, environmental variations are less important over short time scales, as annual recruitment represents only a small fraction of the spawning stock biomass, and longevity minimizes the risk that long periods of poor environmental conditions will result in population declines (King and McFarlane, 2003). As a result, enacting fishing regulations that maintain the appropriate age structure of the spawning stock (e.g. old, highly fecund females) is critical for management (Hixon et al., 2014).

The authors state that "*there are some assertions that observed changes in the Gulf ecosystem are attributable to overfishing, completely ignoring the climate effects*" citing (Sala et al., 2004). The authors derogate the referenced work implying that Sala and colleagues only used a fisherman's appreciation index to make their conclusions that fishery impacts were having widespread effects on fish communities in the GoC. This is not the case, as the authors supported their hypothesis in this study using combinations of catch, catch per unit of effort, number of fishers and boats, mean trophic level of species, and the sizes of fishes. (Sala et al., 2004) do not stand alone it their conclusions. A multitude of robust scientific investigations in the GoC documented overfishing both from registered commercial catch data and fisheries independent data (Cudney-Bueno et al., 2009; Aburto-Oropeza et al., 2015) and significant recoveries of fish biomass when areas are protected from fishing (Stobart et al., 2009; Aburto-Oropeza et al., 2011; García-Rubies et al., 2013). The authors go on to say, *"it becomes clear that changes between the two mentioned periods are clearly associated with different climate regimes"* using a poorly scaled graphic, again without any statistical analysis to corroborate their claims or even describe what they mean as 'climate regimes'.

In our opinion, the most phenomenal proof of how depleted fish populations are in the GoC – regardless of climate variability – is the recovery of fish biomass and assemblage structure in the Cabo Pulmo National Park, where fishing is prohibited (Aburto-Oropeza et al., 2011). Cabo Pulmo is the only no-take area in the GoC that is large (70 $km^2$), well enforced and shows what the Gulf was like before overfishing. In Cabo Pulmo, total fish biomass increased 463% within a decade (1999–2009), relative to unprotected areas in the Gulf of California. None of the unprotected areas surveyed in that study showed any statistically significant changes in fish biomass despite large ENSO variability within the study period. In addition, fish biomass was greater within the small no-take areas within the Loreto Bay Marine Park than at unprotected areas nearby, despite great interannual variability due partly to climate variability (Rife et al., 2013). These studies strongly suggest that fishing is the most important factor determining the abundance of coastal fish populations, not climate variability.

The one critique of Mexico's fisheries management that Arreguín-Sánchez et al. make relates to the upper Gulf of California (UGC) and the contentious issues of the vaquita marina (*Phocoena sinus*) bycatch and the illegal fishing of the totoaba (*Totoaba macdonaldi*). The authors suggest that management measures to protect these species are insufficient as they are focused on the effects of fishing and neglect to account for changes in habitat, in this case runoff from the Colorado river. Although the authors are correct that habitat has not been addressed in fisheries management in the UGC, they also overlook the human dimensions of fisheries which have been discussed widely as the primary factor that has led to management failures in the region (Aburto-Oropeza et al., 2016). The social well-being of fishing communities, current fisheries management strategies, the economic expenses related to fishing activities and supply-chain factors, to name a few are all neglected from the authors' discussions. Arreguin et al.'s lack of formal analyses and broad conclusions perpetuate the idea that the problem for fisheries in the UGC is a lack of freshwater run off and subsequent primary productivity, something for which there is no empirical evidence (Brusca et al., 2017). Such claims are irresponsible and damaging, providing authorities with excuses not to properly enforce local legislation to manage their fisheries.

The broad-scale approach taken by Arreguín-Sánchez et al. means the interpretations they make with their limited analysis only account for single factors assumed to affect ecosystems in isolation while neglecting the very "*simultaneous sources of variation*" they readily acknowledge are important. Their broad conclusions over large, total GoC spatial scales and multiple years contradict other parts of their discussion that note fisheries management should consider "*year-to-year biomass availability and ecosystem dynamics*". Their Gulf-wide view disagrees with many studies that have highlighted the importance of a small spatial-scale approach to manage marine fish stocks successfully (Sala, 2002; Palumbi, 2004; Erisman et al., 2011). Additionally, the authors' approach neglects the importance of synergistic interactions between factors impacting the ecosystems in the GoC. Their study also highlights a fixation on supposed climatic variables (they refer to SST as climate, which is inaccurate) versus total landings correlations, claiming that this one independent variable is responsible for most of the variability observed. We recommend that the authors should at a minimum consider the many additional factors acting on a species or ecosystem before drawing such assertive conclusions about one single factor being the only driver. The approach the authors take limits their ability to accurately describe what are (and should be) inherently complex relationships within ecosystems. As a result, the authors overlook discussions of ecosystem based approaches to fisheries management (EBFM) that acknowledge the importance of considering abiotic, biotic and the human components of ecosystems (Pikitch et al., 2004; Travis et al., 2014).

Arreguín-Sánchez et al. make considerable reference to *"the management"* in Mexico but never reference any documentation that can be used by the reader, nor elaborate further, on the details of this management. The authors broadly state that successful management *"can only be achieved when we know what can and cannot be controlled"*. Considering that the authors' main tenet appears to be the need to incorporate climate into management (more so than the effects of fisheries), it is perplexing and counter-intuitive that they suggest managing fisheries (that which can be controlled) comes secondary to accounting for climate (that which cannot be controlled). Indeed, fisheries scientists and managers reached a consensus decades ago on the basic premise of managing fishing mortality in response to predicted effects of environmental and climate variations on stock productivity (Botsford et al., 1997; Worm and Myers, 2004; Hsieh et al., 2006). Historically, fisheries management in the GoC has not readily acknowledged the ability of fisheries to significantly deplete the biomass of fish stocks, nor the consequences of high fishing effort on non-target species, habitats and the social well-being of local human populations. Arreguín-Sánchez et al. are correct when they allude to a need to seriously evaluate the way fisheries are managed in the GoC. Nevertheless, the current paper provides those with vested interests in the GoC's fishing industry the opportunity to dismiss the importance of harvest regulations and maintain promotions of the idea that regional fisheries management should be based mainly on climate effects. This will likely have deleterious consequences for the fish stocks and fishers in the region, as low catch years will continue to be blamed on climatic anomalies without any rigorous scientific analysis. This will also harm management processes and prevent the establishment of sound fisheries decisions, favoring the decline and overfishing of populations of fish as important as the forage fishes on which whole trophic webs depend. Ultimately this will perpetuate the neglect of the real issues affecting the fisheries and their management in the GoC, such as increasing reliance on government subsidies as landings decline and a lack of foresight regarding the future of the communities surrounding the GoC that rely on fisheries as their primary source of livelihood.

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