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Comments on Buzan et al. "Positive Relationships between Freshwater Inflow and Oyster Abundance in Galveston Bay, Texas"

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Comments on Buzan et al. "Positive Relationships between Freshwater Inflow and Oyster Abundance in Galveston Bay, Texas"

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Abstract Buzan et al. critique Turner's (Estuaries and Coasts 29:345–352, 2006) analysis of the relationship between freshwater inflow and oyster productivity in the Gulf of Mexico, using 16 years of fisheries-independent data for Galveston Bay. They conclude that the catch-per-unit effort (CPUE; number h^{-1}) of marketable oysters increase 1 to 2 years after years with increased freshwater inflows, and they express concerns that water supply managers *may* mis-apply the results of Turner (Estuaries and Coasts 29:345–352, 2006) to justify a reduced freshwater inflow to Galveston Bay. I find no relationship between the CPUE of oyster spat or marketable oyster density and the commercial harvest, but do find a strong inverse relationship between harvest and river discharge in Galveston Bay. There are three possible factors that may explain why the annual variations in the fisheries-independent data are not coherent with the annual variations in commercial harvest: variable levels of water quality, inconsistent fishing effort, and the fact that the fisheries-independent data are not prorated for the area of the reefs actually fished. I concur, completely, with the apprehension that reductions in freshwater inflow will be implemented without examining the full set of assumptions and consequences, and thereby compromise estuarine ecosystem quality, and perhaps permanently, before mistakes can be seen or reversed.

Keywords Oyster harvest · Salinity · Freshwater · Galveston Bay

Introduction

Buzan et al. (2008) analyze 16 years of fisheries-independent oyster abundance data for Galveston Bay, collected as part of a monitoring effort by Texas Parks and Wildlife. The data consist of the catch of market-sized oysters from oyster dredge tows (number h^{-1}). They conclude that there is a direct relationship between freshwater inflow and oyster abundance. They compare their results with those of Turner (2006) who describes an inverse relationship between freshwater inflow and commercial landings for a 54-year data set for Texas. They express concern that water supply managers might reduce freshwater inflow to increase oyster harvest and thereby compromise the fisheries.

Here I discuss the data they use and their results, our commonly held concern that estuarine management efforts using freshwater inflow to control salinity will underestimate, at best, the consequences to the estuary, and explore why the relationship between river discharge and fisheries-independent data and fisheries-dependent data may yield dissimilarities. I found no reliable relationships between the catch-per-unit effort (CPUE) of spat and market-sized oysters, whether lagged or not, or between CPUE and discharge. There is also no linear relationship between the commercial oyster harvest and the market-sized oyster CPUE, but there is an implied curvilinear relationship. These results suggest that there are interesting ecological and societal questions to be addressed about the absence of coherence between the estimates of fisheries-dependent and fisheries-independent data.

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Analysis

Discharge vs. Harvest and CPUE in Galveston Bay

Turner (2006) used the 3-year running average of the discharge of the Trinity River and the total Texas landings for the analysis. These data sets are appropriate data to use to examine the Galveston Bay system because they are strong proxies for the variations in commercial oyster landings and bay-wide salinity. The annual water flow into Galveston Bay (Texas Water Board 2008), for example, is well constrained by the discharge from the Trinity River. A simple linear regression of the net water inflow and the Trinity River discharge yields an R^2 of 0.87 (p=0.001) for 1950–2004. Using the discharge for the Trinity River as a surrogate for the average salinity in Galveston Bay is, therefore, reasonable. The Galveston Bay reefs and fishery accounted for 80–90% of the total State harvest, and combined with the leased acreage represents about 81% of the reported reef acreage in Texas (Kilgen and Dugas 1989).

Several estuarine managers have recognized that there is an inverse relationship between water inflow and oyster harvests in Galveston Bay, or that spring freshets can damage the reefs there. Hofstetter (1977), for example, said: “But, of all the commercially important shellfish, oysters are perhaps the least likely to suffer from prolonged drought in Galveston Bay.” (p. 80), and, “Oyster populations in the upper bay (Trinity Bay) are periodically reduced, or totally destroyed, by spring flooding. Oysters in middle Galveston Bay and in East Bay are killed only in severe flooding such as 1957 and 1973.” (p. iii). Lower levels of river discharge also have identifiable coherent peaks in oyster harvest, with intermediate values between troughs and peaks. The 3-year running average of the landings data for Galveston Bay shown in Turner (2006), for example, is re-plotted in Fig. 1, with the landings data inverted to make identification of the coherent peaks and valleys easier to see. There is a decline in landings from 1985 to 1990 as river discharge is rising, and then it reverses in the early 1990s, and then reverses again, and again. The ‘above annual flows’ that began in 1988 were accompanied by a harvest pattern that was the inverse of the discharge pattern. I identified the peaks and troughs as relative, not absolute amounts, and they clearly demonstrate an inverse coherence between discharge and landings.

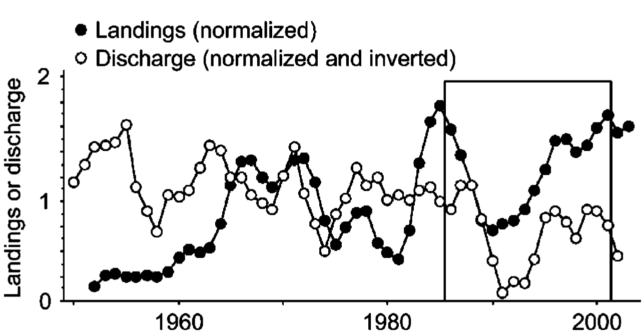

Fig. 1 These are normalized 3-year running averages of the data for the Trinity River discharge and landings used in Turner (2006). The discharge values are inverted by multiplying by −1.0 and then adding 2.0. The *box* outlines the data interval that Buzan et al. (2008) examined

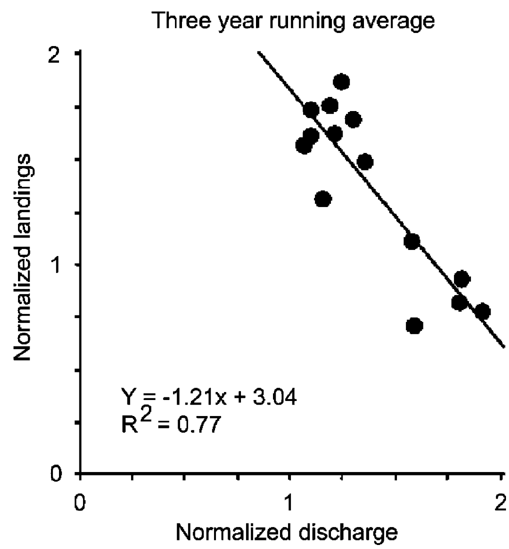

Fig. 2 The relationship between the 3-year running average of a normalized river discharge (Trinity River) and the commercial oyster harvest from 1990 to 2002 (p=0.001)

These coincidental and mirrored changes support the hypothesis that the relationship between the river discharge and the harvest data exists. A plot of the 1990 to 2005 data for normalized flow and landings also yields an inverse relationship (Fig. 2; R^2=0.77; p=0.001). Including many more years may not increase the fit of the linear regression because of changing management, gear, dredged channels, etc., and the growth of the 2,000 ha of new oyster reefs that Powell et al. (1995) said appeared between 1973 and 1989.

A plot of the relationship between the CPUE of marketable oysters and discharge in the same year or later, however, was not significant. I therefore investigated how the CPUE of the spat and marketable oysters were related to each other from one year to the next. Hofstetter (1977, p. iii) described how spat set and survival in Galveston Bay were both related to freshwater inflow, but in different ways: “Although more spat set in years of above normal river flow, survival is better when river flow is below normal. In “wet” years about 36% of the spat survive to market oyster size compared to 49% surviving in “dry” years. In harvest seasons following dry periods, 47% more market oysters are available than in harvest seasons following wet periods.” It is possible that his observations were constrained to a sub-set of the oyster reefs that did not represent the 'average' conditions of all Galveston Bay oyster reefs. I therefore plotted the average CPUE of the spat and the marketable oysters for Galveston Bay, using the same data Buzan et al. (2008) used. There is an absence of a consistent coherence between the two indices of CPUE (Fig. 3). There is also no statistical relationship between oyster landings in Texas and the market size for that year (N=20, p=0.11).

Clearly, however, if the CPUE were zero, then the harvest size would be insubstantial, even if some reefs were under- or over-sampled. A one-site binding hyperbola of the relationship between marketable CPUE and the commercial harvest was created (Fig. 4; R^2=0.26) using GraphPad Software (2005). The plot, if it represents a valid ecological representation, suggests that the variability in either the X or Y variable obscures most of any cause-and-effect relationship between them during most years.

In summary, there is no statistical relationship between several indices of CPUE and the harvest, which seems to me to compromise the usefulness of using the fisheries-independent data to describe the relationships between *harvest* and discharge. I am supportive of efforts to gather fisheries-independent data, and there are many uses for it, but my analysis is about the harvest, not the abundance of oysters, and so it has an, as yet, undemonstrated use for the purpose of predicting variations in harvest.

Rise and Falls in Abundance in the CPUE Data

The evidence discussed by Buzan et al. (2008) does not appear, to me, to provide substantial and consistent evidence of a positive relationship between freshwater inflow and market-sized oyster numbers that is lagged, which is not the same thing as saying it does not exist. They identify examples for the 'upward' trend that are lagged by 2, 1, 2, and 1 years, whereas the examples for the 'downward' trend are lagged 3, 2, 0, 1, and 1 years. This amounts to a total of 8 years with a pattern that Buzan et al. (2008) find is consistent with their hypothesis. There are

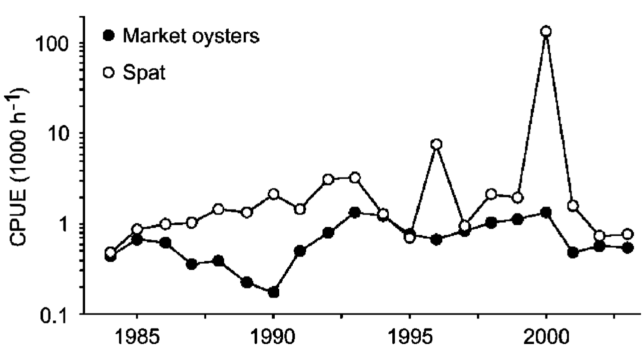

Fig. 3 The catch-per-unit effort (CPUE; number h^{-1}) of spat and market-sized oysters in Galveston Bay

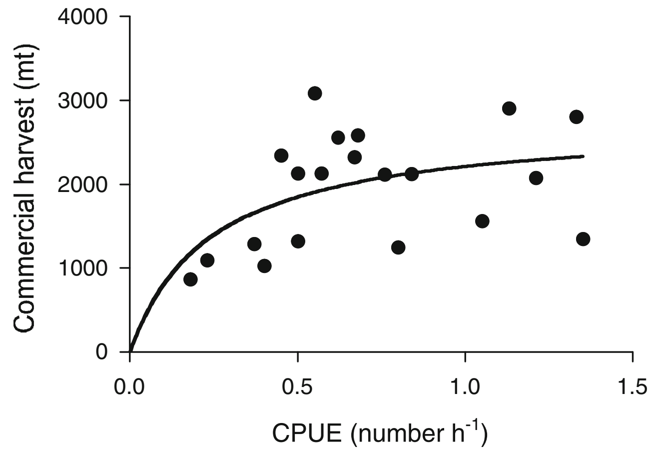

Fig. 4 A one-site binding hyperbola of the relationship between the CPUE of marketable oysters in Galveston Bay and the commercial harvest. The curve was forced through the 0, 0 intercept

3 years when they find that my analysis yields results that are consistent with theirs; these 3 years are also in the 8 years discussed as 'upward' or 'downward' trends. So 3 of 8 years are in agreement with both of our interpretations, if I understand their analysis correctly. The choice of a 2-year lag here is not entirely supported by the differences described in the relationship between flow and CPUE, which is 1–2 years (increasing discharge), 0, or 0–3 years (decreasing salinity). Further complicating the analysis is the absence of a statistical definition of what constitutes an upward or downward difference in CPUE, compared to what occurred in the preceding years.

Explanations

There are three general explanations for the absence of a relationship between the estimates of oyster abundance (from the fisheries-independent data collection effort) and the biomass landed by commercial fishers.

Public grounds and total harvest The CPUE data is from the public fishing grounds, whereas the commercial harvest data is from the entire estuary that is fishable. The public grounds are not the total oyster reef area that is dredged for oysters, and the size of each dredged area is not uniform. Further, the CPUE data are for the density of oysters averaged as the mean of the individual reefs and averaged for the whole estuary. Not all reefs are of the same size, and so they will yield different quantities *if* they are fished. The Redfish Bar, for example, was once the source of the majority of oyster harvest before the 1980s (Hofstetter 1977). The relative sizes of different beds have changed, too. According to Powell et al. (1995), for example, 2,000 ha of new oyster reefs in Galveston formed between

1973 and 1993, which compares to the 2,380 ha of natural reef in the 1970s (Kilgen and Dugas 1989).

Water quality The deteriorating water quality of Galveston Bay has led to an increasing number of algal blooms and fish kills from 1951 to 2006, but the fish kills have declined after a peak in 1980–1985 (Thronson and Quigg 2008). Three of the top five fish kill events in the US from 1980 to 1989 were in Galveston Bay (Thronson and Quigg 2008), and about 59% of the shellfish beds in Galveston Bay are closed to harvest (NOAA 2005). Surely the causal linkages between fish kills and water quality must also have had an influence on oyster yields, if not quality. The amount closed to harvest must change from year to year, as the density of coliform bacteria exceeds health standards. The loadings of coliform bacteria are distributed and absorbed at different rates dependent on a variety of factors, including weather, geomorphology, and salinity (Evison 1988; Mallin et al. 2001; Holland et al. 2004; Kelsey et al. 2004), so it would not be surprising to have some bed closures (and loss of the potential harvest) when river discharge is high. In addition, not all oysters in a 'year-class' are harvested at the same time, of course, and so bed closure in 1 year means that the reef may grow in the un-fished year, to be available for future fishing efforts.

Effort The commercial fishers are not sampling to obtain an 'average' yield, but to optimize their effort. Part of this effort is dependent on the biological availability of marketable oysters, but also on their economic situation, oyster prices, and labor. Fishermen will work more days and longer days if the economic returns for the effort are worth it—using their definition of 'worth'. There is a socio-economic legacy effect of past successes and failures for them that carries over into the effort of the next year (Allen and Turner 1989). This means that we have to be careful about making simple linear regressions for long data sets involving effort and climate.

Discussion

Hofstetter (1977, p. 80) summed up the situation in Galveston Bay in a way that is still applicable and made an essential point for management: "Although a relationship has been shown between low river flow and relatively high oyster population levels, it should not be concluded that reduced river flow will necessarily be beneficial to oysters or other estuarine species."

Obtaining and analyzing fisheries-independent data is an essential component when making informed decisions about fisheries management. It is also important to have sufficient understanding of the interrelationships between the bio-geo-physical influences and the commercial harvest to meet the needs of the oft-stated intention to reach 'sustainability'. Oysters have predators, but also physiological constrains on their growth and variable food requirements, and are harvested within a complex societal matrix. The natural oyster reef is not a computer chip to be programmed according to what some 'want' them to be through precise water management, but a complex system arising from an ancient evolutionary pathway that has not ended; it is exposed, for example, to the recent rise in invasive species, pollution, shell re-deposition, and dredging. I would argue that we are more likely to be working in a dark field of ignorance accompanied by some spots of illuminated insight, than in a bright field of almost complete certainty. If there is one general message to convey to those looking for simple relationships between freshwater inflow and fisheries management, then perhaps it is to think about the 100-year relationships and to consider the uncertainties carefully before manipulating estuarine salinity. I say this because our collective experience is that there will be unforeseen consequences—just as appears will be as the global climate change scenarios we are likely facing are revealed.

If we expect that there is a linear relationship between oyster harvest and freshwater inflow, either positive or negative, then we are likely to be disappointed because that expectation disrespects the known complexities of estuarine food webs and, I think, somewhat arrogantly dismisses the unknowns, which is from where the 'unintended consequences' will certainly arise. It is the role of science to accept and investigate doubt in a way that develops clarity and improves predictability, but it seems to me that absolute predictability is an elusive goal. We should, therefore, accept some variability and even consider embracing that variability. Furthermore, to inspect the assumptions underlying our ecological predictions is part of that effort, and one in which Buzan et al. (2008) are constructive participants.

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