

# Catch Data Can be Misleading when Assessing the State of Fisheries and Fisheries Ecosystems: A Gulf of Mexico Case Study Revisited

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## ABSTRACT

The use of indices to assess the state of fisheries and the health of ecosystems has been widely accepted. The Mean Trophic Level Index is one example, calculated as the mean trophic level of all landed biomass. Recently, marine ecosystems in the Gulf of Mexico (GOM) and US Atlantic south of Chesapeake Bay were reported to be severely overfished and food webs there badly deteriorated, on the basis of a low intercept and subsequent decline in the mean trophic level of the landed species. Here we illustrate, in a case study using landings data from the aforementioned ocean regions, that this metric is poorly suited for assessing the state of fisheries or ecosystem health because of confounding effects of selective fishing practices. This study may be relevant to all US fisheries because the US GOM exceeds all regions except Alaska in the amount and value of commercial landings. By comparing these landings data with fisheries independent data from US GOM estuaries, NMFS long-line data, and shrimp fishery by-catch data from the US GOM, we demonstrate that commercial targeting, gear selectivity, and, in the GOM, high landings of shrimps and menhaden, drive the index as previously calculated.

KEY WORDS: Gulf of Mexico, mean trophic level, selective fishing practices

## Los Datos de Captura Pueden Proporcionar Información Errónea en la Determinación del Estado de las Pesquerías y de los Ecosistemas Pesqueros: Reevaluación de un Estudio de Caso en el Golfo de México

El uso de índices para evaluar el estado de las pesquerías y la salud de los ecosistemas es ampliamente aceptado. El nivel trófico promedio (NTP) es un ejemplo de este tipo de índices. Recientemente, se reportó que ecosistemas marinos en el Golfo de México (GM) y en la región del océano Atlántico Estadounidense al sur de la Bahía de Chesapeake, se encuentran sobre explotados y sus redes alimenticias muy deterioradas. Estos reportes se basan en la evaluación del bajo intercepto y la subsiguiente reducción en el NTP de las especies capturadas. Utilizando datos de captura en las zonas oceánicas antes mencionadas, en este estudio de caso ilustramos que el NTP no es la tasa adecuada para evaluar el estado de las pesquerías o para determinar la salud de un ecosistema debido a efectos impredecibles que suceden en prácticas pesqueras selectivas. Este estudio puede ser relevante a toda la pesca en los Estados Unidos de América (EUA) dado a que, con la excepción de Alaska, el GM-EUA sobrepasa a todas las regiones en la cantidad y el monto de la captura comercial. Mediante la comparación de datos de estas capturas con datos independientes de pesquerías recolectados por el GM-EUA en estuarios, el NMFS en pesca con palangre y por el GM-EUA en pesca camaronesa accesorias, demostramos que las metas comerciales, la selección del arte de pesca y especialmente en el GM, las cuantiosas capturas de camarones y sardina lacha, afectan la interpretación e influyen en el índice en la manera en que se calculaba previamente.

PALABRAS CLAVES: Golfo de México, nivel trófico promedio, prácticas pesqueras selectivas

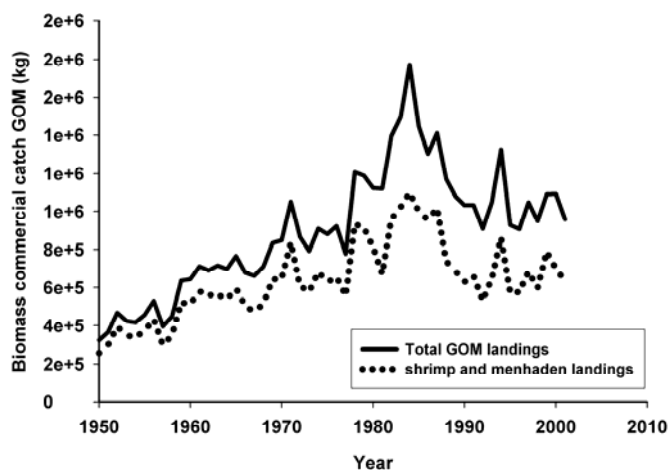
## INTRODUCTION

The movement in support of ecosystem-based management has encouraged the use of indicators of ecosystem status (Link 2005). Among the most high profile and oft-cited indicator of marine ecosystem status is the Mean Trophic Level Index (MTLI, Pauly *et al.* 1998). The use of this index, which represents a weighted average of the trophic level of fisheries landings, began with the pioneering work of Pauly and co-workers (1998), who demonstrated downward trends in the mean trophic level of fisheries landings from a variety of marine ecosystems. Their initial findings have been repeated through subsequent analyses from additional locations (Pauly and Palomares 2005, Pauly *et al.* 2000, Pauly *et al.* 2001). One noteworthy example of a declining mean trophic level comes from analysis of landings data from fisheries operating in the Gulf of Mexico (GOM) and in the Atlantic Ocean south of Chesapeake Bay (Pauly and Palomares

2005); these regions were deemed to be severely overfished, resulting in badly degraded food webs on the basis of a low intercept and subsequent decline in the index. However, fisheries landings in these regions historically have been and are currently dominated by menhaden and several shrimp species, all of which feed at low trophic levels (~2.2 and ~2.6 respectively). Gulf menhaden, *Brevoortia patronus*, supports the second largest U.S. fishery by weight, while penaeid shrimps support the 5<sup>th</sup> largest by value. In Figure 1 can be seen to which extent menhaden and shrimps dominate the total commercial catch in the GOM. We hypothesize that because the MTLI from Pauly and Palomares (2005) is based upon fisheries landings, the MTLI may not be representative of ecosystem status, but has been driven to low values because of the over-representation of shrimp and menhaden in the data. To demonstrate this effect of targeting on the MTLI for the GOM, we have calculated the MTLI for commercial catch

data with and without the targeted low trophic level species, a fisheries independent survey, bycatch data and longline data. We chose this combination of datasets with the following reasoning; first, the effect of targeting can be clearly shown by calculating the MTLI for longline data, which is a selective fishing gear (Bjorndal 1988, Lokkeborg and Bjorndal 1992) that mostly targets higher trophic level species; shrimp or menhaden are invulnerable to this gear type. Once the effect of targeting is demonstrated, the effect of removing the most highly targeted species commercially in the GOM will be evaluated. However, even if excluding shrimp and menhaden increases the MTLI significantly, it does not imply that it is a better representation of ecosystem status. Therefore, we compare both scenarios with survey data, and argue that fisheries independent data are a better representation of ecosystem health. Finally, we calculate the MTLI of bycatch data, mostly to evaluate data that is also not driven by selective targeting, but not as closely associated with the Louisiana estuaries as is some of our survey data.

In summary, we evaluate the possibility that the low MTLI derived from landings data as previously reported by Pauly and Palomares (2005) is driven not by changes in the food web, but by selective commercial targeting, and high landings of low trophic level species.



**Figure 1.** Total commercial fish landings in the Gulf of Mexico (GOM) are compared with the landings of just shrimp and menhaden.

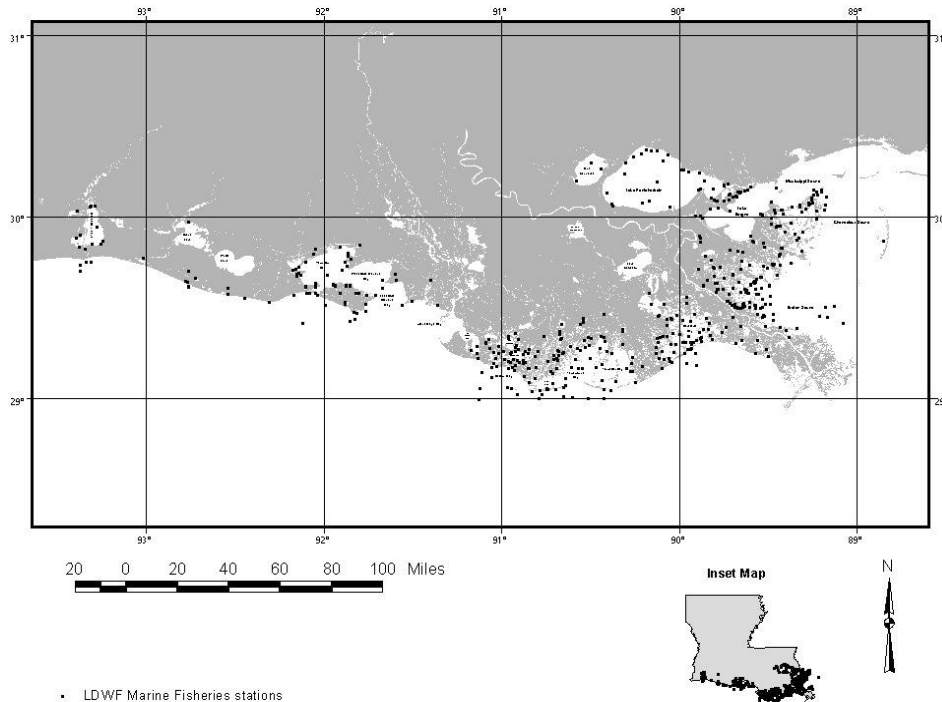
## METHODS

The commercial catch data used are published on the National Marine Fisheries Service website ([http://www.st.nmfs.gov/st1/commercial/landings/annual\\_landings.html](http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html)). Data are available from 1950-2001. We excluded freshwater species that occur in the landings data that are not present in the areas of interest (e.g. carp, frogs), and landings not specified to genus or species. We calculated the MTLI with and without shrimp

(*Farfantepenaeus aztecus*, *Farfantepenaeus duorarum*, *Litopenaeus setiferus*, *Sicyonia brevirostris*, *Pleoticus robustus*, *Xiphopenaeus kroyeri*) and menhaden (*Brevoortia tyrannus* and *B. patronus*) for the GOM and the Atlantic south of Chesapeake Bay, and the GOM alone. We combined the commercial catch data from the GOM and the Atlantic south of Chesapeake Bay next to calculating the MTLI for the GOM alone, because this is the combination of areas Pauly and Palomares (2005) used in their calculation of the MTLI of 'USA only', which we wish to reproduce.

Longline data are from the GOM and were obtained from the NMFS Pascagoula Laboratory (Henwood, NMFS Pascagoula Laboratory, personal communication), data are available from 1995 - 2005. Shrimp bycatch data from the GOM also were obtained from the NMFS Pascagoula Laboratory and are derived from SEAMAP resource surveys (<http://www.seamap.org/>), data are available from 1987 - 2003. The bycatch data from SEAMAP were reported in kilograms per trawling hour. We obtained the estimated number of shrimp trawling hours per year (SEDAR 7 2005), and calculated bycatch in kg/year.

Fishery-independent survey data have been collected by the Louisiana Department of Wildlife and Fisheries (<http://www.wlf.louisiana.gov/>) since 1966 in Louisiana estuaries using a variety of gears. Surveys are still ongoing, we present data including 2006. Figure 2 shows the station locations. At each location in estuaries the surveys use replicated tows of 3.9 m otter trawls against the prevailing current (with 3 mm cod-end liner), replicated hauls of 15.2 m bag seines with 3 mm mesh, and replicated sets of 225 m long by 2.4 m high experimental gill nets with 5, 45 m panels consisting of mesh sizes (cm bar) of 2.5, 3.2, 3.8, 4.4 and 5.1 cm. Trammel nets used are 225 m long by 1.8 m tall, and have three walls. The inner wall is constructed of 4.1 cm bar mesh, and the two outer walls are constructed of 15.2 cm bar. The trammel net is fished by setting it parallel to shore. It is fished as a strike net by running in concentric ever tightening circles around it with a power-boat. Only otter trawls, gills nets and trammel nets are used at stations on the shallow shelf. If weather precludes use of any gear at any station, sampling is rescheduled. All fish and shellfish collected are identified, measured (nearest mm) and weighed (nearest 0.1 g). These methods have remained unchanged over the period of record because of their value as a relative measure of the abundance of species under management. Data are used in stock assessments for recreationally and commercially important finfish species, and for determining the opening day of shrimp seasons. Because each gear is designed to sample different members of the fish and shellfish community with respect to size and habitat affinity, we simply combined weights over all gears over all stations for each species to create the fishery-independent MTLI, calculating the index as described below.



**Figure 2.** Station location of the fisheries independent survey performed by the Louisiana Department of Wildlife and Fisheries since 1966 (source LDWF).

As in previous work (Pauly 1998, Pauly and Palomares 2005; De Mutsert in review), FishBase ([www.fishbase.org](http://www.fishbase.org)) was used to obtain a trophic level for each species reported in the fisheries landings, bycatch and survey data. To calculate the MTLI we used the following equation from Pauly and Palomares (2005):

$$TL_y = \hat{a}_i(TL_i * Y_{yi}) / Y_y$$

where  $TL_y$  = the MTLI in year  $y$ ,  $TL_i$  = the trophic level of species  $i$ , and  $Y_y$  = the catch (in weight) in year  $y$ .

All figures are shown on a scale from 1 to 5, which is the range of trophic levels of all organisms, with 1 representing all primary producers and 5 the apex predators. To test the significance of MTLI slopes and differences in intercepts an ANCOVA in SAS software was used to perform the analyses.

## RESULTS AND DISCUSSION

Figure 3 shows that targeting has a significant effect on the MTLI. Clearly, the longline time series has a significantly higher MTLI than the commercial catch, or any other time series calculated (ANCOVA, intercepts  $p < .0001$ ). This demonstrates that if fishing gear is designed to catch higher trophic level species, it is possible to do so, and in this case the MTLI based upon these catches does not appear to be declining (ANCOVA, slope  $p > 0.05$ ) in the GOM. However, we do not believe that the MTLI derived from longline data

is a true representation of the fisheries ecosystem, but that selective targeting of this gear drives the MTLI to higher values. We believe that the MTLI derived from the complete commercial catch as used in Pauly and Palomares (2005) suffers from the effects of targeting as well.

When we calculated the MTLI for the commercial catch data, we obtained a low initial MTLI (~2.4; Figure 3), similar to results in Pauly and Palomares (2005). This is true whether or not we used combined landings from the GOM and south Atlantic (defined as 'USA only'), or from the GOM alone ('GOM'). The MTLI derived from 'USA only' and from the 'GOM' are almost identical, differing by less than 3% in any year.

However, when we excluded menhaden and shrimp from the commercial catch, the MTLIs calculated under both scenarios have an initial MTLI that is significantly higher (ANCOVA, intercepts  $p < .0001$ ) than with shrimp and menhaden, and similar to other regions where the index has been calculated (~3.0; Pauly *et al.* 2000, Pauly *et al.* 2001, Essington *et al.* 2006).

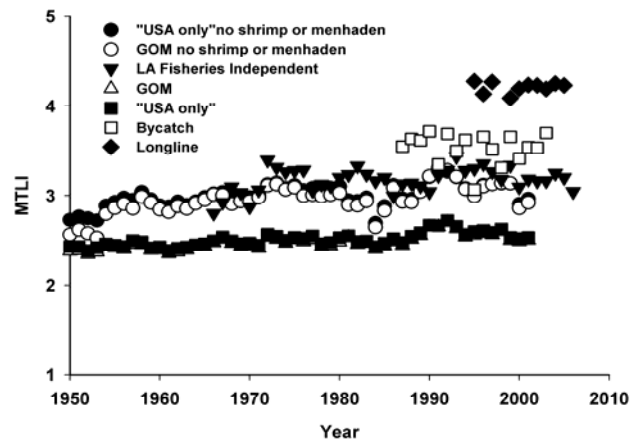
The MTLI derived from survey data closely resembles (ANCOVA, slopes and intercepts  $p > 0.05$ ) that derived from commercial data after landings of shrimp and menhaden were excluded, while it is significantly higher than the commercial catch including shrimp and menhaden (ANCOVA, intercepts  $p < .0001$ ). This demonstrates that commercial targeting of these species not only lowers the MTLI, but also that commercial catch may not reflect ecosystem or food web-scale changes.

Because the fisheries independent survey is purposely

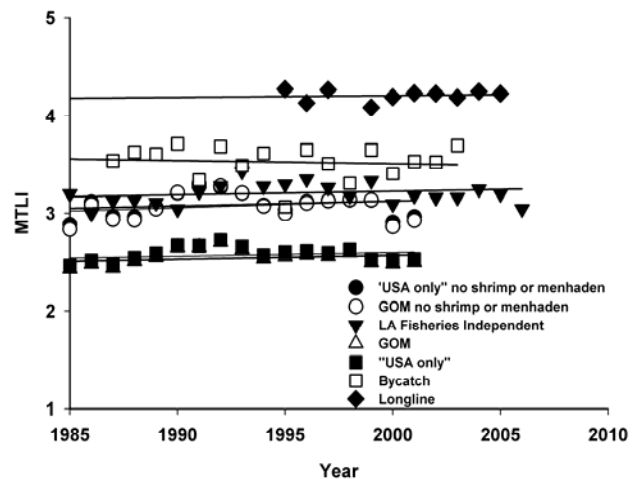
designed to sample over multiple species, size ranges, life history stages, and habitats, we are confident that the MTLI derived from these fisheries independent data is a better representation of the community composition in the ecosystem sampled. When comparing this to the commercial landings data, we recognize that the survey data used here are based upon a smaller area (Louisiana only; Figure 2) than the commercial landings data. Still, this comparison is useful because ~75% of US GOM landings occur in Louisiana (NMFS 2007). Moreover, more than 50% of all U.S. fishery yields have historically been derived from estuarine or estuarine-dependent species (Houde and Rutherford 1993); the fraction is higher in the GOM (Vidal-Hernandez and Pauly 2004). The Louisiana surveys are performed at least monthly at more than 250 locations in estuaries and on the shallow shelf in the northern GOM (~4,000 collections per year) where shrimp and menhaden are abundant, and many of the higher trophic level species that comprise the commercial catches occur in high numbers as juveniles and adults. However, to demonstrate that the fisheries independent survey is not compromised due to restrictions in the spatial extent of sampling locations, we calculated the MTLI based upon bycatch, which is derived from a fishery independent resource survey that is obtained by using a 12.2 m otter trawl to collect samples on the shelf Gulf-wide. Figures 3 and 4 shows that the bycatch derived MTLI is even higher than that derived from the LA survey data (ANCOVA, intercept  $p < .0001$ ). Even though bycatch is not driven by selective targeting, it is also influenced by human decisions and changes in fishing practices (Hall 1996), so we still have more confidence in the MTLI derived from the Louisiana survey data. It is encouraging however, that the bycatch data concur with the survey data in that the MTLI is higher than the index based upon commercial catches.

In Figure 4 we have calculated the trendlines for each time series to visualize the slopes of each index, and highlight the last 20 years to facilitate comparisons with the shorter time series. The calculation of the trendline for each time series is based upon all years available for that time series.

Unlike Pauly and Palomares (2005), we did not find declines in MTLI in any of our calculated time series. While some of the calculations are new to this study (commercial catch without shrimp and menhaden and survey data have positive slopes, ANCOVA,  $p < .0001$ , while the slopes of bycatch and longline data are not significantly different from zero, ANCOVA  $p > 0.05$ ), some were an attempt to reproduce the indices presented in Pauly and Palomares (2005). The 'USA only' and the 'GOM' (including shrimp and menhaden) indices based upon commercial catches have intercepts and positive slopes ( $p < 0.001$ ) that do not differ from one another (ANCOVA,  $p > 0.05$  [slopes and intercepts],  $b = 0.004/\text{year}$ ,  $R^2 = 0.54$  for 'USA only' and 'GOM').



**Figure 3.** Mean Trophic Level Index from 1950-2006. "USA only" is the northern Gulf of Mexico and the Atlantic south of Chesapeake Bay. GOM is the Gulf of Mexico only. Bycatch and longline data are both from the Gulf of Mexico. Overlap can be seen when comparing GOM with USA only, and when comparing the commercial catch without shrimp and menhaden with Louisiana survey data.



**Figure 4.** Mean Trophic Level Index from 1985-2006. Trendlines have been fitted to the data. + indicates a significant positive slope, and significant different intercepts have been indicated with the letters a, b, c and d. There were no significant negative slopes. "USA only" almost completely overlaps GOM.

Similar attempts to reproduce declines in MTLI have failed in other areas (e.g., compare the graphs showing the 'Mediterranean and Black Sea' (Pauly, 1999) with that provided in 2005 by the European Environment Agency (<http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=1848>). Such discrepancies may be attributable to differences in landings data reported by different sources. Pauly and Palomares (2005) used data compiled by the FAO that included some landings from

Mexico, whereas we used data reported by the NMFS. These data do not always agree. We chose to use the NMFS data because collection and management techniques are well described and based upon formal metadata guidelines (The Fisheries Information Network; <http://www.gsmfc.org/fin.html>) as recommended by the NRC (2000), include data reported by state agencies for species not under federal jurisdiction, and are presumed to be the primary source of the FAO data.

As such, we suggest caution when interpreting changes in the mean trophic level over time, and over large geographical areas based upon commercial landings alone. Caution is especially needed if information is not available regarding changes in fishing practices, markets, and data acquisition methods (Essington *et al.* 2006).

Where sufficient data exist, we see value in calculating the MTLI from survey data, because these may not be as susceptible to problems arising from selective targeting and changes in fishing practices. The value of indices derived from fisheries independent data have long been recognized by stock assessment scientists (NRC 1998). Indeed, when we calculated the MTLI from Louisiana survey data, the index has a higher intercept ( $p < 0.001$ ) than the unaltered commercial landings data. The survey data indicate that the MTLI rises slowly over most of the period of record (ANCOVA  $p = 0.009$ ,  $b = 0.005$ ,  $R^2 = 0.20$ ), but may have begun a decline in the mid-1990s (ANCOVA from 1993  $p = 0.0025$ ,  $b = -0.01855$ ,  $R^2 = 0.5417$ ). In this case, we have no reason to believe that targeting and/or overfishing are driving the survey index. Variability and the recent decline in the survey MTLI could be attributed to other factors, such as the degradation of nursery function in coastal Louisiana wetlands. Coastal Louisiana accounts for about 80% of the wetland loss in the continental US (NRC 2006), but commercial landings of species other than gulf menhaden in Louisiana have been increasing over time (Cowan *et al.* In press). In other words, the survey derived MTLI may be reflecting significant changes in the food web of a highly degraded ecosystem, whereas commercial landings do not.

In conclusion, while we recognize the threat of overfishing to the sustainability of fisheries and the ecosystems to which they belong, we question whether the low and declining MTLI for the Gulf of Mexico found in a previous study (Pauly and Palomares 2005) is a true reflection of the fisheries ecosystem, and suggestive of decreasing health and stability of marine food webs. In general, we caution the use of commercial fish landings alone to make statements concerning the state of fisheries and ecosystem health, as these data often are driven by selective targeting, and other human decisions concerning fishing practices. We encourage the development and use of fisheries independent data, as indices like the MTLI can be useful tools if they truly represent community composition.

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