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An evaluation of underlying mechanisms for "fishing down marine food webs"

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Abstract

Since the concept of "fishing down marine food webs" was first proposed in 1998, mean trophic level of fisheries landings (MTL) has become one of the most widely used indicators to assess the impacts of fishing on the integrity of marine ecosystem and guide the policy development by many management agencies. Recent studies suggest that understanding underlying causes for changes in MTL is vital for an appropriate use of MTL as an indicator of fishery sustainability. Based on the landing data compiled by Food and Agriculture Organization (FAO) and trophic information of relevant species in Fishbase, we evaluated MTL trends in 14 FAO fishing areas and analyzed catches of upper and lower trophic level groups under different trends of MTL and found that both the cases of a recovered MTL trend and a generally increasing MTL trend could be accompanied by decreasing catches of lower trophic level species. Further, community structure and exploitation history should be considered in using MTL after excluding species with trophic levels lower than 3.25 to distinguish "fishing-through" from "fishing-down". We conclude that MTL used as an indicator to measure fishery sustainability can benefit from a full consideration of both upper and lower trophic level species and masking effects of community structure and exploitation history.

Key words: mean trophic level, underlying mechanisms, community structure and exploitation history, fishery landings

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1 Introduction

Fishery resources play a critical role in supporting human well-being, from world food security to economic and social development (Halpern et al., 2012). Prolonged heavy fishing pressure and changes in the environment are thought to be the main drivers that result in collapses of many fish populations in the world (Halpern et al., 2008). There is strong evidence that it is difficult to hinder the reverse of downward trends for an already depleted fish stock (Pauly et al., 2002). This calls for the development of indicators that can be easily measured and are effective in monitoring the status of fisheries to avoid being too late to identify fish stock depletion (Jennings, 2005).

The "mean trophic level of fisheries landings" (MTL) was proposed by Pauly et al. (1998) as an indicator for evaluating impacts of fishing, and its use has been supported by several international bodies, including the Convention on Biological Diversity, European Union, and Caribbean Large Marine Ecosystem and Adjacent Project (Foley, 2013). However, it is well known that the indiscriminate use of MTL can lead to misleading or erroneous conclusions in the assessment of impacts of fishing on fish communities (Mutsert et al., 2008; Branch et al., 2010). The overall world fisheries MTL was reported to decline at an alarming rate of 0.1 unit per decade based on FAO's global landing data, which was interpreted as a shift of catches from long-lived and high trophic level predators toward short-lived and low trophic level species (Pauly et al., 1998). On a regional scale, the decline of MTL was also observed in various parts of the world such as Canada (Pauly et al., 2001), Greece (Arancibia and Neira, 2005), Black Sea (Daskalov, 2002), Argentinean-Uruguayan Common Fishing Zone (Jaureguizar and Milessi, 2008), India (Bhathal and Pauly, 2008) and Brazil (Freire and Pauly, 2010). This suggests that the "fishing down marine food webs" (FDMFW) occurred on both global and regional scales.

Recent studies, however, indicate that not all fisheries in the world have the "fishing down marine food webs" effects (Essington et al., 2006; Branch et al., 2010). Instead, the observed changes in MTL were considered resulting from the following four alternative scenarios of fisheries including: "fishing-down"

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fisheries defined as serial replacement of upper trophic level fisheries with lower trophic level fisheries as the former become depleted to economic extinction; "fishing-through" fisheries defined as continuous addition of low trophic level fisheries, rather than a decline of high trophic level fisheries; "based-on-availability" fisheries which target easily accessible and abundant species first before expanding to less accessible stocks with lower abundance; and "increase to overfishing" fisheries with all species being fished with a growing intensity over time until depleted (Branch et al., 2010). The "based-on-availability" scenario has received little supporting field evidence, so there are three primary mechanisms that could be driving the observed change of MTL. The "fishing-down" and "fishing-through" scenarios would result in a decline of catch MTL, while the "increase to overfishing" scenario would not affect catch MTL, but could result in a complete ecosystem collapse (Branch et al., 2010). Thus, a careful examination of mechanisms that drive temporal changes in MTL of catch data is essential for a comprehensive understanding of the impacts of fishing on ecosystems and for developing effective management practices (Foley, 2013). However, few studies have been done to explicitly evaluate these mechanisms that result in observed changes in MTL on a global and local scale.

The mechanism of changes in MTL may be evaluated by a separate examination of temporal dynamics of upper and lower trophic levels of fisheries catches. Pauly and Watson (2005) proposed that a cut-off value of 3.25 ($^{3.25}$MTL) in calculating MTL to emphasize changes in the relative abundance of medium and high-TL species which are often targeted by commercial fisheries. $^{3.25}$MTL is also widely used to eliminate impacts of the voluntary addition and expansion of low trophic level fisheries, which distinguishes "fishing-through" from "fishing-down" (Bhathal and Pauly, 2008; Alleway et al., 2014). This index, however, may fail to measure the magnitude of fishing impacts or the rate at which marine ecosystems are being altered by fishing in areas with a unique community structure and exploitation history.

In this study, we evaluated the mechanism of changes of MTL in global and local scales by examining the temporal dynamics of both upper and lower trophic level fishery catches. Furthermore, we evaluated the effects of community structure and exploitation history on the usefulness of using $^{3.25}$MTL to distinguish "fishing-through" from "fishing-down". The goal of this study is to improve our understanding of mechanisms driving temporal changes in MTL which, although being criticized, is still widely used in monitoring and evaluating impacts of fishing on ecosystems.

2 Materials and methods

2.1 *The data set*

Catch data were obtained from the FAO (http://www.fao.org/fishery/Statistics/global-Capture-production/query/en). Trophic levels (TL) of related species were obtained from the "International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP) Table" of FishBase (http://www.fishbase.org/report/ISSCAAP/ISSCAAPSearchMenu.php). For those species without trophic levels in Fishbase, the trophic information was sourced from their relevant family. Since we focused on the impacts of fishing activities on fishery resources, "marine fishes not identified" and the categories of aquatic plants, miscellaneous aquatic animals, miscellaneous aquatic animals products, whales, seals and other aquatic mammals in ISSCAAP were not included in this analysis.

2.2 *Analysis*

The mean trophic level of fisheries landings in year i (MTL_i) was estimated using the following method developed by Pauly et al. (1998):

$$MTL_i = \frac{\sum_{ij} TL_j Y_{ij}}{\sum Y_{ij}}, \tag{1}$$

where Y_{ij} is the landings of species j in year i; and TL_j is the trophic level of species j.

According to Essington et al. (2006), decline in MTL higher than 0.15 units is evident of ecologically significant fishing down the food web. To reduce the possibility of overestimating "fishing down the food web", we identified "fishing down the food web" as any instance in which MTL exhibited a decline by at least 0.15 units for more than 10 years in this study. Regression analyses were preformed to quantify changes in MTL with time in each area, and the goodness of fit was evaluated using both the coefficient of determination R^2 and statistical significance of trends.

Fishing-in-balance (FiB) index is often used together with MTL in the assessment of impacts of fishing on fisheries ecosystems (Pauly and Palomares, 2005). The FiB index can be used to indicate whether fisheries are balanced in ecological terms (Pauly et al., 2000). The FiB index remains constant if changes in MTL match "ecologically appropriate" changes in landings. An increase in FiB index indicates expansion of a fishery or that bottom-up effects have occurred. A large decrease in FiB index may indicate that fisheries remove so much biomass from the ecosystem that its functioning is impaired (Pauly and Palomares, 2005). The FiB index in year i is defined as

$$FiB_i = \lg\left[Y_i\left(\frac{1}{TE}\right)^{TL_i}\right] - \lg\left[Y_0\left(\frac{1}{TE}\right)^{TL_0}\right], \tag{2}$$

where Y_i corresponds to landings in year i; TL_i is the mean trophic level of the landings in year i; TE is the transfer efficiency, here set at 0.1 (Pauly and Christensen, 1995); and 0 refers to any year used as a baseline to normalize the index (Cury et al., 2005). We used 1950 as the baseline year in this study.

The underlying mechanisms for "fishing-down" and "fishing-through" hypotheses were significantly different. Although "fishing-down" hypothesis predicts continuous declines in catches of upper trophic levels and "fishing-through" hypothesis predicts stable or increasing catches of upper trophic levels, both hypotheses predict an increase in fishes of lower trophic levels for a decrease in catch MTL (Essington et al., 2006). We calculated the catches of both upper and lower trophic levels of fishes during the period of decline, using the MTL of the total catch at the onset of the decline as the dividing point between the high and low trophic level groups. In addition, considering that both successful fishery management and depletion of low trophic levels can lead to a recovering MTL trend. We also continued to partition the total catches for each FAO area into upper and lower trophic levels and described the trends in catches of upper and lower trophic levels when MTL reversed to a significant upward trend (i.e., changes in MTL higher than 0.15 units or more from the year of minimum MTL to the year of 2010) after the "fishing down the food web" occurred. For areas in which MTL displayed a generally increasing trend throughout the study period, we partitioned the total catch into upper and lower trophic levels using MTL of total catch in the baseline year (i.e., 1950). We then fitted a linear regression of lg (*catch*) versus year t for each group to test for possible significant changes over time.

In order to identify community structure in an ecosystem, all the exploited fish species/groups were grouped into three trophic categories (Jaureguizar and Milessi, 2008): herbivores, detritivores and omnivores (TrC1, *TL*=2.0–3.0); mid-level carnivores (TrC2, *TL*=3.01–3.50); and high-level carnivores and top predators (TrC3, *TL*>3.51). In addition, considering that trophic level of cephalopods was relatively high, we made it a separate category. Combining the categories of crustaceans and mollusks (except for cephalopods), we had six categories of exploited species in this study. For testing impacts of exploitation history on the usefulness of $^{3.25}$MTL as an indicator to track changes of medium and high trophic level species in the underlying ecosystem, following Pauly and Watson (2005), MTL values were computed twice for each study area during 1950–2000: one for the entire catch and the other for catch excluding all the species (groups) with *TL*<3.25. Temporal trends in both MTL and $^{3.25}$MTL were evaluated using a linear regression analysis.

3 Results

3.1 *Trends in MTL from global marine catches*

Figure 1a is a summary of global marine catches in the Atlantic, Indian and Pacific Oceans from 1950 to 2000. The landings increased gradually from 14.86 million tonnes in 1950 to a maximum weight of 73.74 million tonnes in 1996. These however changed to a declining trend and fell to 65.30 million tonnes in 2010. The global MTL of the landings declined initially at a rate of 0.057 per decade, changing from 3.50 in 1955 to the lowest value of 3.21 in 1986 (R^2=0.48, P<0.05). A dip occurred in the 1960s and early 1970s because of large increases in Peruvian anchovy (*Engraulis ringens*) landings. After the collapse of the Peruvian anchovy fishery during 1972–1973, the MTL still followed a declining trend from 1973 to 1986 before it gradually increased to 3.37 in 2010 (Fig. 1b). The FiB index increased rapidly from the baseline 0 in 1950 to 0.44 in 1973 (Fig. 1c), suggesting that the decline in MTL has indeed been compensated by increased catches as a consequence of a geographic expansion of the fishery. Afterwards, FiB declined followed by an increase to stabilize at values around 0.54.

Regional analysis showed that the phenomenon of "fishing down marine food webs" occurred in ten of the fourteen FAO fishing areas, of which Northwest Atlantic, Northeast Atlantic, Southwest Atlantic and Southwest Pacific showed a significant declining trend in both MTL and FiB index (Table 1). MTL declined at a rate of 0.24 per decade in the 1965–2010 for the Northwest Atlantic, 0.064 per decade in the 1969–1992 for the Northeast Atlantic, 0.12 per decade in the 1996–2010 for the Southwest Atlantic, and 0.16 per decade in the 2000–2010 for the Southwest Pacific. In contrast, the other six areas showed no significant change or increases in FiB index when fishing down the food web was occurring. Specifically, MTL declined at a rate of 0.040 per decade in the 1982–2010 for the Eastern Central Atlantic and 0.065 per decade in the 1964–2010 for the Eastern Central Pacific. For the remaining four areas, MTL first declined at a speed of 0.17 per decade in 1963–1988 for the Northwest Pacific, 0.18 per decade in 1952–1985 for the Southeast Pacific and 0.08 per decade in 1952–1987 for the Eastern Indian Ocean, and all of them later reversed to an upward trend accompanying by an increasing trend of FiB index. However, after declining at a rate of 0.18 per decade in 1950–1963 and an immediate recovery in 1964–1972, MTL in the Southeast Atlantic stabilized around 3.44 since 1972, and the FiB index strongly decreased from 1972 to 2010 (Table 1). In contrast, MTL in the Western Central Atlantic, Western Indian Ocean, Northeast and Western Central Pacific generally increased over the past six decades (Table 1).

3.2 *Identification of possible underlying mechanisms for observed MTL trends*

Considering catches in the Atlantic, Pacific and Indian Oceans together, we fitted statistical models to time series of catches of both upper and lower trophic level species, and found that both upper (R^2=0.85, P<0.05) and lower trophic level catches (R^2=0.85, P<0.05) increased from 1955 to 1986, implying the occurrence of "fishing-through" phenomenon (Fig. 1d). We further

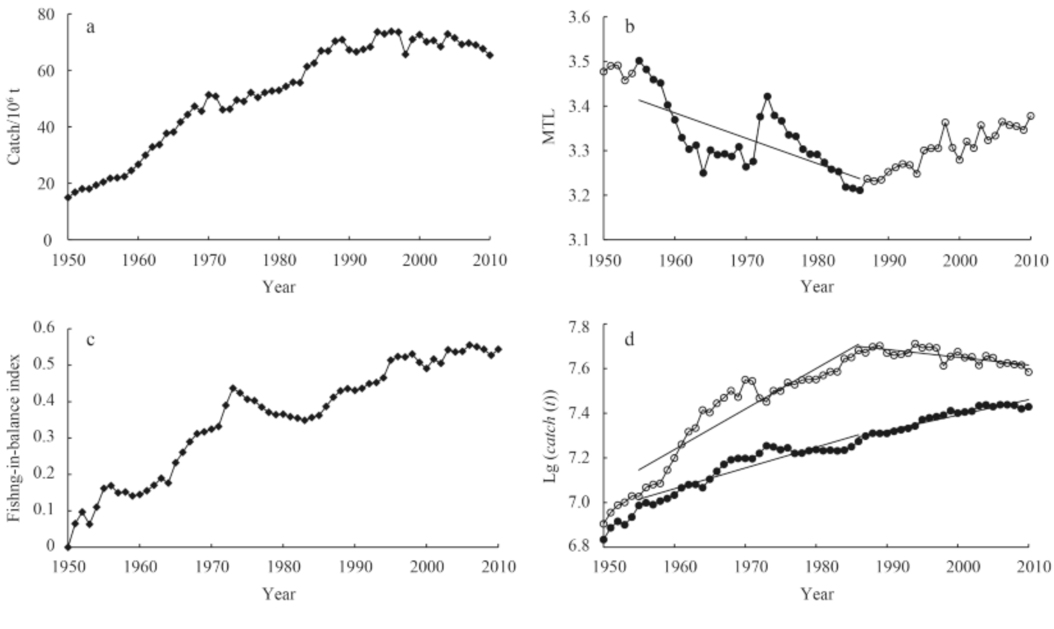

Fig. 1. Temporal trends in the Atlantic, Indian and Pacific Oceans, from 1950 to 2000, for catch (million tonnes) (a); mean trophic level of fishery landings (b); Fishing-in-Balance (FiB) index (c); and time series of log-transformed catches of upper (●) and lower (○) trophic levels (d).

Table 1. Change rate of catch MTL and corresponding change in FiB index, catch of upper and lower trophic level species in the 14 fishing areas of Atlantic, Indian and Pacific Oceans

Geographical entity	Year of regression	MTL decline speed/per decade	Change in FiB index/ per decade	Change in upper trophic level catch/per decade	Change in lower trophic level catch/per decade	Year of regression	MTL recovery speed/per decade	Change in FiB index/ per decade	Change in upper trophic level catch/per decade	Change in lower trophic level catch/per decade
Northwest Atlantic	1965–2010	–0.24	–0.30	–0.23	–0.021					
Northeast Atlantic	1969–1992	–0.064	–0.085	–0.070	no clear trend	1992–2010	0.066	no clear trend	no clear trend	–0.11
Western Central Atlantic	1950–2010	increasing trend	increasing trend							
Eastern Central Atlantic	1982–2010	–0.040	no clear trend	0.025	0.063					
Southwest Atlantic	1996–2010	–0.12	–0.19	–0.057	no clear trend					
Southeast Atlantic	1950–1963	–0.18	0.16	0.15	0.43	1963–1972	0.68	0.93	0.62	no clear trend
						1972–2010	no clear trend	–0.088	–0.082	–0.12
Western Indian Ocean	1984–2010	increasing trend	increasing trend							
Eastern Indian Ocean	1952–1987	–0.080	0.16	0.21	0.27	1987–2010	0.070	0.21	0.17	0.11
Northwest Pacific	1963–1988	–0.17	no clear trend	no clear trend	0.25	1988–2010	0.090	0.078	0.12	–0.068
Northeast Pacific	1950–2010	increasing trend	increasing trend							
Western Central Pacific	1950–1985	increasing trend	increasing trend							
Eastern Central Pacific	1964–2010	–0.065	0.043	0.096	0.12					
Southwest Pacific	2000–2010	–0.16	–0.34	–0.21	no clear trend					
Southeast Pacific	1952–1985	–0.18	0.20	0.075	0.46	1985–2010	0.084	no clear trend	0.25	no clear trend

Note: All the values in the table reached significant level (P<0.05). "No clear trend" in the table means the corresponding P value was not significant. "Increasing trend" means MTL showed significant upward trend.

identified the above ten FAO areas which documented a clear "fishing down the food webs" phenomenon. Of these, upper trophic level catches increased in the Southeast Atlantic, Eastern Indian Ocean, Eastern Central Pacific and Southeast Pacific and showed no trend in the Eastern Central Atlantic and Northwest Pacific, supporting the "fishing-through" hypothesis (Table 1). Whereas, in the North and Southwest Atlantic and Southwest Pacific, upper trophic level catches decreased significantly, indicating an occurrence of fishing-down phenomenon. In addition, instead of presenting an upward trend, lower trophic level catches showed no trend (Table 1).

Notably, MTL for the overall Atlantic, Indian and Pacific Oceans reversed to a clear and steady upward trend after experiencing a significant decline (Fig. 1b). We calculated the catch of upper trophic level and lower trophic level taxa during the period of recovery, using the dividing point in the above "fishing-down/through" test, and found that lower trophic level significantly declined (R^2=0.58, P<0.05) while upper trophic level catches steady increased (R^2=0.92, P<0.05) (Fig. 1d). We continued to identifying the above four FAO areas in which MTL showed significant recovery trend. Although upper trophic level for all the four instances increased or showed no trend, lower trophic level significantly declined in the Northeast Atlantic and Northwest Pacific (Table 1).

For the Western Central Atlantic, Northeast and Western Central Pacific, and Western Indian Ocean, MTL displayed a generally increasing trend with large fluctuations (Table 1). We calculated the catch of upper trophic level and lower trophic level taxa during the entire period, and found that both upper and lower trophic level catches increased in the Western Central Pacific and Western Indian Ocean, with a significant trend (Fig. 2). However, for the Western Central Atlantic, lower trophic level catches showed a strong declining trend since 1984 (R^2=0.53, P<0.05) and upper trophic level catches also gradually decreased from 1998 to 2010 (R^2=0.67, P<0.05). A declining trend of lower trophic level catches was also observed in the Northeast Pacific since 1987 (R^2=0.46, P<0.05) (Fig. 2).

3.3 *Influence of exploitation history on $^{3.25}$MTL to measure changes in ecosystem*

In the Southwest Atlantic Ocean, marine catch peaked in 1997, and then fluctuated between 1.7 and 2.5 million tonnes (Fig. 3a). Catches in the Southwest Atlantic Ocean mainly consisted of TrC3 and cephalopods (Fig. 3a). As one of the most important fishing areas for cephalopods, cephalopods had been increasingly exploited since the 1980s. MTL decreased at a speed of 0.12 per decade in 1996–2010 (R^2=0.84, P<0.05). However, $^{3.25}$MTL initially increased and then became stable after the 1970s

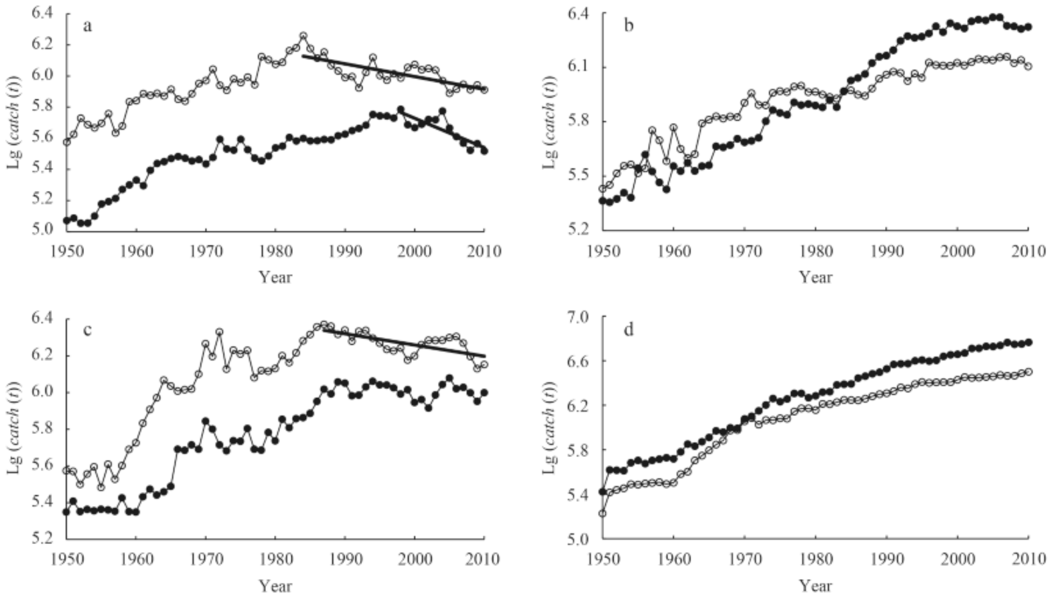

Fig. 2. Time series of log-transformed catches of upper (●) and lower (○) trophic levels during 1950–2010: Western Central Atlantic (a), Western Indian Ocean (b), Northeast Pacific (c), and Western Central Pacific (d).

with no obvious descending trend being observed (Fig. 3b). When both cephalopods and species with trophic level lower than 3.25 were excluded from the analysis, MTL fell steadily since the middle 1990s (R^2=0.80, P<0.05). The phenomenon of "fishing down marine food webs" appeared to occur in the Southwest Atlantic Ocean (Fig. 3c).

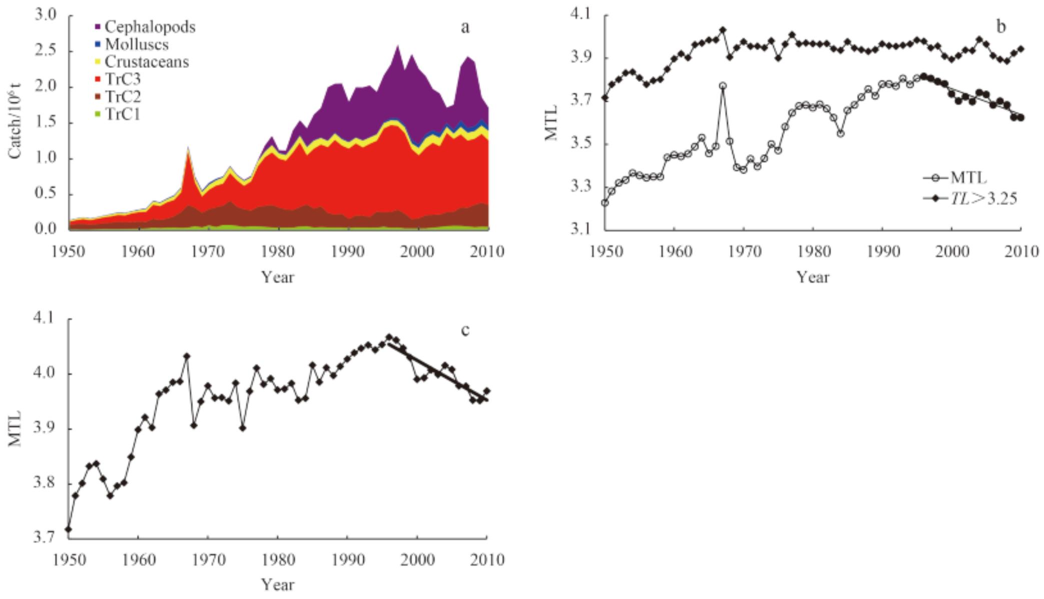

Fig. 3. Trends in marine fisheries landings and MTL in the Southwest Atlantic Ocean from 1950 to 2010. a. Catch profile, b. MTL and $^{3.25}$MTL, and c. MTL with the exclusion of both cephalopods and species whose TL lower than 3.25.

4 Discussion

Fishing activities can greatly change fish community in a relatively short time, affecting the structure and functioning of marine ecosystem (Scheffer et al., 2005; Ainley and Blight, 2009). The choices of fish species targeted in fisheries or/and fish community structure can be reflected in the composition of fisheries landings. MTL of fisheries landing provides an indicator of catch composition in estimating the potential impacts of fisheries on the ecosystem. It has been widely used to assess the impacts of fishing and the efficiency of fishery management despite of its problems identified in many studies (Rochet and Trenkel, 2003; Fulton et al., 2005; Pauly and Watson, 2005; Foley, 2013). Using updated trophic level estimates from fishbase, we calculated MTL of fisheries landings for the Atlantic, Pacific and Indian Oceans, and found MTL in the Atlantic, Pacific and Indian Oceans appeared to decrease at a rate approximately 0.057 per decade in 1955–1986, and then reversed to a rising trend. The above MTL trend is in accordance with the recently reported MTL from global fishery landings (Tacon et al., 2010; Butchart et al., 2010; Branch et al., 2010).

It is necessary to explicitly evaluate the mechanisms of "fishing down marine food webs" because each scenario may correspond to a specific sequence of fishery evolution over time and the underlying ecology associated with different scenarios is remarkably different (Branch et al., 2010; Foley, 2013). To our knowledge, the study of Essington et al. (2006) and Litzow and Urban (2009) are the only two published studies to explicitly evaluate declining catches of upper trophic level taxa during the instances of declining MTL of fisheries landings. However, neither of the above two studies explicitly evaluated catches of low trophic level species. Our analysis showed that both high and low trophic level catches increased during the time period that global MTL was declining, confirmed Essington et al. (2006) findings that "fishing-through" marine food webs is prevalent among marine ecosystems worldwide. We further examined ten FAO fishing areas that showed evidence of substantial fishing down the food web by fitting linear regression to time series of catches of lower and upper trophic level groups. We found that the North and Southwest Atlantic and Southwest Pacific had the "fishing-down" phenomenon, but were not accompanied by an increasing catch of low trophic level species. Although under the "fishing-down" scenario, a decrease in the abundance of top predators would cause an increase in abundance of lower trophic level species in the ecosystem due to the decrease in the predation pressure (Gascuel, 2005). The collapse of high trophic level predators may result in a dramatic transfer of fishing intensity towards the lower trophic level species (Foley, 2013). Just as the cases occurred in the Northwest Atlantic, a collapse of the gadoid fishery in the 1970s resulted in a dramatic transfer of fishing power towards the lower trophic level herring, and result in the subsequent collapse of the herring fishery (Frank et al., 2005). The collapse of high trophic level predators should be viewed as a warning to managers to prevent the transfer of fishing effort towards lower trophic level species (Foley, 2013).

Despite the fact that MTL is expected to recover under successful ecosystem-based management, our analysis in the global and Northwest Pacific Oceans indicate that the recovery of MTL trends may be accompanied by decreasing catches of lower trophic level species. The mechanism of change in MTL in the global and Northwest Pacific Oceans belonged to the "fishing-through" scenario, because a primary characteristic of "fishing through marine food webs" is an initial high trophic level fishery followed by the sequential addition of lower level groups into the fishery (Essington et al., 2006). Although this strategy would not lead to the collapse of upper trophic level predators, lower trophic level species may likely be subject to overexploitation due to the higher exploitation rate and greater sensitivity to environmental changes, and leading to overfished populations. According to Pinsky et al. (2011), patterns of vulnerability in the ocean are dramatically different from those on land, and that both small and large fishes are vulnerable to collapse, and low trophic level species even collapsed twice more likely compared to those for high trophic level species. Thus we suggest to interpret with cautious for the areas showing a recovered MTL trend after occurring of "fishing-through" pattern and identify whether environmental factors or heavy fishing pressure lead to the decreasing trend of lower trophic level taxa so that to prevent the collapse of total biomass.

It is important to note that no decrease in the MTL does not necessarily indicate that fisheries have been properly managed. By comparing upper and lower trophic level catches in the remaining four FAO fishing areas with generally increasing or steady MTL trends, we found that lower trophic level catches in both Western Central Atlantic and Northeast Pacific substantially declined with a gradual increase of catch MTL. In fact, with the development of fishing industry, there were about 54% of fish stocks overfished in the Western Central Atlantic in 2009 (FAO, 2011), two low trophic level species Gulf menhaden (*Brevoortia patronus*, *TL*=2.19) and Atlantic menhaden (*Brevoortia tyrannus TL*=2.25) were the main commercial fish species in this area. Catch of Gulf menhaden in 2010 only reached 43% of the peak value in 1984, and Atlantic menhaden also showed a similar trend as the Gulf menhaden with landings decreasing continuously since 1981 (FAO, 2011). Similarly, lower trophic level Alaska pollock (*Theragra chalcogramma*) declined sharply as a result of reduced recruitment in the late 1980s which further confirmed that an increasing MTL could be accompanied by a declining catch of lower trophic level groups (FAO, 2011). To make a comprehensive evaluation and reduce the risk of erroneous conclusion regarding the impacts of fisheries, further analyses to evaluate the status of lower trophic level fish species are needed. Furthermore, in the Southeast Atlantic Ocean, catches for both upper and lower trophic levels declined significantly while catch MTL was almost steady, which might result from the fishery development similar to the "increase to overfishing" scenario.

Since the study of "Fishing down Marine Food Webs" was published in 1998, evaluation of temporal changes in MTL has been the focus of many studies (Branch et al., 2010; Tsikliras et al., 2015). The decrease of MTL for fisheries landings tends to be closely related to the increase of fishing intensity (Pauly et al., 1998). Meanwhile, MTL may also be affected by the behavior of fishermen and market (Essington et al., 2006; Sethi et al., 2010). When fishing efforts transfer to invertebrates with a high trophic level such as cephalopods, "fishing-down" effect tended to be masked. In fact, the declining catch in many traditional fisheries have led to increased effort to develop the potential of non-traditional species, especially invertebrates such as cephalopods. World cephalopod fisheries have developed rapidly in recent decades, the share of cephalopods in world fish trade was almost 3% by value in 2012 (FAO, 2012). Cephalopods are short-lived ecological opportunists, their populations were closely associated with the variability of environment (Pecl and Jackson, 2008; Coll et al., 2013). There is also evidence that the abundance of cephalopods have increased greatly in areas where there has been overfished of traditional demersal species (Caddy and Rodhouse, 1998). Although $^{3.25}$MTL can eliminate impacts of low trophic level species whose biomass tends to vary widely in response to environmental factors, this index fails to exclude cephalopods whose trophic levels are relatively high and stock abundance is largely environmentally driven. The Southwest Atlantic is one of the most important fishing areas for cephalopods, catches of cephalopods in this area have increased significantly since the 1980s (FAO, 2011), which completely masked the underlying decreasing trend in $^{3.25}$MTL. This suggests that community structure should be taken into consideration when we evaluate for the occurrence of the "fishing down marine food webs" phenomenon.

Trophodynamics plays an important role in the development of an ecosystem-based management for fisheries and biodiversity conservation (Cury et al., 2005). The official data on fisheries catches have been widely used for examining the status of the exploited marine resources (Kleisner et al., 2013). Despite of concerns about the effectiveness of MTL as an indicator of ecosystem structure (Caddy et al., 1998; Mutsert et al., 2008; Branch et al., 2010), MTL uses readily available data to provide a quick and easy glimpse of ecosystem dynamics under fisheries exploitations, and patterns in MTL are useful in understanding how fisheries change over time, which is relevant to recent suggestions that a greater focus is required on how components of ecosystems are fished in relation to one another (Alleway et al., 2014). Our analysis indicates that special attention should be paid to lower trophic level species when interpreting fishing up marine food webs. In addition, to monitor fishery sustainability with distinct community structure and exploitation history, MTL should be used as an initial tool to determine trends, and a more comprehensive suite of ecological indicators is needed to capture ecosystem dynamics.

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