



Spatio-Temporal Declines in Philippine Fisheries and its Implications to Coastal Municipal Fishers' Catch and Income

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The problem of overexploitation in global fisheries is well-recognized. However, published assessment of fisheries spatio-temporal trends at the national scale is lacking for many high biodiversity developing countries, which is problematic since fisheries management is often implemented at the local or national levels. Here, we present the long-term spatio-temporal trends of Philippine fisheries production based on the landed national fish catch data (1980–2012) and fishers' interviews. We found that the total Philippine fish catch volume (Metric Tons MT) of most capture fisheries throughout the country has either stagnated or declined over the last three decades. The decline is even more prominent when evaluating fisheries trends at the provincial level, suggesting spatial serial depletion of the country's fisheries. In contrast, the total Philippine fish catch value (US Dollars US\$ or Philippine Pesos PHP) has continued to increase over time, despite the declining fish catch volume. However, local municipal fishers are experiencing both low fish catch and income, contributing to observable poverty in many coastal communities in the Philippines. The various stakeholders of Philippine fisheries need to recognize the depleted state of Philippine fisheries, and learn from various experiences of collapsed and recovered fisheries from around the world, in order to recover the Philippines' capture fisheries. Lessons from the literature on collapsed fisheries offer the following options for recovery: (1) regulate or reduce fisheries exploitation and other human activities impacting the fisheries to allow fisheries to rebuild or recover, (2) enforce effective networks of marine reserves, (3) engage fishers, consumers, and other stakeholders in fisheries management, (4) improve fisheries science, monitoring, and management capacities, and (5) provide alternative livelihood, skills, and improved education to fishers and their families.

Keywords: fish catch data, fishers' economics, fisheries management, fisheries production, overfishing

INTRODUCTION

The state of global fisheries is continuously declining, with catch rates falling since the 1980's (Pauly et al., 2002). Despite this declining trend in fisheries production, global fishing effort has been continuously increasing (Anticamara et al., 2011). The world's fisheries have resorted to geographic, bathymetric, and taxonomic expansion to cover for declining catches in overexploited fishing grounds (Pauly, 2009). Catches for most trophic levels are still rising, potentially contributing

to increasing fisheries collapse (Branch et al., 2010). To date, the global catch biomass of large predatory fish is estimated to be between 10% (Myers and Worm, 2003) and 60% (Juan-Jorda et al., 2011) of pre-industrial fishing levels, with most stocks fully-exploited, limiting further expansion of these important fisheries. Furthermore, FAO (2012) reported that in 2009, 57.4% of global fish stocks were fully-exploited, 29.9% were overexploited, and only 12.7% were non-fully exploited.

Monitoring and managing fisheries status throughout the globe is essential in maintaining their sustainability, or, in the case of depleted fisheries, facilitating their recovery (Pauly, 2009). Fisheries monitoring and management is typically carried-out at the national or regional level, most of which is being done in developed parts of the world such as North America, Oceania, and parts of Europe (Musick et al., 2000; Jelks et al., 2008). However, more attention must be given to developing nations that exhibit high marine biodiversity and increasing fish catch (i.e., suggesting increasing fishing activity), but often report patchy fisheries data and analysis to FAO or the scientific literature (i.e., data poor countries; Worm and Branch, 2012).

The Philippines, a nation considered to be a major hotspot of marine biodiversity (Roberts et al., 2002), currently lacks quantitative analysis on the long-term, spatio-temporal trends in its national fisheries production. Comprehensive national-scale studies on the trends of Philippine fisheries exist, but focused on particular fisheries sub-sectors (e.g., artisanal fisheries; Muallil et al., 2014a,b), policy and management (Briones, 2007), or total national production only (Sadovy, 2005). Currently, the Bureau of Fisheries and Aquatic Resources (BFAR) in the Philippines is the authority on monitoring the status and productivity of Philippine fisheries. However, the annual Fisheries Profile publications produced by BFAR (accessible at: <http://www.bfar.da.gov.ph/>, accessed 1 August 2015) typically review only short-term trends in fisheries production (i.e., changes in fisheries production from the past 2 or 3 years).

The lack of long-term analysis on Philippine fisheries is surprising, considering the socio-economic importance of fisheries and fishing activities to the country. The Philippines is among the top 15 nations in global marine fisheries capture production (FAO Fisheries Aquaculture Department, 2014), and many Filipinos depend on fish products for both food and livelihood—i.e., Filipinos derive an estimated 43% of their animal protein diet from fish and fish products (FAO, 2001), and over 1.6 million Filipinos were employed in fisheries-related occupations based on 2011 data (BFAR, 2011). The demand for fish products will only increase with time, as the Filipino population has been growing at an average rate of 1.9% from 2000 to 2010, with 2010 population estimates to be at over 92.3 million individuals (NSO, 2014). Thus, there is a great need to examine the Philippine's fisheries trends and its possible implications, in order to help drive science or data-based decision-making in the management of the nation's fisheries.

This study presents the most recent spatio-temporal analysis of Philippine fisheries production based on landed national fish catch and fishers' interview data. The objectives of the study are the following: (1) to quantify the spatio-temporal trends in Philippine fisheries production from 1980 to 2012; (2) to

present the estimates of fishers' fish catch and income from five Philippine fishing provinces; and (3) to explore options and insights for improving the science and management of Philippine fisheries through a literature review focused on the most recent research on fisheries status assessments and recommendations for declining fisheries.

METHODS

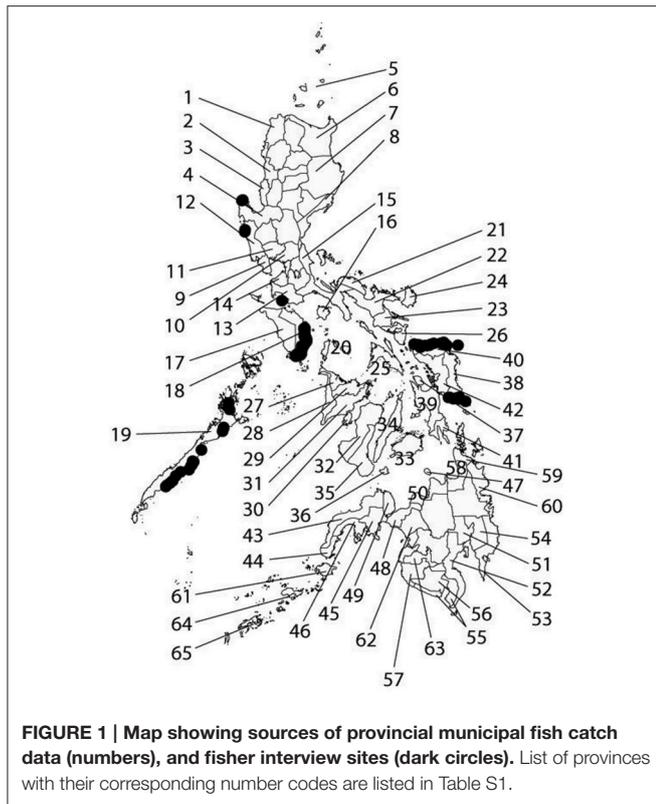
Spatio-Temporal Trends in Philippine Fisheries Production

To analyze the long-term, spatio-temporal trends in Philippine fisheries, we obtained online fisheries data from BFAR, the Philippine government institution, which currently collects and maintains the most complete and up-to-date national database on Philippine fisheries production. However, the online data provided by BFAR is strictly fisheries-dependent (i.e., based on fish catch or landings). Relying solely on catch data to assess fisheries has been criticized as being misleading in estimating the actual status of fish stocks (Branch et al., 2011). Nevertheless, for developing countries such as the Philippines (which lacks the infrastructure and funding to consistently conduct expensive national-scale fisheries-independent surveys), monitoring fish catch data is often the only feasible method of assessment and most readily-available data source (Pauly et al., 2013). In addition, Froese et al. (2012) showed that fish catch data are consistent with trends in biomass data of fully-assessed stocks (i.e., those stocks assessed by fisheries-independent methods), refuting claims on the limited usefulness and misleading nature of fisheries-dependent data.

We also obtained Philippine national fisheries data from BFAR's annual Fisheries Profile publications, from 1980 to 2012 (accessible at: <http://www.bfar.da.gov.ph/>, accessed 1 August 2015). Each annual Fisheries Profile publication contains information on the country's total fisheries production and trade of aquatic resources and top fisheries products for that year. Philippine fisheries data for the years 2013 and 2014 are not yet available to date.

We plotted the temporal trends (from 1980 to 2012) of Philippine fisheries production volume (fish catch in Metric Tons or MT) and value (converted from Philippine Pesos PHP to US Dollars US\$; conversion rate was 43.57 PHP = 1 US\$ as of 5 Aug 2015), for total national production (i.e., all fisheries sectors combined), and production per sector (i.e., commercial fisheries sector, marine municipal fisheries sector, inland municipal fisheries sector, and aquaculture sector). We also examined the mean (\pm standard error SE) fisheries production between successive decades—i.e., 1980–1989, 1990–1999, 2000–2009, and 2010–2012 (henceforth referred to as the 1980's, 1990's, 2000's, and 2010's, respectively)—using one-way ANOVA and Tukey's *post-hoc* analysis.

We then focused our subsequent analysis on the spatio-temporal trends in the marine municipal fisheries sector. We extracted data on marine municipal fisheries fish catch landings (in MT) from the CountrySTAT Philippines database (accessible at: <http://countrystat.psa.gov.ph/>, accessed 1 August 2015), which



sources fish catch data from the Bureau of Agricultural Statistics. Fish catch data is presented as total sum per province. The goal of this analysis is to determine the contributions of each province to Philippine fisheries, and whether the marine municipal fisheries per province showed signs of increasing or decreasing production from 1980s to date. Provinces included in the analysis are shown in **Figure 1**. Province names corresponding to each province code are shown in Table S1.

Status of Municipal Fishers' Catch and Income

To present the status of Philippine fisheries at the level of the fishers themselves, we interviewed a total of 470 coastal municipal fishers from 84 coastal villages or *barangays* belonging to 17 municipalities throughout the Philippines (**Figure 1**). Here, we focused our analyses on the 470 fishers from the municipal marine fisheries sector, due to the following reasons: (1) majority (over 90%) of the fishers in the villages that we visited were coastal municipal fishers (i.e., municipal waters defined as 15 km away from the mainland as defined by the Philippine Republic Act 8550) and only few were commercial and off-municipal water fishers; and (2) coastal resource management and legislation in the Philippines is typically enforced at the municipal level (i.e., within the boundaries of municipal waters).

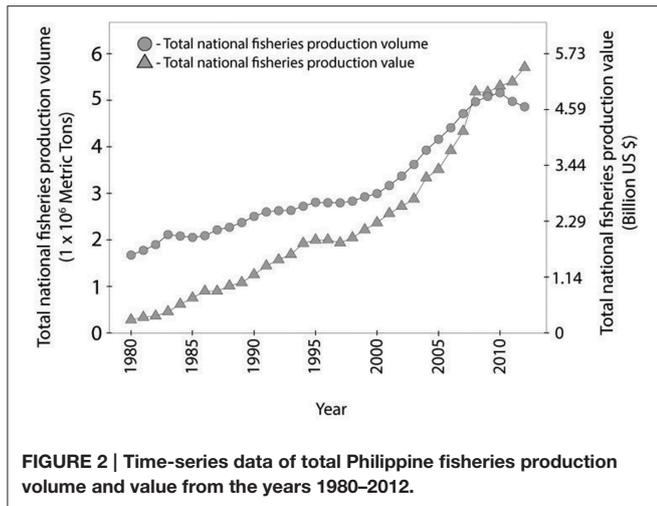
Fishers' interviews were conducted from July 2013 to July 2014. Interviews were conducted one-on-one, where fishers were asked questions regarding their estimated fish catch, fishing effort, and income from fishing. Interviewees were selected at random, or referred by previously-interviewed fishers.

Interview data was used to plot the mean \pm SE fish catch volume (in kg), catch value (in US\$), and fuel cost (in US\$) per hour per fisher. We standardized catch data and fuel expenses to per hour because the amount of time spent fishing was highly variable between fishers. Most coastal fishers in the Philippines use multiple gears and switch gears during a single fishing trip, so we ignored gear types in current analysis and focused on the overall catches and incomes regardless of gears used, for as long as they fished within municipal waters. To compute for fuel cost per fishers, we multiplied each fisher's estimated fuel consumption with mean common gas price estimates for the year 2013 (i.e., estimates taken from the Philippine Department of Energy, accessible at: <https://www.doe.gov.ph/oil-price-monitoring>, accessed 1 August 2015).

Review of Relevant Fisheries Literature on Fisheries Status, Collapse, and Options for Recovery

We reviewed the published peer-reviewed fisheries status assessment literature to determine the following: (1) how many publications reported global or national assessment of fisheries trends; (2) what data types were used in published global or national fisheries assessments; (3) what were the trends in status or spatio-temporal dynamics in assessed fisheries; (4) what were the identified consequences of the observed fisheries trends; (5) what were the drivers of the observed fisheries trends; and (6) what actions were recommended or implemented to recover declining fisheries (assuming that those recommendations were based on the understanding of various authors on the best or effective ways to address fisheries decline).

To conduct the literature review, we used the Web of Science Core Collection online database and queried all literature from 2009 to 2014 (past 5 years) using the search parameters "[marine* AND fishery*]" (accessed March 2014). This initial search yielded nearly 2000 papers, but was filtered to only include studies that presented assessments of target fisheries status (i.e., studies that focused on the structure of management or socio-political factors driving fisheries without quantifying fisheries status were not included). Modeling papers where empirical data was used to present specific case studies were also included. We also included studies that did not explicitly measure the effectiveness of fisheries management strategies for as long as they presented fisheries status assessment, because the main purpose of the literature review was to explore the findings of recent fisheries assessments, rather than to quantify management effectiveness. We separately presented assessment studies on global fisheries (Table S2), and national fisheries (Table S3). Because of the large variation in data types, consequences, drivers, and recommendations provided by authors, we categorized each entry for presentation in the Supplementary Tables. For example, under the recommendations column, "Regulate fishing activity" may refer to any of the following: Total Allowable Catch TAC establishment; fishing quotas; gear restrictions; policing against IUU; fishing vessel limits; and fishing closure seasons. Further details on each category can be found in Table S4. Out of the initial 2000 publications we only included in our review a total of



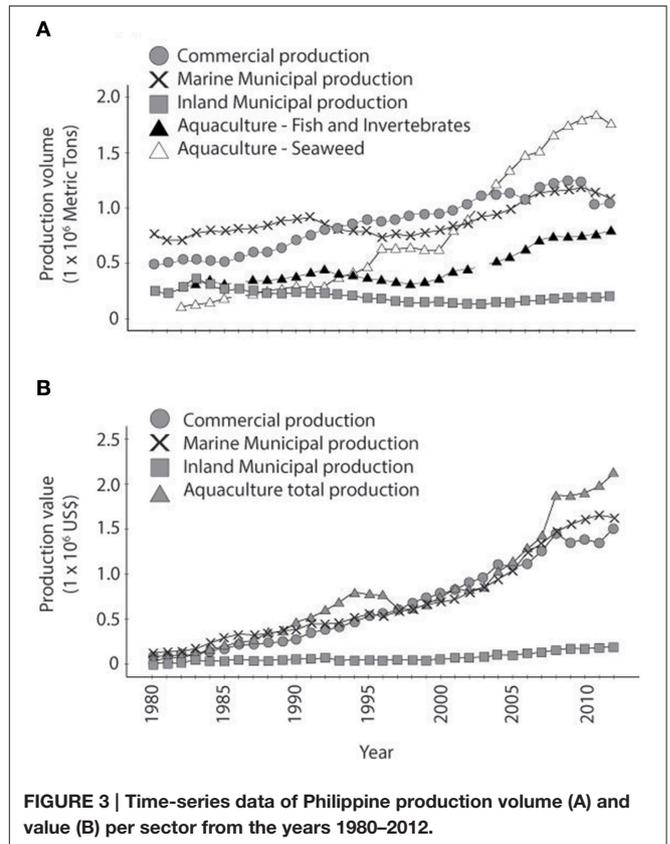
56 peer-reviewed publications that actually documented fisheries status at global or national scales. The rest of the publications mainly focused on various aspects of fisheries such as socio-political and economic issues, management issues, by-catch problems and estimates, etc.

RESULTS AND DISCUSSION

Spatio-Temporal Trends in Philippine Fisheries Production

The total landed Philippine fish catch volume showed a generally increasing trend from 1980 to 2010, followed by a decline in production from 2010 to 2012 (Figure 2). In contrast, total landed Philippine fish catch value showed a continuously increasing trend from 1980 to 2012 (Figure 2). The sector that contributed most to total Philippine fisheries production over the last three decades, in terms of both volume and value, was the aquaculture sector (although most of this was seaweed, which contributed on average about $56 \pm 2.8\%$ of total aquaculture production volume per year), followed by the marine municipal fisheries, commercial fisheries, and inland municipal fisheries sectors, respectively (Figure 3). One-way ANOVA and Tukey's *post-hoc* analysis showed that aquaculture production volume continued to increase significantly between successive decades from the 1980's up to recent times (Figure S2). In contrast, the capture fisheries sectors (e.g., municipal and commercial sectors) showed slight or non-significant increase in production volume since the 2000's, suggesting a stagnation in fish catch. However, the production values of all fisheries sectors continued to increase between successive decades from 1980's to recent times (Figure S3).

The top five provinces that contributed most to marine municipal fisheries production volume from 1980 to 2012, arranged in descending order, were Palawan, Zamboanga del Norte, Iloilo, Negros Occidental, and Surigao del Norte—while the rest of the other provinces contributed much smaller fisheries production volume (Figure 4). A large portion of marine municipal fish catch over the past decade was due to Palawan,



which showed a steep increase in production volume from the year 2000 until 2006, after which its production volume began to drop continuously until 2012. Similarly, Zamboanga del Norte and Negros, two more provinces belonging to the top five marine municipal fisheries producers, experienced noticeable drops in production volume in the late 1980's and early 1990's, respectively, with production failing to return to previous levels ever since. When we examined decadal trends in production volume, we found that 75% of the 65 provinces showed no significant increase in fish catch since the 2000's, suggesting that municipal fish catch has stagnated in those provinces over the last decade (Figure 4, Figure S1, Table S1).

Our examination of long-term, spatio-temporal data of Philippine fisheries reveals that capture fisheries have either stagnated or declined in terms of production volume. The bulk of total production volume of Philippine fisheries since the 2000's has been mainly supplied by aquaculture (albeit mainly seaweeds), rather than wild fish catch, and the country's municipal fish catch is sustained by only a few provinces. Stagnating capture fisheries in the Philippines is a matter of economic and ecological concern, since low wild fish catch could be an indication of depleted fish stocks. Fish catch may not always be an accurate reflection of fish stock status, particularly under conditions of effective management, wherein declines in fish catch records are due to the effectiveness of policies that limit fishing (e.g., enforcement of Total Allowable Catch quotas (TACs) and Marine Reserves (MRs)). However, given the lack

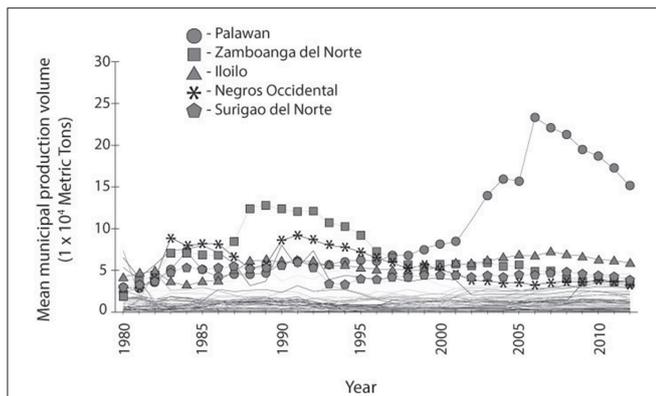


FIGURE 4 | Time-series data of Philippine marine municipal fish catch highlighting the top five fish-producing provinces (indicated by symbols and legends) from 1980 to 2012. Other provinces are represented as lines without symbols, and generally showed much lower fisheries production than the top five provinces.

of enforced fisheries management and the high exploitation rate in many Philippine reefs and coastal areas (Alcala and Russ, 2002; Muallil et al., 2014b), we doubt that the decrease in fish catch recorded in Philippine waters is due to effective fish catch restrictions and management (with the exception of a few well-enforced MRs in the country). Instead, we highly suspect that the decrease in fish catch perhaps reflects the depleted and overexploited status of many Philippine fish species, particularly commercially-important, large-bodied reef fish species (Go et al., 2015).

Previous studies have lamented the un-sustainability of most Philippine fisheries (Sadovy, 2005; Stobutzki et al., 2006; Muallil et al., 2014b). Once exploitation rate exceeds a certain threshold, the number of collapsed species increase, and declines in total fish catch, fish stock biomass, and mean fish body size follow (Worm et al., 2009). Our analysis suggests that Philippine fisheries may indeed be overexploited; fish catch has not increased overtime (and in fact, has decreased for several provinces), despite continuously increasing fishing effort in the country (Briones, 2007), and the increasing number of registered municipal and commercial fishers in the Philippines (according to BFAR's annual Fisheries Profile publications 1980–2012). Evidence in other studies also point to Philippine fisheries' un-sustainability, with most authors citing overfishing as a major factor in the declines of Catch Per Unit Effort (CPUE), catch biomass, diversity, and shifts in fish community structure observed in Philippine waters (Silvestre et al., 2003; Stobutzki et al., 2006; Muallil et al., 2014a; San Diego and Fisher, 2014).

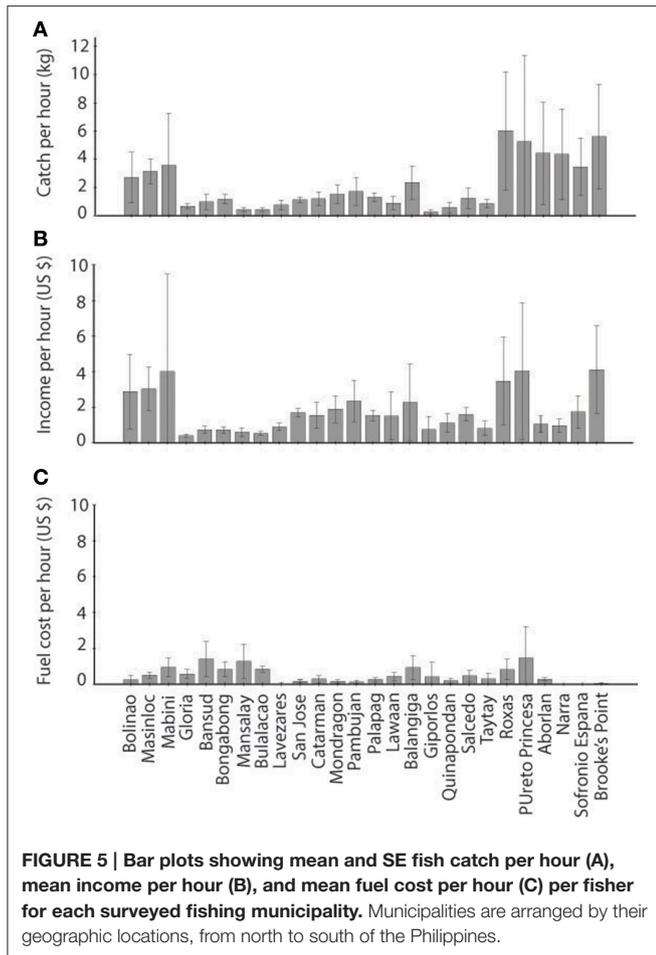
Despite recent declines in fish catch, the value of Philippine fisheries has continued to increase significantly over the last three decades. This could suggest that the market price of fish throughout the country is generally increasing—an effect of the high demand for fish brought about by the growing Filipino population and the declining fish catch in Philippine waters. Increases in the price of fish products could also be due to the increasing cost of fishing itself. For example, fishers may be exerting greater fishing effort (e.g., by spending more time and

fuel fishing or investing in more expensive fishing technology) to compensate for the declining abundance of fish in most coastal areas. Increased costs of fishing, combined with declining fisheries production, will undoubtedly have negative effects on the resource's primary users, the fishers.

Fishers' Fish Catch and Income

The declining fish catch of Philippine capture fisheries is reflected in the low income of most municipal fishers. Based on our interview data, mean fish catch of the average Filipino municipal fisher was 1.87 ± 0.14 kg/h (Figure 5A). Mean catch value of interviewed fishers was 1.7 ± 0.1 US\$/h (Figure 5B), but their mean fuel cost was 0.4 ± 0.0 US\$ per h (Figure 5C). After conversion to daily estimates, we found that the average Filipino fisher earns only about 12.4 US\$ from fishing per day (with a mean of 7.3 ± 0.2 fishing hours per day, based on interviews). By factoring-in their daily fuel cost of about 2.9 US\$ after 7.3 h of fishing, it becomes apparent that most fishers are left with less than 10.0 US\$/day, a value comparable to that found by Muallil et al. (2014b). This amount is hardly enough to pay for a fisher's daily expenses, especially considering that interviewed fishers had an average of 3.3 ± 1.5 dependents to support, in addition to their own personal expenses ($n = 160$ respondents with dependents). Furthermore, fishers generally do not fish every day, or throughout the year (mean of 19.8 ± 0.4 fishing days per month, and 9.7 ± 0.3 fishing months per year based on interviews), and 61% of the interviewed fishers ($n = 303$ respondents) did not have any alternative livelihoods other than fishing.

The low fish catch and income of most fishers, in addition to their over-reliance on fishing as a livelihood, has contributed to the extreme poverty in many Philippine coastal communities. The extreme poverty and continued overexploitation observed in many coastal fishing communities throughout the Philippines is indicative of Malthusian overfishing, wherein per capita fish catch (and subsequently, income) declines over time, as fishers continue to overexploit a rapidly-degrading resource (Pauly, 1990). To alleviate resource degradation, the responsibilities and costs of coastal resource management in the Philippines typically fall to multiple stakeholders. These stakeholders include the following: (1) the municipal Local Government Units (LGUs), who have the political power to establish and enforce coastal management policies based on Philippine Republic Act 8550 (e.g., enforcement of MRs, bans on destructive fishing methods, or implementation of fishing area zoning), (2) national government agencies such as the Bureau of Fisheries and Department of Environment (3) the fisher communities themselves, who have the responsibility to follow and participate in fisheries policy implementation, (4) the donor agencies and non-government organizations, and (5) the consuming public and the fisheries business sectors. However, enforced and sustainable coastal resource management is lacking in many Philippine coastal communities. In addition, fishers have little incentive to support coastal resource management efforts, partly because of the lack of alternative and because equitable distribution of management benefits (e.g., increased fish catch and income) is rare (Christie et al., 2005; but see further



discussions below). However, the various Philippine fisheries stakeholders need to (1) recognize the depleted state of Philippine fisheries, and (2) learn from experiences of collapsed and recovered fisheries from around the world, in order to help improve the current state of Philippine fisheries. Otherwise, maintaining the current status quo will depress the fisheries further and will put all stakeholders at a disadvantage—i.e. the fishers (in terms of lost livelihood and income), the government (in terms of lost fisheries rent), and the consuming public (in terms of lost availability of fish food). There is a great need to further explore the sharing of management costs and benefits to improve current conditions of declining Philippine fisheries by the various concerned stakeholders.

Review of Relevant Literature on Fisheries Trends and Options for Fisheries Recovery

Many of the publications we reviewed documented declining or potentially-declining fisheries across the globe (73% of 56 studies; Tables S2, S3). Only 20% of studies reported stable or recovering fisheries, while 7% gave mixed interpretations on the status of the studied fisheries.

Of the 41 studies that reported declining or potentially-declining fisheries, the most documented consequences were

declining fish catch biomass (73% of 41 studies), poor status of evaluated fish stocks (51%), and low or declining fish catch diversity (39%). Overfishing was the most cited driver of declining fisheries (80% of 41 studies), which includes IUU, increases in fisher population, and implementation of subsidies that increase fishing pressure (e.g., by providing more boats or fishing gear to fishers). Anthropogenic disturbance was the next most cited driver (20%), followed by natural causes (14%). In contrast, many of the studies that documented stable or recovering fisheries reported high or increasing fish catch biomass (64% of 11 studies), good fish stock status (45%), good fish diversity (27%), and economic gains associated with fishing (27%). The most cited driver of these stable fisheries was implementing strategies that regulated fishing activity (91%), mainly through the establishment of fishing quotas, fishing closures, MRs, and policies against illegal fishing. Such strategies are mainly applied in the context of developed countries, but to date have been challenging for developing countries (including the Philippines) to apply because of the associated costs of research and expertise, assessment, management implementation and enforcement, and the costs of providing alternative livelihoods for fishers displaced by management implementation.

Most studies, whether reporting declining or stable fisheries, recommended some form of management for fisheries recovery and sustainability (87% of 56 studies). Among the 49 studies that provided management recommendations, the most frequent suggestion was the direct regulation of fishing activity (71% of 49 papers). Direct regulation of fishing activity could be done through a variety of methods, including the implementation Total Allowable Catch (TACs), fishing quotas, gear restrictions, policing against IUU, fishing vessel limits, fishing closure seasons, fishing permits or licenses, and carefully-implemented fisheries subsidies (i.e., subsidies that do not lead to increased fishing pressure). Among these options, establishment of MRs, gear restrictions, and policing against IUU may be realistically applied to Philippine fisheries management today (though enforcing these policies may be challenging, considering the high costs of management implementation and the spatial variability of multi-gear and multi-species fishing activity in most Philippine coastal areas, Muallil et al., 2014a). Other methods, such as TACs and quotas, are set by data-intensive stock assessments and monitoring that require consistent funding and institutional support—which coastal resource management bodies (e.g., municipal LGUs) in the Philippines generally lack. However, conducting such data-driven assessments is imperative to improve the management of Philippine fisheries, and hopefully, the Philippine government will allocate sufficient funding to cover the costs of fisheries assessment and management in order to rebuild Philippine fisheries and recover the lost fisheries benefits from current overfished and depleted fisheries status. Indeed, the next most frequently-suggested option in the literature was enhancing scientific-based management (40%), which includes conducting research, stock assessments, and monitoring the status of fisheries and other marine resources, to help make data-driven decisions in coastal resource management. Scientifically, assessed stocks are typically in better condition than unassessed stocks throughout the

world, as rigorous assessments usually coincide with increased management attention (Hilborn and Ovando, 2014).

Improving collaboration between stakeholders was also suggested (28%), which means increased transparency and communication between the different levels of management, encouraging co-management, and integrating local knowledge in fisheries assessments and decision-making.

Establishment and enforcement of MRs was also recommended (25%). MRs have a long history as a management tool in the Philippines, and studies have shown that MRs can increase density and biomass of exploited fisheries species inside MR boundaries through protection of adults (Russ and Alcala, 2004; Samoily et al., 2007) and self-recruitment (Almany et al., 2007). However, proper enforcement is vital to MR effectiveness (Samoily et al., 2007), and even long-established MRs can become degraded and depleted when support is lost (Russ and Alcala, 1999, 2003). In addition, few studies have empirically demonstrated the benefits of MRs on surrounding fisheries beyond MR boundaries (Maypa et al., 2002; Russ et al., 2004; Abesamis et al., 2006; Harrison et al., 2012).

Finally, alternative livelihood for fishers (17%), and increasing stakeholder education and awareness (16%) were also recommended, particularly by studies conducted in the Philippines. These two recommended management options help improve the economic status of fishers, while simultaneously alleviating fishing pressure. Livelihood diversification decreases the over-reliance of fishers on a single (and highly fluctuating) resource (Allison and Ellis, 2001), while improved education increases fishers' skills and opportunities to enter occupations other than fishing. Thus, alternative livelihoods and improved education are expected to decrease fishing pressure, though the effectiveness of these projects are determined by the type of alternative livelihood provided and the social and demographic background of fishers (Pollnac and Pomeroy, 2005; Muallil et al., 2013). However, many alternative livelihood projects in the Philippines are discontinued after the project's duration expires, because fishers perceived minimal incentive to continue such projects due to a lack of equitably-distributed benefits (Christie et al., 2005; Pollnac and Pomeroy, 2005). In contrast, projects that successfully sustain implementation are those where (1) fishers are actively involved in project planning and implementation, and (2) benefits of alternative livelihoods and other forms of coastal resource management are equitably distributed among stakeholders (Pollnac and Pomeroy, 2005; Pomeroy et al., 2005). While local communities have the responsibility to comply with these management measures, governing bodies have the responsibility to provide adequate incentives toward effective management (Beddington et al., 2007), so regression back to unsustainable practices is prevented. In the Philippines, capacity-building and alternative livelihood programs are implemented by various government and non-government institutions, which include stock provision for farming and livestock, technical skills development to increase employment opportunities in other fields, and micro-financing from small business as implemented by the local government and various line agencies (Muallil et al., 2014b). Thus, platforms for encouraging reductions in fishing effort through alternative

livelihood programs are taking shape in the country, but need further assessment and improvement, considering the great spatial scale and increasing number of marginalized fishers that rely upon the dwindling fish stocks in most Philippine coastal waters.

Caveats and Future Research

One of the caveats of the current study is that the data used to analyze Philippine fisheries was limited to fish catch data. Although, fish catch has been criticized as being misrepresentative when analyzing fisheries status (Branch et al., 2011), catch data is currently the most complete, publicly-available data type on Philippine fisheries to date. Fish catch data is far from useless, and should be used to infer the status of fisheries wherever it is available, at least tentatively (Pauly et al., 2013). However, stakeholders in Philippine fisheries management should still strive to collect data through fisheries-independent research surveys, monitoring, and stock assessments, which can be used in conjunction with catch data to provide more comprehensive assessments of the nation's fisheries, in the future.

Another caveat is the questionable quality of the Philippine fisheries data. For instance, the existing BFAR database does not take into account Illegal, Unreported, and Unregulated (IUU) fishing. In the Western Central Pacific, which includes the Philippines, it was estimated that IUU comprised 34–38% of total fish catch from 1980 to 2003 (Agnew et al., 2009). This is a large proportion of catch, and implies that levels of overexploitation in Philippine fisheries may be under-reported. In addition, overlaps between catches of municipal and commercial fishers are largely un-accounted for. Moreover, mobility of fishers and their landings (e.g., movement between provinces) are not clearly accounted for in the database, thus preventing analysis of spatial serial fisheries depletion or geographical expansions. Further, improvement in the quality of Philippine fisheries statistics is essential for better fisheries management applications.

A final caveat of the current study is the inconsistency of Philippine fishing effort records to date. Fishing effort was reported inconsistently in BFAR's annual Fisheries Profile publications from 1980 to 2012, i.e., some BFAR publications reported only the number of registered municipal fishing boats or *bancas*, while other BFAR publications reported only the number of fishing operators, or registered commercial fishing vessels. In addition, fishing effort data was patchy and not regularly updated. For example, the BFAR Fisheries Profile for the year 2007 presented registered fishing vessel records from the year 1999. Clearly, there is a great need to improve the consistency of tracking fishing effort in the Philippines, in order to monitor the state of the nation's fisheries more accurately.

Future, research on Philippine fisheries should focus on more in-depth analysis of fish catch rates, exploitation levels, and fish stock status recorded in the country. For example, elucidating fish stock status using Underwater Visual Census (UVC) surveys of coastal areas could provide alternative and non-destructive fisheries-independent data collection to complement fish catch records, considering many important municipal fisheries species (e.g., belonging to families Acanthuridae, Caesionidae, Lutjanidae, Lethrinidae, Labridae (particularly

Scarinae), Nemipteridae, Serranidae, Siganidae, and Kyphosidae) are demersal or reef-associated (Maypa et al., 2002; Abesamis et al., 2006; Muallil et al., 2012, 2014a), and are typically detected by UVC methods. Also, future studies could tap other sources of data not usually accessible online and therefore will be costly to collate. These would include municipal reports, surveys conducted by Non-Government Organizations (NGOs), and the studies of university students and researchers.

In addition, the effects of fisheries management efforts—which include both costs and benefits incurred by all stakeholders involved (Toribio et al., 2013)—should be further explored and analyzed to understand Philippine context of fisheries management. For example, regarding MR establishment, the costs of displacing fishers should be accounted for in addition to the monetary costs of enforcing MR protection (e.g., costs of guardhouse construction, purchase and operations of patrol boats, and costs of manpower to police MRs). Regarding alternative livelihood projects, ensuring the equitable distribution of benefits would give local communities greater incentive to maintain enforced fisheries management, but this also needs to be quantified (Pollnac and Pomeroy, 2005). Such management measures may serve as responses to pressures often faced in developing coastal communities (e.g., overexploited resources, poverty and low income, undernourishment, vulnerability to sudden climactic disturbances), though there are still significant gaps regarding the appropriate responses to particular pressures (Cabral et al., 2013). Thus, there is a great need to study the complexities of fisheries as social-ecological systems (Lebel et al., 2006; Cinner et al., 2012), and to provide specific management recommendations appropriate to the social-ecological dynamics of a particular locality or context (Johnson et al., 2013).

Finally, our examination of long-term, spatio-temporal data of Philippine fisheries highlights the need to examine and monitor Philippine fisheries production at finer spatial scales. For example, the high municipal fish catch in only a few provinces (e.g., Palawan) may have masked the overall stagnation or decline of fish catch in most other provinces (Figure 4). Examining fisheries production at finer scales will allow stake-holders and decision makers to apply appropriate management measures based on the spatial variations in Philippine fisheries between different regions, provinces, and municipalities.

CONCLUSION

Our analysis of Philippine fisheries production suggests that Philippine fisheries production is declining, with the high production volume of the aquaculture sector (i.e., mostly seaweeds) masking the stagnating or declining fish catch of most capture fisheries in recent times. The decline in catch volume of most provincial and municipal fisheries throughout the country is reflected in the low incomes of many Filipino fishers (despite the fact that the total value of capture fisheries continues to increase). Managing fisheries

and coastal resources does not end with the implementation of policies that directly influence fishing pressure (e.g., MR enforcement, fishing bans, and catch quotas). Policies related to community management that indirectly influence fishing pressure, such as increasing education levels and providing alternative livelihood to fishers and their families, should be further explored to help reduce the levels of over-exploitation experienced by Philippine fisheries. The Philippine media, government, scientific communities, and conservation organizations need to clarify the declining state of Philippine fisheries and explore options to recover or rebuild the overexploited fisheries to meet the needs of rapidly increasing Filipino population.

AUTHOR CONTRIBUTIONS

JA conceptualized this paper, actively participated in the data gathering, data analysis, and write-up, and set the overall directions for the paper. He also secured the funding for this work. KG gathered the data actively participated in the data gathering, processing, analysis, and write-up. Both authors equally contributed to the development of this paper.

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SUPPLEMENTARY MATERIAL

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The reviewer SF declares that, despite sharing an affiliation with co-author KG, the review process was handled objectively and no conflict of interest exists.

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