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Climate Change Impacts on Food Security from Marine Resources

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ABSTRACT

Commercial, municipal, and aquaculture fisheries, and the marine ecosystem as a whole, are expected to experience climate change impacts in the coming decades. This is alarming, as marine resources contribute a significant portion (19-36%) to the food supply of the Philippines. Projections reveal that the Philippines shall experience increases in sea surface temperature, more intense storms, locally prolonged droughts, and intense episodic rainfalls. The country is also likely to experience effects of ocean acidification, and sea level rise is projected to be higher than the global estimates for the Philippines. These impacts are additional pressure on top of the many, and mostly anthropogenic pressures which the marine ecosystem is already experiencing. Although the Philippines' high biodiversity can help reduce overall vulnerability, urgent actions are needed to build marine food resiliency.

Keywords:
climate change, food security, marine resources, biodiversity, Philippines

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INTRODUCTION

Demand for seafood worldwide has increased by 150% from the 1970s to 2010s driven mostly by increase in global population. The current average global consumption is 16 kg fish per person per year (FAO 2013). In the Philippines, the protein requirement is set at 62-71 g per day (Philippine Dietary Reference Intake 2015: Summary of Recommendation, FNRI-DOST) with seafood being the principal source of animal protein. People living near the coast are reported to consume 43 kg of seafood per year while those away from the coast still consume 23 kg of seafood per year (FAO 2000; Pedro et al. 2007).

Additionally, fisheries and associated livelihoods are one of the main economic sectors of the Philippine society. These sectors currently provide livelihood to more than 3 million Filipinos. But fishers were also identified as the most impoverished sector of the society with poverty incidence of 39.2%. This reliance on the marine system combined with the high climate exposure makes the Philippines highly vulnerable to climate change.

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IMPACTS ON MARINE RESOURCES

Commercial Fisheries

The specific values differ for each of the Intergovernmental Panel on Climate Change 5th Assessment Report (IPCC AR5) Representative Concentration Pathway Scenarios (RCPs) but the Coupled Model Intercomparison Project Phase (CMIP5) models project that in the near-term climate change scenario (2016–2035), the Western Equatorial Pacific region shall experience significant increases in sea surface temperature (mean ocean surface change of 0.5–0.75°C). Ocean pH is globally projected to decrease 0.1 unit in the near-term. There is a projected seasonal mean percentage precipitation change of up to 10%. More importantly, locally prolonged drought and intense episodic rainfall with increase in variability is the likely scenario. Models also agree that storms will become more intense but the frequency will either decrease or remain unchanged. Global sea-level rise is projected at 20-90 cm per decade with the Western Equatorial Pacific region likely experiencing the higher of these global estimates.

Slow persistent increase in ocean temperature have been associated to distribution limit consequences of marine flora or fauna (Gaston 2000; Carricart-Ganivet 2004; Somero 2010; Tittensor et al. 2010) and have been linked to changes in timing of spawning events (Wilson and Harrison 2003; Donelson et al. 2010; Pankhurst and Munday 2011). Temperature-sensitive species will likely adapt to warming waters by temporarily migrating to deeper waters or permanently migrating to higher latitudes where temperatures will still be conducive for typical functioning. For those that cannot migrate, the prediction is for negatively affected reproduction and recruitment failures (Donelson et al. 2010; Ljunggren et al. 2010; Pankhurst and Munday 2011). Decline of locally available fish populations and eventual local extinction is likely.

IPCC projected the global redistribution of maximum catch potential of about 1,000 exploited marine fish and invertebrate species comparing results of the 10-year averages 2001–2010 and 2051–2060 SRES A1B climate model under a moderate to high warming scenario (Figure 1). Results show that the biggest changes are in the waters of Antarctic and the Western Equatorial Pacific, including the Philippine seas. It should be noted that this projection is a conservative one as it did not take into account potential impacts of overfishing or ocean acidification.

Ocean acidification is thought to have significant impact on areas with lower aragonite saturation levels such as the Antarctic (Orr et al. 2005). Moreover, it has also been observed to negatively affect the recruitment success of temperate species (Simpson et al. 2011; Munday et al. 2009) but may not necessarily be disadvantageous for tropical benthic-spawning marine fishes (Munday et al. 2009b). Hence, the assumption above for reduction of fisheries in the Western Equatorial Pacific region is valid but that for the Antarctic is an underestimate.

The projected seasonal mean percentage precipitation change of up to 10% has an expected consequential reduction of surface salinity up to 0.1 psu (practical salinity unit) in the West Philippine Sea (WPS) and up to 0.2 psu in the Pacific Seaboard (PacSea). Juveniles are most affected by salinity due to osmotic stress

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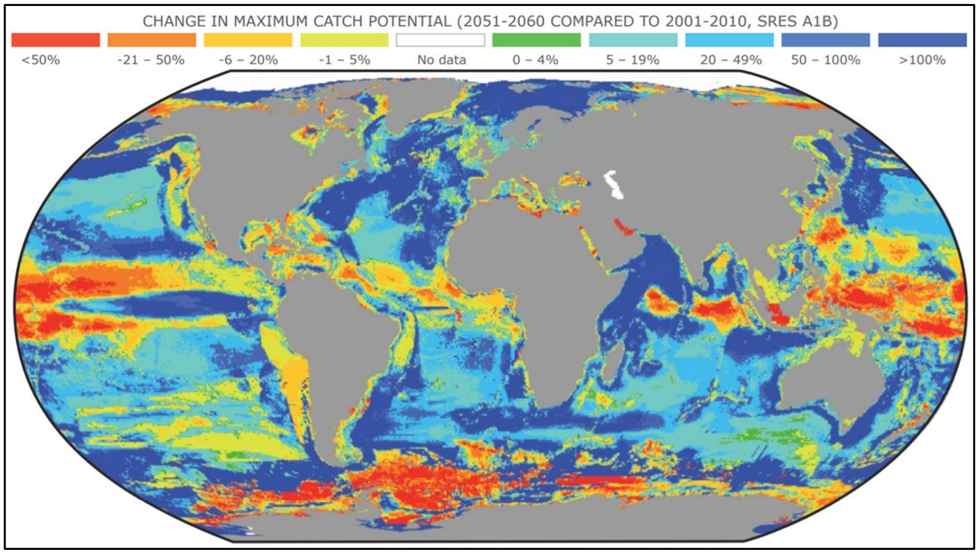

Figure 1. Global redistribution of maximum catch potential of ~1000 exploited marine fish and invertebrate species comparing the 10-year averages 2001–2010 and 2051–2060 SRES A1B (IPCC's Fifth Assessment Report (AR5 WG2 2014).

(Shirangi et al. 2016; Gracia-López et al. 2006). Prolonged changes in salinity also inhibit reproduction of existing population, allowing for dominance of more salinity-tolerant species. Additionally, changes in intensity of wind or precipitation can limit surface manifestation of the upwelling near the coast, and significantly reduce aggregation of target species (e.g., roundscad or *galunggong*; anchovies or *sardinas*). In Southern Philippines, for example, there is an observed significant reduction of sardine fish catch when extreme rainfall limits surface manifestation of the upwelling near the coast (Cabrera et al. 2011).

In addition, storms and intense precipitation bring about sedimentation. Coastal ocean productivity is enhanced from nutrient-rich sediments (Eadie et al. 1994). This could either lead to increase in fish productivity or a potentially harmful algal bloom (HAB) event. This in turn can contribute to water turbidity, anoxia, and toxicity–depending on the algal species. Eutrophication, anoxia, and toxicity can cause massive fish kills (San Diego-McGlone et al. 2008; David et al. 2014). Gobler (2020) has also reported that the observed trends in harmful algal blooms can be attributed partly to the effects of climate change and pollution.

Municipal Fisheries

Municipal fisheries pertain to fish caught within 15km of the coast, defined within the local government code as "municipal waters". Fish caught in these waters can either be pelagic or habitat-associated. Pelagic fisheries will be affected by climate change in the same manner as that discussed under the commercial fisheries section. Habitat-associated fisheries are even more vulnerable.

Coastal habitats such as mangrove forests, seagrass meadows, and coral reefs act as refuge for tropical benthic adults and nursery grounds for the benthic and pelagic young. There are also particular economically-important species that require the presence of all three coastal habitats to be sustainable, such as groupers.

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Coral reefs are highly susceptible to degradation from increases in ocean temperature, reduced calcification due to ocean acidification, and physical damage from strong storms (Munday et al. 2008; Pratchett et al. 2011; Hughes et al. 2003; Hoegh-Guldberg 2011). Increase in temperature result in coral bleaching. Prolonged bleaching can lead to coral death, loss of coral reef structure, and macroalgae overgrowth. Loss of coral cover typically result in the decline of smaller-bodied coral-associated fishes that are dependent on the structure of the reef habitat for shelter (Graham et al. 2008). Only the small generalist species and rubble-dwellers are expected to increase in abundance on degraded coral reefs (Bellwood et al. 2006; Ticzon et al. 2012). These species are generally not utilized as food fish.

During the 1998 mass heating event in the Coral Triangle, majority of the bleaching happened in the east/west corner of the Triangle and the Philippines (Peñaflor et al. 2009). Rates of recovery are site-specific with some lasting months while other sites have never fully recovered.

Between 1751 and 1994, surface ocean pH is estimated to have decreased from approximately 8.25 to 8.14. Ocean pH is globally projected to decrease another 0.1 unit by 2035. Change in ocean pH can lead to loss of integrity of coral reef structure. Combined with strong storms, this can lead to mass coral damage resulting in less complex structure. The complexity of the reef structure has direct influence on the adult and juvenile fish population (Ticzon et al. 2012). Generally, less complex reefs contain less fish population due to loss of refugia.

Intense storms are also likely to uproot shallow water seagrass meadows (Short 1987; Kim et al. 2015) due to increased energy of incoming waves. Storms and associated storm surges were also recently documented to defoliate and damage mangrove stands (Gunderson 2010; Primavera et al. 2016). Old tall mangroves that are taller than the average tree-line are the ones most likely to suffer from the passage of high winds.

In addition, storms or even just intense rainfall can bring about increased nutrient and sedimentation from the watershed. Nutrient input can be good for the seagrass as these meadows are known to be nutrient poor. However, one of the most damaging perennial stresses for corals and seagrass is sedimentation, resulting in compromised health due to murky waters and outright burial leading to mortality. Increased sedimentation can bury coral reefs and seagrass meadows, or at the very least, leave the water murky for extended periods of time. These will compromise coral-symbiont zooxanthellae and seagrass productivity (Gacia et al. 2005; Orth et al. 2006). Mangrove seedlings may also become buried under storm-associated sedimentation.

Sea level rise is expected to lead to a loss of deep water seagrass habitats present at edge of their depth limits due to light availability (Waycott et al. 2009). The combined effect of murky waters, storms and sea level rise will lead to a thinning of the meadows and a decrease in seagrass species diversity. In terms of fisheries, this specifically impacts on seagrass-related fisheries such as that of rabbit fish and prawns. It will also have a cascade effect on larger target fish since seagrass meadows provide food for these higher trophic levels.

For mangroves, moderate rates of sea level rise, enhanced vegetation growth is likely as the ecosystem strives to adapt. At faster rates of sea level rise (SLR) however, mortality ensues as the substrate deepens beyond depths capable of supporting vegetation (Kirwan et al. 2010). Also, adults that are only salinity-tolerant for short periods of time (typically located more landward) will suffer from prolonged exposure to seawater. Over decades, the impacts of sea level rise need notnecessarily be negative, provided landward migration is possible (Waycott et al. 2009).

As habitat health is degraded due to climate change, larger predators will also be affected (Sundblad and Bergström 2014). This can happen in two ways. Both pelagic and demersal predators also use the mangroves, seagrass, and corals as nursery ground. Hence, their population will also be compromised as the habitats get degraded. In addition, as the smaller habitat-affiliated fishes are compromised, the predators may end up migrating to more bountiful, cooler and deeper areas. This will tax small-scale fishers who have limited mobility.

Summarized in Figure 2 is the 30-year data set of temperature, precipitation and sea level rise in the Philippines. Results show that the Philippines naturally divide into 11 climate hazard clusters. The northwestern (Cluster II) and the tip of the northeastern (Cluster X) coastal and marine areas of the Philippines are most prone to extreme temperature and precipitation hazards. In comparison the south Sulu Sea (Cluster XI) and Sulawesi (Cluster VI) are the sites with the lowest magnitude of ocean-climate hazards.

Mariculture

As a consequence of climate and demographic pressure, less food fish captured from the wild are available for every Filipino. Comparing the sum of the

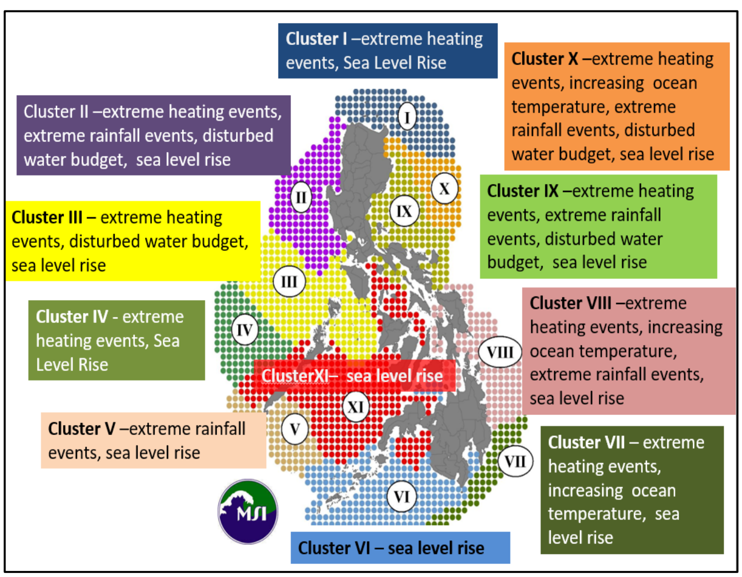

Figure 2. Hazard clusters of the Philippines using temperature, precipitation and sea-level rise from 1980-2010 (David et al. 2015).

reported commercial and municipal catch from 1980 to 2015 with the Philippine population, it is evident that there is an overall decrease of available fish food of 0.16 kg/year/person (Figure 3b).

It can also be surmised from Figure 3b, that the significant decrease in available food fish per capita happened after 1997-99 and 2010-12. The years 1997-99 corresponds to a strong El Niño- to-strong La Niña phenomenon which caused mass coral bleaching in the Philippines (Peñaflor et al. 2009), and can therefore more significantly affect municipal fisheries. This corresponds to the first arrow in Figure 3a where a dip in municipal fisheries was indeed observed. The years 2010-12 experienced strong to moderate La Niña. The increase in rainfall in the Philippines during this time hindered the surface manifestation of upwelling due to the increase in freshwater input (Cabrera et al. 2011). This affected upwelling-related fisheries such as commercial sardine fishery. This corresponds to the second arrow in Figure 3b where a dip in commercial fisheries is observed. These observations show the dependence of capture fisheries on the prevailing climate.

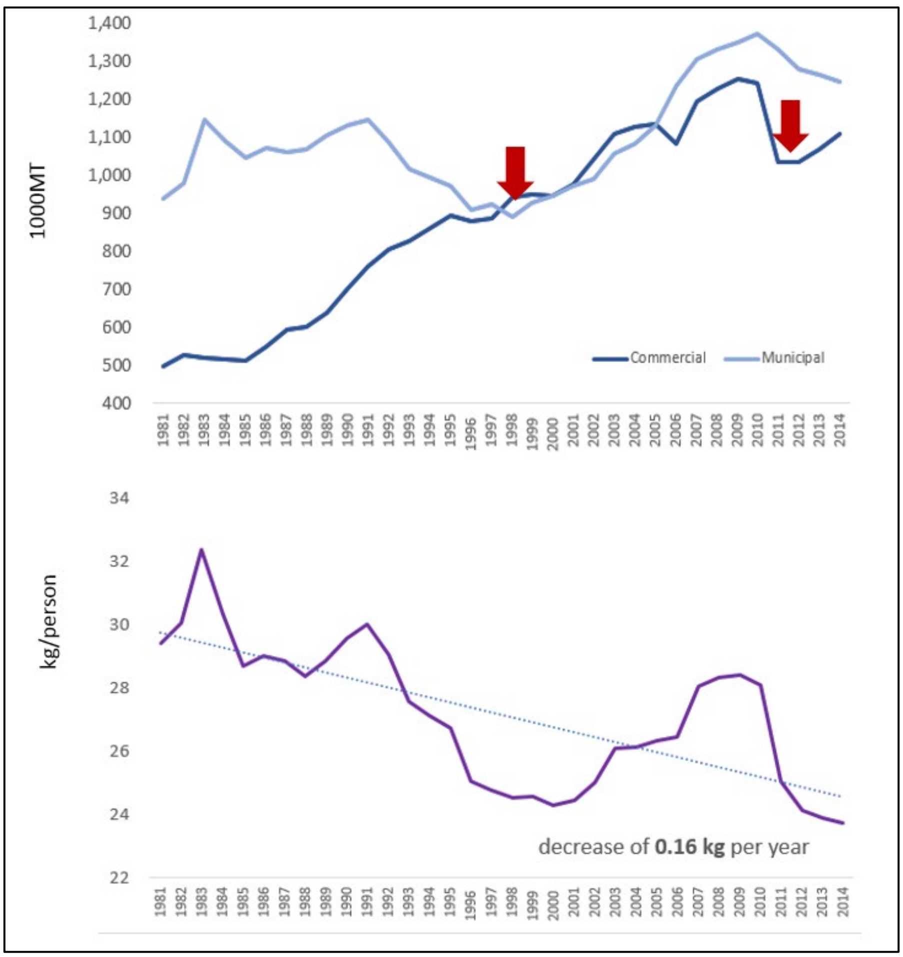

Figure 3. (a) Trend in commercial and municipal fisheries since 1980 and highlighting years on significant decrease; (b) Decrease in food fish per capita for the same period.

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The Bureau of Fisheries and Aquatic Resources (BFAR) has been responding to the food fish shortage by promoting aquaculture/mariculture which is done in a more controlled environment. As such the contribution of finfish culture to our total available food fish has been steadily growing (Figure 4). Currently, it provides 52% of the overall food fish provision of the Philippines (statistic for 2016).

But experience has shown that aquaculture/mariculture is not climate-proof either. Anomalous warming of ocean water affects the oxygen content of the water and has historically resulted to massive fish kills within mariculture sites (David et al. 2014).

Increase in surface ocean temperature and rainfall-induced sedimentation might also abet the formation of algal blooms. Algal blooms impact mariculture either due to its toxic nature or by further reducing the oxygen content of the water. Ocean acidification is also likely to compromise large-scale commercial shellfish culture. Finally, increase in the intensity of storms might also compromise the integrity of the mariculture structures themselves with floods bringing debris-laden rushing waters.

Marine Food Vulnerability

The knowledge of the sensitivity of the different fisheries can be used as a guide to assess the Philippine fish food vulnerability.

The most significant contributors to pelagic commercial fisheries at present are Regions XII and IX. Fisheries in region IX is dependent on the upwelling and will be vulnerable to extreme rainfall events.

For municipal fisheries, Regions IV-A, IV-B, V, VI, IX, ARMM are the highest sources. Regions IV-A, V and XIII will be vulnerable to extreme rainfall. If the watershed is compromised as well, then sedimentation will be an issue and consequently affect both reef-base and seagrass-base fisheries.

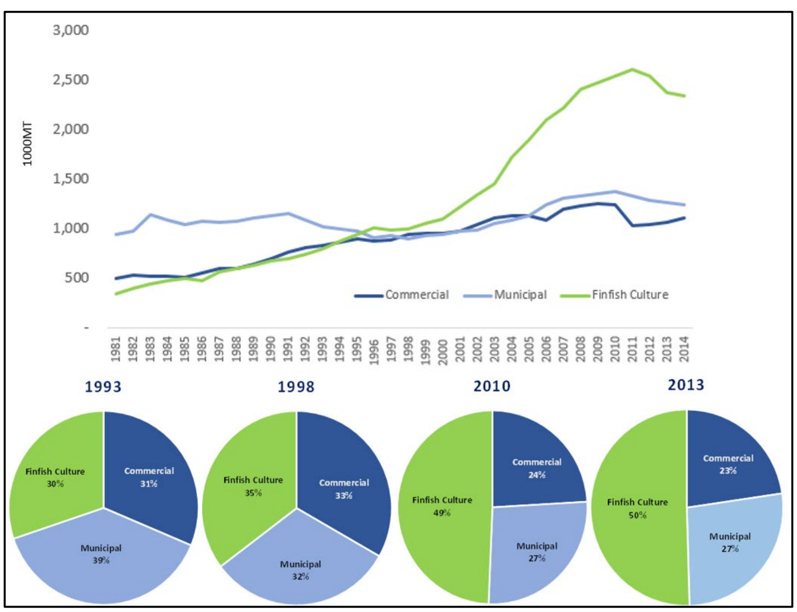

Figure 4. Food fish supply through the years (Data from BFAR).

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For finfish aquaculture/mariculture production, the biggest contribution comes from Regions I, III, IV-A, VI. Finfish culture, in general, are sensitive to oxygen depletion brought about by increase in temperature or anoxia. Extreme heating events have been plaguing the Philippines in all regions except in Region VII, IX and XII. Hence, almost all intensive aquaculture/mariculture are vulnerable. Regions I, III, and IV-A will also be vulnerable to extreme rain events which may lead to episodes of harmful algal blooms.

TO ATTAIN MARINE FOOD RESILIENCY

Our high biodiversity reduces the overall vulnerability since species having similar ecosystem functions allow for adaptation to slow changes.

[1] There is need therefore to conserve and protect the different alluvial, estuarine, and coastal habitats – especially those identified as spawning and nursery grounds. Corollary to this, increased human utilization of the coastal zone, if mismanaged, can further exacerbate the vulnerability.

[2] A comprehensive ridge-to-reef management must therefore be put into place to mitigate human activities that lead to increased input of nutrients and pollutants, or alter the natural buffering capacity of these bio-diverse habitats.

[3] The opportunities to enhance our food security through mariculture should also be fully realized by exploring culture of other indigenous climate-tolerant species without compromising the existing natural biodiversity.

[4] In order to do these, careful site selection must be undertaken– taking into consideration local water renewal, the history and potential of an area for climate-related or bio-chemical stress (e.g., HABs), and potential impact of the mariculture area to surrounding habitat. Enhancement of the adaptive capacity of coastal communities therefore relies heavily on the LGUs through the Philippine local government code. Coastal LGUs need to be made to understand and appreciate their role in the transition towards a climate-adapted archipelago. Their decisions will need to take into account social and economic, as well as, ecological concerns.

[5] Hence, decision makers need to be provided assessments of valuation of coastal ecosystem services, as well as, adaptations costs and benefits. Further, there are still uncertainties on the magnitude of local future scenarios and consequently, lack of quantitative predictions of local future coastal changes.

[6] There is a need to develop local predictive models based on multi-stressor observations and experiments in detailed levels of space and time. Finally, all these science-based data will then have to be communicated to decision-makers and institutions so that their role in the transition towards a climate-adapted archipelago may be realized.

[7] **Therefore, there is a serious need to strengthen the science-to-policy communication sector amongst our ranks.**

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