Coastal Fisheries in Lianga Bay: Its Potential Vulnerability to Climate Change

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Abstract

Capture fisheries is an important economic activity of coastal communities expected to be greatly affected by changing climate, either through degradation of supporting shallow marine habitats or reduced fisher productivity due to adverse weather conditions. Landed catch monitoring was done to determine the status of coastal fisheries in Lianga Bay. Result of the study shows that fish production in the Bay is primarily influenced by seasonal variation. High fish production estimates were observed in southwest monsoon months (June to October) with 1,589.95 tons in 2009 and 2,063.44 tons in 2010. Limited two-year data showed a positive correspondence between fish production and sea surface temperature, however; linking fisheries production to climate changes needs a longer time-series data on coastal fisheries of Lianga Bay.

Keywords: coastal fisheries, fish production, climate change, vulnerability

1. INTRODUCTION

Coastal fisheries are especially affected by decreasing fish stock exacerbated further by changing climatic conditions. There is now enough evidence worldwide that climate change has impacts on coastal ecosystems and fisheries production. Growing concerns on the ability of coastal ecosystems and fishing communities to adapt climatic changes are evident. In order to generate scientific data on the impacts of climate change on coastal ecosystems, the Philippine Government through the Department of Science and Technology (DOST) funded a specific project. This is the "Remote Sensing Information for Living Environment and Nationwide Tools for Sentinel Ecosystems in our Archipelagic Seas (ReSILiENT SEAS) Program for Climate Change (formerly known as Integrated Coastal Enhancement: Coastal Resource Evaluation and Adaptive Management or ICE-CREAM).

One of the components of this research program is the "Climate Change Vulnerability of Coastal Fisheries in Mindanao (CoastFish) of which Lianga Bay is one of the study areas. The study aimed at monitoring fish landing of coastal fisheries in the Bay, which is believed to be potentially vulnerable to the effects of climate-related events such as increased storminess and wave action, increasing sea surface temperatures and intense rainfall.

Climate change conditions are expected to cause significant losses in shallow ecosystems such as coral reefs, mangroves, sea grasses and intertidal habitats that provide shelter and food for coastal fish and shellfish.

Coastal fisheries and small pelagic fisheries along embayments have the most potential exposures to impacts of climate change (Secretariat of the Pacific Community [SPC], 2012; Brander, 2007; Food and Agriculture Organization of the United Nations [FAO], 2008). Thus, climate change can affect the productivity or distribution of fishery resources in a variety of ways (FAO, 2007): whether positively or negatively is difficult to predict (Kennedy, Twilley, Kleypas, Cowan Jr., &

Hare, 2002). Many studies used fish landing data to investigate climate change effects on fisheries (Yañez, et. al, 2002; Chavez, Ryan, Lluch-Cota & Niquen, 2003; Tourre, Lluch-Cota & White, 2007). According to Pauly and Maclean (2003) and Sadovy (2005 as cited by Allison, et al. 2009), fisheries production that supply domestic markets are generally more important for the well-being and socio-ecological resilience of local fishing communities and could be represented using capture fisheries landings (i.e., excluding discards) or catch values. Literature clearly states that fish landing data can examine relationship of fish production values and climatic factors. However, landed catch data in Lianga Bay are not available from the past studies, hence this research.

Information on the vulnerability of the coastal fisheries in Lianga Bay will help the Local Government Units (LGUs) in planning an adaptive management strategy that could somehow mitigate potential impact of climate change. The project also provides methods in fisheries management which can be useful in the development of strategic fisheries monitoring protocols that can regularly monitor climate change effects through fish landing data. This includes analysis fishing effort and catch levels of major gears and fleet of municipal fisheries. Likewise, profiling of fishing effort, analysis of status of fish production, and fisheries' potential vulnerability to changing climate were done.

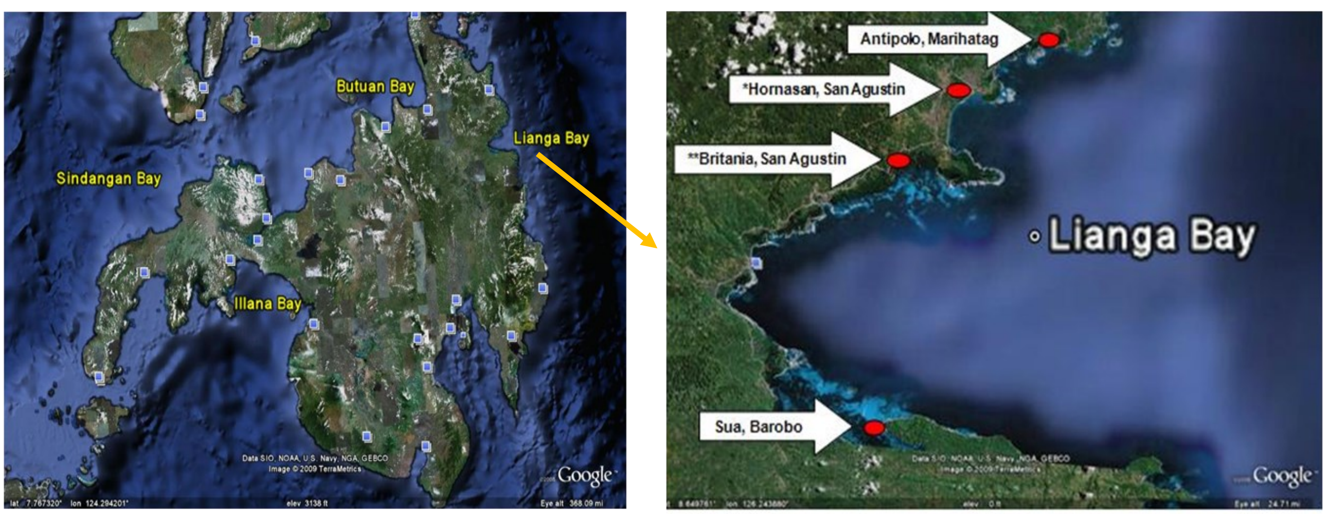
2. METHODOLOGY

2.1. Monitoring of Catches

Entry protocol with Municipal Mayors in the project sites was conducted. Three field enumerators were hired each for the three stations established in the Bay (Fig.1) to monitor daily catches of major gears in designated fish landing areas or fishing village using standard fisheries monitoring sheets. Monitoring of landed catches from within the waters of each bay was done for 15-20 days with 20 fishers regularly monitored in each station.

2.2. Estimating total fish production

Total fish production in the Bay between May 2009 to June 2011 was estimated by



Legend: * Station monitored for year 1 only
** New station monitored for the current year

Figure 1. Map of Mindanao showing the location of four sites of the coast fish project (left) and the Lianga Bay Site with its 3 stations (right)

calculating the total landed catch using a simple extrapolation method or raising factor (Sparre, 2000) to account for unrecorded catches, as follows:

$$RF = N(T)/ n(t)$$

where: N = total number of fishers in each site, T= average number of fishing days/month, n = number of fishers monitored and t = number of fishing days monitored each month. Total landed catch for each municipal station was computed by multiplying the total recorded catch by the raising factor. Subsequently, total production of the Bay was estimated by multiplying the average total landed catch derived from the three stations by the total number of municipalities around the Bay.

2.3. Gathering of climatic data

Satellite data were gathered for chlorophyll A and sea surface temperature and secondary data from PAGASA for total monthly rainfall. These climatic data were processed and correlated against the Baywide fish production using statistical tool.

2.4. Vulnerability Assessment

Vulnerability Assessment - Tool for Understanding Resilience of the Fisheries (VA TURF) by Mamauag, et al. (2012) was used in this study to help communities in gauging the risks which can help them make timely response to climate change.

3. RESULTS and DISCUSSION

Lianga Bay has a 115-kilometer coastline length in Surigao del Sur (Surigao del Sur Profile, 2000) which is around 24% of the total coastline of the province. Municipal fishers in the Bay largely depend on coastal fisheries since 60% of the barangays are coastal.

3.1. Profile on Fishing Effort

3.1.1. Fishers and Boat Types

The coastal fisheries in Lianga Bay is generally subsistence or municipal, involving about 3,288 fishers (MCRMFD Plan of Barobo, 2008;MCRMFD Plan of San Agustin, 2008; MCFP of Marihatag, 2008; LCRMFDP, 2008) of which about 10 percent were monitored by the CoastFish project between 2009 and 2011. Around 48% of the fishers use non-motorized boats, 33% motorized, and 19% have no boats such as fishermen that use spears and gleaning. On the average, there is an equal proportion of motorized and non-motorized boats in the area. This assessment shows fishers in the Bay are subsistence ones except in Barangay Hornasan where motorized boats surpass the non-motorized by about 17.65%. Generally, there is an average of 1.2 fishers for every single boat; however; the number of fishers per boat varies depending upon the boat size and the type of fishing gear or gears used since fishers in the Bay use multiple gears per fishing trip just to have catch.

3.1.2. Gear Types

Fishing gears used in the coastal fisheries of Lianga Bay are very diverse, consisting of seven classes and about 22 modifications according to area of operation and season. There are seven gear types classified in the established landing stations of Lianga Bay with about 22 variations and different local names wherein six gears are widely used (Fig. 2). However, these variations are slightly lower as compared to Lanuza Bay with 30 (Fisheries Improved for Sustainable Harvest [FISH] Project, 2006). There are gears that undergo modifications so that they can be used for certain season only. Bottom set gillnet, bottom set long line, hook and line, hand line, jig and spear fishing are common gears observed across stations throughout the monitoring period. Frequent modifications of fishing gears to specifically adapt to target species in an area is not a good indicator (Green et al., 2004), suggesting an increase in fishing effort to ensure catch of fish. High fishing effort was observed across stations that maybe indicative of an unsustainable coastal fisheries. Other fishing activities in Lianga Bay include gleaning for a variety of marine invertebrates and the use of poisonous substances. Seaweeds farming is also notable as an alternative livelihood options of fishers in the area.

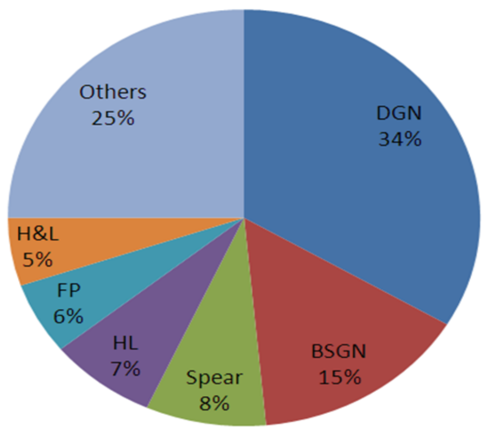


Figure 2. Top six most abundant gears across landing stations in Lianga Bay

3.2. Bay wide Fisheries Production

3.2.1. Production Trends

Lianga Bay had an estimated total production of 6,933.88 tons for the period May 2009 to June 2011 which translates to an estimated annual production of 3,200.25 mt year^{-1}. Bay wide annual production was higher in 2010 (3,597.46 mt) than 2009 (3,293.40 mt) and 2011 (2,281.66 mt). Low production estimate in 2011, however, is possibly biased as the monitoring period covered the months (i.e. northeast monsoon, NEM) of lower catches of this year. The highest catch was recorded in Barangay Sua contributing 41% to the estimated total production while the rest was contributed by Britania, Antipolo and Hornasan 25%, 23% and 11%.

Monthly production fluctuated during the study period. Catches clearly peaked in August 2009 and July 2010 (during the southwest monsoon, SWM) while the lowest catches were observed consistently in February for two years (Fig. 3). Monthly fisheries production rate in Lianga Bay is relatively low which ranges from only 0.32 - 0.94 t km^{-2}. Production rate was relatively higher during the southwest monsoon (June to October) compared to northeast monsoon months (November to March). The estimated baywide annual production rate was highest in 2010 (7.28 t km^{-2}) followed by 2009 (6.67 t km^{-2}) and 2011 (4.62 t km^{-2}) with an average of 6.19 t km^{-2} yr^{-1}. Owing to the small size of Lianga Bay, estimates of production rate were lower than of the other study sites of the CoastFish Project.

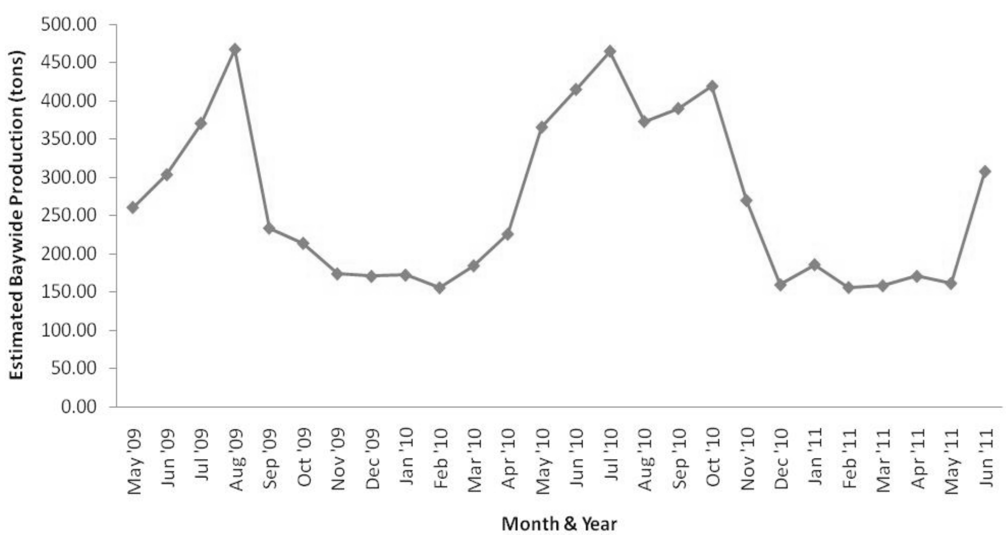


Figure 3. Estimated baywide production in Lianga Bay from May 2009 to June 2011

Although a seasonal trend in fisheries production is apparent in Lianga Bay, it cannot be ascertained from the data if the annual trend is declining or not as no previous landing data is available.

3.2.2. Catch Composition

A total of 177 species compose the landed fish catch in Lianga Bay majority of which are demersal or reef associated (81%) and the rest are small pelagic (14%) and large pelagic (5%). High diversity of demersal species in landed catches shows that the coastal fisheries in Lianga Bay are largely dependent on shallow marine habitats which are predicted the high impact of climatic changes. The major species caught in the Bay (Fig. 4) are the small pelagic fish *Cypselurus* sp. (1,247.05 mt), *Stolephorus* spp. (893 mt) and *Tylosurus* sp. (227 mt) and demersal species such as *Siganus fuscescens* (1,136t) and *Lethrinus* spp. (405t).

Collectively, these abundant fish species comprise about 56% (3,907.74 mt) of the total fish production of Lianga Bay between May 2009 and June 2011. The relative abundance of these species fluctuates considerably from month to month although a trend was observed in the three most abundant species.

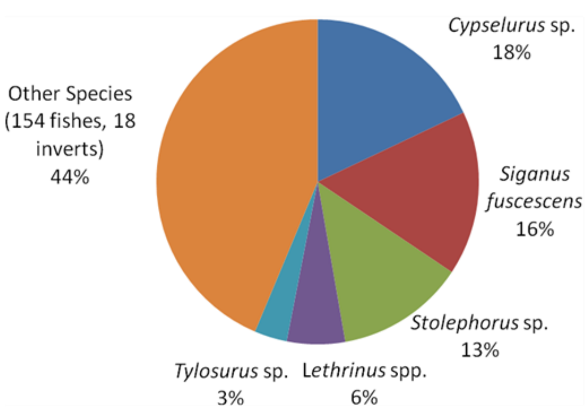


Figure 4. Species composition of landed fish catch across monitoring stations in Lianga Bay from May 2009 to June 2011.

Cypselurus sp. and *Siganus* spp. tend to be more abundant during the northeast monsoon months while *Stolephorus* spp. was more abundant during the southwest monsoon season.

The flying fish *Cypselurus* is a major target fishery in the coastal barangay of Antipolo Older fishermen in the barangay declared that they have been fishing *Cypselurus* since the early 1980s and have experienced declining stocks of this fish. Presently poor catches are further aggravated by frequent strong winds and stormy conditions during the northeast monsoon months when the *Cypselurus* spp. are more abundant. During the early months of the southwest monsoon, fishers of this particular fish stock move to the fishing ground of Tandag, Surigao del Sur where the stock is abundant. Understanding the stock movement and dynamics of this important resource, however; difficult since no comprehensive research had yet been conducted. Since *Cypselurus* is a small pelagic fish stock then it is possible that migration triggered by southwest monsoon winds is associated with food availability in the Tandag fishing ground.

Dominant species in the catch varied from one area to another. Large catches recorded in Sua station was primarily contributed by rabbitfish (*Siganus* spp.) and anchovy (*Stolephorus* spp.) while the catch in Antipolo mainly composed of flying fish *Cypselurus* spp. (73%) caught by drift gill net. The main species landed in Hornasan was the skipjack tuna *Katsuwonus pelamis* while demersal species of *Lethrinus, Siganus* and *Nemipterus* were commonly landed in Britania.

3.2.3. Catch Rates, Revenues and Fisher's Income

The 22 fishing gear variations operating in Lianga Bay are classified into three categories, namely: traditional gears (10), highly efficient gears (9) and seasonal gears (3) (Table 1). Drift gillnet and modified beach seine contributed 19% and 14% to the total landed catch,

Table 1. Catch rates and average income of various gears employed in the coastal fisheries of Lianga Bay

Fishing Gear	Code	Average Catch Rate (kg/gear/day)	Ave. CPUE (Kg/fisher/day)	Ave. Net Daily Income (PHP)	Ave. Net Monthly Income (PHP)
A. Traditional Gears					
Bottom Set Gill Net	BSGN	4.48	2.14	121	2,964
Bottom Set Long Line	BSLL	6.46	6.06	396	7,926
Crab Gill Net	CGN	1.26	1.22	98	1,979
Fish Corral	FC	2.96	2.93	135	2,090
Fish Pot	FP	5.24	4.69	318	2,541
Hook and Line	H&L	1.97	1.89	142	1,191
Handline	Handline	4.38	3.78	276	1,379
Jig	Jig	2.72	2.62	174	1,174
Spear Fishing	SF	5.35	5.29	309	6,414
B. Efficient Gears					
Boat Lift Net	BLN	35.14	10.30	230	1,766
Drift Gill Net	DGN	4.11	3.08	172	3,269
Drive-in-Net	DIN	12.79	2.30	159	2,232
Drift Longline	DLL	12.55	8.66	831	1,612
Encircling Gill Net	EGN	10.37	2.53	197	2,754
Modified Beach Seine	Mod. BS	24.39	4.75	140	1,969
Modified BSGN	Mod. BSGN	15.82	4.42	178	3,922
Surface Gill Net	SGN	7.69	2.54	158	2,496
Trammel Net	TN	5.51	2.49	147	2,845
C. Seasonal Gears					
Beach Seine	BS	18.54	2.50	173	2,636
Modified H&L	Mod. H&L	6.29	5.76	450	4,496
Stationary Lift Net	SLN	7.89	6.76	289	2,890
Tuna Troll Line	TTL	33.44	16.57	1,355	9,482

respectively. Other productive gears are the bottom set gillnet (16%), bottom set long line (13%) and spear fishing (9%). Traditional fishing gears in the Bay are operated year-round including some of the efficient gears such as drift gillnet and trammel net. The rest of efficient gears are operated according to the seasonality of their target species.

On a bay wide scale, efficient fishing gears like boat lift net, modified beach seine, drive-in net and drift long line, and seasonal ones such as tuna troll line, beach seine and modified bottom set gillnet obtain higher average catch rates (ranging from 5.51 to 35.14 (kg $gear^{-1}$ $trip^{-1}$) than traditional gears. These efficient gears, however, incur high fishing costs in terms of fuel, food and crew size as their fishing operations are often offshore. On the other hand, traditional gears such as crab gillnet, fish corral, hook and line, and jiggers with low catch rates often target fish from reefs and other near shore habitats, and, thus, incur lower fishing costs. Low catch rates of these fishing gears can be attributed to the declining stocks of near shore demersal fish resources and increasing number of fishers using these gears. Comparison of average catch rates among fishing gears using t-test revealed no significant difference ($p=0.05$) between the southwest and northeast monsoons.

Average catch per unit effort (CPUE) varied among gears in Lianga Bay. Relatively high average CPUE (16.67 kg $fisher^{-1}trip^{-1}$) was obtained by tuna troll line athough this fishing gear is abundant during northeast monsoon season. Other gears with higher CPUE values (6.06 – 10.30 kg $fisher^{-1}$ $trip^{-1}$) are boat lift net, drift long line, stationary lift net and bottom set longline. High CPUE obtained from these fishing gears does not always convert to higher income for fishers due to large expenses incurred during fishing operation. Fishing gears involving a bigger crew size (e.g. boat lift net) adopt a sharing system where a greater share of the net income accrues to the boat and gear owner.

Basically, fishers with high income are those that use gears which catch high-value fishes, such as tuna troll line, drift long line and modified hook and line which obtain higher average net income per trip. Traditional gears (e.g. bottom set long line, fish pot and spear fishing) target high-value demersal species also earn high average net daily income. Average net monthly income, however, are relatively small, except for tuna troll line which can reach Php 9,482.48 during the tuna season towards the end of southwest monsoon and in northeast monsoon months.

Majority of the fishermen in the Bay earn income below Php 5,000.00 per month. The poverty threshold for the Philippines in 2009 was a per capita income of PHP 16,841 a year (Virola, 2011) or a monthly income of around PHP 1,403.42 is considered as living below the poverty line. According to this baseline, fishers in Lianga Bay using hook and line, hand line, and jiggers live below the poverty line especially that most of fishing household has an aggregate family income where only the fisher earns income. Changing climatic factors such as increasing storminess and heavy precipitation are expected to negatively influence coastal fisheries production in Lianga Bay and, consequently, fishers' income.

3.2.4. Seasonal Variations in Fisheries Production

Annual fish production pattern in Lianga Bay exhibits seasonal variations, although a longer data set is needed to establish long-term trends. Significantly high fish production (t-test $p<0.05$) was observed during the southwest monsoon months (*habagat*) with an average of 1,826.69 tons while lower production was noted during the northeast monsoon (*amihan*) with an average 893.81 tons. General associations of seasonal variation with fish production in the Bay is made based on fish landing data only as oceanographic information such as current patterns and nutrient levels are not available which can be helpful in describing seasonal variations in fish abundance.

Analysis of the monthly catch data on pelagic and demersal fishes also shows that both fish groups have low catches during the northeast monsoon. High production during southwest monsoon months might be attributed to the favorable weather condition in the Bay that allows fishers to fish longer. In contrast, northeast monsoon brings strong winds and waves that shorten fishing time and hence, lower catch.

3.3. Climate Effects on Fish Production

Statistical analysis on readily accessible climate factors such as satellite data on cholorophyll a (*Chl a*) and sea surface temperature (SST), and total monthly rainfall (TMR) from PAGASA shows that SST has significant effect on fish production ($P<0.00$) while both Chlorophyll a and TMR ($P>0.22$ and $P>0.94$) have no apparent influence on fish production. Analysis of variance (ANOVA) as shown in Table 2 reveals that combination of the three climatic signals would surely affect fish production in the Bay based on ($P<0.000$).

The lack of positive correspondence between *Chl a* and fish production in Lianga Bay may be attributed to the dominance of demersal fish in the landed catches. Positive correspondence between Chl a and fish production is most apparent in small pelagic fisheries, such as in Butuan Bay and Dipolog-Sindangan Bay where sardine production was found positively correlated with *Chl a* abundance (De Guzman et al., 2012). Small pelagic fish are dependent on plankton abundance and play a central role in the food web (Checkeley, Alheit, Oozeki & Roy, 2009) and are ideal targets for testing the impact of climate variability on marine ecosystems (Alheit, 2002).

Another climatic signal investigated was TMR which negatively correlates also with production. In this sense, precipitation in Lianga Bay does not affect fish production which may imply that fishermen are already used to this particular scenario by fishermen since this area experiences rains regardless of what monsoon season per noticeable observation. Positive association of SST with production cannot be considered as effect of a climatic signal but could be an influence of monsoons (C. Villanoy, personal communication, October 2011) since during NEM, the Bay experiences frequent rains and strong cold wind which basically lowers the SST. Low production in Lianga Bay is primarily attributed to lower fishing effort (e.g. number of fishing days and fishing time duration) due to unfavorable weather condition rather than to lower SST as a climate signal. Fishers claimed they experienced much stronger winds and storminess during NEM now than in the past. High production in SWM on the other hand, is due to good weather condition that allow fishing at a longer time.

3.4. Vulnerability Assessment of Coastal Fisheries and Ecosystem

The Resilient SEAS Program for Climate Change developed the Coastal Integrity for Vulnerability Assessment Tool (CIVAT) and Tool for Understanding Resiliency of the Fisheries (TURF) by Mamauag et al, 2011. These tools adopt the vulnerability analyses concept from IPCC Vulnerability Assessment for Fisheries. Inter governmental Panel on Climate Change states that vulnerability to climate change depends upon three key elements: exposure (E) to physical effects of

Table 2. Regression analysis, baywide production versus *Chl a*, SST, rainfall

The regression equation is

Baywide Production = - 2264 - 307 Chl a + 85.7 SST + 0.0035 rainfall

Predictor	Coef	SE Coef	T	P
Constant	-2263.9	478.4	-4.73	0.000
Chl a	-306.8	240.6	-1.28	0.216
SST	85.71	15.60	5.50	0.000
Rainfall	0.00347	0.04594	0.08	0.940

S = 62.58 R-Sq = 70.2% R-Sq (adj) = 66.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	202902	67634	17.27	0.000
Residual Error	22	86166	3917		
Total	25	289068			

Source	DF	Seq SS
Chl a	1	34218
SST	1	168661
Rainfall	1	22

climate change; the degree of intrinsic sensitivity (S) of natural resource system or dependence of the national economy upon social and economic returns from that sector; and the extent to which adaptive capacity (AC) enables these potential to offset potential impact.

Results of vulnerability assessment of LB fisheries presented in this paper is based on TURF analysis based on the criteria of fish, reef fish/habitat and socio-economic attributes. The exposure variable used in this analysis is wave action during monsoons because of available data and from apparent observation.

Table 3 shows Marihatag and San Agustin have high degree of exposure to wave action and coupled with medium sensitivity can expect high potential impact of climate change to fisheries. This scenario can be worsened due to medium adaptive capacity of the two municipalities resulting in high vulnerability of the fisheries sector. These two municipalities, however, have low sensitivity on socio-economic attributes and, thus, have low adaptive capacity which is attributed to their dependence on fishing and farming as their main sources of income.

Demersal catches that comprise major landings in the Bay show potential vulnerability to climate change since these demersal species are greatly dependent on reef areas. Kennedy et al. (2002) cited that coral reefs which are already threatened by multiple stressors such as abusive fishing practices, pollution, increased disease outbreaks and invasive species, would be at risk from changes in seawater chemistry, temperature increase, and sea-level rise.

4. CONCLUSIONS AND RECOMMENDATIONS

Calm seas during the southwest monsoon favor fishers a longer fishing time and consequently higher production and income. Consequently, low production in northeast monsoon is strongly attributed to frequent rains and strong cold wind that limit fishing effort resulting to low income for fishermen. Results show that fish production in Lianga Bay is strongly influenced by season, although positive correspondence with SST, a known climate variable, was identified by statistical test. A longer time-series analysis, however, is needed to firmly establish climate linkages with fish production. Vulnerability assessment, on the other hand, indicated that the Bay's fisheries and the socio-economic well-being of coastal communities in the Bay has high potential vulnerability to impacts of changing climate and with only a medium adaptive capacity to deal with them. Long term fish landed monitoring

Table 3. Results of vulnerability assessment of the fisheries and socio-economics sectors of Lianga Bay communities

SITE	Exposure	Sensitivity	Potential Impact	Adaptive Capacity	Vulnerability
Fisheries					
Marihatag	High	Medium	High	Medium	High
San Agustin	High	Medium	High	Medium	High
Barobo	Medium	Medium	Medium	Medium	Medium
Socio-Economic					
Antipolo	High	Low	Medium	Low	High
Britania	High	Low	Medium	Low	High
Sua	Medium	Low	Low	Medium	Medium

data should be conducted to generate sufficient or decadal data in order to observe concrete production pattern.

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