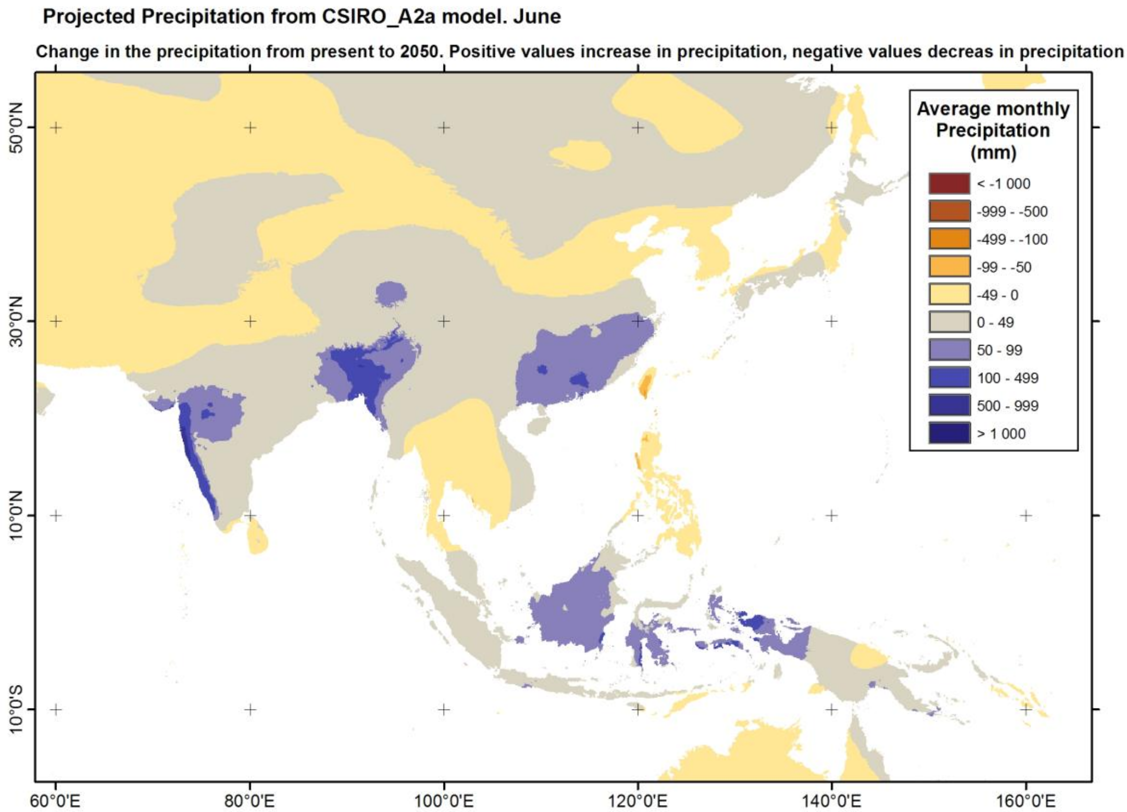
Strengthening Adaptive Capacities to the Impacts of Climate Change in Resource poor Small-scale Aquaculture and Aquatic resources-dependent Sector in the South and South-east Asian Region - AquaClimate



Predicted future Climate change 2020 and 2050

Tromso, Norway

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1. Selection of climate change model and scenario

Climatic factors, such as air and water temperature, and precipitation and wind patterns, strongly influence fish health, productivity and distribution. An analysis was made of the 16 models used in the Asia Pacific region and the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) – A1, A2, B1 and B2 to be used as the basis for predicting future climate for this study. In addition a decision was made on the commonly considered time periods – 2020s (2010-2039), 2050s (2040-2069) to be used. Another factor that was considered in choosing the model was the availability of the data and that the output can be effectively used in combination with GIS. GIS facilitates the analysis of multiple layers of data and allows statistical analysis of multiple factors while maintaining their spatial representation.

The analysis recommended the use of the CSIRO climate model available from WORLDCLIM and the A2 scenario "business as usual".

The A2 scenario can be summarised as follows;

- a very heterogeneous world.
- self-reliance and preservation of local identities.
- Fertility patterns across regions converge very slowly, which results in continuously increasing population.
- Economic development is primarily regionally oriented
- per capita economic growth and technological change more fragmented and slower than other storylines.

The output from this climate model and scenario was used to predicted future Climate Change for the 4 case study areas for the timescales Present, 2020 and 2050.

Climate changes that were considered included;

- Temperature increase and seasonal patterns
    - minimum average monthly temperature
    - maximum average monthly temperature
- Precipitation change and patterns for the
    - Municipalities indicating precipitation at the farm ponds
    - River water shed area indicating potential change in river flows
- Sea Level Rise
- Storm surge risk
- Tidal fluctuation cycles

2. Predicted future climate for case study area in the Philippines

Figure 1: Geographical areas of predicted Climate change – the river watershed area and the two municipalities.

	
River watershed area modelled for climate change	Location of the Municipalities and milkfish ponds

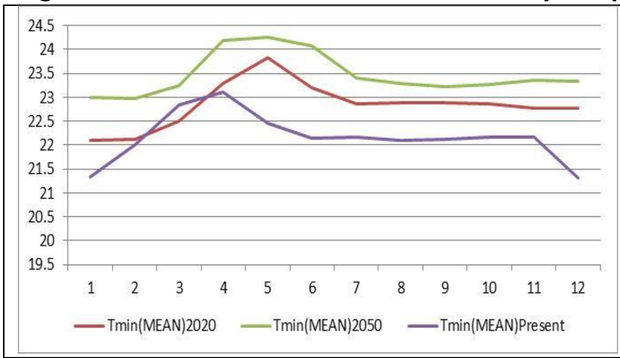
2.1 Temperature change predictions

Temperature predictions for Tropical Asia (IPCC)
According to IPCC analysis for tropical Asia, temperature scenarios suggest that temperature would increase although the amount of warming is projected to be less than the global average. IPCC also predict that there will be differences within the region, depending on proximity to the sea and that warming is projected to be least in the islands and coastal areas throughout the Philippines.

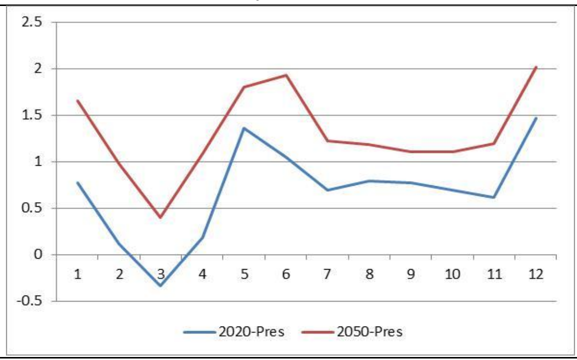
Minimum monthly mean temperature
The analysis of the CSIRO climate model for Scenario A2 predict that for the minimum monthly mean temperature for Barotak Nuevo and Dumangas in 2020 there will be an increase in average monthly temperature of 0.75 ^{o}C in January and from July to November and that there will be an increase in average monthly temperature of 1.2 ^{o}C in May and December (see Figure 2 below).

Predictions for 2050 are that there will be an increase in minimum mean monthly temperatures of 1 to 1.5 ^{o}C in January and from July to November and there will be an increase in average monthly temperature of 2 ^{o}C in May and December.

Figure 2: Predicted minimum mean monthly temperature mean for 2000, 2020 and 2050



Minimum monthly temperature mean for 2000, 2020 and 2050



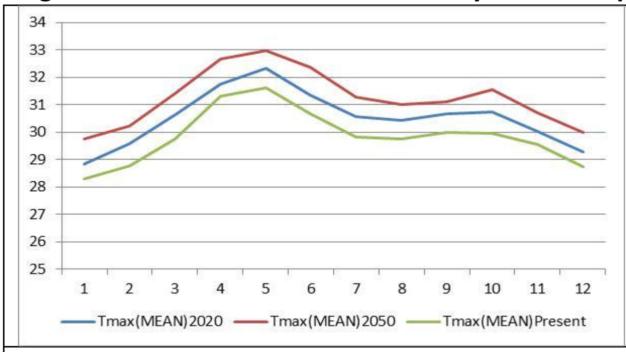
Minimum monthly temperature mean difference between 2000 and 2020 and between 2000 and 2050.

The consequence for milkfish pond culture should be positive as higher minimum pond water temperatures will improve growth rate, Food Conversion Rate and pond productivity during the colder seasons. The difference in minimum average monthly pond water temperature will be relatively consistent however the increase above 2000 temperatures will vary monthly with higher than average temperatures in May, June and December and lower than average in February and March.

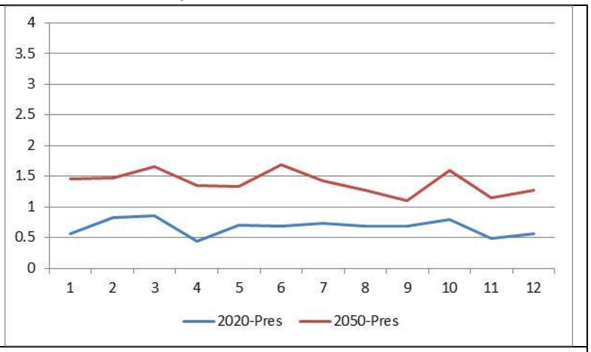
Maximum monthly mean temperature

The predicted increase in maximum monthly mean temperature for Barotak Nuevo and Dumangas for 2020 is that there will be an increase in average monthly temperature of between 0.5 to 0.8 ^{o}C and for 2050 that there will be an increase in average monthly temperature of between 1.1 and 1.6 ^{o}C. This increase will be relatively consistent throughout the year.

Figure 3: Predicted maximum monthly mean temperature for 2000, 2020 and 2050



Maximum monthly temperature mean

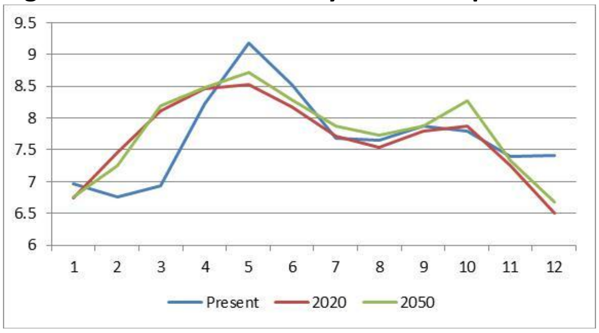


Maximum monthly temperature mean difference

The consequence of this predicted temperature increase in 2020 will be that the maximum monthly mean temperature will be around 0.65 ^{o}C higher in the peak temperature month of May and in 2050 will be 1.5 ^{o}C higher. The present peak maximum monthly temperature of 31.5 ^{o}C in the month of May will be prolonged for 3 months by 2020 and reaching 32.3 ^{o}C and 5 months by 2050 reaching 33 ^{o}C which may be close to the highest temperature tolerance of Milkfish.

Monthly temperature fluctuations

Figure 4. Predicted monthly mean temperature fluctuation between minimum and maximum



The predictions for 2020 are that there will be a higher fluctuation in January (0.5 ^{o}C) and February (1 oC) but with less fluctuation in May (0.5 ^{o}C). The predictions for 2050 are that there will be higher fluctuation in January and October (0.5 ^{o}C) and February (1 ^{o}C) but less fluctuation in May (0.5 ^{o}C)

The predicted temperature difference between minimum and maximum monthly temperature mean will increase in the early part of the year causing greater stress to fish and peak natural feed production.

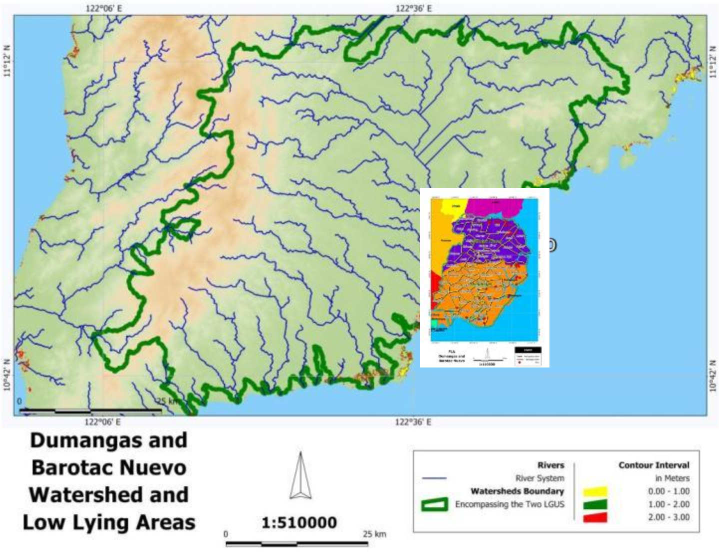
Milkfish ponds are very shallow and so are particularly prone to high water temperatures especially in the afternoon hours and water temperature fluctuation between day and night.

2.2 Precipitation change predictions

The IPPC predict (IPCC 2007) that precipitation for tropical Asia will increase in wet-season rainfall in both SouthWest and Northeast Monsoon. A more consistent and much larger rainfall increases are predicted for the wet season and increases in average rainfall intensity along with associated increases in the projected frequency of heavy rainfall events.

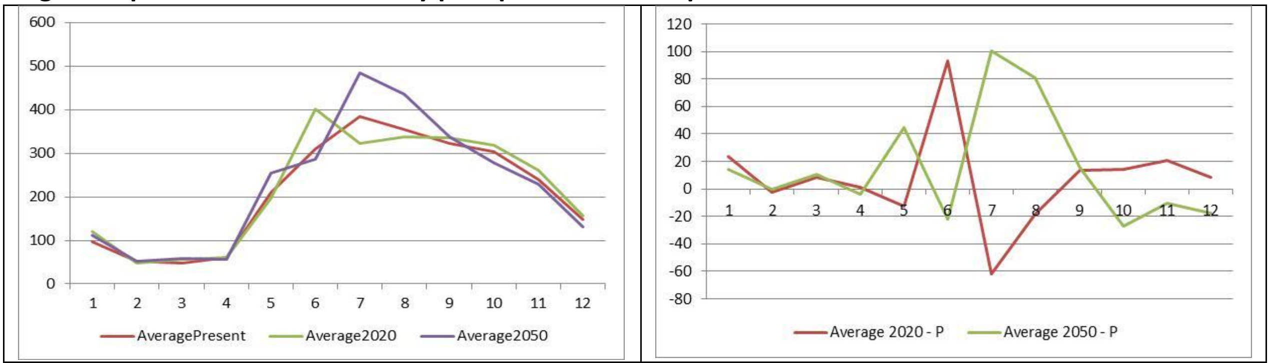
Predicted Precipitation of Barotak Nueva and Dumangas Municipalities and watershed

Figure 5. Areas used for predicting future climate change (river catchment area and municipalities).



The predicted mean monthly precipitation on the pond farm areas and in the watershed (river flow) are given in Figure 6.

Figure 6. predicted mean monthly precipitation on the pond farm areas and in the watershed



Precipitation Average monthly mean (mm\month)	Precipitation difference (mm\month)

The predicted precipitation change for 2020 was that there would be slightly higher (20 mm /month) rainfall with higher rainfall in June (100 mm) and lower rainfall in July (60 mm).

The predicted climate change for 2050 was that there would be higher precipitation in the first half of the year (20 mm), lower in the second half of the year (20 mm) and higher precipitation in May (40 mm) and July and August (90 mm).

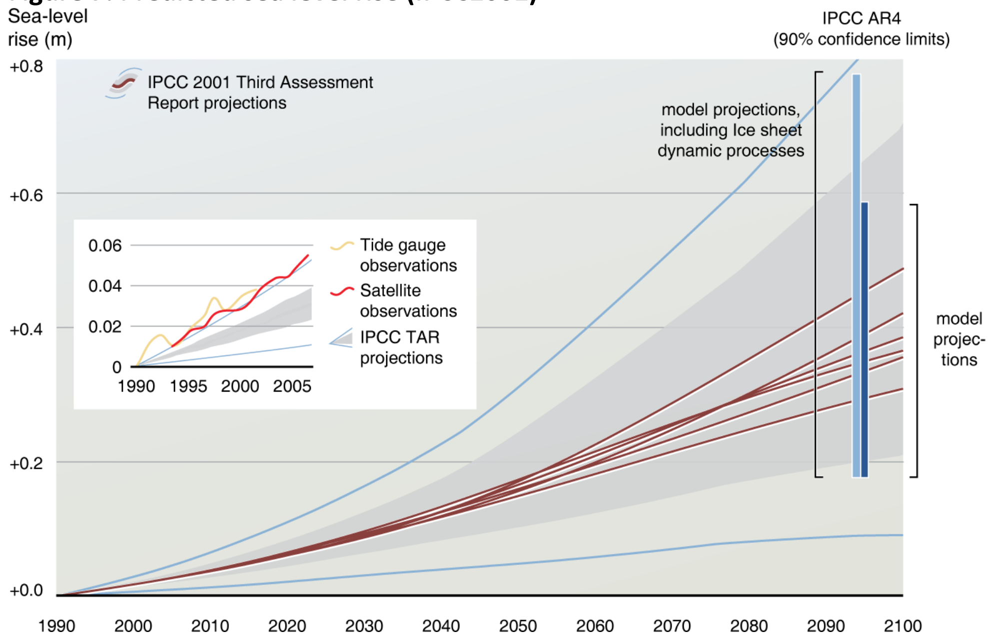
The potential consequences of this are that the change in rainfall pattern there will be greater river flow in July leading to greater severity of flooding over a larger extent of area than present time.

The production of the natural feed "lablab" is very sensitive to sudden heavy rains especially if it occurs during the pond preparation stage. Therefore many fishpond operators now use artificial feeds for the nursery stage.

2.3 Sea level rise change predictions

In 2001 the IPCC (IPCC 2001) made predictions for projected sea level rise for the various SRES scenarios with a prediction for A2 scenario of 6 cm rise by 2020 and 18 cm rise by 2050.

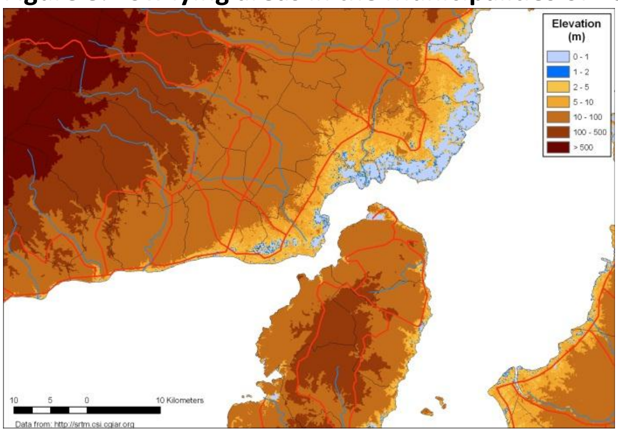
Figure 7. Predicted sea level rise (IPCC2002)



However the measured changes are following the most pessimistic predictions and if this continues, then the sea level rise will be 12 cm rise by 2020, 30 cm rise by 2050 and close to a meter by 2100. In addition there are some regional differences in sea level rise.

The Milkfish ponds in Dumangas and Barotak Nueva are located close to sea level and are prone to flooding from the increase in river height and exceptional high tides and storm surge exasperated by sea level rise.

Figure 8. Low lying areas in the Municipalities of Barotak Nuevo and Dumangas



2.4 Storm surge predictions

Storm surge is water that is pushed toward the shore by the force of the winds swirling around the storm. This advancing surge can combine with the normal tides to create the storm tide, which can dramatically increase the mean water level. In addition, wind driven waves are superimposed on the storm tide. This rise in water level can cause severe flooding in coastal areas, particularly when the storm tide coincides with the normal high tides.

The milkfish pond areas of Barotak Nuevo and Dumangas are prone to storm surge from the North-east monsoon winds and storms due to the long fetch.

Figure 9. Potential low lying areas that could be prone to storm surge

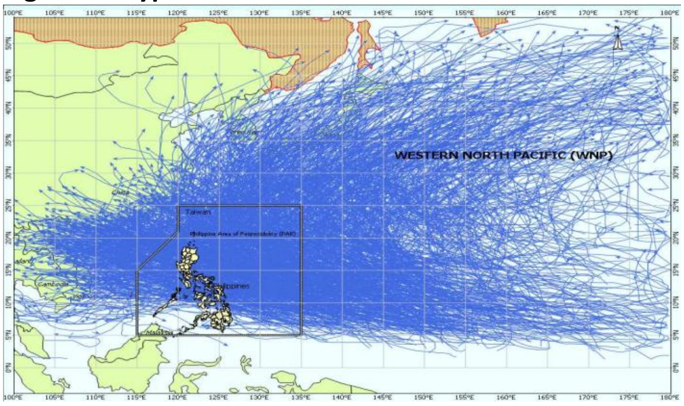
	
Fetch from the North-east	Low lying areas prone to storm surge

2.5 Predicted change in typhoons pattern (IPCC)

The IPCC (IPCC2007) declared that it was difficult to predict future change in typhoon frequency, path and intensity. However recent studies indicate that the maximum potential intensities of cyclones will remain the same or undergo a modest increase of up to 10-20%. These predicted changes are small compared with observed natural variations and fall within the uncertainty range in current studies.

The figure below show the Typhoon tracks since 1945

Figure10. Typhoon tracks since 1945



For example Tropical storm Ondoy (international name Ketsana) hit the Philippines on September 26, 2009, causing widespread flooding. Ondoy, the equivalent of a Category I storm, brought an unusually high volume of rain which inundated the central part of Luzon. Tropical storm Ondoy was quickly followed by typhoon Pepeng (international name Parma). Typhoon Pepeng, a Category III storm, affected the Philippines during October 3-9, 2009, following an irregular path which crossed over Central and Northern Luzon three times. It initially brought powerful winds with gusts of up to 230 km/hr then an extended period of heavy rains, with cumulative rainfall amounts exceeding 1,000 mm in some areas. The resulting rainfall and river floods should only occur on average once in every 50 years.

Typhoons can devastate milkfish pond farms by damaging infrastructure, escape of fish, stress and mortality.

2.6 Predicted change in Extreme Events

The IPCC predict that there will be increasing frequency and intensity of extreme events particularly droughts during the summer months and El Niño events, increase in extreme rainfall and winds associated with Typhoons, intense rainfall events causing severe floods and heat waves/hot spells in summer of longer duration, more intense and more frequent.

Small-scale Milkfish farmers have had to endure occasional extreme events in the past but increasing frequency and increasing severity place great strain on the farm resources to recover. The Farmers need to be supported by calamity insurance for such events that are declared a disaster.

3. Predicted Climate change for the Vietnam case study areas in the Mekong river delta area.

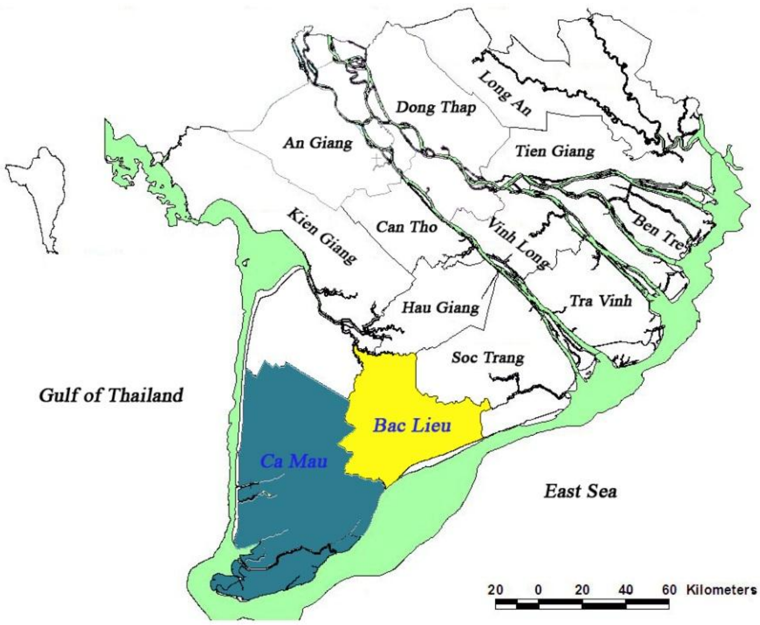
Future predicted climate change was predicted using the downscaled CSIRO Climate model with the SRES Scenario A2 – Business as usual for the years, Present, 2020 and 2050.

The area was modeled at 2 scales. The provincial level and the Mekong river catchment basin. This allowed analysis of precipitation in the Mekong river catchment to predict river flows and precipitation and temperature at the farm level.

Figure 11. Mekong river catchment basin

The case study Provinces of Ca Mau and Bac Lieu were analysed for the Vietnam shrimp case study and the provinces of CanTho, An Giang, Don Thap and Vin Long were analysed for the Vietnam Pangasius catfish case study.

Figure 12. Case study Provinces

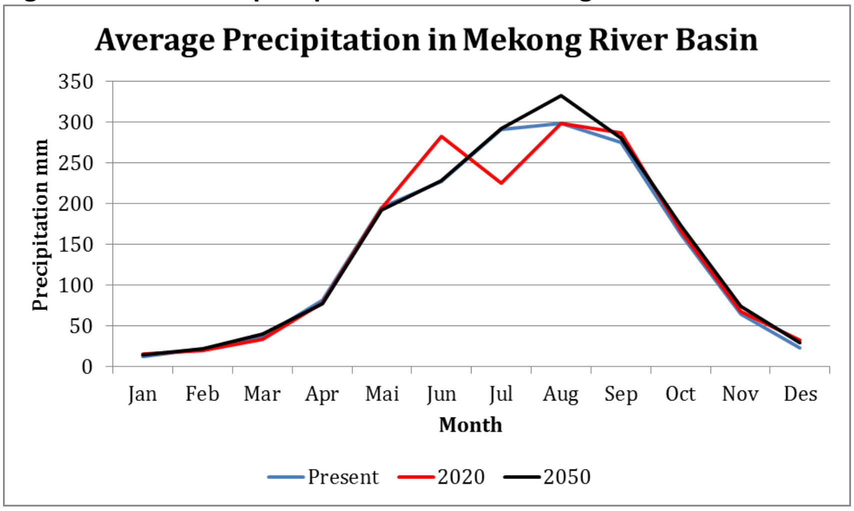


3.1 Predicted future precipitation

Precipitation in Mekong catchment basin

The predicted monthly precipitation in the Mekong River catchment area is predicted to be similar between the present and 2020.

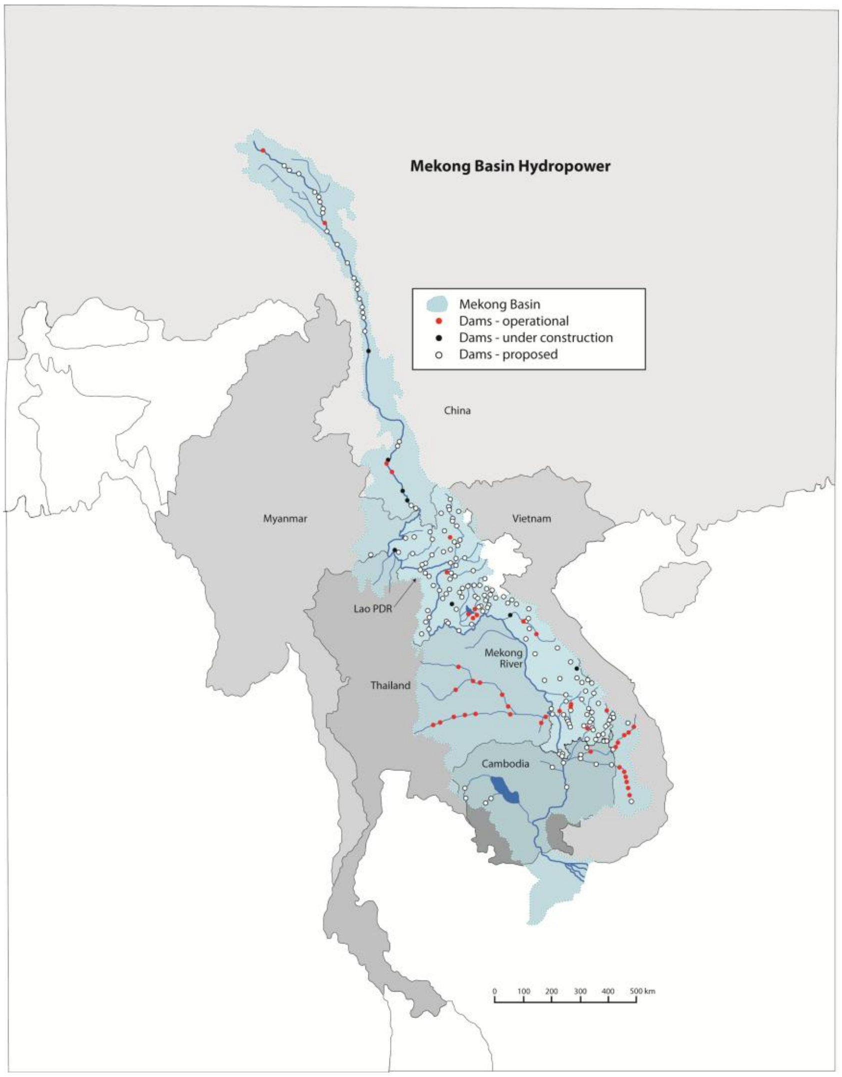
Figure 13. Predicted precipitation in the Mekong River basin



However, peak rainfall is predicted to be 10% higher in the month of August meaning that at peak river flow, 10% additional water may be passing down the river
This together with the increasing sea level will increase the risk of floods.

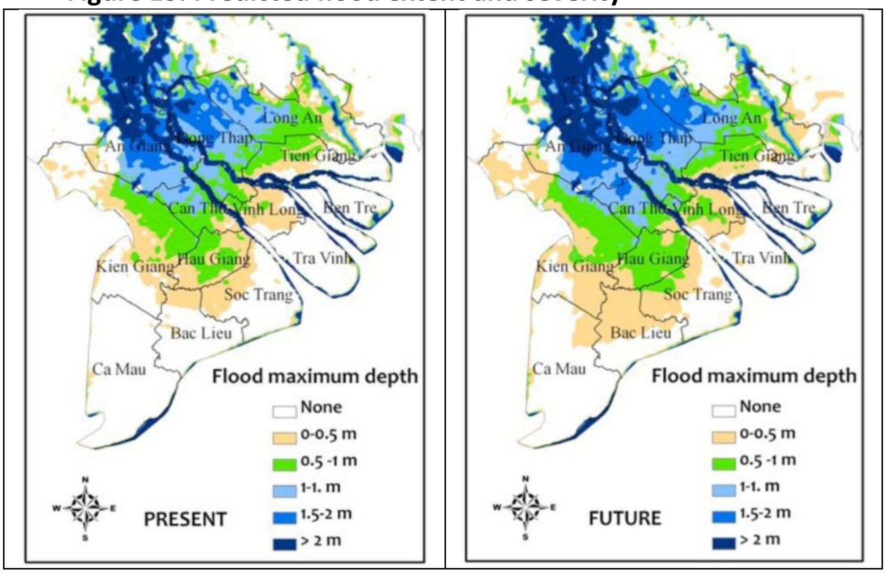
However, the Mekong is already heavily dammed, with many more dams planned and under construction.

Figure 14. Constructed and planned dams along the Mekong river.



Peak river flow may therefore be controlled by 2050 resulting in less flooding than predicted but with slight increase in severity and extent in the north of Bac Lieu and the North-east of Ca Mao.

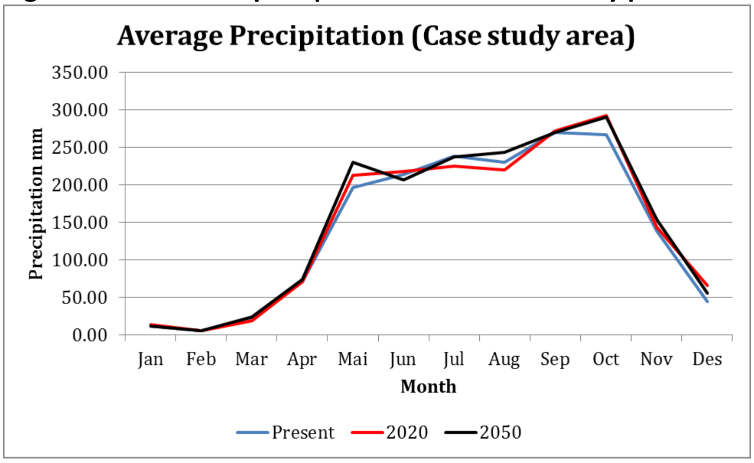
Figure 15. Predicted flood extent and severity



Predicted precipitation at Case study area.

The precipitation at the case study provinces is predicted to be very similar to present precipitation levels

Figure 16. Predicted precipitation in the case study provinces.



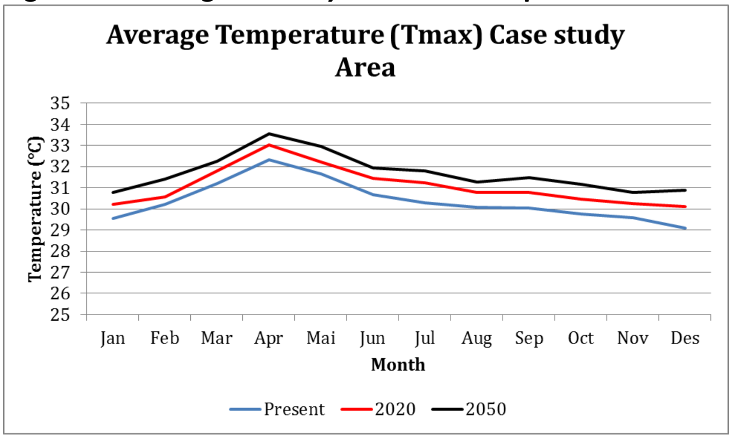
Although the precipitation at the case study areas is not predicted to change significantly in total rainfall and the seasonality of the precipitation will remain the same, the IPCC predicted (IPCC 2007) that when rainfall occurs, it will be heavier i.e. there will be stronger downpours of rain

3.2 Temperature

Average monthly maximum temperature

The average monthly maximum temperature is predicted to rise with time.

Figure 17. Average monthly maximum temperature at the Province level

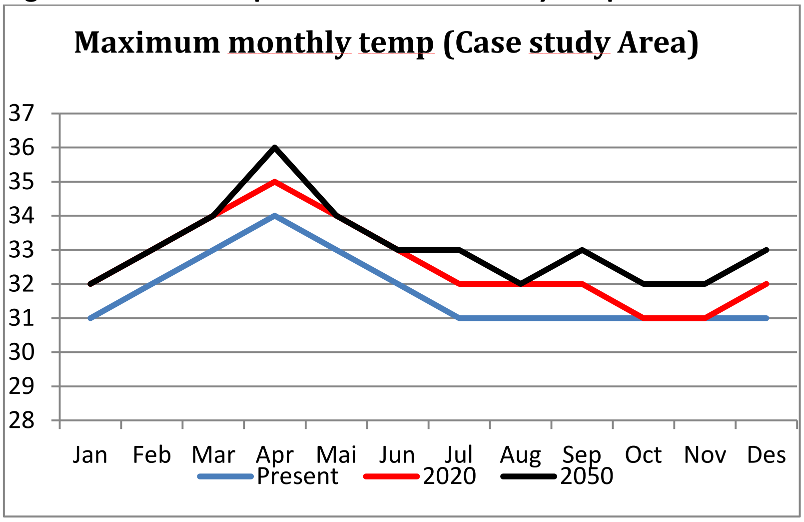


It is predicted that average monthly maximum temperatures will increase by 0.7 oC by 2020 and 1.32 oC by 2050 and that present maximum monthly temperatures will be the same temperature or more for 2.5 months (March to May).

Peak Max monthly temperature

The peak maximum temperatures are predicted to increase in April.

Figure 18. Predicted peak maximum monthly temperatures at Provincial level.



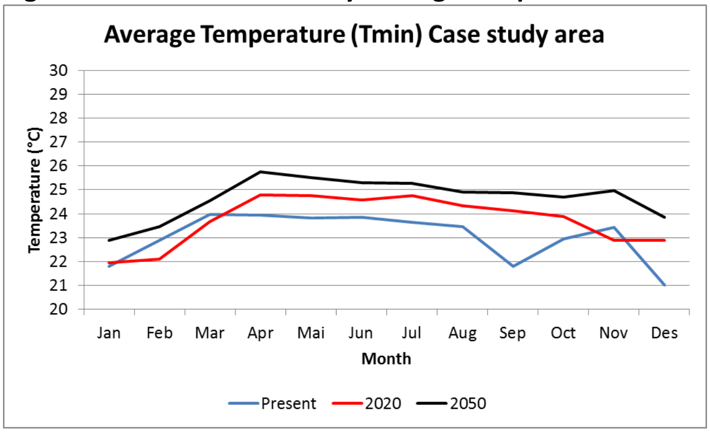
It is predicted that average monthly maximum temperatures will increase by 0.83 ^oC by 2020 and 1.33 ^oC by 2050. The peak monthly temperatures will be 1 ^oC higher (35 ^oC) in 2020 and 2 ^oC higher (36 ^oC) in 2050.

This could cause thermal stress for the shrimp at peak maximum temperatures as well as low water oxygen levels and possible impact to pond productivity.

Minimum monthly average temperature

The average monthly minimum temperature is also predicted to rise.

Figure 19. Minimum monthly average temperatures at Provincial scale

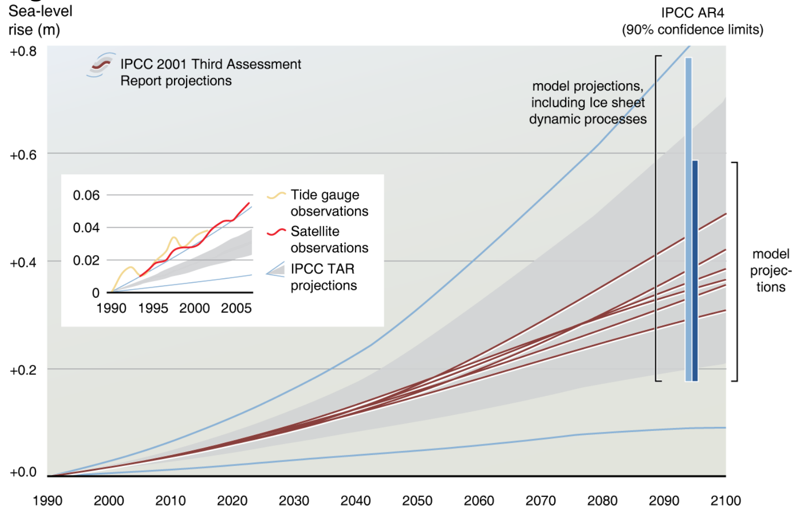


The shrimp will benefit from warmer temperatures between June and January leading to improved growth rate, improved pond productivity and reduced white spot disease outbreaks.

3.3 Predicted Sea Level Rise

Sea level is predicted to rise with time. Under the A2 scenario, it was predicted to rise by 8 cm by 2020 and 18 cm by 2050. However, sea level is rising more quickly than predicted and at the most pessimistic rate.

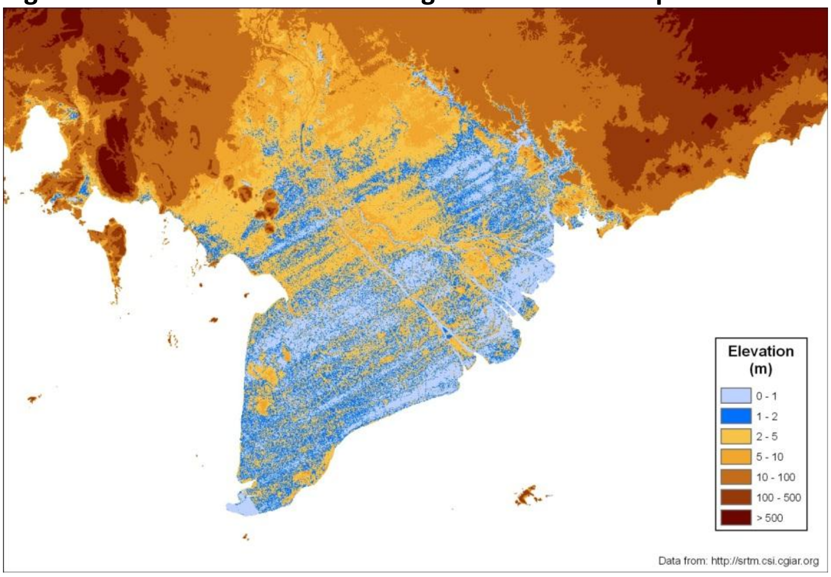
Figure 21. Predicted sea level rise.



If the observed sea level rise continues at the present rate then sea level could be 12 cm higher in 2020 and 30 cm higher in 2050.

This in conjunction with increased storms will mean stronger and more frequent storm surges and seawater flooding of farms close to the coast and in lowlying areas.

Figure 21. Elevation of the Mekong river delta above present sea level.



Increasing sea level rise will also result in increased saltwater intrusion into the Mekong river delta area with increasing salinity December to March and increasing salinity deeper into the delta.

3.4 Predicted increase in Ocean acidification

Continuing Carbon emission from the burning of fossil fuel for electricity production and for transport will be taken up in increasing amounts by the ocean leading to increased acidification and decrease in pH.

Figure 22. Predicted ocean acidification.

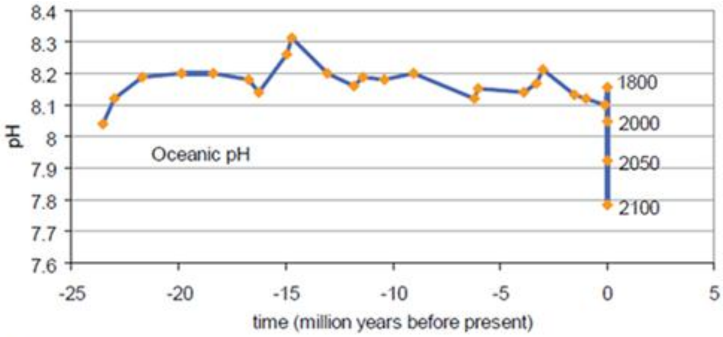


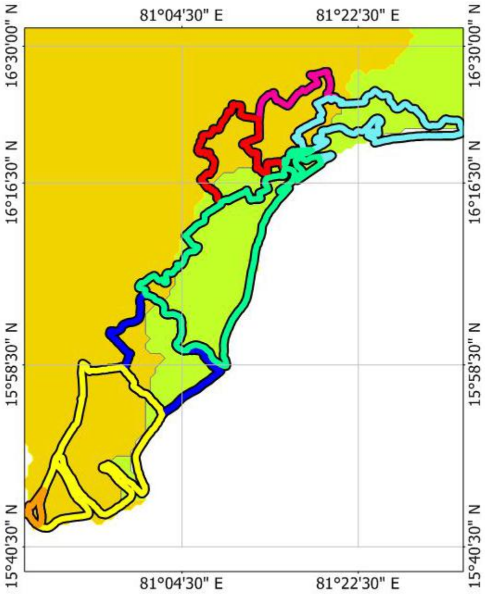
Figure 1. Past and contempory variability of marine pH. Future predictions are model derived values based on IPCC mean scenarios (from Turley *et al*, 2006. Cambridge University Press, 8, 65-70).

It is predicted that ocean pH will be below 8 by 2020 and close to 7.9 by 2050. At pH of 7.8 coral, molluscs, and plankton production will be greatly affected and shrimp larval development delayed.

4. Predicted future climate in the India case study area

The case study areas in India were those shown in Figure 23 below.

Figure 23. Case study areas



4.1 Predicted future precipitation

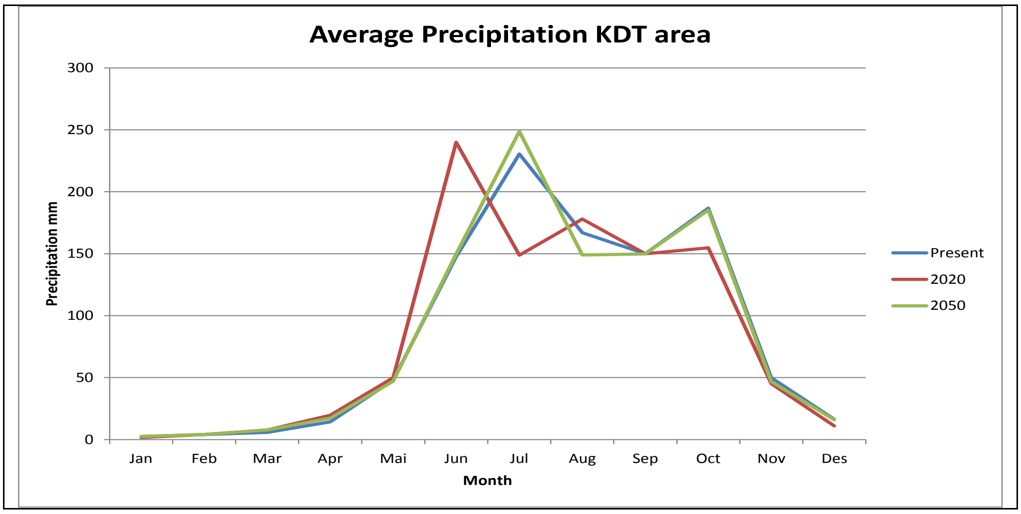
The total predicted monthly precipitation in the case study area is predicted to be slightly less than present in 2020 and similar between the present and 2050.

Table 1. Average monthly Precipitation in the case study areas area (mm)

Months	Present	2020	2050
Jan	2.53	1.72	2.53
Feb	4.01	4.01	4.01
Mar	5.72	7.69	7.79
Apr	14.29	19.60	17.25
May	47.94	49.90	47.14
Jun	147.60	239.92	149.81
Jul	230.49	148.82	248.75
Aug	166.89	178.04	149.03
Sep	150.00	150.00	149.87
Oct	186.76	154.70	185.15
Nov	49.98	45.06	46.83
Dec	16.38	10.97	15.98
Total	1022.59	1010.44	1024.14

However it is predicted that the monsoon rains will start one month earlier (June) in 2020 but then be the same as present in 2050 (July).

Figure 24. Average monthly Precipitation case study areas



The peak rainfall is predicted to be similar as present meaning that at peak river flow will also remain the same as present. However the increasing sea level will increase the risk of floods and storm surge along the coast.

4.2 Predicted future temperature

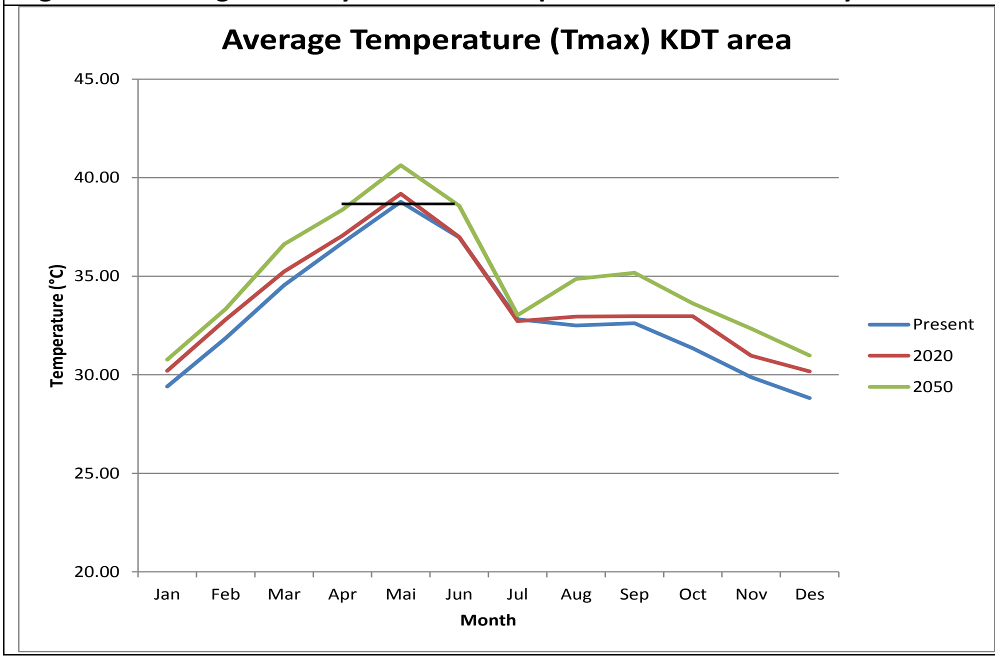
The average monthly maximum temperature is predicted to rise with time.

Table 1. Average monthly maximum temperature in case study areas

month	Present	2020	2050
Jan	29.40	30.20	30.76
Feb	31.86	32.80	33.33
Mar	34.55	35.24	36.62
Apr	36.69	37.06	38.37
May	38.77	39.18	40.63
Jun	36.97	36.99	38.58
Jul	32.81	32.72	33.02
Aug	32.50	32.96	34.86
Sep	32.62	32.97	35.17
Oct	31.34	32.97	33.62
Nov	29.87	30.97	32.34
Dec	28.82	30.17	30.98
Average	33.02	33.69	34.86

It is predicted that average monthly maximum temperatures will increase by 0.65 ^{o}C by 2020 and 1.84 ^{o}C by 2050 and that present maximum monthly temperatures will be the same temperature or more for 2 months (April to June).

Figure 25. Average monthly maximum temperature in the case study area



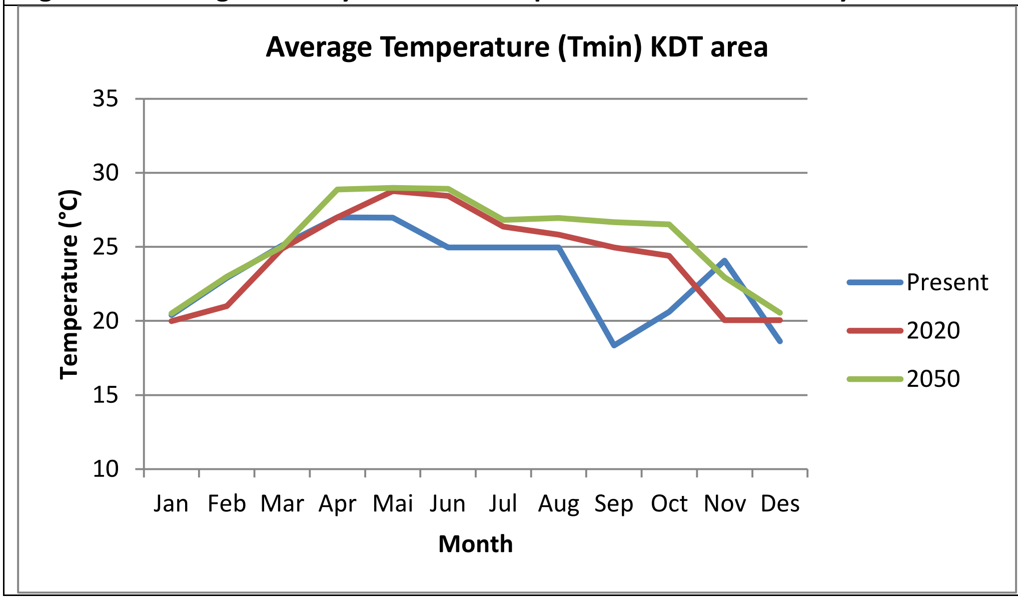
This increased peak pond water temperature cause thermal stress for the shrimp as well as low water oxygen levels and possible impact to pond productivity.

Table 2. Average monthly minimum temperature in KDT area

month	Present	2020	2050
Jan	20.39783	19.97656	20.51216
Feb	22.89963	20.99935	22.98168
Mar	25.09233	24.87084	24.99935
Apr	26.99842	26.99109	28.87759
May	26.97115	28.76571	28.98587
Jun	24.96864	28.44675	28.90531
Jul	24.95762	26.36297	26.81246
Aug	24.95372	25.82235	26.95018
Sep	18.34234	24.95372	26.66577
Oct	20.61025	24.40052	26.5154
Nov	24.07812	20.05225	22.94281
Dec	18.63015	20.05225	20.55263
Average	23.24	24.31	25.48

The increase temperature during the colder moths will have a beneficial effect on shrimp growth, pond productivity and reduced white spot disease outbreaks.

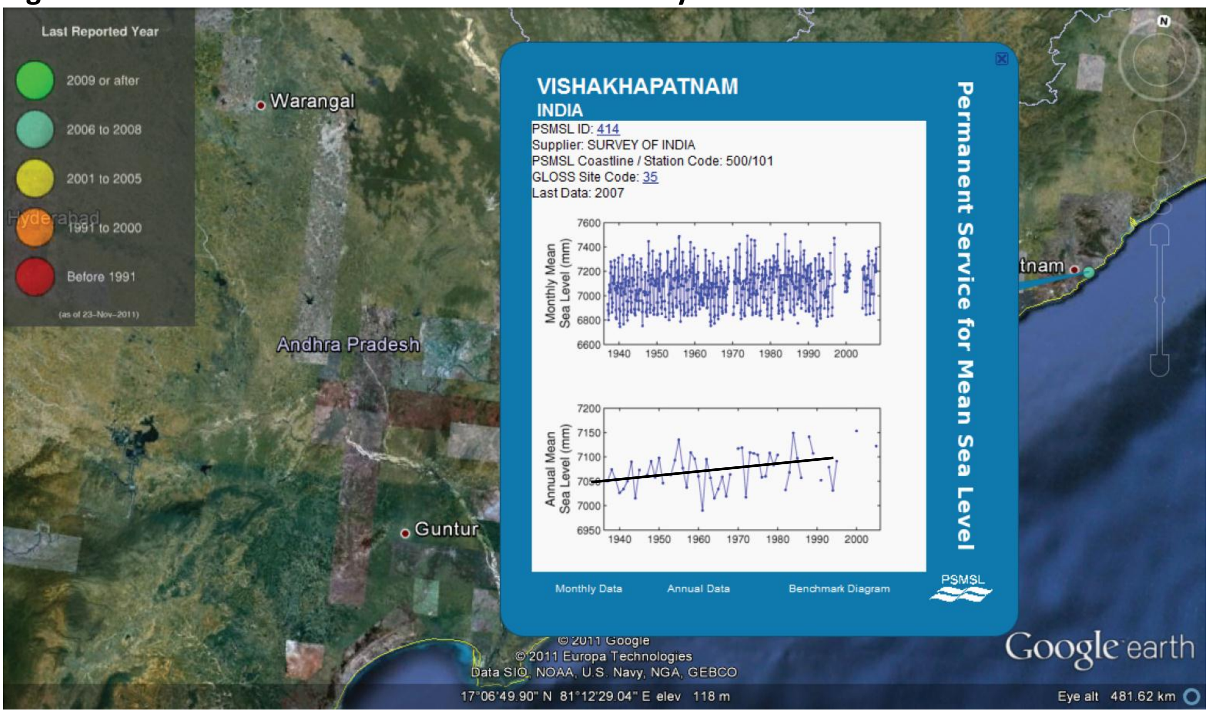
Figure 26. Average monthly minimum temperature in the case study area



4.3 Predicted Sea Level Rise

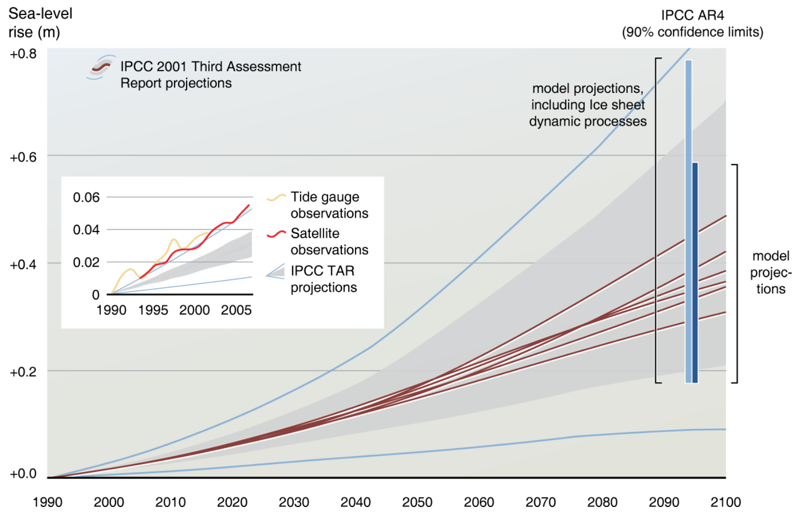
Sea level rise is already occurring in the case study area and an increase of almost 10 cm has been measured between 1940 and 1995.

Figure 27. Measured sea level rise in the case study area.



Sea level is predicted to rise with time. Under the A2 scenario, it was predicted to rise by 8 cm by 2020 and 18 cm by 2050. However, sea level is rising more quickly than predicted and at the most pessimistic rate.

Figure 28. Predicted sea level rise.

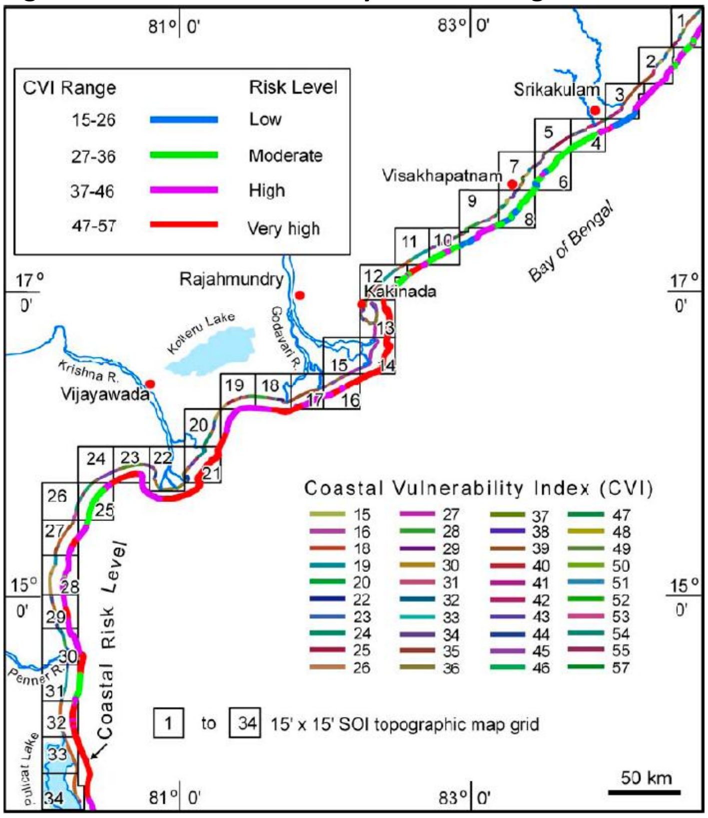


If the observed sea level rise continues at the present rate then sea level could be 12 cm higher in 2020 and 30 cm higher in 2050.

Increasing sea level rise will also result in increased saltwater intrusion into the river delta areas with increasing salinity and increasing salinity deeper into the delta areas.

This in conjunction with increased storms will mean stronger and more frequent storm surges and seawater flooding of farms close to the coast and in low lying areas.

Figure 29. coastal vulnerability to storm surge



4.4 Predicted increase in Ocean acidification

Continuing Carbon emission from the burning of fossil fuel for electricity production and for transport will be taken up in increasing amounts by the ocean leading to increased acidification and decrease in pH.

Figure 30. Predicted ocean acidification.

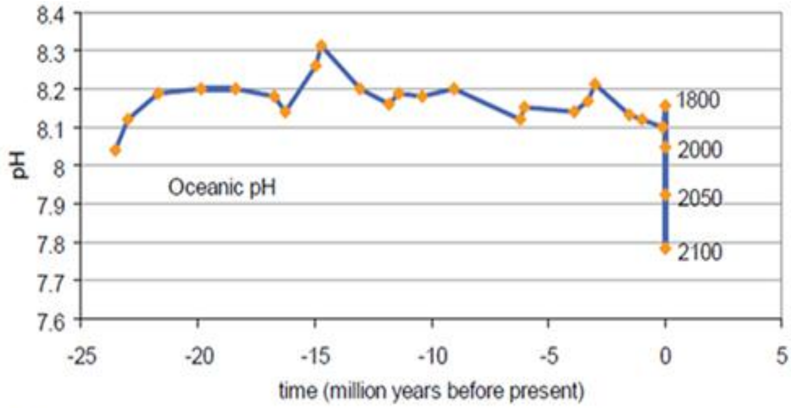


Figure 1. Past and contempory variability of marine pH. Future predictions are model derived values based on IPCC mean scenarios (from Turley *et al*, 2006. Cambridge University Press, 8, 65-70).

It is predicted that ocean pH will be below 8 by 2020 and close to 7.9 by 2050. At pH of 7.8 coral, molluscs, and plankton production will be greatly affected and shrimp larval development delayed.