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Impact of tropical cyclones on fishers livelihood: A review

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Abstract
Fishing is the source of survival for the people residing at coastal belt, but their life has sudden ups and downs due to climatic changes. Encounter of Tropical Cyclones is the prominent issue among issues faced by the fishers. This paper summarizes about the tropical cyclone (TCs), its structure and trend in comprehensive manner. It also focuses on summarizing the problems faced by fishers and TCs extensive impact on the livelihood of the fishers. Chronological study encompassing tropical cyclones and the problems faced by the fishers during the cyclone was made to find the impact of tropical cyclone on the fisher's livelihood. The study reveals the list of issues faced by not only the fishers and their dependents also. Tropical cyclones almost ruin their lives and made them either to live in a hell like place even without proper drinking water and sanitation or to migrate. Authorities are suggested to take steps regarding generation of additional sources of income, arranging cooperative societies for financial supporting and having insurance for their boats. So that at least they can revive themselves form the mess.

Keywords: tropical cyclone, fishing, fishers, livelihood

1. Introduction

Fishing is the prominent source livelihood for the people living in coastal areas and that is the only source of their survival. Tropical Cyclones (TC) have drastic unimaginable impact on the means of support of the fishers and their dependents. This paper is a chronological investigation of studies related to the effect of Tropical Cyclones on the properties and the economy of fishers.

1.1 Tropical cyclones

Tropical cyclones are warm- cored and more intense in nature. The atmospheric vortexes that is developed in warm tropical oceans used to have horizontal scale which is typically extended from to hundreds to thousand kilo meters in to the depth of the tropospheric layer [14]. The intense form of TC often has an eye structure during the times when there is no cloud and precipitation exists [62]. The studies of [42] and [152] explained that cyclones in developed stage naturally have warm and dry eyes with notable reversal in tropospheric layer. When the hurricane abates the inversion level rises and the state of the eye also changes [88, 9] the studies of [68] on aircraft observations and the idealized numerical model explains in the first stage the TC eye formation is covered by dry air and there after it is covered by equivalent potential temperature will become low. Oh the next stage the equivalent potential temperature will become high with high humidity. And they concluded that the humidity is shifted from the eye wall and the convective clouds are developed.

An intense TC is highly uneven, considerable disproportionate structures are often and the inertial stability is extremely high in the inner-core region. Another notable factor of an intense TC is the presence of active spiral rain bands outside the convective eye wall based on the differences in dynamics and thermodynamics, these rain bands are categorised as rain bands and outer rain bands [12].

The sea surface temperature of Bay of Bengal during Day time and Night time have been analysed from 1985 to 2009 to discover the geographical distribution and the seasonal variations and to find the long term trend of temperature. The studies reviled that seasonal variations and geographical distribution is prominently associated with the indigenous weather and climatic conditions whereas the long term trend of temperature is associated with global changes in climatic conditions as well as Global Warming.

And this sustain non-recurring climatic conditions is the cause of TC which used to change the pattern of rainfall and as well as the drought. Intensified cyclones have the power of bringing permanent changes in the economic and routine lifestyle of the fishing people of Bay of Bengal [17].

1.2 Tropical Cyclone Structure
Here we are discussing about the axisymmetric and asymmetric structure of mature Tropical cyclones, spiral rain bands, concentric eyeballs, annular hurricane structures, and about the tropical cyclones inner core size.

a. Spiral Rain bands
Tropical Cyclone has distinct features such Spiral rain bands. On the other side, they can produce severe weather; they may interact with the eyewall, the intensity and the TC structure may changes in various ways [102, 97, 98, 91, 139, 141, 94, 103]. The activity of spiral rain bands and their association with the eyewall and the storm scale rotation are important to the structure and the intensity changes of TC. Form the works of [140], the dynamics and radial extent, the spiral rain bands with a range of 2-3 times of RMW are denoted as inner spiral rain bands, those are out of that range are referred as outer spiral rain bands. From these rain bands, the outer rain bands can be classified as quasi-stationary rain bands and spiral rain bands. The qui stationary rain bands are forced by quasi steady forcing like vertical wind shear. Spiral rainbands may of two kinds namely inner spiral rainband and out spiral raniband. Generally interaction with neighbouring mesoscale convective systems and variability of the core vorticity distribution would be the causes of movement of the outer spiral rainbands [164, 118, 119, 152, 130, 46, 80, 16]. And these outer spiral rainband has notable association with latency gravity waves –gravity waves [75, 29, 151, 104]. But recent studies are contradicted with the earlier views and the behaviours of outer helix rainbands are distinctive from inertia–gravity waves [123, 80, 117]. Inner Spiral rianbands are associated with vortex Rossby waves (VRWs) [15, 46, 105, 90]. These inner spiral rainbands has a prominent role in mixing potential vorticity among the eye and the eyewall. Studies of [142, 20, 109] are also supporting the VRW role in inner spiral rainbands.

b. Axisymmetric Structure
The initial movements of intense Tropical Cyclone is measured as a warm cored partially axisymmetric tycoon in incline wind hydrostatic balance excluding in the frictional boundary layer near to the layer of upper troposphere [111]. Layover on the primary movements is secondary movement which is radial and vertical one. This will result to both diabatic heating and momentum forcing including surface friction. The ancillary movement conveys high absolute angular force which is also an inward spin. The warm structure of mid upper troposphere and the thermal wind balance denote a reduction in peripheral wind above the boundary layer [153]. However this aspect TC does not indicates any information about the determinants of radial locality of the extreme wind occurring places [11] The radius of maximum wind, the determinant of outwards slope of the eye wall and the information about the determinant of the vertical decaying rate of the maximum vague wind are also not presented [165] The studies [122, 25] explained that the outward slope of the radius of maximum wind decreases with increasing the storm intensity. This result was re-examined by the report [128] based on both observations and theoretical grounds. Authors [60] stated that the outward slope of the Radius of Extreme Wind increases with increasing the radius of extreme wind itself and it is not related with the TC concentration. The study of models [33, 127] explains the outward slope of the RMW is shown to closely follow the Absolute Angular Momentum (AAM) surface above the boundary layer. He also noted that there is no relationship between the vertical slope of Radius of Extreme Wind and its intensity. Generally the magnification of a TC is supplemented by the eye wall contraction [18]; the outward slope of the eyewall may decrease when the storm intensifies [25]. Several research [128, 155, 99], explains the perpendicular decay rate of the extreme tangential winds in the Tropical Cyclones. Authors [38] explained that the perpendicular profile of the normalized maximum tangential wind in the upper portion of inflow boundary layer shares a common shape that is almost regardless of the storm intensity and the Radius of Extreme Wind. They also address that a considerable deviations exist partially due to the super gradient /sub gradient motions related with the unbalanced flow in the inflow boundary layer which is forced by surface friction as discussed previously [63, 140, 64] and Their findings have some practical implications for the initialization of 3-dimensional TC structure in high-resolution dynamical models. Since then we have no sufficient observations to determine the initial vertical structure and outward slope of TC eyewalls. Earlier work [127, 128] is serving as a base.

c. Waves and Asymmetric Structure
Even though the innermost structure of an intense Tropical Cyclone is quasi axisymmetric, sometimes we could find asymmetric structure is also. This structure is characterized by spreading Vortex Rossby Waves (VRW), and multidimensional eye walls resulting from dynamical instability or externally forced convective disproportionateness [141, 21, 22] and these may limit the intensity of inner core of TC [135, 137, 158, 154]. These asymmetries in the inward circle are prominently related with the movement of vortex Rossby waves whose re-establishing power is the radial Potential Vorticity (PV) gradient of the axisymmetric TC vortex [90, 15, 136, 135, 137], has made an extensive study about the nature of vortex Rossby waves and their connection with eyewall convection and the activity of inner spiral rain bands [110]. They pointed two types of VRWs namely sheared VRWs and the distinct VRWs [110]. They also found that the VRWs are the reason for the inner spiral rain band and for the formation of multi -dimensional eye wall structure [49, 11, 76, 120, 126, 113, 68].

d. Tropical Cyclone Inner-core Size
The inner core size of the tropical cyclone and its size and intensity are the main factors defining the horizontal range of critical winds and heavy rain induced by a TC [155] The size of TC also impacts the TC motion [41, 40] and regulates the meridional transport of moisture, momentum and heat, which affects the tropical-extra tropical transactions and the atmospheric overall circulation [35]. The size of TC is a significant factor for hurricane surge models and a significant factor manipulating the ocean upwelling under the TC [101, 57]. This is the reason behind the researchers attention on TC and the physical mechanisms associated with TC [156, 157, 61, 50, 8]. As the size of TC has its own importance, it can be measured in various ways like ranges of the eye, gale force wind (17 m s-1), hurricane-force wind (33 m s-1), damaging-force wind

(25.7 m s-1), and RMW. [92, 45, 86, 146, 66].

e. Concentric eyewall structure

Concentric eyewall structure use to form in deep and intense TCs [74, 48]. When the intensity and the structure of TC changes that will lead to progress of concentric eyewall and concentric eyewall cycle [140, 129, 53]. This pattern was first noted by [153]. They observed that during some phases of intense TCs, spiral rainband procedure a half-done or complete ring of convection with intense rainfall in the outside of the eyewall of the TC. This sphere generally holds a distinct local extreme tangential wind and a combination in radial wind, this pattern resemble to the primary eyewall so it is commonly called as concentric or secondary eyewall. Observations proved that the concentric eyeywalls only formulate during intense TCs and the required major changes from case to case but the concentric eyewall use to continue form few hours to even more than a day [69].

f. Annular Hurricane

This is a new set of TCs was identified on the basis of infrared pictures from satellite and aircraft reconnaissance data. Compared with other kinds of TCs, an annular hurricane appears specifically axisymmetric and has huge circular eye region encircled by an extensive eyewall with an almost unvarying circle of deep convection and has no specific spiral rainbands exterior of the eyewall [67]. Stated that annular hurricanes use to have systematic formation features, it is strong and steady concentrations and these are found in only in certain conditions. Once the annular hurricanes form it will remain for several days in based on the environmental conditions [158].

1.3 Tropical Cyclone Trend

In past 25 years the annual frequency of Tropical Cyclones has been increased by 0.0492 cyclones per year. During this study period Bay of Bengal alone has 5.48 cyclones per year or it can be stated Bay of Bengal has encountered a cyclone once every 9.49 weeks. If the same frequency continuous we can expect a cyclone once every 7.08 weeks or 7.35 storms per year by 2050. The study of [124] stated the encounter of cyclone has doubled in last 122 years especially the month of November and May is the peak season for cyclone and the intensity of cyclone 17% to 25% high during these months. Coastal cities are more prone to cyclone during these months. Strong heat may weaken of vertical wind shear which may pave way to progress of severe cyclones even in the months of summer monsoon, and ventilation in the troposphere normally weakens cyclones [159].

2. Impact on fisher's livelihood

According to FAO (2007) 20% of the world's protein requirement is cater by the Fish foods, but due to the growth in population the climatic conditions, species and ecosystems, and the fisheries has underwent drastic changes [32]. The fishers residing at developing nations are used to work from shore or work with small boats in coastal areas and sometimes even in inland water sources [4]. Their contribution to the economy is nominal only [132], but they are also the integral part of society as they are the suppliers of a specific food segment.

The changes in geographical conditions and increase in population has increases the hazards of coastal erosion, storm surge, tidal flood, salinity intrusion, water logging and cyclone [56, 55, 44]. The coastal area of Tamil Nadu use to get affected by the cyclones which indirectly influences the fishing and agricultural activates and the biodiversity of the eco system. This paper is mainly focus on, how the cyclone dilapidate the livelihoods of the fishing community. According to the advisory panel of World Commission on Environmental and Development (1987), "livelihood as adequate stocks and flows of food and cash to meet basic needs". "Livelihood includes the skills, the assets (Human, physical, natural, financial and social capital), the activities and the right to use all these things together for the survival of the individual house hold", [13]. A notable part of coastal life is based in the activities like fishing and agriculture, so the adverse effect and sufferings due to cyclone is enormous. The variability and variations in climatic conditions, and the fluctuations in the quantum of rainfall will either cause enhanced droughts or excessive rain fall; both have their own adverse effect on the livelihood of the fishers. Tropical cyclones will affect the ecology of aquatic lives, so the fishing and fishing related industries will suffer, so people started migrating to cities for their survival [108, 116]. For the purpose of sustainable growth and poverty abolition, various policies have been framed and the "Sustainable Livelihood Approach" has been progressively extended with the objective of poverty concentrated development activities [28]. Due to natural disaster like cyclone, the coastal communities are experiencing migration form their living place due to following reasons. First one is due to escalation of natural disasters and slow on se of the same will leads to migration. Secondly the negative effects of climate changes impacts livelihood, security, health and food, the next reason is the rising of sea level make the coastal areas uninhabitable. The last reason is the struggle with limited natural resources would be the main source of problems which pushes the people to move from their places [6, 7, 100, 161].

Especially the Bay of Bengal is cyclone prone zone; almost 7% of the global cyclonic storms are generated in this region [45]. Even though the factors like Sea Surface Temperature (SST), vertical wind shear, mid-tropospheric humidity, are considered as constructive for cyclone forming specifically at Bay of Bengal [164, 162, 84], Sea Surface Temperature is considered as the major drive for cyclogenesis or of storm intensification [149, 73, 27] In disparity to the general trend, certain cyclones are reporting decline trend during the southwest monsoon [83, 59]. In the situation of global warming also SST is considered as the factor embanking the cyclonic formations [33, 147, 87, 35] and it has conflicting, uncertain, difficult destructive powers [34, 79, 136, 67]. It is expected that the course of global warming may intensify the cyclone activates [72] so that it will cause even more destructions to the coastal communities. Certain elements of cyclone are identified as the cause of devastation; they are very vigorous winds, condensed and prolonged rain and storm surge [71]. Every year 5 to 10 TC start in Andaman Sea and Bay of Bengal and every year some of them make landfalls in coastal regions [3]. Some of them become powerful cyclones causing heavy damages to the survival and properties of the people at coastal belt. Particularly the coastline of Bangladesh is exposed to tropical cyclones and associated storm surges in the past.

Tropical cyclones even intensify the disruptions in fishing operations, fisher's livelihood and the land based infrastructural facilities available at coastal areas [148]. The impacts of cyclone like rise in sea level, heavy rain fall, variations in temperature, and erosion results helplessness of fishery-dependent livelihoods especially to the small scale fishing community [115, 96, 23, 31, 58, 54, 30]. During the times of cyclone they may not be able to do their work regularly; they have to wait until the cyclone weakens. Sometimes the strong cyclones destroy their boats and fishing nets and spoil their entire livelihood. Even the shelter, drinking water source and basic sanitation facilities would also become issue to the fishers during cyclonic events [52].

2.1 Impact of cyclone on Fishing days
The rough weather conditions of cyclone challenge the work of fishers; they are vulnerable to climate extremes and make fishing as fragile. Tropical cyclones may damage their residence, fish- landing jetty road, boat, and other assets and make them jobless. Low level of education, Ingenuousness and inaccessibility of other occupations made the life of fishers as insecure. Sometimes they ought to go for fishing even in worst climatic conditions.

2.2 Impact of cyclone on fisher's properties
The cyclones cause damages and sometimes loss to assets of the people residing in coastal region. It destroys the shelter, boats and their other means of survivals also. During the saviour cyclones and when the warning signals mount, the families of fishers may decide to move to safeguard their lives even that may not be possible sometimes because the trees uprooted by the cyclone may create mess in the road access, the combination of wind and rain may stopped their other means of commutation, fear of harm by flying wreckage due to storm is another factor that frightens people regarding moving from cyclone prone zone to other areas [2].

2.3 Impact of cyclone on fishing expenditure
A complete successful fishing trip requires at least three days of sailing. Normally every fisher group borrow some money form money lenders at high rate of interest for the purpose of purchasing fuel and other utilities for each fishing trip. According to standard orders, the fisher must return to the shore when the signal number three is issued (MODM, 1998), because it is considered as the signal of potential danger and rough sea conditions. During this situations the fisherman has to come back frequently from the sea. This kind of incomplete trip cause significant loss especially during the peak fishing period. Sometimes they even loss their boats and fishing nets and again they need to go to the money lenders to purchase the same.

2.4 Impact of cyclone on women and children
Instead of going to school, the children are forced to get involved in the fishing activities and they were taught to cope up heavy rain, cold wind and strong sunshine [52]. Women and children are more defenceless to cyclones due to various reasons. Women may willing to move from the cyclone affected place to safeguard their children, but their attire and their long hair intrude them to swim in tidal waves [47]. Also the issues like class, caste, religious believes prevents women in moving from affected areas. Alone with the problems of cyclone, the women also encounter issues like lack of pace to lodge, lack of power facility and poor sanitation [2].

2.5 Impact of cyclone on Migration
Migration witnesses the changes in ecosystem. There are various kinds of migration out of that moving temporarily for survival which is otherwise called as leaving in order to stay. Fishers use to migrate within a specific geographical location to exploit different species; some short-term relocations are for a period less than a fishing season to track fish stocks; and some periodic relocations last up to for one or more seasons to foreign fishing settlements [93]. Their materialistic losses during the times of cyclone force them to migrate to a different job, which they may not have experience and willingness to do.

3. Conclusion
Tropical cyclones or the so called 'atmospheric heat engines' gain heat power from the warm sea water and strengthen their momentum by gaining more heat and moisture as they move through warm areas of the sea [131]. In this paper we had discusses the structure and trends of tropical cyclone. These have to be clearly understood to take precautionary steps as it has abundant impact on the livelihood of the fishers. The wickedest sufferers of climate change disasters are the petty-earning small fishers who are daily bread winners living in the coastal areas. They are facing devastating difficulties during the times of cyclones. During life-threatening events poor fishers have to admit death as their uncertain effort neither survive them in the sea nor permit to return to coastline. Abandon fishing journeys is very common to protect their lives. Moreover, fishing nets and boats destruction or loss by high waves, cyclone and tidal surges makes them jobless. To get them out form these pathetic condition following suggestions are made based on the chronological reviews.

4. Suggestions
We have the power of pausing the natural calamities; instead we have to see how we can protect our people form sufferings. The sufferings of fishers during the time of cyclone is massive, even though completely avoiding the issues faced by the fishers is not possible, their situation can be managed in following ways. Initially it is highly recommended to have assets which are easily convertible in to cash to cater unexpected needs during the period of cyclone [125]. Fisher's physical assets are weak in nature and damage easily, so it is important to promote calamity insurance which is considered to be one of the best measures to protect fishing community form damages due to cyclone. The insurance arrangement permits all people as well as the poor to moderate unexpected shocks from climate changes and life-threatening events. Adequate finance facilities should also be arranged through cooperative societies, so that they need not depend on money lenders. Since the cyclones have the power of destroying the survival source of fishers, they can be motivated to grow shrimp, prawn and crab in the coastal ecosystems including ponds, tanks, waterlogged areas, canals and creeks [51, 26] as supportive means of survival. They can be given practical training on fish farming and extension works including garment designing and embroidering cloths and create handy crafts with coconut leaf [52] so that they can manage their basic needs even encountered by cyclones.

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