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Indigenous Traditional Ecological Knowledge of Tamil Nadu Fisher folks: to Combat the Impact of Climate and Weather Variability

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This study explores the significant role of indigenous traditional ecological knowledge (ITEK) in weather forecast prediction and fishing related activities in the coastal villages of Tamil Nadu. In total, 33 rural coastal villages were studied for different uses of ecological indicators in seasonal predictions based on oceanographic parameters, hydro-geological, astrophysical, meteorological and biological conditions. We focused on oral dialects from traditional fishing practitioners, local community leaders and fishers as efficient respondents to carry out the study. In addition, we also attempted to develop a template of seasonal ecological calendar based on ecological indicators of Tamil Nadu coastline. This conceptualisation can also be absorbed on a synoptic scale as an integration framework of ITEK and scientific innovations. On the other perspective, it is so factual that adaptation of ITEKs in the current decades is in verge of extinction due to several factors such as modernization, technological advancements and waning intergenerational knowledge transmissions. In the face of losing ITEKs, it is crucial to integrate ITEKs in the scientific seasonal forecasting of environmental changes and climatic events to facilitate better decision making policies on adaptation and mitigation strategies. It is highly essential to build the concept of conservation and documentation of ITEK to solve the climate crisis and effective decision making. In the recent years, the approach of integrating biophysical and social sciences on understanding earth science is an emerging concept to enhance climate knowledge. Application and integration of ITEKs with scientific ecological modelling systems possess tremendous potential to develop accurate scientific forecasts and reliable future predictions.

Keywords: Forecast, Indicators, Indigenous traditional ecological knowledge, Integration, Tamil Nadu, Weather
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In the face of global climate change, some major impacts such as rise in temperature, fluctuations in monsoon patterns, melting of ice caps and glaciers and increased ocean acidity are greatly affecting the marine environment. The rate of impact and vulnerability is drastically increasing and hence it is crucial to enhance the adaptive requirements in the developing countries. National adaptation plans and several international communities are identifying tools and approaches to assess and monitor the inter-annual and intra-annual spatio-temporal climatic variability to ensure a sustainable future. To predict and forecast the seasonal and climate variability in advance, several ocean condition forecasting models were developed in the wake of the Indian Ocean tsunami occurred in the year 2004. Tsunami is one of the major climatological disaster that shook most coastal states of India and many developing countries of South Asia. This disastrous event caused severe economic damages and loss of human lives in millions within a few minutes of the mishap.

However, few ancient tribes called the Jarawas, the forest inhabitants of the Andaman and Nicobar Islands, India, survived the havoc. Government officials and anthropologists reported that, their indigenous traditional ecological knowledge of the movement of "wind, sea and birds" must have saved Jarawas from the wrath of the tsunami. These tribes recognized variations in natural climatic conditions through their traditional knowledge and protected themselves from extreme impacts. This incident emphasizes the importance of traditional knowledge on dealing with ecological adversities. International panel on climate change stated that indigenous knowledge serves as a basis for developing adaptation and sustainable management of environmental resources from changes[1]. Moreover, the Convention on Biological Diversity-Article 8 (J) emphasizes on

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Traditional Knowledge, innovations and practices. It encompasses the contracting party to be "subjected to national legislation, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and property use of biological diversity and promote their wider application with the approval and involvement of the holders of such information, innovations and practices and encourage the equitable sharing of the advantages arising from such innovations and practices".

Traditional, Indigenous, and Local Ecological Knowledge (TEK, IEK, and LEK, respectively) are referred to as the source of knowledge about species, ecosystems, or practices held by people whose lives are closely linked to their natural setting[2,3]. Traditional Knowledge or Indigenous Traditional ecological knowledge (ITEK) is defined as the practices, information, innovation and knowledge of the indigenous communities to ensure conservation and sustainable use of biodiversity. With the advent of modernized scientific technology in the present decade, traditional communities, yet use varied composites of meteorological, hydrological and biological factors as indicators to predict the prevailing climate and weather conditions. These indicators are recognized based on priori traditional knowledge gained over centuries and passed on from generation to generation. These observations are also adapted from the empirical annotations on the environment and ecological interactions.

It is evident from the light of several reports that indigenous traditional ecological knowledge is applied in the forestry, farming and fishing activities. Fisher-folks across the world greatly depend on indigenous weather and climate forecasting practices to inform their day-to-day fishing practices and decisions. Fishers use weather, wind and current patterns in prediction of fish harvesting grounds and they also monitor climatological, meteorological and astronomical indicators to pursue fishing in conditions of uncertainty. The current study aims to document the traditional ecological knowledge of the coastal villages of Tamil Nadu. This work is the archival of literature collation and primary information from local communities on customary fish harvesting practices and climate-weather related predictions. It also discusses on the integration of TEK with seasonal, weather and climate forecast models and predictions to additionally augment the forthcoming technological and scientific advancements related to risk management and decision making.

Background

Scientific contributions and documentation of indigenous traditional ecological knowledge of climate science, weather predictions and forecasts are very few. There are significant studies on indigenous traditional ecological knowledge in specific branches of sciences, including biodiversity conservation, environmental indicators and sustainable resource management. Documentation of these practices attributes understanding on the environmental conditions in a better way. Few frontline studies are evidences of isostatic rebound and sea-level change from oral history of Inuits of Arctic Ocean[4], past climatic conditions of Yukon[5], environmental changes in the Hudson Bay Bioregion and Northern River basins through traditional knowledge[6], the Mackenzie Basin Impact study[7]; ITKs and impacts of climate change in the Arctic[8]; indigenous knowledge for predictions of environmental changes in Pacific Islands[9]; traditional knowledge of weather forecast and climate predictions in Chimanimani district of Zimbabwe[10]. Some of the recent notable contributions from Indian perspective are: nature lessons for weather forecasting[11]; traditional knowledge and bio-indicators of Mizoram, Northeast of India[12]; case studies on indigenous technical knowledge in capture fishery of Ernakulam district, Kerala[13]; perspectives of small scale fishing communities on climate change[14]; proverbs related to ITKs of Kerala coast[15]; ITK of Indian marine fishermen with reference to climate change[16]; indigenous forecast practises of farmers of Coimbatore district, Tamil Nadu[17] and traditional knowledge of Tamil Nadu fishers on climate change[18]. All of these studies recommended that aboriginal or indigenous elders are able to differentiate subtle patterns, seasonal variations in ecosystem structure and functions. Some studies have even detailed the large-scale developments and need of climate change related assessments for the sustainable future with mobilization of credible indigenous traditional knowledge system. These studies tend to be evidential to understand the need and essentials of traditional knowledge system towards understanding of changing climatic conditions and environment. Conceptual frameworks bridging the traditional knowledge of indigenous communities and scientific approaches are to be introduced and amplified.

Materials and methods

Study site

The study area includes Southeast coast of India extending from Chennai to Kanyakumari in the state of Tamil Nadu (Fig. 1). Tamil Nadu covers 720 km of Indian coastline encompassing the major biologically diverse and productive regions along the east coast of India. There are 573 marine fishing villages and 407 fish landing centres in the coast. The total fisher folk population is 8.02 lakh as reported in the marine fisheries census 2010[19]. Fisher folk communities from seven coastal districts and one union territory such as Chennai, Kanchipuram, Cuddalore, Nagapattinam, Tuticorin, Rameswaram, Kanyakumari of Tamil Nadu and Pondicherry coastline were surveyed. These are the major coastal districts covering the extent of the Coromandel Coast, Palk Bay and Gulf of Mannar. The coastal districts were selected based on the type of fishing sector and total fisher folk population in the region. Overall 33 rural fishing villages from each district involving in mechanised, motorised and non-mechanised (traditional) fishing sectors were selected for the study (listed in Table 1).

Ethnographic Survey

Ethnographic exploratory surveys in the selected villages were carried out in the months of July to December 2018. The interviews were performed using the series of semi-structured, flexible and open-ended questions focusing on different traditional fishing practices, ecological indicators, weather and climate related predictions, year of practice and source adopted. The respondents are the local experts of the village, community leaders, head of fishermen co-operative society and experienced traditional fishing practitioners. Age of respondents ranged from 18 to 85. Most of the respondents were males who were involved in fishing and fishing related occupations such as fish processing and marketing. Female respondents were comparatively lesser than male respondents. This may be due to the fact that they were involved in fish vending, processing and marketing activities and hence, most of them denied spending time for the interview. However, some female respondents from Self-Help Groups of the particular villages were willingly contributing to the survey. Group discussions, one-one direct interview,

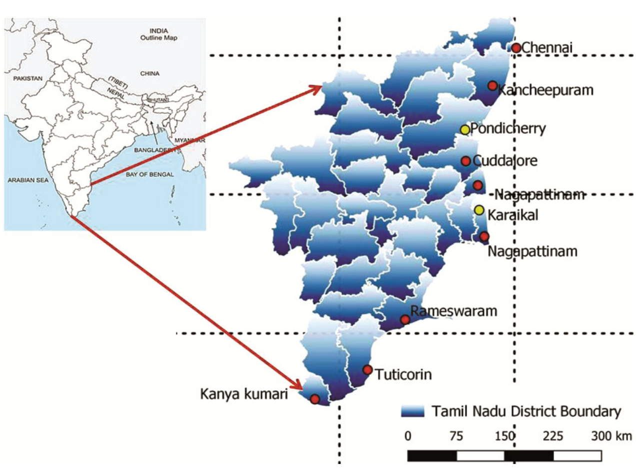

Fig. 1 — Map representing coastal districts of Tamil Nadu coastline selected for the survey

Table 1 — Geographical positions of the coastal villages surveyed during the study

Districts	Villages	Latitude and Longitude
Chennai	Kasimedu	13.0827° N, 80.2707° E
Kanchipuram	Devaneri	12.6511° N, 80.2049° E
	Sadraskuppam	12.5247° N, 80.1659° E
	Kovalam	13.0827° N, 80.2707° E
	Mamallapuram	12.6121° N, 80.1969° E
Cuddalore	Singarathoppu	11.4364° N, 79.4650° E
	Sonamkuppam	11.4326° N, 79.4645° E
	Cuddalore OT	11.7480° N, 79.7714° E
Nagapttinam	Poompuhar	11.1503° N, 79.8437° E
	Seruthur	10.6722° N, 79.8451° E
	Nagapattinam Harbour	10.7607° N, 79.8500° E
	Velankanni	10.6819° N, 79.8437° E
	Keezhamoovarkarai	11.2130° N, 79.8454° E
	Kalikuppam	10.9780° N, 79.8486° E
	Samanthanpettai	10.4740° N, 79.5042° E
Pondicherry	Karaikal	10.9254° N, 79.8380° E
	T.R. Pattinam	10.8653° N, 79.8325° E
Tuticorin	Tharuvaikulam	8.8922° N, 78.1707° E
	Inigo Nagar	8.7894° N, 78.1611° E
	Thirespuram	8.4854° N, 78.9432° E
	Vellaipatti	8.5129° N, 78.9482° E
Rameswaram	Pamban	9.2798° N, 79.2291° E
	Mandapam North	9.2770° N, 79.1252° E
	Mandapam South	9.2876° N, 79.3129° E
	Seeniyappatharga	9.1635° N, 79.6553° E
	Vedhalai	9.1621° N, 79.7439° E
Kanyakumari	Kanyakumari harbour	8.5179° N ,77.3218° E
	Muttom	8.1247° N, 77.3307° E
	Chinnamuttom	8.0943° N, 77.5614° E
	Kovalam	8.4004° N, 76.9787° E
	Enayam	8.2243° N, 77.1837° E
	Manakudy	8.0911° N, 77.4774° E
	Pallam	8.0998° N, 77.4336° E

telephonic interviews, participatory rural appraisal methods and diagramming the indicators were carried out. During the survey, related TEK types cited in the literatures were also showed as visual cues to trigger memories on their awareness and insights on traditional methods and indicators. This enhanced the interest of participants/respondents to guide us on their perceptions and values. The respondents were from the ancient ancestral and modern Dravidians who were conversant in Tamil, Hindi and Urdu. All the deliberations and elicit information were conducted in Tamil and the elicit dialects from the fisher folks were prudently documented.

Results and discussion

Indigenous Knowledge off Tamil Nadu coast:

The traditional fisher folks of Tamil Nadu coastline perceive several ecological indicators in their environment to predict and diagnose the climate and weather patterns for fishing and fish harvesting and also for predicting natural hazards. These practices are diverse and are followed by most of the coastal villages of the entire Tamil Nadu coastal stretch (listed in Table 2). For the recent modernized fishermen who pursue technology oriented fishing practices, the traditional methods are an additional strength and asset that are learned and adopted from their ancestors for more than 3-5 generations, i.e., in approximate 2 million ancestors. The first-face stereotype response from the fishermen respondents of different village for the question "how did you learn these indigenous methods?" the reply is "We follow fishing ever since my great grandparent's generation and we understand it is from our ancestral origin. We are continuing it for thousands of years. We learned this from our parents, they taught us, and we believe we are brought up off the sea". These assessments, predictions and interpretations of weather and climate patterns are carried out by observing the environmental factors. The observation skills were developed from studying the behaviour of living organisms, astronomical and meteorological indicators. These methods were not deployed without following any principles or theories, but are the results of several ancient experimentations, a close understanding of nature and logical reasoning from daily life experiences. These experiments, observations and experiences were verified in an institutional setting called as indigenous academy of survival[20]. In comparison between the different types of fishing sectors, most of the respondents are from motorised and non-mechanised/ traditional fishing types and are noted to be the hangers-on the indigenous knowledge predictions.

Aboriginal knowledge of fisher folks on different Ecological Indicators:

Oceanographic Indicators:

Wind and Ocean current

Since time immemorial, traditional fisher folks of the coast perceive physical oceanographic conditions such as wind, ocean-current, waves and tidal patterns to predict climate events such as monsoons, cyclones,

Table 2 — Some of the aboriginal knowledge of common indigenous traditional ecological indicators reported by fisher folks of Tamil Nadu coast

Indicators	Significance	Branch of applications	Coastal Districts
Moon phase	Onset of rain by observing the shape of crescent	Astrophysical	Chennai, Kanchipuram and Kanyakumari
Star constellations	Navigation through canals and towards fishing ground	Astrophysical	Nagapattinam, Rameswaram, Tuticorin
Wind movement	Identifying the directions for gear operations	Oceanographic	All the coastal districts
Sea grass beds, Corals and Mud-banks	Navigation towards fishing grounds	Geo-topological	Gulf of Mannar
Halo around the sun	Storm, erratic rains and cyclones	Astrophysical	Nagapattinam and Kanyakumari
Warm surface waters	Determination of fish abundance	Biological	Rameswaram and Tuticorin
Bad odour	Determination of fish abundance	Biological	Rameswaram and Tuticorin
Stocks of Cormorants, Gulls and Dolphins	Determination of fish abundance	Biological	Nagapattinam, Rameswaram and Tuticorin
Bubbles in the water surface	Indication of storm and sometimes specific fish shoals	Meteorological and Biological	Kanyakumari
Hopping Sea snakes	Indication of cyclone	Meteorological	Tuticorin and Kanyakumari
Wind and Tidal patterns	Fish harvesting and gear operation	Meteorological	Kanyakumari

weather and other natural hazards. Directions of wind (Kaatru) and ocean current (Neerottam) was identified by the fisher folks to determine the suitable fishing grounds with higher fish availability and for navigation in sea. The geographical directions were assumed by understanding of landward and seaward side. From the land/shore facing towards the sea is called as "Villangu", right side is "Kachaan" and left side is "Kondal" and behind i.e. landward side is called as "Karai". With respect to the directions, wind from landward (Karai) to seaward (Villangu) occurs during June to September (southwest monsoon season), During October to February (northeast monsoon and inter-monsoon season), wind from seaward side (Vilangu) blow towards land (Karai). When the wind is strong from right towards left (Kachaan→Kondal) is hard-hitting in the months of April to June (inter-monsoon season) and this wind is locally named as "Kachaan Kaatru" and its vice-versa (Kondal→Kachaan) occur in the months of October to November (northeast monsoon season). Wind blowing from seaward to right side (Villangu→Kachaan) to landward to left side (Karai→Kondal) is called Chozha Kondal Kaatru, which is prominent throughout the early inter-monsoon season (April to June). Wind speed is highest to be about 60-70 kmph during the Chozha Kachaan Kaatru, and in this season, wind blows from seaward to left side (Villangu→Kondal) to landward to right side (Villangu to Kachaan). This wind is unfavourable to carry out fishing and it is strong in the months of April to June. Vaadai Kondal Kaatru which is distinct wind pattern and it blows from landward to left side (Karai→Kondal) to seaward to right side (Villangu to Kachaan). Similarly, Vaadai Kachaan is the wind that blows from landward to right side (Karai→Kachaan) to seaward to left side (Villangu→Kondal) and this wind is an indicator for cyclones and storms in the northeast monsoon season. Fig. 2 represents the pictorial diagrammatic representation of wind patterns and directions drawn by the fisher folks of Tuticorin coastal district. Ocean water currents are called as Neerottam, the current from sea to land (Chozha Neerottam), from land to sea (Vaadai Neerottam), left to right (Kondal→Kachaan) is called as Kondal Neerottam and vice-versa is Kachaan Neerottam. Fig. 3 represents the local names of ocean currents and its directions and its seasonal indication in the environment. These statements were also comparative to the indigenous technical and traditional knowledge on seasonal variations of winds and currents from southeast coast of India described by Panipilla and Marirajan, (2011)[21]. The shoals of tuna, seer fish and sail fish can be predicted using the wind patterns observed during the Vaadai Kaatru. Kachan Kathu/ Sonivellam is an indicator for the abundance of Mathi (the Sardine fish). Wind speed and directions are also observed towards safe and proper craft and gear operations for fishing[13].

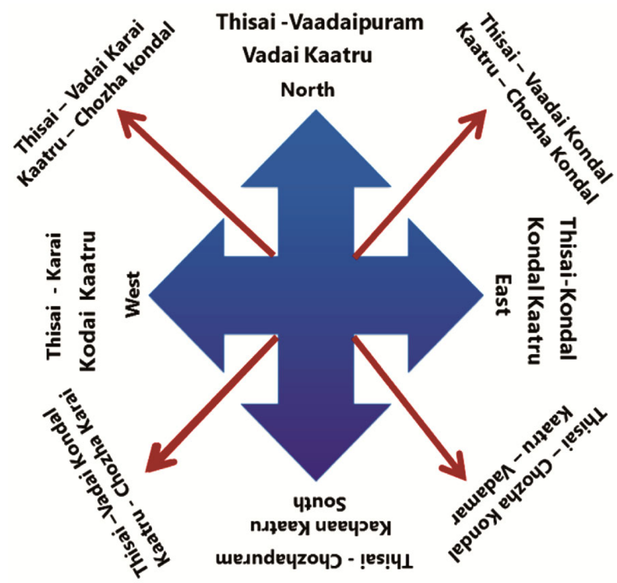

Fig. 2 — Vector diagram of geographical directions of winds as depicted by the fisher folks off Tamil Nadu coastline

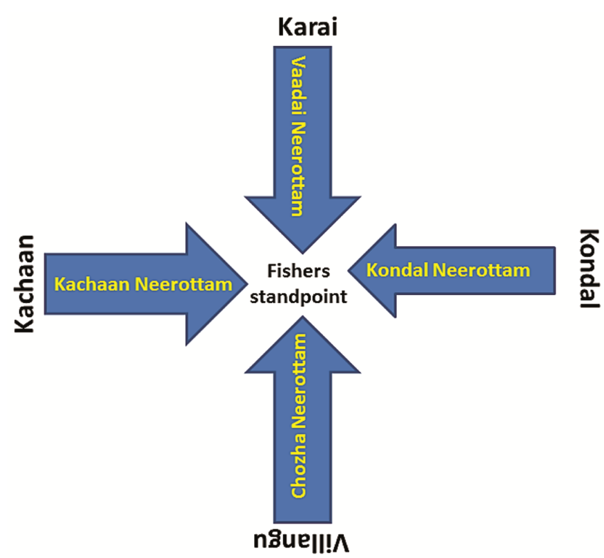

Fig. 3 — Vector diagram of geographical directions of water currents as depicted by the fisher folks off Tamil Nadu coastline

Waves and Tides

Wave and tidal patterns are influenced by physical forcing such as winds and currents. Waves are the crests and trough formed in the surface waters of the sea by wind energy. Whereas, tides are formed due to the gravitational pull of the sun and the moon. This reinforcement during the times of new moon and full moon generates ocean bulges which move landward producing high tide and so the opposite. [22]Sethi et al., 2011 stated that the fisher folks following indigenous traditional knowledge systems always notice the waves for 7 to 9 times before they venture into the sea. The same statement was discussed during our current work and the fisher folks responded positively, their reaction was "We observe waves before we drive into the sea for fishing, we count the waves, we know the considerable peak altitude of waves, we also depend on the speed and smoothness of the 7^{th} to 9^{th} wave from the initial time of observation, this will aid us to judge the roughness of the sea". Similarly, the small scale fishers of Kanyakumari coast perceive high tide and low tide durations to exploit mussel fishing. As the mussels get exposed during the low tide phase, it tends to be the favourable time for the fishers to collect mussels from the rocky beds. Enayam, Enayam Puthenthurai, Midalam and Kodiyapattinam are the coastal villages involved in mussel fishing practices. The fishers use the way old method called "Skin-diving", an adaptation from Chank diving and Pearl fishing. They use scalpel ("Aruva kathi") and bag net ("Katcha Vala") to scrap and fish mussels from the rocky beds[23]. Roughness in sea, cyclonic and turbid conditions in the sea shore are also considered to be some important indicators for tracing the natural hazards.

Astrophysical Indicators:

Sun, Moon and Stars

The sun, moon and stars are essential astral energies that generate and bombard life on earth. They are significant in stabilising and maintaining the standard temperatures, climate events and weather conditions in the current persisting environments. These celestial components are witnessed as attributes for identifying and determining the weather conditions in certain environments by traditional communities for agricultural farming, forestry and fishing purposes. Few agro-pastoralists use astrological constellations and position of sun, moon and stars to interpret the seasonal variations[24]. This can be substantiated with the reports on position changes of Milky-Way in accordance with the seasons[10]. In the current study, we noticed respondents explaining some pragmatic practises such as using astral stars for navigation purposes in the night times. Stars are called as "Velli" in the colloquial language of Tamil Nadu fishers. Stars such as "Vidivelli" and "Kurushuvelli" (so called as Ghost star) are used in directing the fishers towards the previously identified fishing grounds. Fishers of the coastline also depend on moon phases for yielding more fish catch. They are the masters in understanding the Solunar theory[25], which still remains as a cynical and complicated concept for many natural scientists. In veracity, this concept of following the phases of Solunar (So-Sun; lunar-Moon) is still actively practiced by the fisher folk communities of Tamil Nadu coastline. Fishers are keen in noticing the sun-rise /sun-set/ moon-rise/moon-set time in advance and correlate the period with the new moon or full moon phase and the wind-tidal patterns. The lunar phase is strongly followed by the fishers targeting for higher catch. In addition, two combinatorial factors with moon-phase considered are physical forcing, weather patterns and seasonal transitions which may greatly influence the feeding and breeding period of fishes. This solar and lunar transit times are alleged to be varying spatially with global positions and altitudes. Besides this, full moon is said to bring minimal fish catch due to increased light incidence whereas new moon is the suitable phase to yield maximum fish catches. Halo around sun, a thick red line or a patch encircling moon with cloudy high winds are also considered to be indication of rainfall, roughness in sea, cyclonic and turbid conditions in the sea.

Hydro-geological and ecological structures as indicators:

According to the traditional knowledge of fisher folks, they understand the existence of ecological and hydro-geological structures surrounding their coastal villages since many years. Different types of ecosystems include coral reefs etymologically called as "Par or Challi", Sea grass (Kadalpul/paasi/thallai) ecosystem, Sea weed (Kadal Paasi) ecosystem and Mangrove (Alayathimarangal) ecosystem. Detailed study on traditional ecological knowledge on sea grass ecosystem of Tamil Nadu coast was carried out by Newmaster et al., 2011[26].

Fishers also depend on the geographical distribution of these ecosystems, hydro-geographical or topographical features such as seafloor i.e., muddy areas (Cherupaguthi) and Sandy bottom (Manalpaguthi). Fishing ground predictions and navigation towards fishing grounds are recognized based on these topographical features and the distribution of ecological structures in the sea. Fisher folks identify these hydrological and ecological elements adapted from their practical experience without using any modernised gadgets akin to GPS (Global Positioning System) and they are very much aware of the ecological services provided by the surrounding ecosystems and hence seem to be interested and involved in conserving these ecosystems for sustainable management.

Meteorological Indicators:

Fisher folks observe the cloud formation, colours and the direction of passing clouds as meteorological indicators to predict onset of rainfall, cyclone and storm. Ancestrally adopted knowledge and familiarity with seasonal patterns of precipitation and temperature for decades makes them to promptly prefigure the climate and weather conditions. This was also stated by Santhanam, 2005[27] and he has reported that fishers predict the movement of clouds and colour of clouds to plan their fishing operations and time of reach to their fishing grounds. Some of the other indicators explained by the respondents are drought environments, water scarcity, dryness in groundwater level and low riverine inflow. Some of the winds are also responsible for dissipating the rain clouds are locally termed as "Karumegam/ Karmegam". These indicators are found to be relating to the rise in temperature and low rainfall patterns of the year. In addition, the local communities also predict weather patterns by observing the diameter of the halo spectacle around the sun or moon as displays of rainfall in the impending days. Increased water temperature or the warm water is indicated as the abundance of seer fishes and sardines. Cloudy and rainy-cloudy weather patterns are displays of the abundance of Scombridae family. Appearance of air-bubbles in the water is said to be the indicator of storm and presence of mackerel shoals.

Biological Indicators:

Water colour

In general, we perceive water colour in the ocean, sea or coastal region as blue, green or sometime yellow. Based on the different constituents such as plankton (phytoplankton and zooplankton), chromophoric dissolved organic matter and other dissolved inorganic suspended materials, the ocean colour will spatio-temporally vary. This variability in constituents and colour of the ocean water is considered to be the major indicators for fish catch predictions and harvesting techniques. Presence of chlorophyll pigmentation in phytoplankton provides green colouration to the ocean water whereas, presence of turbidity reflects from yellowish to reddish colour spectrum. The clear water without chlorophyll or turbidity is often perceived as blue colour. During the survey, it was very interesting to note that the fishers of Tamil Nadu coastline has named each colour variability observed in the ocean. The water mass flowing towards south is called as Vandaithanni/ Kraipputhanni/ Vannivellam. In the months of monsoon season (June to September), the water masses enables the migration of fishes from north to south. Ratha Kraippu (Red coloured water mass), Pachaikraippu (Green coloured water mass), Vellaikraippu (white coloured water mass) are the indicators for the abundance of Scombridae (seer fishes) and Carangidae (Trevallies and Jack fishes). Porupputhanni (Clear water/ Bluish colour) is the indicator of the family – Belonidae /Xiphidae /Istiophoridae (Murrels), Rathaikraippu/ Kalanguthanni (turbid water) is also the indicator for small pelagics such as Mackerel, Sardines, Anchovies and Silver bellies. Vandaikraippu is so-called to be turbidity incidence/ very turbid water is an indicator for very less fish abundance and the fish harvest is perilous.

Water Odour

Ocean and coastal waters are definite to a specific odour produced by the sulphur generating phytoplankton over the light incident surface waters of the sea. For instances, this odour may also be formed during the initial phases of coastal upwelling inducing oxygen deficient zones in the region. Bad odour accompanied with dead fish is the signal of less abundance of fishes in the sea. This indicator is observed by the fishers of coastal villages of Tuticorin and Rameswaram along the southeast coast of India. Coastal upwelling in the southeast of India is reported to be influenced by the local environmental conditions, physical conditions and anthropogenic influx[28]. In the initial phases of upwelling, the conditions are unfavourable for the fishes due to oxygen depletion and in the latter phases, the upwelling region tend to be the most suitable fishing grounds with nutrient rich phytoplankton concentration and maximum availability of fishes[15].

Aggregation of worms, fishes, mammals, sea snakes and birds

Traditional fishers are also dependent on identifying the fish shoals using the aggregation of fish schools, sea-birds and marine mammals. This characteristic aids them to understand about the inter-linked prey-predator relationships in the trophic level. Sea-birds are suitable indicator taxon of biological indicators to monitor the changing ocean environment at different trophic level. Few species of sea-birds are migratory from different directions across the globe. Marine mammals and sea-birds plays major role as top-predators in the food-web of the marine ecosystem. They share and compete with each other for prey or predatory fishes. Appearance of small pelagic fishes as prey is a signal of environmental fluctuations in the trophic level[29]. In the current study, the local communities discussed about the appearance of fish shoals such as tuna, mackerel, seer fishes, sardines and anchovies and the correlation of fish shoals with water colour to choose their fishing grounds, which was detailed in the last section. Similarly, appearance or aggregation of dolphins (locally called as "Ongal", aggregation of dolphins named as "Ongal Koottam") is an indicator for sardine and mackerel shoals. Birds such as cormorants and gulls are also added to the lists as indicators of small pelagic fish shoals. If the fishers notice worms in the fish catch or neither observed many sea snakes hooped to each other is believed to be an indication of storms in the near future. Immediate change of water current and wind directions are noted by the observations of dead/live stranding of marine mammals, which is considered as bad indicator to carry out fishing. These responses were also described by Lekshmi et al., 2011[16] and Raja et al., 2014[18].

Threats to Indigenous Traditional Ecological Knowledge

Regardless to the usage of diverse ecological indicators, sustainability of expending these knowledge systems is very challenging in the future years. There are numerous limiting factors that defy these practices and we could see that the knowledge on ITEKs is disappearing in an alarming rate. We intend to outline the threats to ITEKs in this section, firstly to describe is the decline of knowledge base to the younger generations, the ancestral way of passing the information to the younger generation is weakening. The intergenerational knowledge transmission is getting interrupted and such practices should be taught or could even be included in the educational curricula. Most of the aged-groups and young generations involved in fishing are dependent on modernised technological advancements and information systems. The oral codes are neither preserved as a document and thus cannot be successfully transferred across generations. These practices should be taught since childhood so the individual may not be ignorant to these historical viewpoints. Secondly, it is the ambiguity in using old traditional terminologies and weakening of shared memories and experiences through the fishing activity, as it is relatively different from the former years. There are even negative discernments developing towards the traditional indicators due to changing climate events in the environment. All these conditions attribute severe threats to the use of shading ITEKs in the present decades. In consent to the debility of these practices, pertinent acknowledgment and development of database or documentation of the practises are to be instantaneously employed. This will be beneficial for conservation of the ITEKs sustainably for effective application of the knowledge system in climate change related decision making and policy recommendations.

Integrating scientific advancements and Indigenous Traditional ecological Knowledge (ITEK)

In conceptualisation to address the safety prerequisites and counteractive safekeeping from disastrous events, Government of India has introduced region-specific, reliable and user-friendly modern weather and climate monitoring and forecast systems post Indian Ocean tsunami event 2004. There were several policies on adaptation and mitigation strategies devised by the non-government consortiums and government organisations.

Contextual and region-specific, user-friendly weather forecast information systems will pave a way to determine the resilience of fisher folks to the temporal variability in climate change. Such knowledge base can also be established by instigating collaborative research involving traditional community practitioners, natural and social scientists. Few literatures explored the question of integrating scientific advancements on weather forecast to ITEKs are Mugabe et al., 2010[30], Osbahr and Allan (2003)[31]. These studies justified that the scientific knowledge and predictions remain inconsistent to the society as it fails incorporating ITEKs to their forecasts. We anticipate witnessing the fisher folks in this context; and it was also noted that the fishers of Tamil Nadu coastline are keen to use the scientific forecasts when represented in their local ITEK jargons. This perception of accepting scientific contributions in their folkloric way is an expectancy factor among the fisher folk communities from different coastal states of India. It is also evidential that this integration framework is blooming up in the recent decades and beginning to merge with the local communities as some of the adaptation and mitigation systems.

Despite this, we also wanted to profile out mentioning the applications of satellite remote sensing involved in dissemination of weekly and daily based marine fishery advisories and forecast information services which are currently active in India. These advisory services are distributed to the fisher folks since 1990s to ensure safety during disastrous events. Ministry of Earth Sciences and its divisional organizations such as Indian National Centre for Ocean Information Services (INCOIS), Indian Institute of Tropical Meteorology (IITM), Indian Meteorological Department (IMD), Indian Space Research Organization-Space Application Centre (ISRO-SAC) are involved in conducting research and development works in major components of earth and ocean climatic conditions and delivering these developments as societal applications since ever decades. These organisations are expecting to appraise with regimentation on integration of ITEKs to the scientific contributions on climate predictions, weather forecast and monitoring systems. Moreover, munificent fisher welfare related socio-economic validation projects on forecast advisory services were also developed across the coastal states of India to initiate participatory approach of local communities to gain knowledge on ITEKs; And in the same line, the outputs on ITEKs will be a substantial contribution in displacing the existing scientific forecast approaches to the local communities.

Development of seasonal ecological calendar - a framework for improved adaptation and mitigation strategies towards climate risks

Traditional ecological knowledge is mostly used in the recent years by modern industry to develop sui generis forecast systems to provide resilient and substantial benefits. Governments and multi-stake holder parties should develop a mandate to establish an ad-hoc working groups on transforming these TEKs as commitments into reality. This could also efficiently contribute in conservation and sustainable management of marine resources and also develop scientific platform to perform research on climate change and variability and its vulnerability. Based on the template of ecological calendar proposed by Prober et al., 2011[32], we attempted to develop a skeletal framework of seasonal ecological calendar for the Tamil Nadu coastline (Fig. 4a & Fig. 4b). In the Fig. 4a. we used the seasonal classification as southwest, northeast and transition months as reported by Tomzcak and Godfrey, 2004[33]. The ecological indicators as explained by the respondents and relative research articles were integrated as a baseline to the calendar as a template. With additional inputs such as increasing the respondents and creating an exclusive database to register the reported and unrecorded traditional ecological indicators will enable us to build an informative integrated ecological calendar. On further developing such consistent seasonal ecological models and frameworks with co-designed information will be congruent to the fisher folk's expectancies and carry outs. The framework also emphasises reconsideration of decision-making involving climate scientists, farmers and policymakers to reach common ideologies and relevant forecast techniques. Moreover, it is essential to create extension processes on capacity building and fisher folk empowerment, to link the gaps with education, science and cultural concepts. This context will enable us to conserve these ITEKs sustainably and we can also build the scientific and technological contributions with more outreach and efficacy.

Seasonal Variability	Northeast (winter) monsoon					Transition	Southwest (summer) monsoon					Transition
Months	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**
Winds[21]	**Vaadai Kaatru** - Abundance of Kilichaimeen, Mayilmeen (Carangidae, Istiophoridae/Xiphidae)				**Chozha Kachaan** **Kachaan Kaathu** - wind speed (60-80 kmph); **Chozha Kondal** - Indicator of Choorai (Tuna), Keerai (Yellow Fin Tuna)		**Chozha Kondal**				**Kondal Kaatru; Vaadai Kaatru**	
											VaadaiKaatru	
Ocean currents[21]	**Vaadai Neerottam** - Murrel season (Belonidae abundance)				Chozha Neerottam - Lean Fishing Season							**Vaadai Neerottam**
			Kondal Neerottam - Abundance of many fish species				**Kachaan Neerottam** - Tough fishing season					
Water colour[18]		**Ratha Kraipu (Red colour) / Kalanguthanni** - Indicator of Sardines, Anchovies and Carangids					**Pachai Kraipu (Green colour)** - Indicator of Scombridae and Beloniformes					
Macroalgae	***Padina & Gracilaria sp.*** - Lesser diversity reported[34,35]						***Padina, Gracilaria & Ulva sp.*** - Higher diversity was reported in this season					
Seagrass	Presence of ***Halophila ovalis*** ('Saethupasi") patches are perceived as dark muddy zones, indicator for fishing shrimps, crabs and fishes whereas, presence of ***Halophila ovata*** ("Pottalpasi"), Pottal means clear water zones which has less fish population and not suitable for fishing[26]						Increased growth of dominant seagrass species such as ***Cymodocea serrulata*** and ***Syringodium oestifolium*** were observed in the monsoon season, due to optimum temperature, low salinity, pH and addition of nutrients (indicator of healthy spawning, breeding and feeding grounds of marine fishes and mammals)[36].					
Sea birds							Shearwater flocks - indicator of Sardines and Anchovies; Terns - indicator of shrimp species ***Fenneropenaeus indicus*** and ***Metapenaeus dobsoni***[37]					
Phytoplankton							Diatom blooms during upwelling, change in water colour - indicator for abundance of pelagic fishes such as Sardines and Mackerel[38,39]					

Fig. 4a — Seasonal ecological calendar based on integration of ITEKs of Tamil Nadu fisher folks and scientific reports and publications

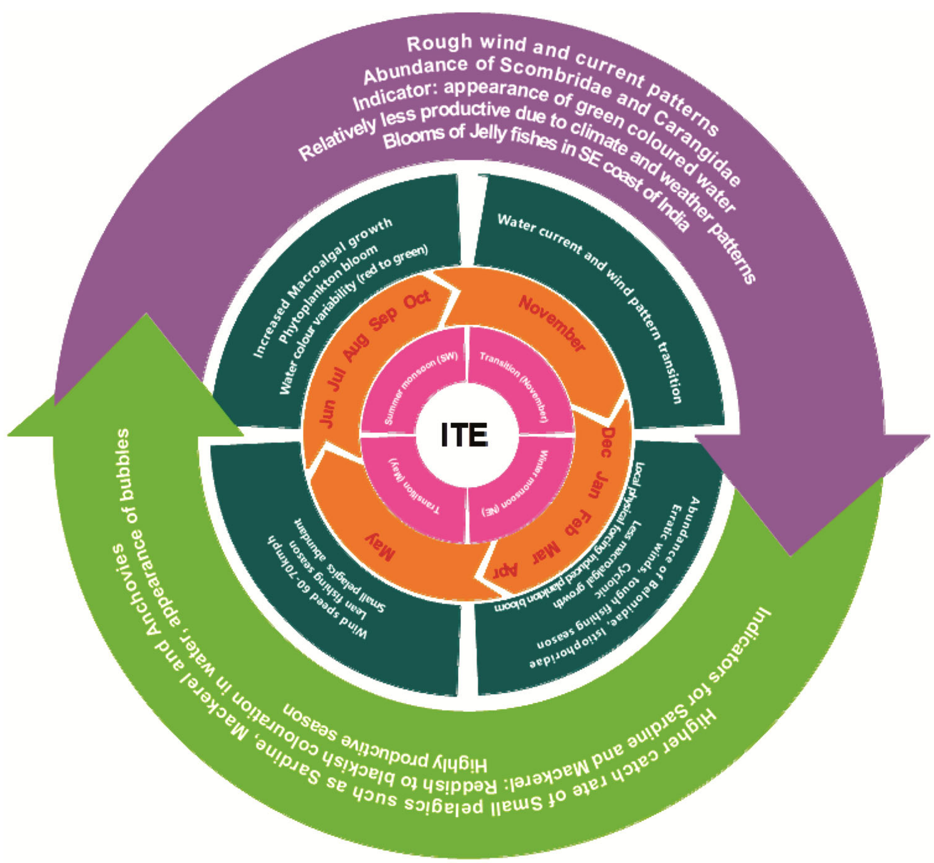

Fig. 4b — Seasonal Ecological calendar framework for Tamil Nadu coastline – an attempt to link scientific forecast to ITEK

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References

1 Bernstein L, Bosch P, Canziani O, Chen Z, Christ R, et al., Intergovernmental Panel on Climate Change Fourth Assessment Report *(AR4)*, (2010).

2 Gadgil M, Berkes F, & Folke C, Indigenous Knowledge for Biodiversity Conservation, *Ambio*, 22 (2) (1993) 151–156.

3 Berkes F, *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*, Taylor and Francis, Philadelphia, 19 (1999) 209.

4 Spink J, Historic Eskimo awareness of past changes in sea level, *The Musk-Ox*, 5 (1969) 37–40.

5 Cruikshank J, Glaciers and climate change: perspectives from oral tradition. Arctic 54(4) (2001) 377–93

6 Huntingdon, Henry P, Review of Voices from the Bay: Traditional Ecological Knowledge of Inuit and Cree in the Hudson Bay Bioregion, in Arctic, 2 (51) (1998) 168-169.

7 Cohen SJ, *Makenzie Basin Impact Study (MBIS) Final Report: Summary of Results*, (1997).

8 Riedlinger D & Berkes F, Contributions of traditional knowledge to understanding climate change in the Canadian Arctic, *Polar Rec (Gr Brit)*, 37 (203) (2001) 315–328.

9 Chand SS, Chambers LE, Waiwai M, Malsale P, & Thompson E, Indigenous Knowledge for Environmental Prediction in the Pacific Island Countries, *Weather Clim Soc*, 6 (4) (2014) 445–450.

10 Risiro, Joshua; Mashoko, Dominic; Doreen; Tshuma, T.; Rurinda E, Weather Forecasting and Indigenous Knowledge Systems in Chimanimani District of Manicaland, Zimbabwe, *J Emerg Trends Educ Res Policy Stud*, 3 (4) (2012).

11 Acharya S, Presage Biology: Lessons from nature in weather forecasting, *Indian J Tradit Knowl*, 10 (1) (2011) 114–124.

12 Chinlampianga M, Traditional knowledge, weather prediction and bioindicators : A case study in Mizoram, Northeastern India, *Indian J Tradit Knowl*, 10 (1) (2011) 207–211.

13 Salim S Shyam, Antony O P, Indigenous Technical Knowledge (ITK) in capture fisheries : A case study in Vypeen island of Ernakulam district, 4 (11) (2013) 7-10.

14 Salagrama V, Climate Change and Fisheries : Perspectives from Small-scale Fishing Communities in India on Measures to Protect Life and Livelihood. Samudra Monograph. (2012) 1-52.

15 Swathi Lekshmi PS and Dinesh Babu AP, Indigenous Technical Knowledge and ancient proverbs of the coastal fisher folk of Kerala and their implications, *Indian J Tradit Knowl*, 8 (2) (2009) 296–297.

16 Swathi lekshmi, P.S., A.P. Dineshbabu, G.B. Purushottama Sujitha Thomas, Geetha Sasikumar *et al*., Indigenous Technical Knowledge (ITKs') of Indian Marine Fishermen with reference to Climate Change, Central Marine Fisheries Research Institute, (2013) 1-122

17 Anandaraja N, Rathakrishnan T, Ramasubramanian M, Saravanan P, & Suganthi NS, Indigenous weather and forecast practices of Coimbatore district farmers of Tamil Nadu, *Indian J Tradit Knowl*, 7 (4) (2008) 630–633.

18 Raja. S., Geetha. R. SJK and EV, Traditional Knowlege among fishers of coastal Tamil Nadu with Special reference to Climate Change, In: *Cultutal landscapes, Indigenous Knowledge and Biotechnological tools for Biodiversity Conservation*, (2014) 15–22.

19 Central Marine Fisheries Research Institue, *Marine Fisheries Census of Tamil Nadu 2010*, Kochi, (2010) 421.

20 Odora-Hoppers, C. Indigenous Knowledge and the Integration of Knowledge Systems: Towards a Conceptual and Methodological Framework. In C. Odora Hoppers (Ed.), Indigenous Knowledge and the Integration of Knowledge Systems: Towards a Philosophy of Articulation. Claremont, South Africa: New Africa Books (2002) 139-143.

21 Panipilla, Robert and Marirajan T, A Participatory Study of the Traditional Knowledge of Fishing Communities in the Gulf of Mannar, India The communities of Chinnapalam and Bharathi Nagar, *Samudra Monograph*, (2014) 1–120.

22 Sethi SN, Sundaray JK, Panigrahi A, & Chand S, Prediction and management of natural disasters through indigenous Technical Knowledge, with special reference to fisheries, *Indian J Tradit Knowl*, 10 (1) (2011) 167–172.

23 Mary MD, Saritha K, Jansi M, & Patterson J, Brown Mussel *Perna indica* Fishery in Kanyakumari District , South East and West Coast of India, 6 (5) (2014) 400–407.

24 Speranza CI, Kiteme B, Ambenje P, Wiesmann U, and Makali S, Indigenous knowledge related to climate variability and change: Insights from droughts in semi-arid areas of former Makueni District, Kenya, *Clim Change*, 100 (2) (2010) 295–315.

25 Knight JA, Solunar Tables for Fishermen Produced by Register-Guard, *Regist*, (1949).

26 Newmaster AF, Berg KJ, Ragupathy S, Palanisamy M, Sambandan K, et al., Local Knowledge and Conservation of Seagrasses in the Tamil Nadu State of India, *J Ethnobiol Ethnomed*, 7 (1) (2011) 37.

27 Santhanam R, ITK on wind and weather pattens, In: *Society for Ecological Restoration*, (2012).

28 Qasim SZ, Biological Productivity of the Indian Ocean, *Indian J Mar Sci*, 6 (12) (1977) 122–137.

29 Mondreti R, Davidar P, Péron C, and Grémillet D, Seabirds in the Bay of Bengal large marine ecosystem: Current knowledge and research objectives, *Open J Ecol*, 03 (02) (2013) 172–184.

30 Mugabe FP, CP Mubaya, D Nanja, P Gondwe, A Munodawafa, E Mutswangwa, I Chagonda, P Masere, J Dimes CM, Use of Indigenous Knowledge Systems and Scientific Methods for Climate Forecasting in Southern Zambia and North Western Zimbabwe., *Zimbabwe J Technol Sci*, 1 (1) (2010).

31 Osbahr, H and C A, Indigenous knowledge of soil fertility management in southwest Niger, *Geoderma 111*, 3 (4) (2003) 457–479.

32 Prober, S. M., M. H. O'Connor and FJW, Australian Aboriginal Peoples' Seasonal Knowledge: a Potential Basis for Shared Understanding in Environmental Management, *Ecol Soc*, 16 (2) (2011) 1–12.

33 Tomczak, M., and J. S. Godfrey, *Regional Oceanography: An Introduction*, Pergamon, New York (1994).

34 Sahayaraj K and Singh J, Seasonal Changes on the Diversity and Abundance of Intertidal Macroalgae at Four Southern Districts of Tamil Nadu, India, *Ecologia*, 6 (1) (2016) 13–18.

35 John Peter Paul, J. and Mahadevi B, Distribution and Seasonal Variation of Some Caulerpa species (Green Seaweed) in Thoothukudi Region , The South East Coast of Tamil Nadu , India Distribution and Seasonal Variation of Some Caulerpa species (Green Seaweed) in Thoothukudi Region , The So, *Int J Pure Appl Biosci*, 2 (3) (2018) 135–138.

36 Govindasamy C, Arulpriya M, Anantharaj K, Ruban P, and Srinivasan R, Seasonal variations in seagrass biomass and productivity in Palk Bay , Bay of Bengal, India, 5 (July) (2013) 408–417.

37 Jeyabaskaran, R and Mohan, Gishnu and Mohammed, Abbas A and Abhilash, K S and Vishnu, P G and Khambadkar, L R and Kripa V, Distribution and Foraging Behaviour of Seabirds in Southwest coast of India, In: *International Symposium on 'Marine Ecosystems - Challenges and Opportunities (MECOS 2)*, (Kochi), (2014).

38 Kuthalingam MD., Observations on the feeding habits of some sardines together with the key to the identification of the young ones of the genus Sardinella, *Rec Indian Museum*, (1961) 455–469.

39 Velappan Nair, R. and Subrahmanyam, R. The Diatom, Fragilaria Oceanica CLEVE, an indicator of abundance of the Indian Oil Sardine, Sardinella longiceps CUV. and VAL., *Curr Sci*, 2 (1955) 41–42.