CHAPTER 2: REVIEW OF LITERATURE

2.1 INTERNATIONAL STATUS

Sea anemones are particularly abundant (Guiler, 1959), and are known to be a significant influence in aquatic ecosystems in coastal nitrogen processes and interaction structures. Ecological surveys and *in situ* data are very scarce which are important for a wider understanding of these animals and the entire ecosystem. Some features, such as the numbers of tentacles and mesenteries, muscle shape or cnidae thickness, is often highly variable and require proper understanding experience (England, 1987).

Research on sea anemones received worldwide attention following Verrill's (1928) monograph on **Hawaiian shallow water** Anthozoa identifying 21 species of sea anemones. Dunn (1974a) document the rediscription of the the species *Macranthea cookie* described by Verrill (1928) as *Radianthus papillosa* in Hawaii, first described by Kwietniewski (1898) as *Stichodactis papillosa* documented from Ambon. Dunn (1974b) also redescribed another species *Anthopleurua nigrescens*, originally described by Verrill (1928) as *Tealiopsis nigrescens*. Dunn (1974c) identified the Hawaiian *Actiniogeton sesere* described earlier from Torres Strait (Haddon and Shackleton, 1893). Dunn (1978) described a new species *Anthopleura handi* from Malacca Strait, Malaysia, which is an internally brooding intertidal Actinian. Dunn (1983) from the Antarctic and sub-Antarctic regions reported 15 species of sea anemones including 3 new species from two orders, Actiniaria and Ptychodactiaria (1 species). Fautin (1983) redescribed the six species of Actiniarians anatomically: *Isosicyonis alba* belongs to family Actiniidae, *Actinostola crassicornis, Antholoba achates, sicyonis erythrocephala and stomphia selaginella* belongs to family Actinostolidae, *Actinoscyphia plebeian* belongs to famiy Actinoscyphiidae that had gone under 18 different names.

For at least 150 years, sea anemone fauna of **Maxico** has been formally studied (Verrill, 1869; Carlgren, 1950 and Carlgen, 1951). The anemones of the central Californian coast from the area between Bodega head and Carmel described in detail by Hand, 1955. *Urticina lofotensis* Damelssen, 1890; a vivid crimson actiniid sea anemone inhabits the coastal zone of California studied for gametogenesis and reproductive periodicity in detail by Wedi and Dunn, 1983. Fautin *et al*., (1987) described a new species of Acontiate sea anemone *Acontiophorum niveum* collected from Mission Bay, California. *A. elegantissima* (Genus *Anthopleura*) is the most widespread and wide-ranging species distributed from Alaska to central Baja California along the rocky intertidal (Hand, 1955; Francis, 1979 and McFadden *et al*., 1997). Lajeunesse and Trench, 2000 indicate that the geographical distribution of the dinoflagellates present in this species is related to the latitude-created temperature cline. *Anthopleura elegantissima* was also studied for the distribution of Symbionts along a light gradient in an intertidal cave showing the fact that the stability of intact symbioses in adult hosts is a striking feature of this system; in both temperate and tropical environments (Secord and Parker, 2005). Daly (2004) discerns three species, i.e. *Anthopleura dowii, Bunodactis mexicana, or Bunodosoma californica* from Gulf of California based on detailed anatomy, colour patterns, column types and habitat preferences. Though few studies document sea anemone fauna from many sites of Mexico coral reefs (Daly, 2004; Gonzalez-Solis, 1985; Rosado- Matos, 1990; Gonzalez-Munoz, 2005; Velez-Alavez, 2007 and CONANP 2006), formal taxonomic identification was beyond their scope. Gonzalez *et al*., 2013 documented seven species of anemones from coral reefs in the southern Gulf of Mexico i.e, *Anemonia sargassensis* Hargitt, 1908; *Anthopleura pallida* Duchassaing and Michelotti, 1864; *Bunodosoma cavernatum* (Bosc, 1802); *Isoaulactinia stelloides* (McMurrich, 1889); *Actinoporus elegans* Duchassaing, 1850; *Lebrunia coralligens* (Wilson, 1890) and *Tricolour calliactis* (Le Sueur, 1817). Recently, the first inventory of sea anemones from the southern Gulf of California (Mexico) has been published and provided taxonomic diagnoses, internal and external anatomy images, cnidae size ranges and shapes and geographic and bathymetric distribution, presenting taxonomic diagnostic features for each species (Barragan *et al.,* 2019). They confirm the records for

30 species from the Mexican Pacific, 23 of them from the Gulf of California and 15 of those present in La Paz Bay.

For many years, due to the unique marine biota, the **Galapagos Islands** have been of great interest to evolutionary biologists (e.g., Glynn and Wellington, 1983; Kay, 1991; Zullo, 1991 and Okey *et al*., 2003). Actinian fauna of this island found scattered earlier: Marical (1966) reported unnamed species of *Bundodactis*; Keybens (2000) reported two species of sea anemones but these were not identified: Okey *et al*., (2003, 2004) documented on Fernandina "Anemone barrens." Daly and Fautin, 2004 reported a new sea anemone, *Anthopleura mariscali*, seems to be one of the Galapagos Islands' endemic species. Fautin *et al*., 2007 present the first inventory on shallow water sea anemones with documentation of species i.e. *Phymanthus papillosa* (Lesson, 1830), *Aiptasia sp*., *Anthopleura nigrescens* (Verrill, 1928), *Bundosoma grandis* (Vreill, 1869), *Telmatactis panamensis* (Vreill, 1869), *Calliactis* “polypus” and *Antiparactis* sp. from Galapogas island.

Marine biodiversity research of **Costa Rica** has increased in recent years, but the Actinians is less studied group in comparison with Scleractinians and Octocorals of Pacific and Caribbean coastal (Breedy, 2009 and Cortes, 2009a). Excoffon *et al*., 2009 reported and redescribed the sea anemone *Nemanthus californicus* Carlgren, 1940 with anatomy notes from North Pacific coast of Costa Rica. Acuna *et al*., 2012(b) recorded the sea anemone *Anthopleura nigrescens* (Verrill, 1928) first time from Mata Limon on the Pacific coast of Costa Rica and concluded that this Actiniarian could be widely distributed in the Indo-Pacific. Acuna *et a*l., 2013 documented few new records of sea anemone from Costa Rica, *Bunodosoma granuliferum* (Le Sueur, 1817), *Phialoba steinbecki* Carlgren, 1949, *Phymanthus crucifer* (Le Sueur, 1817), *Aiptasia* sp., *Anthopleura elegantissima* (Brandt, 1835), *Bunodosoma grande* (Verrill, 1869), *Calliactis polypus* (Forsskal, 1775), *Telmatactis panamensis* (Verrill, 1869), *Anthopleura nigrescens* (Verrill, 1928), *Boloceroides* sp. Costa Rica's Actinian fauna currently consists of 16 species based on this study.

The Pacific and Caribbean coasts of Republic **Panama** are 1,700 km wide and 1,287 km long, respectively, and the continental shelf islands, islets, and cays are home to a rich marine biodiversity. With the identification of eleven actinian species, all reported from the Panama Gulf, Verrill (1869, 1870), enlist sea anemones from the Pacific coast. The research the ecology of Panama's Caribbean marine anemones was done by Sebens (1976), made an effort to study the habitat resource used by anemones and study anemone and coral interactions. He also described the Sea anemone species found at the Caribbean end of the Panama Canal: C*. gigantea*, *Ricordea florida* (Duchassaing & Michelotti, 1860), *Rhodactis sanctithomae* (Duchassaing & Michelotti, 1860), *Phymanthus crucifer* (Le Sueur, 1817), *Stoichactis helianthus* [now *Stichodactyla helianthus* (Ellis, 1768)], *Bartholomea annulata* (Le Sueur, 1817), *Lebrunia danae* (Duchassaing & Michelotti, 1860), *Heteractis lucida* [now *Ragactis lucida* (Duchassaing de Fonbressin & Michelotti, 1860)], *Bunodosoma granulifera* (Le Sueur, 1817), *Paradiscosoma neglecta* (Duchassaing & Michelotti, 1860)], In addition, Dunn (1981) registered *S. helianthus* while *Bunodosoma granulifera* was recorded by McCommas (1991) on the Colon coast. Guzman and Guevara (1998a, 1998b, 1999, 2001) documented the presence of Actiniarian *B. annulata* (Le Sueur, 1817), *C. gigantea, Bartholomea lucida* [now *Ragactis lucida* (Duchassaing de Fonbressin & Michelotti, 1860)] and *Epicystis crucifer* [now *Phymanthus crucifer* (Le Sueur, 1817)], as coral reef-related species from same place. Garese *et al*., 2009 compiles and updated the current literature information and presents an inventory of marine anemones from Panama coasts. 26 species of sea anemones have been reported, out of which 14 species all belonging to the Actiniaria Order and grouped into five families are found along the Pacific Coast. Sea anemone named *Bartholomea annulata* (Lesueur) *and Heteractis lucida* (Duchassaing and Michelottiare) from Jamaica, Haiti, Panama, and Venezuela (Caribbean region) was studied for assotiation of alpheid shrimp by Knowlton *et al.,* 1985.

Though sea anemones are abundant along the coast of **Chile**, very little information on these species is available. Very scant information was availabe on Chilean sea anemones have been published (Carter, 1965; Zamponi and Excoffon, 1992, 1995; Stotz, 1979 and Dayton *et al*., 1995). Riemann and Gallardo, 1990 described the new species *Saccactis coliumensis* belong the genus *Saccactis* Lager, 1911 (family Actiniidae) living under hypoxic conditions on the central Chilean shelf. The most prominent characteristics of new species (the dehcate ruff, the gill-like vesicles the tentacles and its thick pedal disc ectoderm with thin, delicate spirocysts and cillia-like structures) can be considered adaptive in this specific environment. Stotz (1979) examines the association between the vertical distribution of the midlittoral and infralittoral region and the morphological structures or structural behavior of the following marine anemones: *Phymactis clematis* Drayton, 1846, *Anthothoe chilensis* Lesson, 1830 and *ntholoba achates* Drayton, 1846. A new species of sea anemone, *Anemonia alicemartinae* n. sp. described by Haussermann and Forsterra, 2001 from rocky shores of north and central Chile., such a conspicuous species was not identified in previous surveys of Chilean sea anemones indicates that it has increased in abundance and/or extended its range over the past 50 years. Haussermann and Forsterra, 2003 reported the first evidence of for coloniality in sea anemones, *Cereus herpetodes* McMurrich, 1904 from Chile forms flabello-meandroid colonies through intratentacular budding. This Findings support the hypothesis of Stanley and Fautin, 2001 that the merger of the order Scleractinia with the orders Actiniaria and Corallimorpharia may be more phylogenetically accurate. Haussermann and Farsterra, 2005 reported the distribution patterns of Chilean shallow water anemones along with their taxonomic and zoogeographic relationships between South East Pacific, South West Atlantic and Antarctic actinary fauna. Haussermann (2006) reported the biodiversity, distribution patterns and zoogeographic implications of sea anemones, including new records for the fjord region of Chile. Supplementary data was published with discussion of latitudinal, longitudinal, and bathymetrical distribution patterns of Actiniarian with a special focus on the fjord region. Lopez *et al*., 2013 studied the Potential dispersal mechanisms of the cryptogenic anemone, Anemonia alicemartinae. Haussermann and Forsterra,

2001. They investigate that individual uses at least two dispersal mechanisms: intra habitat, which allows individual to select among local conditions, and inter habitat, which could facilitate colonization of new sites. The identification and taxonomy of sea anemone; including guidelines for sampling, preservation and examination was demonstrated by Haussermann (2004). Morden protocol for identification presented here reveal important taxonomical, morphological, biological and ecological information.

A minimum oxygen zone (OMZ) off Oregon reportedly ranges from near the coast to at least 1,200 m in the Northeastern Pacific. It is now expanding and contains virtually no oxygen, thus threatening the marine life in it. There is little known about the taxonomy and distribution of Sea anemone fauna from the deep northeastern Pacific Ocean.By contrast, the intertidal and shallow subtidal fauna of this area was well studied, with approximately 30 species recorded in shallow habitats (e.g. Gotshall, 1994; Fautin and Hand, 2007). In these deep-water ecosystems there are approximately 35 species along with the notes on widely distributed species estimated by Wendy (2010). The only known species from the northeastern Pacific Ocean are: *Corallimorphus denhartogi* Fautin, White, and Pearson, 2002, *Anthosactis nomados* White, Wakefield Pagels, and Fautin, 1999, *Sagartiogeton californicus* (Carlgren, 1940), *Corallimorphus pilatus* Fautin, White, and Pearson, 2002, *Bolocera kensmithi* n. sp., *Paraphelliactispabista* Dunn, 1982, and *Sicyonis careyi* n. sp. Fautin and Hand,1989 documented the new species, *Metridium giganteum* along with Systematics of sea anemones belonging to genus *Metridium* from the west coast of north america. Relative abundance and distribution patterns of two photosynthetic algal symbionts hosted by two temperate anemones, *A. xanthogrammica* and *Anthopleura elegantissima* from the Pacific investigated by Secord and Augustine, 2000. This study evidence the importance of the individual physiological capabilities of symbiont, environmental conditions, and therefore the biology of host play move into influencing host symbiont interactions, and ultimately, in determinative the distribution patterns of zoxenthellates above all *Anthopleura* spp.

Detailed diversity of is well studied in medusozoan cnidarians (Stepanjants *et al.,* 2006) but members of their sister group, Anthozoa, are not well known from the **deep polar seas**. Actinostolidae Carlgren, 1893; Halcampidae Andres, 1883; Kadosactidae Stephenson, 1920; Limnactiniidae Carlgren, 1921; Liponematidae Hertwig, 1882, Octineonidae Fowler, 1894; Bathyphellidae Carlgren, 1932 are the members belong the order Actiniaria with a bipolar distribution (Fautin, 2008). Dunn (1982) and Cairns *et al*., 2007 also recorded the genus leval bipolar distribution including member of taxa: *Actinernu*s Verrill, 1879; *Bolocera* Gosse, 1860; *Capnea* Forbes, 1841; *Kadosactis* Danielssen, 1891; *Protanthea* Carlgren, 1891. Documentation of Two new species of Sea anemone, *Antipodactis scotiae* and *A. awii* from polar seas belongs to family Antipodactidae fam. Nov is the addition to biopolar family of Sea anemones (Rodriguez *et al*., 2010). The absence of information about the inhabitants of the deep polar seas complicates the discernment of broader patterns of distribution.

Davenport *et al.,* 2011 investigated the Coelenteron contents of *Actinia equina* sea anemones, sampled from upper and lower height on exposed, semi-exposed and sheltered shore in southwestern **Ireland** and conclided that this species pre-predominantly scavenges on macro-faunal transport and feed on smaller food items. Wood (2013) published the book on Sea anemones and corals of Britain and Ireland. He reported the sea anemones along with their different habitat preferences: shallow water, hard substratum, soft seabed (sand, gravel, mud) and attached to another animal.

Sea anemone *Metridium senile* was investigated for the the abundance and size-distribution from stations of Limfjorden, **Denmark,** located at a mussel fishing ground and in an nearby area that have been closed for mussel dredging (Riis and Dolmer, 2003). Brolund *et al*., 2004 examined the *Heteractis magnifica* assembledge as host anemone and distribution of the resident anemonefish from southern tip of the Sinai Peninsula. They conclude that home range size of anemonefish was positively correlated with depth.

South Africa's high marine species richness may largely be attributed to the habitat diversity of the region, which incorporates cool temperate, warm-temperate and subtropical zoo-geographic provinces. Through reporting an additional 23 species from the area (Carlgen, 1938) and increasing the total number of South African Actiniaria up to 41 species, Carlgren made a significant contribution to the South African Actiniarian system to date. However, after that scattered scattered documentation of Sea anemone species were reported are: three tropical species, *Entacmaea quadricolour, Heteractis magnifica and Stichodactyla mertensii* documented by Dunn (1881); *Preactis millarda*e discovered by England and Robson, 1984; *Metridium senile* from Cape Town Harbour, Table Bay by Griffiths *et al.,* 1996; *Sagartia ornata* from Saldanha Bay by Acuna *et al*., 2004; *Actinia ebhayiensis* (representatives of the species long known as '*Actinia equina'* in fact represented an un-described) by Schama *et al*., 2012; *Edwardsia isimangaliso* from Lake St Lucia described by Daly *et al*., 2012. Laird (2013) updated the information on the systematics and distribution patterns of all South African sea anemones. In addition, range extensions for 40 of the species were reported, and two new species i.e, *Halianthella* n. sp and *Edwardsia isimangaliso* were added to the order Actiniaria. Laird and Griffiths, 2016 published the additions to the South African sea anemone fauna, with expanded distributional ranges for known species along with 12 new records.

Fariman *et al*., 2015 documented two species of sea anemones for the first time from the southeastern coast of **Iran,** Chabahar Bay: *Stichodactyla haddoni* Saville-Kent, 1893 and *Stichodactyla tapetum* Hemprich & Ehrenberg in Ehrenberg, 1834 (family Stichodactylidae) . This study presents a new locality record and information about *Stichodactyla haddoni* and *Stichodactyla tapetum* found from the tropical sea. Three Sea anemone species *Stichodactyla haddoni, Entacmaea quadricolour* and *Anthopleura artemisia* from Qeshm and Hengam islands, northern Persian Gulf of Iran studied for Symbiont algae coexisting with them (Moghaddam *et al.,* 2018). The findings suggest that the ambient environmental parameters may play a key role in dictating sea anemones to host a symbiotic alga preferably the type that increases their fitness.

The marine invertebrate fauna from the **Pakistan coast** is poorly known (Kazmi and Naushaba, 2013) and even less is known on cnidarian biodiversity. Up to date Actiniarian fauna, is represented by four species: *Metapeachia tropica* (Panikkar, 1938), *Anemonia indica* Parulekar, 1968, *Actinothoe modesta* Verrill, 1866, and *Phytocoetes gangeticus* Annandale, 1915, which were mentioned in a combined report on cnidarians of Bangladesh and Pakistan ; also updated in Checklist of cnidarians from Pakistani waters (Haque, 1977; Fautin, 2013; Morandin *et al*.,2015 and Fautin, 2013). Kazmi (2016) documented the occurrence of sea anemone *Diadumene lineata* (Verrill, 1869) for the first time from the mid intertidal zone on barnacles at Sand Spit, Karachi of Pakistani coast (Indian Ocean). He recorded the occurrence of this invading species, most likely as an anti-lessepsian migrant from the Mediterranean Sea through the Suez Canal, considered one of the most spectacular biological invasions in the contemporary ocean. Gul and Haussermann, 2017 documented the five new records of Sea anemone with first distribution records from Pakistani water: *Hormathianthus tuberculatus, Neoaiptasia commensali, Anthopleura waridi, Paracondylactis sinensis and Entacmaea quadricolour.*

The South **China** Sea in the Central Indo-Pacific is a large marine region that may harbour a rich marine diversity. Existence of gigantic Sea anemones were documented in the china sea by Collingwood (1868) with the note on association with quasi-parasitic fish. Hou *et al*., 2005 studied the preserved soft tissue of sea anemone *Archisaccophyllia kunmingensis* collected from the rocks nearthe city of Kunming, China and concluded that the preserved life assembly provides a unique snapshot of anemone life in Lower Cambria and offers evidence for interactions with current actinians and calcified corals. Li *et al.*, 2013 documented two acontiate sea anemones, *Phytocoetes sinensis* n. sp. (Family Halcampactinidae) and *Telmatactis clavata* (Stimpson, 1855) (Family Andvakiidae) from the coastal region of Chinese waters. So far the species in the western Pacific is known only from warm waters.

Sea anemone data of **Korea** appears to divide into four biogeographic regions. Cha and Song (2001, 2002) reported the 11 species of sea anemone belongs to 8 family, among which 5 species are newly recorded from Korean water. As a result of the study done by Cha *et al*., 2004 the Korean Actiniarian fauna updated to total number 23. Environmental clistering analysis of actiniarian distribution pattern of Korea was studied by cha *et al*., 2004 concluded that geospatial clustering has the power to delimit marine organism ranges within relatively small geographic areas.

Actiniarian fauna of **Japan** Previously documented from the Great Bay, Possjet Bay and in the area of the Far East Marine Biosphere Natural Reserve (Averincev, 1967; Kostina, 1985, 1987). The sea anemone species *Isactinernus quadrilobatus* Carlgren, 1918 and *Synactinernus flavus* Carlgren, 1918 collected from southern Japan were rediscribed by Fautin and Hartog, 2003 with the note of range extension. Sanamyan and Sanamyan, 2006 described the detail taxonomy of three species of Cribrinopsis and two species of Urticina from Kamchatka, Commander Islands, and the Sea of Okhotsk. Kostina (2009) reported the six species of sea anemone belonging to six genera and five families i.e *Edwardsia japonica, Synandwakia cf. multitentaculata, Charisea saxicola, Oulactis orientalis, Cnidopus japonicas* and *Metridium senile fimbriatum*. The sea anemone, *Metedwardsia akkeshi* Uchida, 1932, was originally described from Lake Akkeshi, Hokkaido. Izumi *et al.*, 2018 re-described *M. akkeshi* providing more detailed information about characteristic morphological features and the cnidom and also discuss the possible location of “Akkeshi Cove”, the site where *M. akkeshi* was originally collected.

The sea anemone *H. Magnifica* is one of the dominant species in the ocean of **Malaysia** (Kee *et al*., 2007), making it a possible predictor for evaluating Pulau Tioman water conditions. Khoo and Mazlan, 2013 provide a baseline data on the daily yield values of the anemone, which will help authorities monitor the water conditions in surrounding waters further. The medusivorous sea anemones *Entacmaea medusivora* Fautin and Fitt, 1991 are known to contain two anchial lakes: Jellyfish Lake in Palau (Fautin and Fitt 1991) and Kakaban

Lake in East Kalimantan, Indonesia (Tomascik and Mah, 1994). Hoeksema et al., 2015 reported the in situ photographic evidence of a benthic Anthozoan species predating on more than one species of Scyphozoa for the first time from the Kakaban Lake.

Fautin *et al*., 2009 recorded the sixteen species of Sea anemones from intertidal and shallow subtidal water of **Singapore**. Among which ten species were new records of sea anemones. Yap *et al*., 2014 described *Synpeachia temasek* new genus, new species, and redescription of *Metapeachia tropica* and also provide the a key to some members of the Haloclavidae that differentiates the new genus. Fautin *et al*., 2015 include data on the occurrence and distribution of six species of intertidal and shallow subtidal sea anemones from the Republic of Singapore, including five new country records: *Stephensonactis ornata* Panikkar, 1936; *Pelocoetes exul* Annandale, 1907; *Bunodosoma goanense* den Hartog and Vennam, 1993; *Actinoporus elongatus* Carlgren, 1900; Paracondylactis sinensis Carlgren, 1934. The sea anemone *Paracondylactis singaporensis* (England, 1987) and *P. hertwigi* (Wassilieff, 1908) rediscribed from the north, south, and west coasts of Singapore and the Southern Islands by Fautin and Tan, 2016.

Fautin (1988) identified 22 species of Corallimorpharian and Actiniarian from the at Madang Province, **Papa New Guinea** from the waters below 30 m deep. A new species of sea anemone, *Anthopleura buddemeieri* Fautin, is described by Fautin, 2005 from Fiji and Papua New Guinea with Remarks on *Anthopleura asiatica a*nd *Gyractis sesere*.

Factor such as tropical East Australian Current, Rainfall, Episodic fresh water flooding, temporary extirpation of corals, risk of introduction of invasive species are potentially relevant to the sea anem one fauna of Moreton Bay, **Australlia**. It has been estimated that the 110 species of anemones recorded from Australia, including its Antarctic waters (Fautin, 2008), constitute maybe half of Australia's Actinians (Wol stenholme and Wallace 2004). Davie and Davie, 1998 mentioned eight species of Actiniaria in a guide to the Moreton Bay biota: *Actinia tenebrosa, Oulactis muscosa, Aulactinia veratra,* *Boloceroides mcmurrichi, Stichodactyla haddoni, Macrodactyla doreensis, Entacmaea quadricolour and Heteractis crispa*. Fautin *et al*., 2008 reporeted 19 species of Sea anemones predominantly tropical to subtropical, with 14 species known primarily from the tropics, and four known primarily from the temperate zone; the other was not identified to species and also provide key to living sea anemones from Moreton Bay.

Several species of Actinia, Isactinia and Cnidopus are confused in **New Zealand**, partially because there has been no significant or recent monograph on New Zealand Actiniidae. Ottaway (1975) defined the taxonomic characters of genus *Actinia* Linnaeus, 1758, *Isactinia* Carlgren, 1900, and *Cnidopus* Carlgren,1934; which are currently represented by four species : *Actinia tenebrosa* Farquhar, 1898; *Actinia striata* Quoy & Gaimard, 1833; *Isactinia olivacea* Hutton, 1879 and *Cnidopus veratra* (Drayton, 1848).

For many taxa, morphology-based identification is not enough to delineate individual species (Schmidt-Roach *et al*., 2012), data-based initiatives such as the Barcode of Life that collate DNA sequencing information greatly enhance the accuracy and degree of comparability among specimens. For the majority of DNA bar-coding comparisons between species the mitochondrial (mtDNA) gene region Cytochrome c oxidase subunit I (COI) is ideal (Herbert *et al.,* 2003). However, some taxonomic groups, such as Anthozoans, have slow evolving mitochondrial gene regions and COI may not be useful for identifying species because of the low levels of variation in sequences (Shearer *et al*., 2002).

Investigation of the bar-coding utility of a partial COI gene fragment in marine anemones and two additional markers suggesting species recognition potential was studied by Dohna and Kochzius, 2016: the highly polymorphic Internal Transcribed Spacer II (Flot *et al*., 2013 and Oliverio *et al*., 2009) and the Homing Endonuclease Gene (HEG) within the COI self-splicing group I Intron (Goddard and Burt, 1999; Goddard *et al.,* 2006). Results disappoint the use of ITS II for barcoding in Actinians as an alternative to COI, as it shows similar limitations to COI. Evaluation of phylogenetic signal of a suite of markers commonly used for phylogenetic inference, explore the properties of mitochondrial and nuclear ribosomal genes in the cnidarians order Actiniaria, using both an ordinal - and familial - scale sample of taxa. Daly et al., 2010 documented first such study for potential markers such as 12S rDNA, 16S rDNA, 18SrDNA and 28S rDNA for Hexacorallians and complements the existing studies of variability at the level of Actinian species (Stoletzki and Schierwater, 2005; Acuna *et al.,* 2007; Worthington-Wilmer and Mitchell, 2008). Gusmao and Daly, 2010 established the relationships among members of Hormathiidae family using DNA sequences (12S, 16S, 18S, 28S and COIII) to study the systematics and evolution of sea anemones.

Morphological variation of the three different marginal tentacular morphs of *Phymanthus crucifer* reported earlier (Duerden, 1897, 1898, 1900, 1902; Stephenson, 1922 and Verrill 1900, 1905), challenges the value of this feature as a genus level character within Phymanthidae. Gonzalez-Munoz *et al*., 2015 portray molecular distinctions that would enable morphs to be separated into different species or corroborate the broad phenotypic plasticity of species via mitochondrial DNA sequences (12S rDNA and 16S rDNA and cox3) regions. Rodriguez *et al*., 2015 test the monophyly and higher-level relationships of the Order Actiniaria and applied the multiple analytical methods to a dataset of five molecular markers (three mitochondrial and two nuclear) for 156 taxa. They proposed a new classification at higher-level and discussion of evolutionary significance and the putative functional of several morphological attributes within Actiniaria.

Recent studies have suggested that Southern Ocean diversity is comparable to many temperate and non-reef tropical habitats (Chown *et al*. 2015). Southern Ocean faunal diversity is poorly understood, with many species only taxonomically described in the early 1900s, leaving other species as one species to be incorrectly identified or grouped together. The most modern approach using genetic techniques may help to resolve some of these differences, such as sequencing of DNA. Watson (2017) test the potential of the mitochondrial regions COI and 16S along with the nuclear region ITS and ITS2 for Antarctic sea anemones. Molecular Phylogenetic studies of Sea

Anemone Genus *Anemonia* were reported from Larak Island in the Persian Gulf (Zolgharnein and Hoseini, 2016). This study documented the partial sequences of COI genes of 16 sea anemones (order: Actiniaria) with the newly identified anemone (*Anemonia* sp.)

Coral reefs have played a crucial role in shaping the ecosystems that over the past 200 million years have dominated tropical oceans. A major contributing factor to the loss of coral reefs is still widespread coral bleaching (Glynn, 1993; Brown, 1997a and Hoegh-Guldberg *et al*., 1997). When corals experience extreme and sustained thermal stress, they are affected by their symbiotic relationship with the algae (of the Symbiodiniaceae family) (Lajeunesse *et al*., 2018) and can ultimately break down, a phenomenon widely known as coral bleaching. The loss of symbiodiniaceae in the host leads to an energy deficit that can eventually lead to the death of the coral. Since 1979 there have been six major events of coral bleaching, with the resulting coral mortality affecting reefs in all parts of the world. The frequency and intensity of such bleaching events are expected to increase as sea surface temperature (SST) continues to rise under climate change (Pandolfi *et al*., 2011 and Hooidonk *et al*., 2013). Coral bleaching, in turn, requires costly acclimation responses in the symbionts and host, with cell metabolism and structure reorganization (Kaplan *et al.,* 2004). Acclimation responses include photo protective compounds such as fluorescent proteins and accessory pigments, heat shock proteins, compatible solutes, enzymatic and non-enzymatic antioxidants, and structural changes to maintain the structure and function of cells and organs (Lesser, 2006 and Baird *et al*., 2009).

The expression of stress proteins (HSPs) is a mechanism commonly used by cells to counter such deleterious effects that are found in almost all organisms (Feder and Hofmann, 1999). HSPs are considered to have functions for species under natural conditions that experience great physical stress such as changes in temperature. To test in situ responses to such temperature stress, few experiments have been carried out on species in the field. An example study would be one on an intertidal species undergoing *in situ* natural stress variations such as major changes in temperature resulting from cycles of emersion with tidal regimes. These questions were explored in intertidal mussels, *Mytilus* sp, collected in winter and summer during single tidal cycles or over an annual cycle (Helmuth and Hofmann, 2001; Hofmann and Somero, 1995). Most of the studies were performed in controlled laboratory situations where acclimatization and HSP regulation are easier to follow (Hofmann and Somero, 1995; Hofmann and Somero, 1996; Roberts *et al*., 1997).

Members of two major heat shock proteins (HSPs) families, HSP70 and HSP90, was identified for Differential gene expression profiles in Symbiodinium sp. (clade C) of scleractinian coral *Acropora millepora* with full-length sequences suggest the diverse roles of these molecular chaperones during heat stress response (Rosic *et al*., 2011). HSP70 -like gene, deemed HSP/c, was identified in the coral *Seriatopora hystrix*, and expression of this gene was measured in both the host coral and endosymbiotic dinoflagellates (Mayfield *et al*., 2011). Collectively, such study shows the dual compartment nature which helps to generate a framework for evaluating molecular-level changes within corals exposed to changes in their environment.

Role of Heat shock protein has been also investigated in Sea anemone as defence mechanism to the thermal stress. Choresh *et al*., 2001 studied the expression of 60-kDa HSP (HSP60) as acclimatization (a phenotypic adaptation) to changes in seawater temperature (SWT) in a zooxanthellate sea anemone *Anemonia viridis*, along the Israeli Mediterranean shores. This research offers further use of HSP60 as a possible bio-monitor, in addition to other HSPs such as HSP70 (Koziol *et al*., 1996; Pyza *et al*., 1997), which will make it possible to assess the impact of environmental changes on marine organisms. Thus, the available literature indicates the expression of HSPs in marine invertebrates may help predict their ability to survive future short-term and long-term temperature changes.

2.2 NATIONAL STATUS

India's coastal areas are lined with variety of aquatic habitats, such as estuaries, rocky beaches, coral reefs, mangroves, lagoons, sandy beaches and mudflats marked by diverse biotic and abiotic processes. India's western and eastern costs differ in terms of geo-morphology. The west coast is exposed to rocky shores, headland and mudflats, while the east coast has lagoons, marshes, deltas and beaches (Venkataraman and Wafar, 2005).

The sea anemone fauna of the entire ocean, consisting of 42 families, 200 genera and about 800 animals, though representing a very low pat to the marine biota as a whole, is ecologically a large population to aquatic invertebrates (Carlgen, 1949). Insufficient knowledge of the magnitude and abundance of sea anemones is a result of the absence of exploitation along and within India's vast marine and eustarine environment. Actinian sea anemone fauna in India has, however, been reported from a few places so far: Port Canning (West Bengal), Chilka Lake (Orissa), Adyar Backwaters and Mannar Gulf (Tamil Nadu), Cochin Backwaters and Ashtamudi Lake (Kerala), Gulf of Kachchh (Gujarat), Mumbai, Malvan (Maharashtra), Goa, Andaman and Nicobar Islands.

Earlier Actiniarian species was documented as a part of in the general faunal study of Lower Bengal and Chilka lake (Annandale 1907, 1915). Panikkar (1936) published on the morphology and systematic role of two brackish-Actiniaria Phytocosteopsis ramunnii and Stephensonactis ornate belonging to the Madras family Halcampactiidae. Later he recorded Madrash's study of Actinian fauna: Phytocoetes gangeticus Annandale, with an account of the post-lraval growth and the occurrence of neoteny in the anemone; Boloceractis, Gen. Nov., discusses the morphology and systematic relationships along with its asexual reproduction (Panikkar, 1937 a, b, c). Parulekar documented the fauna of sea anemone with few new records from Bombay and Goa along with note on symbiosis of *Neoaiptasia commensali* gen nov with the hermit crab (Parulekar, 1967; 68; 69 (a,b,c); 71). General behavior and ecology of anemone, Anthopleura nigrescens was observed by Mathew (1972) from the intertidal rocky shore of Kerala, with their resistance to various grades of salinity.

Parulekar (1990) listed 40 species of sea anemones from 33 genera belonging to 17 families from India, 13 of which were reported for the first time. Out of 40 species, 24 are marine species, 13 are estuarine species, while 3 are common to both habitats. Among that, *Halcampa capensis* carlgen 1938, *Alicia sansibarensis* carlgen 1990*, Glyphoperidium bursa* Roule,1909; *Glyphostylum calyx,* Roule,1909, *Parabundodactis inflexibilis*, Carlgen 1928; *Stoichactis giganteum*, Forskal 1775; *Phymanthus loligo* H and E E hrenbarg, 1834; *Bathydactylus valdiviae*, Carlgen 1929 and *Paraphellia sanzoi* Colabresi 1926 are recorded for the first time from India. Description of two new species *Edwardsia jonessi* Seshaiya and Cutress, 1969 from Porto Novo and *Paracondylactis sagarensis* Battacharya 1979 were added to the record. Hartog and Vennam, 1993 documented the five Actiniarian species *Anthopleura anjunae* spec, nov., *Bunodosoma goanensis* spec, nov., *Synantheopsis parulekari* spec, nov., *Paracondylactis cf. sinensis* Carlgren, 1934, and *Stichodactyla haddoni* (Saville-Kent, 1893) from West coast of India along with details of synonymy, cnidom and distribution of these species.

A dichotomous key to 5 species of Sea anemone belonging to 4 genera from Mangrove ecosystem of Kerala was published by Chakravarty *et al.*, 2005: *Pelocoetes exul* Annandale 1915; *Phytocoeteopsis ramunii* Panikkar 1936; Diadumene *schilleriana* Stoliczka 1869; *Edwardsia jonesii* Seshaiya & Cuttress 1971; and Paracondylactis *indica* Dave 1957. As a part of the faunal survey for estuaries and mangrove fringed coastal districts of Odisha, Mitra and Pattanayak, 2013 described the short taxonomical detail, habitat-choice and distribution of a total of 9 species : *Pelocoetes exul* Annandale, 1915 *Phytocoetes gangeticus* Annandale, 1915; *Edwardsia jonesii* Seshaiya & Cuttress, 1969; *Edwardsia tinctrix* Annandale, 1915; *Diadumene schilleriana* Stoliczka, 1869; *Mena limnicola* Annandale, 1915; *Mena chilkaeae* Annandale, 1915;*Paracondylactis sinensis* Carlgren, 1949 and ; *Nevadneglauca* Annandale,

1915. Kumar *et al*., 2015 published the first record of an intertidal sea anemone *Anthopleura buddemeieri* Fautin, 2005 from Verkala beach, south west coast of India indicating the distribution range extension of such species to Western Indian Ocean.

Madhu and Madhu (2007) identified 10 species marine anemones from the 14 sites of Andaman island. Documentation on collection of *Aiptasia mutabilis* Gravenhorst, 1831 from rocky shore of Port Blair extends the known geographic distribution in India (Sachithanandam *et al*., 2011). In the intertidal and subtidal regions of the Andaman and Nicobar Islands, fifteen species of sea anemones were reported by Raghunathan *et al*., 2014. Out of which *Actinodendron glomeratum* Hadden, 1898; *Anthopleura handi* Dunn, 1978; *Phymanthus buitendijk*i Pax, 1924; *Telmatactis decora* Hemprich and Ehrenberg, 1834; *Calliactis miriam* Hadden and Shackleton, 1893 are new records to India. sea anemone diversity and distribution status of 54 species belonging to 40 genera and 20 families of sea anemones also reported in this paper from Indian waters. The data on diversity and distribution as well as the range and substrate preferences of 20 species of sea anemones in Andaman and Nicobar Islands was summarised by Choudhury *et al.,* 2015. Choudhury *et al.,* 2015 published the First record of black coral associated new species of Sea anemone,*Nemanthus annamensis* Carlgren 1943 (Family: Nemanthidae) documented with morphological description, ecological and geographical distribution From Andaman and Nicobar. Raghunathan and Choudhury, 2017 described the two species, *Diadumene leucolena* (Verrill, 1866) and *Actinodendron arboreum* (Quoy & Gaimard, 1833) under the families Actinodendronidae and Diadumenidae as new addition of sea anemone fauna from Andaman and Nicobar Islands. Afterward they provide the dtaied taxonomical features of two newly recorded species *Stichodactyla tapetum* (Hemprich & Ehrenberg in Ehrenberg, 1834), *Pelocoetes exul* (Annandale, 1907) from Andaman and Nicobar Islands and three newly recorded Actiniarian anemones: *Thalassianthus aster* Ruppell & Leuckart, 1828

Actinoporus elegans Carlgren, 1900, *Heterodactyla hemprichii* Ehrenberg, 1834 from Indian waters (Raghunathan and Choudhury, 2018).

Gujarat being the western proximity of India harbours the longest coastline of approximately 1650 km. The Gujarat state coastline is divided primarily into three coastal areas, i.e. Gulf of Kachchh, Saurashtra coast and Gulf of Khambhat. Hornell (1916), who researched marine fauna in the coastal region of Okha, Gulf of Kachchh, conducted the first systematic study of marine biodiversity at Gujarat.

In the past decade some work on marine biodiversity in Gujarat has been conducted (Deshmukhe *et al*., 2000; Nair, 2000 and ICMAM, 2002). Saurashtra Coastline of Gujarat state is distinguished by its rocky, sandy and muddy intertidal zones with rich and varied flora and fauna diversity (Nayar and Appukuttan, 1983). The substratum primarily consists of miliolite and laterite stone deposits, which offer a totally different ecosystem for the intertidal species (Sarvaiya, 1989). Anthozoans are class of Cnidarians which form integral part of coral reef environment. Some of the documents available for Scleretians and zoanthid orders belong to class Anthozoa from Gujarat coastal area are listed:Narara's ecological and environmental hazard assessment with particular regard to corals was stidied by Dave (2011) and Sudhanshu (2011); Pandya (2015) and Kumari (2016) reported the ecological evaluation, distribution pattern and community structure of zoanthids along the coast of Saurashtra. Joshi (2016) investigated the impact assessment of coral reef ecosystem with special reference to climate change. Identification of few Anthozoans as part of the Macrobenthic Population Assemblage from the Saurashtra Coast Zones was documented by Gohel (2016) and Parmar (2018). However, the sea anemone fauna from Gujarat coast are still insufficiently studied. Scattered information on sea anemone of Gujarat have been published through some handful of papers: *Paracondylac indicus, Stoichactis giganteum, Phymanthus loligo, Paraphellia sanzoi, Anemonia indicus, Boloceroides mcmurrichi and Metridiumsenile* reported along with their intertidal distribution and habitat preferences from Gulf of Kachchh

(Parulekar, 1990). *Bundosoma goanensis, Synantheopsis parulekari* and *Stichodactyla haddoni* describedand discussed with synonym, cnidae and distribution details from Gulf of Kachchh (Hartog and Vennam, 1993).

Sea anemones are known to feed on several fish species by venomous tentacles (Mariscal, 1966 and Gudger, 1941), but they are also noted for their symbiotic relationship, on various fish (Mariscal, 1972 and Day, 1878), shrimp (Bruce, 1976) and crabs (Biosearch v 1.2, 2009). One of the classic examples of symbiosis is the mutualism between sea anemone and hermit crab. A related relationship between an unconfirmed species of small sea anemone and a gastro pod species, Nassarius olivaceus (Bruguiere, 1789) on the Narara reef was recorded by Dave and Mankodi, 2009. Katwate and Sanjeevi, 2010 published a study with attempts to ascertain the availability of one such Sea anemone *Stichodactyla haddoni* Saville-Kent, 1893 and its symbiotic fauna, habitat preferences and distribution from Gulf of Kachchh. *Stichodactyla gigantean* (Forskal, 1775) *and Stichodactyla haddoni* (Saville-Kent, 1893) *have been recorded as Gulf of Kashchh associated reef fauna* (Ramamamoorthy *et al.,* 2012 and Kamboj *et al.*, 2014). Probably since from the documentation and description of few species earlier in Gujarat, no inventory has been published yet for the sea anemone fauna for Saurashtra coastal zone.

The identification by DNA sequences for sea anemone groups is the basis for taxonomy and bar-coding DNA. *Heteractis crispa, Stichodactyla helianthus, Actinia equina* and *Oulactis orientalis* cytolysin sequence verification was also performed to create a genetic relationship through a phylogenetic study of Indian sea anemone species (Karthikayalu *et al*., 2010). Biju Kumar *et al*.,2015 confirmed the occurrence of an intertidal sea anemone *Anthopleura buddemeieri* from the Indian coast indicates the expanded range of this species to the Western Indian ocean and provides the sequence data of the mitochondrial gene cytochrome oxidase 1 (CO1) for this species.

Sea anemone fauna are not adequately studied at morphological molecular level from the Gujarat coast. Hence to enhance the details on Actinarians of Gujarat and create as baseline information for diversity and applications of Sea anemone, this study was carried out as a part of survey for sea anemone diversity along the intertidal zone of Saurashtra coast of Gujarat.

The mass coral bleaching has been reported on India's coral reefs at different spatial and temporal scales. One of the important reef of India i.e., Andaman and Nicobar Islands also showed evidences of coral bleaching in the past during 1998, 2002, 2005, 2010 (Dharani *et al*., 2012; Marimuthu *et al.,*2011 and Mondal *et al.,* 2014). During the month of April and May 2010, Krishnan *et al*., 2011 recorded signs of coral bleaching ranging from 37% to 70% at different locations which is suspected to be caused by elevated sea surface temperatures. After 2010, the coral bleaching was also recorded on the consecutive year affecting 400 coral species, with the extent of 69.83 to 90 % on different Islands (Mondal *et al.,* 2014). Coral bleaching was recorded during the April 2016 due to thermal stress in the North Bay of Andaman Islands. The *in situ* observations corroborate the bleaching alert, as indicating their capacity in providing early signs of coral bleaching.

The Gulf of Kachchh region, which is climatologically adapted coral reef region of India. Arthur (1995) recorded coral bleaching in the Gulf of Kachchh during the summer months of Gujarat and concluded that it was a normal summer response of corals to the increase in summer temperature as the coral species in these latitudes are adapted to a wide range of intertidal temperature fluctuations. He reported a rise in relative coral bleaching in the Kachchh Gulf following El Nino Southern Oscillation during the summer of 1998 and considered it to be a higher level of coral bleaching than a normal summer response. In 2010 WTI (Wild Life Trust of India) ecologists confirmed coral bleaching at Mithapur, Gulf of Kachchh (www.wti.org.in). Occurrence of coral bleaching in 7 scleractinian species was recorded on Pirotan Island during September 2014. They supposed the SST and sedimentation might be responsible for coral bleaching in this Island. They added that high SST in the Island could be due to delay in the southwest moonsoon's onset, resulting in extended summer cycles (Adhavan *et al*., 2014).

Arora *et al.,* 2016 recorded summer 2016 as warm enough to cause bleaching in hard corals as well as in other zooxanthellate invertebrates such as Actiniarian and indicate synergistic use of geophysical parameters such as SST obtained from remote sensing satellite along with early on-site monitoring of bleaching responses that help predict or warn of bleaching on a timely basis.

2.3 ORIGIN OF THE WORK

Gujarat is a maritime state that still lacks the record of macro benthic fauna diversity, harbouring the longest coastline among all states of India. The coastal areas of the Gujarat state are divided into three major regions viz. Gulf of Kachchh, Saurashtra coast and Gulf of Khambhat. The coastal area of these three regions supports different types of marine habitats such as mangroves, coral reefs, rocky shores, sandy shores and mud flats. Most of the studies for intertidal diversity were confined to Gulf of Kachchh and Gulf of Khambhat. Many findings of researches have been documented along Saurashtra coast were mainly limited to diversity of Scleractinians, Zoanthids, Molluscans and Arthropods with some biological aspects. During the literature survey on the diversity of Gujarat, there has been no comprehensive report found on the taxonomic diversity of macro benthic invertebrate's fauna from Saurashtra coast including taxonomic detail on Order Actiniarian fauna.

Identifying Anthozoans species based strictly on morphological character led to a dispute due to phenotypic plasticity of these organisms. Review shows that DNA bar-coding has been applied successfully to a very large number of taxa, but remains challenging for basal diploblasts, and discussions are ongoing on appropriate molecular markers. Work based on Anthozoans bar-coding has dealt with Scleractinians and Zoanthids almost exclusively, with little interest from Actiniarians group. Documentation of molecular markers show that 18S has the greatest degree of resolution for the focused taxa of Actiniarians.

To fill the gap of biodiversity data and coastal characteristics, it is very much essential to document Actiniarians diversity at morphological and molecular level along with some of the ecological aspects for such rich coastal resource.