REPRODUCTIVE BIOLOGY
OF SCLERACTINIAN CORALS IN ANDAMAN AND NICOBAR ISLANDS

FINAL TECHNICAL REPORT

August 2014 to July 2017

DR. C. RAGHUNATHAN
Principal Investigator

SUBMITTED TO
The Secretary
Ministry of Environment, Forest and Climate Change
Government of India
Indira Paryavaran Bhawan, Jor Bagh Road
New Delhi - 110 003

SUBMITTED BY
ZOOLOGICAL SURVEY OF INDIA
Ministry of Environment, Forest and Climate Change
Government of India
Port Blair - 744 102, A&N Islands

June 7, 2018

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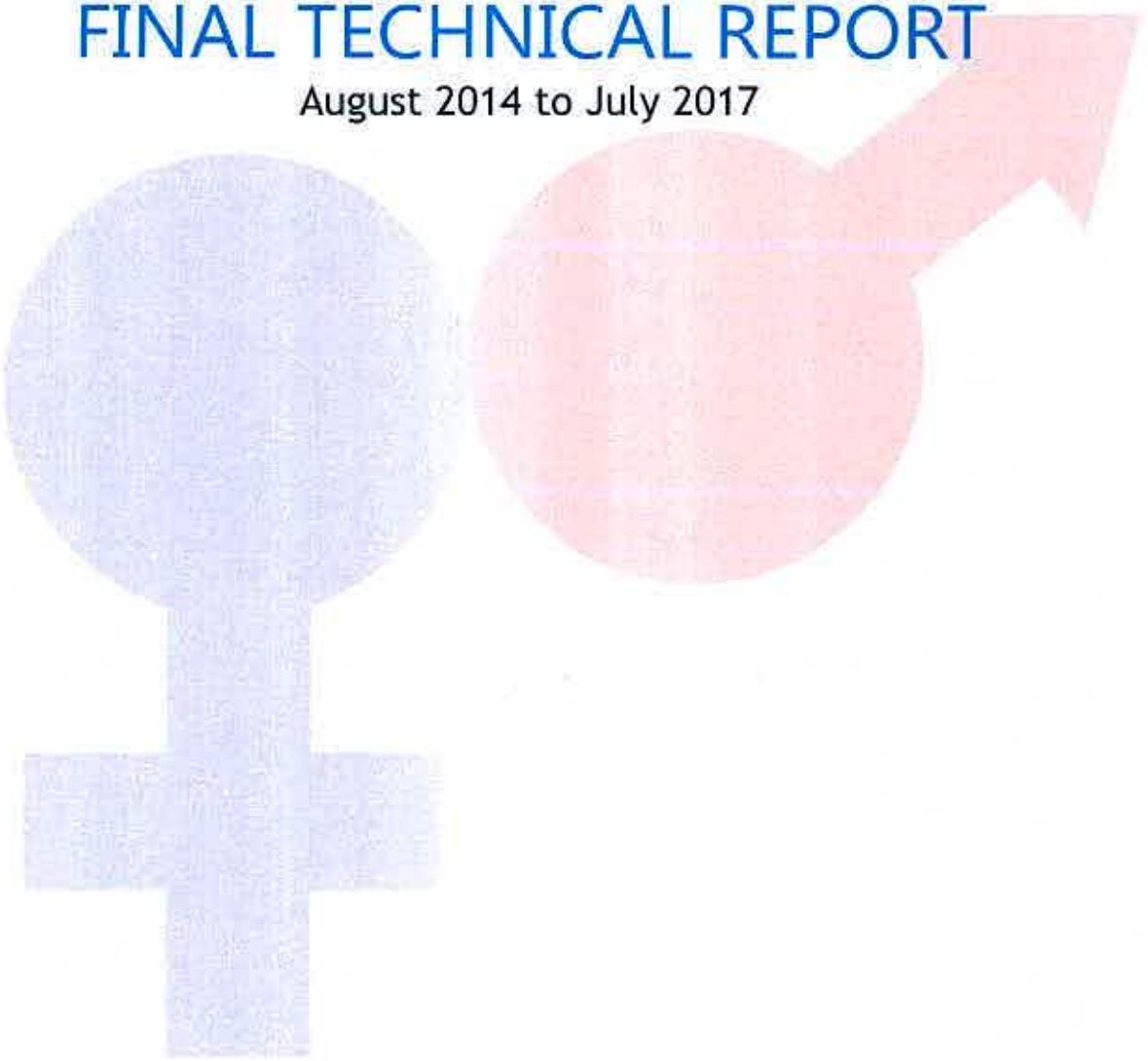

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CONTENTS

Appendix III

FINAL TECHNICAL REPORT
Part-I

1.	**Name & Address of the Principal Investigator (PI)**	:	Dr. C. Raghunathan Scientist-E Zoological Survey of India Andaman and Nicobar Centre Haddo, Port Blair- 744 102 Andaman and Nicobar Islands
2.	**Telephone & Fax No.**	:	Tel. 03192 – 230115 / 237582/ 233148 Fax 03192 – 230115
3.	**Project Details**		
3.1	**Title**	:	Reproductive Biology of Scleractinian Corals in Andaman and Nicobar Islands
3.2	**Sanction Number (Date & Year)**	:	No. 14/16/2013-RE dated 16th July 2014
3.3	**Date of Start**	:	1st August 2014
3.4	**Date of completion**	:	31st July 2017
4.	**Financial Details**	:	
4.1	**Total Outlay**	:	₹ 44, 45,000. 00
4.2	**Amount received so far**	:	₹ 33, 36,250. 00
4.3	**Amount utilized so far**	:	₹ 44, 27,900. 00
4.4	**Projected requirements for the remaining period**	:	₹ 10, 91,650. 00
5.	**Staff** **Research Associate/Senior Research Fellow/JRF/TA/FA, etc.**	:	Two JRFs/SRFs and one Field Assistant
6.	**Permanent equipment sanctioned /procured (Please give details such as Name, Model, Accessories, etc. & date on which these were purchased by the Awardee or received from the MoEF&CC)**	:	1) SLR Camera with underwaer housing (Model: Nikon & Ikelite) Date of purchase: 10.12.2014, 08.01.2015 and 25.05.2015 2) Scuba diving equipments (Model ScubaPro) Date of purchase: 20.09.2014 and 28.01.2015
7.	**Percentage utilization of Permanent equipment**	:	100%

Part- II

1. SCIENTIFIC COMPONENTS OF THE PROJECT

Coral reefs are the largest structures on earth's biological origin. They are the most diverse and beautiful of all marine habitats, often called as "rainforest of the sea. It occupies less than one tenth of one percent of the world's ocean surface, about half the area of France, yet they provide a home for twenty-five percent of all marine species, including fish, molluscs, worms, crustaceans, echinoderms, sponges, tunicates and other cnidarians. Paradoxically, coral reefs flourish even though they are surrounded by ocean waters that provide few nutrients. They are most commonly found at shallow depths in tropical waters, but deep water and cold water corals also exist on smaller scales in other areas. Scleractinian corals are foundation species on coral reefs because they provide the complex three dimensional structures and primary framework of the reef, and essential habitats and other important resources for many thousands of associated species (Harrison and Booth, 2007). These corals are distinguished from other members of the Class Anthozoa (Phylum Cnidaria) such as soft corals, by their continuous hard calcareous calcium carbonated crystal exoskeleton, which form the essential building blocks of the reef ecosystem when cemented together by crustose coralline algae. Corals are widely distributed throughout the world's seas and deeper ocean environments, the scleractinians are particularly significant in shallow tropical and subtropical seas where the mutualistic symbiosis between the coral polyps and their endosymbiotic dinoflagellates (zooxanthellae) fuels light enhanced calcification and rapid growth of reef-building corals, resulting in coral reef development.

1.1.Coral Reproduction

Corals can reproduce in two ways; the first one is asexual reproduction which is more widely known as budding and sexual reproduction which is broadcast spawning or brooding. When corals reproduce asexually, colonies are started with just one coral polyp. The polyp is known as the 'founder' and it reproduces through a process known as budding. This process is repeated over and over for the entire life of the coral colony. Each new polyp is genetically identical to the 'founder' polyp. As hard coral colonies grow, layers of limestone are laid down, and the polyps move up to the new layer. Corals have developed an array of strategies for effective reproduction. In addition to the diverse methods of asexual reproduction, different means of sexual reproduction exist. These can be categorized based on coral sexuality, and the way gametes are released and fertilized.

1.1.1. Gonochorism

A number of coral families harbour species which are gonochoric, which means males and females exist as separate individuals. The Dendrophyllidae family harbours several genera which utilize this reproductive strategy, such as *Turbinaria, Tubastrea, Leptopsammia, Heteropsammia, Rhizopsammia, Cladopsammia,* possibly *Duncanopsammia, Dendrophyllia* and *Balanophyllia*. These gonochoric animals mainly brood their eggs, which exceptions such as the genus *Turbinaria*, containing species which release gametes into the water.

1.1.2. Hermaphroditism

The majority of stony coral species, such as *Acropora* sp. is hermaphroditic or bisexual. Polyps of such colonies display both active male and female gonads, called testes and ovaries, respectively. These species often release egg/sperm bundles during summer periods, after which the sperm cells are released and fertilize the eggs. Some species also display self-fertilization, or selfing. This feature occurs amongst some brooding corals. This may occur within the same polyp, or in between polyps of the same colony. Several species display a unique form of sexuality which involves a transition from one sex to the other, called sequential hermaphroditism. This transition can occur from male to female, called protandry or from female to male, called protogyny.

1.1.3. Parthenogenesis

Parthenogenesis occurs when egg cells undergo cellular mitosis and start embryonic development without prior fertilization. This yields an individual which is similar to its parent, as no genetic contributions have been made by a male partner. The advantage of this strategy is that female organisms are still able to reproduce in the absence of males. The major downside is that the genetic variation of a given population decreases as a result. This decreases the overall fitness of the population, which means it is less able to adapt to changing conditions. Hereditary defects may also become more apparent. Parthenogenesis seems to be quite uncommon amongst corals, and has been reported for *Pocillopora damicornis* and *Porites* sp.

1.1.4. Broadcasting

Many coral species expel their gametes into the water column annually, during a process called broadcast spawning. This reproductive strategy is common amongst species from the Faviidae, Euphyllidae and Acroporiidae families. Members from the Faviidae and Acroporiidae families, such as *Favia, Favites, Acropora* and *Montipora* sp. are usually hermaphroditic, and release egg/sperm bundles into the water through the oral pores of their polyps. Broadcasting species usually expel impressive amounts of gametes, of which only a small fraction yields offspring. The fecundity of these corals is therefore very high under ideal circumstances. Their offspring, in the shape of planula larvae, are an important part of the meroplankton present in the ocean and are consumed by many organisms such as crustaceans and whales. Eventually, a small portion (possibly less than 1%) settles onto a reef which may be hundreds of kilometers away from its location of origin.

1.2.Coral Reefs of Andaman and Nicobar Islands

The reef corals of the Andaman and Nicobar Islands belong to the Indo-west Pacific faunal province. The Andaman and Nicobar Islands are just northwest of the central area of greatest marine biodiversity, referred to as the 'Coral Triangle', an area enclosing the Philippines, central and eastern Indonesia, and northern and eastern Papua New Guinea (Hoeksema, 1992). The Andaman and Nicobar group of Islands consists of 572 islands are located in the Southeast of the Bay of Bengal, between 6°-14° N latitude and 91°- 94° E longitude. Almost all the islands of the Andaman and Nicobar groups exhibit narrow, linear and extensively well-developed fringing reefs. Most of them, like those at Nicobar, have healthy reefs with a large biodiversity. The

reef flats are dominated by massive *Porites* and Faviids that form the chief frame builders. The shore-ward side is generally with luxuriant growth of arborescent genera such as *Acropora, Pocillopora, Seriatopora, Stylopora* etc. The reefs are rich in soft corals (Pillai, 1996). The wind ward side slopes down to a depth of 350-540 m and is subjected to the monsoonal winds. A total of 577 species of scleractinian corals reported from Andaman and Nicobar Islands. Coral reef ecosystem of Andaman and Nicobar Islands habours 112 species of sponges, 220 species soft corals, 837 species of crustaceans, 32 species of gastrotricha, 1282 species of molluscs, 220 species of opisthobranchs, 25 species of siphonculates, 430 species of echinoderms, 1485 species of fishes, 25 species of sea snakes, 4 species of turtles, 1 species of crocodile, 5 species of dolphin and 1 species of dugong. Serious natural threat to these reefs in the last two decades was infestation with the crown-of-thorns starfish.

Over the last two decades, studies on coral reproduction has continued to grow substantially and has expanded into many reef regions that were not previously well represented, including equatorial and tropical regions of high coral species richness and biodiversity, and some subtropical reef regions (Richmond, 1997; Guest *et al.*, 2005a; Harrison and Booth, 2007; Baird *et al.*, 2009a). As Richmond and Hunter stated in a 1990 review, reproductive data were available for 40% of known species from the tropical Pacific, 30% of Caribbean coral species and only 6% of Red Sea species. Data on scleractinian coral reproductive modes such as variation in sexuality (gonochorism versus hermaphroditism), seasonality, and periodicity among coral species have been used in an attempt to categorize the reproductive strategies of scleractinian corals. Several hypotheses have been proposed. One hypothesis states that the reproductive variability is due to energetic limitation (Kojis, 1986; Ward, 1995a). As reproductive activity involves energetic expenditure, under certain energetic conditions different reproductive pathways may exist. Fecundity and the ratio of male to female colonies may be regulated by a variety of internal and external processes (Rinkevich and Loya, 1987; Ward, 1995a). Studies on the reproductive biology of corals is completely lacking in India except the report on reproductive season and maturation time of *Acropora* sp made by Raj and Patterson (2010) in Gulf of Mannar.

1.3.Review of literature

Recent research on coral reproduction has resulted in substantial new information and has almost doubled the number of coral species for which sexual reproductive data are now available, from more than 230 species in the late 1980s (Harrison and Wallace, 1990; Richmond and Hunter, 1990) to at least 444 species by 2010. The current global data generally confirm and extend many of the trends and patterns highlighted in earlier studies, and some recent advances in our understanding of sexual reproduction in corals. Sexual reproduction in scleractinian corals has been widely studied in many regions of the world, and substantial new information has become available since earlier detailed reviews on this subject by Fadlallah (1983), Harrison and Wallace (1990), and Richmond and Hunter (1990), with more recent topic reviews provided by Richmond (1997), Harrison and Jamieson (1999), Kolinski and Cox (2003), Guest *et al.* (2005a),Harrison and Booth (2007), and Baird *et al.* (2009a). Corals have a relatively simple life cycle involving a dominant benthic polyp phase and a shorter planula larval phase. The polyp phase is characterized by growth of tissues and skeleton that often includes one or more forms of asexual budding or reproduction; and repeated cycles of sexual reproduction (iteroparity) involving the production of gametes, fertilization, embryo development, and a larval phase that is usually planktonic and dispersive to

some degree (Harrison and Wallace 1990). If the planula survives and successfully attaches and settles permanently on hard substratum, it metamorphoses from the larval form into a juvenile polyp that initiates the formation of the calcium carbonate exoskeleton. Subsequent growth during an initial pre-sexual juvenile phase leads to development of the adult form that becomes sexually reproductive which completes the life cycle (Harrison and Wallace, 1990).

Mass coral spawning is likely to occur in some other reef regions with diverse coral assemblages where gametogenic cycles and maturation are highly synchronized within and among populations of many species during brief seasonal breeding periods. Large multi-specific coral spawning events have been increasingly recorded in some other Indo-Pacific regions. Diverse reproductive patterns ranging from highly synchronized gamete maturation and multi-specific spawning by more than ten coral species and many corals occurring during one or a few nights, through to less synchronous multi-specific spawning by fewer corals and species and more extended breeding seasons have now been recorded from many Indo-Pacific regions, including: Japan (Heyward *et al.*, 1987; Shimoike *et al.*, 1992; Hayashibara *et al.*, 1993; van Woesik, 1995; Nozawa *et al.*, 2006; Mezaki *et al.*, 2007; Baird *et al.*, 2009b), Taiwan (Dai *et al.*, 1992; Kawaguti, 1940), the Philippines (Bermas *et al.*, 1992; Vicentuan *et al.*, 2008), Palau (Kenyon, 1995; Penland *et al.*, 2004; Kawaguti 1941a, b), Yap (Kenyon 1995), Guam (Heyward, 1988a; Richmond and Hunter, 1990; Richmond 1997), Singapore (Guest *et al.*, 2002, 2005a, b), Thailand (Piromvaragorn *et al.*, 2006; Kongjandtre *et al.*, 2010), Indonesia (Tomascik *et al.*, 1997; Baird *et al.*, 2009a), Papua New Guinea (Oliver *et al.*, 1988; Baird *et al.*, 2009a), Solomon Islands (Baird *et al.*, 2001), Fiji and Western Samoa (Mildner, 1991), Line Islands (Kenyon 2008), French Polynesia (Carroll *et al.* 2006), subtropical eastern Australia (Wilson and Harrison, 1997, 2003; Harrison, 2008), Egyptian Red Sea (Hanafy *et al.*, 2010), and some other Indo-Pacific regions (Richmond 1997; Baird *et al.*, 2009a). In the South Pacific region, coincident spawning records after full moon periods in the austral spring and summer seasons occur on reefs throughout the Great Barrier Reef up to 1,200 km apart (Willis *et al.*, 1985; Babcock *et al.*, 1986; Oliver *et al.*, 1988), and north to the Solomon Islands (Baird *et al.*, 2001), and east to French Polynesia (Carroll *et al.*, 2006). Corals also successfully reproduce in more extreme temperate latitude environments such as in Kuwait (Harrison, 1995; Harrison *et al.*, 1997), and at higher latitude regions where populations are at, or near, their latitudinal limits (van Woesik, 1995; Wilson and Harrison, 1997, 2003; Harii *et al.*, 2001; Nozawa *et al.*, 2006; Harrison 2008). Therefore, as noted by van Woesik (1995), there is no indication that these coral populations in marginal reef and cooler temperate environments are non-reproductive pseudopopulations. Reproductive patterns documented in Hawaiian corals range from brooding throughout the year in a few species, to seasonal peak reproduction in spring and summer months for broadcast spawning and some brooding species, and although some species have overlapping spawning periods, there is no evidence of large multispecific or mass spawning events (Edmondson, 1929, 1946; Harrigan, 1972; Stimson, 1978; Krupp, 1983; Richmond and Jokiel, 1984; Jokiel, 1985; Jokiel *et al.*, 1985; Heyward, 1986; Hodgson, 1988; Hunter, 1988; Richmond and Hunter, 1990; Harrison and Wallace, 1990; Kenyon, 1992; Schwartz *et al.*, 1999; Neves, 2000; Kolinski and Cox, 2003). Reproductive patterns are evident among the 14 coral species studied in the Equatorial Eastern Pacific region (EEP), where only two brooding species have been recorded, and extended breeding seasons occur in thermally stable environments but shorter seasonal breeding occurs during warm periods in seasonally varying upwelling environments (Glynn *et al.*, 1991, 1994, 1996, 2000, 2008; Colley *et*

al. 2002, 2006; Glynn and Colley, 2009). Some coral species in the EEP exhibit unusual or contrasting reproductive characteristics compared with other regions.

1.3.1. Reproductive pattern

Reproductive patterns have been widely studied in the Caribbean and other western Atlantic regions (Szmant, 1986; van Woesik *et al.*, 2006). Multispecific spawning by a small number of coral species has been recorded on some reefs in the Caribbean (van Veghel, 1993; Steiner, 1995; de Graaf *et al.*, 1999; Sanchez *et al.*, 1999; Bastidas *et al.*, 2005; Rodríguez *et al.*, 2009), in the Gulf of Mexico (Gittings *et al.*, 1992; Hagman *et al.*, 1998a, b; Vize, 2006), and subtropical Bermuda (Wyers *et al.*, 1991). Long-term spawning records from the Gulf of Mexico show that the timing of spawning for species is highly consistent between years, but most species have unique spawning "windows" during the main spawning nights when no other coral species have been observed to spawn (Vize *et al.*, 2005). In other western Atlantic corals, gametogenesis and spawning patterns are often synchronous within species or populations exhibit split-spawning over consecutive lunar cycles, but some species spawn at different lunar phases or different seasons and exhibit some degree of temporal reproductive isolation (Wyers, 1985; Szmant, 1986, 1991; Soong, 1991; Steiner, 1995; Acosta and Zea, 1997; de Graaf *et al.*, 1999; Mendes and Woodley, 2002a; Vargas-Angel and Thomas, 2002; Alvarado *et al.*, 2004; Bastidas *et al.*, 2005; Vargas-Angel *et al.*, 2006; van Woesik *et al.*, 2006; Rodriguez *et al.*, 2009). An unusual feature of the western Atlantic coral fauna is that it contains a high proportion of brooding species (Szmant, 1986) and reproductive patterns among Atlantic brooding species.

1.3.2. Asexual reproduction

Asexual reproduction produces genetically identical modules that may prolong the survival of the genotype, vival of the species. Different modes of asexual production can be distinguished; asexual budding of polyps leads to the formation of coral colonies, while various forms of asexual reproduction result in the production of new modules that form physically separate but genetically identical clones (ramets) (Highsmith, 1982; Cairns, 1988; Harrison and Wallace, 1990; Richmond, 1997). Most hermatypic coral species (Wallace, 1999; Veron, 2000) and about 26% of the known ahermatypic azooxanthellate coral species (Cairns, 2007) form colonies via asexual budding of polyps and are therefore modular, iterative colonial organisms. Budded polyps usually form by growth and internal division of existing polyps (intratentacular budding) or development of new polyps from tissues adjacent to, or between, existing polyps (extra-tentacular budding) (Vaughan and Wells, 1943; Wells, 1956; Cairns, 1988; Veron, 2000). In most colonies, these budded polyps remain interconnected, and the colony is partly integrated via nerve and muscular networks within the thin veneer of tissues that overly the skeleton they secrete (Gladfelter, 1983; Harrison and Booth, 2007). The formation of coral colonies through modular iteration of budded polyps, and associated growth of their supportive and protective exoskeleton, provide important ecological and evolutionary advantages for colonial species. Colonial growth enables corals to grow much larger than most single polyps; thus, colonies can occupy more space and more effectively compete for resources by growing above the reef substratum or over other benthos, and colonies can survive the death of individual polyps and partial colony mortality (Jackson and Coates, 1986; Rosen, 1990; Hughes *et al.*, 1992). Increased size reduces the mortality risk in juvenile corals and increases colony

biomass and resource acquisition, leading to increased reproductive output as the number of gravid polyps and fecundity increases with size and age; hence, larger colonies can dominate gamete production within coral populations, unless reproductive senescence occurs (Kojis and Quinn, 1981, 1985; Babcock, 1984, 1991; Szmant-Froelich, 1985; Rinkevich and Loya, 1986; Harrison and Wallace, 1990; Hall and Hughes, 1996; Goffredo and Chadwick-Furman, 2003; Zakai *et al.*, 2006).

These processes include colony fragmentation resulting from storm and wave impacts or other damage, colony fission, longitudinal and transverse division, polyp expulsion or polyp "bail-out," growth and detachment of polyp balls, and budding of polyps from an anthocaulus or regenerating tissues (Wells, 1966; Rosen and Taylor, 1969; Sammarco, 1982; Krupp *et al.*, 1992; Kramarsky-Winter and Loya, 1996; Kramarsky-Winter *et al.*, 1997; Gilmour, 2002; Borneman, 2006). In addition, asexual production of brooded planulae occurs in populations of the common reef coral *Pocillopora damicornis* (Stoddart, 1983; Ayre and Miller, 2004; Sherman *et al.*, 2006), and in *Tubastrea coccinea* and *Tubastrea diaphana* (Ayre and Resing, 1986). *Oulastrea crispata* may also brood asexually produced planulae during periods when sexual reproduction has ceased (Nakano and Yamazoto, 1992; Lam, 2000).

1.3.3. Influence of environmental parameters on coral reproduction

Sexual reproductive processes in corals appear to be strongly influenced by various environmental factors that act as proximate factors regulating and synchronizing reproductive cycles and gamete maturation, and as ultimate causes that exert evolutionary selective pressure through enhanced reproductive success (Harrison and Wallace, 1990). Synchronized spawning within coral populations leads to higher concentrations of gametes that promotes enhanced fertilization success (Oliver and Babcock, 1992; Willis *et al.*, 1997; Levitan *et al.*, 2004), which increases planula production and the probability of successful reproduction among corals that spawn together. Earlier studies indicated that seasonal changes in sea temperature, day length, wind or current patterns, lunar cycles of night irradiance, and daily periods of light and dark may act as proximate cues operating on progressively finer time scales to synchronize reproductive cycles and breeding among many corals (Yonge, 1940; Szmant-Froelich *et al.*, 1980; Babcock, 1984; Harrison *et al.*, 1984; Jokiel *et al.*, 1985; Simpson, 1985; Fadlallah, 1985; Willis *et al.*, 1985; Babcock *et al.*, 1986; Kojis, 1986b; Hunter, 1988; Oliver *et al.*, 1988; Harrison and Wallace, 1990). More recent hypotheses have been proposed that correlate reproductive patterns with environmental factors that may act as additional or alternative proximate or evolutionary controls on sexual reproduction in corals. These include a combination of warm temperature and absence of heavy rainfall (Mendes and Woodley, 2002a), solar insolation cycles (Penland *et al.*, 2004; van Woesik *et al.*, 2006), and the duration of regional calm periods that may enhance fertilization and larval retention (van Woesik, 2009). Environmental factors known to stress corals and negatively affect sexual reproduction include: thermal stress (Kojis and Quinn, 1984; Edmunds *et al.*, 2001; Nozawa and Harrison, 2002, 2007; Bassim *et al.*, 2002; Krupp *et al.*, 2006; Negri *et al.*, 2007; Meyer *et al.*, 2008; Randall and Szmant 2009; Yakovleva *et al.*, 2009), ultraviolet radiation (Gulko, 1995; Wellington and Fitt, 2003; Torres *et al.*, 2008), coral bleaching (Szmant and Gassman, 1990; Omori *et al.*, 2001; Ward *et al.*, 2002; Baird and Marshall, 2002; Mendes and Woodley, 2002b), lowered salinity (Edmondson, 1946; Richmond, 1993; Harrison, 1995; Vermeij *et al.*, 2006; Humphrey *et al.*, 2008), and increased sedimentation and turbidity (Kojis and Quinn, 1984; Jokiel, 1985; Gilmour,

1999; Fabricius *et al.*, 2003; Humphrey *et al.*, 2008). Sublethal and toxic levels of pollutants also impair or prevent successful coral reproduction, including increased nutrients (Tomascik and Sander, 1987; Ward and Harrison, 1997, 2000; Harrison and Ward, 2001; Bassim and Sammarco, 2003), oil pollutants and dispersants (Loya, 1976; Rinkevich and Loya, 1977, 1979c; Loya and Rinkevich, 1979; Peters *et al.*, 1981; Guzmán and Holst, 1993; Harrison, 1993, 1995; Negri and Heyward, 2000; Lane and Harrison 2002), trace metals (Heyward, 1988b; Reichelt-Brushett and Harrison, 1999, 2000, 2004, 2005; Negri and Heyward, 2001), herbicides and insecticides (Negri *et al.*, 2005; Markey *et al.*, 2007), and mixtures of pollutants in storm water runoff (Richmond, 1993). These stress effects are likely to be exacerbated by climate change impacts, including modified thermal environments that may disrupt reproductive cycles in corals and inhibit larval settlement and post settlement survival. Furthermore, increased carbon dioxide absorption resulting in decreased seawater pH and aragonite saturation state ("ocean acidification") is likely to interfere with initiation of calcification in newly settled coral polyps and reef building by hermatypic corals (Albright *et al.*, 2008; Jokiel *et al.*, 2008). As coral reproduction appears to have a narrower tolerance to stress than other life functions (Harrison and Wallace, 1990), it is essential to maintain ecologically appropriate environmental conditions to enable successful reproduction by corals.

1.4.Objectives of the project

1. Studies on fecundity of corals in selected families at different seasons
2. Studies on growth and regeneration pattern by sexual and asexual mode of reproduction.
3. Studies on substrate specificity for the settlement of coral's Planula larvae
4. Coral replantation studies on selected species in permanent monitoring plots
5. Studies on coral life cycle from Planula to adult in *ex-situ* condition.

2. AREA OF WORK

i) State: Andaman and Nicobar Islands
ii) District: South Andaman
iii) Location:

The study is being carried out in the following four locations in South Andaman (Fig. 1)

(1) Pongibalu (Lat.: 11°30.958'N & Long.: 92°39.201'E):

Pongibalu falls outside the boundary of Mahatma Gandhi Marine National Park. The wave action in the study area is minimal throughout the year. This reef area harbours diversified scleractinian corals and their associated faunal communities. The depth of the study site is in between 0.6 m and 30 m, has the tidal amplitude near about 2 m. The sea substratum in the study area is rocky coupled with live and dead corals. The place is well known for the transition zone for the freshwater transport from Rutland Island to Port Blair area. There is no impact of tourism at Pongibalu as it is restricted place.

(2) Rifleman Island (Lat.: 11°30.837'N & Long.: 92°38.767'E):

It is one of the 16 islands of Mahatma Gandhi Marine National Park. The island represents diversified scleractinian corals in its continental shelf region. The depth ranges from 2 m to 43 m. The extensive live cover of scleractinian corals and their vertical distribution made this island a special interest of research for the said project. This island is falls under protected area.

(3) Jolly Buoy Island (Lat.: 11°30.119'N & Long.: 92°37.112'E):

Jolly Buoy Island is also one of the 16 islands of Mahatma Gandhi Marine National Park. It is very famous for underwater corals and the pristine clear beach. This island is well known as tourist spot and offers an amazing view of underwater coral and marine life. Jolly Buoy Island is located about 50 km from Port Blair in Andaman and Nicobar Islands. Jolly Buoy Island is an ideal place for scuba diving and snorkeling. Impact on coral reef biodiversity can be measured due to impact of tourism.

(4) North Bay (Lat.: 11°43.006'N & Long.: 92°45.465'E):

This is one of the well-known tourist places of Port Blair adjoining areas of Andaman and Nicobar Islands. People used to enjoy the beautiful coral reef biodiversity by SCUBA diving and snorkeling at this place. The sea-walk has already been introduced and has been going on for over a year now. Along with sea walk, water-scooter ride and other water sports or activities are on in this place. The diversified of scleractinian corals and associated faunal communities are quite healthy at this area. The studies can reveal the impact of tourism on the scleractinian lives.

All the selected four study areas were selected on the basis of their strategic location, diversity of scleractinian corals and anthropogenic impacts on them. Among

the four areas, two are tourist destination while other two are restricted place. So the impact of the tourism on reproduction of corals can be assessed.

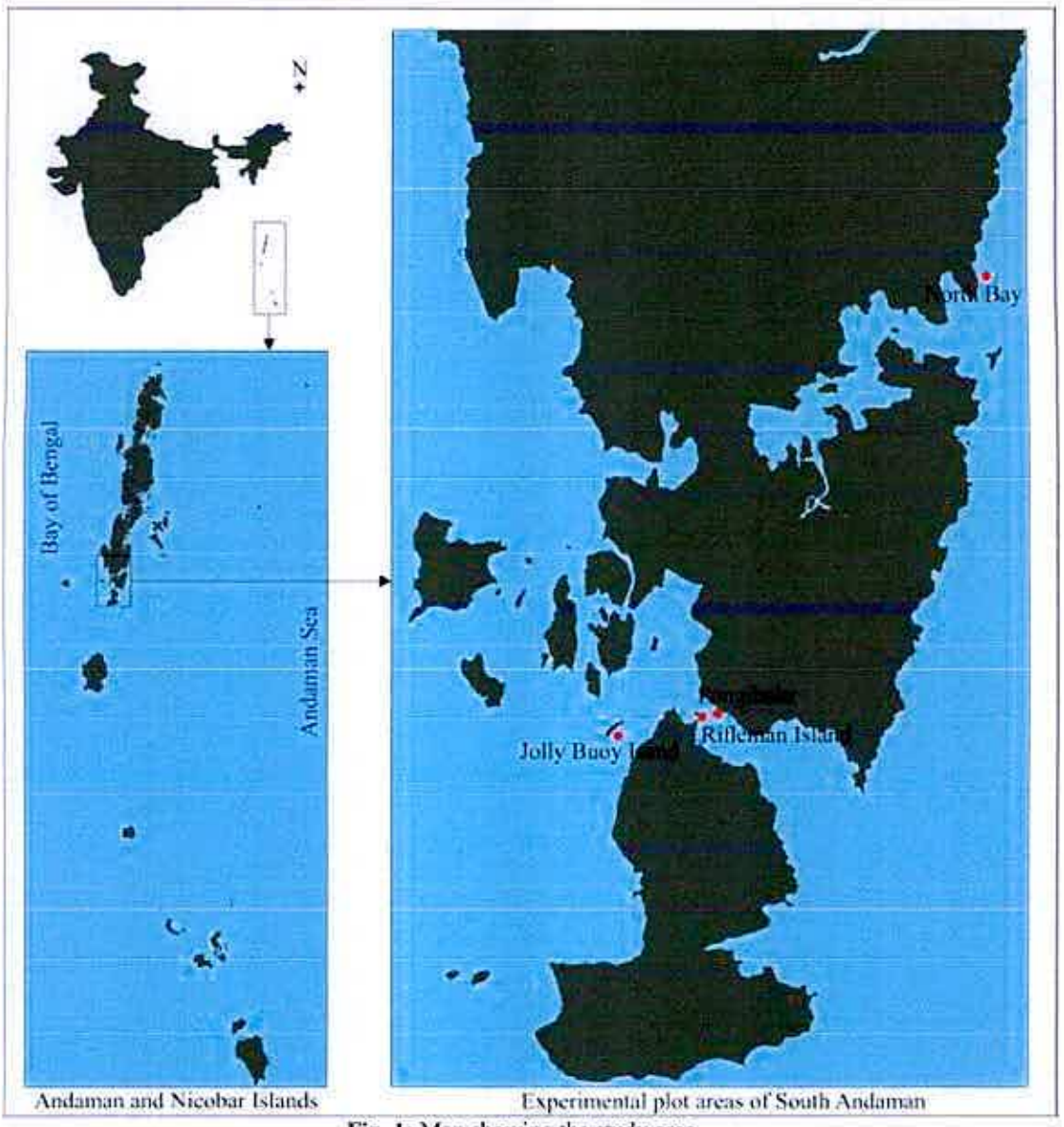


Fig. 1: Map showing the study area

2.1.Species composition of Corals in study area

The scleractinian corals of Indian waters are highly diverse than other parts of the tropical reefs. Intensive surveys were carried out to explore the species composition in South Andaman region while initiating the project. A total of 346 species (recent valid names according to www.coralsoftheworld.org) of scleractinian corals belonging to 73 genera and 15 families were reported from the study sites of South Andaman (Table 1, Plate 1). Among them the family Acroporidae is dominant as it represented by 85 species of scleractinians. A total of 330 species of scleractinian corals were reported together from Pongibalu, Rifleman Island, Jolly Buoy Island and adjoining areas of South Andaman while North Bay represented 128 species (Fig. 2). The species

diversity index of North Bay (H'=2.21) was recorded lesser than the other three areas (H'=3.39) (Fig. 3).

Table 1: Species composition of corals at three study areas of South Andaman

Sl. No.	Species	North Bay	Pongibalu, Rifleman Island & Jolly Buoy Island adjoining areas
	Family ACROPORIDAE Verrill, 1902		
	Genus *Acropora* Oken, 1815		
1.	*Acropora gemmifera* (Brook, 1896)		•
2.	*Acropora granulosa* (Milne Edwards and Haime, 1860)		•
3.	*Acropora grandis* (Brook, 1892)	•	•
4.	*Acropora vaughani* Wells, 1954		•
5.	*Acropora nasuta* (Dana, 1846)		•
6.	*Acropora anthocercis* (Brook, 1893)		•
7.	*Acropora valenciennesi* (Milne Edwards and Haime, 1860)		•
8.	*Acropora divaricata* (Dana, 1846)	•	•
9.	*Acropora striata* (Verrill, 1866)		•
10.	*Acropora humilis* (Dana, 1846)		•
11.	*Acropora forskali* (Ehrenberg, 1834)		•
12.	*Acropora plana* Nemenzo, 1967		•
13.	*Acropora torresiana* Veron, 2000		•
14.	*Acropora cardnus* (Dana, 1846)		•
15.	*Acropora pectinata* Veron, 2000		•
16.	*Acropora insignis* Nemenzo, 1967		•
17.	*Acropora squarrosa* (Ehrenberg, 1834)		•
18.	*Acropora sekiseiensis* Veron, 1990		•
19.	*Acropora yongei* Veron and Wallace, 1984		•
20.	*Acropora caroliana* Nemenzo, 1976		•
21.	*Acropora chesterfieldensis* Veron and Wallace, 1984	•	•
22.	*Acropora latistella* (Brook, 1891)	•	•
23.	*Acropora polystoma* (Brook, 1892)		•
24.	*Acropora microclados* (Ehrenberg, 1834)		•
25.	*Acropora copiosa* Nemenzo, 1967		•
26.	*Acropora robusta* (Dana, 1846)		•
27.	*Acropora digitifera* (Dana, 1846)		•
28.	*Acropora subuata* (Dana, 1846)		•
29.	*Acropora cophodactyla* (Brook, 1892)		•
30.	*Acropora horrida* (Dana, 1846)		•
31.	*Acropora palmerae* Wells, 1954		•
32.	*Acropora selago* (Studer, 1878)	•	•
33.	*Acropora papillare* Latypov, 1992		•
34.	*Acropora elseyi* (Brrok, 1892)		•
35.	*Acropora cerealis* (Dana, 1846)		•
36.	*Acropora hemprichii* (Ehrenberg, 1834)		•
37.	*Acropora tenuis* (Dana, 1845)		•
38.	*Acropora bruggemanni* (Brook, 1893)		•
39.	*Acropora echinata* Dana, 1846		•

40.	*Acropora exquisita* Nemenzo, 1971		•
41.	*Acropora variolosa* (Klunzinger, 1879)		•
42.	*Acropora longicyathus* (Milne Edwards and Haime, 1860)		•
43.	*Acropora massawensis* Marenzeller, 1906		•
44.	*Acropora monticulosa* (Bruggemann, 1879)		•
45.	*Acropora rudis* (Rehberg, 1892)		•
46.	*Acropora muricata* (Linnaeus, 1758)	•	•
47.	*Acropora tutuilensis* (Hoffmeister, 1925)		•
48.	*Acropora loripes* (Brook, 1892)		•
49.	*Acropora hyacinthus* (Dana, 1846)		•
50.	*Acropora natalensis* Riegl, 1995		•
51.	*Acropora secale* (Studer, 1878)		•
52.	*Acropora samoensis* (Brook, 1891)	•	•
53.	*Acropora pinguis* Wells, 1950		•
54.	*Acropora florida* (Dana, 1846)		•
55.	*Acropora cateriformis* (Gardiner, 1898)		•
56.	*Acropora donei* Veron and Wallace, 1984		•
57.	*Acropora speciosa* (Quelch, 1886)	•	
	Genus *Isopora* Studer, 1878		
58.	*Isopora elizabethensis*Veron, 2000		•
59.	*Isopora cuneata* (Dana, 1846)		•
60.	*Isopora palifera* (Lamarck,1816)		•
	Genus *Montipora* de Blainville, 1830		
61.	*Montipora verrucosa* (Lamarck, 1816)		•
62.	*Montipora informis* Bernard, 1897	•	•
63.	*Montipora verruculosus* Veron, 2000		•
64.	*Montipora meandrina* (Ehrenberg, 1834)		•
65.	*Montipora florida* Nemenzo, 1967		•
66.	*Montipora vietnemensis* Veron, 2000		•
67.	*Montipora undata* Bernard, 1897	•	•
68.	*Montipora turtlensis* Veron and Wallace, 1984		•
69.	*Montipora mollis* Bernard, 1897		•
70.	*Montipora hispida* (Dana, 1846)		•
71.	*Montipora taiwanensis* Veron, 2000		•
72.	*Montipora verrilli* Vaughan, 1907		•
73.	*Montipora spumosa* (Lamarck, 1816)		•
74.	*Montipora peltiformis* Bernard, 1897	•	•
75.	*Montipora venosa* (Ehrenberg, 1834)		•
76.	*Montipora caliculata* (Dana, 1846)		•
77.	*Montipora angulata* (Lamarck, 1816)		•
78.	*Montipora grisea* Bernard, 1897	•	•
79.	*Montipora efflorescens* Bernard, 1897		•
80.	*Montipora effusa* Dana, 1846		•
81.	*Montipora monasteriata* (Forskal, 1775)		•
82.	*Montipora corbettensis* Veron and Wallace, 1984		•
83.	*Montipora porites* Veron, 2000		•
84.	*Montipora gaimardi* (Bernard, 1897)		•

85.	*Montipora turgescens* Bernard, 1897	•	
	Genus *Astreopora* de Blainville, 1830		
86.	*Astreopora myriphthalma* (Lamarck, 1816)	•	•
87.	*Astreopora suggesta* Wells, 1954	•	•
88.	*Astreopora incrustans* Bernard, 1896		•
89.	*Astreopora ocellata* Bernard, 1896		•
90.	*Astreopora listeri* Bernard, 1896		•
	Family POCILLOPORIDAE Gray, 1842		
	Genus *Pocillopora* Lamarck, 1816		
91.	*Pocillopora damicornis* (Linnaeus,1758)	•	•
92.	*Pocillopora eydouxi* Milne Edwards and Haime, 1860		•
93.	*Pocillopora elegans* Dana, 1846	•	•
94.	*Pocillopora woodjonesi* Vaughan, 1918		•
95.	*Pocillopora verrucosa* (Ellis and Solander, 1786)	•	•
96.	*Pocillopora meandrina* Dana, 1846		•
97.	*Pocillopora kelleheri* Veron, 2000		•
	Genus *Stylophora* Schweigger, 1819		
98.	*Stylophora pistillata* Esper, 1797	•	•
99.	*Stylophora danae* Milne Edwards and Haime, 1850		•
100.	*Stylophora subseriata* (Ehrenberg, 1834)		•
	Genus *Seriatopora* Lamarck, 1816		
101.	*Seriatopora hystrix* Dana, 1846	•	•
102.	*Seriatopora stellata* Quelch, 1886		•
103.	*Seriatopora aculeata* Quelch, 1886		•
	Family OCULINIDAE Gray,1847		
	Genus *Galaxea* Oken, 1815		
104.	*Galaxea fascicularis* (Linnaeus,1767)	•	•
105.	*Galaxea astreata* (Lamarck, 1816)	•	•
	Family SIDERASTERIDAE Vaughan and Wells, 1943		
	Genus *Psammocora* Dana, 1846		
106.	*Psammocora digitata* Milne Edwards and Haime, 1851	•	•
107.	*Psammocora profundacella* Gardiner, 1898	•	•
108.	*Psammocora haimeana* Milne Edwards and Haime, 1851	•	•
109.	*Psammocora obtusangula* (Lamarck, 1816)	•	•
110.	*Psammocora nierstraszi* Horst, 1921		•
111.	*Psammocora vaughani* Yabe and Sugiyama, 1936		•
	Genus *Siderastrea* de Blainville, 1830		
112.	*Siderastrea radians* (Pallas, 1766)		•
	Genus *Pseudosiderastrea* Yabe and Sugiyama, 1953		
113.	*Pseudosiderastrea tayamai* Yabe and Sugiyama, 1935		•
	Genus *Coscinaracea* Milne Edwards and Haime,1848		
114.	*Coscinaraea monile* (Forskal, 1775)	•	•
115.	*Coscinaraea crassa* Veron and Pichon, 1980		•
116.	*Coscinaraea columna* (Dana, 1846)		•
117.	*Coscinaraea exesa* (Dana, 1846)		
	Family AGARICIIDAE Gray, 1847		

	Genus *Pachyseris* Milne Edwards and Haime, 1849		
118.	*Pachyseris gemmae* Nemenzo,1955	•	•
119.	*Pachyseris rugosa* (Lamarck, 1801)	•	•
120.	*Pachyseris speciosa* (Dana, 1846)		•
	Genus *Gardineroseris* Scheer and Pillai, 1974		
121.	*Gardineroseris planulata* (Dana, 1846)	•	•
	Genus *Pavona* Lamarck,1801		
122.	*Pavona duerdeni* Vaughan, 1907	•	•
123.	*Pavona minuta* Wells, 1954	•	•
124.	*Pavona cactus* (Forskal, 1775)	•	•
125.	*Pavona calvus* (Dana, 1846)		•
126.	*Pavona venosa* (Ehrenberg, 1834)	•	•
127.	*Pavona decussata* (Dana, 1846)		•
128.	*Pavona diffluens* (Lamarck, 1816)		•
129.	*Pavona varians* Verrill, 1864	•	•
130.	*Pavona bipartita* Nemenzo, 1980	•	•
131.	*Pavona explanulata* (Lamarck, 1816)		•
132.	*Pavona gigantean* Verrill, 1896		
133.	*Pavona frondifera* (Lamarck, 1816)	•	
	Genus *Coeloseris* Vaughan,1918		
134.	*Coeleseris mayeri* Vaughan, 1918	•	•
	Genus *Leptoseris* Milne Edwards and Haime,1849		
135.	*Leptoseris mycetoseroides* Wells, 1954	•	•
136.	*Leptoseris explanata* Yaba and Sugiyama, 1941		•
137.	*Leptoseris hawaiensis* Vaughan, 1907	•	•
138.	*Leptoseris solida* (Quelch, 1886)		•
139.	*Leptoseris cuculata* (Ellis and Solander, 1786)		•
140.	*Leptoseris incrustans* (Quelch, 1886)		•
141.	*Leptoseris yabei* (Pillai and Scheer, 1976)	•	•
142.	*Leptoseris striata* Fenner and Veron, 2000		•
143.	*Leptoseris foliosa* Dinesen, 1980	•	•
144.	*Leptoseris scabra* Vaughan, 1907	•	
145.	*Leptoseris tubulifera* Vaughan, 1907		
	Family ASTROCOENIIDAE Koby, 1890		
	Genus *Stylocoeniella* Yabe and Sugiyama, 1935		
146.	*Stylocoeniella guentheri* Bassett-Smith, 1890		•
147.	*Stylocoeniella armata* (Ehrenberg, 1834)	•	
	Family FUNGIIDAE Dana,1846		
	Genus *Cantharellus* Hoeksema and Best, 1984		
148.	*Cantharellus doederleini* (Marenzeller, 1907)		•
	Genus *Cycloseris* Milne Edwards and Haime,1849		
149.	*Cycloseris costulata* (Ortmann, 1889)	•	•
150.	*Cycloseris patelliformis* (Boschma, 1923)		•
151.	*Cycloseris colini* Veron, 2000		•
152.	*Cycloseris vaughani* (Boschma, 1923)		•
153.	*Cycloseris somervillei* (Gardiner, 1909)	•	
154.	*Cycloseris erora* (Doderlein, 1901)	•	
155.	*Cycloseris curvata* (Hoeksema, 1989)		•

	Genus *Ctenactis* Verrill, 1864		
156.	*Cteanactis echinata* (Pallas, 1766)	•	•
157.	*Cteanactis crassa* (Dana, 1846)	•	•
158.	*Ctenactis triangularis* Mondal and Raghunathan, 2013		•
159.	*Ctenactis albitentanculata* Hoeksema, 1989		•
	Genus *Fungia* Lamarck,1801		
160.	*Fungia scutaria* Lamarck, 1801	•	•
161.	*Fungia paumotensis* Stutchbury,1833	•	•
162.	*Fungia danai* Milne Edwards and Haime, 1851	•	•
163.	*Fungia fungites* (Linnaeus, 1758)	•	•
164.	*Fungia concinna* Verrill, 1864		•
165.	*Fungia scabra* Doderlein, 1901		•
166.	*Fungia horrida* Dana, 1846		•
167.	*Fungia repanda* Dana, 1846	•	•
168.	*Fungia klunzingeri* Doderlein, 1901	•	•
169.	*Fungia corona* Doderlein, 1901		•
170.	*Fungia granulousa* Klunzinger, 1879		•
171.	*Fungia sruposa* Klunzinger, 1879	•	•
	Genus *Sandalolitha* Quelch, 1884		
172.	*Sandalolitha dentata* Quelch, 1884		•
173.	*Sandalolitha robusta* Quuelch, 1886	•	•
	Genus *Herpolitha* Eschscholtz, 1825		
174.	*Herpolitha weberi* Horst, 1921	•	•
175.	*Herpolitha limax* (Houttuyn, 1772)		•
	Genus *Polyphyllia* Quoy and Gaimard,1833		
176.	*Polyphyllia talpina* (Lamaarck, 1801)	•	•
	Genus *Podabacia* Milne Edwards and Haime,1849		
177.	*Podabacia lankaensis* Veron, 2000		•
178.	*Podabacia crustacea* (Pallas, 1766)	•	•
179.	*Podabacia sinai* Veron, 2000		•
	Genus *Lithophyllon* Rehberg, 1892		
180.	*Lithophyllon lobata* Horst, 1921	•	•
181.	*Lithophyllon undulatum* Rehberg, 1892	•	•
	Family MUSSIDAE Ortmann, 1890		
	Genus *Symphyllia* Milne Edwards and Haime, 1848		
182.	*Symphyllia recta* (Dana, 1846)	•	•
183.	*Symphyllia agaricia* Milne Edwards and Haime, 1849	•	•
184.	*Symphyllia hassi* Pillai and Scheer, 1976		•
185.	*Symphyllia erythraea* (Klunzinger, 1879)		•
186.	*Symphyllia radians* Milne Edwards and Haime, 1849	•	•
187.	*Symphyllia valenciennessii* Milne Edwards and Haime, 1849		•
	Genus *Lobophyllia* de Blainville, 1830		
188.	*Lobophyllia hemprichii* (Ehrenberg, 1834)	•	•
189.	*Lobphyllia robusta* Yabe and Sugiyama, 1936		•
190.	*Lobophyllia corymbosa* (Forskal, 1775)	•	•
191.	*Lobophyllia pachysepta* Chevalier, 1975		•
	Genus *Isophyllia* Milne Edwards and Haime, 1851		

192.	*Isophyllia rigida* (Dana, 1846)		•
	Genus *Australomussa* Veron, 1985		
193.	*Australomussa rowleyensis* Veron, 1985	•	•
	Genus *Parascolymia* Wells, 1964		
194.	*Parascolymia australis* (Milne Edwards and Haime, 1849)		•
195.	*Parascolymia vitiensis* Bruggemann, 1877		•
	Genus *Acanthastrea* Milne Edwards and Haime, 1848		
196.	*Acanthastrea faviaformis* Veron, 2000		•
197.	*Acanthastrea hemprichii* (Ehrenberg, 1834)	•	•
198.	*Acanthastrea echinata* (Dana, 1846)		•
199.	*Acanthastrea regularis* Veron, 2000	•	•
200.	*Acanthastrea brevis* Milne Edwards and Haime, 1849		•
201.	*Acanthastrea maxima* Sheppard and Salm, 1988		•
	Family FAVIIDAE Gregory, 1900		
	Genus *Favia* Oken, 1815		
202.	*Favia danai* Verrill, 1872		•
203.	*Favia maxima* Veron and Pichon, 1977		•
204.	*Favia lizardensis* Veron and Pichon, 1977		•
205.	*Favia speciosa* Dana, 1846	•	•
206.	*Favia marshae* Veron, 2000		•
207.	*Favia favus* (Forskal, 1775)		•
208.	*Favia helianthoides* Wells, 1954	•	•
209.	*Favia rotumana* (Gardiner, 1899)		•
210.	*Favia rotundata* (Veron and Pichon, 1977)		•
211.	*Favia pallida* (Dana, 1846)	•	•
212.	*Favia matthaii* Vaughan, 1918	•	•
213.	*Favia stelligera* (Dana, 1846)		•
214.	*Favia maritima* (Nemenzo, 1971)		•
215.	*Favia truncatus* Veron, 2000	•	•
216.	*Favia albidus* Veron, 2000		•
217.	*Favia veroni* Moll and Borel-Best, 1984		•
218.	*Favia laxa* (Klunzinger, 1879)		•
219.	*Favia amicorum* (Milne Edwards and Haime, 1830)		•
220.	*Favia laddi* (Wells, 1954)		•
	Genus *Caulastrea* Dana, 1846		
221.	*Caulastrea furcata* Dana, 1846		•
	Genus *Plesiastrea* Milne Edwards and Haime, 1848		
222.	*Plesiastrea versipora* (lamarck, 1816)		•
	Genus *Leptoria* Milne Edwards and Haime,1848		
223.	*Leptoria irregularis* Veron, 1990		•
224.	*Leptoria phrygia* (Ellis and Solander, 1786)		•
	Genus *Diploastrea* Matthai, 1914		
225.	*Diploastrea heliopora* (Lamarck, 1816)	•	•
	Genus *Oulastrea* Milne Edwards and Haime, 1848		
226.	*Oulastrea crispata* (Lamarck, 1816)		•
	Genus *Favites* Link, 1807		
227.	*Favites abdita* (Ellis and Solander, 1786)		•

228.	*Favites acuticollis* (Ortmann, 1889)	•	•
229.	*Favites micropentagona* Veron, 2000	•	•
230.	*Favites bestae* Veron, 2000		•
231.	*Favites halicora* (Ehrenberg, 1834)		•
232.	*Favites chinensis* (Verrill, 1866)		•
233.	*Favites flexuosa* (Dana, 1846)	•	•
234.	*Favites paraflexuosa* Veron, 2000		•
235.	*Favites pentagona* (Esper, 1794)	•	•
236.	*Favites complanata* (Ehrenberg, 1834)	•	•
237.	*Favites russelli* (Wells, 1954)		•
238.	*Favites vasta* (Klunzinger, 1879)		•
239.	*Favites spinosa* (Klunzinger, 1879)	•	•
	Genus *Platygyra* Ehrenberg, 1834		
240.	*Platygyra pini* Chevalier, 1975	•	•
241.	*Platygyra sinensis* (Milne Edwards and Haime, 1849)	•	•
242.	*Platygura ryukyuensis* Yabe and Sugiyama, 1936	•	•
243.	*Platygyra deadalea* (Ellis and Solander, 1786)		•
244.	*Platygyra crosslandi* Matthai, 1928		•
245.	*Platygyra acuta* Veron, 2000		•
246.	*Platygyra lamellina* (Ehrenberg, 1834)		•
247.	*Platygyra verweyi* Wijsman-Best, 1976	•	•
248.	*Platygyra contorta* Veron, 1990		•
	Genus *Oulophyllia* Edwards and Haime , 1848		
249.	*Oulophyllia levis* (Nemenzo, 1959)		•
250.	*Oulophyllia crispa* (Lamarck, 1816)		•
	Genus *Astrea* Lamarck, 1801		
251.	*Astrea curta* (Dana, 1846)		•
252.	*Astrea annuligera* Milne Edwards and Haime, 1849		•
	Genus *Paramontastraea* Huang & Budd, 2014		
253.	*Paramontastrea salebrosa* (Nemenzo, 1955)		•
	Genus *Phymastrea* Milne Edwards and Haime, 1848		
254.	*Phymastrea colemani* Veron, 2000		•
255.	*Phymastrea magnistellata* Chevalier, 1971		•
256.	*Phymastrea valenciennesi* (Milne Edwards and Haime, 1860)	•	•
	Genus *Leptastrea* Milne Edwards and Haime, 1848		
257.	*Leptastrea purpurea* (Dana, 1846)	•	•
258.	*Leptastrea pruinosa* Crossland, 1952		•
259.	*Leptastrea aequalis* Veron, 2000		•
260.	*Leptastrea transversa* Klunzinger, 1879	•	•
	Genus *Goniastrea* Milne Edwards and Haime ,1848		
261.	*Goniastrea edwardsi* Chevalier, 1971	•	•
262.	*Goniastrea retiformis* (Lamarck, 1816)	•	•
263.	*Goniastrea pectinata* (Ehrenberg, 1834)	•	•
264.	*Goniastrea minuta* Veron, 2000	•	•
265.	*Goniastrea aspera* Verrill, 1905		•
266.	*Goniastrea palauensis* (Yabe and Sugiyama, 1936)		•
267.	*Goniastrea favulus* (Dana, 1846)	•	•

268.	*Goniastrea peresi* (Faure and Pichon, 1978)	•	
	Genus *Cyphastrea* Milne Edwards and Haime, 1848		
269.	*Cyphastrea japonica* Yabe and Sugiyama, 1932		•
270.	*Cyphastrea ocellina* (Dana, 1864)		•
271.	*Cyphastrea serailia* (Forskal, 1775)	•	•
272.	*Cyphastrea chalcidicum* (Forskal, 1775)	•	•
273.	*Cyphastrea microphthalma* (Lamarck, 1816)		•
274.	*Cyphastrea agassizi* (Vaughan, 1907)		•
	Genus *Colpophyllia* Milne Edwards and Haime, 1848		
275.	*Colpophyllia natans* (Houttuyn, 1772)		•
	Genus *Echinopora* Lamarck, 1816		
276.	*Echinopora pacificus* Veron, 1990	•	•
277.	*Echinopora fruticulosa* (Ehrenberg, 1834)		•
278.	*Echinopora lamellosa* (Espper, 1795)	•	•
279.	*Echinopora forskaliana* (Milne Edwards and Haime, 1849)		•
280.	*Echinopora hirsutissima* Milne Edwards and Haime, 1849	•	•
281.	*Echinopora gammacea* Lamarck, 1816	•	•
	Family PECTINIIDAE Vaughan and Wells, 1943		
	Genus *Oxypora* Saville Kent,1871		
282.	*Oxypora crassispinosa* Nemenzo, 1979	•	•
283.	*Oxypora glabra* Nemenzo, 1959	•	•
	Genus *Echinophyllia* Klunzinger,1879		
284.	*Echinophyllia orpheensis* Veron and Pichon, 1980	•	•
285.	*Echinophyllia echinoporoides* Veron and Pichon, 1980		•
286.	*Echinophyllia aspera* (Ellis and Solander, 1786)		•
	Genus *Mycedium* Oken,1815		
287.	*Mycedium elephantotus* (Pallas, 1766)		•
	Genus *Pectinia* Oken, 1815		
288.	*Pectinia paeonia* (Dana, 1846)	•	•
289.	*Pectinia alcicornis* (Saville-Kent, 1871)		•
290.	*Pectinia lactuca* (Pallas, 1766)		•
	Genus *Echinomorpha* Veron, 2000		
291.	*Echinomorpha nishihirai* (Veron, 1990)		•
	Family PORITIDAE Gray, 1842		
	Genus *Porites* Link, 1807		
292.	*Porites solida* (Forskal, 1775)	•	•
293.	*Porites murrayensis* Vaughaan, 1918		•
294.	*Porites monticulosa* Dana, 1846	•	•
295.	*Porites cylindrica* Dana, 1846	•	•
296.	*Porites latistellata* (Quelch, 1886)		•
297.	*Porites stephensoni* Crossland, 1952	•	•
298.	*Porites rus* (Forskal, 1775)	•	•
299.	*Porites densa* Vaughan, 1918	•	•
300.	*Porites lobata* Dana, 1846	•	•
301.	*Porites nodifera* Klunzinger, 1879		•
302.	*Porites horizontalata* Hoeffmeister, 1925	•	

303.	*Porites sillimaniana* Nemenzo, 1976	•	
304.	*Porites porites* (Pallas, 1766)	•	
305.	*Porites australiensis* Vaughan, 1918		
	Genus *Goniopora* de Blainville, 1830		
306.	*Goniopora lobata* Milne Edwards and Haime, 1860		•
307.	*Goniopora minor* Crossland, 1952		•
308.	*Goniopora columna* Dana, 1846	•	•
309.	*Goniopora eclipsensis* Veron and Pichon, 1982		•
310.	*Goniopora fruticosa* Saville-Kent, 1893		•
311.	*Goniopora pearsoni* Veron, 2000		•
312.	*Goniopora albiconus* Veron, 2000		•
313.	*Goniopora minuta* Veron, 2000		•
	Genus *Alveopora* de Blainville, 1830		
314.	*Alveopora allingi* Hoeffmeister, 1925		•
315.	*Alveopora gigas* Veron, 1985		•
	Family MERULINIDAE Verrill,1866		
	Genus *Hydnophora* Fischer de Waldheim,1807		
316.	*Hydnophora microconos* (Lamarck, 1816)	•	•
317.	*Hydnophora exesa* (Pallas, 1766)	•	•
318.	*Hydnophora grandis* Gardiner, 1904		•
319.	*Hydnophora rigida* (Dana, 1846)		•
	Genus *Merulina* Ehrenberg, 1834		
320.	*Merulina scabricula* Dana, 1846	•	•
321.	*Merulina ampliata* (Ellis and Solander, 1786)	•	•
	Genus *Scapophyllia* Milne Edwards and Haime, 1848		
322.	*Scapophyllia cylindrica* Milne Edwards and Haime, 1848	•	•
	Family DENDROPHYLLIIDAE Gray, 1847		
	Genus *Turbinaria* Oken, 1815		
323.	*Turbinaria reniformis* Bernard, 1896	•	•
324.	*Turbinaria peltata* (Esper, 1974)		•
325.	*Turbinaria stellulata* (Lamarck, 1816)		•
326.	*Turbinaria frondens* (Dana, 1846)		•
327.	*Turbinaria radicalis* Bernard, 1896	•	•
328.	*Turbinaria mesenterina* (Lamarck, 1816)		•
	Genus *Dendrophyllia* Grey, 1847		
329.	*Dendrophyllia robusta* (Bourne,1905)	•	•
	Genus *Tubastrea* Lesson, 1829		
330.	*Tubastrea coccinia* Lesson, 1829	•	•
331.	*Tubastrea diaphana* Dana, 1846	•	•
332.	*Tubastrea micrantha* Ehrenberg, 1834		•
	Genus *Rhizopsammia* Verrill, 1869		
333.	*Rhizopsammia verrilli* van der Horst, 1922		•
	Genus *Balanophyllia* Wood, 1844		
334.	*Balanophyllia merguiensis* Duncan, 1889		•
335.	*Balanophyllia vanderhorsti* Cairns, 2001		•
	Family EUPHYLLIDAE Veron, 2000		
	Genus *Physogyra* Quelch, 1884		

336.	*Physogyra lichtensteini* (Milne Edwards and Haime, 1851)	•	•
	Genus *Plerogyra* Milne Edwards and Haime, 1848		
337.	*Plerogyra sinuosa* (Dana, 1846)		•
	Genus *Catalaphyllia* Wells, 1971		
338.	*Catalaphyllia jardinei* (Saville-Kent, 1893)		•
	Genus *Euphyllia* Dana, 1846		
339.	*Euphyllia glabrescens* (Chamisso Eysenhardt, 1821)	•	•
340.	*Euphyllia paraglabrescens* Veron, 2000		•
341.	*Euphyllia ancora* Veron and Pichon, 1980		•
342.	*Euphyllia crispata* Chevalier, 1971		•
	Family CARYOPHYLLIDAE Gray, 1847		
	Genus *Heterocyathus* Milne Edwards and Haime, 1848		
343.	*Heterocyathus aequicostatus* Milne Edwards and Haime, 1848		•
	Genus *Paracyathus* Milne Edwards and Haime, 1848		
344.	*Paracyathus indicus* Duncan, 1899		•
345.	*Paracyathus stokesi* (Milne Edwards and Haime, 1848)		•
	Genus *Polycyathus* Duncan, 1889		
346.	*Polycyathus verrilli* Duncan, 1889		•
	Total number of species	128	330

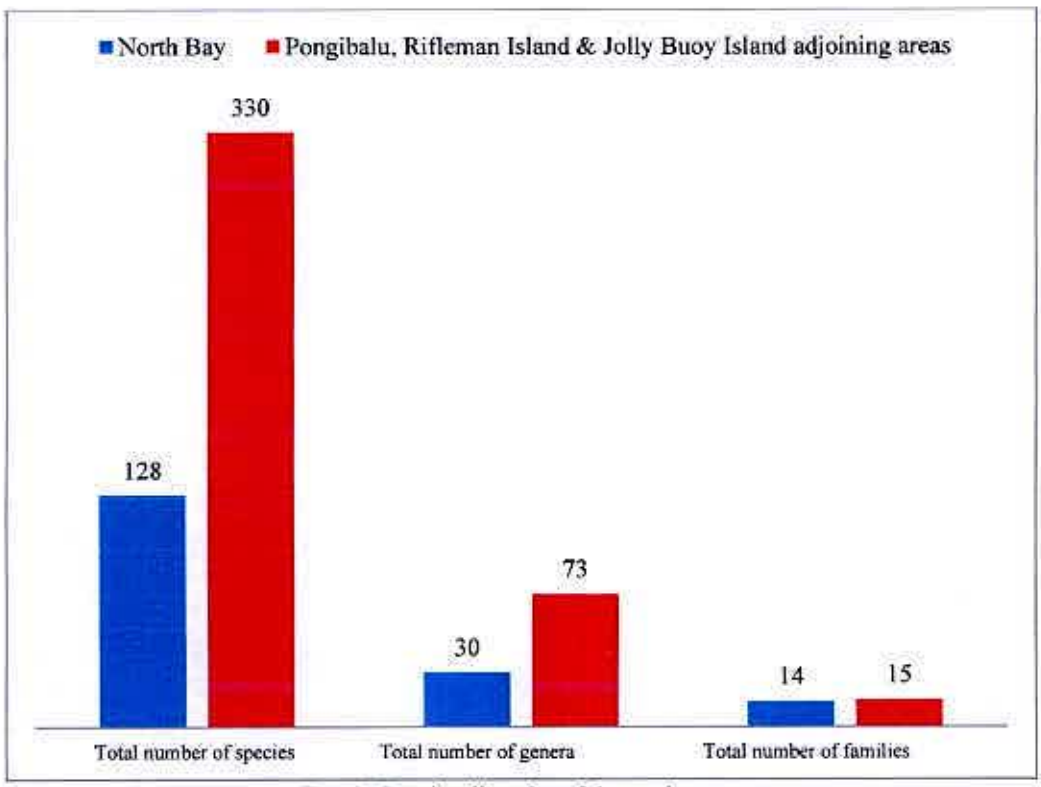


Fig. 2: Species diversity of the study areas

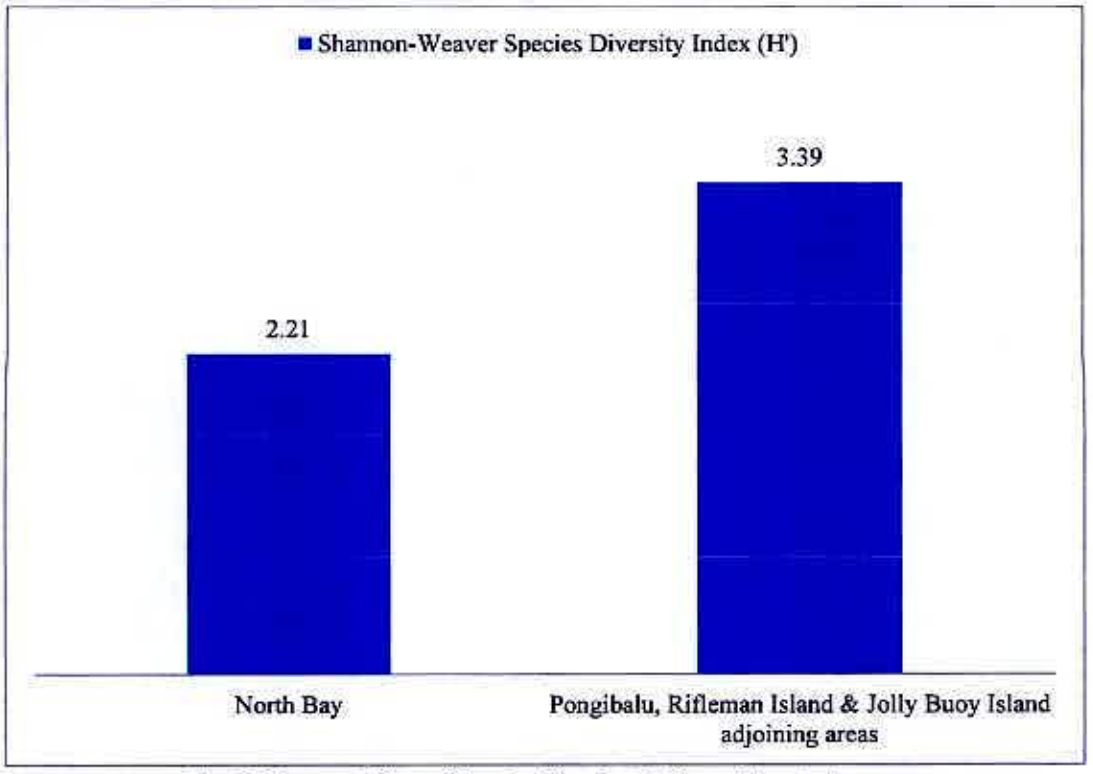


Fig. 3: Shannon-Weaver Species Diversity Indices of the study areas

Plate 1: Scleractinian corals of South Andaman

Acropora gemmifera (Brook, 1892)

Acropora robusta (Dana, 1846)

Acropora muricata (Linnaeus, 1758)

Acropora papillare Latypov, 1992

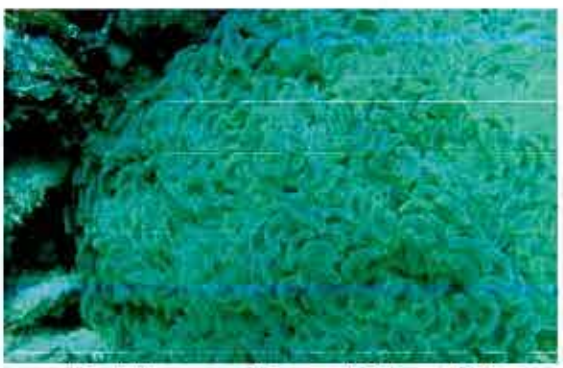
Acropora spicifera (Dana, 1846)

Acropora tenuis (Dana, 1846)

Plate 1: Contd.

Diploastrea heliopora (Lamarck, 1816)

Echniopora pacificus Veron, 1990



Euphyllia ancora Veron and Pichon, 1979

Fungia fungites (Linnaeus,1758)

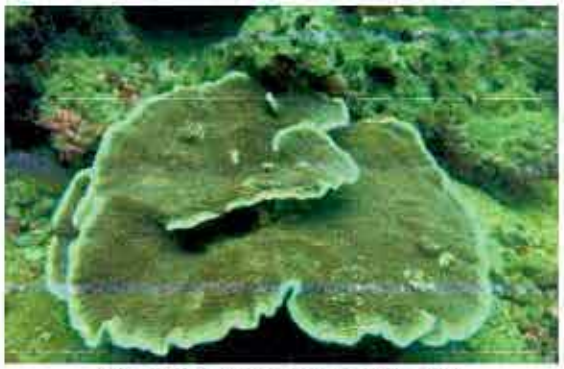
Leptoria phrygia (Ellis and Solander, 1786)

Lithophyllon lobata (Horst, 1921)

Plate 1: Contd.

Lobophyllia hemprichii (Ehenberg, 1834)

Oxypora crassispinosa Nemenzo, 1979



Pachyseris gemmae Nemenzo, 1955

Pocillopora eydouxi Milne Edwards and Haime, 1860

Porites cylindrica Dana, 1846

Porites lutea Milne Edwards and Haime, 1860

3. A BRIEF RESUME OF THE WORK DONE SINCE THE INCEPTION OF THE PROJECT

1. Four locations viz., Pongibalu, Rifleman Island, Jolly Buoy Island and North Bay in South Andaman region were selected for the study. Preliminary surveys were conducted during the period of two years in these study areas to assess the diversity of scleractinian corals and it resulted with 346 species. Of which, 128 species encountered from North Bay while altogether 330 species recorded from rest of the locations.

2. The *in-situ* experimental studies on growth pattern of three species of corals under the family Fungiidae (*Fungia paumotensis* Stutchbury 1833 and *Fungia repanda* Dana 1846) and Acroporidae (*Acropora muricata* (Linnaeus, 1758)) were conducted and data collected based on the monthly observation for the period of two years for fungoid corals and all three years for acroporid coral. The mean quarterly growth rate of *Fungia paumotensis* was 0.342 ± 0.025 cm while it was 0.203 ± 0.038 cm for *Fungia repanda*. *Acropora muricata* showed the monthly growth rate of 2.41 ± 0.59 cm at Pongibalu and 1.79 ± 0.41 cm at North Bay.

3. Regeneration studies on 11 species of fungiid corals were carried out by artificially excising the coralla. During the period of 2014-5, it was observed that the colonial species *Polyphyllia talpina* showed highest (0.33cm) development in unit length whereas the *Fungia scruposa* showed the lowest (0.03cm). During 2015-16, the highest (0.78) regeneration of unit length was seen in *Polyphyllia talpina* and lowest (0.08) was recorded in only *Herpolitha weberi* during second year i.e., August 2015 to July 2016. In *Fungia fungites* and *Fungia repanda,* maximum regeneration was seen in the portion of corals where excision was made through the mouth (1/2 mouth). Presence and absence of mouth play a crucial role for the regrowth of fungiids. *Fungia paumotensis* showed highest regeneration (0.71) of in this category during August 2015 to July 2016.

4. The recruitment and growth pattern of scleractinian corals under eight families viz., Acroporidae, Faviidae, Siderastreidae, Mussidae, Agariciidae, Poritidae, Pectinidae and Fungiidae observed in one square meter area from North Bay and Pongibalu. Due to the wide diversification and organizational variability, growth studies of scleractinian corals were made on the type such as massive, sub-massive, encrusting, corymbose, branching and solitary mushroom corals. Twenty six live corals from North Bay and 21 live corals from Pongibalu were observed for the period of three year. During the first year i.e., August 2014 to July 2015, the data indicated that, an average growth rate at North Bay for the species under the family Portidae was 7mm/yr. while for Mussidae it was 9.5mm/yr. However for the species under the family Acroporidae was 60mm/yr. The growth data obtained from the corals of Pongibalu shown that 11mm/yr., 43mm/yr. and 24.25mm/yr. for the families Poritidae, Pocilloporidae and Acroporidae respectively. During second year i.e., August 2015 to July 2016, the data indicated that, lowest average growth rate for the species under the family Portidae was 7.6mm/yr. while the highest of average growth for 3 species under the family Acroporidae was 64.3mm/yr at North Bay area. The growth data obtained from the corals of Pongibalu shown that lowest growth rate 8mm/yr was recorded for the species under the family Faviidae while highest 44.3 mm/yr was

recorded for the species under the family Pocilloporidae. During the third year i.e. August 2016 to July 2017, lowest average growth rate was recorded for the species under the family Portidae was 9.1 mm/yr. while the highest of average growth was recorded for 3 species under the family Acroporidae was 75.3mm/yr at North Bay area. In Pongibalu, lowest growth rate of 8mm/yr was recorded for the species under the families Faviidae and Poritidae and highest 43.8 mm/yr was recorded for the species under the family Pocilloporidae.

5. Settlement of planula larvae of corals in *in-situ* condition were monitored by employing rectangular concrete plates (20 × 20 cm) prepared by using 10% of coralline rubbles at four location of the study. During the period of 1st year, deployment, maximum settlement of planula larvae was found on February to April 2015 (2 - 30 larvae) and it was minimum during August to October 2014 (3-7 larvae) while second year of the observation denoted the alike comprehensive result of progressive settlement of planula larvae during the period of February to April 2016 (3-37 larvae) while minimum during August to October 2015 (6 to 14 larvae). During the final year i.e. 2016-2017, maximum settlement of 8-35 planula larvae was recorded during February to April 2017 and the minimum of 5-15 planula larvae was recorded during August to October 2016.

6. After the settlement and growth of planula during 2014-15, three species of corals viz. *Pocillopora damicornis, Rhizopsammia verrilli* and *Tubastrea concinnia* were identified on the plates. Their growth rate for the period 3 three month from settlement is 25 mm, 4 mm and 5mm diameter respectively. During 2015-16, settlement and development of a total of 26 colonies and solitary individuals under 14 species such as *Porites solida* (2 colonies), *Favia speciosa* (4 colonies), *Favites pentagona* (1 colony), *Porites lobata* (2 colonies), *Favia matthaii* (1 colony), *Favia albidus* (1 colony), *Lobophyllia hemprichii* (1 colony), *Favia lizardensis* (1 colony), *Acropora* sp. (1 colony), *Hydnophora microconos* (1 colony), *Tubastrea micrantha* (1 colony), *Tubastrea coccinea* (2 colonies), *Rhizopsammia verrillii* (4 individuals) and *Montipora* sp. (3 colonies) were recorded from the plates. During 2016-17, settlement and development of a total of 33 colonies and solitary individuals under 13 species such as *Porites solida* (4 colonies), *Porites lutea* (3 colonies), *Porites lobata* (4 colonies), *Favia speciosa* (4 colonies), *Favites pentagona* (2 colonies), *Favia matthaii* (1 colony), *Favia albidus* (1 colony), *Favia lizardensis* (1 colony), *Acropora* sp. (4 colonies of different 4 species), *Tubastrea micrantha* (1 colony), *Tubastrea coccinea* (4 colonies), *Rhizopsammia verrillii* (1 individuals) and *Montipora* sp. (3 colonies of different 3 species) were recorded from the plates.

7. The rate of sediment deposition was also monitored monthly at Pongibalu and North Bay to denote the role of sedimentation of settlement pattern scleractinian corals and the impact of tourism to enhance the rate of sedimentation. During 2014-15, it was observed that a total maximum sediment deposition was observed at North Bay region (163.86 mg/cm/year) in comparison to Pongibalu (75.10 mg/cm/year). Maximum sediment was recorded during September at North Bay while minimum sedimentation was seen at Pongibalu during March 2015. During 2015-16, it was observed that a maximum sediment deposition was observed at North Bay region (171.14 mg/cm^2/year) in comparison to Pongibalu (63.08 mg/cm^2/year). Maximum sediment was recorded during September 2015 at North

Bay while minimum sedimentation was seen at Pongibalu during April 2016. During 2016-17, it was observed that a maximum sediment deposition was observed at North Bay region (182.75 mg/cm^2/year) in comparison to Pongibalu (61.04 mg/cm^2/year). Maximum sediment was recorded during September 2016 at North Bay while minimum sedimentation was seen at Pongibalu during February 2017.

8. Coral transplantation experiment was set-up at Pongibalu area during July 2015. Initially 3 plots (1m × 1m) were set at the depth of 2 m to measure the survivability of scleractinian corals. Fragments of eight species of corals viz. *Acropora muricata, Acropora austera, Pocillopora damicornis, Seriatopora hystrix, Hydnophora rigida, Cyphastrea microphthalma, Porites annae* and *Porites rus* were transplanted at the plot areas for the development. The length of the coral colonies were taken during the period deployment. The experimental set-up of coral transplantataion was established in a metal frame (1m × 1m) at the depth of 4m at Pongibalu area during May 2016. Twenty five coral fragments of eight species viz., *Acropora muricata, Acropora robusta, Acropora latistella, Porites cylindrical, Porites attenuata, Porites rus, Pocillopora verrucosa, Seriatopora hystrix* were transplanted to record their development.

9. The studies on the *ex-situ* observation on corals are initiated *Lobophyllia hemprichii* and *Acropora muricata* to identify their spawning period.

10. The selected physico-chemical parameters of the seawater in the reef area of these four sites were monitored from August 2014 to July 2017. In 2014-2015, it is indicated that, the mean surface seawater temperature, salinity and turbidity ranged from 27.5 to 29.0°C, 32.46 to 34.72 ppt and 220 to 610 NTU respectively. During 2015-16, the mean surface seawater temperature, salinity and turbidity ranged from 27.7 to 30.4°C, 32.72 to 34.47 ppt and 185 to 720 NTU respectively. During the final year of the proposed project, the mean surface seawater temperature ranged from 28.2 to 29.3°C at all the study areas, salinity ranged from 32.56 to 34.34 ppt and pH ranged between 7.3 at Pongibalu to 7.6 in Jolly Buoy Island while the intertidal exposure was same during the study period of 3 years.

4. METHODOLOGY FOLLOWED

4.1. Physico-chemical parameters

The surface seawater samples were collected from all the stations of study for the estimation of following parameters.

4.1.1. Temperature:

Surface seawater temperature was measured using standard mercury thermometer.

4.1.2. Salinity:

The seawater salinity data was collected at all the places of study by using hand-held Refractometer, Model ERMA, Japan.

4.1.3. pH:

The seawater pH was measured soon after collection of water sample using Portable Water Quality Analyzer, Model SYSTRONICS Water Analyzer 371.

4.1.4. Transparency:

The transparency of seawater column was measured by using Secchi disc from surface of sea to assess the depth of light penetration.

4.1.5. Turbidity:

The seawater turbidity was measured by Turbidity Meter Model EUTECH Instruments ECTN100IR, Singapore.

4.1.6. Coordinates:

The data on the coordinates of the survey area were collected by using Global Positioning System, Model GARMIN 12 Channel GPS.

4.2. Assessment of corals

4.2.1. Assessment of coral reef cover, species distribution, diversity and status:

The coral reef diversity and status survey were carried out by Manta Tow Survey method (English *et al.,* 1994) in shallow reef areas and deeper parts were surveyed by SCUBA diving. The corals were videographed /photographed for species level identification and their distribution fixed by hand-held Global Positioning System.

4.2.2. Assessment of coral reef health:

The species-wise assessment of live corals has been done by randomly laying out 20m long Line Intercept Transects (LITs) covering various zones in shallow- upto 6 m, medium- 6-15m and deeper reef-16-30m (English *et al.,* 1994).

4.2.3. Species diversity:

The species diversity of phytoplankton and zooplankton was calculated according to the Shanon-Weiner formula.

$$H' = \Sigma Pi \ln Pi$$

Where Pi = proportion of the ith species in the collection and H'= Diversity of a theoretically infinite population.

4.3. Growth pattern by asexual reproduction

The experimental study was designed to carry out in natural habitat of Acroporidae and Faungiidae corals to document their growth pattern at Pongibalu and North Bay, South Andaman at 10 m depth. *Fungia paumotensis* Stuchbury, 1833 and *Fungia repanda* Dana, 1846, the two species under the same genus of Fungiidae family and *Acropora muricata* (Linnaeus, 1758) under Acroporidae family were selected for the study. Fungiidae corals were examined in Pongibalu only while Acroporidae corals were examined in both the areas. Corals from other families such as Faviidae, Siderastreidae, Mussidae, Agariciidae, Poritidae and Pectinidae were selected randomly for the observation of growth pattern among the recorded 19 families of scleractinian corals of Andaman and Nicobar Islands. Underwater growth study and regular monitoring was made by SCUBA diving. Underwater morphological measurements of on growth were made with the help of verniar calipers (Aerospace, 074 15376) and centimeter scale. Growth data were collected in each 3 months interval for Fungiidae corals where monthly data were procured for Acroporidae corals (Chadwick-Furman *et al.*, 2000) from August 2014 to July 2016. The studies were carried for the three years i.e. August 2014 to July 2017 for Acropoid corals. Data were collected on the length of fungiids along their mouth axis and width which is perpendicular to the mouth axis while length of axial corallites was measured for the acroporid corals (Abe, 1940; Bablet, 1985). All the experimental specimens were kept in a net made enclosures area of reef slope to restrict their movement to control missing data for fungiid corals. The ring structure at the ventral side of the fungiid corals was studied to document the annual growth (Abe, 1940; Chadwick-Furman *et al.*, 2000). Length frequency method will be applied to demonstrate the multimodal length distribution of a population of different age groups (Peterson, 1891). The growth rate of the fungiidae corals will also be determined by Von Bertalanffy's growth curve and Ford-Walford method on completion of study using computerized non-linear regression method using SPSS software (Von Bertalanffy, 1938). Confirmation of species identification was made depending on the photographs in conjunction with Veron and Pichon (1979), Veron and Wallace (1984), Hoeksema (1989), Veron (2000) and Venkataraman *et al.* (2003).

4.4. Experimental regeneration of corals

The field experimental study was made at Pongibalu Jetty in South Andaman. The study was conducted *in situ* condition at the depth of 4 m. Eleven species of mushroom corals such as *Fungia paumotensis* Stuchbury, 1833, *Fungia fungites* (Linnaeus, 1758), *Fungia repanda* Dana, 1846, *Fungia klunzingeri* Doderlein, 1901, *Fungia corona* Doderlein, 1901, *Fungia scruposa* Klunzinger, 1879, *Ctenactis crassa* (Dana, 1846),

Polyphyllia talpina (Lamarck, 1801), *Herpolitha weberi* (Houttuyn, 1772), *Herpolitha limax* Horst, 1921 and *Cycloseris costulata* (Ortmann, 1889) under five genera were selected to make the experiments on them. All the above said live samples were collected from the study area by employing SCUBA diving and kept primarily in a net bag in the experimental site. Corals were excised by circular rock saw (BOSCH, GDC 34m, F 002 G30 110, 000017314) with the presence of continuous flow of seawater. The studies were made in conjunction with Glynn method (Glynn *et al.*, 1994). The steady water flow will prevent the excessive generation of heat during the excision as well as it will avoid tissue drying. The excision was made in various patterns such as-half cut through the mouth in vertical and horizontal plane, two terminal parts for elongated coralla, only terminal part of coralla, cone shaped part from mouth to perimeter, peripheral part only etc. All the fragmented specimens were tagged with individual identity number to make proper study on them and kept in the experimental plot for *in situ* observation by SCUBA diving. All the experimental specimens were kept in natural habitat within hollow, cylindrical enclosure with a diameter of 1m. Observation and monitoring was made on regular interval for a total of 12 months from August 2014 to July 2015 to record the regeneration pattern of fungiid corals. Photographs were taken by a digital camera (Sony Cyber Shot, DSC-T900, 12.1 megapixels, marine pack). Morphometric measurements of regenerated parts were made with the help of verniar calipers (Aerospace, 074 15376) and centimeter scale. Confirmation of species identification was completed depending on the photographs in conjunction with Veron and Pichon (1979), Hoeksema (1989), Veron (2000) and Venkataraman *et al.* (2003).

4.5. Substrate specificity for the settlement of coral's Planula larvae

Four areas viz. Pongibalu, North Bay, Rifleman Island and Jolly Buoy Island were selected initially to study the settlement pattern of scleractinian corals (Table 2). The settlement plate (20 cm × 20 cm) for the scleractinian corals was prepared in laboratory with 10% coral rubble (Lee *et al.*, 2009). Coral rubble was used, without removing the calcareous coralline algae (CCA) and other small attached organisms (such as attached bivalves). The coral rubble was sun dried for several days and then crushed into powder, using a hammer. The coral rubble was mixed with cement, river sand and freshwater and was poured into (20 cm × 20 cm) frame. The substrata were then dried in full sunlight for several days. Six types of artificial settlement substrata will be used to examine coral-larval settlement preferences: (a) acrylic plates, (b) PVC plates, (c) glass plates, (d) ceramic tiles, (e) cement tiles, and (f) cement tiles containing 10% of coral rubble (10% CR).

Table 2: Experimental plots for coral settlement studies

Plot-1	Plot-2	Plot-3	Plot-4
Place: Pongibalu Jetty	Place: Rifleman Island	Place: Jolly Buoy Island	Place: North Bay Wreck
Lat. 11°30.958'N	Lat. 11°30.837'N	Lat. 11°30.119'N	Lat. 11°43.006'N
Long. 92°39.201'E	Long. 92°38.767'E	Long. 92°37.112'E	Long. 92°45.465'E
Depth: 10m	Depth: 2m	Depth: 5m	Depth: 7m
No. of Plates: 3	No. of Plates: 3	No. of Plates: 3	No. of Plates: 3

Observation and monitoring were made on regular interval for a total of 12 months from August 2014 to July 2015 to record the new recruitment of scleractinian

corals on the experimental plates as well as natural reef habitat of the said places. Photographs were taken by a digital camera (Sony Cyber Shot, DSC-T900, 12.1 megapixels, marine pack). Morphometric measurements of regenerated parts were made with the help of verniar calipers (Aerospace, 074 15376) and centimeter scale. Confirmation of species identification was made depending on the photographs in conjunction with Cairns (1991, 1994, 1997, 1999, 2001), Veron and Pichon (1976, 1979, 1982), Veron *et al.* (1977) Veron and Wallace (1984), Veron (2000), Wallace (1999) and Venkataraman *et al.* (2003). Undersea sedimentation traps were placed at Pongibalu and North Bay area to record the rate of sedimentation. Monthly observations were made by collecting the samples from the experimental plots.

4.6. Experimental transplantation of corals

Scleractinian corals are most fragile biological creatures of marine ecosystem and used to face threats in natural and anthropogenic ways. It is most required to combat with the threat by means of transplantation of corals to save them from destruction. Physico-chemical parameters such as suitable temperatures, turbidity, water quality, depth, and others paly the prime role for the maintenance of reef ecosystem. To have a successful coral transplantation, conditions must be appropriate for the corals to experience minimal amounts of stress during and after transplantation. Timing of the transplantation is also critical. Coral fragments broken off by storms or other means can be transplanted to labs or nurseries for further growth. Planulae can also be cultured in labs and taken to nurseries for growth. After they are suitable to thrive in the wild, the coral is then planted at the transplant site. An alternative method involves taking either these fragments or whole coral colonies, and transplanting them directly to a transplant site. The attachment methods can be managed by three methods such as Cement: This involves cementing the coral to a cement base then is then placed on the ground of the transplant site. It can be attached to the ground by cable ties. Steel ties: This method involves attaching cable ties to the coral and then driving the other end into the ground to hold them in place. Natural reef areas: This method involves just replacing the corals or fragments of corals into the substratum bed or ground and this method was adopted for the present study. Fragments of eight species viz., *Acropora muricata, Acropora austera, Pocillopora damicornis, Seriatopora hystrix, Hydnophora rigida, Cyphastrea microphthalma, Porites annae* and *Porites rus* were transplanted in the Pongibalu reef on July 2015. Again, 25 colonies of scleractinian corals under eight species viz., *Acropora muricata, Acropora robusta, Acropora latistella, Pocillopora verrucosa, Seriatopora hystrix, Porites attenuata,* and *Porites rus* were transplaned in a quadrate frame for their development during May 2016.

5. ACHIEVEMENTS & DEFICIENCIES

All the five objectives were targeted during the study under this project. The results on the objectives are satisfactory and provided adequate new information about the reproductive biology of scleractinian corals of Andaman and Nicobar Islands.

5.1. Survey

A total of sixty eight surveys were conducted during August 2014 to July 2017 at four selected sites (Fig. 1) of South Andaman to acquire the quantitative and qualitative data on diversity, density, distribution of scleractinian corals and to conduct the *in-situ* experimental studies. The undersea surveys were carried out by employing Self–Contained Underwater Breathing Apparatus (SCUBA) diving and snorkeling or skin diving (Plate 2). Twenty four surveys were exclusively carried out at night employing SCUBA diving to observe the behavioural pattern of scleractinian corals (Plates 3 & 4). Preliminary surveys were conducted in these study area resulted with the recording of 346 species of scleractinian corals from Pongibalu, Rifleman Island, Jolly Buoy Island and North Bay. Of which 128 species encountered from North Bay while altogether 330 species recorded from rest of the three islands (Table 1 & Plates 1 & 4).

5.2.Studies on growth and regeneration pattern by asexual reproduction

In-situ growth study:

The growth pattern of the scleractinian corals was monitored. Thirty live specimens of *Fungia paumotensis* and *Fungia repanda* were maintained at Pongibalu at the depth of 10m to get quantitative data of their growth rate (Table 3). There was no report of mortality of the experimental animals during the study period. The data of growth rates were analyzed at 3 months interval for the period of 2 year.

***Fungia paumotensis* Stutchbury, 1833** (Fig. 4)

The quarterly mean growth rate of *Fungia paumotensis* was 0.342 ± 0.025 cm. The width of the corals varied linearly with the length of the corals (Fig. 5). The morphology of the 30 coral polyps were elongated or slightly oblong in shape which can be justified with the ratio of width and length (0.705 ± 0.167). The relationship of width and length in morphological character i.e. width and length ratio of the polyps were constant (Fig. 6). The constancy of the ratio indicates the regularity of their structure plane without any changes in future of their life span. This is the isometric growth pattern of life. The size of the corals increased with the time. It depends on the initial stage. The growth rate of this species decreased linearly with the increased coral size (Fig. 7).

Plate 2: Day survey by SCUBA diving

LIT studies

LIT studies

LIT studies

Undersea digitization

Undersea data documentation

Undersea data documentation

Plate 3: Night surveys by SCUBA diving

Plate 4: Scleratinian corals with extended polyps during night time

Acropora plantaginea (Lamarck, 1816)

Lobophyllia hemprichii (Ehrenberg, 1834)

Symphyllia radians MED&H, 1849

Platygyra ryukyuensis Yabe and Sugiyama, 1936

Fungia fungites (Linnaeus, 1758)

Goniastrea pectinata (Ehrenberg, 1834)

Plate 4: Contd.

Fungia scutaria Lamarck, 1801

Porites cylindrical Dana, 1846

Diploastrea heliopora (Lamarck, 1816)

Ctenactis echinata (Pallas, 1766)

Rhizopsammia verrill van der Horst, 1922

Tubastrea micrantha Ehrenberg, 1834

Fig. 4: *Fungia paumotensis* Stutchbury, 1833

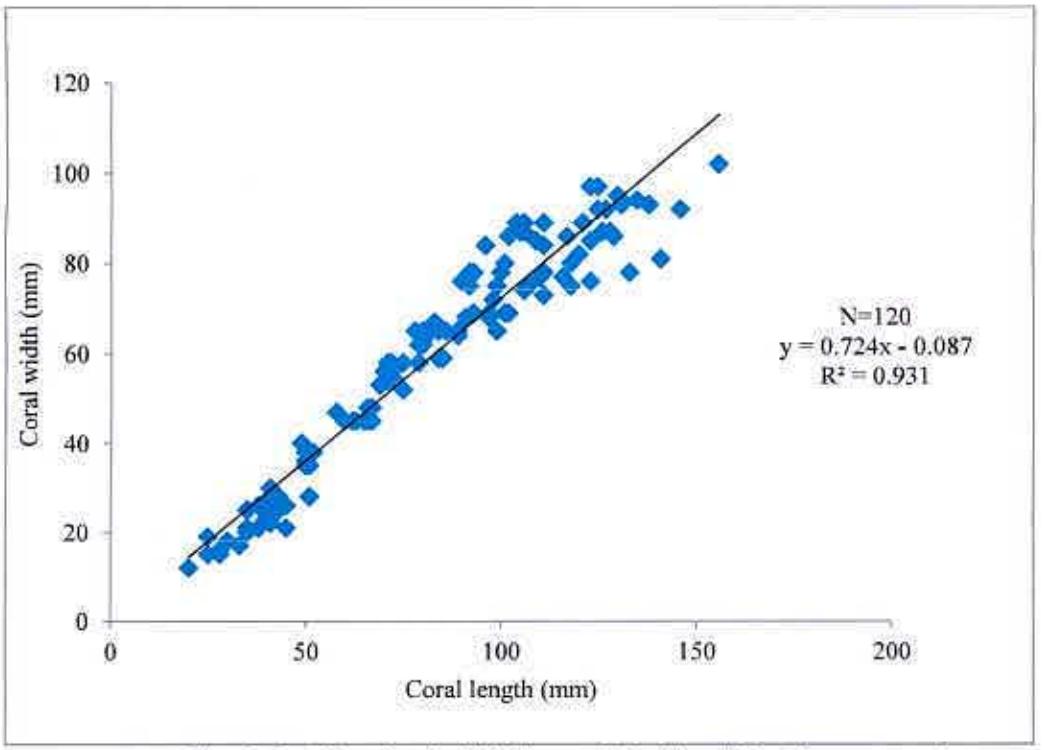


Fig. 5: Coral length and width linear relationship of *Fungia paumotensis*

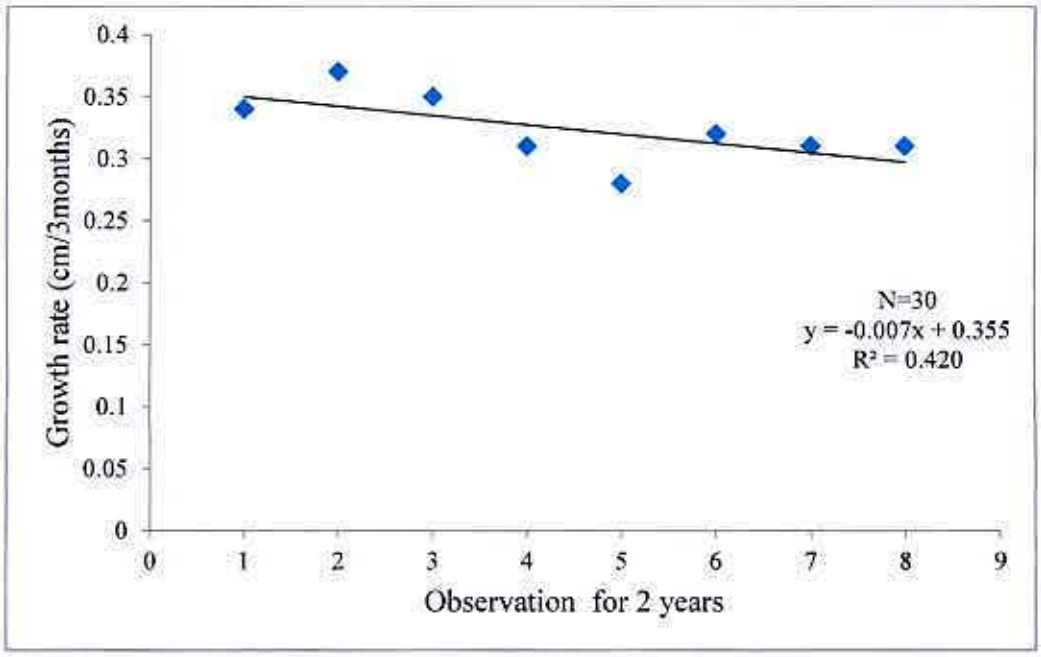


Fig. 6: Graph showing polyp width: length ratio of *Fungia paumotensis*

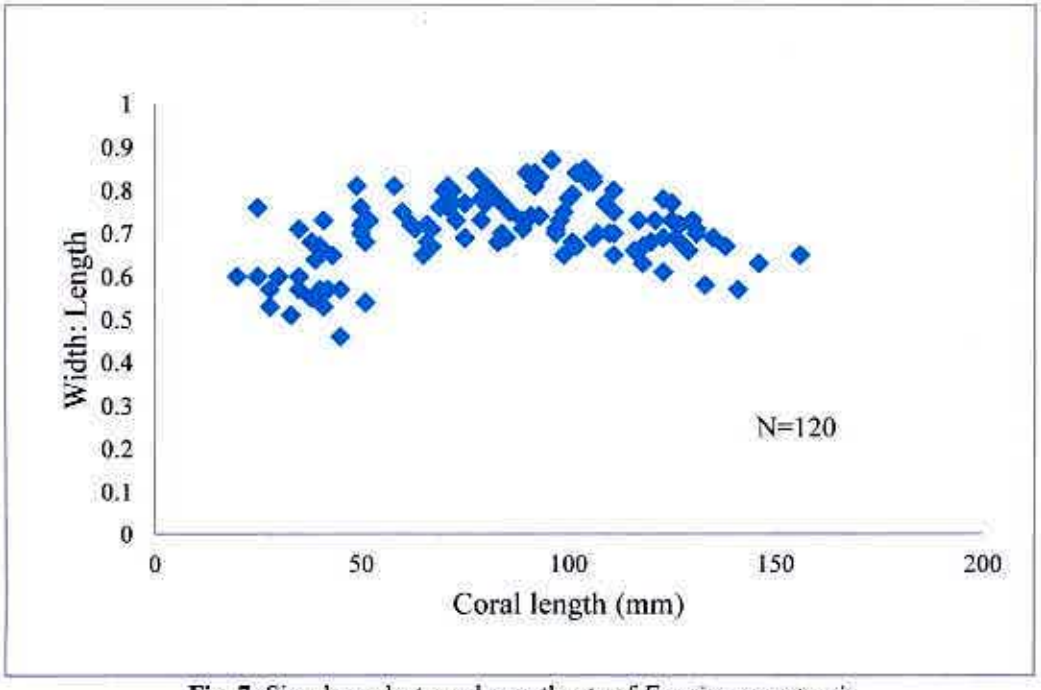


Fig. 7: Size dependent coral growth rate of *Fungia paumotensis*

***Fungia repanda* Dana, 1846** (Fig. 8)

The quarterly mean growth rate of *Fungia repanda* was 0.203 ± 0.038 cm. The polyps of this species are circular shaped mostly. Depending on the shape of this species only diameter was documented to observe and analyze the growth pattern. It was observed that the mass of this species increased exponentially with the diameter (Fig. 9). As two species were considered to carry out experiments, diameter was described as length to make comparative analysis during inter-species relationship. The coral showed a same morphological structure i.e. circular shaped during the entire lifespan. The size of the

corals increased depending on the age. The growth rate of this species decreased linearly with the increased coral size (Fig. 10).

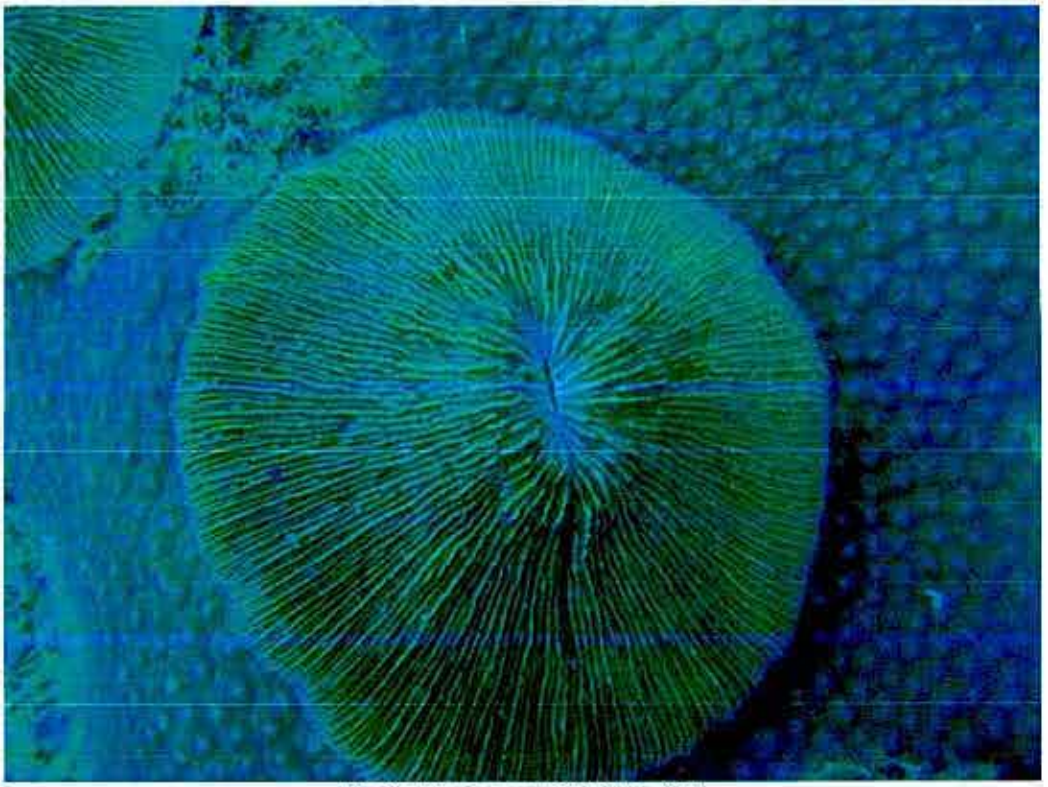


Fig. 8: *Fungia repanda* Dana, 1846

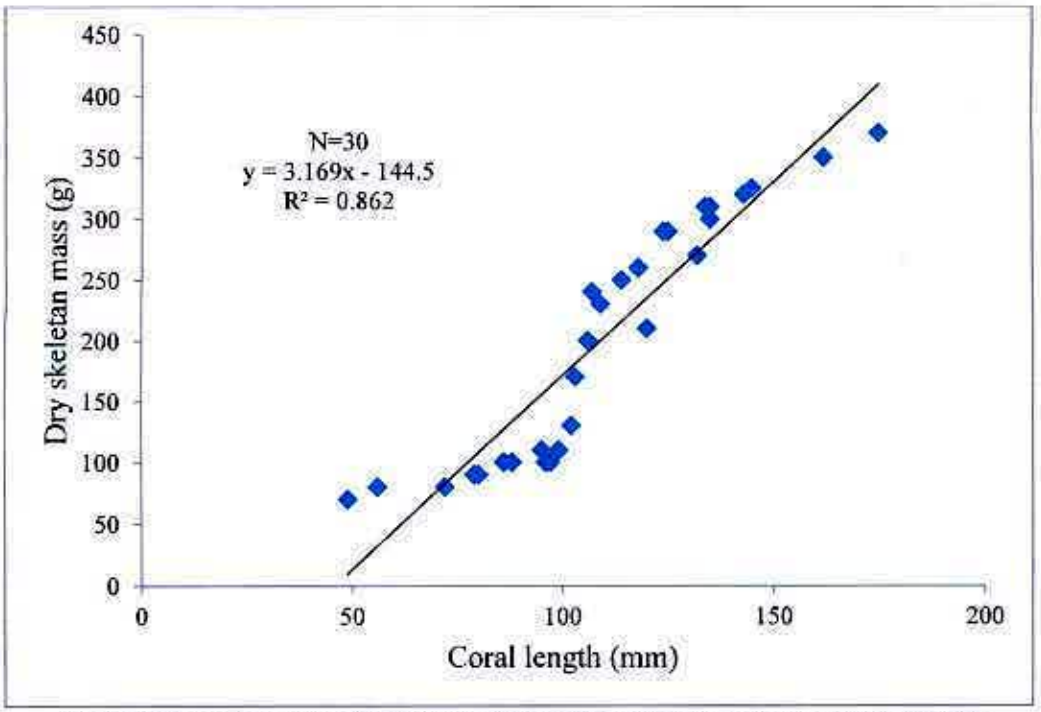


Fig. 9: Exponential relationship of coral length and dry skeletal mass of *Fungia repanda*

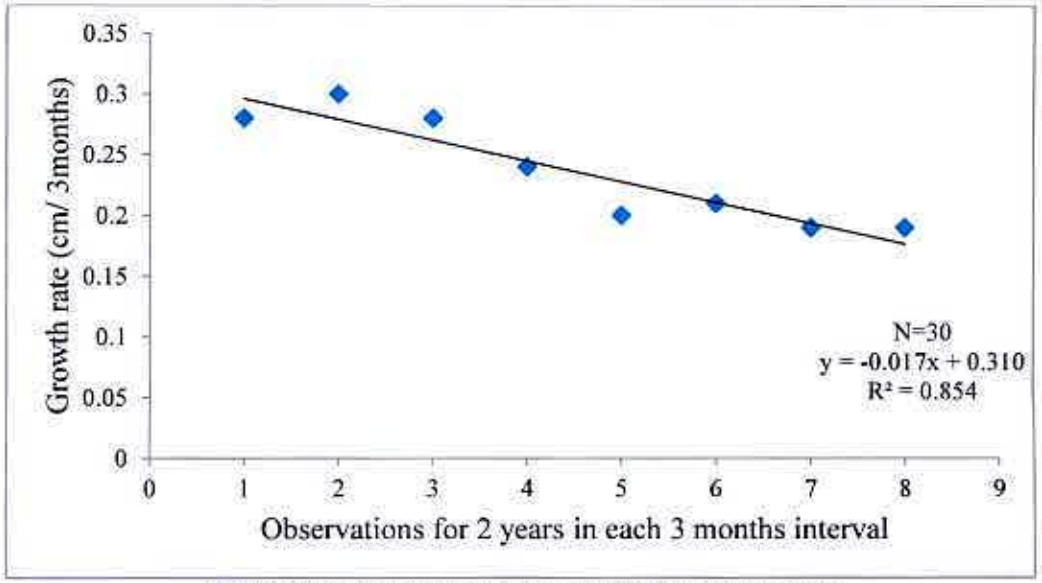


Fig. 10: Size dependent coral growth rate of *Fungia repanda*

Table 3: Experimental study on the growth rate of faviid corals for the period of two years

Sl. No.	*Fungia paumotensis*	Initial Length (cm)	Final Length after 2 years (cm)	*Fungia repanda*	Initial Length (cm)	Final Length after 2 years (cm)
1	Exp/Gr/pau/S1	9.01	11.39	Exp/Gr/rp/S1	9.45	11.35
2	Exp/Gr/pau/S2	7.64	9.86	Exp/Gr/rp/S2	8	10.48
3	Exp/Gr/pau/S3	7.53	10.71	Exp/Gr/rp/S3	8.84	10.46
4	Exp/Gr/pau/S4	7.98	10.56	Exp/Gr/rp/S4	8.01	9.55
5	Exp/Gr/pau/S5	10.71	13.49	Exp/Gr/rp/S5	8.73	10.41
6	Exp/Gr/pau/S6	10.52	13.44	Exp/Gr/rp/S6	8.91	10.03
7	Exp/Gr/pau/S7	11.95	14.03	Exp/Gr/rp/S7	7.72	9.64
8	Exp/Gr/pau/S8	9.91	12.45	Exp/Gr/rp/S8	7.65	9.55
9	Exp/Gr/pau/S9	9.17	11.93	Exp/Gr/rp/S9	6.03	7.93
10	Exp/Gr/pau/S10	8.55	11.19	Exp/Gr/rp/S10	8.29	10.11
11	Exp/Gr/pau/S11	7.02	9.82	Exp/Gr/rp/S11	10.1	9.5
12	Exp/Gr/pau/S12	10.26	12.94	Exp/Gr/rp/S12	10.24	11.96
13	Exp/Gr/pau/S13	9.07	11.93	Exp/Gr/rp/S13	11.72	13.28
14	Exp/Gr/pau/S14	9.08	11.76	Exp/Gr/rp/S14	12.2	14.4
15	Exp/Gr/pau/S15	8.52	10.84	Exp/Gr/rp/S15	11.65	13.35
16	Exp/Gr/pau/S16	11.56	12.86	Exp/Gr/rp/S16	10.64	12.26
17	Exp/Gr/pau/S17	11.23	14.17	Exp/Gr/rp/S17	11.54	12.94
18	Exp/Gr/pau/S18	13.05	15.95	Exp/Gr/rp/S18	6.82	8.58
19	Exp/Gr/pau/S19	10.14	13.06	Exp/Gr/rp/S19	3.71	5.41
20	Exp/Gr/pau/S20	9.53	12.77	Exp/Gr/rp/S20	3.05	5.15
21	Exp/Gr/pau/S21	9.55	12.85	Exp/Gr/rp/S21	6.01	7.79
22	Exp/Gr/pau/S22	8.05	11.15	Exp/Gr/rp/S22	9.69	10.99
23	Exp/Gr/pau/S23	7.22	9.78	Exp/Gr/rp/S23	11.32	14.12
24	Exp/Gr/pau/S24	9.93	12.77	Exp/Gr/rp/S24	12.61	13.69

25	Exp/Gr/pau/S25	9.41	12.37	Exp/Gr/rp/S25	14.35	15.89
26	Exp/Gr/pau/S26	10.51	13.59	Exp/Gr/rp/S26	15.66	16.98
27	Exp/Gr/pau/S27	9.73	12.73	Exp/Gr/rp/S27	10.65	12.05
28	Exp/Gr/pau/S28	10.33	13.11	Exp/Gr/rp/S28	7.61	8.81
29	Exp/Gr/pau/S29	8.42	11.24	Exp/Gr/rp/S29	6.78	8.18
30	Exp/Gr/pau/S30	8.11	11.19	Exp/Gr/rp/S30	5.3	7.38

***Acropora muricata* (Linnaeus, 1758)** (Plate 5 & 6)

Studies of growth rate of acroporid coral was made on *Acropora muricata* at Pongibalu and North Bay. The initial length of the axial corallite was 27 cm at Pongibalu while 7.4 cm at North Bay. Monthly growth rate was 2.41 ± 0.59 at Pongibalu while 1.79 ± 0.41 at North Bay area. The monthly growth rate of *Acropora muricata* at Pongibalu and North Bay for 3 years is depicted in Figs. 11 and 12.

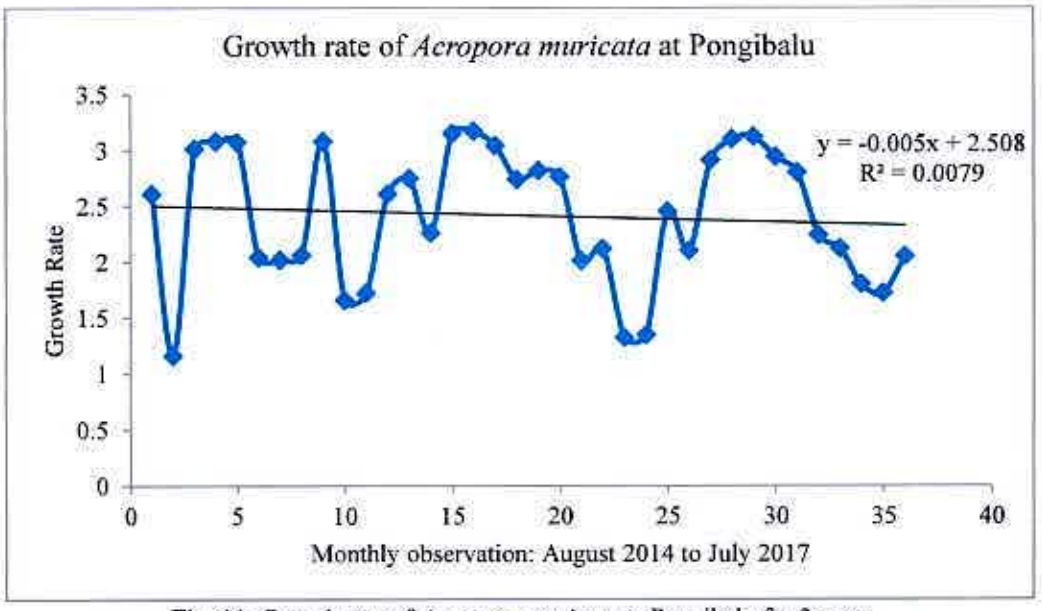


Fig. 11: Growth rate of *Acropora muricata* at Pongibalu for 3 years

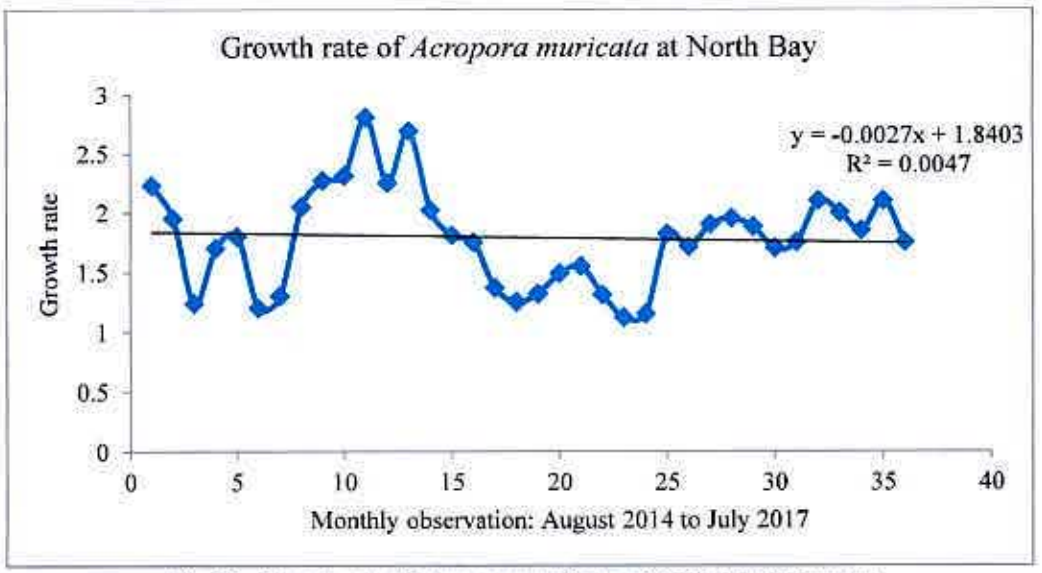


Fig. 12: Growth rate of *Acropora muricata* at North Bay for 3 years

Plate 5: *In-situ* study on the growth of *Acropora muricata* at North Bay

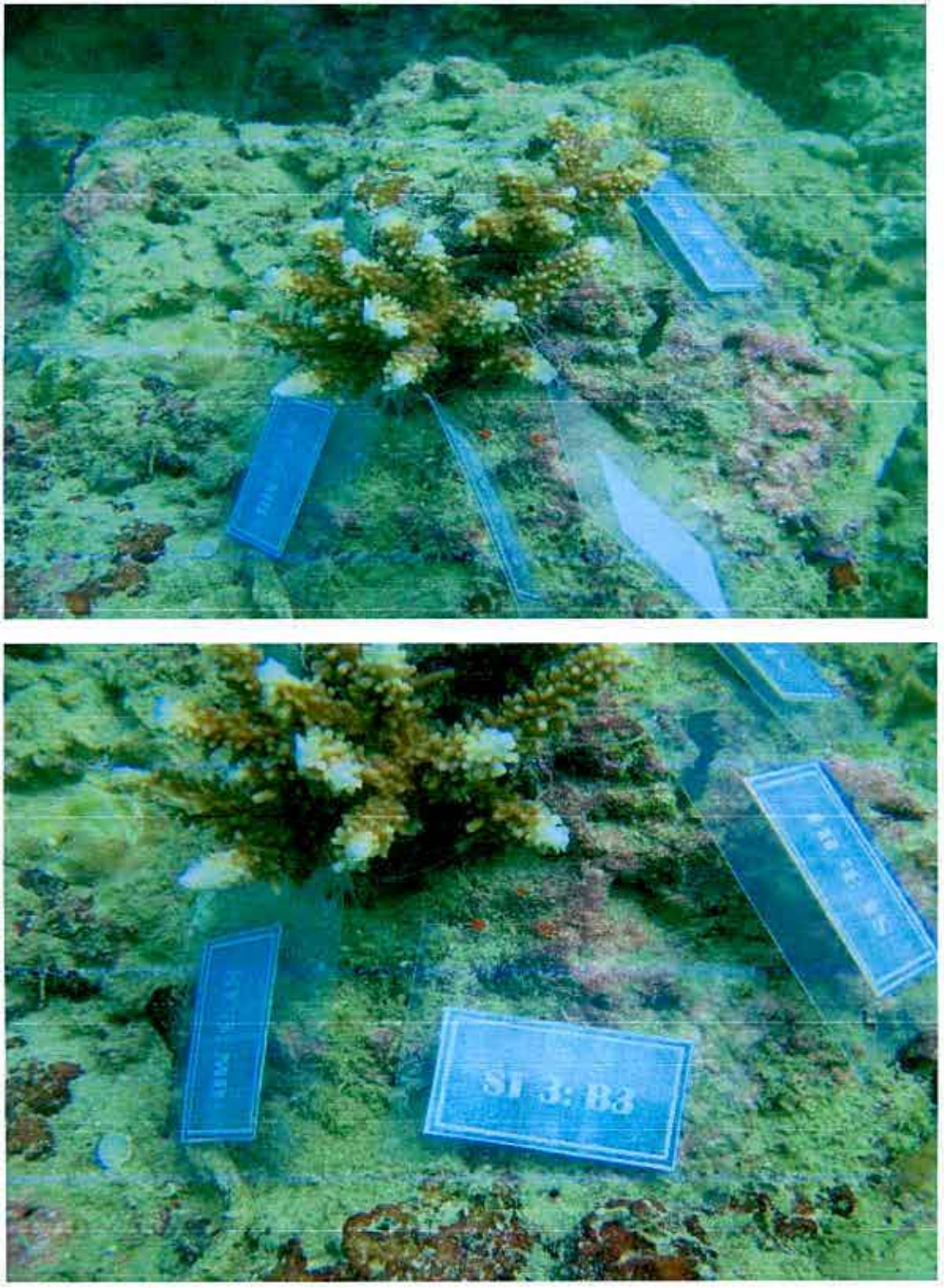


Plate 6: *In-situ* study on the growth of *Acropora muricata* at Pongibalu

Experimental regeneration:

Eleven species of corals were studied for an experimental regeneration in their natural habitat. Solitary free livings as well as colonial fungiids were considered for conducting this experiment (Table 4). Coralla were excised carefully in various manners to observe the regeneration pattern of them. Excision was made from single to multiple as described in the Table 4. The excision was done mainly in two patterns. One was made along the radiating septa of the fungiids and the other was made in perpendicular to the septa. The skeleton of the fungiids healed within a period of 10-20 days from the day of excision. As the individuals were kept in the natural habitat, exposed cut portion of the corals were partially covered with several fouling organisms like algae, tunicates, sponges etc. The aggregation of the fouling organism was notified within the first 30days and persisted for a long time on many of the specimens. All the excised corals, used for experimental studies were survived throughout the study period of 24 months. The process of development can be described according the following categorizes.

Incision through mouth and axial furrow:

The septa of excised portion began to regenerate with in a period of 2 months if that portion has mouth and the other specimens started to regenerate mouth and axial furrow with that time. The mouth can be seen as the terminal part due to vertical and horizontal excision. The terminal portion of mouth started to develop septa for the completion of existing mouth as well as to form multiple mouth or extra mouth within the period of 4 months.

Incision of terminal part with whole mouth:

The portion which had whole mouth did not form any extra mouth during the regenerative developmental process.

Incised portion without mouth:

The incised portion of corals without mouth started to form multiple mouth or extra mouth to make that one as complete one within the period of 4 months.

Formation of anthoblast:

In some corals, it was seen that anthoblast was formed near the mouth portion and got detached from an anthocaulus.

The development of axial furrow and corallites showed a well developmental stage for the colonial fungiids. The septa and the mouth showed a smooth development of their structural organization with the period of 180 days. The mouth showed its development as a complete mouth with the period of one year and complete new corallites (in case of colonial fungiids). Observation was made for next two months to look after their regeneration pattern after the complete development of mouth and axial furrow and corallites.

Deviations in regeneration pattern are observed among the specimens and were examined morphometrically to make comparative account among the species studied.

The process of regeneration was seen in the form of development of skeletal part of the scleractinians. The structure, shape, size are the features to control the regeneration pattern. Small portion of coral showed a higher degree of regeneration than the larger portion. Regeneration pattern of 11 species of corals were quantified in unit length development to compare inter species. It was seen that the colonial species *Polyphyllia talpina* showed highest (0.33cm) development in unit length whereas the *Fungia scruposa* and *Herpolitha webei* showed the lowest (0.03cm) for the first year i.e., August 2014 to July 2015 while the highest (0.78) regeneration of unit length was seen in *Polyphyllia talpina* and lowest (0.08) was recorded in only *Herpolitha webei* during second year i.e., August 2015 to July 2016. All the species under the genus *Fungia* showed a less variable range of regeneration pattern. The values are very close to each other. The additions of skeletal part as the form of regeneration were clearly documented while the lighter colour tissue and the septal part were seen as non-parallel to the polyp. Intra species development of regeneration was also observed in the 3 species out of 11 depending upon the cut direction. With the extent of observation, it was seen that portion of coralla without mouth of *Fungia paumotensis* showed higher degree of regeneration in skeleton length whereas the minimum was seen in the part of coralla where only one terminal part was cut (without damaging the mouth). In *Fungia fungites* and *Fungia repanda* maximum regeneration was seen in the portion of corals where cut was made through the mouth (1/2 mouth) first year i.e., August 2014 to July 2015, while *Fungia paumotensis* showed highest regeneration (0.71) of in this category during August 2015 to July 2016. Presence and absence of mouth play a crucial role for the regrowth of fungiids. The usual higher level of development was observed among those which had mouth by any means. New growth of septa in fan shaped structure was formed from the mouth region. Development in skeleton could be found from the inner septal edges as well as outer septal edges. The inner spetal edges form mouth parts whereas outer septal edges form polyp margins (Plates 7-12). The comparative analysis of regeneration details during a period of 2 years are given in fig. 13.

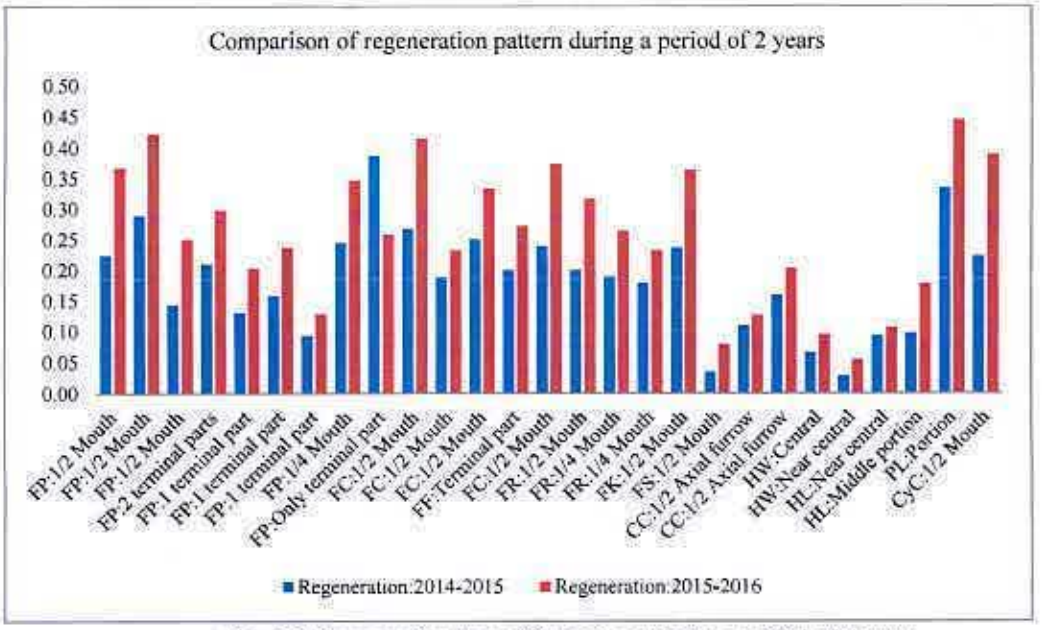
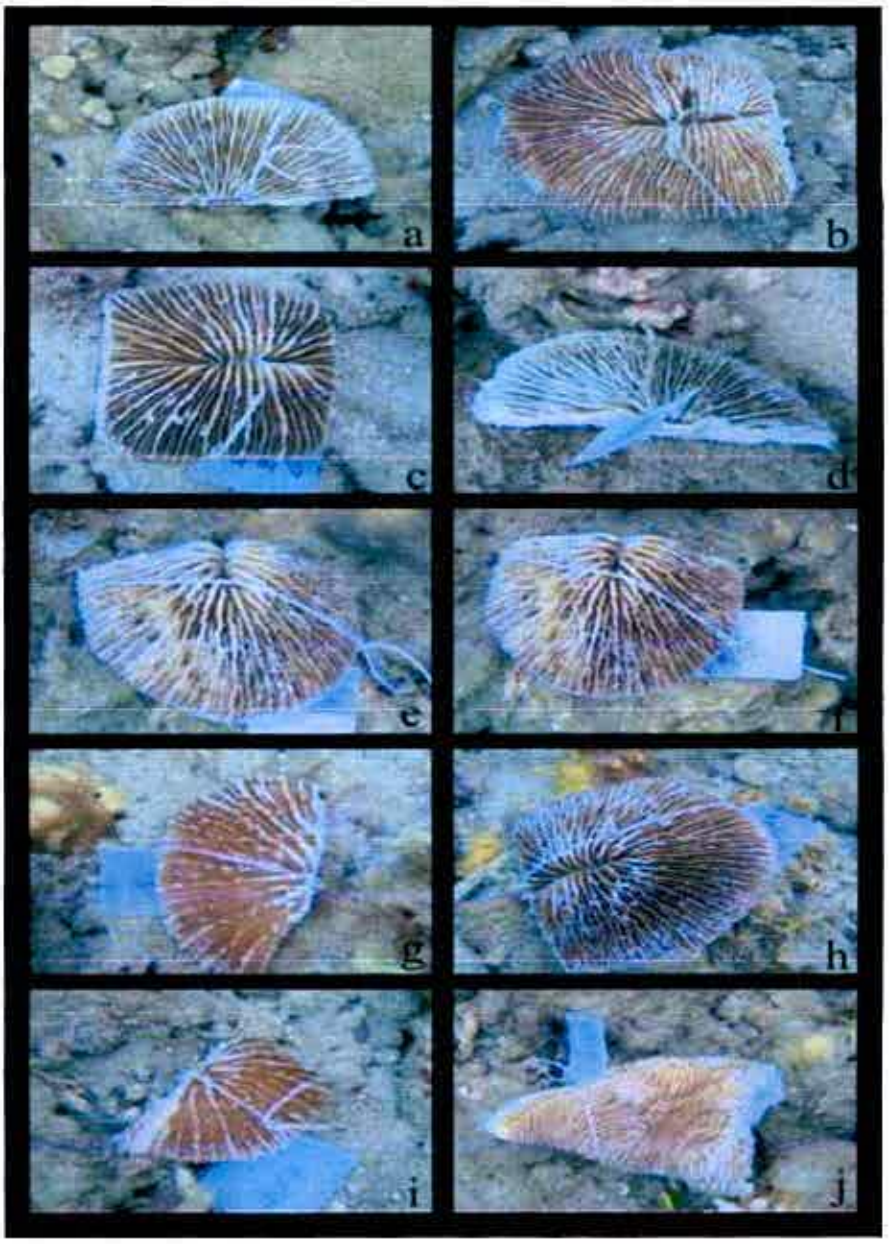


Fig. 13: Regeneration rate of fungoid corals for a period of 2 years

Table 4: Experimental regeneration of fungiids for the period of two years

Sl. No.	Species	Excised Position	Mouth/ Axial furrow Position in Coralla	Length during (cm) excision	Length after Regeneration (cm)	Regenerated Length (cm)	Mouth/ Axial furrow Status	Extra New Mouth formation
1.	*Fungia paumotensis*	1/2 Mouth	Terminal	4.9	7.8	2.9	Mouth completed	
		1/2 Mouth	Terminal	4.5	7.7	3.2	Mouth completed	
		1/2 Mouth	Terminal	5.6	7.8	2.2	Mouth completed	4
		2 terminal parts	Central	5.7	8.6	2.9	No changes	
		1 terminal part	Beside terminal	6.9	9.2	2.3	No changes	
		1 terminal part	Beside terminal	7.6	10.6	3	No changes	
		1 terminal part	Beside terminal	8.6	10.5	1.9	New mouth	5
		1/4 Mouth	Terminal	4.9	7.8	2.9	Mouth completed	1
		Only terminal part	No mouth	3.1	5.1	2	New mouth	
2.	*Fungia corona*	1/2 Mouth	Mouth terminal	4.1	6.9	2.8	Mouth completed	
		1/2 Mouth	Mouth terminal	6.9	9.8	2.9	Mouth completed	
		1/2 Mouth	Mouth terminal	3.6	5.7	2.1	Mouth completed	
3.	*Fungia fungites*	Terminal part	No mouth	7	10.3	3.3	New mouth	4
		1/2 Mouth	Mouth terminal	6.7	10.8	4.1	Mouth completed	
4.	*Fungia repanda*	1/2 Mouth	Mouth terminal	6	9.1	3.1	Mouth completed	
		1/4 Mouth	Mouth terminal	5.3	7.7	2.4	Mouth completed	
		1/4 Mouth	Mouth terminal	5.6	7.9	2.3	Mouth completed	
5.	*Fungia klunzingeri*	1/2 Mouth	Mouth terminal	5.5	8.8	3.3	Mouth completed	
6.	*Fungia scruposa*	1/2 Mouth	Mouth terminal	8.9	9.9	1	Incomplete	1
7.	*Ctenactis crassa*	1/2 Axial furrow	Axial furrow terminal	11.9	14.7	2.8	Axial furrow not extended	
		1/2 Axial furrow	Axial furrow terminal	6.9	9.4	2.5	Axial furrow not extended	
8.	*Herpolitha weberi*	Central	Terminal and Elongate	10.6	12.3	1.7	Incomplete	
9.	*Herpolitha limax*	Near central	Terminal and Elongate	22	23.8	1.8		
		Near central	Terminal and Elongate	14.1	16.9	2.8		
		Middle portion	Terminal and Elongate	6.2	7.9	1.7		
10.	*Polyphyllia talpina*	Portion	Axial furrow throughout the	3.6	6.4	2.8	Axial furrow extended	
11.	*Cycloseris costulata*	1/2 Mouth	Mouth terminal	3.6	5.8	2.2	Mouth completed	

Plate 7: Experimental excision of fungiids

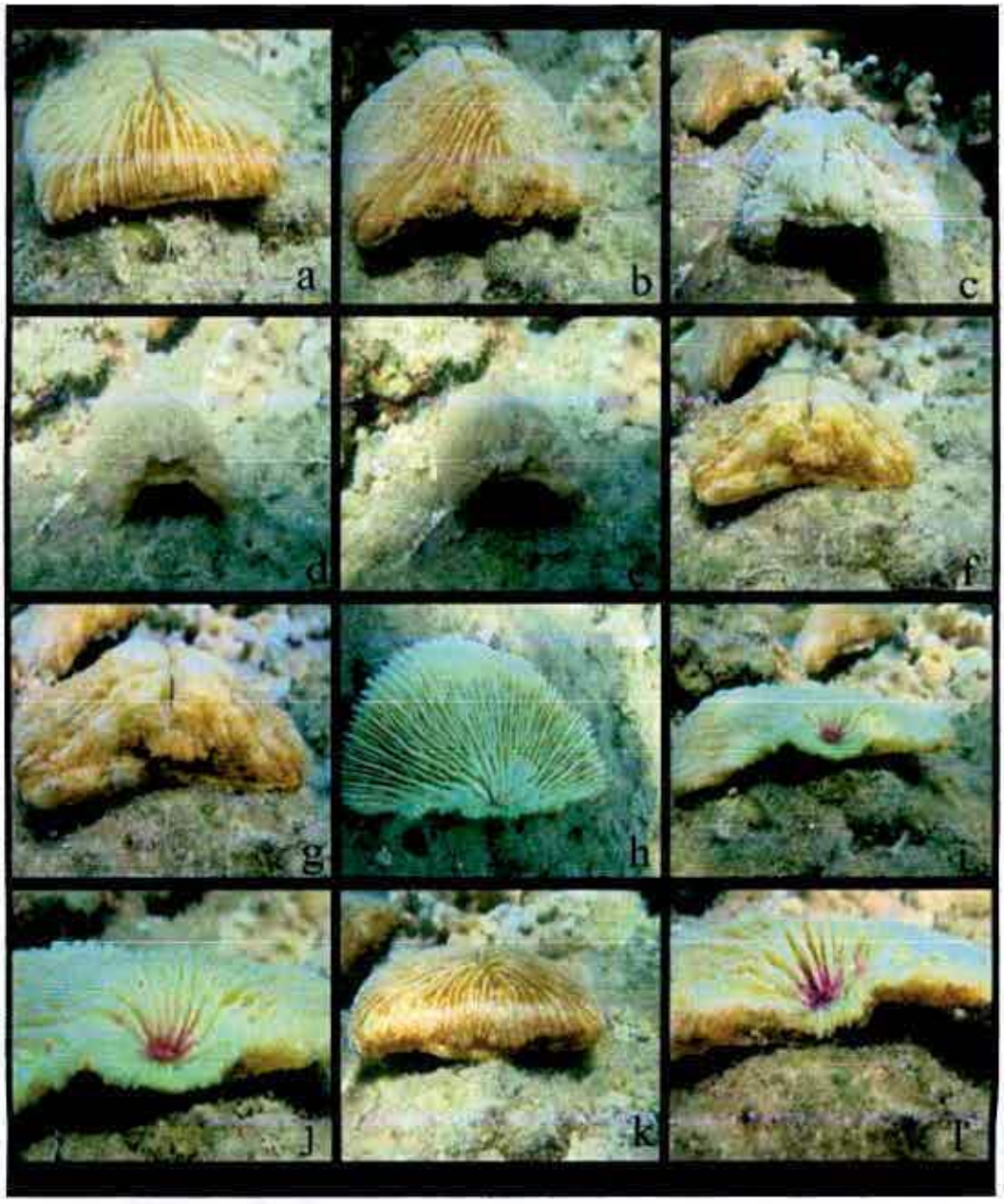


a-Fungia repanda (Excised through half of the polyp); b- *Fungia paumotensis* (Excised one terminal portion); c- *Fungia paumotensis* (Excised two terminal portions); d- *Fungia repanda* (Excised through half of the polyp); e- *Fungia paumotensis*(Excised through half of the polyp); f- *Fungia paumotensis*(Excised through half of the polyp); g- *Fungia klunzingeri* (Excised through half of the polyp); h- *Fungia paumotensis* (Excised one terminal portion); i- *Fungia klunzingeri* (Excised through half of the polyp); j- *Herpolitha weberi* (Excised through the central portion).

Plate 8: Fouling and regeneration after 30 days

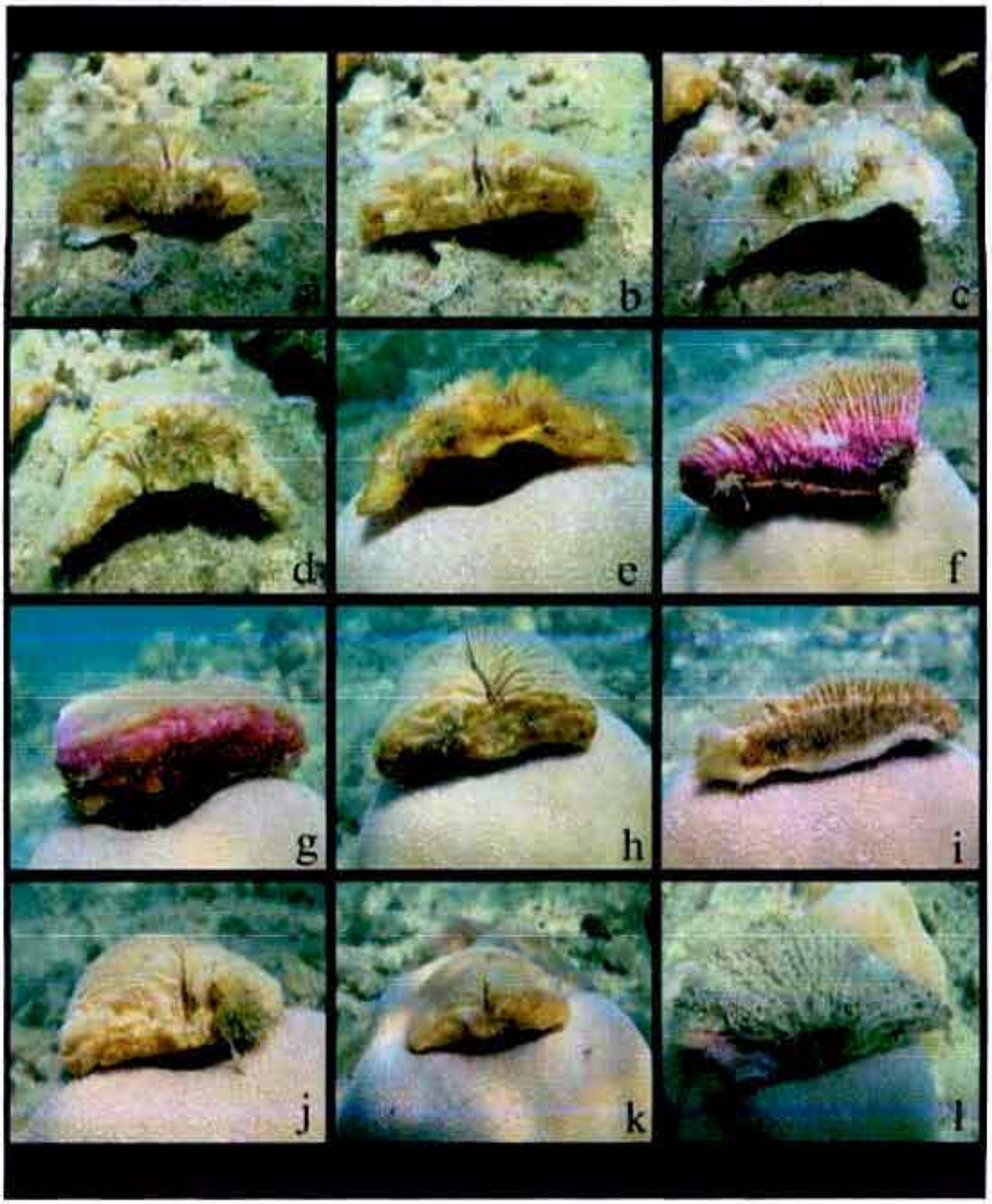
Fouling and regenerated portion of excised part of different mushroom corals *a- Fungia paumotensis*; b- *Fungia paumotensis*; c- *Herpolitha weberi*; d- *Fungia paumotensis*; e- *Fungia repanda*; f- *Fungia paumotensis*; g- *Fungia paumotensis*; h- *Fungia paumotensis*; i- *Polyphyllia talpina*; j- *Fungia fungites*; k- *Fungia fungites*; l- *Polyphyllia talpina*

Plate 9: Regeneration of fungiids after 60 days



Regeneration of excised part of different mushroom corals *a- Fungia paumotensis*; b- *Fungia paumotensis*; c- *Ctenactis crassa*; d- *Polyphyllia talpina*; e- *Polyphyllia talpina*; f- *Fungia paumotensis*; g- *Fungia paumotensis*; h- *Fungia repanda*; i- *Fungia repanda*; j- *Fungia repanda*; k- *Fungia paumotensis;* l- *Fungia repanda*

Plate 9: Contd.



Regeneration of excised part of different mushroom corals *a- Fungia paumotensis*; b- *Fungia paumotensis*; c- *Ctenactis crassa*; d- *Herpolitha weberi*; e- *Fungia klunzingeri*; f- *Fungia fungites*; g- *Fungia fungites*; h- *Fungia paumotensis*; i- *Fungia paumotensis*; j- *Fungia paumotensis*; k- *Fungia paumotensis*; l- *Fungia repanda*

Plate 10: Regeneration of fungiids after 180 days

Development of excised mouth structure and of septal portion of different mushroom corals *a- Fungia repanda*; b- *Fungia paumotensis*; c- *Ctenactis crassa*; d- *Fungia repanda*; e- *Fungia fungites*; f- *Fungia fungites*; g- *Fungia paumotensis*; h- *Fungia paumotensis*; i- *Fungia corona*; j- *Fungia klunzingeri*; k- *Fungia paumotensis*; l- *Ctenactis crassa*

Plate 11: Regeneration of fungiids after 360 days

Development of excised mouth, extra mouth structure and of septal portion of different mushroom corals *a- Fungia paumotensis*; b- *Fungia paumotensis*; c- *Fungia paumotensis*; d- *Ctenactis crassa*; e- *Fungia fungites*; f- *Fungia fungites*; g- *Ctenactis crassa*; h- *Fungia paumotensis*; i- *Polyphyllia talpina*; j- *Herpoltha weberi*

Plate 12: Regeneration of fungiids after 720 days

Complete development of excised mouth, extra mouth structure and of septal portion of different mushroom corals *a- Fungia paumotensis*; b- *Fungia paumotensis*; c- *Fungia paumotensis*; d- *Ctenactis crassa*; e- *Fungia fungites*; f- *Fungia fungites*; g- *Polyphyllia talpina*; h- *Fungia paumotensis*; i- *Ctenactis crassa*; j- *Herpoltha weberi;* k- *Herpoltha weberi;* l- *Herpoltha weberi*

Recruitment and growth of corals

The recruitment and growth pattern of slecractinian corals under eight families viz., Acroporidae, Faviidae, Siderastreidae, Mussidae, Agariciidae, Poritidae, Pectinidae and Fungiidae observed in one square meter area from North Bay and Pongibalu. Due to the wide diversification and organizational variability, growth studies of scleractinian corals were made on the type such as massive, sub-massive, encrusting, corymbose, branching and solitary mushroom corals. Twenty *six live corals* from North Bay (Table 5 and Fig. 14) and 21 live corals from Pongibalu (Table 6 and Figs. 15 & 16) were observed for the period of three year. The Annual growth rates of the selected species for North Bay and Pongibalu are represented in figs. 17 & 18.

For the first year i.e., August 2014 to July 2015, the data indicated that, an average growth rate at North Bay for the species under the family Portidae was 7mm/yr. while for Mussidae it was 9.5mm/yr. However for the species under the family Acroporidae was 60mm/yr. The growth data obtained from the corals of Pongibalu shown that 11mm/yr., 43mm/yr. and 24.25mm/yr. for the families Poritidae, Pocilloporidae and Acroporidae respectively.

For the second year i.e., August 2015 to July 2016, the data indicated that, lowest average growth rate for the species under the family Portidae was 7.6mm/yr. while the highest of average growth for 3 species under the family Acroporidae was 64.3mm/yr at North Bay area. The growth data obtained from the corals of Pongibalu shown that lowest growth rate 8mm/yr was recorded for the species under the family Faviidae while highest 44.3 mm/yr was recorded for the species under the family Pocilloporidae. Presence of species under the genus *Seriatopora* under the family Pocilloporidae represented higher growth rate in comparison with species under other genus of the said family.

For the third year i.e. August 2016 to July 2017, the data revealed that, lowest average growth rate for the species under the family Portidae was 9.1 mm/yr. while the highest of average growth for 3 species under the family Acroporidae was 75.3mm/yr at North Bay area. The growth data recorded from the sclerctainian corals of Pongibalu represented that lowest growth rate 8 mm/yr was recorded for the species under the families Faviidae and Poritidae while highest 43.8 mm/yr was recorded for the species under the family Pocilloporidae. Presence of species under the genus *Seriatopora* under the family Pocilloporidae represented higher growth rate of 48.5 mm/yr in comparison with species under other genus of the said family.

Table 5: Recruitment and growth of corals in North Bay

Sl. No.	Species	Initial length/radius (cm) (August 2014)	Annual length/radius (cm) (July 2015)	Growth rate (mm)/year	Annual length/radius (cm) (July 2016)	Growth rate (mm)/year	Annual length/radius (cm)(July 2017)	Growth rate (mm)/year
1.	*Porites solida*	12.2	12.8	6	13.6	8	14.2	6
2.	*Porites cylindrica*	4.2	4.7	5	5.3	6	6	7
3.	*Lobophyllia hemprichii*	23.4	24.3	9	25.5	12	26.5	10
4.	*Porites solida*	33.2	33.9	7	34.9	10	35.4	5
5.	*Porites solida*	21.5	22.3	8	23.3	10	24.1	8
6.	*Acropora cerealis*	24.8	33.3	85	41.8	85	52.2	104

7.	*Porites cylindrica*	25.2	25.9	7	26.6	7	27.3	7
8.	*Porites lutea*	4.9	5.3	4	5.6	3	6.2	6
9.	*Porites monticulosa*	16.5	17.2	7	18.2	10	19.3	11
10.	*Acropora plantaginea*	34.9	42.8	79	51.6	88	62.1	105
11.	*Porites lobata*	3.7	4.2	5	4.9	7	5.7	8
12.	*Echinopora lamellosa*	10.4	12.7	23	17.2	45	20.1	29
13.	*Porites lutea*	15.9	16.5	6	17.2	7	18.5	13
14.	*Lobophyllia hemprichii*	2.3	3.1	8	4.6	15	6.5	19
15.	*Porites monticulosa*	9.1	9.6	5	10.5	9	11.2	7
16.	*Favites halicora*	6.6	7.9	13	9.5	16	10.8	13
17.	*Porites cylindrica*	7.2	7.7	5	8.4	7	9.5	11
18.	*Symphyllia agaricia*	6.8	7.8	10	9	12	10.5	15
19.	*Fungia paumotensis*	5.9	6.3	4	7.1	8	8.9	18
20.	*Porites cylindrica*	18.4	19.7	13	21	13	22.5	15
21.	*Favites pentagona*	2.3	2.9	6	3.7	8	4.5	8
22.	*Porites cylindrica*	7.2	8.2	10	9.2	10	10.1	9
23.	*Porites cylindrica*	7.5	8.4	9	9.3	9	10.3	10
24.	*Acropora cerealis*	4.8	6.5	17	8.5	20	10.2	17
25.	*Porites cylindrica*	12.2	12.8	6	13.4	6	14.1	7
26.	*Porites cylindrica*	13.7	14.6	9	15.5	9	16.4	9

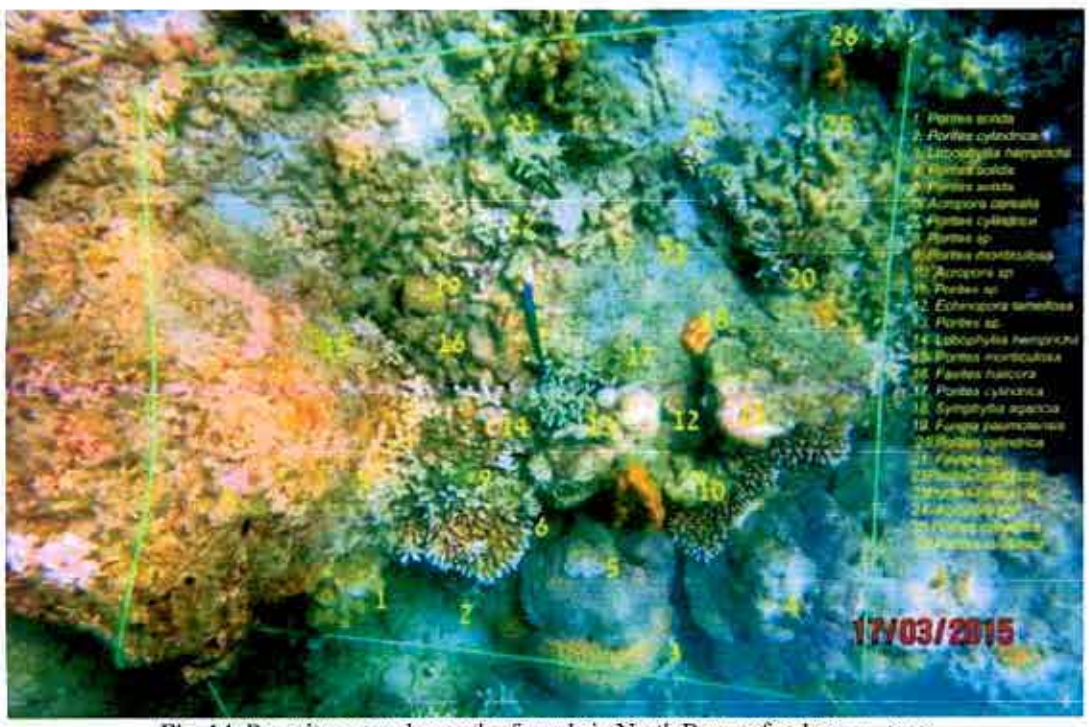


Fig. 14: Recruitment and growth of corals in North Bay reef at 1 sq. m. area

Table 6: Recruitment and growth of corals in Pongibalu

Sl. No.	Species	Initial length/radius (cm) (August 2014)	Annual length/radius (cm) (July 2015)	Growth rate (mm)/year	Annual length/radius (cm) (July 2016)	Growth rate (mm)/year	Annual length/radius (cm)(July 2017)	Growth rate (mm)/year
1.	*Seriatopora hystrix*	18.2	24.3	61	30.6	63	35.4	48
2.	*Fungia paumotensis*	10.2	11.3	11	12.4	11	13.3	9
3.	*Lithophyllon undulatum*	2.1	2.9	8	3.9	10	5.1	12
4.	*Lithophyllon undulatum*	3.4	4.1	7	4.9	8	6	11
5.	*Lithophyllon undulatum*	1.8	2.5	7	3.6	11	4.5	9
6.	*Lithophyllon undulatum*	2.8	3.6	8	4.7	11	5.9	12
7.	*Acropora* sp.	3.9	6.3	24	8.9	26	11.5	26
8.	*Acropora* sp.	3.5	6.1	26	8.8	27	12.1	33
9.	*Acropora* sp.	2.9	6.0	31	9.2	32	12.3	31
10.	*Leptastrea purpurea*	1.9	2.6	7	3.5	9	4.2	7
11.	*Porites solida*	15.7	16.8	11	17.8	10	18.5	7
12.	*Pavona bipartita*	6.8	8.3	15	9.9	16	12.1	22
13.	*Porites solida*	7.2	8.4	12	9.5	11	10.4	9
14.	*Seriatopora hystrix*	13.7	18.9	52	24.5	56	30.1	56
15.	*Acropora* sp.	2.3	3.9	16	5.8	19	7.2	14
16.	*Porites solida*	7.1	8.1	10	9.2	11	10	8
17.	*Seriatopora hystrix*	21.8	27.2	54	32.5	53	37.1	46
18.	*Leptastrea purpurea*	6.9	8.2	13	9.6	14	10.5	9
19.	*Seriatopora hystrix*	2.9	4.6	17	6.5	19	8.8	23
20.	*Pocillopora damicornis*	17.5	19.3	18	21.2	19	23.5	23
21.	*Seriatopora hystrix*	9.1	14.8	57	20.4	56	27.1	67

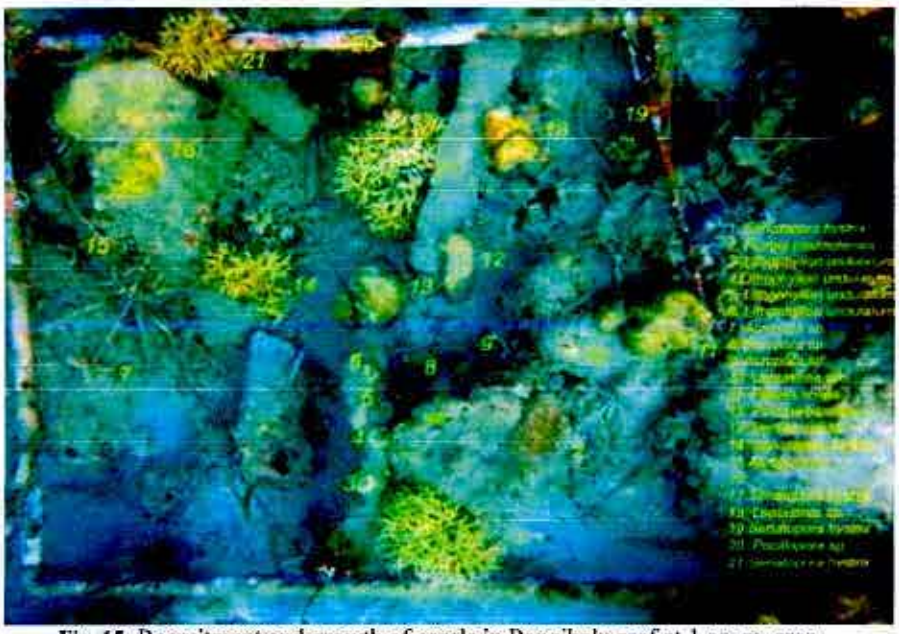


Fig. 15: Recruitment and growth of corals in Pongibalu reef at 1 sq. m. area

Fig. 16: Recruitment and growth of *Lithophyllon undulatum* in Pongibalu reef

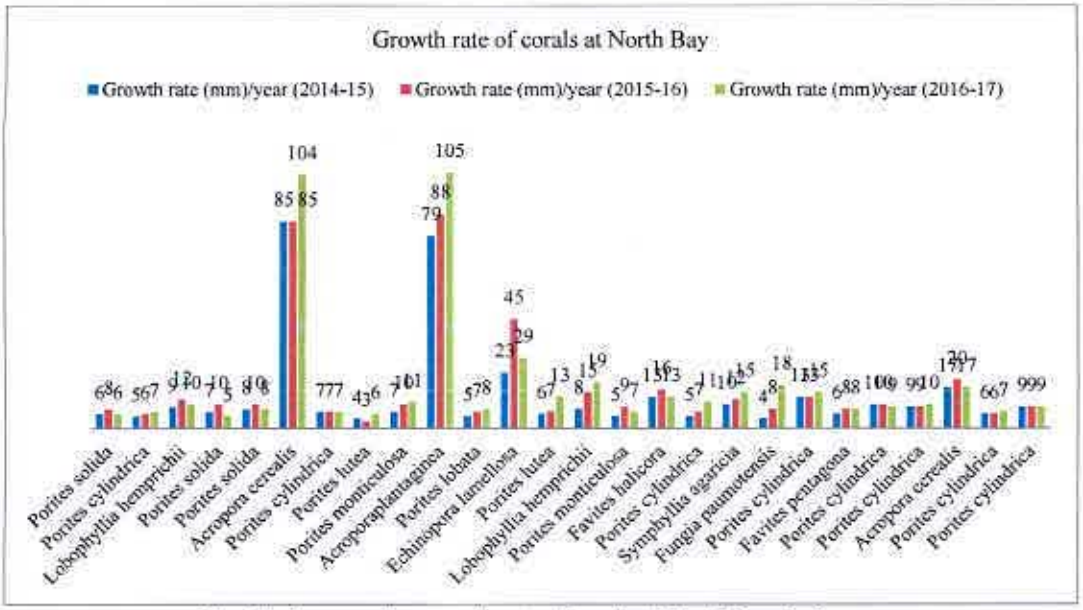


Fig. 17: Comparative growth rate of corals at North Bay for 3 years

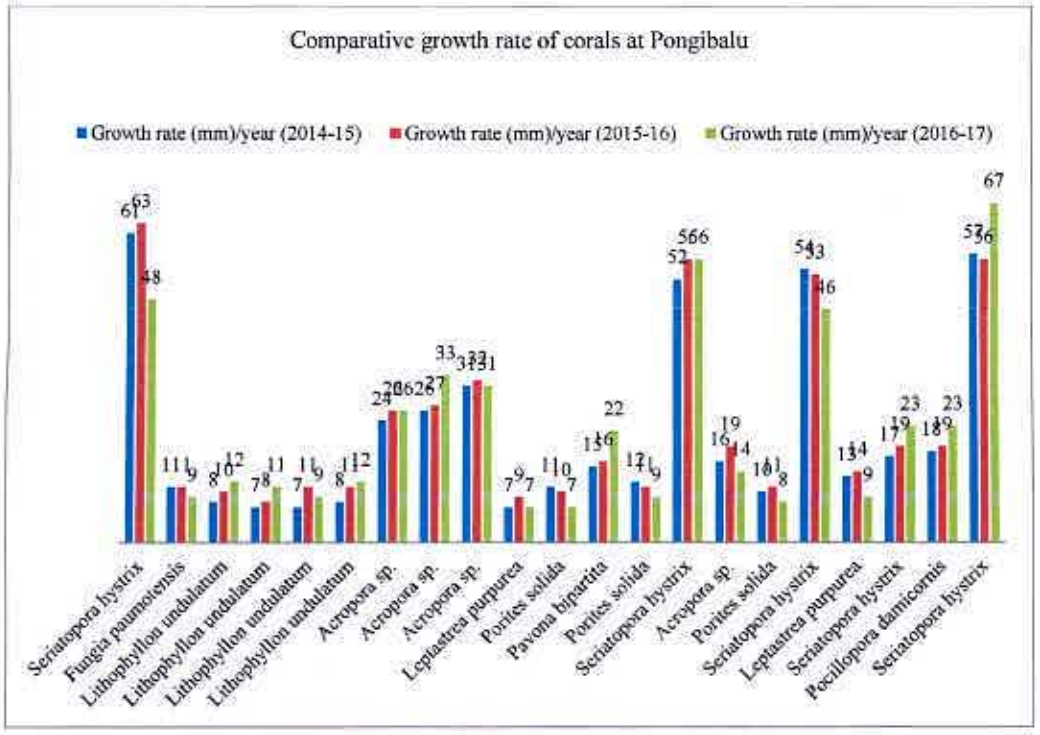


Fig. 18: Comparative growth rate of corals at Pongibalu for 3 years

5.3. Studies on substrate specificity for the settlement of coral's Planula larvae

Settlement of Planula:

The settlement patterns of the corals were observed at four places of South Andaman during the period of 3 years. The settlement of the planula larvae was seen at all the four places (Figs. 19 & 21). Maximum settlement was observed in Rifleman Island while minimum was seen at North Bay region. Settlement of planula larvae of corals in *in-situ* condition were monitored by employing rectangular concrete plates (20 × 20 sq. cm.) prepared by using 10% of coralline rubbles at four location of the study. During the period of first year of deployment, maximum settlement of planula larvae was found on February to April 2015 (2 - 30 larvae) and it was minimum during August to October 2014 (3-7 larvae) while second year of the observation denoted the alike comprehensive result of progressive settlement of planula larvae during the period of February to April 2016 (3-37 larvae) while minimum during August to October 2015 (6 to 14 larvae). During the final year i.e. 2016-2017, maximum settlement of 8-35 planula larvae was recorded during February to April 2017 and the minimum of 5-15 planula larvae was recorded during August to October 2016.

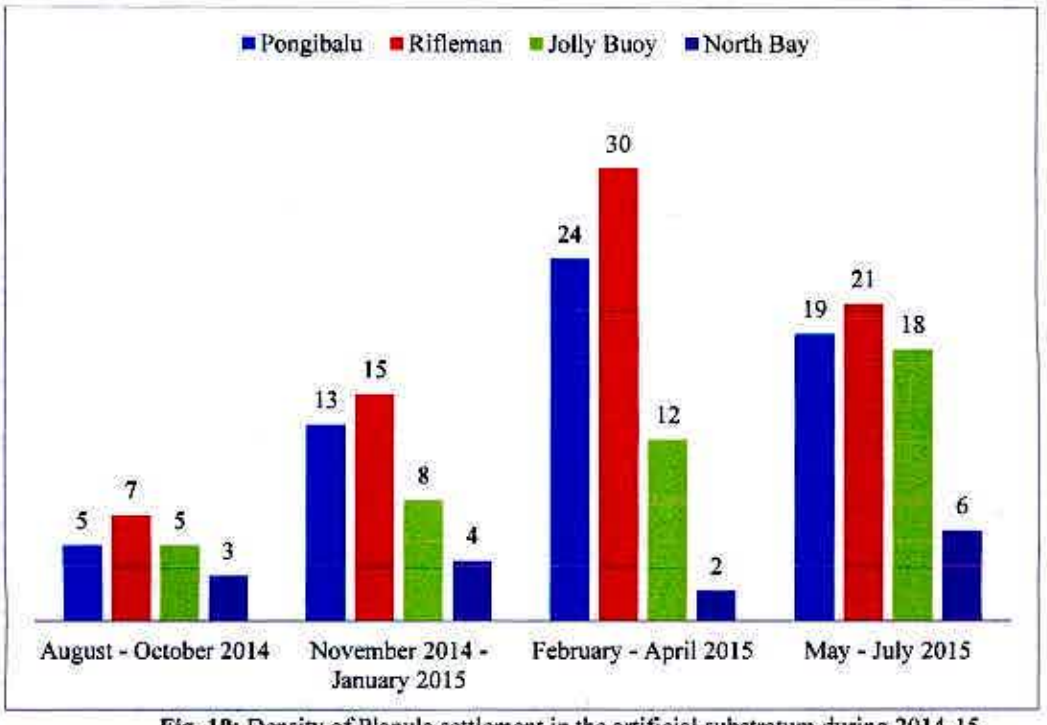


Fig. 19: Density of Planula settlement in the artificial substratum during 2014-15

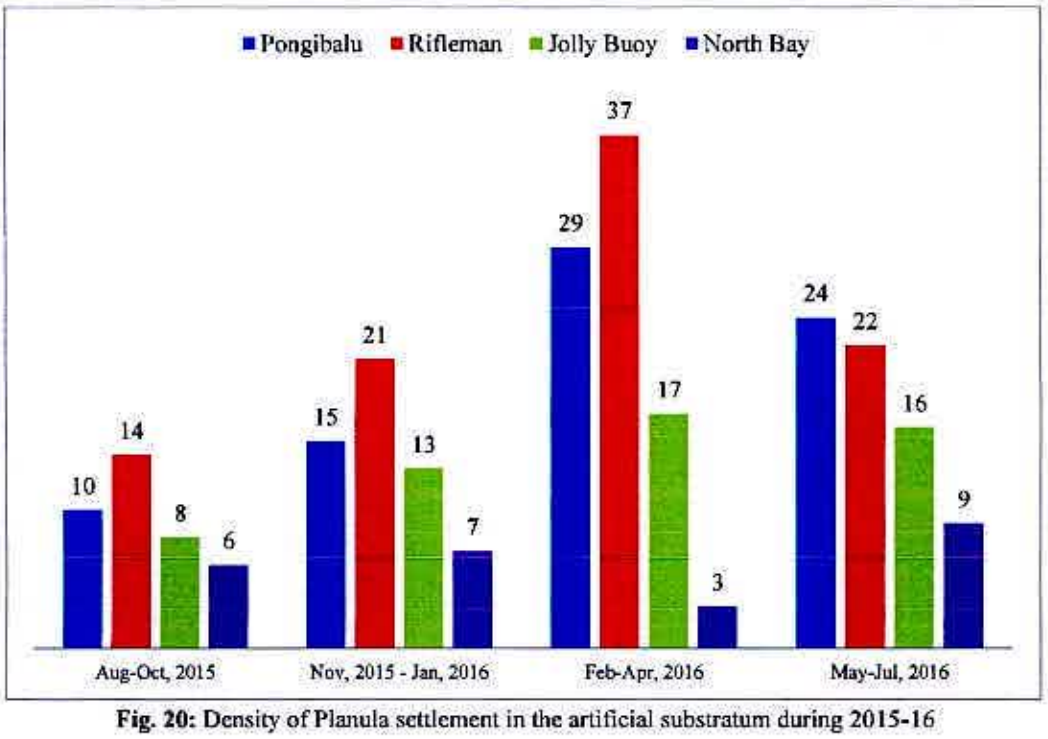


Fig. 20: Density of Planula settlement in the artificial substratum during 2015-16

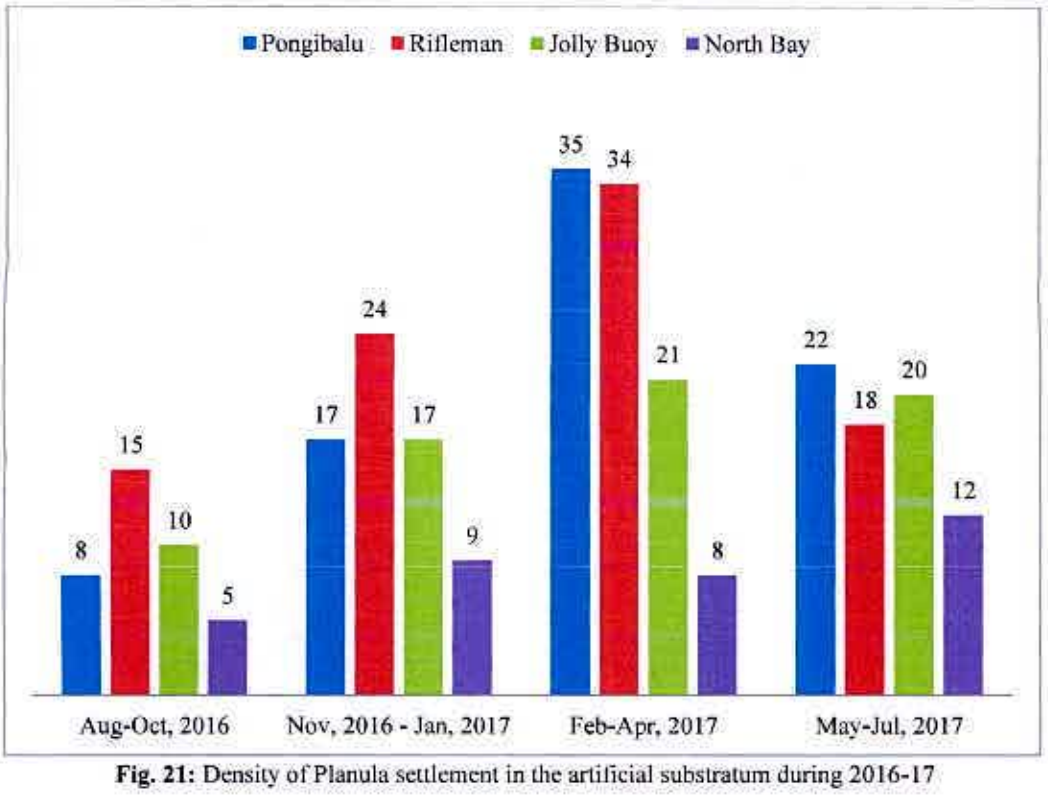


Fig. 21: Density of Planula settlement in the artificial substratum during 2016-17

During 2014-2015:

Settlement and development of *Pocillopora damicornis, Rhizopsammia verrilli* (two individuals) and *Tubastrea conccinia* (2 colonies) was recorded from the plates.

Table 7: Development of settled scleractinian corals on experimental plates

Sl. No.	Species	Measurement
1.	*Pocillopora damicornis*	25 mm × 16 mm × 15 mm
2.	*Rhizopsammia verrilli*	4 mm & 3 mm (dia)
3.	*Tubastrea conccinea*	5 mm & 4 mm (dia)

During 2015-2016:

Settlement and development of a total of 26 colonies and solitary individuals under 14 species such as *Porites solida* (2 colonies), *Favia speciosa* (4 colonies), *Favites pentagona* (1 colony), *Porites lobata* (2 colonies), *Favia matthaii* (1 colony), *Favia albidus* (1 colony), *Lobophyllia hemprichii* (1 colony), *Favia lizardensis* (1 colony), *Acropora* sp. (1 colony), *Hydnophora microconos* (1 colony), *Tubastrea micrantha* (1 colony), *Tubastrea coccinea* (2 colonies), *Rhizopsammia verrillii* (4 individuals) and *Montipora* sp. (3 colonies) were recorded from the plates. Measurements of the said corals are depicted in table 8.

Table 8: Development of settled scleractinian corals on experimental plates

Sample No.	Species	Measurement
1.	*Porites solida*	9 mm × 12 mm
2.	*Favia speciosa*	10 mm × 13 mm
3.	*Favia speciosa*	10 mm × 12 mm
4.	*Favites pentagona*	9 mm × 16 mm
5.	*Porites lobata*	10 mm × 22 mm
6.	*Favia matthaii*	10 mm × 14 mm
7.	*Porites solida*	8 mm × 11 mm
8.	*Favia albidus*	12 mm × 14 mm
9.	*Lobophyllia hemprichii*	24 mm (dia)
10.	*Porites solida*	5 mm × 7 mm
11.	*Favia lizardensis*	9 mm × 10 mm
12.	*Favia speciosa*	12 mm × 14 mm
13.	*Favia speciosa*	6 mm × 7 mm
14.	*Porites lobata*	5 mm × 8 mm
15.	*Acropora* sp.	32 mm × 21 mm
16.	*Hydnophora microconos*	11 mm × 12 mm
17.	*Tubastrea micrantha*	31 mm × 25 mm × 13 mm
18.	*Tubastrea coccinea*	14 mm & 15 mm (dia)
19.	*Tubastrea coccinea*	14 mm & 12 mm (dia)
20.	*Rhizopsammia verrillii*	2 mm
21.	*Rhizopsammia verrillii*	2 mm
22.	*Rhizopsammia verrillii*	4 mm
23.	*Rhizopsammia verrillii*	7 mm
24.	*Montipora* sp.	22 mm × 19 mm
25.	*Montipora* sp.	9 mm × 12 mm
26.	*Montipora* sp.	70 mm × 12 mm

During 2016-2017:

Settlement and development of a total of 33 colonies and solitary individuals under 13 species such as *Porites solida* (4 colonies), *Porites lutea* (3 colonies), *Porites lobata* (4 colonies), *Favia speciosa* (4 colonies), *Favites pentagona* (2 colonies), *Favia matthaii* (1 colony), *Favia albidus* (1 colony), *Favia lizardensis* (1 colony), *Acropora* sp. (4 colonies of different 4 species), *Tubastrea micrantha* (1 colony), *Tubastrea coccinea* (4 colonies), *Rhizopsammia verrillii* (1 individuals) and *Montipora* sp. (3 colonies of different 3 species) were recorded from the plates.

Table 9: Development of settled scleractinian corals on experimental plates

Sample No.	Species	Measurement
1.	*Porites solida*	9 mm × 12 mm
2.	*Porites solida*	6.5 mm × 8.1 mm
3.	*Porites solida*	7.2 mm × 10.1 mm
4.	*Porites solida*	8.7 mm × 11 mm
5.	*Porites lutea*	8.8 mm × 9.5 mm
6.	*Porites lutea*	7.2 mm × 7 mm
7.	*Porites lutea*	3 mm × 2.3 mm
8.	*Porites lobata*	10.1 mm × 22 mm
9.	*Porites lobata*	5 mm × 3.2 mm
10.	*Porites lobata*	9.4 mm × 15.3 mm

11.	*Porites lobata*	6.2 mm × 12 mm
12.	*Favia speciosa*	10 mm × 13 mm
13.	*Favia speciosa*	7.1 mm × 5.8 mm
14.	*Favia speciosa*	18.2 mm × 19.1 mm
15.	*Favia speciosa*	10.15 mm × 17.2 mm
16.	*Favites pentagona*	19.2 mm × 18.3 mm
17.	*Favites pentagona*	14.5 mm × 12.8 mm
18.	*Favia matthaii*	15.2 mm × 17.3 mm
19.	*Favia albidus*	18.5 mm × 17.2 mm
20.	*Favia lizardensis*	14.1 mm × 17.9 mm
21.	*Acropora* sp. 1	52.8 mm × 76.5 mm
22.	*Acropora* sp. 2	46.5 mm × 77.9 mm
23.	*Acropora* sp. 3	64.9 mm × 110.1 mm
24.	*Acropora* sp. 4	71.1 mm × 124.5 mm
25.	*Tubastrea micrantha*	45 mm × 35 mm × 22 mm
26.	*Tubastrea coccinea*	24 mm & 17.4 mm (dia)
27.	*Tubastrea coccinea*	19 mm & 17.1 mm (dia)
28.	*Tubastrea coccinea*	25 mm & 22.5 mm (dia)
29.	*Tubastrea coccinea*	41 mm & 34.9 mm (dia)
30.	*Rhizopsammia verrillii*	27.1 mm
31.	*Montipora* sp. 1	45.1 mm × 29.7 mm
32.	*Montipora* sp. 2	27.5 mm × 28.2 mm
33.	*Montipora* sp. 3	108.7 mm × 43.5 mm

Measuremensts of the colonies are given in plates 13 to 16.

Sedimentation rate:

The rate of sediment deposition was also monitored on monthly basis at Pongibalu and North Bay to denote the role of sedimentation of settlement pattern scleractinian corals caused by anthropogenic activities (Plate 17).

During August 2014 to July 2015:

It was observed that a maximum sediment deposition was observed at North Bay region (163.86 mg/cm^2/year) in comparison to Pongibalu (75.10 mg/cm^2/year). Maximum sediment was recorded during September at North Bay while minimum sedimentation was seen at Pongibalu during March (Fig. 22).

Plate 13: Deployment of plates for planula settlement

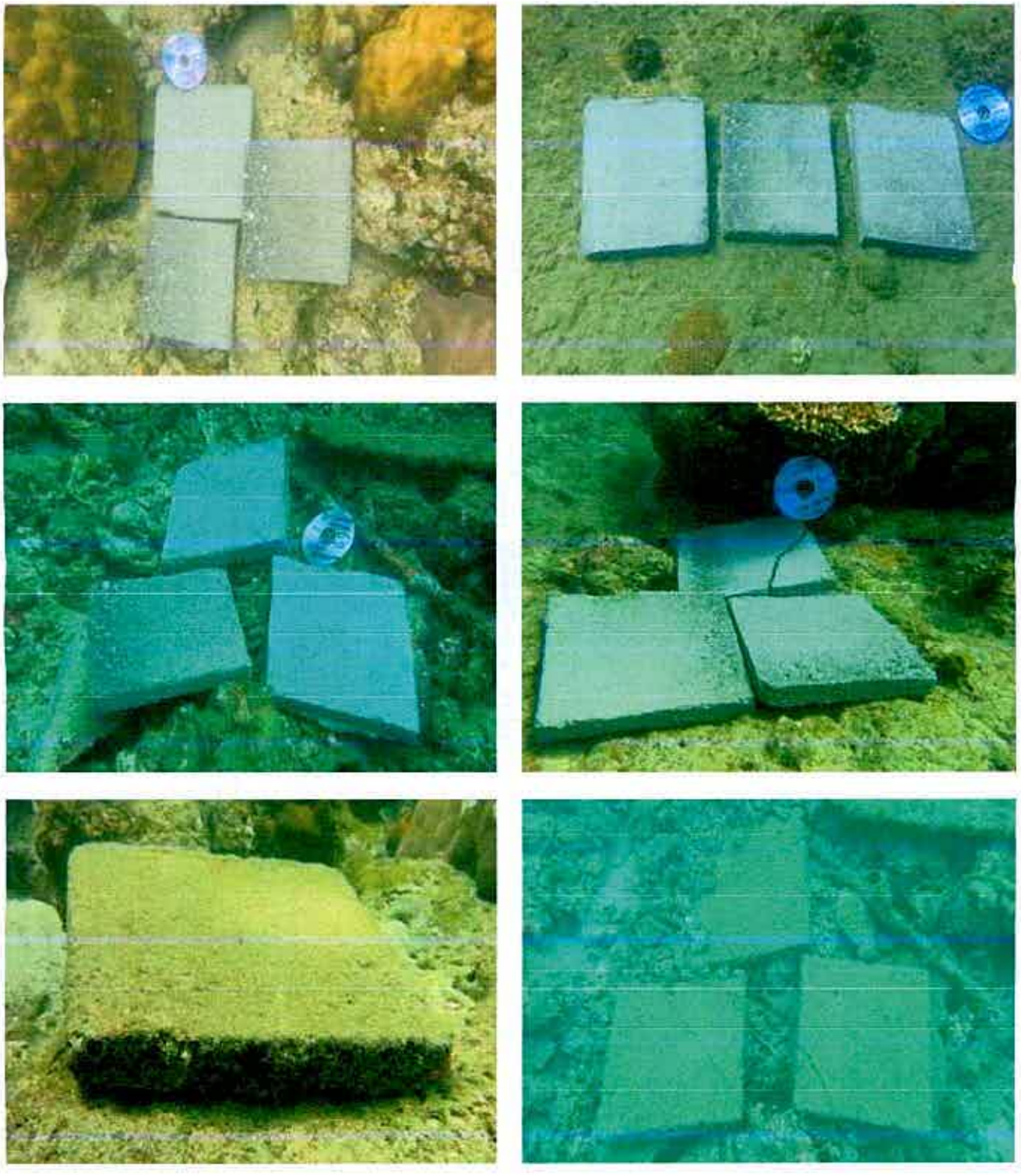
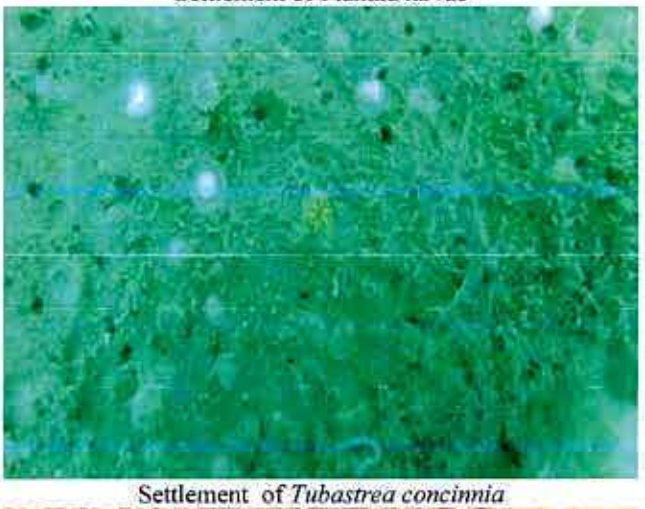


Plate 14: Settlement of Planula larvae and development

Settlement of Planula larvae

Settlement of Planula larvae

Settlement of Planula larvae



Settlement of *Tubastrea concinnia*

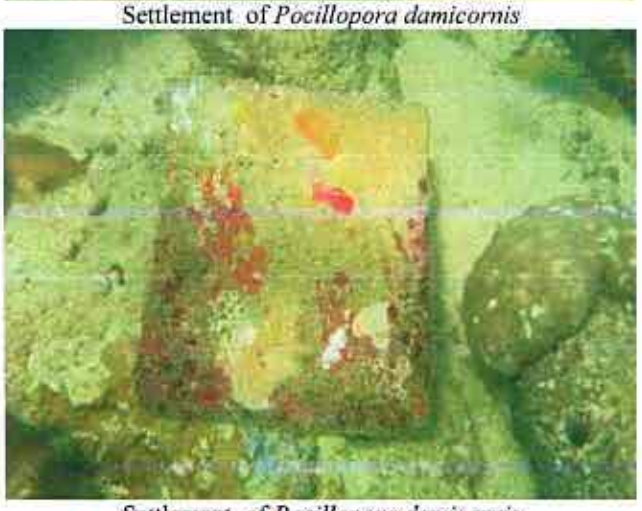
Settlement of *Tubastrea concinnia*

Settlement of *Rhizopsammia verrilli*

Plate 15: Development of Scleractinian corals

Settlement of *Pocillopora damicornis*

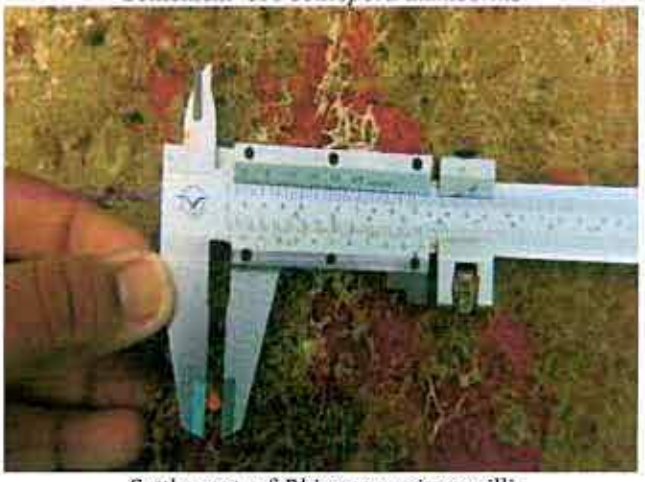
Settlement of *Pocillopora damicornis*



Settlement of *Pocillopora damicornis*

Settlement of *Pocillopora damicornis*

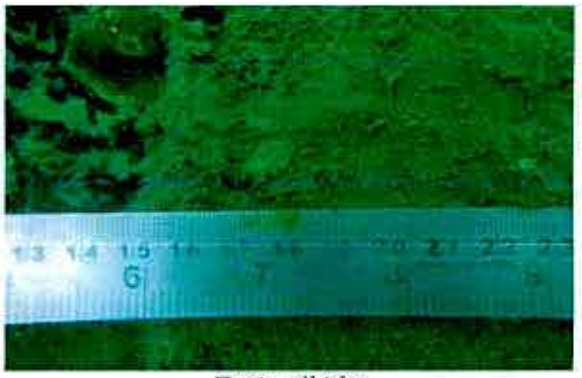
Settlement of *Pocillopora damicornis*



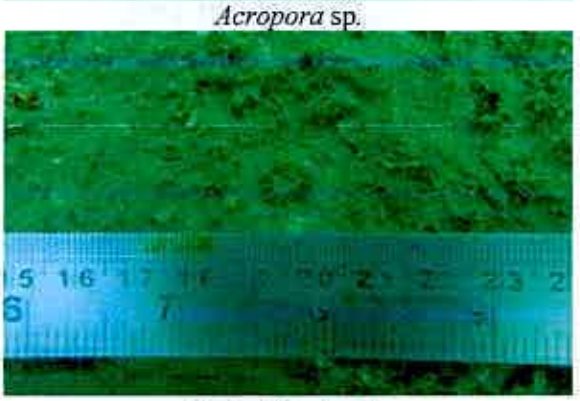
Settlement of *Rhizopsammia verrilli*

Plate 16: Development of Scleractinian corals

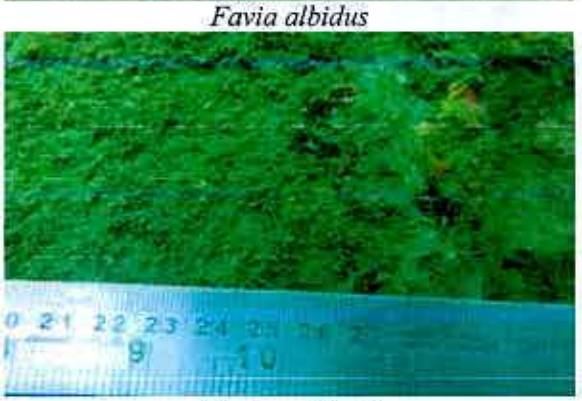
Acropora sp.



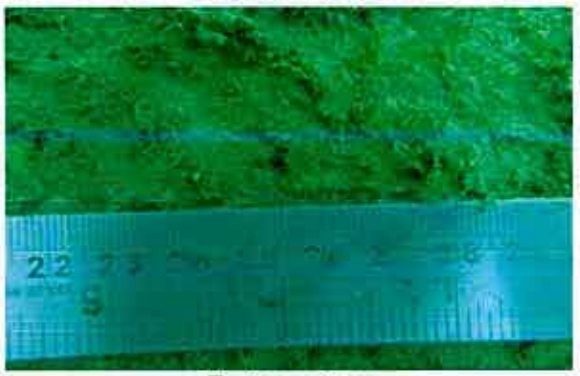
Favia albidus



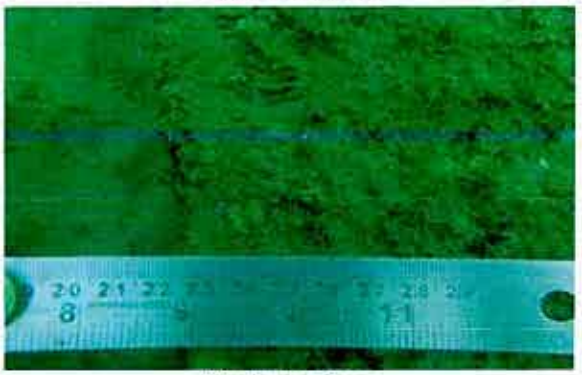
Favia lizardensis



Favia matthaii



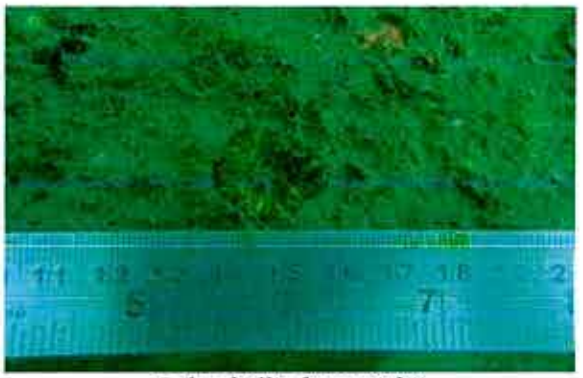
Favia speciosa



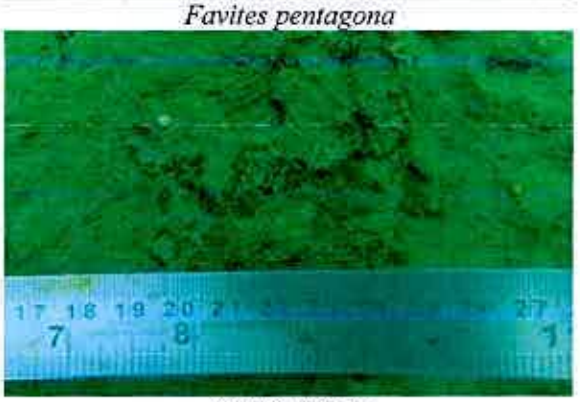
Favia speciosa

Plate 16: Contd.

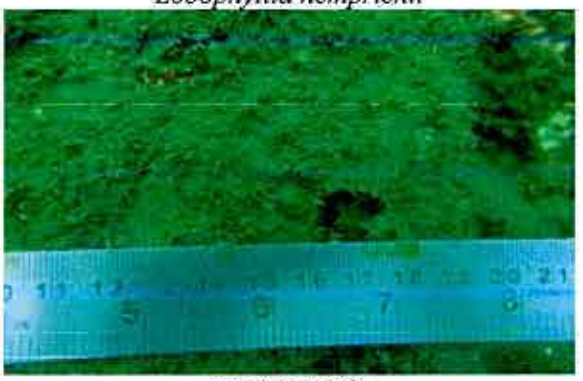
Favites pentagona



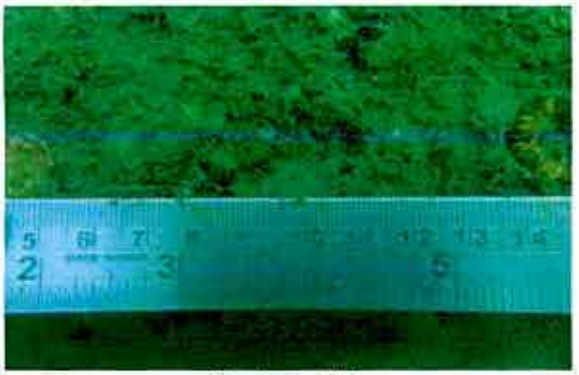
Lobophyllia hemprichii



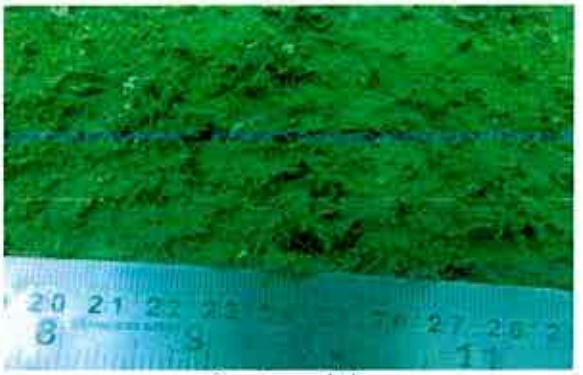
Porites lobata



Porites solida



Porites solida



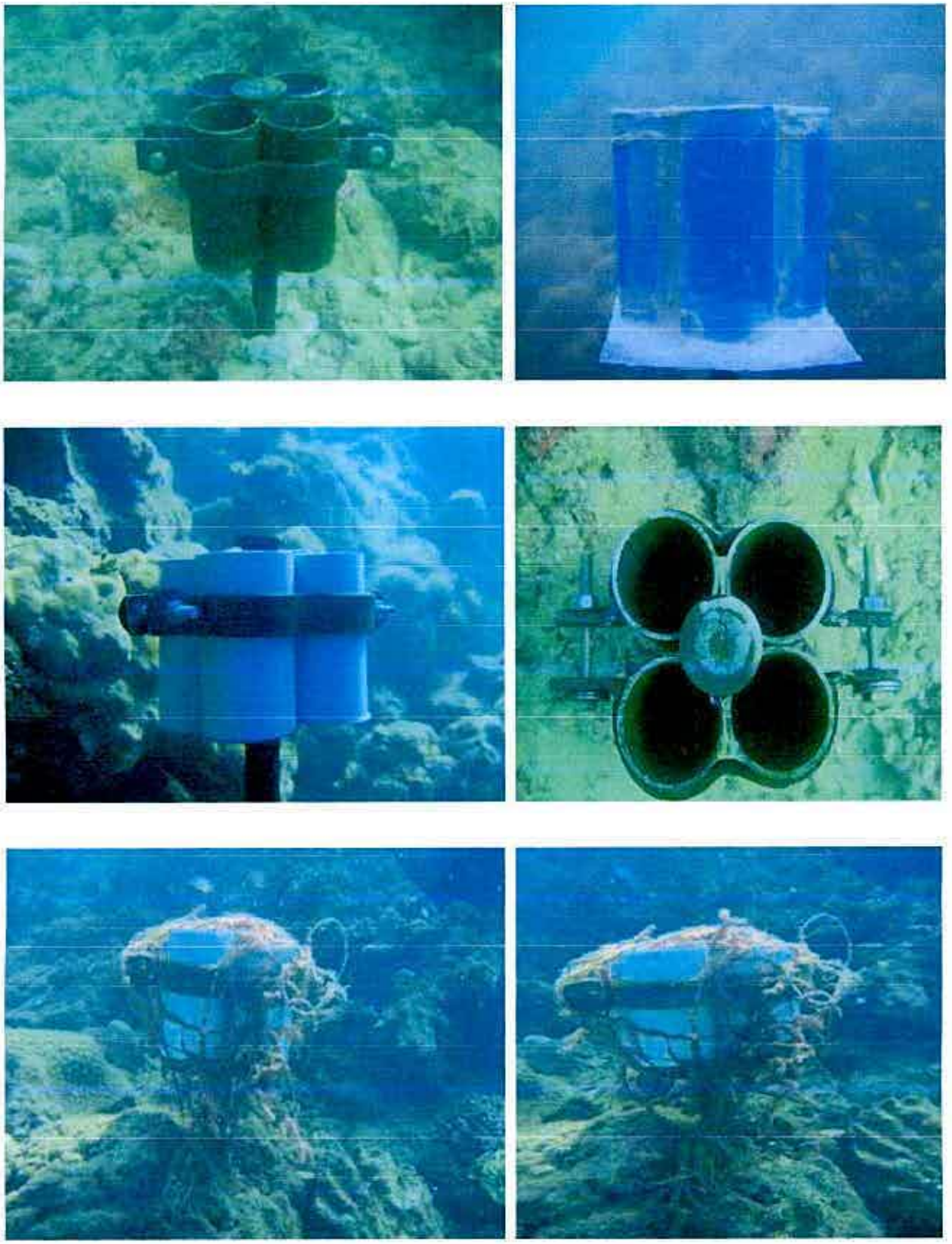
Porites solida

Fig. 22: Rate of sedimentation on reef area of North Bay and Pongibalu (mg/cm^2/day) from August 2014– July 2015

During August 2015 to July 2016:

It was observed that a maximum sediment deposition was observed at North Bay region (171.14 mg/cm^2/year) in comparison to Pongibalu (63.08 mg/cm^2/year). Maximum sediment was recorded during September 2015 at North Bay while minimum sedimentation was seen at Pongibalu during April 2016 (Fig. 23).

Plate 17: Sediment trap at study areas



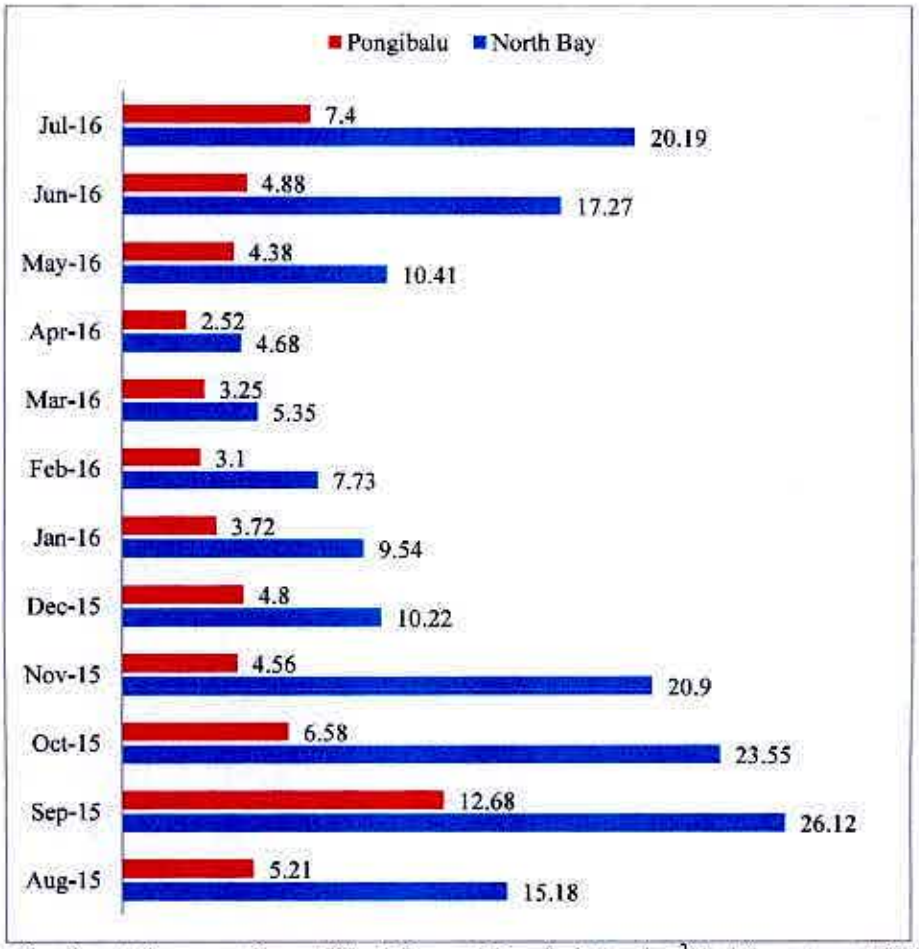


Fig. 23: Rate of sedimentation on reef area of North Bay and Pongibalu (mg/cm^2/day) from August 2015– July 2016

During August 2016 to July 2017:

It was observed that a maximum sediment deposition was observed at North Bay region (182.75 mg/cm^2/year) in comparison to Pongibalu (61.04 mg/cm^2/year). Maximum sediment was recorded during September 2016 at North Bay while minimum sedimentation was seen at Pongibalu during February 2017 (Fig. 24).

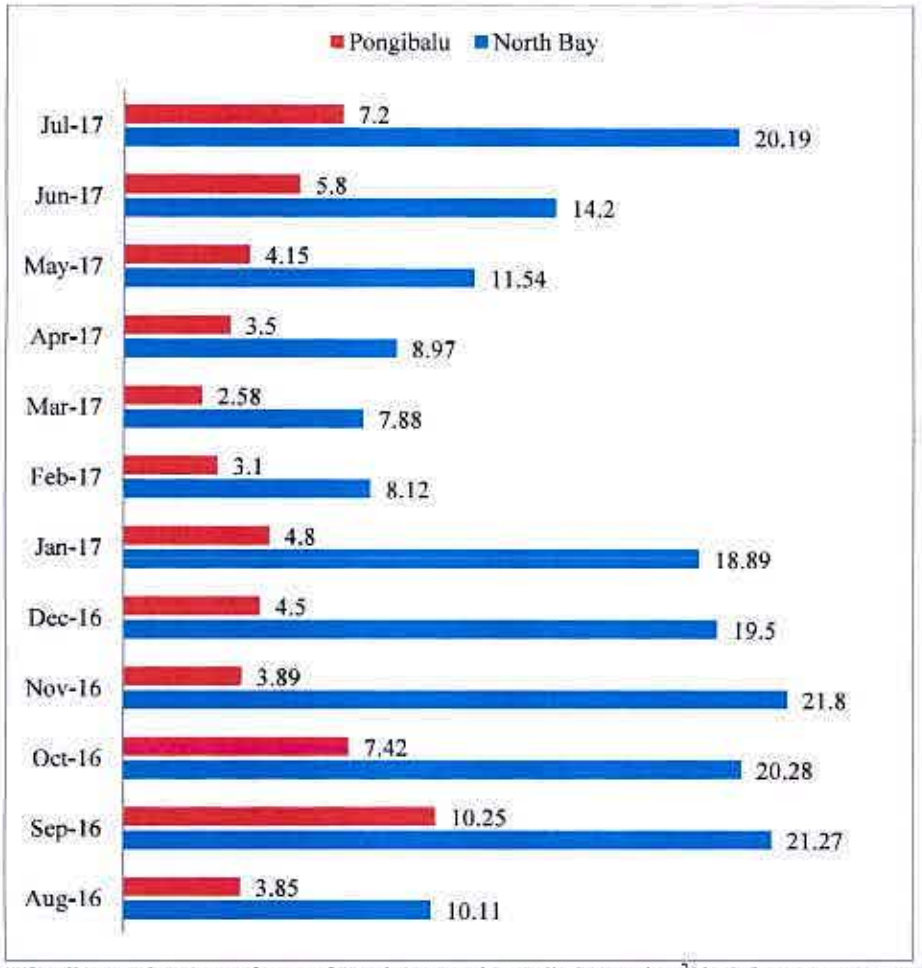


Fig. 24: Rate of sedimentation on reef area of North Bay and Pongibalu (mg/cm^2/day) from August 2016– July 2017

5.4. Coral transplantation studies on selected species

Experimental set up during July 2015:

Coral transplantation experiment was set-up at Pongibalu area during July 2015. Initially 3 plots (1m × 1m) were set at the depth of 2 m to measure the survivability of scleractinian corals. Broken parts of eight species of corals viz., *Acropora muricata, Acropora austera, Pocillopora damicornis, Seriatopora hystrix, Hydnophora rigida, Cyphastrea microphthalma, Porites annae* and *Porites rus* were transplanted at the plot areas for the development. The length of the coral colonies were taken during the period deployment (Fig. 25 & Plate 18). The transplantation of of all the colonies were successful and and growth of the colonies was recorded. It was recorded that the growth rate of the corals were maximum during the period of November, 2015 to January 2016 in comparison with other two data of quarterly studies. Mostly all the species species of corals attended higher growth rate during the period. *Acropora muricata* represented the maximum growth of 49 mm during the period of 9 months (July 2015 to April 2016) while *Porites annae* showed minimum of 5 mm for the same period.

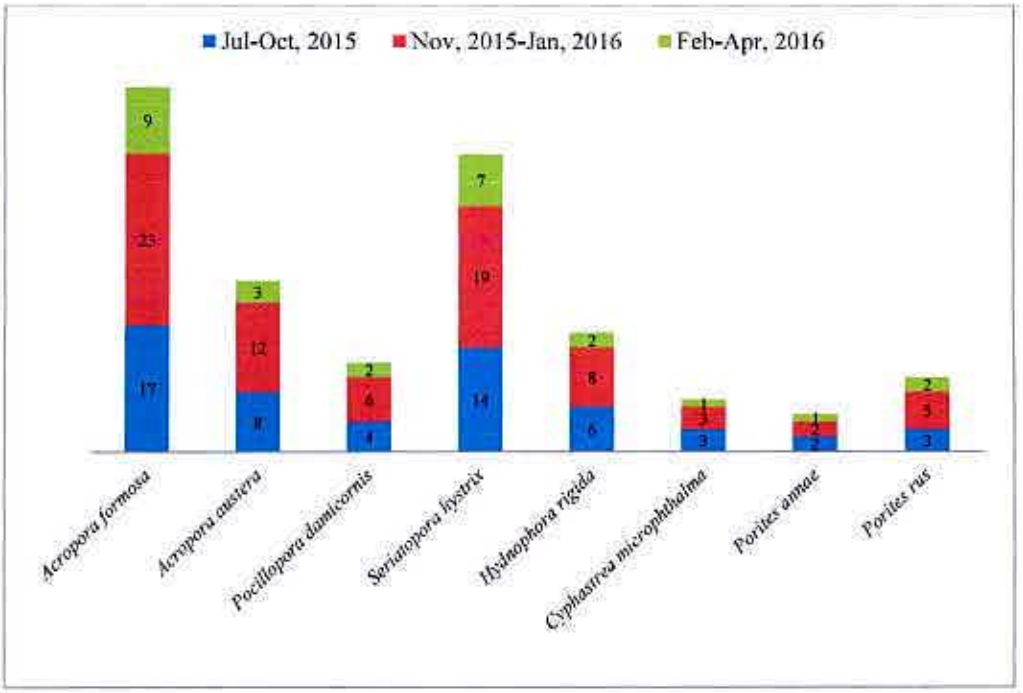


Fig. 25: Growth rate (mm/ quarter yr) of corals after transplantation since July 2015

All the coral colonies were bleached during the period of April 2016 due to the increased sea surface temperature. The growth rate of the coral fragments were reduced during the period of February to April 2016 due to bleaching effect and gradually transformed into dead fragments. Hence, another experimental set up was required to establish to carry out the experimental processes.

Experimental set up during May 2016:

Another experimental set-up of coral transplantataion was established in a metal frame (1m × 1m) at the depth of 4m at Pongibalu area during May 2016. Twenty five coral fragments of eight species viz., *Acropora muricata, Acropora robusta, Acropora latistella, Porites cylindrica, Porites attenuata, Porites rus, Pocillopora verrucosa, Seriatopora hystrix* were transplanted to record their development (Plate 19). The intial length of the coral fragments was recorded (Table 10). The length of the corals varies from 6.1 to 29.8 cm.

Table 10: Intial average length of coral fragments for coral transplantation experiments

Sl. No.	Species	Intial length (cm)
1.	*Acropora muricata*	18.4
2.	*Acropora robusta*	29.8
3.	*Acropora latistella*	15.9
4.	*Porites cylindrica*	8.2
5.	*Porites attenuata*	7.4
6.	*Porites rus*	8.6
7.	*Pocillopora verrucosa*	6.1
8.	*Seriatopora hystrix*	11.3

Plate 18: *In situ* plots for transplanted corals at Pongibalu in 2014-15

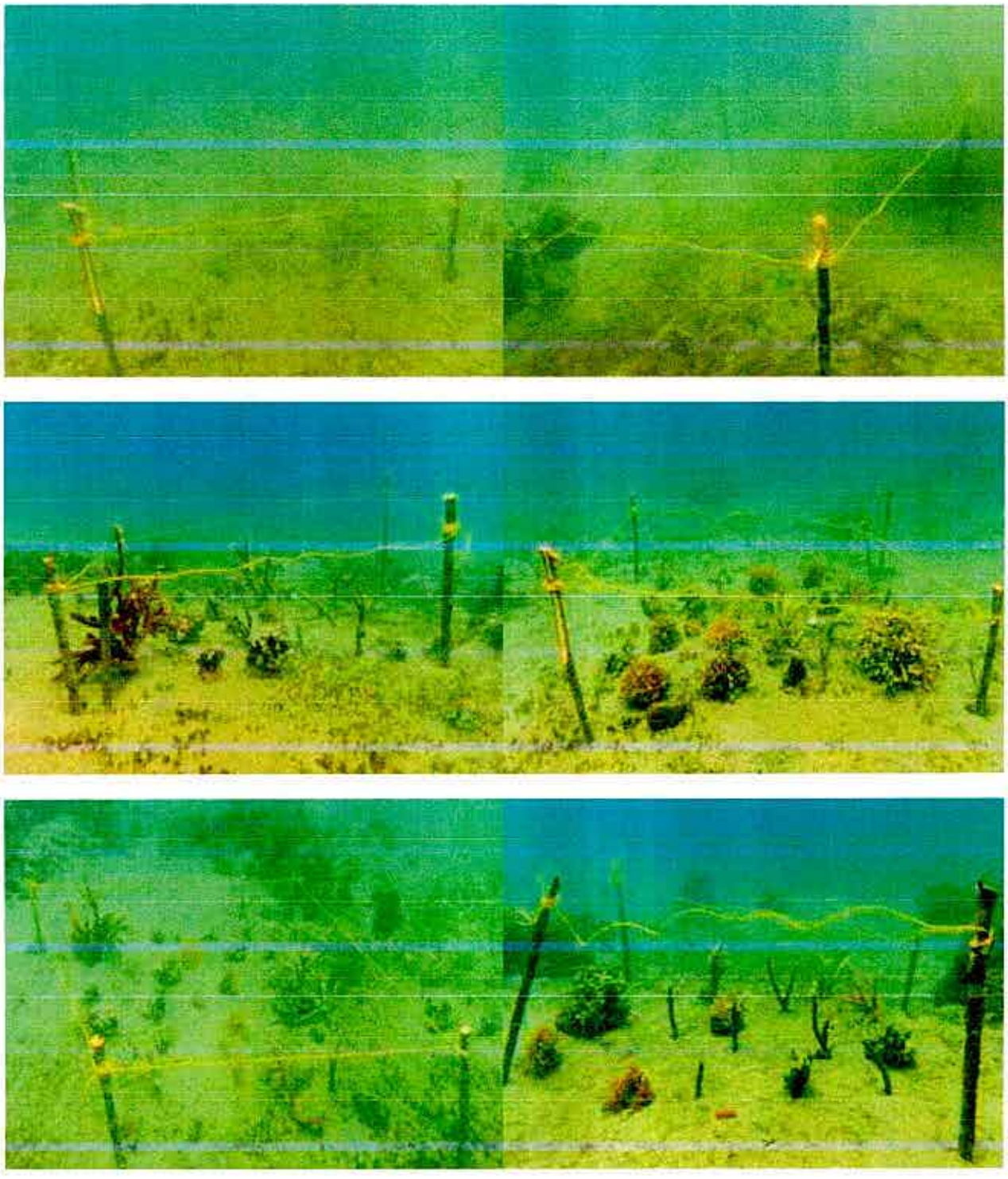
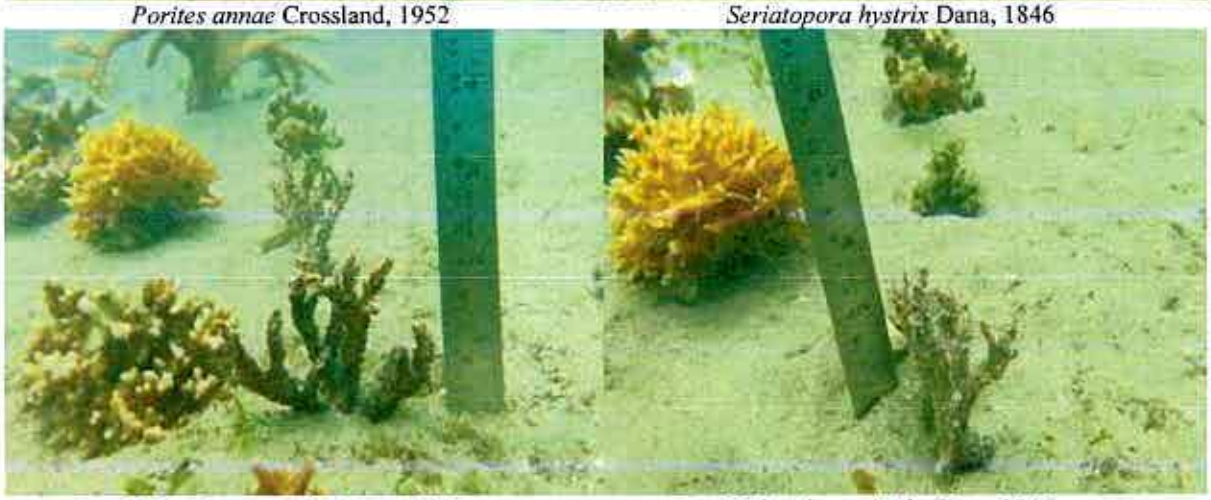


Plate 18: Contd.

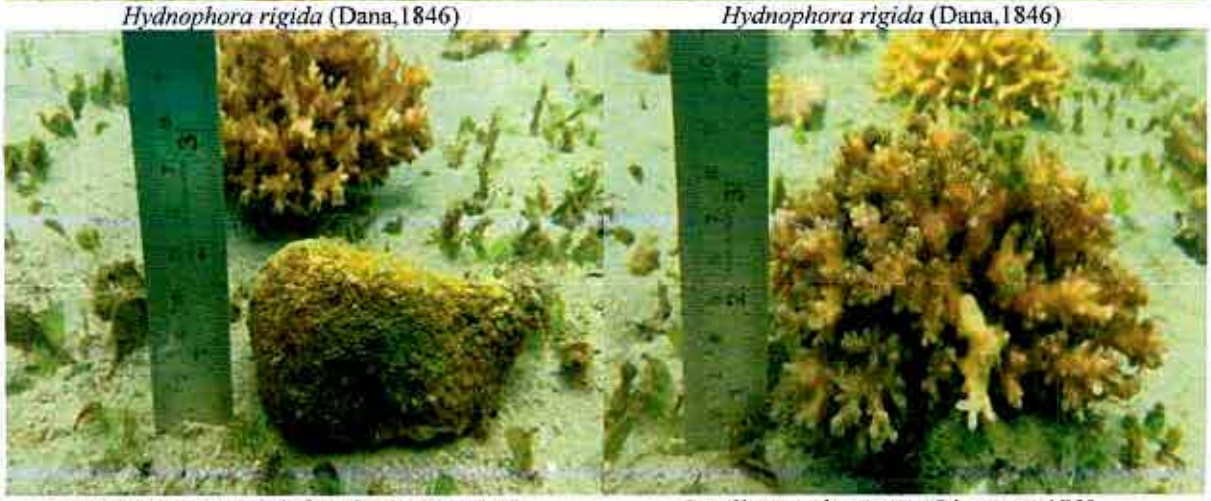
Porites annae Crossland, 1952

Seriatopora hystrix Dana, 1846



Hydnophora rigida (Dana,1846)

Hydnophora rigida (Dana,1846)



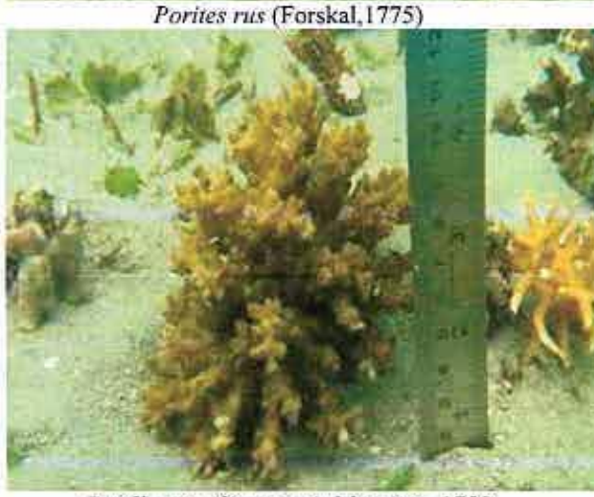
Cyphastrea microphthalma (Lamarck, 1816)

Pocillopora damicornis Linnaeus, 1758

Plate 18: Contd.

Porites rus (Forskal,1775)

Porites rus (Forskal,1775)



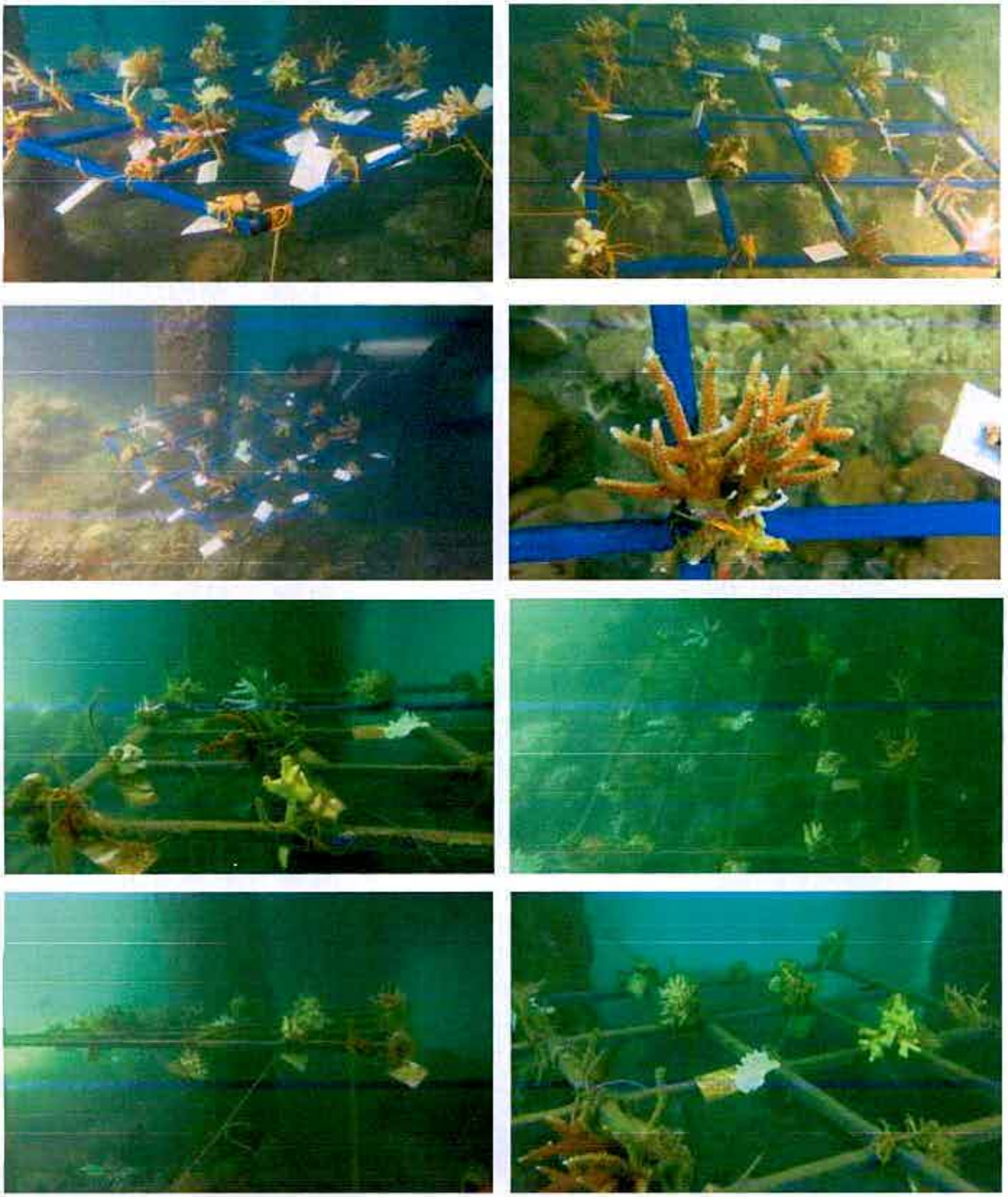
Pocillopora damicornis Linnaeus, 1758

Porites rus (Forskal,1775)

Acropora formosa (Dana, 1846)

Acropora formosa (Dana, 1846)

Plate 19: *In situ* plots for transplanted corals at Pongibalu in 2015-17



5.5. *Ex-situ* observation on coal life cycle

The studies on the *ex-situ* observation on corals are initited *Lobophyllia hemprichii* and *Acropora muricata* to identify their spawning period (Plate 20).

5.6. Physico-chemical parameters

The physico-chemical parameters of the seawater are the prime factors indicating the quality of the coastal waters which directly influence the primary and secondary productivities, and tertiary producers in the marine environment. The data on these parameters obtained from seawater samples collected from all the places of present study and the results are depicted in table 11-13.

During 1st year - August 2014 to July 2015:

The mean surface seawater temperature ranged from 27.5 to 29.0°C at all the study areas. The difference of salinity ranged from 32.46 to 34.72 ppt recorded might be attributed to the rainfall followed by runoff in these regions. The concentration of hydrogen ions (pH) varied between stations and it was 7.3 at Pongibalu to 7.7 in Rifleman and Jolly Buoy Island.

Table 11: Physio-chemical Parameters in seawater of South Andaman

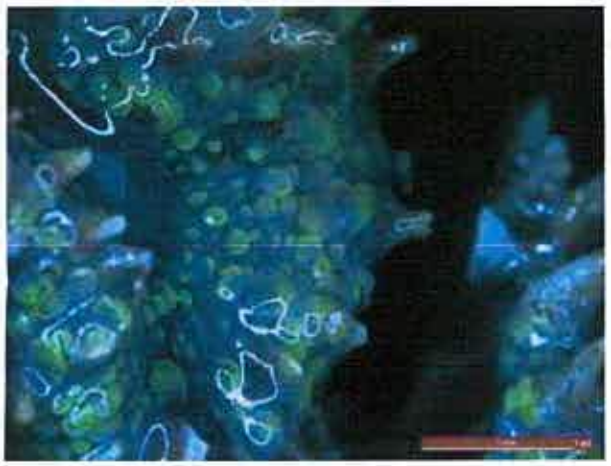
Sl. No.	Area	Temp. (°C)	Salinity (ppt)	pH	Transparency (m)	Turbidity (NTU)	Intertidal exposure (m)
1.	Pongibalu	28.5	32.46	7.3	8.2	470	30
2.	Rifleman Island	28.5	33.09	7.7	9.3	340	00
3.	Jolly Buoy Island	27.5	34.72	7.7	10.6	220	20
4.	North Bay	29.0	33.12	7.5	7.2	610	40

The transparency in terms of penetration of light in the seawater column was also measured at all the places and it ranged from 7.2 m at North Bay to 10.6m at Jolly Buoy Island. The quintessence of the results acquired for seawater transparency indicated that all the stations of study have high light penetration. The turbidity of seawater was also measured by Nudson Turbidity Unit (NTU) and it was found minimum (220) at Jolly Buoy Island and maximum (610) at North Bay area. The higher level of turbidity might be due to sediment laden rainwater runoff in this region. The intertidal exposure during low tide at the surveyed area ranged from 00 to 40m at North Bay.

During 2nd year - August 2015 to July 2016:

The mean surface seawater temperature ranged from 27.7 to 30.4°C at all the study areas. The difference of salinity ranged from 32.72 to 34.47 ppt recorded might be attributed to the rainfall followed by runoff in these regions. The concentration of hydrogen ions (pH) varied between stations and it was 7.3 at Pongibalu to 7.5 in Rifleman and Jolly Buoy Island.

Plate 20: Monitoring of spawning period



Lobophyllia hemprichii (Ehrenberg, 1834)

Lobophyllia hemprichii (Ehrenberg, 1834)

Acropora muricata (Linnaeus, 1758)

Acropora muricata (Linnaeus, 1758)

Table 12: Physio-chemical Parameters in seawater of South Andaman

Sl. No.	Area	Temp. (°C)	Salinity (ppt)	pH	Transparency (m)	Turbidity (NTU)	Intertidal exposure (m)
1.	Pongibalu	30.2	32.72	7.4	10.12	360	30
2.	Rifleman Island	28.0	32.90	7.3	10.85	310	00
3.	Jolly Buoy Island	27.7	34.47	7.5	13.54	185	20
4.	North Bay	30.4	33.64	7.3	6.5	720	40

The transparency ranged from 6.5 m at North Bay to 13.54 m at Jolly Buoy Island. The Nudson Turbidity Unit (NTU) was minimum (185) at Jolly Buoy Island and maximum (720) at North Bay area. The intertidal exposures of all the four study areas are same as it was recorded during last year.

During Final or 3rd year - August 2016 to July 2017:

The mean surface seawater temperature ranged from 28.2 to 29.3°C at all the study areas. The difference of salinity ranged from 32.56 to 34.34 ppt recorded might be attributed to the rainfall followed by runoff in these regions. The concentration of hydrogen ions (pH) varied between stations and it was 7.3 at Pongibalu to 7.6 in Jolly Buoy Island.

Table 13: Physio-chemical Parameters in seawater of South Andaman

Sl. No.	Area	Temp. (°C)	Salinity (ppt)	pH	Transparency (m)	Turbidity (NTU)	Intertidal exposure (m)
1.	Pongibalu	29.2	32.56	7.5	10.18	350	30
2.	Rifleman Island	28.5	32.71	7.5	11.5	290	00
3.	Jolly Buoy Island	28.2	34.34	7.6	13.8	170	20
4.	North Bay	29.3	33.51	7.3	7.1	690	40

The transparency ranged from 7.1 m at North Bay to 13.8 m at Jolly Buoy Island. The Nudson Turbidity Unit (NTU) was minimum (170) at Jolly Buoy Island and maximum (690) at North Bay area. The intertidal exposures of all the four study areas are same as it was recorded during last 2 year.

6. RESULTS OF ACADEMIC IMPORTANCE

(1) Species identification:

A total of 346 species of scleractinian corals belonging to 71 genera and 15 families were reported from the three study sites of South Andaman during the surveys period. Among them the family Acroporidae is dominant as it represented by 90 species of scleractinians. A total of 330 species of scleractinian corals were reported from Pongibalu, Rifleman Island, Jolly Buoy Island and adjoining areas of South Andaman while North Bay represented 128 species of scleractinian corals.

(2) Knowledge on coral reproduction and recruitment

The data acquired from the present project will be providing the knowledge on reproductive pattern, larval development, settlement, recruitment and growth of scleracinian corals in Indian waters. As of now no such details on these aspects are available in Indian context.

7. RESULTS OF PRACTICAL IMPORTANCE

(1) Status survey on Scleractinian corals
Scleractinian corals are Schedule-I animal under IW(P) Act, 1972. The status of the scleractinian corals were also monitored during the project work.

(2) Preparation of Management Action Plan
The data on the scleractinian corals obtained through the project can be utilized for the preparation of management action plan as well as enforcement of effective conservation.

(3) Capacity Building Programme
Training on the coral recruitment and transplantation study and survey and monitoring techniques of corals adopted for this study will be useful to enhance the reef areas wherever the status of coral is poor.

(4) Development of Reef areas
New reef areas can be developed with the knowledge of reproductive biology and successful transplantation method. Broken parts of the scleractinian corals can be used for the formation of coral garden in a new area.

(5) Resilience against coral damage
The studies on the growth and regeneration pattern of scleractinian corals will be a helpful to understand the general resilience biology of the corals which will be helpful to make conservatory measures against the nature and anthropogenic damages of live coral reef structures.

8. PUBLICATIONS

10 papers were published while preparation of manuscript is under progress.

9. STATEMENTS

(i) Statement by PI with reference to overall performance and attainment of the objectives of the project

An overall performance made in the project is satisfactory and objectives of the projects being achieved as scheduled.

(ii) Any other information(s) related to the project work

The project work was carried out successfully.

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Signature of the PI

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