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On the growth of newly settled corals on concrete substrates in coral reefs of Pandan and Setan Islands, West Sumatera, Indonesia

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Indra Junaidi Zakaria

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Zusammenfassung

Die Küste West Sumatras erstreckt sich von 00,00° bis 01,30° S und 98,00° bis 101,25° O. Generell ist der Zustand der Korallenriffe schlecht. Lediglich ein Standort ist in sehr gutem Zustand (4%), wohingegen 22% in schlechtem Zustand und 74% sogar hochgradig geschädigt sind. Vor einigen Inseln gibt es nur noch vereinzelt Korallen. Gründe dafür sind Fischerei mit Explosivstoffen und Giften, rücksichtsloses Ankern, Sedimentation, Industrieabwässer, das Sammeln von Korallen als Souvenirs und eine Reihe von natürlichen Ereignissen, die zu Schädigungen führen, u.a. die Effekte des El Niños in 1997.

Es gab eine Reihe von Anstrengungen von den indonesischen Provinz- und Zentralregierungen, bis hin zu gemeinsamen Aktionen mit den Nachbarländern, um Maßnahmen zum Schutz und zur Rehabilitation der west-sumatraischen Riffe einzuleiten. Die Fischerei mit Explosivstoffen ist seit 1993 durch ein Gesetz des Gouverneurs (Nr 04/IST/GSB/1993) verboten. Bestandsaufnahme, Forschung und Monitoring der Korallenriffbedingungen werden seit 1993 gemeinsam vom Zentrum für Fischereistudien (PSPP), Knotenpunkt 1 Sumatra des indonesischen Korallenriffverbandes (Simpul 1 IACRS) und dem Zentrum für marine Tropenökologie in Bremen (ZMT) durchgeführt. Daraus entstand später die Zusammenarbeit mit der Asiatischen Enwicklungsbankprojekt COREMAP (Coral Reef Monitoring and Management Project) der Weltbank, und die Errichtung eines Korallenriff Trainings und Informationszentrums wurde in Angriff genommen.

In Ergänzung der oben aufgeführten Maßnahmen wurden Forschungsarbeiten zur natürlichen Wiederbesiedlung durch Korallen in West Sumatra weitergeführt. Von den Ergebnissen erhoffen wir uns, dass die Ansiedlung lebender Korallen mit Hilfe von Zementsubstraten beschleunigt werden kann. Diese Korallen sollen dann zur Rehabilitation der inselnahen Riffe eingesetzt werden sowie für Korallenfarmvorhaben zum Zwecke des Handels mit Zierorganismen.

Die vorliegende Studie über die Ansiedlung von Steinkorallen verwendete Zementsubstrate (20 x 20 x 2 Zentimeter) und wurde zwischen Februar 2000 und Januar 2002 in den Korallenriffen der Inseln Pandan (100° 8`16,91“ E und 0° 55`55,51“ S) und Setan 100° 22`51,74“ E und 1° 08`09,13“ S) durchgeführt. Sechs Metallständer mit einer Größe von 50 x 50 Zentimeter an der Oberseite und 60 x 60 Zentimeter an der Unterseite sowie einer Gesamthöhe von 50 Zentimeter wurden konstruiert, an die die Substrate mit Draht befestigt wurden. Sie wurden in flachem Wasser ausgebracht (5 m Tiefe).

Nach jeweils einem, drei, zwölf und vierundzwanzig Monaten wurden einzelne Substrate (jeweils drei Replikate) entnommen und untersucht. Alle Kolonien, die sich angesiedelt hatten, wurden gezählt und die Gattung oder Art wurde bestimmt.

Bei 16 Arten von adulten Korallen aus sechs Familien wurde außerdem der Reifegrad bestimmt und der zeitliche Verlauf der sexuellen Reproduktion verfolgt. Die folgenden Parameter wurden festgehalten: Anwesenheit von Gonaden, Gonadenindex, Fertilität und Farbe der Gonaden. Zusätzlich wurden Planktonproben herangezogen, um die Anwesenheit von Eiern oder Planulalarven zu beobachten. Beide Untersuchungen ermöglichen das Aufspüren der Beziehungen zwischen der Besiedlung, dem Timing der Reproduktion von reifen Korallen und dem Auftreten von juvenilen Korallen.

Die Gesamtzahl von neuen Korallenkolonien in den **monatlichen** Proben war nach zwei Jahren bei der Insel Setan mit 218 Kolonien deutlich höher als bei Pandan (83 Kolonien). Während des gesamten Untersuchungszeitraum von 24 Monaten wurde Neuansiedlung in 19 Monaten bei Setan registriert, wobei das monatliche Maximum im Juni 2001 mit 30 Kolonien erreicht wurde. Im Gegensatz dazu wurden bei Pandan nur in 14 Monaten Neuansiedlungen registriert, mit einem Maximum im November 2003 (15 Kolonien).

Eine Varianzanalyse (ANOVA mit log-transformierten Daten) der Gesamtzahl von Neuansiedlungen zeigt hochsignifikante Unterschiede hinsichtlich Ort und Monat sowie eine signifikante Interaktion zwischen Ort und Monat.

Die monatlichen Untersuchungen bei Pandan ergaben Ausiedlung von insgesamt sechs Arten aus drei Familien (*Pocillopora damicornis*, *Pocillopora* sp., *Styllopora* sp. (Pocilloporidae), *Acropora* sp., *Montipora aequituberculata* (Acroporidae), *Porites* sp. (Poritidae)) und sowie einige Exemplare, die nicht näher bestimmt werden konnten. Dagegen wurden bei Setan 10 Arten aus sechs Familien (*Pocillopora damicornis*, *Pocillopora* sp., *Styllopora* sp. (Pocilloporidae), *Acropora* sp., *Montipora* sp. (Acroporidae), *Porites* sp. (Poritidae), *Galaxea* sp., *G. fascicularis* (Oculinidae), *Merulina* sp. (Merulinidae), *Platygyra* sp. (Faviidae) und einige nicht zu bestimmende Arten gefunden.

Basierend auf den **dreimonatlichen** Untersuchungen (Jahreszeit) ergab sich eine Gesamtkolonienzahl von 235 auf Setan und 54 auf Pandan. Generell gab es Ansiedlung in allen vier „Jahreszeiten", wobei die meisten in der Zwischensaison II des ersten Jahres registriert wurden (20 Kolonien bei Setan, 8 bei Pandan). In der Zwischensaison I des zweiten Jahres gab es 124 Neuansiedlungen auf Setan und 11 auf Pandan.

Auch hier zeigt die Varianzanalyse signifikante Unterschiede zwischen den Orten und den 3-Monatsintervallen, wohingegen keine signifikante Interaktion zwischen Ort und Jahrezeit gefunden werden konnte.

Die taxonomische Untersuchung der dreimonatlichen Proben ergab für die Insel Pandan sechs Arten aus vier Familien (*P. damicornis*, *Pocillopora* sp. (Pocilloporidae), *Acropora* sp., *M. aequituberculata* (Acroporidae), *Porites* sp. (Poritidae)) und nicht indentifizierte Exemplare. Dagegen waren bei Insel Setan acht Arten aus vier Familien (*P. damicornis*, *Pocillopora* sp., *Styllopora* sp., *Seriatopora* sp. (Pocilloporidae), *Acropora* sp., *Montipora* sp. (Acroporidae), *Porites* sp. (Poritidae)) und nicht identifizierte Exemplare.

Basierend auf der **jährlichen** Probennahme wurden bei Pandan drei Korallenkolonien nach dem ersten und zehn nach dem zweiten Jahr gefunden. Die Werte für Setan sind ähnlich, mit drei Kolonien nach dem ersten und sieben Kolonien nach dem zweiten Jahr. Die durchschnittliche Anzahl von Neuansiedlungen war damit auf Pandan (2.17) höher als auf Setan (1.67). Außerdem war die Ansiedlung im zweiten Jahr (2.83) besser als im ersten Jahr.

Die Varianzanalyse zeigt hier keine signifikanten Unterschiede zwischen Setan und Pandan. Im Gegensatz dazu war der Unterschied zwischen den Jahren hochsignifikant ($p< 0.01$). Die identifizierten Arten bei Pandan waren: *P. damicornis*, *Galaxea* sp., *Acropora* sp., *A. cerealis*, *A. verweyi*, und *M. aequituberculata*. Bei Setan wurden folgende Arten gefunden: *P. damicornis*, *A. cerealis*, *Acropora* sp., *M. scrabicula* (Merulinidae), und *Leptoseris* sp. (Agariciidae).

Die mittleren Ansiedlungen nach **zwei Jahren Exposition** bei Setan (5.67 Kolonien) waren nicht signifikant höher als bei Pandan (1.67). Hier ergab die Artbestimmung bei Pandan: *P. damicornis*, *P. verrucosa*, *A. cerealis*, and *M. aequituberculata*, und für Setan: *P. damicornis*, *Leptoseris* sp, *M. scrabicula, A. cerealis*, und *P. verrucosa*.

Die monatliche Gesamtdichte von Kolonien, die sich über den Zeitraum von zwei Jahren ansiedelten, variierte zwischen 0.00 und 52.33 Kolonien m^{-2} bei Pandan und 0.00 und 107.17 Kolonien m^{-2} bei Setan. Bei den Dreimonatsproben ergaben sich folgende Dichten: 3.47 – 138.19 Kolonien m^{-2} für Pandan und 6.95 – 159.72 Kolonien m^{-2} für Setan. Im Vergleich dazu ergab die jährliche Probennahme 10.42 Kolonien m^{-2} (Pandan erstes Jahr) und 34.72 Kolonien m^{-2} (Pandan zweites Jahr), sowie bei Setan 10.42 (erstes Jahr) und 24.31 Kolonien m^{-2} (zweites Jahr). Die Untersuchung nach insgesamt zwei Jahren Exposition ergab 17.36 Kolonien m^{-2} für Pandan und 59.03 Kolonien m^{-2} für Setan.

Es wird vermutet, dass jeweils die adulten Korallen vor Ort die Quelle für die Rekrutierung der neuen Korallen auf den Substraten waren. Diese Vermutung stützt sich auf die Übereinstimmung im Timing mit dem Reifen der Gonaden der Adulten (Gonaden Index II und III) von 16 Arten, die in der Nähe der Untersuchungsstandorte vorkamen (*A. cerealis*, *A. donei*, *A.*

gemnifera, *A. nana*, *A. nasuta*, *A. robusta*, *A. sarmentosa*, *A. verweyi, Astreopora myrophtalma*, *Favia speciosa*, *Galaxea asrtreata*, *Hydnopora microconos*, *Porites lobata*, *P. lutea*, *P. damicornis*, und *P. verrucosa*). Außerdem erfolgte die Ansiedlung genau zu dem Zeitpunkt, an dem die Korallen der Umgebung Eier produzierten bzw. Planula Larven in der Wassersäule gefunden wurden.

Die ozeanographischen Parameter (Temperatur an der Wasseroberfläche und an Boden, Transparenz, Sedimentation, pH und Salinität) und Regenfall waren während des Untersuchungszeitraums innerhalb der Toleranzwerte für Korallengemeinschaften und hatten, mit Aushnahmen des Regenfalls in Pandan, keine signifikanten Einfluss auf die Ansiedlung von korralen auf den künstlichen Substraten.

Summary

West Sumateran waters are located between 00^{O} 00’ to 01^{O} 30 ‘ S and 98^{O} 00’ to 101^{O} 25’ E. The general conditions of its coral reefs are poor. Only one location of the total reef area is in a very good (4%), but 22 % are in a bad state, and 74 % are highly damaged**.** On several islands there are only few living corals present. Reasons for these conditions are fishing by explosives and poison, careless anchoring, sedimentation, industrial waste, sampling of corals for souvenirs**,** and various natural events causing damage, e.g. effects of El Niño in 1997.

Many efforts have been attempted by the Indonesian’s state and local governments, even joint efforts with foreign government agencies have set up measures of preservation and rehabilitation of West Sumatra coral reefs. Fishing with explosives has been banned by Governor’s Instruction No. 04/SNT/GSB/1993. Inventory research and monitoring of coral reef conditions have been jointly performed by PSPP (Centre for Fisheries Studies) of the Bung Hatta University of Padang, Simpul 1 Region Sumatra (Indonesian Association Coral Reef Studies) and ZMT (Centre for Tropical Marine Ecology) Bremen, Germany since 1993. Later, the participation in the World Bank/ADB projects COREMAP (Coral Reef Monitoring and Management Project) and the establishment of a Coral Reef Information and Training Centre (CRITC) were offered.

Aside from the above-mentioned efforts, research on coral colonization in its natural habitat is continued in West Sumatra. From the results of the research, we hope that resettlement of living corals by means of concrete substrates can be realised. The resettled corals will then be used in rehabilitation of damaged coral reefs oft West Sumatra and for projects on culturing for ornamentals from coral farming.

The study on colonization of scleractinian corals using concrete substrates (20 x 20 x 2 cm) at coral reefs of Pandan (100^{o} 8’ 16.91” E and 0^{o} 55’ 55.51 S) and Setan Islands (100^{o} 22’ 51.74“ E and 1^{o} 07’ 09.13“ S) was conducted from February 2000 to January 2002. Six metal racks with a size of 50 x 50 cm at the top and 60 x 60 cm at the bottom as well as 50 cm total height were constructed to hold the substrates by wire. They were deployed at shallow waters (in 5 m depth).

Every month, every three months, and after one year, and after two years individual substrates (three replicates) were removed and investigated. The analysiz included counts of total coral colonies and determination of coral species or genera, which settled on the substrates.

Sexual maturation and the timing of reproduction were identified in 16 species of adult corals from 6 families. The following parameters were recorded: presence of gonads, Gonad Index, fecundity, and colour of gonads. In addition, plankton samples were used to monitor the occurrence of eggs and planulae of corals. Both observations allowed for detecting relationships between coral settlement, the timing of the reproduction of mature corals, and the presence of juvenile corals.

The total number of settled coral colonies in the **monthly** samples after two years was greater at Setan Island (218 colonies) than at Pandan Island (83 colonies). Colonies settled during 19 months at Setan Island, where maximum settlement rates occurred in June 2001 (30 colonies). At Pandan Island, new colonies established during 14 months, maximum monhtly settlement rates were found in November 2000 (15 colonies).

The analysis of variance (ANOVA) of the total number of coral colonies settled on the substrates with log (x +1) transformed data, shows highly significant differences between locations and months as well as a highly significant interaction between locations and months ($p < 0.01$).

At Pandan Island, that there were six species from three families (*Pocillopora damicornis*, *Pocillopora* sp., *Styllopora* sp. (Pocilloporidae), *Acropora* sp., *Montipora aequituberculata* (Acroporidae), *Porites* sp. (Poritidae)), as well as several unidentified species. At Setan Island, there were ten species from six families (*P. damicornis*, *Pocillopora* sp., *Styllopora* sp. (Pocilloporidae), *Acropora* sp., *Montiora* sp. (Acroporidae), *Porites* sp. (Poritidae), *Galaxea* sp., *G. fascicularis* (Oculinidae), *Merulina* sp. (Merulinidae), *Platygyra* sp. (Faviidae)), and unidentified species.

Based on the sampling **every three months (seasons)**, the total number of coral colonies settlements at Setan Island was 235 colonies and 54 colonies at Pandan Island. The settlements of coral colonies generally occurred in all seasons at both locations. Maximum settlement was recorded in the intermediate season II of the first year of investigation (20 colonies for Setan Island and 8 colonies for Pandan Island) and in the intermediate season I (124 colonies for Setan Island and 11 colonies for Pandan Island) and II (46 colonies for Setan Island and 11 colonies for Pandan Island) of the second year of investigation.

The analysis of variance of the total number of coral colonies settled on the substrates with log (x + 1) transformed data, shows significant differences between locations and three-month periods (seasons) ($p < 0.05$) but no significant interaction between locations and three-month periods.

At Pandan Island, six species from four families (*P. damicornis*, *Pocillopora* sp. (Pocilloporidae), *Acropora* sp., *M. aequituberculata* (Acroporidae), *Porites* sp. (Family Poritidae)), and unidentified species were recorded. Meanwhile, At Setan Island, eight species from four families (*P. damicornis*, *Pocillopora* sp., *Styllopora* sp., *Seriatopora* sp. (Pocilloporidae), Ac*ropora* sp., *Montipora* sp. (Acroporidae), *Porites* sp. (Poritidae)), and unidentified species occured.

In the samples taken **every year**, there were three coral colonies settling on the substrates after the first year and 10 coral colonies after the second year at Pandan Island. At Setan Island, there were three colonies after the first year and seven colonies after the second year. The mean number of coral settlements at Pandan Island (2.17 colonies) was higher than at Setan Island (1.67 colonies). In addition, the settling of coral colonies after the second year (2.83 colonies) was greater than after the first year of investigation.

The analysis of variance shows that the settling of coral colonies on the substrates did not differ between Pandan and Setan ($p > 0.05$), whereas the difference between years was highly significant ($p < 0.01$).

The species found at Pandan Island were *P. damicornis*, *Galaxea* sp., *Acropora* sp., *A. cerealis*, *A. verweyi*, dan *M. aequituberculata*, whereas at Setan Island, there were *P. damicornis*, *A. cerealis*, *Acropora* sp., *M. scrabicula* (Merulinidae), and *Leptoseris* sp. (Agariciidae).

The means of coral colonies settlements **after two years at** Setan Island (5.67 colonies) were not significantly higher than at Pandan Island (1.67 colonies). The species found at Pandan Island were *P. damicornis*, *P. verrucosa*, *A. cerealis*, and *M. aequituberculata*, whereas at Setan Island, there were *P. damicornis*, *Leptoseris* sp., *M. scrabicula, A. cerealis*, and *P. verrucosa*.

The monthly total density of coral colonies which settled over the two years sampling period ranged between 0.00 and 52.33 colonies.m^{-2} at Pandan Island and 0.00 and 107.17 colonies.m^{-2} at Setan Island. The total density of coral colonies that settled during three-month periods (seasons) varied between 3.47 and 138.19 colonies.m^{-2} at Pandan Island and 6.95 and 159.72 colonies.m^{-2} at Setan Island. Based on investigations every year total density of coral colonies at Pandan Island were 10.42 colonies.m^{-2} (first year) and 34.72 colonies.m^{-2} (second year), whereas at Setan Island, 10.42 colonies.m^{-2} (first year) and 24.31 colonies.m^{-2} (second year). The investigation after two years resulted in total densities of coral colonies of 17.36 colonies.m^{-2} at Pandan Island and of 59.03 colonies.m^{-2} at Setan Island.

The adult corals that lived in each location probably were the source of the coral colonies, which settled on the concrete substrates at the both locations. This assumption is based on the similarity between the timing of reproduction of adult corals (with Gonad Index II and III) from

16 species, which were present in the vicinity of the experimental sites (*A. cerealis*, *A. donei*, *A. gemnifera*, *A. nana*, *A. nasuta*, *A. robusta*, *A. sarmentosa*, *A. verweyi, Astreopora myrophtalma*, *Favia speciosa*, *Galaxea asrtreata*, *Hydnopora microconos*, *Porites lobata*, *P. lutea*, *P. damicornis*, and *P. verrucosa*). In addition, the settlement occurred in both locations when surrounding corals produced eggs or planulae larvae were found in the water column.

Oceanographic parameters (sea surface and bottom temperature, transparency, sedimentation, pH, and salinity) and rainfall did not show any extreme values during this study at both locations and generally did not significantly influence the growth of coral communities. Only rainfall had a significant positive on the coral settlement at Pandan Island.

Ringkasan

Perairan Sumatera Barat terletak antara 00^o 00' sampai 01^o 30 ' Lintang Selatan dan 98^o 00' sampai 101^o 25' Bujur Timur, yang secara umum kondisi terumbu karangnya telah rusak. Hanya satu lokasi yang sangat bagus kondisinya (4%), kemudian 22 % dalam kondisi yang buruk dan 74 % dalam kondisi yang rusak, bahkan beberapa pulau hanya beberapa persen saja karang hidup ditemui. Penyebab kerusakan ini adalah penggunaan bom dan racun dalam pengangkapan ikan, labuh jangkar sembarangan di atas terumbu karang, sedimentasi, limbah industri dan pengambilan karang untuk soufenir serta beberapa pengaruh yang diakibatkan oleh dan perubahan alami, seperti efek El-Nino.

Telah banyak usaha dilakukan untuk melindungi serta memperbaiki kondisi ini baik oleh pemerintah Indonesia maupun pemerintah daerah Propinsi Sumatera Barat. Melarang menangkap ikan dengan bahan peledak (Instruksi Gubernur No. 04/SNT/GSB/1983). Kerjasama lembaga Perguruan Tinggi Universitas Bung Hatta (PSPP) dengan Simpul 1 Wilayah Sumatra (Kelompok Studi Terumbu Karang Indonesia) dan ZMT (Centre for Tropical Marine Ecology) Bremen, Jerman sejak tahun 1993. Kemudian bantuan Bank Dunia/ADB melalui proyek COREMAP (Coral Reef Monitoring and Management Project) dan mendirikan Pusat Informasi dan Pelatihan Terumbu Karang (CRITC).

Selain dari kegiatan tersebut, dilakukan penelitian (studi) menumbuhkan karang di atas subtrat buatan dengan harapan karang yang tumbuh dapat digunakan untuk memperbaiki terumbu karang yang rusak. Kemudian juga diharapkan dapat dipakai sebagai salah satu acuan untuk kegiatan budidaya karang sebagai pengganti usaha pengambilan karang untuk soufenir.

Studi tentang menumbuhkan karang ini menggunakan subtrat buatan dari semen (20 x 20 x 2 cm), dilakukan di perairan terumbu karang Pulau Pandan (0^o 55' 55.51 Lintang Selatan dan 100^o 8' 16.91" Bujur Timur) dan Pulau Setan (1^o 07' 09.13" Lintang Selatan dan100^o 22' 51.74" Bujur Timur) dari bulan Februari 2000 sampai Januari 2002. Tiga buah rak besi dengan ukuran 50 x 50 cm bagian atas dan 60 x 60 cm bagian bawah dengan tinggi 50 cm digunakan sebagai tempat untuk mengikatkan subtrat buatan yang diletakan di dasar perairan pada kedalaman 5 meter. Sekali sebulan, sekali tiga bulan atau berdasarkan periode musiman, sekali satu tahun dalam periode 2 tahun dan setelah dua tahun, setiap individu substrat dengan tiga buah ulangan diambil dan diamati. Pengamatan yang dilakukan adalah jumlah koloni karang, jenis atau genus karang serta jenis organisme lain yang menempel di subtrat. Untuk menduga karang yang menempel di substrat buatan berasal dari hasil reproduksi karang dewasa di sekitar perairan penelitian, dilakukan pengamatan reproduksi 16 species karang dewasa dari 6 famili yang dianggap mewakili species yang ada, dengan parameter kehadiran gonad, tingkat kematangan gonad, warna gonad dan jumlah fekunditas, serta pengambilan sample plankton dengan mengindentifikasi kehadiran telur dan planula karang, yang kesemuanya dilakukan setiap bulan.

Jumlah keseluruhan koloni karang yang menempel di subtrat buatan pengamatan **setiap bulan** dari tiga buah ulangan (0.288 m^2) setelah dua tahun di Pulau Setan, yaitu 218 koloni lebih banyak dibandingkan dengan Pulau Pandan dengan jumlah 83 koloni. Dari total 24 bulan pengamatan, di Pulau Setan koloni karang menempel sebanyak 19 bulan, dengan penempelan terbanyak terjadi pada bulan Agustus 2000 (25 koloni) dan bulan Juni 2001 (30 koloni). Sedangkan di Pulau Pandan koloni karang terjadi sebanyak 14 bulan, dengan penempelan terbanyak terjadi pada bulan Nopember 2000 tahun pertama penelitian, yaitu15 koloni dan bulan Mei, September serta Nopember 2001 tahun kedua penelitian sebanyak enam koloni.

Berdasarkan analisis varian (ANAVA) letak lokasi penelitian, bulan yang berbeda serta interaksi antara letak lokasi dengan bulan yang berbeda memberikan pengaruh sangat nyata terhadap penempelan koloni karang disubstrat buatan ($p < 0.01$).

Ada enam spesies dari tiga famili yang ditemukan menempel di subtrat buatan yang di tanam di perairan Pulau Pandan, yaitu: *Pocillopora damicornis*, *Pocillopora* sp., *Stylopora* sp. (Famili Pocilloporidae), *Acropora* sp., *Montipora aequituberculata* (Famili Acroporidae), *Porites* sp. (Famili Poritidae), dan beberapa species yang tidak dapat diidentifikasi (spesies tidak teridentifikasi). Sedangkan di Pulau Setan ditemukan sepuluh spesies dari enam Famili, yaitu: *P. damicornis*, *Pocillopora* sp., *Styllopora* sp. (Pocilloporidae), *Acropora* sp., *Montiora* sp. (Acroporidae), *Porites* sp. (Poritidae), *Galaxea* sp., *G. fascicularis* (Oculinidae), *Merulina* sp. (Merulinidae), *Platygyra* sp. (Faviidae) dan spesies tidak teridentifikasi.

Berdasarkan pengamatan **sekali tiga bulan (setiap musim)**, jumlah keseluruhan koloni karang menempel di Pulau Setan setelah dua tahun sebanyak 235 koloni juga lebih banyak dibandingkan dengan Pulau Pandan, dimana jumlah koloni karang menempel 54 koloni. Secara umum penempelan koloni karang terjadi disetiap musim di kedua lokasi penelitian, tetapi penempelan terbanyak terjadi pada musim pancaroba II di tahun pertama penelitian dan pada musim pancaroba I serta II di tahun kedua penelitian.

Hasil analisis varian menunjukan perbedaan letak lokasi penelitian dan perbedaan musim memberikan pengaruh yang nyata bagi penempelan koloni karang ($p < 0.05$). Sedangkan interaksi antara letak lokasi penelitian dan perbedaan musim tidak berbeda nyata ($p > 0.05$).

Pengamatan berdasarkan musim ini, di Pulau Pandan ditemukan lima spesies dari tiga famili yang menempel, yaitu: *P. damicornis*, *Pocillopora* sp. (Famili Pocilloporidae), *Acropora* sp., M. *aequituberculata* (Famili Acroporidae), *Porites* sp. (Famili Poritidae) and spesies tidak teridentifikasi. Sedangkan di Pulau Setan ditemukan delapan spesies yang juga berasal dari empat famili, yaitu: *P. damicornis*, *Pocillopora* sp., *Styllopora* sp., *Seriatopora* sp. (Pocilloporidae), *Acropora* sp., *Montipora* sp. (Acroporidae), *Porites* sp. (Poritidae) and spesies tidak teridentifikasi.

Selanjutnya pengamatan **tiap tahun**, di Pulau Pandan jumlah koloni karang menempel adalah tiga koloni ditahun pertama dan 10 coloni di tahun kedua. Sementara di Pulau Setan sebanyak tiga koloni di tahun pertama dan tujuh koloni ditahun kedua.

Berdasarkan analisis varian hanya pengamatan tiap tahun yang memberikan pengaruh sangat nyata terhadap penempelan koloni karang ($p < 0.01$). Sedangkan lokasi pulau dan interaksi antara lokasi pulau dan tiap tahun pengamatan tidak berbeda nyata ($p > 0.05$).

Spesies yang ditemukan di Pulau Padan adalah: *P. damicornis*, *Galaxea* sp., *Acropora* sp., *A. cerealis*, *A. verweyi* dan *M. aequituberculata*. Sementara di Pulau Setan, yaitu: *P. damicornis*, *A. cerealis*, *Acropora* sp., *M. scrabicula* (Merulinidae) dan *Leptoseris* sp. (Agariciidae).

Berdasarkan analisis t-test, meskipun jumlah koloni yang ditemukan di Pulau Setan (17 koloni) **setelah dua tahun** pengamatan lebih banyak di bandingkan dengan Pulau Pandan (lima koloni), ternyata tidak ada perbedaan yang yata antara kedua lokasi tersebut ($p > 0.05$). Sementara spesies yang ditemukan di Pulau Padan adalah: *P. damicornis*, *P. verrucosa*, *A. cerealis* dan *M. aequituberculata* dan di Pulau Setan, yaitu: *P. damicornis*, *Leptoseris* sp., *M. scrabicula, A. cerealis* dan *P. verrucosa*.

Total kepadatan dari koloni karang yang menempel di substrat buatan dengan pengamatan setiap bulan berkisar antara 0.00 – 52.33 koloni.m^{-2} di Pulau Pandan dan 0.00 – 107.17 koloni.m^{-2} di Pulau Setan. Kemudian total kepadatan koloni karang yang menempel, yang diamati setiap tiga bulan sekali (setiap musim) berkisar antara 3.47 – 38.19 koloni.m^{-2} di Pulau Pandan dan 6.95 – 159.72 koloni.m^{-2} di Pulau Setan. Selanjutnya pengamatan setiap tahun sekali, total kepadatan koloni karang yang menempel di Pulau Pandan adalah 10.42 koloni m^{-2} di tahun pertama dan 34.72 m^{-2} di tahun kedua penelitian. Sedangkan di Pulau Setan di temukan 10.42 koloni m^{-2} di tahun pertama dan 24.31 koloni m^{-2} di tahun kedua. Terakhir, dari hasil pengamatan setelah dua tahun total kepadatan koloni karang yang menempel adalah 17.36 koloni m^{-2} di Pulau Pandan dan 59.03 koloni m^{-2} di Pulau Setan.

Pada umumnya spesies karang yang menempel pada permukaan substrat di Pulau Pandan lebih panjang dan lebih lebar serta mempunyai laju pertumbuhan yang lebih tinggi dibandingkan dengan species karang yang menempel pada substrat buatan di Pulau Setan.

Koloni karang yang menempel pada permukaan subtrat buatan di kedua lokasi penelitian, induknya diduga berasal dari karang dewasa yang ada di kedua lokasi penelitian tersebut. Hal ini didasarkan kesamaan waktu penempelan karang dengan waktu reproduksi (dengan GI II dan III) dari 16 spesies karang dewasa yang mewakilli (*A. cerealis*, *A. donei*, *A. gemnifera*, *A. nana*, *A. nasuta*, *A. robusta*, *A. sarmentosa*, *A. verweyi, Astreopora myrophtalma*, *Favia speciosa*, *Galaxea asrtreata Hydnopora microconos Porites lobata*, *P. lutea*, *P. damicornis* dan *P. verrucosa*) serta ditemukannya planula dan telur di perairan lokasi penelitian ini.

Parameter oseanografi yang meliputi: suhu permukaan dan suhu dasar perairan, tingkat kecerahan, sediment, pH dan Salinitas, di kedua lokasi penelitian di pengaruhi oleh curah hujan selama penelitian ini masih dalam batas normal kehidupan dan pertumbuhan karang. Hanya curah hujan yang mempengaruhi proses penempelan koloni karang di substrat buatan di Pulau Pandan.

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Contents

Introduction

1.1 Introduction to the problem

West Sumatera waters in Indonesia are located between 00^{O} 00' to 01^{O} 30 ' S and 98^{O} 00' E to 101^{O} 25' E. The general conditions of its coral reefs are poor. Only one location of the total reef area is in very good (4%), but 22 % are in good to average condition, and 74 % are bad or even highly damaged (Kunzmann and Efendi, 1994; Kunzmann, 1997; own direct observations from 1998 to now, Kunzmann, 2002). On several islands there are only few living corals present. Reasons for these conditions are fishing by explosives and poison, careless anchoring, sedimentation, industrial wastes (Kunzmann, 1998; Kunzmann, 2002), and collecting corals for souvenirs (Efendi and Syarif, 1995), and raw material for buildings (Zakaria, 1999). Various natural events also causing damage are, e.g. effects of El Nino in 1997 (Wiratno, 1998; Dahuri et al., 2001).

Many efforts have been attempted by the Indonesian's state and local governments, even joint efforts with foreign government agencies have set up measures of preservation and rehabilitation of West Sumatera coral reefs. Fishing with explosives has been banned by Governor's Instruction No. 04/INT/GSB/1993. Inventory research and monitoring of coral reef conditions have been jointly performed by PSPP (Centre for Fisheries Studies) Bung Hatta University of Padang, Simpul 1 Region Sumatera (Indonesian Association Coral Reef Studies) and ZMT (Centre for Tropical Marine Ecology) Bremen, Germany since 1993 (Kunzmann, 1998). Later on, the participation in the Worldbank/ADB project COREMAP (Coral Reef Monitoring and Management Project) and the establishment of a Coral Reef Information and Training Centre (CRITC) were offered (Zakaria, 2001; Kunzmann, 2002) to PSPP.

Aside from the above mentioned efforts, research on coral resettlement in its natural habitat is continued in West Sumatera. Recruits of natural corals are partly replanted as seed for rehabilitation of locations with dead coral reefs.

Settlement can also occur on concrete (artificial) substrate. According to research done by Van Moorsel (1988), Fisk and Harriott (1990), English et al., (1994), Harriott and Banks (1995), Maida et al., (1995), Oren and Benayahu (1997), Abrar (1997), Mundy (2000), concrete substrate can be successfully implanted in a location with dead coral reefs.

The growth of corals highly depend on the season (Yap and Gomez, 1981; Wallace and Bull, 1981), and abiotic factors such as light, tides, temperature, salinity, and sedimentation (Fisk, 1982; Hunte and Wittenberg, 1992; Miller, 1995; Riegl et al., 1996). Other factors are also involved but could not be investigated in this thesis.

1.2 Background information

Ecosystem and anthropogenic use

A coral reef is an ecosystem, which has important functions and roles for marine biodiversity and for economical development of people or communities, which live at coastal areas (Suharsono, 1996). Various kinds of marine organisms, which are utilized by humans such as molluscs, crustaceans, echinoderms, fishes, and seaweed live and develop in this ecosystem (Sukarno, 1993; Carol and Parsons, 1997; Nontji, 2000; Dahuri et al., 2001).

Coral reefs with plentiful resources have been used for long times by local people for food supply. Besides that coral reefs supplied medical resources and served as knowledge resource (Sukarno, 1993; Suharsono, 1996).

In West Sumatera, Indonesia, most of the people live in coastal areas. Generally they depend on fishery for living, which is performed in shallow waters and coral reefs. Besides fishing ground, coral reefs, especially corals are taken for souvenirs and as raw material for building. According to Kunzmann and Efendi (1994), Kunzmann (1997), Kunzmann (1998), and Zakaria (2001), however, these coral reefs have been more or less destroyed.

Destroyed coral reefs can recover naturally or by engineering processes (Veron, 1993; English et al., 1994; Nontji, 2001). The natural process can be supplemented by preservation of coral reefs, such as conservation measures to make sure that people exploit it in a reasonable way.

Some rules to preserve coral reef ecosystems are provided by the International Union for Natural Resources (IUCN) in 1982. There it was stated that the coral reef ecosystem, as typical of tropical zones, should be a protected ecosystem. The Indonesian government has constituted Marine Protected Areas (MPA) and Marine Parks (MP) with an area of 28 000 km^2 until 1998, and wants to achieve around 300 000 km^2 of marine protected areas until 2000 (Kunzmann, 1998). According to Governor Instruction No. 04/SNT7GSB/1993 the local Government (Pemerintah Propinsi) of West Sumatera has prohibited fishery activities which are using explosives.

Reestablishment of coral reefs can be achieved by several methods. One is to provide colonies of corals to the destroyed habitat by colonisable substrates. After attachment of young corals on artificial substrates, these can be placed in an area of a destroyed coral reef or even without a coral reef at all, if that area provides suitable conditions for coral survival (Fisk and Harriot, 1990; Clark and Edwards, 1994).

Reproduction of corals

Coral colonization of coral free areas can occur by dispersal of larvae during sexual reproduction or fragments during asexual reproduction (Suharsono, 1984; Veron, 1993; Rinkevich, 1996; Birkeland, 1997).

Corals are true colonies, made up of hundreds to thousands of interconnected polyps. Colonies grow through the asexual process of budding, during which new polyps are generated. Additional polyps can be formed when one polyp divides into two (intratentacular budding), or sometimes a new mouth with tentacles can simply form in the space between two adjacent polyps (extratentacular budding). If the polyps and tissues formed by these asexual processes remain attached to the parent colony, the result is considered growth and is seen as an increase in colony size. If polyps or buds become detached from the parent colony this can give rise to a new colony (Richmond, 1987; Richmond and Hunter, 1990).

New coral colonies can be formed asexually in several ways. Fragmentation is common among finely branched or relatively thin plating corals (Highsmith, 1982). Coral fragments, including the underlying skeleton, may become detached from parent colonies as a result of wave action, storm surge, fish predation, or other sources of physical impact. If a fragment lands on solid bottom, it may fuse to the surface and continue to grow through budding (Knowlton et al., 1981).

Sexual reproduction offers two opportunities for new genetic combination to occur: (1) crossing over during meiosis in the formation of eggs and sperm, and (2) the genetic contribution of two different parents when eggs are fertilized by sperm. These serve to add genetic variation to populations, which may lead to enhanced survival of a species. In corals, the resulting embryo develops into a ciliated planula larva. Planulae are particularly well adapted for dispersal and can seed the reef of origin, nearby reefs, or reefs hundreds of kilometres away (Richmond, 1987; Richmond and Hunter, 1990).

The types of sexual reproduction of coral have several modes, namely: gonochorism, hermaphroditism, brooding, spawning, self-fertilization, outcrossing, and hybridisation. If a species has separate males producing sperm and females producing eggs, it is said to be gonochoric. If, however, a single individual of a species is capable of producing both eggs and sperm, it is said to be hermaphroditic. According to Harrison and Wallace (1990) approximately 25% of the coral species studied to date (e.g. species of *Porites* and *Galaxea*) are gonochoric.

Furthermore Rinkevich and Loya (1979b) and Kojis and Quin (1981) reported that most acroporids, faviids, some pocilloporids, *Styllophora pistilata* and *Goniastrea favulus* are hermaphrodites.

Coral display two distinct modes of sexual reproduction that differ in the way the gametes come into contact with each other. In brooding species, eggs are fertilized internally, with the embryo developing to the planula stage inside the coral polyp. Alternatively, spawning species release eggs and sperm into the water column, where subsequent external fertilization and development takes place (Richmond and Hunter, 1990).

In some experiments, it has been shown that sperm do not fertilize eggs from the same colony until 6 hours after release, and even then, observed rates of self-fertilization are less than 10%. The same eggs treated with sperm from another colony of the same species demonstrated fertilizations rates of 70 –100% within 2 hours of gamete release (Heyward and Babcock, 1986; Richmond, 1993).

Laboratory experiments have demonstrated that hybridisation does occur among corals. This has been observed not only among closely related species within the same genus, but across genera (Richmond, 1993, 1995; Willis et al., 1985; Kenyon, 1993). In one case, fertilization of *Acropora digitifera* and *A. gemmifera* was unidirectional. *A. digitifera* can be fertilized by sperm form *A. gemmifera*, but eggs of *A. gemmifera* were not fertilized by *A. digitifera* sperm (Richmond, 1995).

During sexual reproduction a new coral colony may derive from larvae of either planktonic or benthic nature (Bothwell, 1981; Chornesky and Peters, 1987; Harisson and Wallace, 1990; Bermas et al., 1992; Dai et al., 1992; Hayashibara et al., 1993; Veron, 1993; Suharsono, 1996). The dispersal of coral larvae is mainly determined by abiotic factors, such as currents, temperature, light, salinity, and sedimentation (Fisk, 1982; Nybakken, 1988; Harisson and Wallace, 1990; Suharsono, 1996).

Larval development

The planula larvae that develop from brooding and spawning corals are similar in some aspects. They are ciliated, rich in lipids, and have chemoreceptors used for detecting of appropriate substrates for settlement and metamorphosis. The brooded larvae tend to be larger than those developed from spawned gametes. They possess zooxanthellae, and are capable of settling immediately upon release from the parent colony. The smaller larvae that develop from spawning corals require time to reach a stage capable of settlement and metamorphosis. Smaller eggs of the spawning coral genera *Leptoria*, *Goniastrea* and *Montastrea* averaging 350 – 400 µm in diameter, require 18 hours before they become ciliated and capable for settlement, whereas the large eggs of many spawning *Acropora* species take nearly 72 hours to reach the same stage of development (Richmond, 1988).

Larval recruitment

Recruitment of corals on the reef depends on the ability of larvae to identify an appropriate site for settlement and metamorphosis. Settlement of coral larvae is a change from a planktonic existence to a benthic lifestyle, and usually includes attachment to the reef. In order for settled larvae to survive and develop into young corals, they must settle at an appropriate location. The criteria for appropriate sites include substratum type, water motion, salinity, adequate sunlight for zooxanthellae, limited sediment deposition, and sometimes specific algal species or biological films of diatoms and bacteria (Birkeland, 1977).

Metamorphosis is a developmental process during which a larva undergoes a series of morphological and biochemical changes while completing the transformation to the benthic juvenile stage (Pawlik and Hadfield, 1990; Richmond, 1988).

During metamorphosis, a commitment is made to the settlement site. A calcified basal plate is secreted along with the first skeletal cup, and tentacles complete with stinging cells known as nematocysts form, surrounding the mouth. A new coral colony will develop from this first or primary polyp through growth, budding and continued calcification (Richmond, 1988).

Abiotic factors

Coral reefs are generally restricted to waters being never below 18^{o}C and not exceeding 36^{o}C, with an optimal range of 26 – 29^{o}C. This is expressed in latitudinal patterns of coral reef distribution and diversity (Miller, 1995; Suharsono, 1996; Birkerland, 1997). Within this range, certain corals will grow faster or slower, depending of temperature. Drastic thermal shifts can result in reduced coral vitality (e.g., bleaching, reproduction inhibition) or, in extreme instances, total destruction of entire reef systems (Birkeland, 1997).

The other limiting factor of growth of corals is salinity. Corals as well as coral reefs are limited to areas of reasonably normal marine salinity (32 – 35), but they can grow at a high levels of salinity (42) (Nybakken, 1988; Birkerland, 1977). Below these levels, carbonate secretion is progressively dominated by vermetids, oysters, serpulids, and cyanobacteria. Low salinity (and turbidity) is a primary reason why extensive corals reefs do not occur in the vicinity of major rivers mouths (e.g. the Amazon and Orinoco rivers of northern South America discharge into seas that are otherwise suitable for reef development) (Birkeland, 1997).

It is known that sedimentation is an important factor controlling coral growth and thus reef development (Hubbard, 1986; Rogers, 1990). Sedimentation can interfere with corals directly by influencing growth rates (Hubbard and Scaturo, 1985), metabolism (Dalmeyer et al., 1982) and fecundity (Tomascik and Sanders, 1985), as well as by causing histopathological damage (Peters and Pilson, 1985); it can also interfere indirectly, at the population level, by either reducing of facilitating larval settlement (Rogers et al., 1984; Te, 1992; Hunte and Wittenberg, 1992).

In Indonesia shallow water habitats are influenced during different seasons, which are rainy season (November - January), intermediate season I (February – April), dry season (May – July), and intermediate season II (August – October). According to Yap and Gomez (1981) and Wallace and Bull (1981) coral growth and dispersal is strongly influenced by seasonal changes.

In addition to physico-chemical parameters of the seawater available, suitable substrate is another factor, which determines the establishment of new coral colonies. Skeletons of dead corals or calcareous shells of molluscs are naturally appropriate substrates for attachment of coral larvae. Natural substrate is very limited at shores or islands where a coral reef has been destroyed (Bothwell, 1982). In order to provide such substrate, artificial ones with similar conditions to a natural substrate (iron, concrete, cement, and plastic), can be offered. In several studies a concrete substrate fulfilled these criteria (Van Moorsel, 1988; Fisk and Harriott, 1990; English et al., 1994; Abrar, 1997; Oren and Benayahu, 1997; Mundy, 2000).

1.3 Hypotheses and objectives

From the provided background, the following hypotheses shall be tested:

1. Coral attachment on an artificial substrate is influenced by:
   (a) month
   (b) season
   (c) geography and condition of settlement area (influenced by sedimentation and freshwater from river discharge to those without this influence).
2. Sexual reproduction of different coral species is influenced by seasons.

3. Juvenile corals found in specific areas are expected offspring of mature corals in that region.

To test these hypotheses the following objectives are to be considered:

a. To investigate the effects of different months and seasons and the effect of different locations (close to the mainland and far from the mainland) on coral settlement and growth.

b. To identify the species or genera of corals, which settle, grow and reproduce on two different coral reef locations in different months and seasons.

c. To find out whether settlement, growth and reproduction on two different coral reef locations are related to each other.

d. To find out exact timing of gonad presence, gonad index, fecundity, and colour of gonad of corals.

e. To detect relationships between coral settlement with the timing of maturation and the presence of juvenile corals.

1.4 Expected use of results

From the results of the research, we hope that resettlement of living corals by means of concrete substrates can be realised. The resettled living corals will then be used in rehabilitation of damaged coral reefs in the waters of the islands near West Sumatera and is of use for projects on mariculture of ornamentals, particularly coral farming.

2. Materials and Methods

2.1 Study site

The investigations were performed in the waters of West Sumatera (Sumatera), Indonesia, at the following locations: Setan Island (about 10.57 miles southwest of Padang, or 0.5 miles southwest of Sumatera Island) and Pandan Island, which is 12.72 miles west of Sumatera mainland (Plate 2.1 and 2.2; Figure 2.1). This research was carried out within two years (February 2000 to January 2002).

Setan Island is located 1° 07' 09.13" S and 100° 22' 51.74" E and belongs to the subdistrict of Bungus Teluk Kabung, Padang, West Sumatera, Indonesia. The size of Setan is 645.4 m^2 and 114.5 m circumference. The shallow area of coral reefs is about 1000 m^2. Setan Island is situated close to Sumatera mainland (a cove island) and strongly influenced by the Sungai Pisang river and Sungai Pisang settlement (2000 inhabitants). A variety of coral species grows around the island. At the northern and western side of Setan Island several species of seaweeds are growing. Furthermore, on the eastern and southern side little mangrove bushes were found. Several species of molluscs and bivalves occur around this island. In addition, 47 species of reef fish were recorded from 13 Families, among them; *Cromis margaritifer* (Caesionidae), *Thalasoma luanare* (Labridae), *Hemiochus acuminatus*, Lutjanidae, Nemipteridae, and Serranidae (Yunaldi, 2000).

The location of Pandan Island is at 0° 55' 55.51" S and 100° 8' 16.91" E belongs to the subdistrict of Padang Barat, Padang, West Sumatera, Indonesia. Pandan (an oceanic island) with a size of 1557 m^2 and 1476 m circumference is one of the more distant islands within the Padang archipelago, and therefore less influenced by river discharge and anthropogenic disturbance. Pandan is well suited for this type of research, because a large variety of coral species grows around the island and there is only little anthropogenic influence. The percentage of living corals and their diversity is high and the surrounding area of coral reef is 4070 m^2. The island has sandy beaches all around.

Plate 2.1: Pandan Island

Plate 2.2. Setan Island

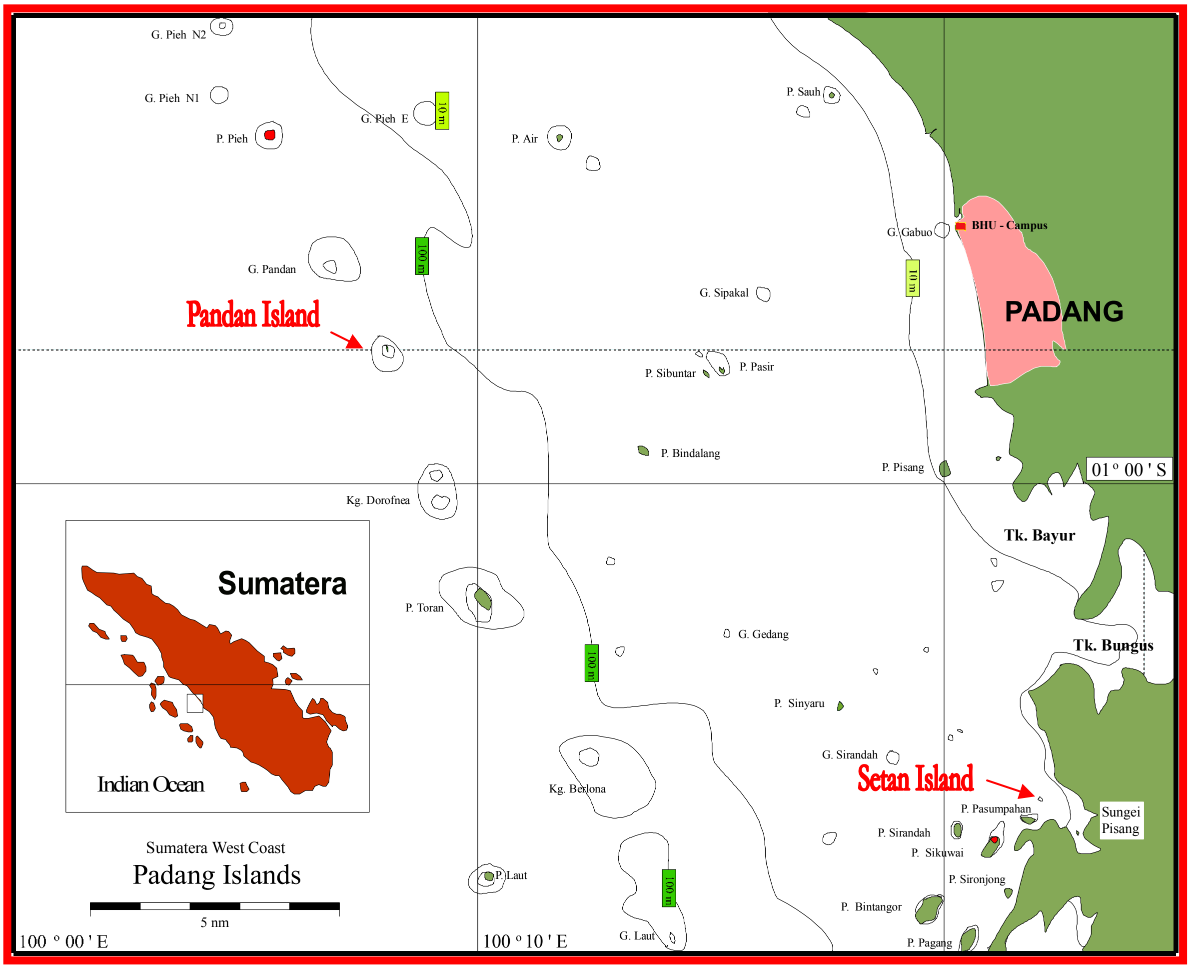


Figure 2.1: Research locations (Pandan and Setan Islands, map from Kunzmann and Zimmermann, 1993)

2.2 Materials and instruments

Following recommendations from previous works, (Van Moorsel 1988; Fisk and Harriott 1990; English et al. 1994; Harriott and Banks 1995; Maida et al. 1995; Oren and Benayahu 1997) 170 concrete plates of 20 x 20 x 2 cm size were used for settlement of juvenile corals. Six metal racks with a size of 50 x 50 cm at the top and 60 x 60 cm at the bottom as well as 50 cm total height (Plate 2.3) were deployed to hold the substrates attached by wire. These sizes were chosen so that the substrates were attached in an oblique 75° angle to the coral reefs. This position seemed to be beneficial for juvenile corals to settle on all surfaces of the concrete substrates. In order to follow sexual maturation and to investigate possible periodicity in reproduction preservation with formaldehyde, formic acid and seawater was used.

Plate 2.3: Metal racks holding the concrete substrates attached by wire and a small sediment trap in the center

For transport to the islands the boat "Porites" (12.5 m length, 3 m wide, and 120 HP engine) had been rented. For Scuba and skin diving the necessary equipment as well as slate, pencil and labelling material for substrates and adult corals was used. Laboratory analysis included binocular microscopy as well as pictures taken by a photo camera (Canon). Water quality analysis was done by refractometer, secchi disk, pH-meter, and alcohol thermometer. UW documentation was performed with an underwater photo camera (Nikonos). Sediment traps were utilized for sediment collection, plankton nets (mouth opening of 25 cm, 200 μm mesh size), for collections of plankton, eggs and planulae of corals larvae. Rainfall data were taken from the office of Meteorology and Geophysics, Tabing, Padang, West Sumatera, Indonesia.

2.3 Research methods

2.3.1 Direct survey on research locations

Newly settled corals on the deployed substrates were monitored in regular time intervals. In addition, potential synchronous spawning events in mature corals and the occurrence of planulae in the water column were observed in order to predict settlement of coral larvae.

a. Growth of newly settled corals on concrete substrates in coral reefs

To analyse the newly settled corals on the substrates, samples were taken every month, every three months, and every year over two years. A randomised factorial (A x B) design with three replicates was used in those data to estimate the difference of total number of coral colonies settlements. For the monthly samples, Factor A is observation by month, namely (A1 to A24) monthly observation for 2 years. Factor B is island locations, namely (B1) an island close to Sumatera or a cove island (Setan Island) and (B2) an island far away from Sumatera or an oceanic island (Pandan Island). For the three months samples, Factor A is observation every three months, namely (A1 to A8) 3-monthly observation for 2 years. These short periods are necessary to cover the different seasons (see chapter 1). Factor B is again island locations, (B1) and (B2). For the yearly samples over two years, Factor A is observation by year, namely (A1) and (A2) the first and second yearly observation for 2 years. Factor B is again island locations. Data on the observation after 2 years using t-test with two samples (island locations) and three replicates (concrete substrates) was used.

The artificial substrates in both locations are concrete substrates placed at 5 m depth and attached to the metal racks. The depth of 5 m ensures growth of several coral species, because sun light penetration for photosynthesis is ideal (Maida et al., 1995; Hunte and Wittenberg, 1992). In addition damage by e. g fishermen is relatively limited.

The exact location for the deployment of the substrates on the island was determined visually based on the condition of the coral reef, by means of a Manta-tow and subsequent line transects. Criteria for the location included percent of coral reef cover (> 25 %) and species diversity (> 15 different species). For placing the substrates Scuba diving was used.

At each location, three racks were placed with 5 m space between them. On each rack the substrates were fixed with wire (Plate 2.1). Exact positions at Pandan east were 00º 57‘ 01” S and 100º 08’ 34” E (Rack I), 00º 57‘ 01” S and 100º 08’ 33” E (Rack II), 00º 57‘ 01” S and 100º 08’ 32” E (Rack III). At Setan west the respective locations were 01º 07‘ 08” S and 100º 22’ 45” E for Rack I, 01º 07‘ 09” S and 100º 22’ 44” E for Rack II and 01º 07‘ 08” S and 100º 22’ 43” E for Rack III.

Every month, every three months, and every year over a sampling period of two years (February 2000 to January 2002) individual substrates have been removed and investigated. After removal the substrates were replaced with new ones. After removal and investigation of individual substrates was done on the next month after collection of mature coral tissue and plankton samples for juvenile coral. One of the substrates was not taken up for two years but the colony diameters were recorded regularly and identified only at the end of the experiment.

b. Collection of mature coral tissue.

Every month tissue samples of adult corals (> 15 cm diameter) from 16 dominant species were taken to follow sexual maturation and to investigate possible periodicity in reproduction. Colonies of 16 dominant species (three parallel samples) were tagged and tissue samples were collected three days before full moon. A similar method was used by Dai et al. (1992) to predict the timing of maturing and spawning for some coral species.

From branching corals, 3 - 5 cm long branches were collected. From massive corals, live tissue and skeleton with approximately 10 cm^2 in surface area were removed with a hammer and chisel. From each species three parallel samples were obtained and preserved in 10% formaldehyde-seawater for 24 hours. Then the tissue samples of adult corals were submerged in 8 % formic acid for 48 hours for decalcification (Dai et al., 1992; Shlesinger et al., 1998).

c. Plankton samples for eggs and planulae

Plankton samples were taken regularly to monitor the occurrence of eggs and planulae of corals on three or four days after the full moon. According to Richmond and Hunter (1990), Dai et al. (1992), Shimoike et al. (1992), Stobart et al. (1992) and McGuire (1998) the timing of spawning for some coral species can be accurately predicted from the lunar cycle, because gametes generally are released several days after the full moon.

Plankton samples were taken vertically and horizontally with a plankton net (diameter of 25 cm and a mesh size of 200 μm). For preserving of samples 4 % formaldehyde was used.

d. Oceanographic measurements

Oceanographic measurements as well as amount of sedimentation were checked at every field trip (time 10.00 - 15.00 WIB) with three replicates. Measurements included temperature (sea surface and bottom temperature) (°C) with alcohol thermometer (precisions 0.1), transparency (m) with secchi disk (precisions 0.01 m), pH with pH-meter (precisions 0.1), and salinity with refractometer (precisions 0.1). The type of sediment trap used was a modified type after English et al. (1994) (Plate 2.3).

2.3.2. Laboratory analysis

a. Identification of newly grown corals on the substrates

After removal, the substrates were carefully inspected. Identification was done on species or genus level, total polyps were counted, sizes of colonies were measured, and other species as well as the condition of substrates (dirty or clean) were recorded. Taxonomic identification was based on respective literature Ditlev (1980), Myers and Randall (1983), Veron (1993), and English et al. (1994).

b. Observation of coral maturity

The collected coral tissues were detached from the skeleton using forceps. Thereafter presence of sperm and eggs was verified by microscope / binocular. Moreover egg development (Gonad Index), fecundity (mean eggs/ 5 polyps) and colour of gonads were determined. To monitor the Gonad Index the approach of Rinkevich and Loya (1979a and b), Stoddart and Black (1985), Kruger and Schleyer (1998), Schlesinger et al (1998) was used.

c. Sorting of the plankton net samples

From the plankton samples eggs and planulae were extracted and identified by microscope/binocular. Volumes of samples were 2 x 25 ml.

2.4 Data analysis

a. Total number of coral colonies and coral species on differently exposed substrates

The total number of coral colonies and coral species on differently exposed substrates are the grand total of all samples (replicates, every month, every three months and every year) over a sampling period of two years as well as after two years. To detect differences of conditions between samples ANOVA (analysis of variance) from the SPSS program (Statistical Package for the Social Sciences, version 10.0) was used. After two years the t-tests analysis (Wardlaw, 1985; Steel and Torrie, 1991) was applied.

b. Density of coral colonies, density and relative density of coral species on the substrates

Density of coral colonies and coral species on the substrates were calculated according to Bakus (1990) and Soegianto (1994):

Density of coral colonies (Dc) = Total number of individual coral colonies /Area of substrate ($0.288\ m^2$)

Density of coral species (Ds) = Total number of colonies of one species /Area of substrate ($0.288\ m^2$)

$$\text{Relative Density (RDs)} = \frac{\text{Density of colonies of one species}}{\text{Density of colonies of all species}} \times 100\ \%$$

The area of the concrete plates ($0.288\ m^2$) is the total area on which corals could settle in the three replicates and is derived from 2 x (20 x 20 cm) front and backside and 4 x (20 x 2 cm) edges multiplied by 3 (replicates).

c. Growth of coral species

The analysis of the rate of average growth in this study was focused only on corals species. The rate of average monthly growth of coral species was calculated with the formula:

Growth (G) = Lenght and width of colony (mm) / Time (month)

d. Abundance of eggs and planulae

The samples of eggs and planulae were calculated by direct count methods (Michael, 1984)

$$n = \frac{a.c.}{L}$$

Where : n = total juvenile or eggs / liter

a = average of juveniles or eggs / ml sub sample

c = sub sample volume (ml)

L = volume of filtered water (liter)

e. Oceanographic parameters and rainfall

To detect differences in oceanographic parameters in both locations, ANOVA (analysis of variance) from the SPSS program (Statistical Package for the Social Sciences, version 10.0) was used. Thereafter Spearman-Rank-correlation was applied to explore relationships between rainfall and oceanographic parameters, and between oceanographic parameters.

f. Relationship between oceanographic parameters and rainfall with settlement of coral colonies

To analyse relations between oceanographic parameters (sea surface and bottom temperature, transparency, sedimentation, pH, and salinity), as well as rainfall and of settlement of coral colonies (only for every one months) multi-Regression analysis was used.

3. RESULTS

3.1 Growth of newly settled corals on concrete substrates in coral reefs

3.1.1 Total number of coral colonies and species settlements every month, over a sampling period of two years

Figure 3.1 shows details of the total number of settled coral colonies on three replicates of concrete substrates (0.288 m^2) every month, over a sampling period of two years in both locations. The monthly total number of coral colonies settlements ranged between 0 – 30 colonies at Setan Island and 0 – 15 colonies at Pandan Island. Furthermore, the total numbers of colonies in the monthly samples after two years were 218 colonies at Setan Island and 83 colonies at Pandan Island, respectively. From the total 24 months of investigation, coral colonies only settled during 19 months (February, March, April, May, June, July, August, September, October, November 2000, January, February, June, July, August, September, October, November, and December 2001) at Setan Island, and 14 months (March, August, September, October, November, December 2000, February, March, May, August, September, October, November, and December 2001) at Pandan Island (Figure 3.1). This indicated that the total number of settled colonies at Setan Island is higher than at Pandan Island.

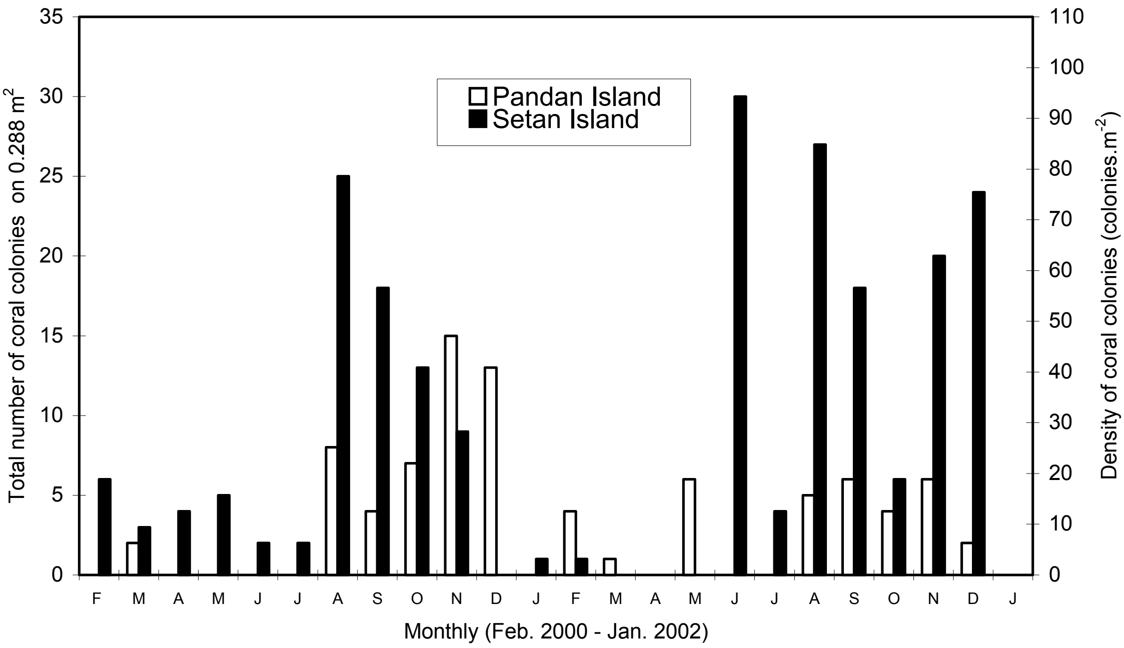


Figure 3.1: Total number (on 0.288 m^2) and density (colonies.m^{-2}) of coral colonies settled on the concrete substrates every month, over a sampling period of two years at Pandan and Setan Islands (Feb. 2000 – Jan. 2002)

It is also evident from Figure 3.1 that most colonies settled at Pandan Island in the period between August and December (complete intermediate season II and the beginning and the middle of the rainy season) for both years of investigation (in November 2000 with 15 colonies and in May, September, and November 2001 with six colonies). Moreover, at Setan Island, settlements occurred in the period of August (25 colonies) to November (complete intermediate season II and the beginning of the rainy season) for the first year of investigation and in June (30 colonies), August, and December for the second year (Figure 3.1).

The analysis of variance (ANOVA) of the total number of coral colonies settled on the substrates with log (x+1) transformation, shows high significant differences among locations, months, and the interaction between locations and months ($p < 0.01$; Table 3.1).

Table 3.1. Two-way ANOVA with log (x+1) transformed of the total number of coral colonies settled on the substrates every month, over a sampling period of two years at Pandan and Setan Islands, ** highly significant, df: degrees of freedom, SS: sum of squares, MS: mean square, p: probability

Source	df	SS	MS	F-value	p-value
Island locations	1	1.07	1.07	15.30**	< 0.01
Months	23	7.45	0.32	4.63**	< 0.01
Island locations * Months	23	3.12	0.14	1.94**	< 0.01
Error	96	6.71	0.07		
Total	144	31.89			

Six species (from three families) were identified during the monthly collections at Pandan Island. These species are *Pocillopora damicornis*, *Pocillopora* sp., *Stylophora* sp. (Family Pocilloporidae), *Acropora* sp., *Montipora aequituberculata* (Family Acroporidae), and *Porites* sp. (Family Poritidae) as well as several species, which could not be identified because of damages and missing references (Figure 3.2). Moreover, ten species from six families and several unidentified species were found on the Setan Island places (Figure 3.3). They are *P. damicornis*, *Pocillopora* sp., *Stylophora* sp. (Pocilloporidae), *Acropora* sp., *Montipora* sp. (Acroporidae), *Porites* sp. (Poritidae), *Galaxea* sp., *G. fascicularis* (Oculinidae), *Merulina* sp. (Merulinidae), *Platygyra* sp. (Faviidae), and unidentified species.

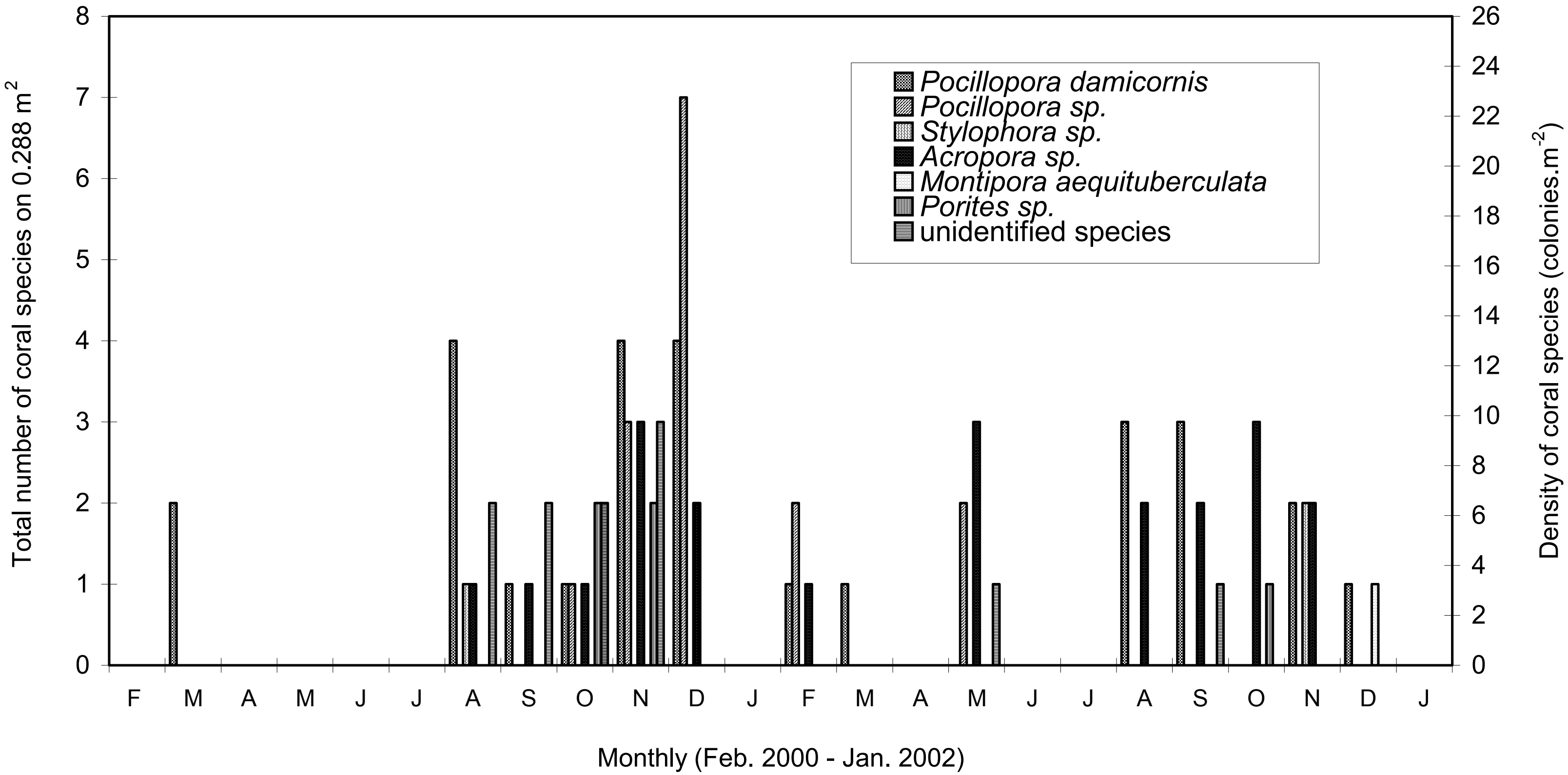


Figure 3.2: Total number (on 0.288 m^2) and density (colonies.m^{-2}) of coral species settled on the concrete substrates every month, over a sampling period of two years at Pandan Island (Feb. 2000 – Jan. 2002)

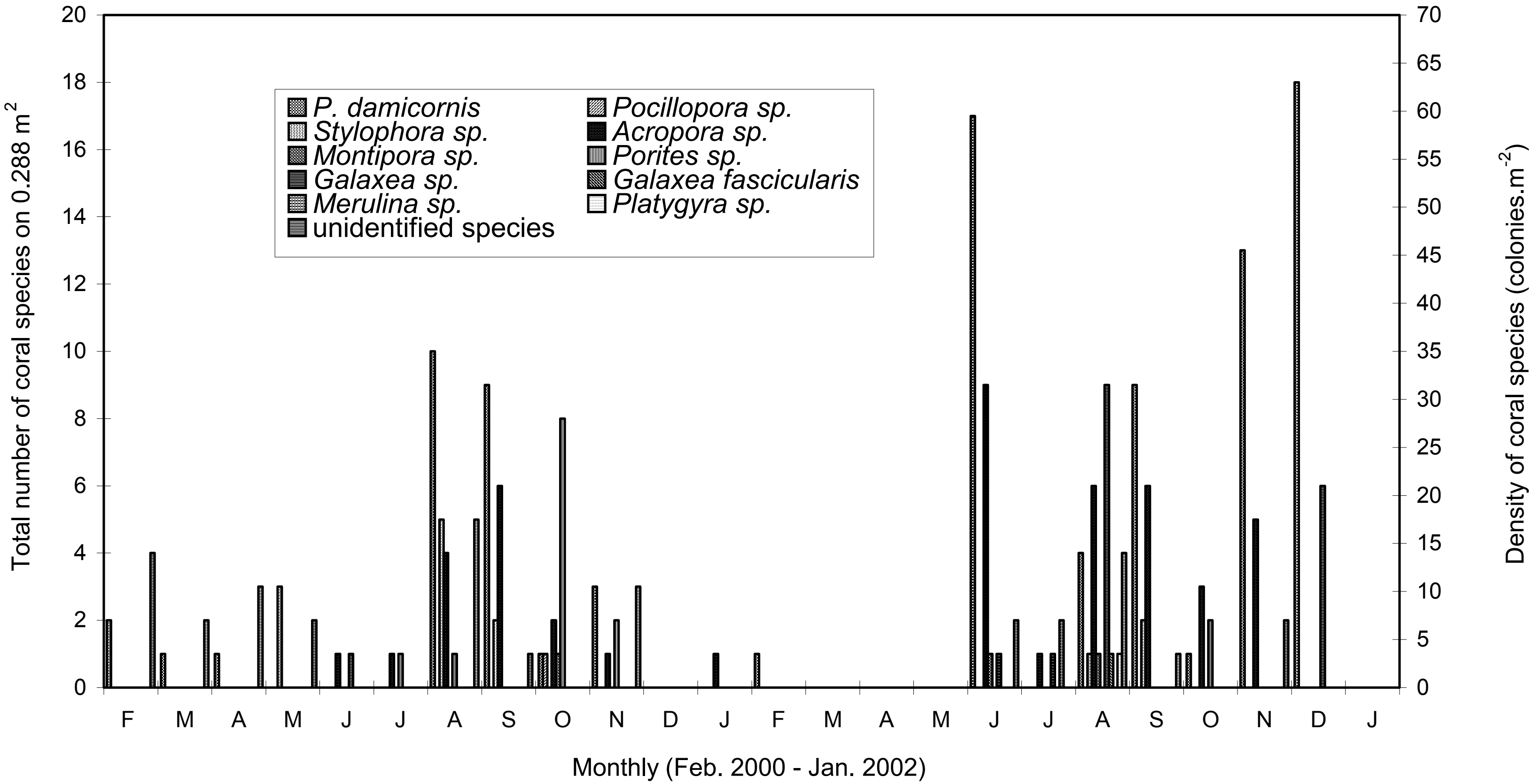


Figure 3.3: Total number (on 0.288 m²) and density (colonies.m⁻²) of coral species settled on the concrete substrates every month, over a sampling period of two years at Setan Island (Feb. 2000 – Jan. 2002)

Figure 3.2 also shows that *P. damicornis* is most abundant followed by *Acropora* sp., *Pocillopora* sp., unidentified species, *Porites* sp., *Stylophora* sp., and *M. aequituberculata*. Like at Pandan Island, *P. damicornis* was most numerous also at Setan Island. *Acropora* sp., unidentified species, *Galaxea* sp., *Porites* sp., *Stylophora* sp., *Montipora* sp., *Merulina* sp., *Platygyra* sp., *Pocillopora* sp., and *G. fascicularis* followed in lesser number (Figure 3.3).

From a total of 24 months of investigation, *P. damicornis* settled during 12 months at Pandan Island and 13 months at Setan Island. This species amounts to 27 colonies at Pandan Island, with four colonies in August, November, and December 2000, one colony in September, October 2000, February, March, and December 2001, three colonies in August and September 2001, and two colonies in March 2000 and November 2001. Meanwhile, at Setan Island, it was found with total of 90 colonies, with two colonies in February 2000, one colony in March, April, October 2000, February, and October 2001, ten in August 2000, nine in September 2000 and 2001, three in November 2000, 17 in June 2001, four in August 2001, 13 in November 2001, and 18 in December 2001

Acropora sp. was found on the substrates in the 11 months period at Pandan Island and during 12 months at Setan Island. At Pandan Island, it grew in one colony in August, September, October 2000, and February 2001, three colonies in November 2000, May, and October 2001, two in December 2000, August, September, and November 2001. For Setan Island, *Acropora* sp. settled with one colony in June, July, November 2000, January, and July 2001, four colonies in August 2000, six in September 2000, August, and September 2001, two in October 2000, nine in June 2001, three in October 2001, and five colonies in November 2001.

Pocillopora sp. was recorded only five months at Pandan Island, whereas at Setan Island, it was two months. The total number of colonies of this species was found to be 15 at Pandan Island, namely: one colony in October 2000, three in November 2000, seven in December 2000, and two in February and May 2001, whereas one colony in October 2000 and August 2001 for Setan Island.

Unidentified species settled during six months at Pandan Island and 11 months at Setan Island. It was two colonies in August, September, and October 2000, three in November 2000, and one colony in May and September 2001 for Pandan Island. Whereas for Setan Island, this species occurred in four colonies in February 2000 as well as August 2001, two in March, May 2000, June, and November 2001, five in August 2000, and one colony in September 2000 and 2001.

Porites sp. settled with two colonies in October and November 2000, and one in October 2001 at Pandan Island, whereas at Setan Island, it was observed with one colony in July and August 2000, eight colonies in October, and two colonies in November and October 2001.

In the case of *Stylophora* sp. only one colony was found in August 2000 and two in November 2001 at Pandan Island and amounted to three colonies in March 2000, five in August, two in September 2000 and 2001, and one colony in August 2001 for Setan Island.

The least numerous species at Pandan Island is *M. aequituberculata,* which was only found in one colony in December 2001.

Other species, which settled only at Setan Island, are *Galaxea* sp., *Montipora* sp., *Merulina* sp., *Platygyra* sp., and *G. fascicularis*. *Galaxea* sp. grew with one colony in June 2000, June, and July 2001, nine colonies in August 2001 and six colonies in December 2001. *Montipora* sp. occurred in one colony in October 2000, June and August 2001. *Merulina* sp. appeared only in two colonies in August 2001. Both *G. fascicularis* and *Platygyra* sp. were found with one colony in October 2000 and August 2001.

3.1.2 Total number of coral colonies and species settlements every three months (seasons), over a sampling period of two years

The results from the three months expositions (seasons), over a sampling period of two years show two to 124 colonies with total of number 235 coral colonies at Setan Island and one to 11 colonies with total number of 54 coral colonies settled at Pandan Island (Figure 3.4). This indicated that the total number of coral colonies settled at Setan Island is much higher than at Pandan Island. Furthermore, it is evident that the settlement of coral colonies generally occurred during all seasons in both locations. However, most started to grow in the intermediate season II of the first year of investigation. In the second year of investigation this changed to the intermediate seasons I and II.

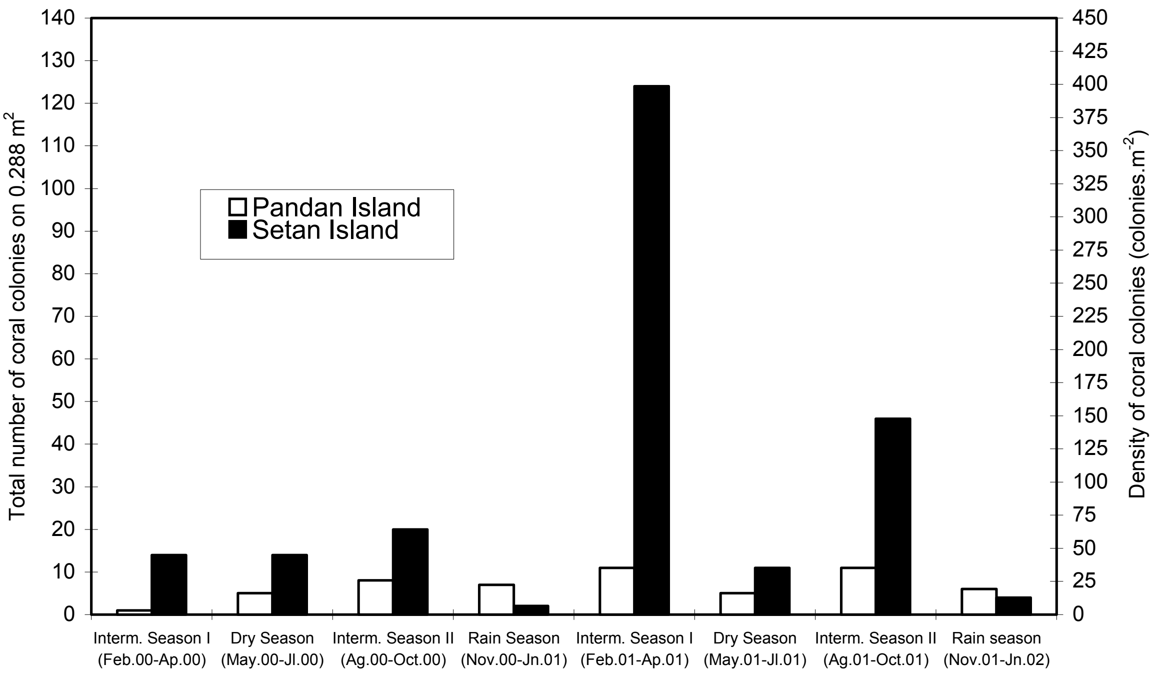


Figure 3.4: Total number (on 0.288 m^2) and density ($colonies.m^{-2}$) of coral colonies settled on the substrates every three months (seasons), over a sampling period of two years at Pandan and Setan Islands (Feb. 2000 – Jan. 2002)

The analysis of variance (ANOVA) on the total number of coral colonies settlements with log (x + 1) transformation, shows significant differences in locations and times ($p < 0.05$), whereas no significant differences on the interaction between locations and times was evident (Table 3.2).

Table 3.2. Two-way ANOVA with log (x+1) transformed of the total number of coral colonies settled on the substrates every three months (season), over a sampling period of two years at Pandan and Setan Islands, *: significant, ns: not significant, df: degrees of freedom, SS: sum of squares, MS: mean square, p: probability

Source	df	SS	MS	F-value	p-value
Island locations	1	1.04	1.04	6.64*	< 0.05
Seasons	7	2.80	0.40	2.55*	< 0.05
Island locations * Seasons	7	0.98	0.14	0.89^{ns}	> 0.05
Error	32	5.03	0.16		
Total	48	24.03			

Sample collections on three month intervals at Pandan Island found five species from three families, which could be identified namely: *P. damicornis*, *Pocillopora* sp. (Family Pocilloporidae), *Acropora* sp., *M. aequituberculata* (Family Acroporidae), *Porites* sp. (Family Poritidae), and several unidentified species (Figure 3.5). Meanwhile, seven species from three families could be identified

(*P. damicornis*, *Pocillopora* sp., *Stylophora* sp., *Seriatopora* sp. (Pocilloporidae), *Acropora* sp., *Montipora* sp. (Acroporidae), and *Porites* sp. (Poritidae)), and several species were not identifiable (unidentified species) at Setan Island (Figure 3.6).

Figure 3.5 shows that *Acropora* sp. at Pandan Island is more abundant than *P. damicornis*, *M. aequituberculata*, unidentified species, *Pocillopora* sp., and *Porites* sp., respectively. At Setan Island, *P. damicornis* was most dominant followed than *Acropora* sp., unidentified species, *Stylophora* sp., *Porites* sp., *Montipora* sp., *Pocillopora* sp., and *Seriatopora* sp., respectively (Figure 3.6).

Acropora sp. settled during seven times at Pandan Island and was absent in the intermediate season I period (February – April 2000), whereas for Setan Island it was present at all times of the investigations. At Pandan Island, this species consisted of 12 colonies; three colonies from the dry season (May – July 2000), five from the intermediate season II (August – October 2000), and four colonies from the rainy season (November 2000 – January 2001) during the first year of observation. Furthermore, 12 additional colonies, with three colonies in each season were detected during the second year of observation. At Setan Island, it consisted in the first year of two colonies in the intermediate season I, four in the dry season, five in the intermediate season II, and one colony in the rainy season, while 26 colonies in the intermediate season I, one colony in the dry season, 18 colonies in the intermediate season II, and the last two colonies in the rainy season were found in the second year.

P. damicornis was recorded in both locations seven times during the seasonal investigation, and was not found in the intermediate season I (February – April 2000) at Pandan Island and in the rainy season (November 2000 – January 2001) at Setan Island. During the first year, it occurred in one colony in the dry season (May – July 2000) and three colonies each in the intermediate season II as well as the rainy season and in all seasons, i.e. seven colonies in the intermediate season I, one colony in the dry season, and two colonies each of the intermediate season II and the rainy season for the second year. This species occurred in 89 colonies alltogether at Setan Island, with two colonies in the intermediate season I, five in the dry season, and seven in the intermediate season II during the first year, and 56 colonies settled in the intermediate season I, two in the dry season, 16 in the intermediate season II, and one colony in the rainy season during the second year.

Unidentified species were obtained only during two seasons at Pandan Island, whereas at Setan Island, they appeared at five time periods. It settled in two colonies in the intermediate season I (February – April 2000), and one colony in the intermediate season II (August – October 2001). In addition, this species was found in the intermediate season I (six colonies) and in the intermediate season II (two colonies) in the first year period. However, during the second year, it occurred in the intermediate season I (18 colonies), the dry season (two colonies), and in the intermediate season II (one colony).

M. aequituberculata occurred in four colonies only at Pandan Island. These were three colonies in the intermediate season I, and one colony in the rainy season. These colonies were found in the second year of investigation.

Pocillopora sp. grew one colony in the intermediate season I in the first and the second year of observation at Pandan Island. Meanwhile, at Setan Island, it settled only in the second year (one colony in the intermediate season I and two colonies in the dry season).

The least numerous species, *Porites* sp., which was present only at Pandan Island, was found with two colonies that settled only in the second year of investigation (in the intermediated season I and II). The total of 18 colonies of *Porites* sp. were recorded in all seasons during both years of investigation.

There are three species which settled only at Setan Island, namely: *Stylophora* sp., *Montipora* sp., and *Seriatopora* sp. *Stylophora* sp. grew as one and 11 colonies in the intermediate season I, one in the dry season, and two and eight colonies in the intermediate season II for both years of observation. *Montipora* sp. presented one colony in the intermediate season I (February – April 2000), two colonies in the dry season (May – July 2000), and one colony in intermediate season I (February – April 2001). The least numerous species, which is *Seriatopora* sp., occurred in two colonies only during the intermediate season II in the first year of observation.

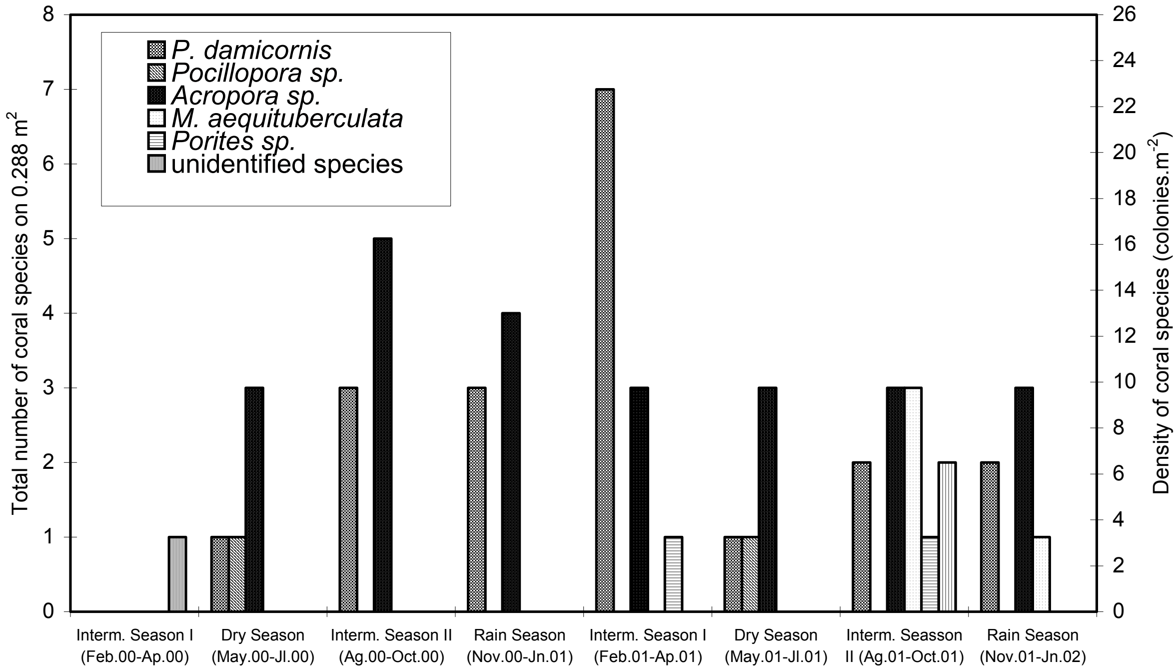


Figure 3.5: Total number (on 0.288 m²) and density (colonies.m⁻²) of coral species settled on the plates every three months (seasons), over a sampling period of two years at Pandan Island (Feb. 2000 – Jan. 2002)

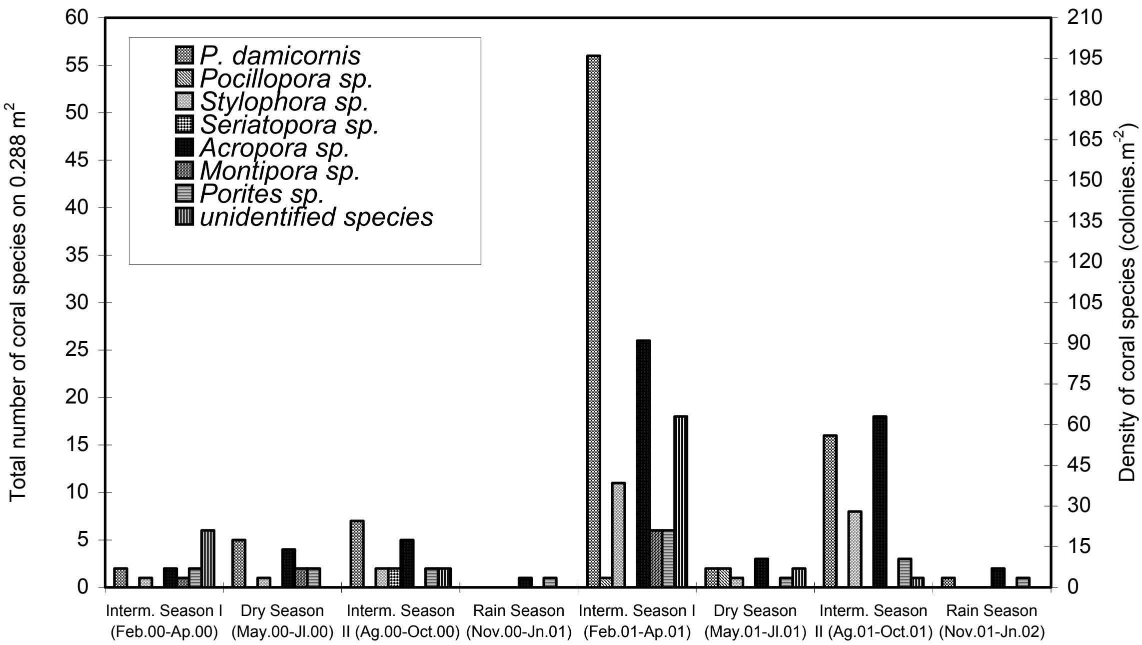


Figure 3.6: Total number (on 0.288 m²) and density (colonies.m⁻²) of coral species settled on the substrates every three months (seasons), over a sampling period of two years at Pandan Island (Feb. 2000 – Jan. 2002)

3.1.3 Total number of coral colonies and species settlements every year, over a sampling period of two years

There were three colonies settling during the first year of investigation and 10 colonies after the second year of observation at Pandan Island. Meanwhile, at Setan Island, three colonies in the first year period and seven colonies for the second year were found (Figure 3.7).

The analysis of variance (Table 3.3) showed that the locations and interaction between the locations and times of observation did not give different effects on the settling of coral colonies on the substrates ($p > 0.05$). However, times of observation showed highly significant effects ($p < 0.01$).

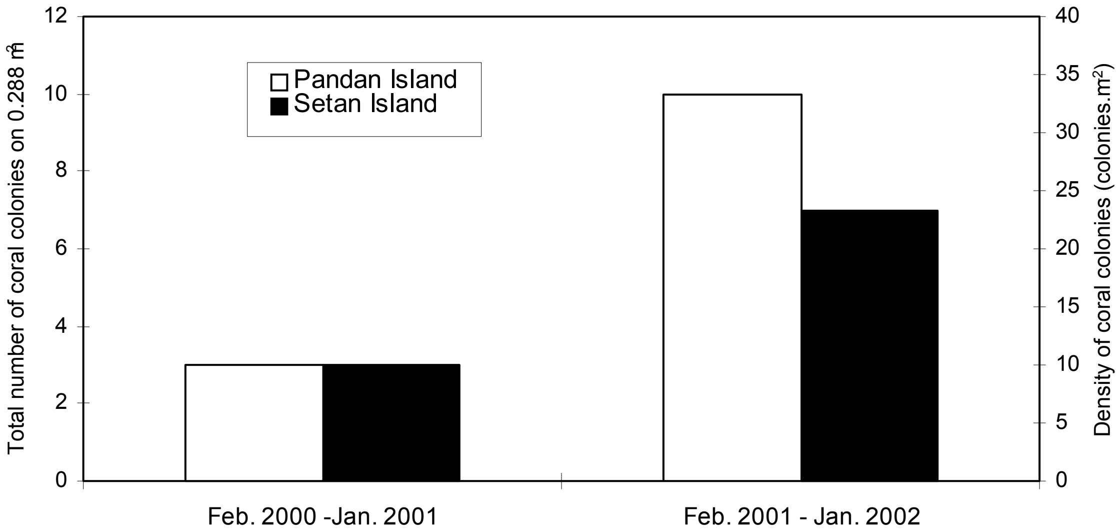


Figure 3.7: Total number (on 0.288 m^2) and density (colonies.m^{-2}) of coral colonies settled on the substrates every year, over a sampling period of two years at Pandan and Setand Islands (Feb. 2000 – Jan. 2002)

Table 3.3. Two-way ANOVA of the total number of coral colonies settled on the substrates every year, over a sampling period of two years at Pandan and Setan Islands,** : highly significant, ns: not significant, df: degrees of freedom, SS: sum of squares, MS: mean square, p: probability

Source	df	SS	MS	F-value	p-Value
Island Location	1	0.75	0.75	1.13^{ns}	> 0.05
Years	1	10.08	10.08	15.13**	< 0.01
Island Location*years	1	0.75	0.75	1.13^{ns}	> 0.05
Error	8	5.33	0.67		
Total	12	61.00			

Although the locations of research between Pandan and Setan Islands have no different effects in the settling of coral colonies on the substrates, the mean quantitative value at Pandan

Island (2.17 colonies) is much higher than at Setan Island (1.67 colonies) (See Appendix 1, Table A.1.1). In addition, the settling of coral colonies after the second year of observation (2.83 colonies) is greater than after the first year of observation (one colony). The highest mean settlement occurred at Pandan Island after the second year (3.33 colonies), while the lowest was found at Pandan and Setan Islands after the first year (one colony) (See Appendix 1, Table A.1.2 and A.1.3).

After the first year of investigation at Pandan Island, two specimens of *P. damicornis* and one specimen of *Galaxea* sp. were identified, while after the second year period, two of both *P. damicornis* and *Acropora* sp., one of both *A. cerealis* and *A. verweyi*, and four of *M. aequituberculata*, respectively were detected (Figure 3.8).

During the first year at Setan Island, three colonies of *P. damicornis* were obtained, while for the second year, three of *P. damicornis* and one colony of all five *A. cerealis, Acropora* sp., *Merulina scrabicula* (Merulinidae), and *Leptoseris* sp. (Agariciidae), respectively were found (Figure 3.9).

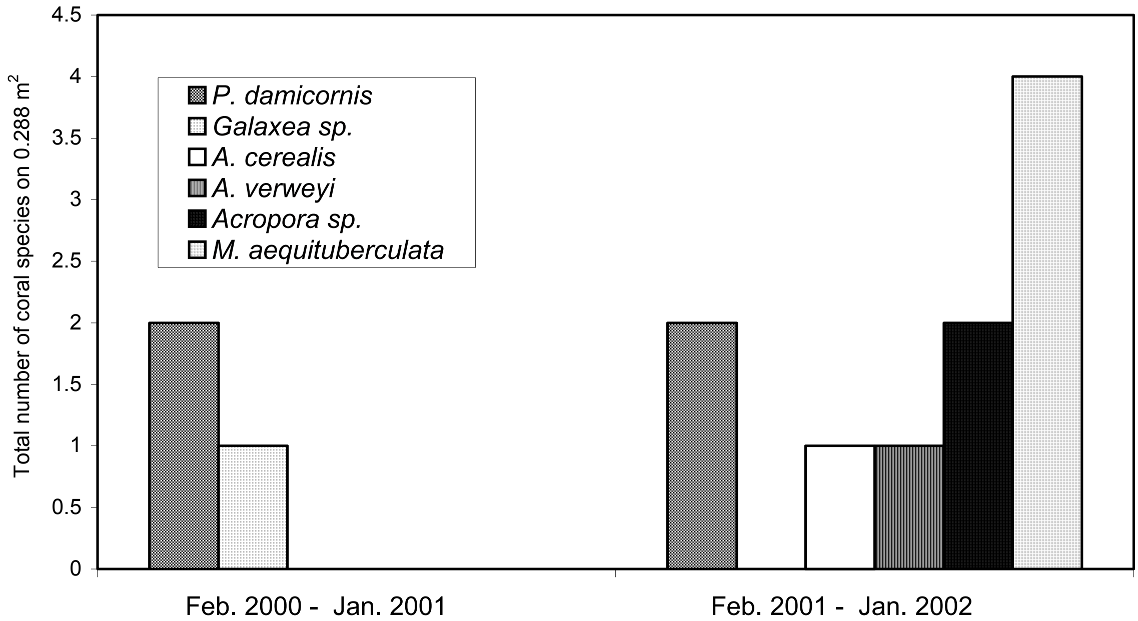


Figure 3.8: Total number of coral species settled on the substrates (0.288 m^2) every year, over a sampling period of two years at Pandan Island (Feb. 2000 – Jan. 2002)

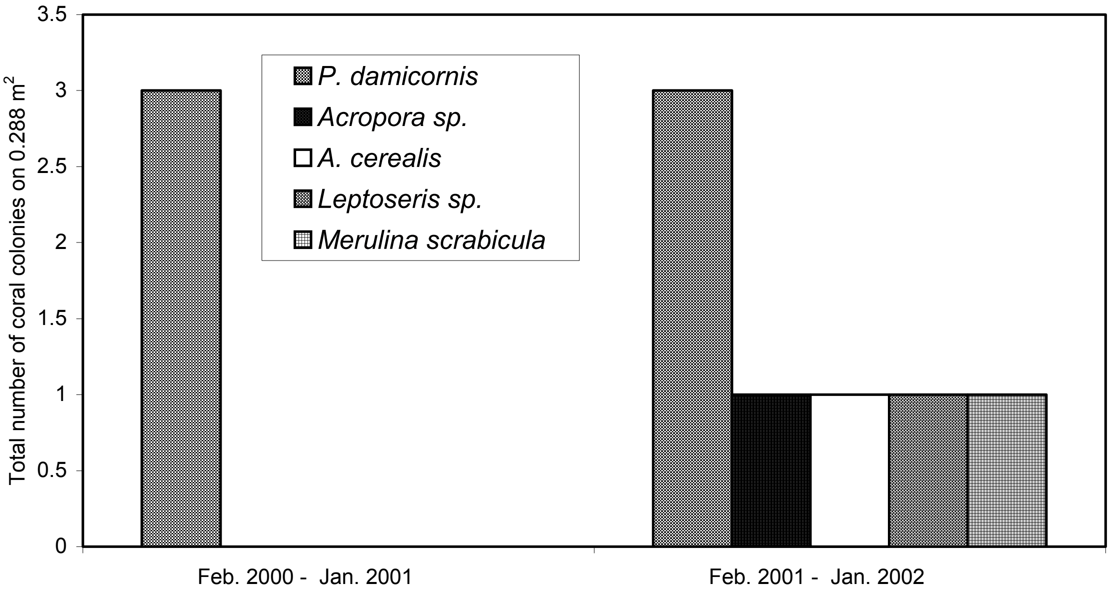


Figure 3.9: Total number of coral species settled on the substrates (0.288 m^2) every year, over a sampling period of two years at Setan Island (Feb. 2000 – Jan. 2002)

3.1.4 Total number of coral colonies and species settlements after two years

Five colonies from four species at Pandan Island and 17 colonies from five species at Setan Island were detected after two years of investigation (Figure 3.10). The species found at Pandan Island consisted of *P. damicornis* (two colonies) and *P. verrucosa*, *A. cerealis*, and *M. aequituberculata* (one colony each). Moreover, *P. damicornis* (ten colonies), *Leptoseris* sp., *Merulina scrabicula*, and *A. cerealis* (two colonies each) as well as *P. verrucosa* (one colony) were identified at Setan Island (Figure 3.11). Quantitatively, *P. damicornis* is more abundant than all other species in both locations.

Although the result of independent sample t-test (see Appendix A.1, Table A.1.4) gave no significant difference ($p > 0.05$), the mean coral colonies settlements after two years at Setan Island (5.67 colonies) were higher than at Pandan Island (1.67 colonies) (see Appendix A1, Table A.1.5).

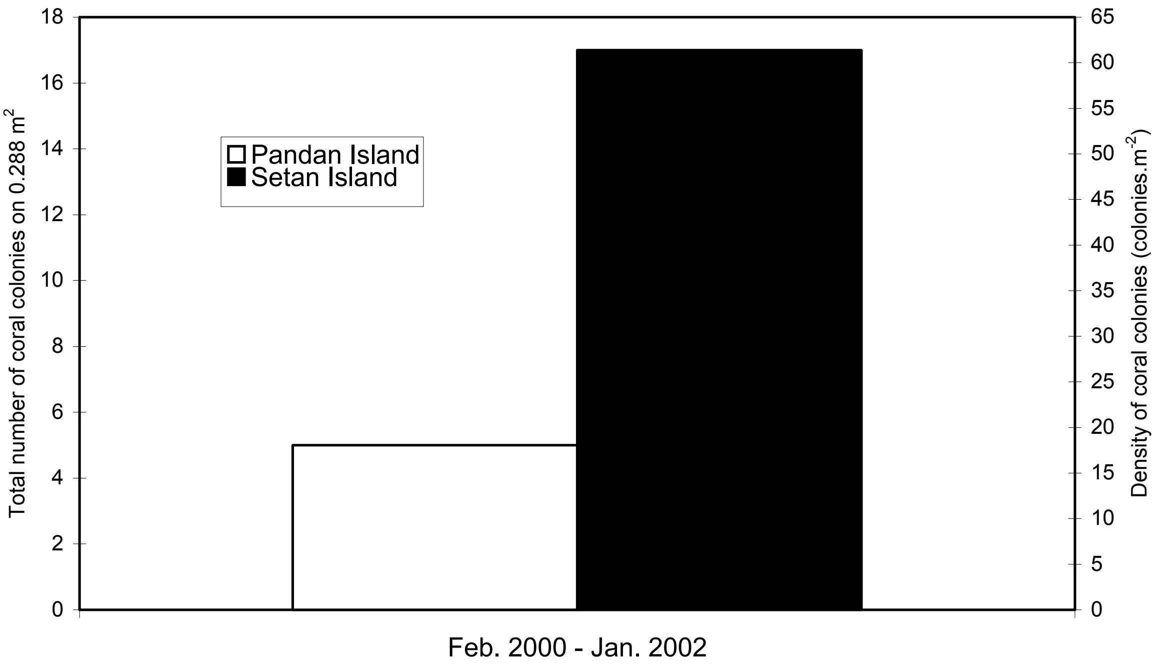


Figure 3.10: Total number (on 0.288 m^2) and density (colonies.m^{-2}) of coral colonies settled on the substrates after two years at Pandan and Setand Islands (Feb. 2000 – Jan. 2002)

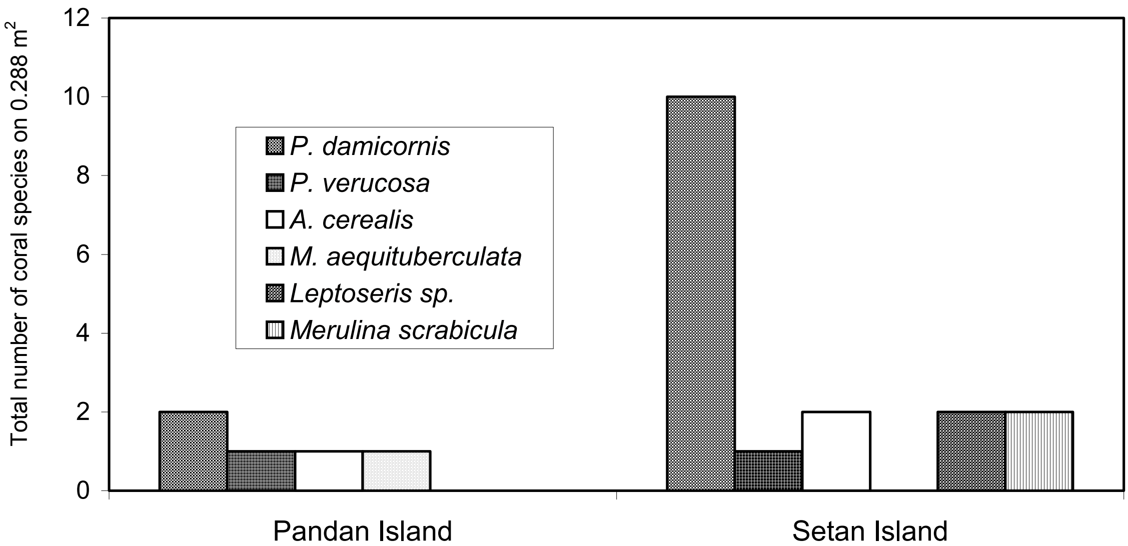


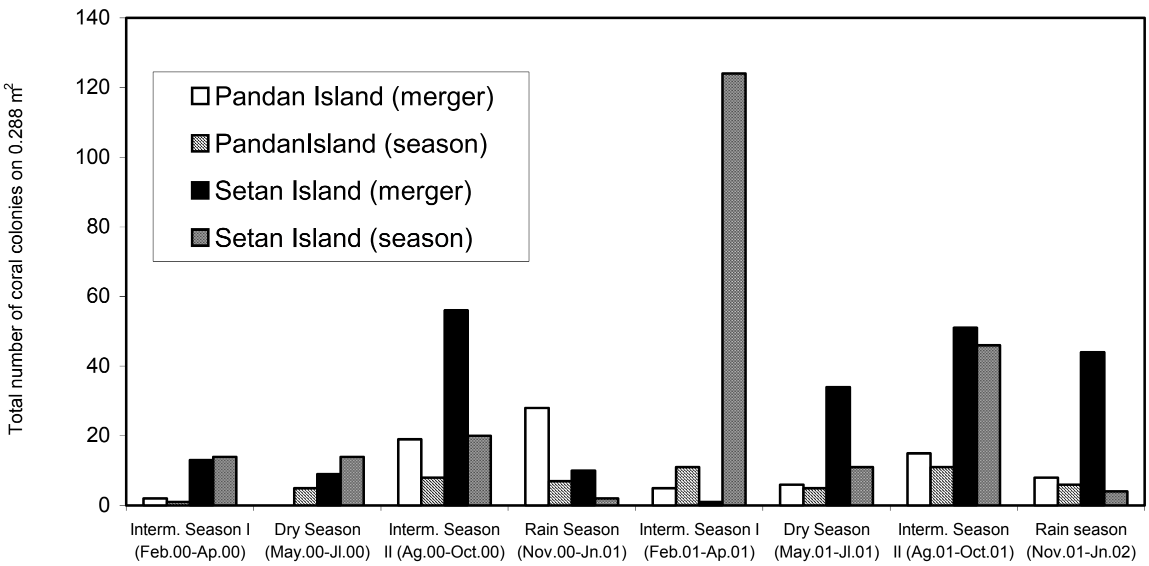
Figure 3.11: Total number of coral species settled on the substrates (0.288 m^2) after two years at Pandan and Setan Islands (Feb. 2000 – Jan. 2002)

3.1.5 Comparison of coral colonies settlements between monthly, three monthly (seasons), and yearly period, and after two years

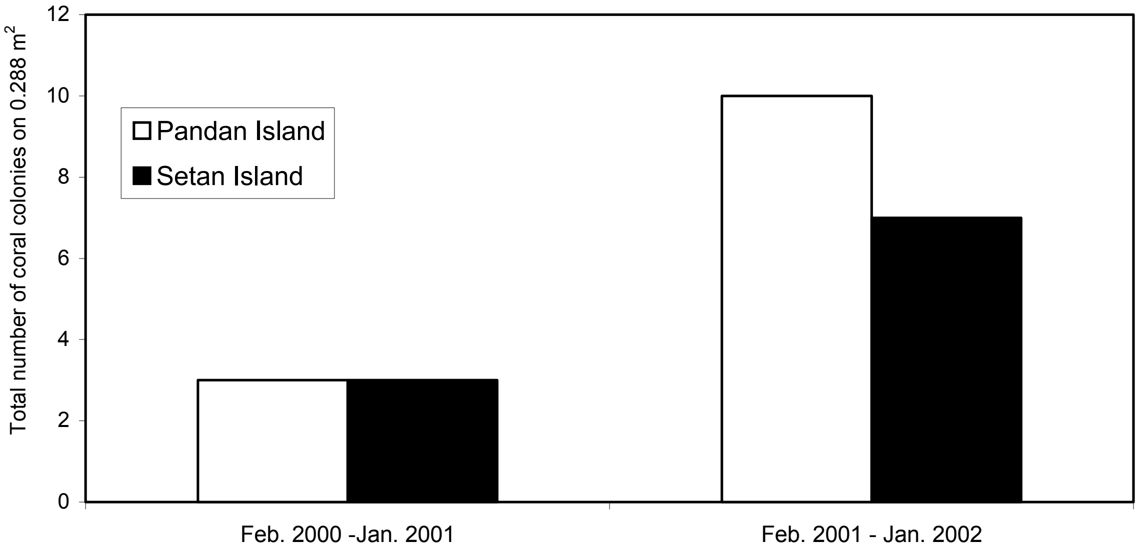
Comparison of coral colonies settlements between each month in the three months interval, every three months (seasons), every year of observation, and after two years are shown in Figure 3.12a,b and c. It is evident from those figures that the total colonies in monthly observations of the three months interval show highest numbers. These differences imply that the longer the time needed for the substrates placed in the water, a decrease on coral colonies settlements was obtained. This indicates that there is a competition between coral colonies, coralline algae, algal turfs, barnacles, and mussels on the all surfaces of the substrates.

The competition of coral colonies with other species on the concrete plates at Pandan Island based on visual observation shows that coralline algae were predominant followed by algal turfs, barnacles, and mussels, respectively. At Setan Island, however, alga turfs were more abundant than coralline algae, barnacle, and mussels, respectively. Coralline algae on the substrates at Pandan Island grew faster than other species, because of good water quality such as transparency and sedimentation in term of good photosynthesis. In contrast, at Setan Island in which algal turfs predominated on the substrates, sedimentation was higher than at Pandan Island, causing higher growth rates in coralline algae, but it would not influence the algal turfs.

a)



b)



c)

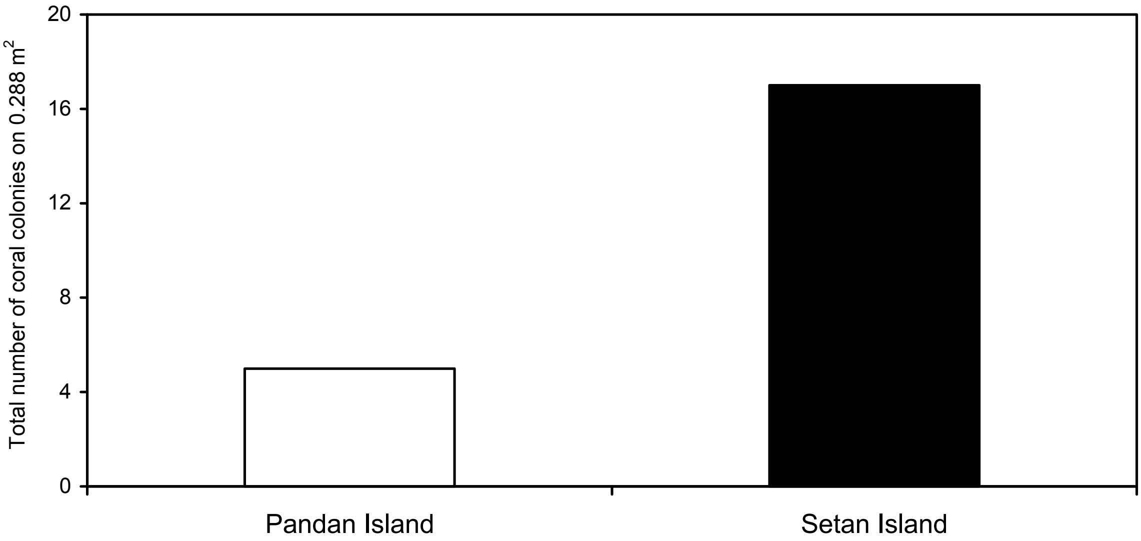


Figure 3.12.a.b, and c: Comparison of coral colonies settlements between monthly, three monthly (seasons), and yearly period, and after two years at Pandan and Setan Islands from February 2000 – January 2002

3.1.6 Monthly density of coral colonies and monthly density and relative density of coral species settlements during the two years of sampling period

Density of coral colony settlements on the substrates is defined as the total number of individual coral colonies per area of substrates on the three replicates, while the density of coral species settlements on the substrates is the total number of one species per area of substrates on the three replicates. However, in this study, I only analysed density of coral colony settlements, while this analysis applied for coral species using density and relative density values.

The monthly density of coral colonies settled on the substrates ranged between 0.00 – 52.33 colonies.m^{-2} at Pandan Island and 0.00 – 107.17 colonies.m^{-2} at Setan Island (Figure 3.1). The highest density at Pandan Island during the first year occurred in November 2000 with 52.33 colonies.m^{-2}, whereas for the second year, it appeared in May (20.83), September (20.84), and in November 2001 with 20.83 colonies.m^{-2}. Furthermore, at Setan Island, it was found in August 2000 with 86.81 colonies.m^{-2} for the first year, and in June 2001 with 107.17 colonies.m^{-2} (the second year). Meanwhile, the lowest density (0.00 colonies.m^{-2}) at Pandan Island was recorded during the interval February to July 2000, and in January 2001 for the first year period, while for the second year, it occurred in April, June, July 2001, and in January 2002. In addition, the lowest density of 0.00 colonies.m^{-2} at Setan Island was detected in December 2000 for the first year, and in the period March to May 2001, and in January 2002 (the second year).

Based on species, the total density and relative density of *P. damicornis* (93.76 colonies.m^{-2}; 32.53%) is highest at Pandan Island. *Acropora* sp. (72.94; 32.53 %), *Pocillopora* sp. (52.10; 18.07%), unidentified species (38.21; 13.25%), *Porites* sp. (17.37; 6.02%), *Stylophora* sp. (10.42; 3.62%), *M. aequituberculata* (3.47 colonies.m^{-2}; 1.21%), respectively, followed in lesser numbers. The overall monthly density and relative density of all species are shown in Figure 3.2 and 3.13.

At Setan Island, the total density and relative density of *P. damicornis* (312.5 colonies.m^{-2}; 41.28%) is also higher than other species such as *Acropora* sp. (144.88; 21.10%), unidentified species (100.72; 13.30%), *Galaxea* sp. (62.50; 8.26%), *Porites* sp. (48.62; 6.42%), *Stylophora* sp. (45.15; 5.96%), *Montipora* sp. (10.41; 1.38%), *Merulina* sp. (6.95; 0.92%), *Platygyra* sp. (3.47; 0.46%), *Pocillopora* sp. (3.47; 0.46%), and *G. fascicularis* (3.47 colonies.m^{-2}; 0.46%), respectively. The density and relative density of all species are presented in Figure 3.3 and 3.14.

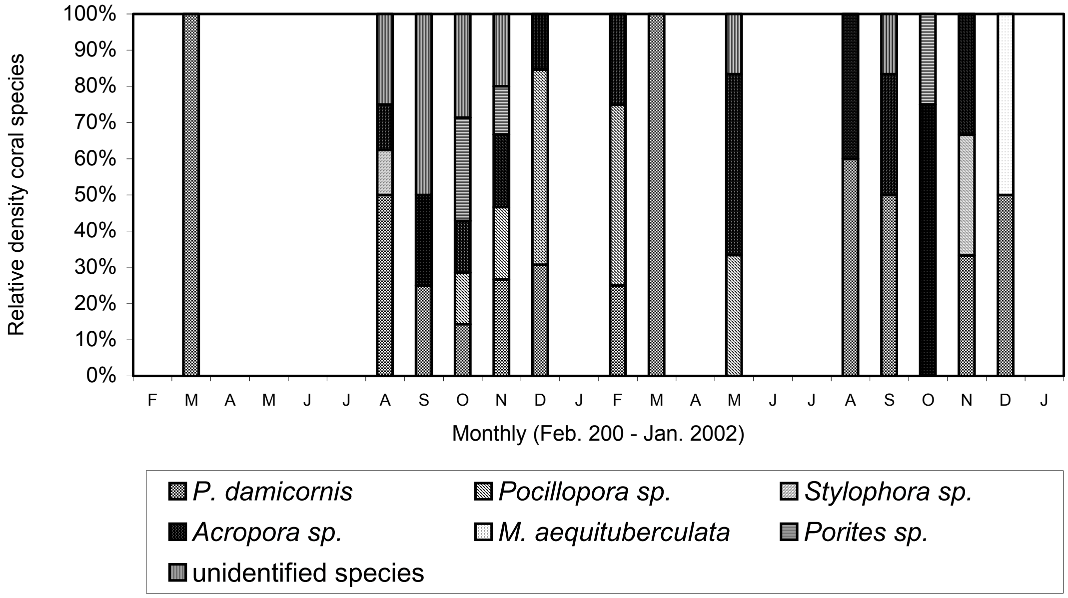


Figure 3.13: Relative density (RD) coral species (%) settled on the concrete substrates every month, over a sampling period of two years at Pandan Island

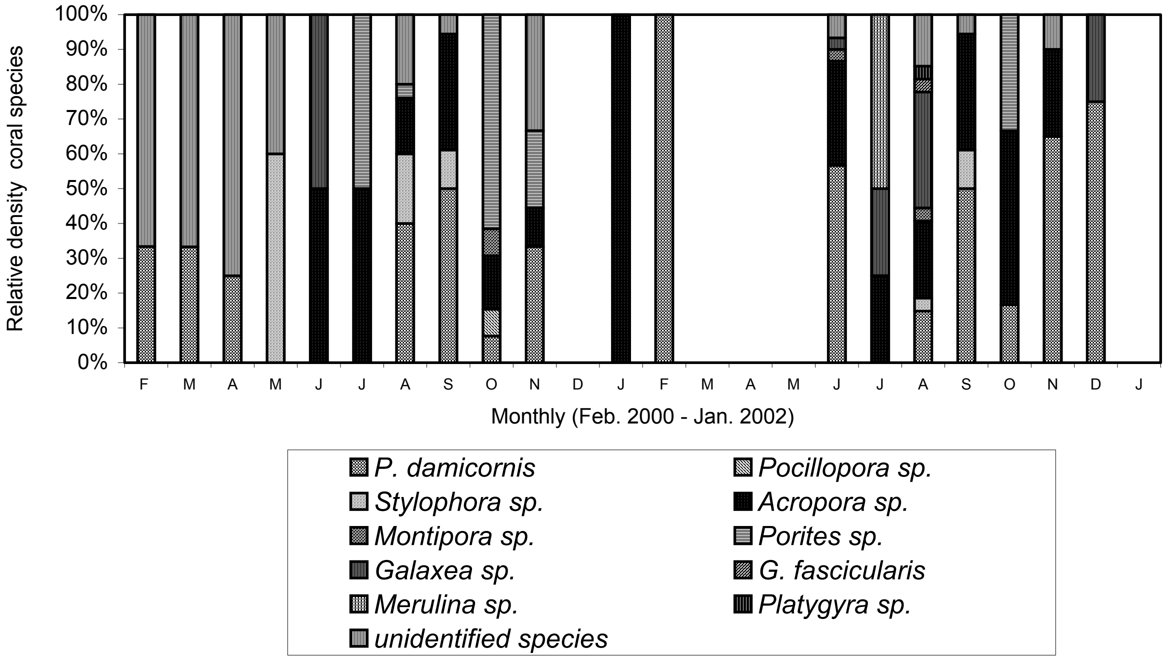


Figure 3.14: Relative density (RD) coral species (%) settled on the concrete substrates every month, over sampling two years at Setan Island

3.1.7 Density of coral colonies and density and relative density of coral species settlements every three months (seasons), over a sampling period of two years

Density of coral colonies settled in every three months (seasons) varied between 3.47 – 38.19 colonies.m^{-2} at Pandan Island and 6.95 – 159.72 colonies.m^{-2} at Setan Island (Figure 3.4). The highest density at Pandan Island was found during the intermediate season II with an average value of 27.78 colonies.m^{-2} (in the first year) and 38.19 colonies.m^{-2} for the intermediate season I and II periods for the second year of observation. In contrast, the lowest density in the first year of investigation occurred during the intermediate season I (3.47 colonies.m^{-2}), whereas for the second year, it was recorded in the dry season with a value of 17.36 colonies.m^{-2}. At Setan Island, the highest density appeared in the intermediate season II (69.45 colonies.m^{-2}) for the first year and in the intermediate season I (430.56) and II (159.72 colonies.m^{-2}) during the second year period. The lowest density was observed in the rainy season for both years of investigation (6.95 and 13.89 colonies.m^{-2}). Generally, the total density of coral colonies settled at Setan Island was higher than at Pandan Island (Figure 3.4).

From eight samplings in different seasons at Pandan Island, only unidentified species with a value of density and relative density of 3.47 colonies.m^{-2} and 100% was found in the intermediate season I. For the next intermediate season I, the density and relative density of *P. damicornis* (24.31 colonies.m^{-2}; 63.64%) was greater than *Acropora* sp. (10.42; 27.28%), and *Porites* sp. (3.47; 9.08%), respectively. Furthermore, during the first and the second period of the dry season, *P. damicornis* (3.47 colonies.m^{-2}; 19.99%) showed similar values as *Pocillopora* sp., and was lower than *Acropora* sp. (10.42 colonies.m^{-2}; 60.02%).

During the intermediate season II for the first year period, the highest density and relative density were represented by *Acropora* sp. with a value of 17.36 colonies.m^{-2} and 62.49% followed by *P. damicornis* (10.42 colonies.m^{-2} and 37.51%). For the second year, both *Acropora* sp. and *M. aequituberculata*, which had the same values (10.47 colonies.m^{-2} and 27.33%), were dominant followed by both *P. damicornis* and unidentified species (6.95 and 18.14%) and *Porites* sp. (3.47 colonies.m^{-2} and 9.06%), respectively.

Finally, in the rainy season, *Acropora* sp. (13.89 colonies.m^{-2} and 57.14%) was more abundant than *P. damicornis* (10.42 colonies.m^{-2} and 42.86%) for the first year. In addition, during the second year, *Acropora* sp. (10.47 colonies.m^{-2} and 50.12%) was most numerous followed by *P.damicornis* (6.95 and 33.27%), and *M. aequituberculata* (3.47 colonies.m^{-2} and 16.61%). Those results are summarized in Figure 3.5 and 3.15.

There were also eight investigations in different seasons at Setan Island, which are presented in Figure 3.6 and 3.16. Firstly, in the intermediate season I of the first year, the density and relative density of *P. damicornis*, *Acropora* sp., and *Porites* sp. were similar (6.95 colonies.m^{-2} and 14.29 %), and were higher than both *Stylophora* sp. and *Montipora* sp. (3.47 and 7.14%), and unidentified species (20.83 colonies.m^{-2} and 42.84%). In the next year period, the highest density and relative density was reported for *P. damicornis* (194.45 colonies.m^{-2} and 45.16%) followed by *Acropora* sp. (90.28 and 20.97%), unidentified species (62.50 and 14.52%), *Stylophora* sp. (38.19 and 8.87%), both *Montipora* sp. and *Porites* sp., with each of 20.83 and 4.84%, and *Pocillopora* sp. (3.47; 0.80%).

Secondly, during the dry season in the first year, *P. damicornis* (17.36 colonies.m^{-2} and 35.70%) was more abundant than *Acropora* sp. (13.89 and 28.56%), both *Montipora* sp. and *Porites* sp. (each of 6.95 and 14.30%), and *Stylophora* sp. (3.47 colonies.m^{-2} and 7.14%), respectively. Meanwhile, for the second year period, the density and relative density of *Acropora* sp. (10.42 colonies.m^{-2} and 27.27%) was higher than other species i.e. all three *P. damicornis*, *Pocillopora* sp., and *Pocillopora* sp. (6.95 and 18.19%), and both *Stylophora* sp. and *Porites* sp. (each of 3.47 colonies.m^{-2} and 9.08%).

Thirdly, the highest density and relative density in the intermediate season II period of the first year was found for *P. damicornis* (24.31 colonies.m^{-2} and 35.00%) followed by *Acropora* sp. (17.36 and 25.00%), and all four of *Stylophora* sp., *Seriatopora* sp., *Porites* sp., and unidentified species (each of 6.95 colonies.m^{-2} and 10.00%). Meanwhile, during the second year, *Acropora* sp. (62.50 colonies.m^{-2} and 39.13%) was more abundant than *P. damicornis* (55.56 and 34.79%), Stylophora sp. (27.28 and 17.39%), *Porites* sp. (10.42 and 6.52%), and unidentified species (3.47 colonies.m^{-2} and 2.17%), respectively.

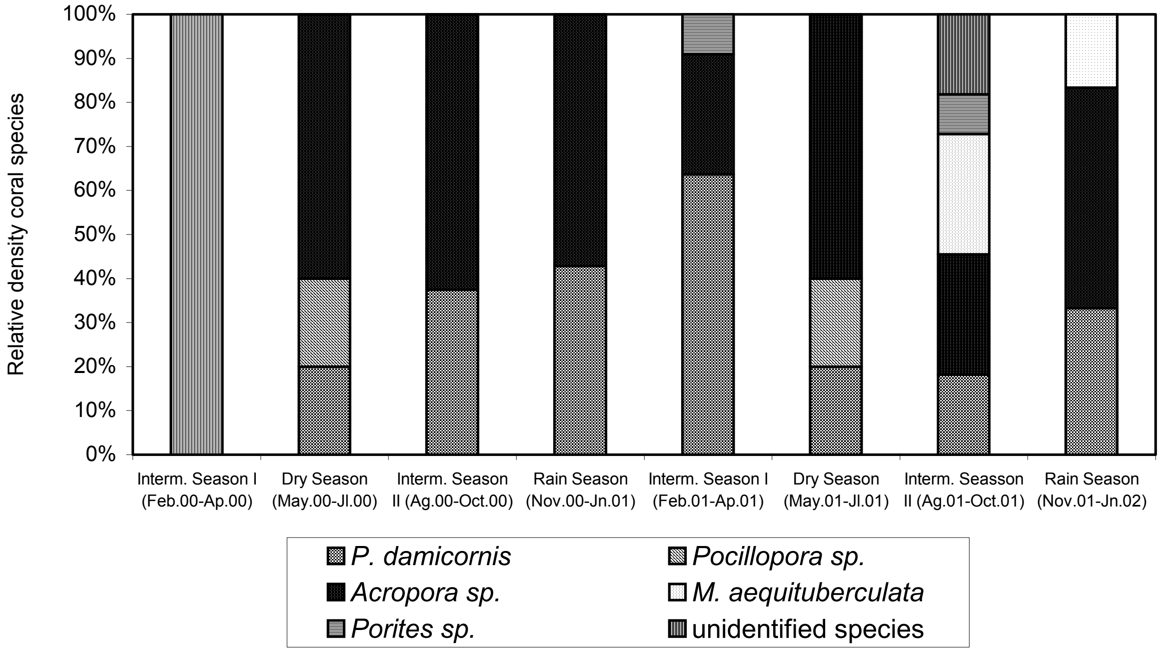


Figure 3.15: Relative density (RD) coral species (%) settled on the concrete substrates every three months (season), over sampling two years at Pandan Island

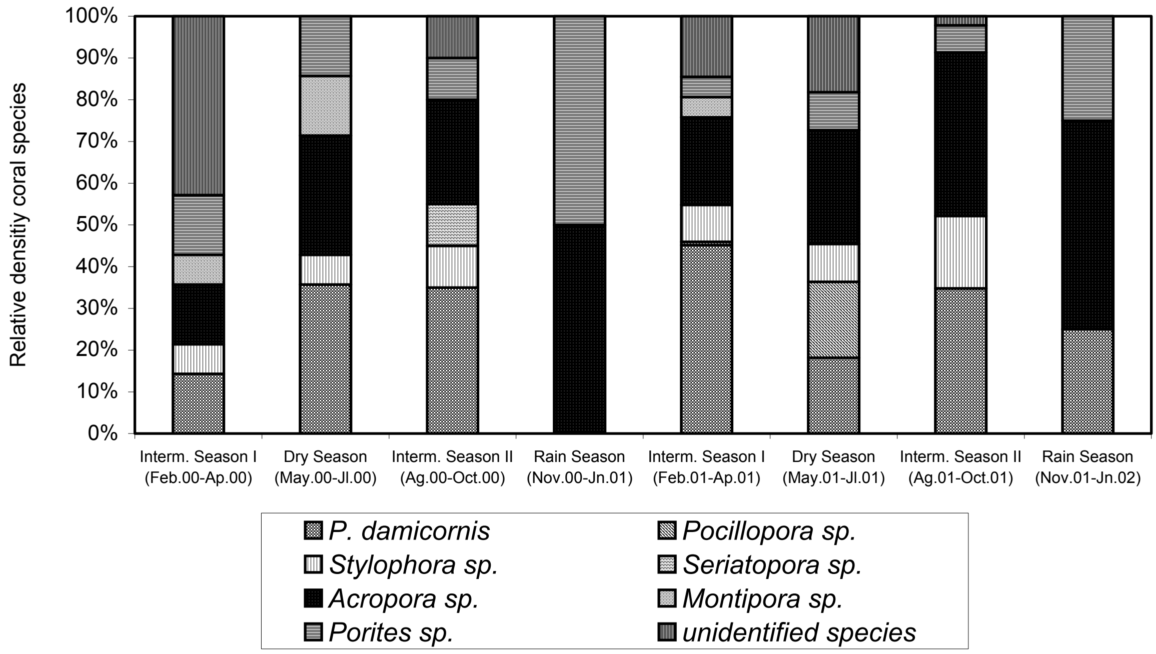


Figure 3.16: Relative density (RD) coral species (%) settled on the concrete substrates every three months (season), over sampling two years at Setan Island

Finally, during the rainy season for the first year of investigation, *Acropora* sp. has the same value of density and relative density as *Porites* sp. (each of 3.47 colonies.m^{-2} and 50%). For he second year of observation, *Acropora* sp. with a value density of 6.95 colonies.m^{-2} and relative density of 50%) was the most abundant followed by both *P. damicornis* and *Porites* sp. (3.47 colonies.m^{-2} and 25%). All the details are shown in Figure 3.6 and 3.16.

3.1.8 Density of coral colonies and density and relative density of coral species settlement every year, over a sampling period of two years

Figure 3.7 shows that the density of coral colonies settled on the substrates in the first year of observation at Pandan Island are 10.42 colonies.m^{-2} and 34.72 colonies.m^{-2} for the second year period. At Setan Island, it was 10.42 colonies.m^{-2} during the first year and 24.31 colonies.m^{-2} in the second year of investigation.

The density and relative density of coral species settlement investigated during the first year period at Pandan Island were 6.95 colonies.m^{-2} and 66.70% for *P. damicornis* and 3.47 colonies.m^{-2} and 33.30% for *Galaxea* sp. For the second year, there were 13.89 colonies.m^{-2} and 40.00% for *M. aequituberculata*, each of 6.95 and 20.01% for *P. damicornis* and *Acropora* sp., and each of 3.47 colonies.m^{-2} and 9.99**%** for *A. cerealis* and *A. verweyi*, respectively. Densities are shown in Table 3.4.

Table 3.4. Density (D) (colonies.m^{-2}) and relative density (RD) (%) coral species settled on the substrates every one year, over sampling two years at Pandan Island

No	Taxonomy	Feb. 2000 - Jan. 2001		Feb. 2000 - Jan. 2001	
		D	**RD**	**D**	**RD**
I	**Pocilloporidae**				
	P. damicornis	6.95	66.70	6.95	20.01
II	**Oculinidae**				
	Galaxea sp.	3.47	33.30	-	-
III	**Acroporidae**				
	A. cerealis	-	-	3.47	9.99
	A. verweyi	-	-	3.47	9.99
	Acropora sp.	-	-	6.95	20.01
	M. aequituberculata	-	-	13.89	40.00
	Total	**10.42**	**100**	**34.73**	**100**

At Setan Island, in the first year, only the single species *P. damicornis* with a value density and relative density of 10.42 colonies.m^{-2} and 100% was found (Table 3.5). During the second year of observation, data were recorded for *P. damicornis* (10.42 colonies.m^{-2}; 42.88%) and for *Acropora* sp., *A. cerealis*, *Leptoseris* sp., and *Merulina scrabicula* with each of 3.47 colonies.m^{-2} and 12.28%, respectively (Table 3.5).

Table 3.5. Density (D) (colonies.m^{-2}) and relative densities (RD) (%) coral species settled on the plates every one year, over sampling two years at Setan Island

No	Taxonomy	Feb. 2000 - Jan. 2001		Feb. 2000 - Jan. 2001	
		D	**RD**	**D**	**RD**
I	**Pocilloporidae**				
	P. damicornis	10.42	100	10.42	42.88
II	**Acroporidae**				
	Acropora sp.	-	-	3.47	14.28
	A. cerealis	-	-	3.47	14.28
III	**Agariciidae**				
	Leptoseris sp.	-	-	3.47	14.28
IV	**Merulinidae**				
	Merulina scrabicula	-	-	3.47	14.28
	Total	**10.42**	**100**	**24.30**	**100**

3.1.9 Density of coral colonies and density and relative density of coral species settlements after two years

Figure 3.10 shows that the density of colonies settled on the substrates after two years at Setan Island with a value of 59.03 colonies.m^{-2} is higher than at Pandan Island (17.36 colonies.m^{-2}).

The highest density and relative density of species settlements at Pandan Island was observed for *P. damicornis* (6.95 colonies.m^{-2} and 40.03%) followed by *P. verucosa*, *Acropora cerealis*, and *M. aequetuberculata* with each of 3.47 colonies.m^{-2} and 9.99%, respectively (Table 3.6). Furthermore, at Setan Island, the density and relative density of *P. damicornis,* which was 34.72 colonies.m^{-2} and 58.81%, is much higher than *A. cerealis*, *Leptoseris* sp., and *Merulina scrabicula* with each of 6.95 and 11.77% as well as *P. verucosa* (3.47 colonies.m^{-2} and 5.88%) (Table 3.7).

Table 3.6. Density (colonies.m^{-2}) and relative density (%) coral species settled on the substrates after two years at Pandan Island

No	Taxonomy	February 2000 - January 2002	
		Densities (D)	**Relative Densities (RD)**
I	**Pocilloporidae**		
	P. damicornis	6.95	40.03
	P. verucosa	3.47	19.99
II	**Acroporidae**		
	A. cerealis	3.47	19.99
	M. aequituberculata	3.47	19.99
	Total	17.36	100

Table 3.7. Density (colonies.m^{-2}) and relative density (%) coral species settled on the substrates after two years at Setan Island

No	Taxonomy	February 2000 - January 2002	
		Densities (D)	**Relative Densities (RD)**
I	**Pocilloporidae**		
	P. damicornis	34.72	58.81
	P. verucosa	3.47	5.88
II	**Acroporidae**		
	Acropora cerealis	6.95	11.77
III	**Agariciidae**		
	Leptoseris sp.	6.95	11.77
IV	**Merulinidae**		
	Merulina scrabicula	6.95	11.77
	Total	59.04	100

3.1.10 Average growth rate of coral species settlements on the concrete substrates

In the present study, the analyses of average growth rates are focused only on coral species settled on the substrates. Because of unpredictable problems such as difficulties in monitoring of coral species in the water column, limitedness of time in using scuba equipment, very small individual coral species settling on the substrates, and that individuals were not found usually during monthly sample collection, the measurements, therefore, were done only after a different time schedule.

The analyses of average growth rates of coral species was peformed by measuring the average length, width, and height of colonies, and also total polyp inhabited by coral species settled on the plates. Those measurements were conducted after one month, after three months, after one year, and after two years of investigation, respectively. The results (only after one year and after two years) were then divided by months to predict monthly average growth rates of coral species.

a. After one month

The average in length and width of individuals, and total polyp of seven coral species settled on the substrates at Pandan Island and eleven coral species at Setan Island after one month are presented in Table A.2.1 and Table A.2.2 (see Appendix 3). The seven species at Pandan Island were *P. damicornis*, *Pocillopora* sp., *Stylophora* sp., *Acropora* sp., *M. aequituberculata*, *Porites* sp., and unidentified species. Furthermore, at Setan Island, there were *P. damicornis*, *Pocillopora* sp., *Stylophora* sp., *Acropora* sp., *Montipora* sp., *Porites* sp., *Galaxea* sp., *G. fascicularis*, *Merulina* sp., *Platygyra* sp., and unidentified species. The profiles of six species, which settled on the substrates after one month, are shown in Plate 3.1.

The average length and width of *P. damicornis* settled after one month for all the years of investigation at Pandan and Setan Island are presented in Figure 3.17. From a total of 24 months of investigation, *P. damicornis* settled during 12 months at Pandan Island and 13 months at Setan Island. At Pandan Island, the average length and width of this species ranged from 0.63 to 2.50 mm and 0.40 - 2.00 mm, respectively. The longest occurred in March 2001, whereas the shortest was in December 2000. At Setan Island, it was 0.40 – 4.67 mm and 0.30 – 3.34 mm with the longest in August 2000, and the shortest in February 2001.

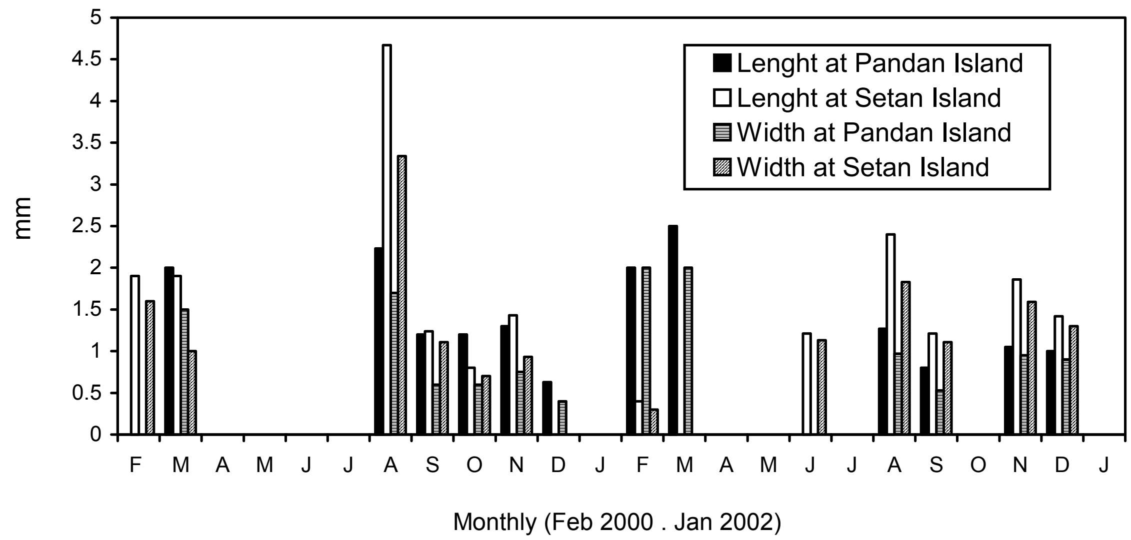


Figure 3.17: Average length and width after one month as well as monthly settlements of *P. damicornis* at Pandan and Setan Islands

Pocillopora sp. settled only during five months at Pandan Island, whereas at Setan Island, it was two months (Figure 3.18). The average length and width varied between 0.29 - 2.70 mm and between 0.20 - 2.50 mm, with the longest occurred in May 2001 and the shortest was found in October and December 2000 for Pandan Island. At Setan Island, the longest (20 mm) and the widest (1 mm) were recorded in April 2000, whereas the shortest (0.70 mm) and narrowest (0.30 mm) were in October 2000.

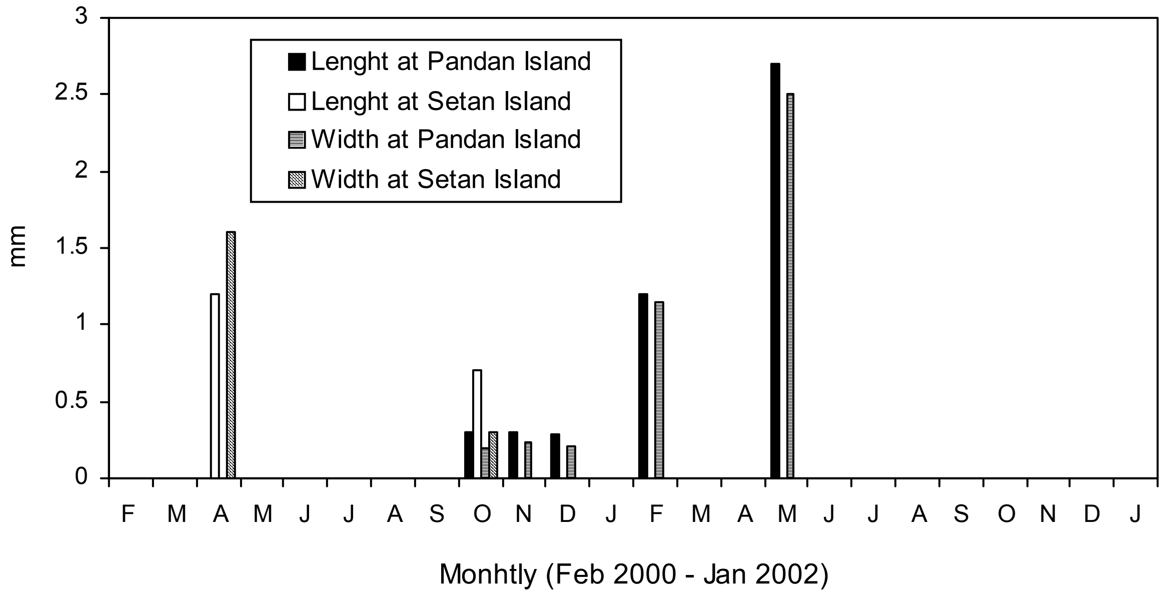


Figure 3.18: Average length and width after one month as well as monthly settlements of *Pocillopora* sp. at Pandan and Setan Islands

Stylophora sp. settled in August 2000 with an average length and width of 1.60 mm and 1.05 mm and in November 2001 (1.35 mm and 1.05 mm) at Pandan Island (Figure 3.19). At Setan Island, its average length and width were found in five months ranging from 0.90 to 4.10 mm and from 0.60 to 1.80 mm. The longest individual appeared in August 2000 and the shortest was in September 2001 (Figure 3.19).

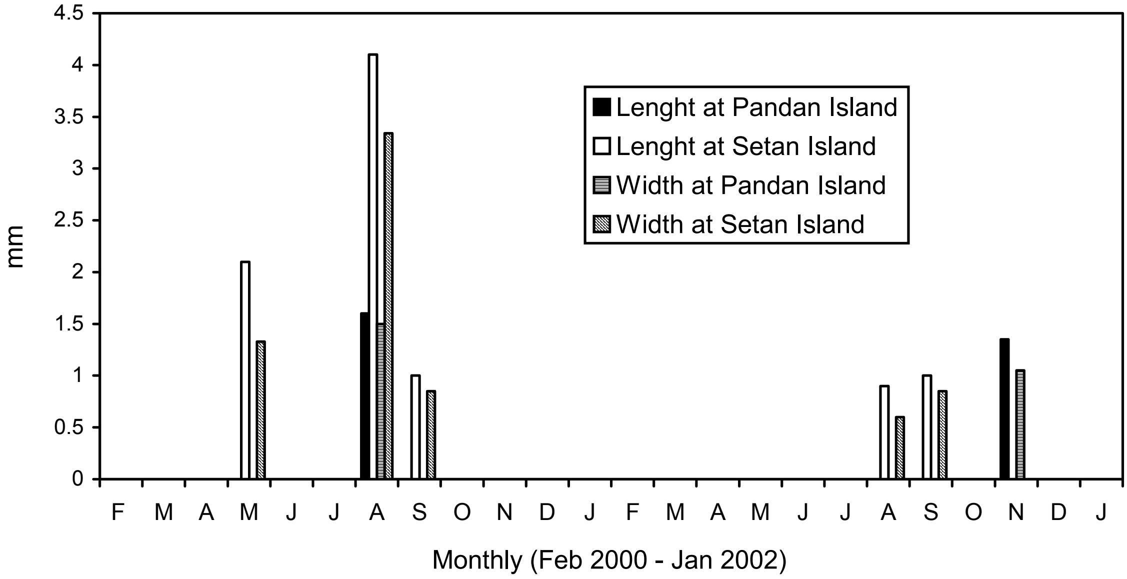


Figure 3.19: Average length and width after one month as well as monthly settlements of *Stylophora* sp. at Pandan and Setan Islands

From the total of 24 months of investigation, *Acropora* sp. settled during 11 months at Pandan Island and 12 months at Setan Island (Figure 3.20). At Pandan Island, the average length and width of this species ranged from 0.30 to 2.45 mm and from 0.20 to 1.40 mm. The longest and widest of individuals appeared in May 2001, whereas the shortest was in September 2000. Furthermore, at Setan Island, it was 1.00 – 3.54 mm and 0.30 – 2.77 mm with the longest in August 2001, and in October 2001 for the shortest.

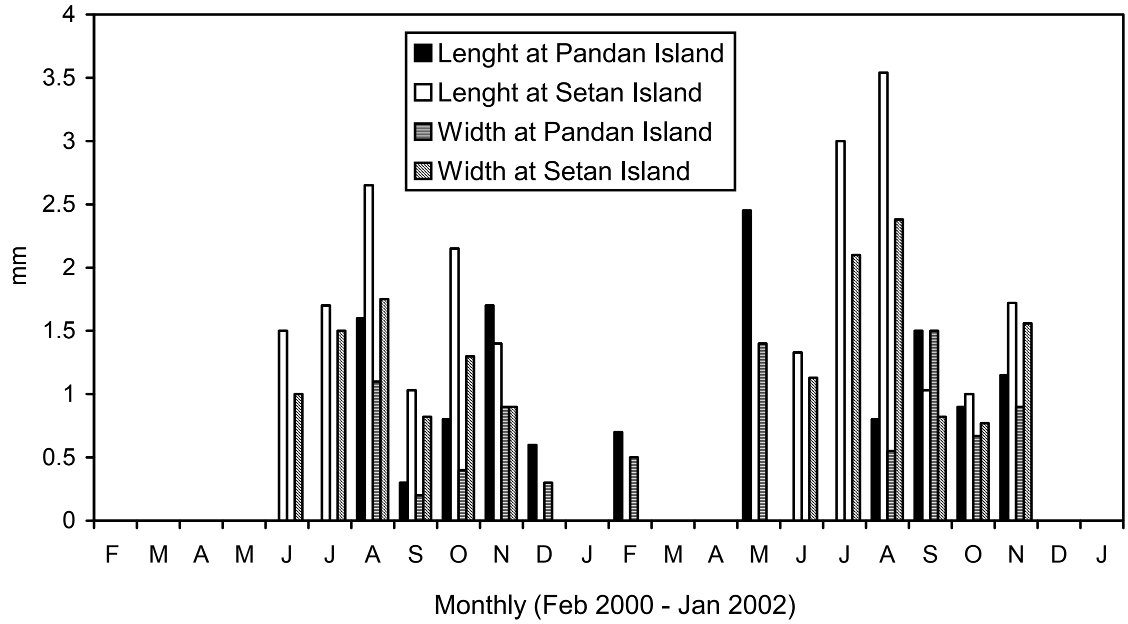


Figure 3.20: Average length and width after one month as well as monthly settlements of *Acropora* sp. at Pandan and Setan Islands

M. aequituberculata was found only in December 2001 at Pandan Island. The average length and width were 21.00 mm and 4.00 mm (Figure 3.21).

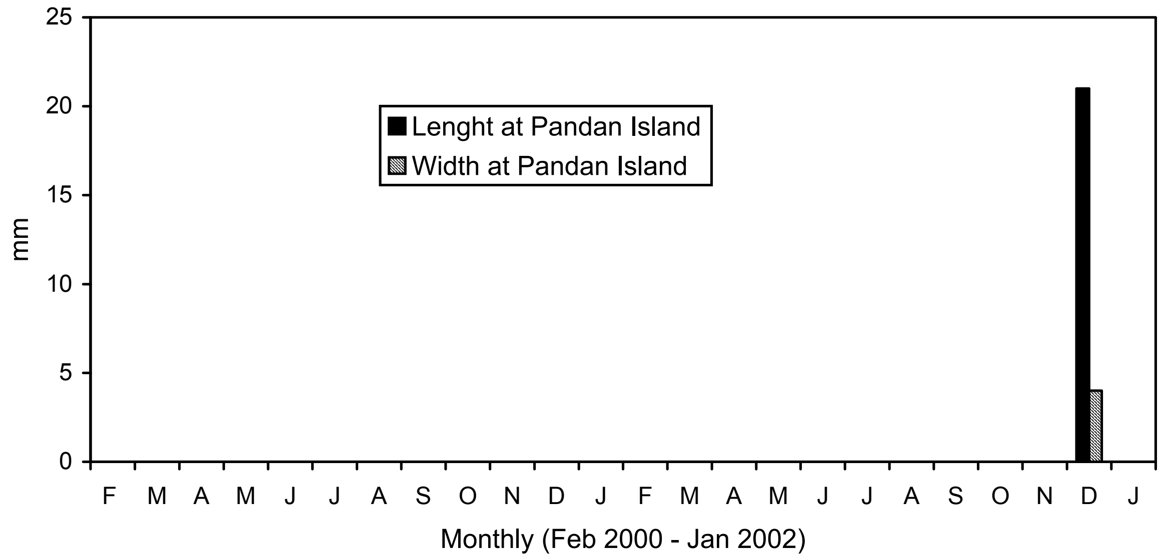


Figure 3.21: Average length and width after one month as well as monthly of settlements of *M.aequituberculata* at Pandan Island

Montipora sp. settled on the substrates only at Setan Island during the three months of investigation; in October 2000 with an average length of 0.70 mm and width 0.70 mm, in June (0.80 mm and 0.70 mm), and August 2001 (1.00 mm and 1.00 mm), (Figure 3.22).

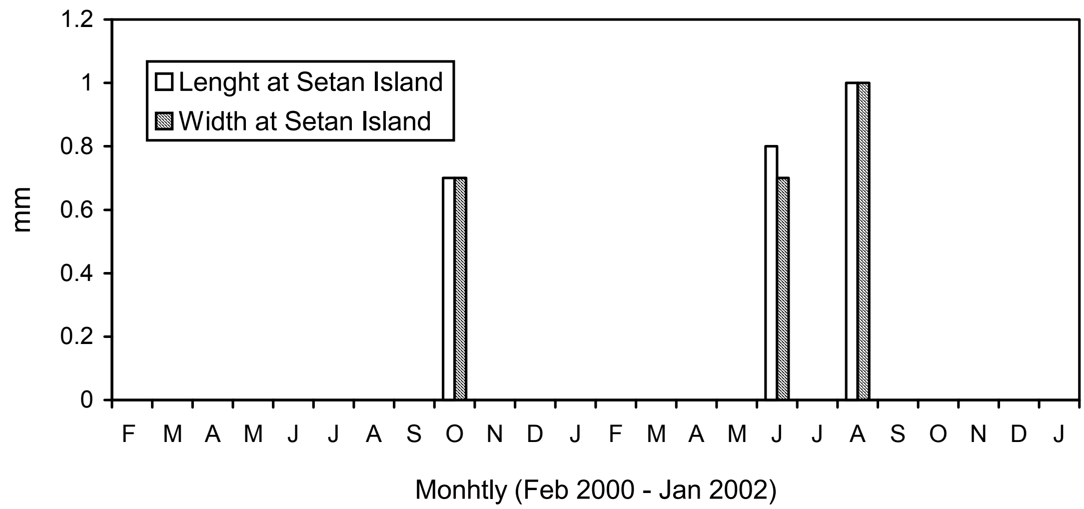


Figure 3.22: Average length and width after one month as well as monthly settlements of *Montipora* sp. at Setan Island

The average length and width of *Porites* sp. after one month at Pandan and Setan Islands are presented in Figure 3.23. At Pandan Island, this species settled only during the three months, while at Setan Island, it occurred in the five months period. The average length and width of this species settled at Pandan Island ranged between 0.35 and 0.70 mm and from 0.25 to 0.50 mm, respectively. The longest and widest individuals were obtained in November 2000, whereas the shortest was in October 2000. At Setan Island, it varied between 0.30 - 1.80 mm and 0.25 - 1.00 mm, respectively. The longest individual was found in August 2000, whereas the shortest was in November 2000.

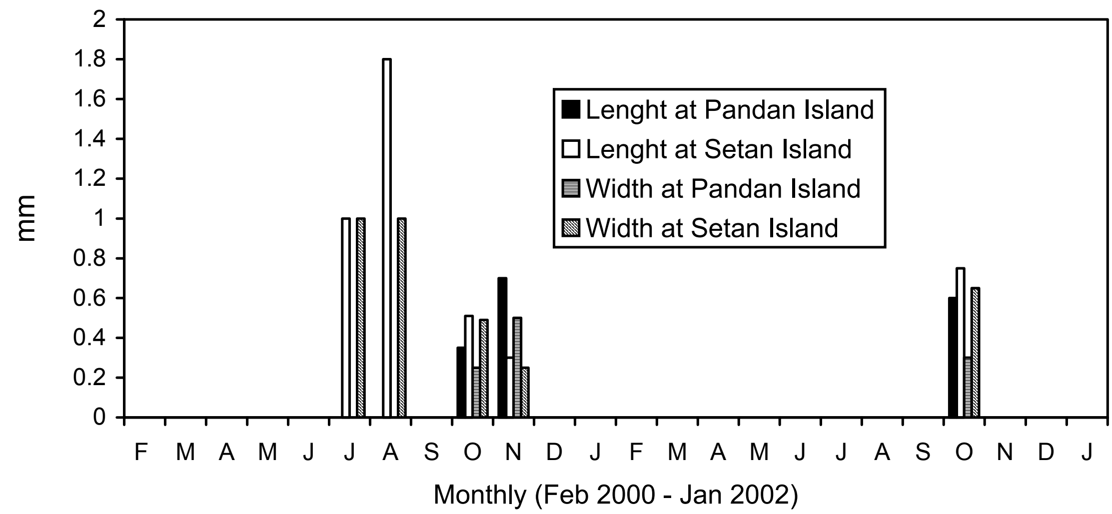


Figure 3.23: Average length and width after one month as well as monthly settlements of *Porites* sp. at Pandan and Setan Islands

Galaxea sp. settled on the substrates only at Setan Island and was present in five months. The average length and width of this species varied from 1.00 to 3.00 mm and 0.08 - 2.00 mm, with the longest and widest of individuals occurred in July 2001, whereas the shortest individual was found in June 2001 (Figure 3.24).

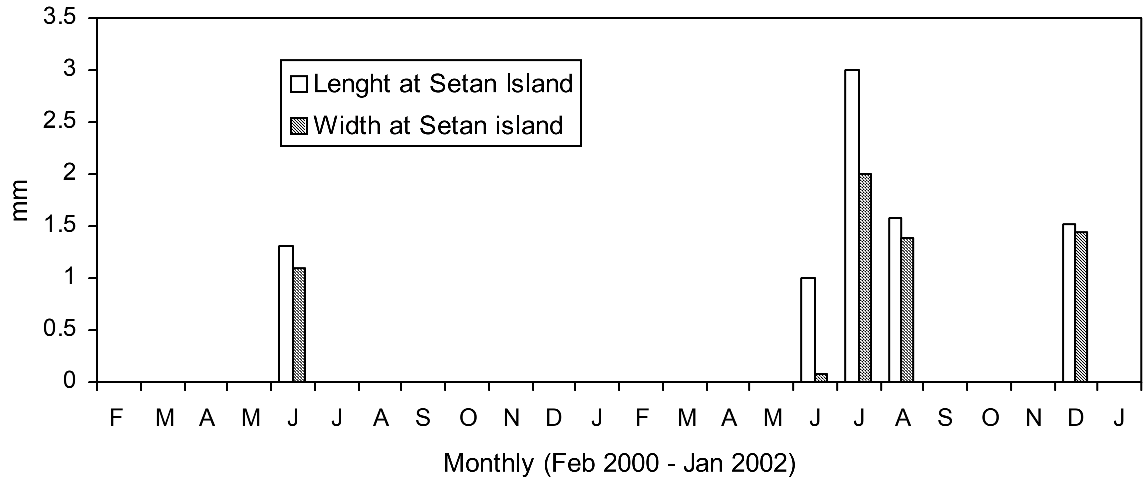


Figure 3.24: Average length and width after one month as well as monthly settlements of *Galaxea* sp. at Setan Island

All three *G. fascicularis*, *Merulina* sp., and *Platygyra* sp. settled only in one month at Setan Island (Figure 3.25, 3.26, and 3.27). *G. fascicularis* was recorded in August 2000 with an average length and width of 2.40 mm and 2.40 mm. *Merulina* sp. appeared in July 2001 (2.00 mm and 1.75 mm), and *Platygyra* sp. was found in August 2001 (1.40 mm and of 1.30 mm).

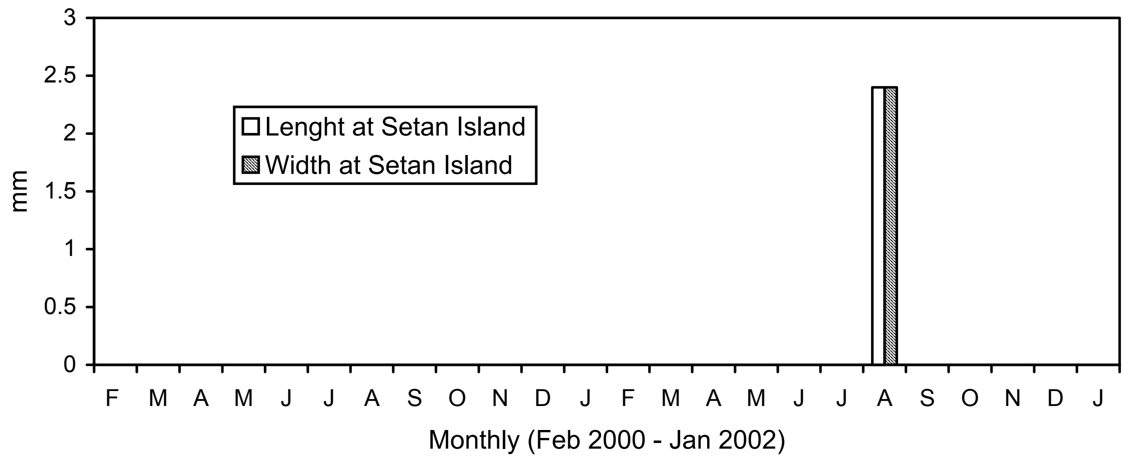


Figure 3.25: Average length and width after one month as well as monthly settlements of *G. fascicularis* at Setan Island

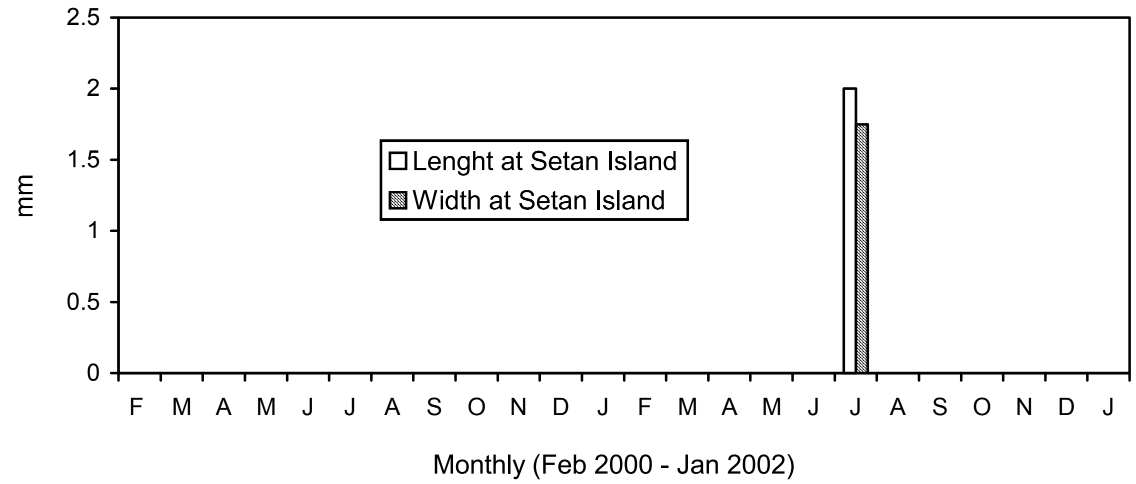


Figure 3.26: Average length and width after one month as well as monthly settlements of *Merulina* sp. at Setan Island

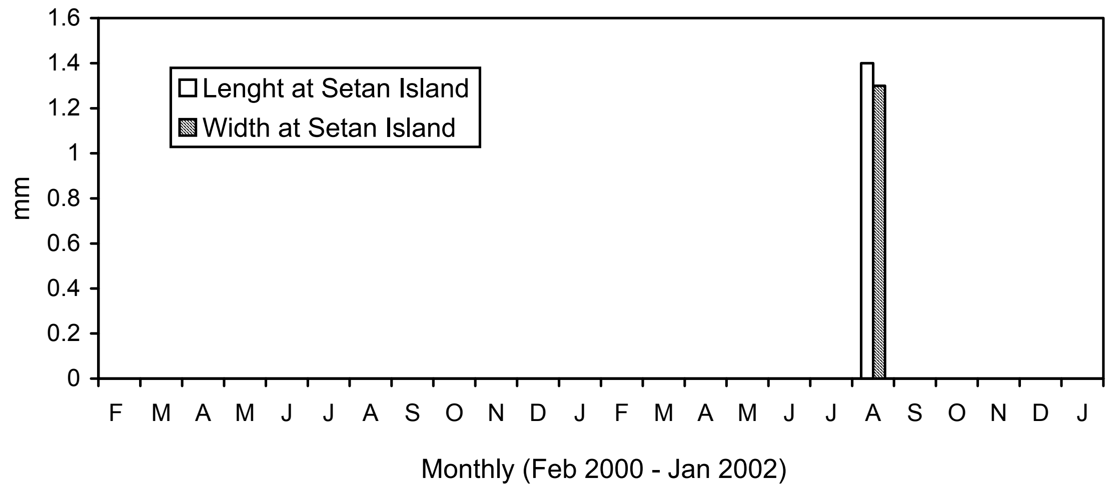


Figure 3.27: Average length and width after one month as well as monthly of settled *Platygyra* sp. at Setan Island

From the total 24 months of investigation, unidentified species settled during six months at Pandan Island and 11 months at Setan Island (Figure 3.28). At Pandan Island, the average length and width of this species ranged between 0.30 - 1.60 mm and 0.20 - 1.05 mm respectively, with the longest and widest of individuals occurred in August 2000, whereas the shortest individuals were found in the interval September to October 2000. At Setan Island, it was from 0.30 to 3.00 mm and 0.20 – 2.20 mm, respectively. The longest individual was recorded in November 2001, whereas the shortest was in March 2000. During May 2000 and June 2001, their average length and width could not be calculated (damages).

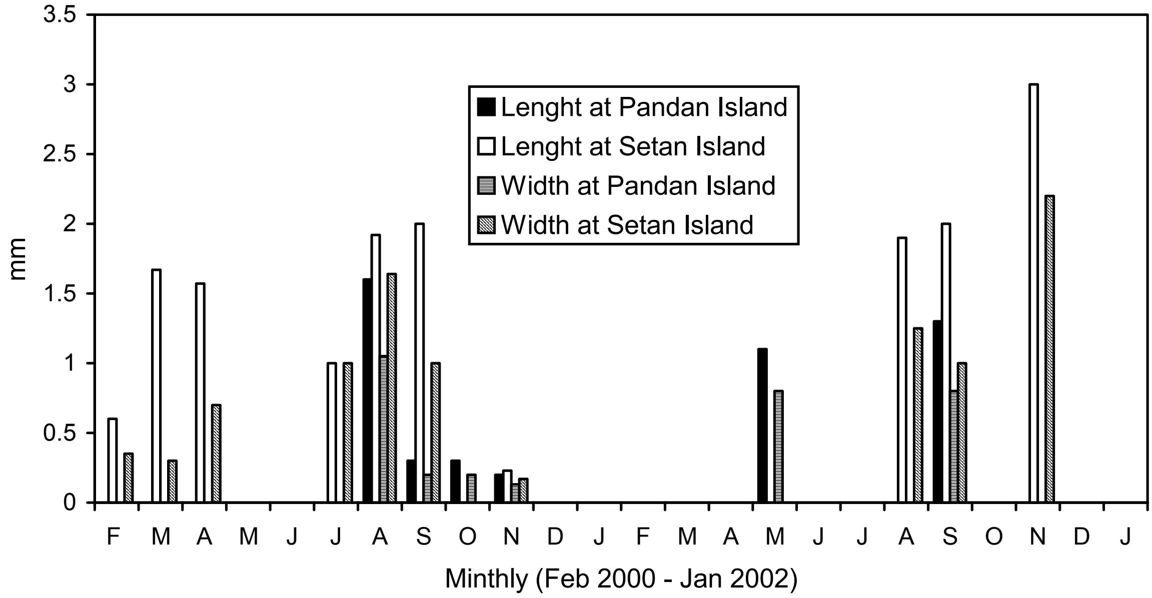
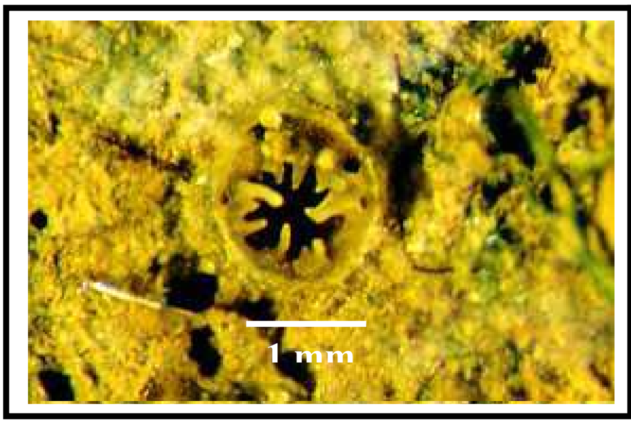
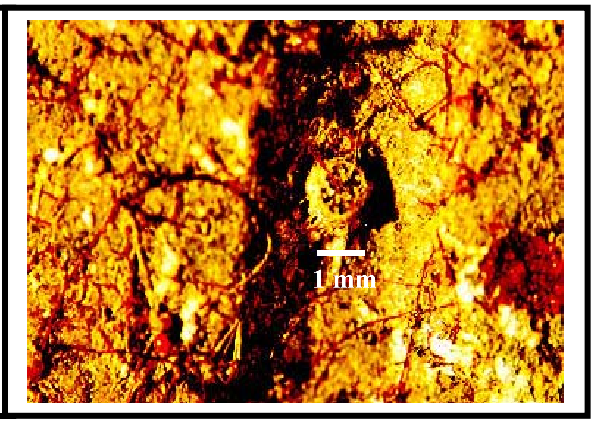


Figure 3.28: Average length and width after one month as well as monthly settlements unidentified species at Pandan and Setan Islands

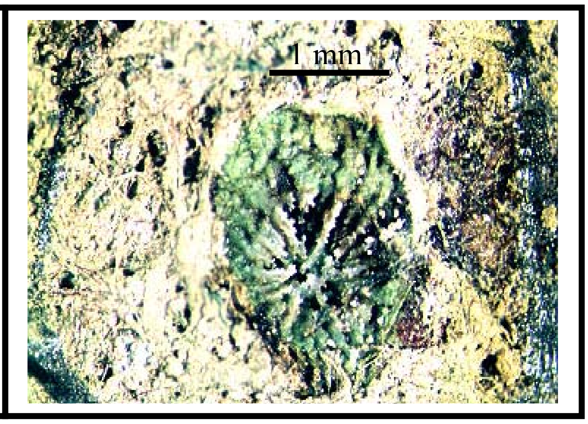


Galaxea sp.

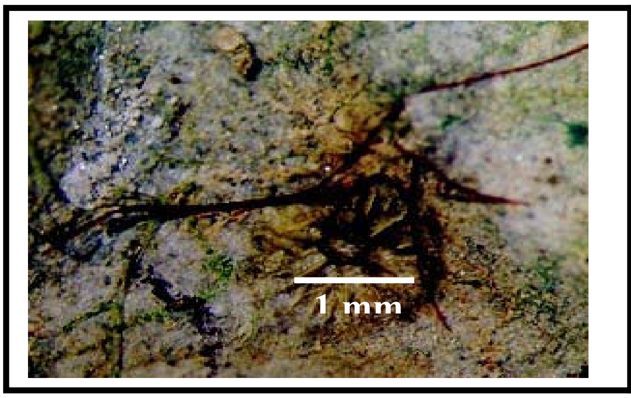


Porites sp.

Pocillopora damicornis



Montipora sp.



Merulina sp.

unidentified species

Plate 3.1: Micrographs of six species, which settled on the substrates after one month

b. After three months

The average length, width, and total polyp of six coral species (*P. damicornis*, *Pocillopra* sp., *Acropora* sp., *M. aequituberculata*, *Porites* sp., and unidentified species) at Pandan Island and eight species (*P. damicornis*, *Pocillopra* sp., *Stylophora* sp., *Seriatopora* sp., *Acropora* sp., *Montipora* sp., *Porites* sp., and unidentified species) at Setan Island after three months are shown in Table A.2.3 and A.2.4 (see Appendix 2). Some profiles of these species settling on the substrates after three months are presented in Plate 3.2.

Figure 3.29 shows the average length and width of *P. damicornis* settled at Pandan and Setan Islands after three months (seasonal investigation). Generally, *P. damicornis* settled in both locations in all times during the seasonal investigation, except in the intermediate season I (February – April 2000) at Pandan Island and in rainy season (November 2000 – January 2001) at Setan Island. The average length and width of this species at Pandan Island varied between 0.50 - 4.23 mm and 0.37 - 3.30 mm. The longest and the widest of individuals occurred in the intermediate season II period (August – October 2000), whereas the shortest individual was found during the rainy season (November 2000 – January 2001). At Setan Island, it ranged between 0.45 – 3.30 mm and 0.25 - 2.00 mm, with the longest and the widest appeared during the dry season (May – June 2000) (2.74 mm and 2.34 mm), whereas the shortest was in the intermediate season I period (February – April 2001) with an average length of 0.45 mm and width of 0.25 mm.

At Pandan Island, *Pocillopora* sp. settled during both dry seasons with an average length of 3.10 mm and width 3.00 mm, while at Setan Island, it was recorded in the intermediate season I period (February – April 2001) (2.10 mm and 0.70 mm) and during dry season (May – July 2001) (3.00 mm and 2.50 mm), respectively (Figure 3.30).

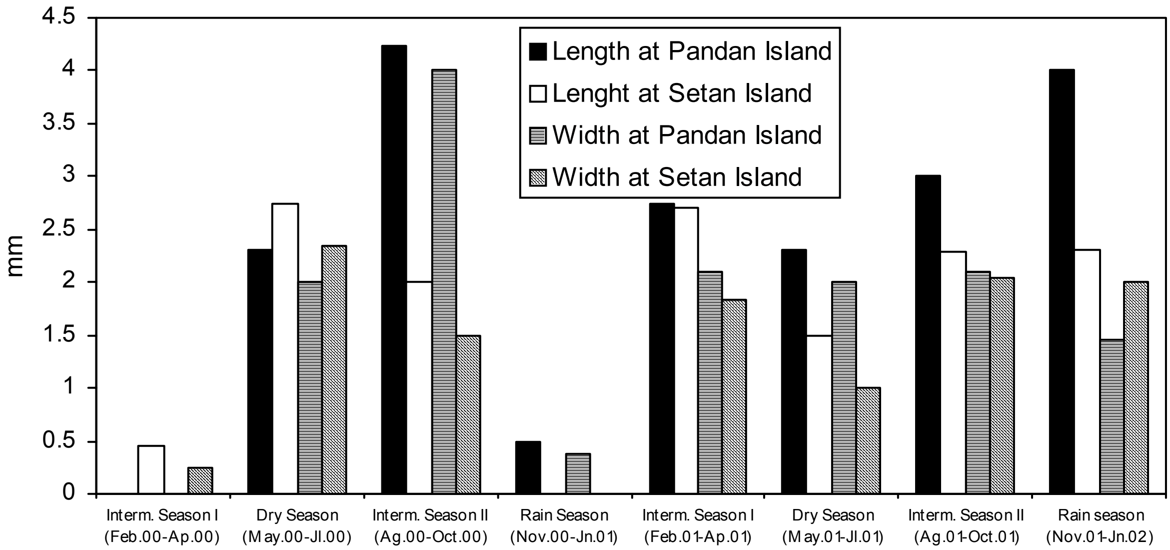


Figure 3.29: Average length and width after three months as well as seasonally (every three months) settlement of *P. damicornis* at Pandan and Setan Islands

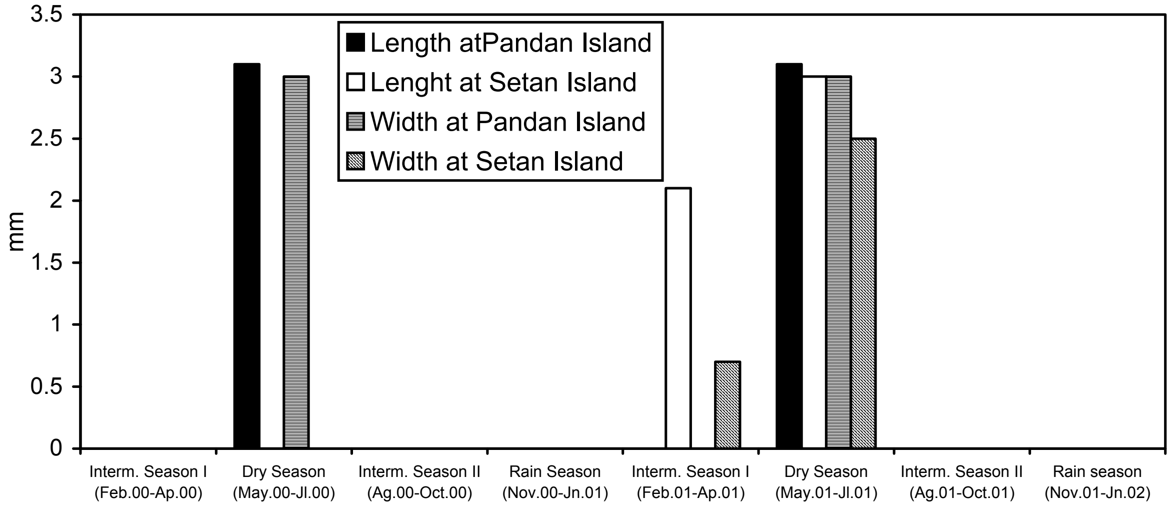


Figure 3.30: Average length and width after three months as well as seasonally (every three months) settlement of *Pocillopora* sp. at Pandan and Setan Islands

Stylophora sp. settled on the substrates only at Setan Island during six times of eight investigations. The average length and width of this species were 0.50 - 1.98 mm and 0.30 - 1.53 mm with the longest and widest occurred in the intermediate season II period (August – October 2001), whereas the shortest was found during the intermediate season I (February – April 2000). The average length and width are specifically shown in Figure 3.31.

At Setan Island, *Seriatopora* sp. settled on the substrates only in the intermediate season II (August - October 2000) with an average length of 0.45 mm and width of 0.35 mm (Figure 3.32).

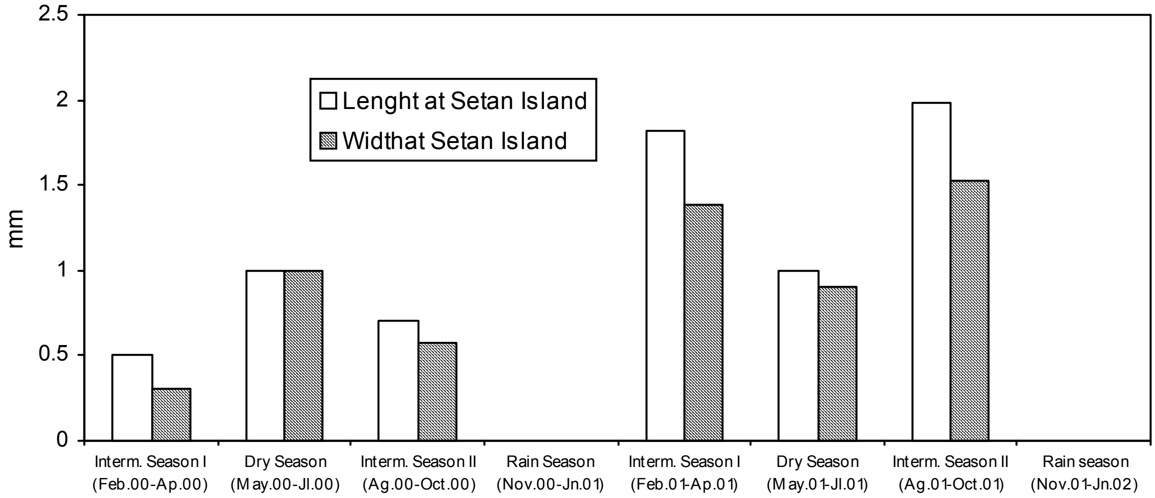


Figure 3.31: Average length and width after three months as well as seasonally (every three months) settlement of *Stylophora* sp. at Setan Island

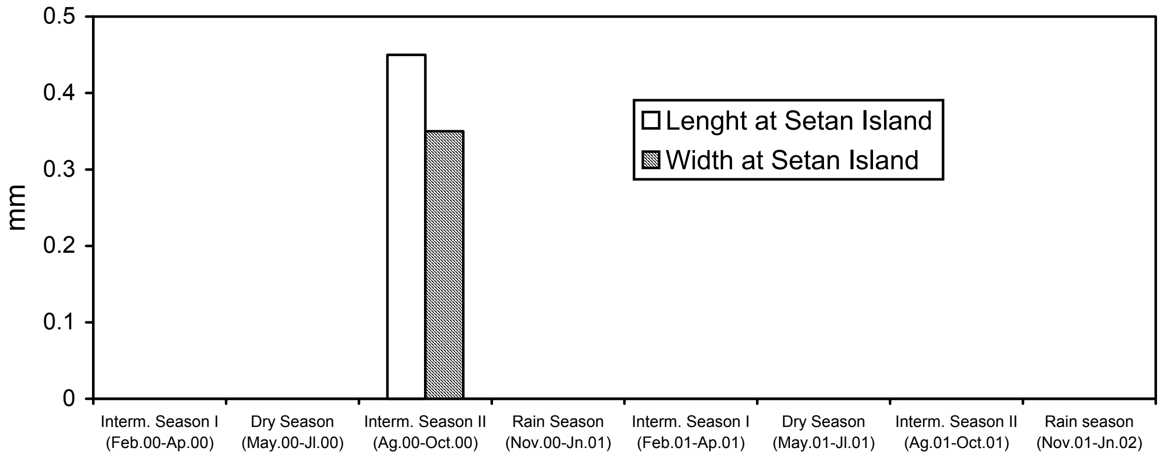


Figure 3.32: Average length and width after three months as well as seasonally (every three months) settlement of *Seriatopora* sp. at Setan Island

Acropora sp. settled during seven times at Pandan Island and was absent in the intermediate season I period (February – April 2000) (Figure 3.33). The average length and width of this species varied between 1.05 - 11.33 mm and 0.53 - 10.00 mm. The longest and widest were found during the rainy season II (November 2001 – January 2002), whereas the shortest appeared in the rainy season I (November 2000 – January 2001). Furthermore, at Setan Island, it was presen during all times of investigations with an average length of 0.50 - 14.00 mm and width of 0.30 - 9.00 mm. The longest and widest of individuals were obtained during the intermediate season I

(February – April 2000), whereas the shortest occurred in the rainy season period (November 2000 – January 2001).

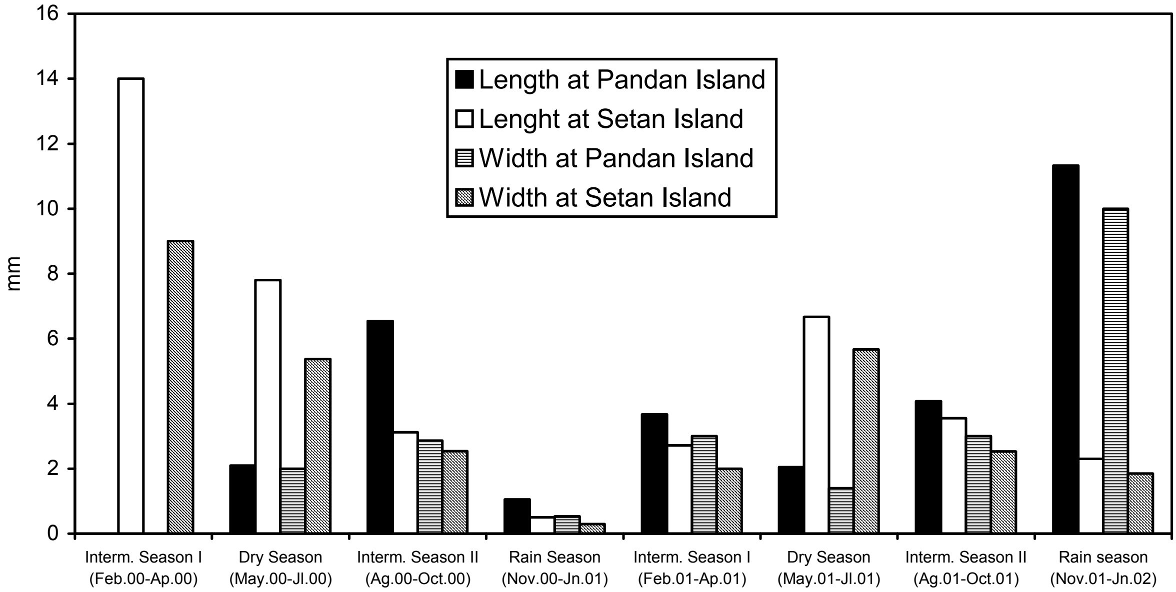


Figure 3.33: Average length and width after three months as well as seasonally (every three months) settlement of A*croporora* sp. at Pandan and Setan Islands

M. aequituberculata settled on the substrates only at Pandan Island during two seasons (Figure 3.34). The longest and widest of individuals were obtained in the rainy season period (November 2001 – January 2002) with an average length of 30.00 mm and width of 20.00 mm, whereas the shortest and narrowest were found during the intermediate season II (August – October 2001) with the values of 23.33 mm and 14.67 mm.

Montipora sp. was found only at Setan Island in the three seasons period (Figure 3.35). There were during the intermediate season I (February - April 2000) with an average length of 2.00 mm and width of 0.90 mm, the dry season (May – July 2000) (2.60 mm and 2.10 mm), and at the end of intermediate season I period (February – April 2001) (0.58 mm and 0.48 mm), respectively.

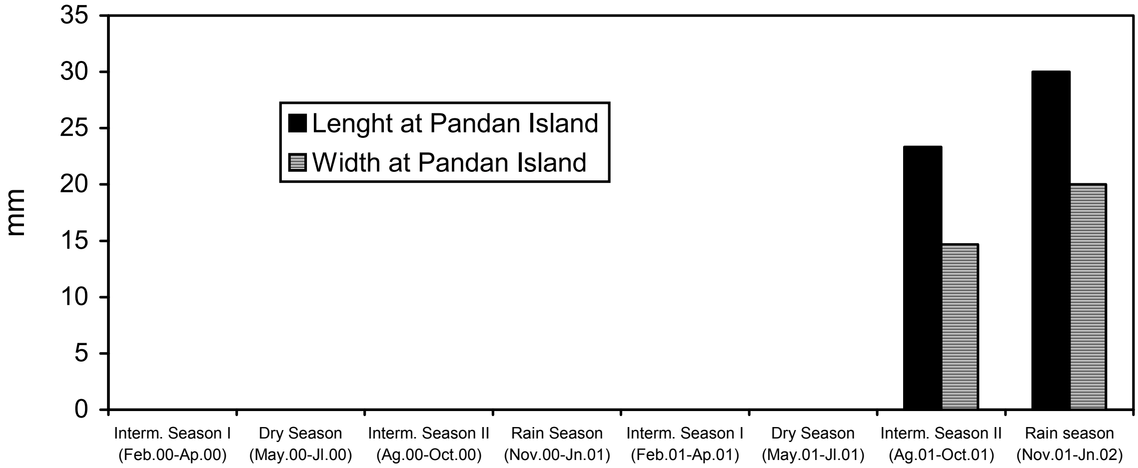


Figure 3.34: Average length and width after three months as well as seasonally (every three months) settlement of *M. aequituberculata* at Pandan Island

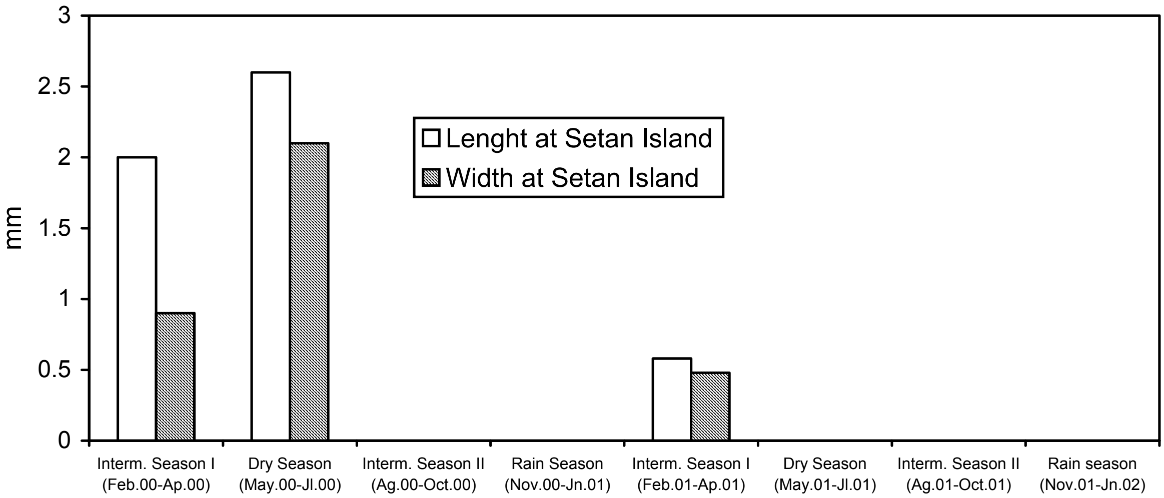


Figure 3.35: Average length and width after three months as well as seasonally (every three months) settlement of *Montipora* sp. at Setan Island

At Pandan Island, *Porites* sp. was obtained during the intermediate season I (February – April 2001) with an average length of 1.20 mm and width of 1.00 mm and in the intermediate season II period (August – October 2001) (2.00 mm and of 1.30 mm), respectively. Moreover, for Setan Island, *Porites* sp. was found in all investigations with an average length of 0.50 – 8.00 mm and width of 0.40 –3.00 mm (Figure 3.36). The longest and widest occurred in the rainy season period (November 2001 – January 2002), whereas the shortest was recorded during the dry season (May – July 2001).

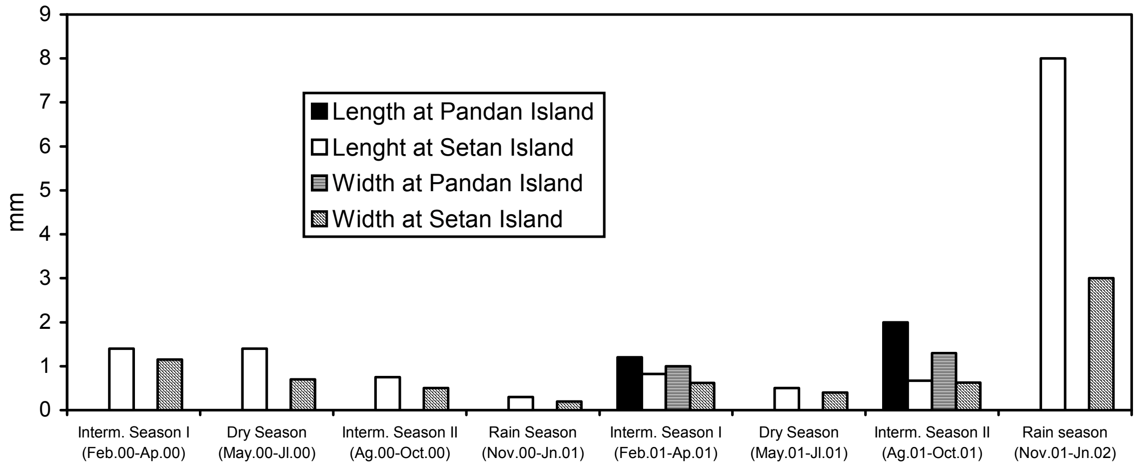


Figure 3.36: Average length and width after three months as well as seasonally (every three months) settlements of *Porites* sp., over a sampling period of two years at Pandan and Setan Islands

Unidentified species settled only during two seasons at Pandan Island (Figure 3.37). There were during the intermediate season I (February – April 2000) with an average length of 4.00 mm and width of 3.00 mm and in the intermediate season II (August – October 2001) (6.50 mm and 5.50 mm). Furthermore, at Setan Island, it appeared in the five times period with average length and width between 0.70 - 5.00 mm and 0.40 - 1.00 mm. The longest and widest occurred during the intermediate season I (February – April 2000), whereas the shortest was recorrded in the dry season period (May – April 2001).

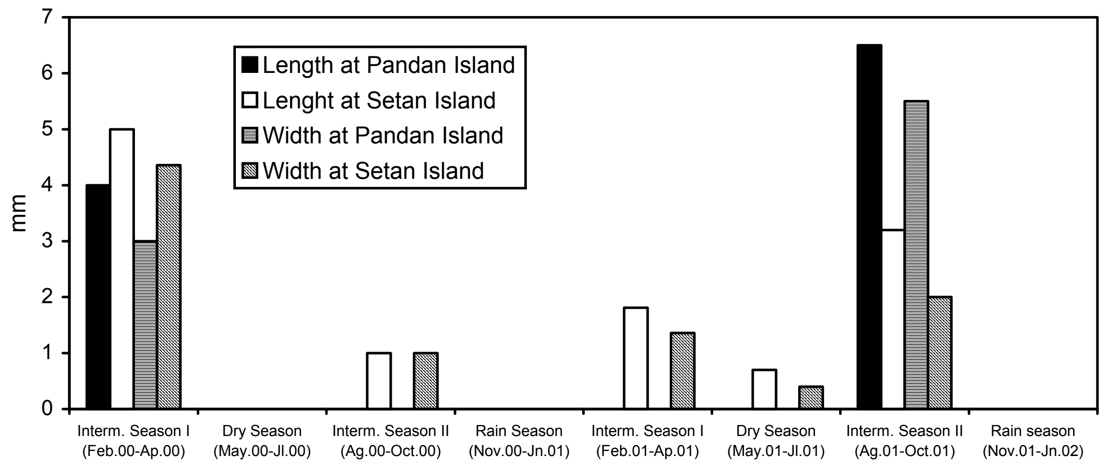
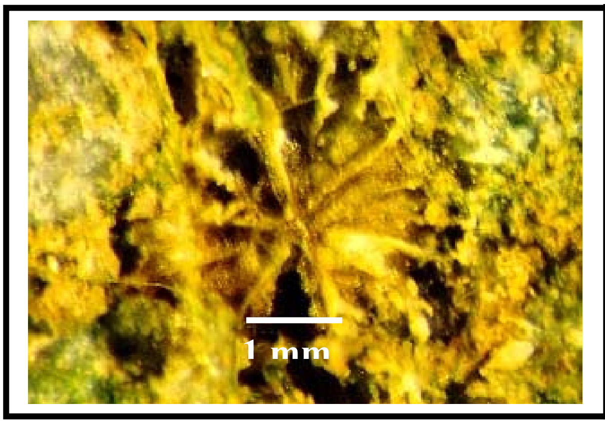
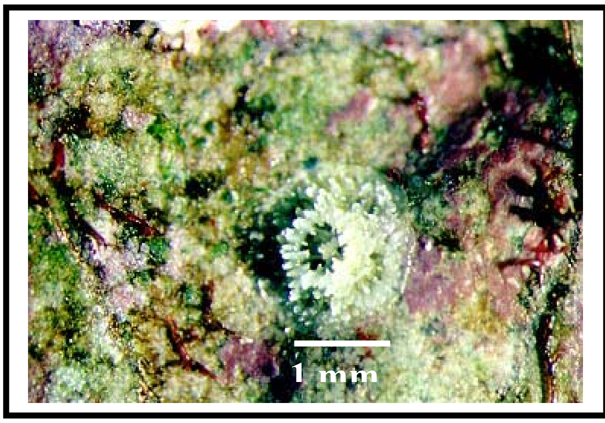


Figure 3.37: Average length and width after three months as well as seasonally (every three months) settlement of unidentified species at Pandan and Setan Islands

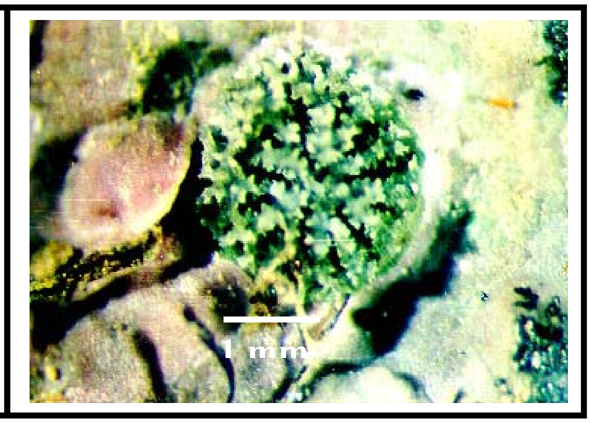


Galaxea sp.

unidentified species

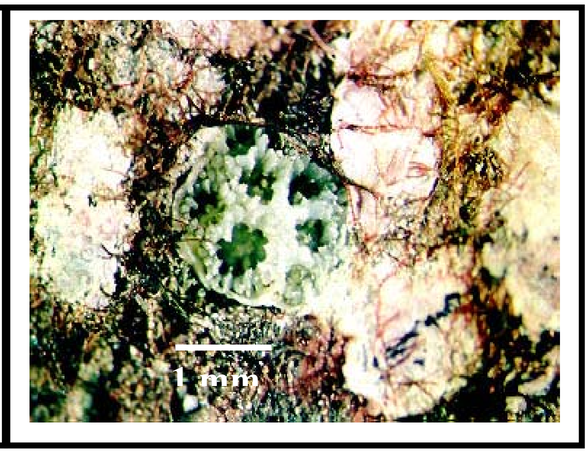


Pocillopora damicornis



Porites sp.

Acropora sp.



Pocillopora sp.

Plate 3.2: Micrographs of the species settled on the concrete substrates after three months

c. After one year

The average length, width, and height, and total polyp of six coral species settled on the substrates at Pandan Island after the first and second year of investigations are shown in Table 3.8. At Setan Island, it is presented in Table 3.9 for five coral species. The profiles of several species are shown in Plate 3.3.

P. damicornis, with branching form, was found settling during both years of observation at Pandan Island. The average length and width after the first year were 21.00 mm and 21.00 mm with an average growth rate of 1.75 mm per month. After the second year, it was 25.00 mm with an average growth rate of 2.08 mm per month for the average length and 6.00 mm (1.33 mm per month) for the average width, further the average height was 17.50 mm with growth rate of 1.46 mm per month.

At Setan Island *P. damicornis* was also recorded during both years of investigation. The average length and width of this species were equal in size (35.00 mm; 2.91 mm per month) and height (29.00 mm; 2.41 mm per month) found in the first year period, was higher than at Pandan Island. Meanwhile, after the second year, with the average length (21.67 mm; 1.81 mm per month), width (18.56 mm; 1.56 mm per month), and height (19.67 mm; 1.64 mm per month) sizes were samller than at Pandan Island.

Galaxea sp. (sub massive of form) settled only in the first year at Pandan Island. This species had the average length and width an equal in size of 12.00 mm; 1.00 mm per month, and the average height was 5.00 mm (0.42 mm per month).

Table 3.8. Average length (L), rate of length per month (L/M), average width (W), rate of width per month (W/M), average height (H), rate of tall per month (H/M) in mm and total polyp of six coral species settled on the substrates at Pandan Island after the first and the second years of investigation

	Feb 2000 - Jan 2001							Feb 2001 - Jan 2002						
Species	**L**	**L/M**	**W**	**W/M**	**H**	**H/M**	**Polyp**	**L**	**L/M**	**W**	**W/M**	**H**	**H/M**	**Polyp**
P. damicornis	21.00	1.75	21.00	1.75	-	-	many	25.00	2.08	16.00	1.33	17.50	1.46	many
Galaxea sp.	12.00	1.00	12.00	1.00	5.00	0.42	many	-	-	-	-	-	-	many
Acropora sp.	-	-	-	-	-	-	-	18.50	1.55	11.50	0.96	19.00	1.58	many
A. cerealis	-	-	-	-	-	-	-	15.00	1.25	15.00	1.25	10.00	0.83	many
A. verweyi	-	-	-	-	-	-	-	10.00	0.83	10.00	0.83	8.00	0.67	many
M. aequituberculata	-	-	-	-	-	-	-	22.25	1.85	16.25	1.35	-	-	many

The other species of *Acropora* sp., *A. cerealis*, *A. verweyi*, and *M. aequitubercula* settled only in the second year. *Acropora* sp., branching coral, had an average length of 18.50 mm with an average growth rate of 1.55 mm per month, width of 11.500 mm (0.96 mm per month) and height of 19.00 mm (1.58 mm per month). The average length and width of *A. cerealis* were 15.00

mm (1.25 mm per month), and average height of 10.00 mm (0.83 mm per month). The next species is *A. verweyi* had an average length and width of 10.00 mm (0.083 mm per month), and height of 8.00 mm (0.67 mm per month). *M. Aequituberculata* is an encrusting in form, was found with an average length of 22.25 mm (1.85 mm per month) and width of 16.25 mm (1.35 mm per month), respectively.

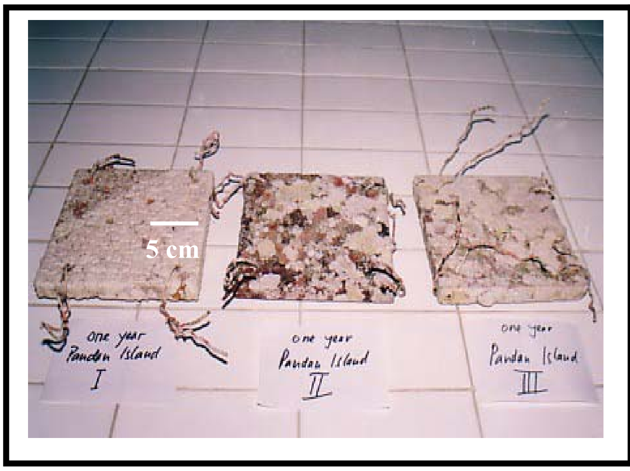
Table 3.9. Average length (L), rate of length per month (L/M), average width (W), rate of width per month (W/M), average height (H), rate of tall per month (H/M) in mm and total polyp of six coral species settled on plates at Setan Island after the first and the second years of investigation

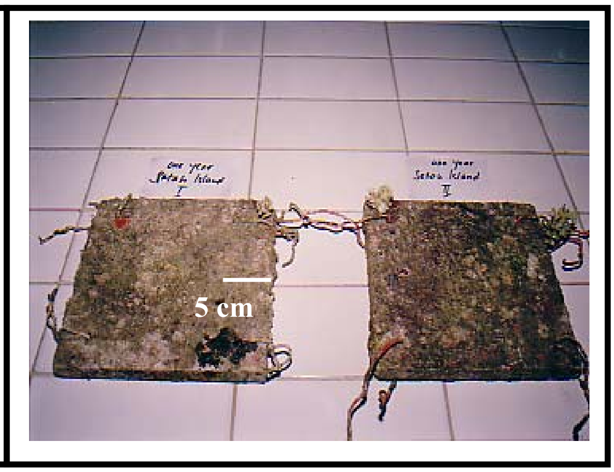
	Feb 2000 – Jan 2001							Feb 2001 - Jan 2002						
Species	**L**	**L/M**	**W**	**W/M**	**H**	**H/M**	**Polyp**	**L**	**L/M**	**W**	**W/M**	**H**	**H/M**	**Polyp**
P. damicornis	35.00	2.91	35.00	2.91	29.00	2.41	many	21.67	1.81	18.67	1.56	19.67	1.64	Many
Acropora sp.	-	-	-	-	-	-	-	18.00	1.50	16.00	1.33	12.00	1.00	Many
A. cerealis	-	-	-	-	-	-	-	30.00	2.50	24.00	2.00	10.00	0.83	Many
Leptoseris sp.	-	-	-	-	-	-	-	19.00	1.58	10.00	0.83	-	-	Many
M. scrabicula	-	-	-	-	-	-	-	30.00	2.50	25.00	2.08	-	-	Many

Acropora sp., *A. cerealis*, *Leptoseris* sp., and *M. scrabicula* were found at Setan Island only after the second year. *Acropora* sp. had an average length of 18.00 mm (1.50 mm per month), width of 16.00 mm (1.33 mm per month), and height of 12.00 mm (1.00 mm per month) was lower than at Pandan Island. The average length, width, and height of *A. cerealis* were 30.00 mm (2.50 mm per month), 24.00 mm (2.00 mm per month), and 10.00 mm (0.83 mm per month), respectively was greater than at Pandan Island. *Leptoseris* sp. was recorded with average length of 19.00 mm (1.58 mm per month) and width 10.00 mm (0.83 mm per month). *M. scrabicula* had an average length of 30.00 mm (2.50 mm per month) and width of 25.00 mm (2.08 mm per month).

Galaxea sp.

Pocillopora damicornis





Concrete substrates on Pandan Island

Concrete substrates on Setan Island

Plate 3.3: Photos showing few species and conditions of the concrete substrates after one year of exposition

d. After two years

There were four species (*P. damicornis*, *P. verucosa*, *A. cerealis*, and *M. aequituberculata*) found settling on the substrates at Pandan Island after two years and five species (*P. damicornis*, *P. verucosa*, *Acropora* sp, *Leptoseris* sp., and *M. scrabicula*) at Setan Island. The average length, width, and rate growth rates as well as total polyps of those species are shown in Table 3.10.

Table 3.10. Average length (L), rate of length per month (L/M), average width (W), rate of width per month (W/M), average tall (H), rate of tall per month (H/M) in mm and total polyp of six coral species settled on the substrates at Pandan and Setan Islands after two years

	Pandan Island							Setan Island						
Species	L	L/M	W	W/M	H	H/M	Polyp	L	L/M	W	W/M	H	H/M	Polyp
P. damicornis	40.00	1.67	40.00	1.67	22.5	0.24	many	11.40	0.48	9.60	0.400	8.13	0.34	many
P. verrucosa	45.00	1.88	40.00	1.67	35.00	2.91	many	40.00	1.67	30.00	1.25	20.00	0.83	many
A. cerealis	40.00	1.67	40.00	1.67	30.00	1.25	many	-	-	-	-	-	-	many
Acropora sp.	-	-	-	-	-	-	-	25.15	1.05	19.25	0.80	9.00	0.19	many
Leptoseris sp.	-	-	-	-	-	-	-	45.50	1.90	27.50	1.15	-	-	many
M. scrabicula	-	-	-	-	-	-	-	47.50	1.98	37.50	1.56	-	-	many
M. aequituberculata	70.00	2.91	61.00	2.54	40.00	1.67	many	-	-	-	-	-	-	-

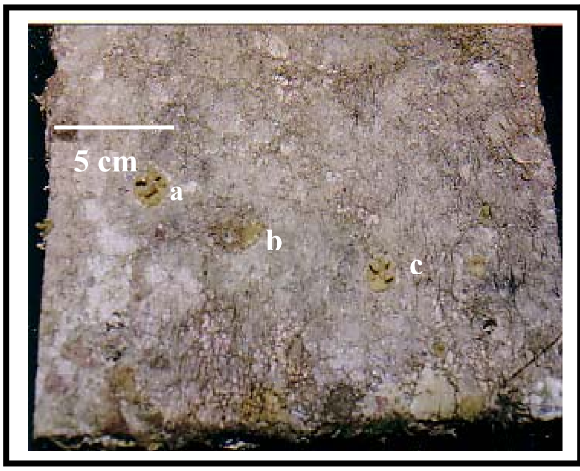
The average length and width (40.00 mm with the average growth rate of 1.67 per month) and average height (22.50 mm; 0.24 mm per moth) of *P.damicornis* after two years at Pandan Island was higher than at Setan Island (average length of 11.40 mm; 1.67 per month, width of 9.60 mm; 0.40 per month, and height of 8.13 mm; 0.34 per month) (Table 3.10).

P. verrucossa had an average length of 45.00 mm (1.88 mm per month), width of 40.00 mm (1.67 mm per month), and height of 35.00 mm (2.91 mm per month) after two years at Pandan Island, while at Setan Island, its average length, width, and height was 40.00 mm (1.67 mm per month), 30.00 mm (1.25 mm per month), and 20.00 mm (0.83 per month), respectively. This indicated that the average growth rate of *P. verrucosa* at Pandan Island was greater than Setan Island.

Acropora cerealis was obtained settling only at Pandan Island with an average length and width of 40.00 mm (1.67 mm per month) and height of 30.00 mm (1.25 mm per month). The other species is *M. aequituberculata* (70.00 mm and 2.91 mm per month for average length; 61.00 mm and 2.54 per month for average width; 40.00 mm and 1.67 mm per month for average height), respectively.

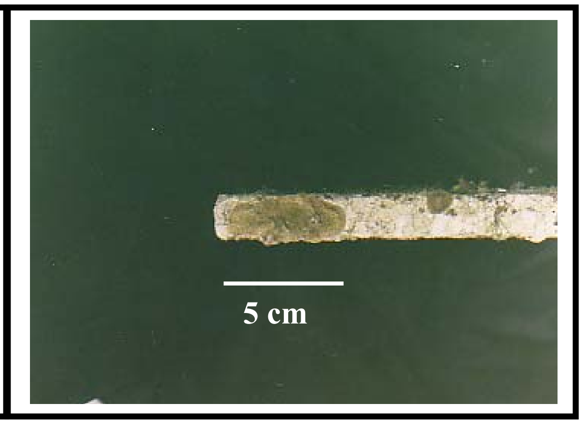
Furthermore, there were three species, namely; *Acropora* sp., *Leptoseris* sp., and *M. scrabicula*, which were found settling only at Setan Island. *Acropora* sp. had an average length of 25.15 mm with the average growth rate of 1.05 mm per month, width of 19.25 (0.80 mm per month), and the average height of 9.00 mm (0.19 mm per month). The average length and width of *Leptoseris* sp. were 45.50 mm (1.90 mm per month) and 27.50 mm (1.15 mm per month). *M. scrabicula* was recorded with an average length of 47.55 mm (1.98 mm per month) and width of 37.50 mm (1.56 mm per month).

The profiles of those species, which settled on the substrates after two years of investigation, are shown in Plate 3.4.



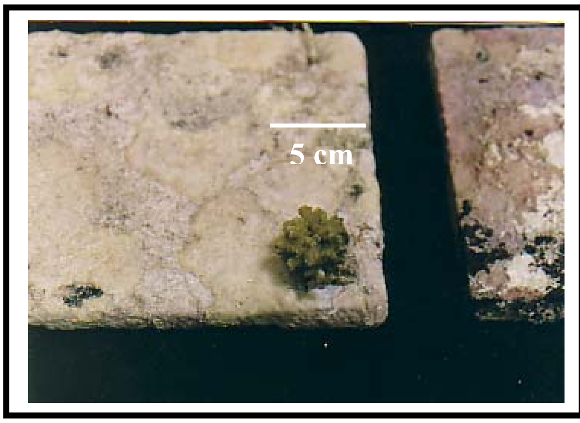
Pocillopora damicornis (a, b, and C)

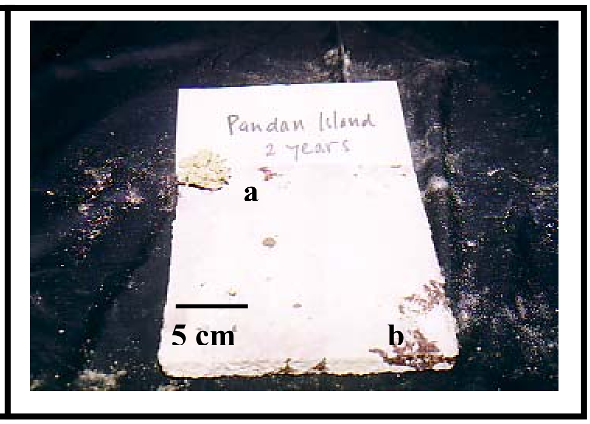
Montipora aequituberculata



Acropora sp. (a), *Merulina scrabicula* (b), and *Leptoseris* sp. (c)

M. aequituberculata





Pocillopora damicornis

Pocillopora damicornis (a) and *A. cerealis* (b)

Plate 3.4: Photos of several species and conditions of the substrates after two years of exposition

3.2 Collecting of mature coral tissue

The aim of collecting the tissue samples from adult corals was to follow their sexual maturation and to investigate the timing of reproduction. The tissue samples were collected from 16 dominant species. The parameters investigated included presence of gonads (male and female), egg development (Gonad Index), fecundity, and colour of gonads.

Based on literature and previous research, the Gonad Index (GI) can be divided into the following criteria;

GI I (Preliminary Stage):

the boundary between eggs was not clear, eggs are usually difficult to count and are generally transparent.

GI II (Continued Stage):

the boundary between eggs can be seen, eggs can be counted, and the colour of eggs are cream, white, yellow and brown, depending on species.

GI III (Mature Stage):

eggs are ready to spawn. If the corals are brooding species, eggs are fertilized internally. Consequently, the development of the planulae stage occurs inside the coral polyp and is ready to be released into the water column. However, if the corals are spawning species, eggs, and sperm are ready to be released into the water column where subsequent external fertilization and development take place. Colour of gonads are generally white, white to cream, cream, yellow, dark yellow, white to pink, pink, brownish, brown, brown to yellow, and yellow to brown.

GI IV (Last Stage):

gonad had spawned and the gonad tissue is generally empty. The colour of gonad is transparent.

The stages of Gonad Index are showed on plate 3.5, 3.6, 3.7, 3.8, 3.9, 3.10, 3.11, 3.12 and 3.13.

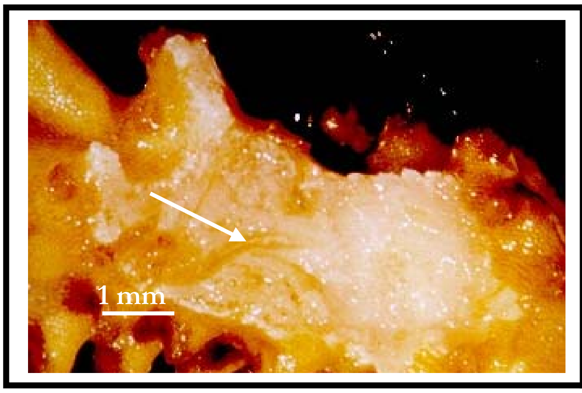


Plate 3.5: Stage I of Gonad Index of Brooding System

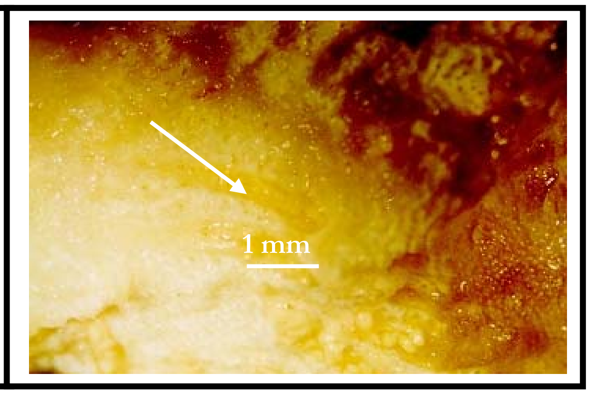


Plate 3.6: Stage II of Gonad Index of Brooding System

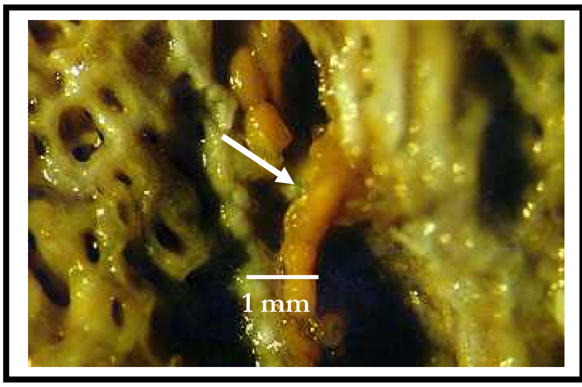


Plate 3.7: Stage III of Gonad Index of Brooding System

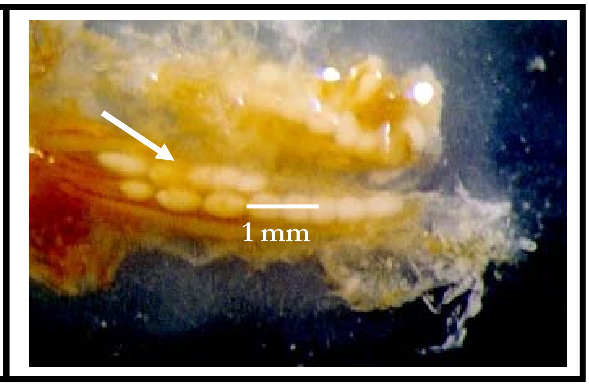


Plate 3.8: Stage III of Gonad Index of Brooding System

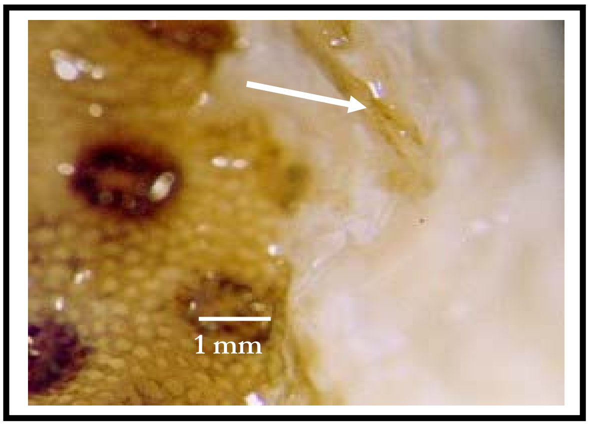


Plate 3.9: Stage IV of Gonad Index of Brooding System

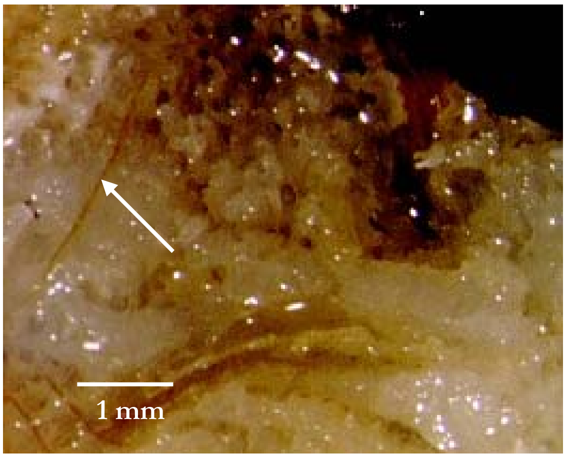


Plate 3.10: Stage I of Gonad Index of Spawning System

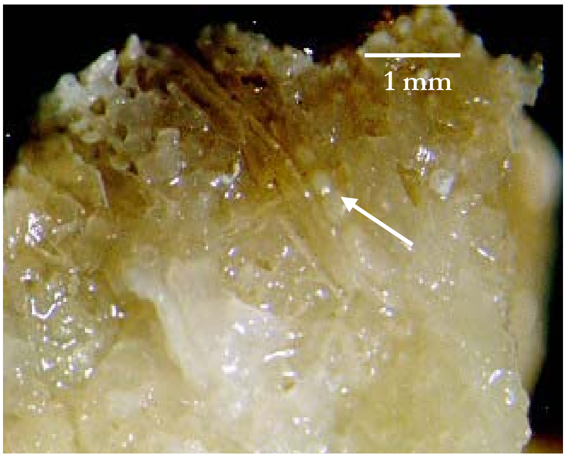


Plate 3.11: Stage II of Gonad Index of Spawning System

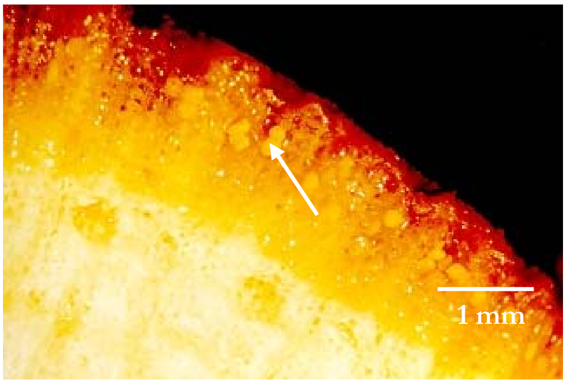


Plate 3.12: Stage III of Gonad Index of Spawning System

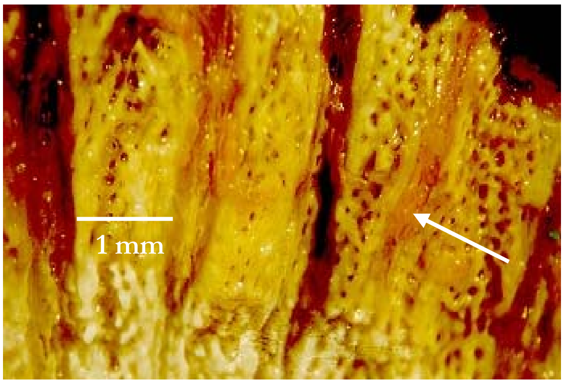


Plate 3.13: Stage IV of Gonad Index of Spawning System

A. <u>Family Acroporidae</u>

Nine species from the family Acroporidae were taken to follow their sexual maturation and to investigate the period of reproduction, namely: *A. cerealis*, *A. donei*, *A. gemnifera*, *A. nana*, *A. nasuta*, *A. robusta*, *A. sarmentosa*, *A. verweyi* and *Astreopora myrophtalma*. All these species are branching corals, except of *Astreopora myrophtalma*, which is a massive coral.

1. *A. cerealis*

<u>Pandan Island</u>

The average initial diameter of *A. cerealis* coral head (three replications) that was taken at Pandan Island was 14.5 cm. The monthly investigation over two years sampling period showed that gonads (male and female) of *A. cerealis* were found in June 2000 and 2001 and in the interval October to December 2001.

Based on the seasons, mature gonads occurred in the middle of the dry season of the first year. Whereas during the second year, it was observed in the middle of the dry season, at the end of intermediate season II, and in the beginning as well as in the middle of the rainy season. However, the potential time of fertilization was when the Gonad Index is at the GI III stage.

Gonad Index observed each month were at the II and III stages (Table 3.11). The average fecundity per five polyps varied between 9.13 ± 1.41 and 13.53 ± 1.73 to GI II and 7.00 ± 0.00 – 13.07 ± 1.98 to GI III (mean ± SD n=15). The colour of eggs were cream or white. All gonads observed were single gonads.

<u>Setan Island</u>

The average diameter of *A. cerealis* collected at Setan Island was 19.3 cm. The presence of gonads (male and female) during the first year was recorded only in March 2000. The gonads were double gonads (13.53 ± 1.73 and 13.00 ± 0.00) with GI III stage and had yellow colour, similar to those mentioned in the middle of intermediate season I. During the second year, they appeared in March (GI III) as double gonads (11.53 ± 1.46 and 12.33 ± 0.72) and had yellow colour, in April (GI IV) as single gonad (9.53 ± 1.25) and the colour was transparent, in June (GI III) as single gonad (6.27 ± 0.96) and the colour was cream, in July (GI I/II) as single gonad (10.07 ± 2.05) and had transparent colour, in September (GI III) as single gonad (12.00 ± 0.00) with yellow colour, and in October (GI III), November (GI II/III), and December (GI III) 2001 as single gonad with cream colour (Table 3.11).

All of the above mentioned gonad stages also occurred in the middle and at the end of intermediate season I, dry season, the intermediate of season II as well as in the beginning, and in the middle of the rainy season. However, the most potential time of fertilization was in the middle of intermediate season I, dry season, middle and the end of intermediate season II, and in the beginning and the middle of the rainy season when the Gonad Index was at the GI III stage.

Table 3.11. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *A. cerealis*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	**Months**	**Presence of Gonad**		**Gonad Index**		**Fecundity**		**Colour**	
		Pandan	**Setan**	**Pandan**	**Setan**	**Pandan**	**Setan**	**Pandan**	**Setan**
2000	February	-	-	-	-	-	-	-	-
							13.53 ± 1.73		
	March	-	M/F	-	III	-	13.00 ± 0.00	-	yellow
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	M/F	-	II	-	13.53 ± 1.73	-	cream	-
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	-	-	-	-	-	-	-	-
	October	-	-	-	-	-	-	-	-
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2001	January	-	-	-	-	-	-	-	-
	February	-	-	-	-	-	-	-	-
							11.53 ± 1.46		
	March	-	M/F	-	III	-	12.33 ± 0.72	-	yellow
	April	-	M/F	-	IV	-	9.53 ± 1.25	-	transparent
	May	-	-	-	-	-	-	-	-
	June	M/F	M/F	II / III	III	9.13 ± 1.41	6.27 ± 0.96	cream	cream
	July	-	M/F	-	I / II	-	10.07 ± 2.05	-	transparent
	August	-	-	-	-	-	-	-	-
	September	-	M/F	-	III	-	12.00 ± 0.00	-	yellow
	October	M/F	M/F	III	III	13.07 ± 1.98	14.33 ± 1.84	cream	cream
	November	M/F	M/F	III	II/III	8.27 ± 0.88	8.47 ± 0.64	white	cream
	December	M/F	M/F	III	III	7.00 ± 0.00	9.27 ± 1.28	white	cream
2002	January	-	-	-	-	-	-	-	-

2. A. donei

<u>Pandan Island</u>

The average initial diameter of *A. donei* from Pandan Island was 16.9 cm. During the first year, gonads in *A. donei* were not found (Table 3.12). However, in the second year period, the gonads occurred in the beginning and at the end of intermediate season I (February and April 2001), as well as in the middle of the rainy season (October 2001). All gonads, which had yellow and cream colours, appeared as double gonads with fecundity between 9.13 ± 0.74 and 12.00 ± 1.51 and Gonad Index III, except in April 2001 where GI stage was also detected. The potential times of fertilization were in February, April 2001 (the intermediate season I), and October 2001 (the rainy season).

<u>Setan Island</u>

The average diameter of *A. donei* that was taken from Setan Island was 37.1 cm. The presence of gonads during the first year were recorded in February (double gonads) and April 2000 (single gonad) or could be found in the beginning and at the end of intermediate season I. The colour of gonads were yellow and cream. Furthermore, it was also detected in September 2000 (the middle of intermediate season II), but GI and fecundity could not be identified. In the second year, the gonads occurred in February (GI III) as double gonad (9.20 ± 1.47 with 11.00 ± 0.77) with yellow colour, June (GI III) as double gonad (8.20 ± 1.01 with 10.07 ± 1.39) with cream colour, and in July (GI II), August (GI III), September (GI II), October (GI III), November (GI III), as single gonad with cream colour (Table 3.12).

The gonads also appeared in the beginning of intermediate season I and in the middle and at the end of the dry season, and in the intermediate season II, as well as in the beginning of the rainy season.

Table 3.12. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *A. donei*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	M/F	-	III	-	12.00 ± 0.85 12.00 ± 0.00	-	yellow
	March	-	-	-	-	-	-	-	-
	April	-	M/F	-	I	-	11.07 ± 0.70	-	cream
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	-	M/F	-	not clear	-	not clear	-	transparent
	October	-	-	-	-	-	-	-	-
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2001	January	-	-	-	-	-	-	-	-
	February	M/F	M/F	III	III	9.13 ± 0.83 9.13 ± 0.74	9.20 ± 1.47 11.00 ± 0.77	yellow	yellow
	March	-	-	-	-	-	-	-	-
	April	M/F	-	I / III	-	12.00 ± 0.32 10.00 ± 1.81	-	cream	-
	May	-	-	-	-	-	-	-	-
	June	-	M/F	-	III	-	8.20 ± 1.01 10.07 ± 1.39	-	cream
	July	-	M/F	-	II	-	13.00 ± 0.54	-	cream
	August	-	M/F	-	III	-	11.07 ± 1.67	-	cream
	September	-	M/F	-	II	-	7.07 ± 1.53	-	cream
	October	M/F	M/F	III	III	10.00 ± 1.46 12.00 ± 1.51	13.00 ± 0.00	yellow	cream
	November	-	M/F	-	III	-	7.00 ± 0.00	-	cream
	December	-	-	-	-	-	-	-	-
2002	January	-	-	-	-	-	-	-	-

3. *A. gemnifera*

Pandan Island

The average initial diameter of *A. gemnifera* collected at Pandan Island was 19.8 cm. The monthly investigation over a sampling period of two years showed that gonads of *A. gemnifera* were found only in December 2000 and in January 2001, or in the middle and at the end of the rainy season (the first year). For the second year, they appeared in May and July 2001 (in the beginning and at the end of the dry season), September 2001 (the middle of intermediate season II), and November as well as December 2001 or in the beginning and at the end of the rainy season. The potential time of fertilization lies in July (in the middle of intermediate season II) and December (the middle of the rainy season) (Table 3.13).

Table 3.13. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *A. gemnifera*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	-	-	-	-	-	-	-	-
	October	-	-	-	-	-	-	-	-
	November	-	F	-	I	-	not clear	-	transparent
	December	M/F	-	I	-	7.00 ±1.07	-	white	-
						3.00 ± 0.00			
2001	January	M/F	-	I	-	6.33 ± 1.99	-	white	-
	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	M/F	-	I	-	13.00 ±0.54	-	transparent
						4.29 ± 0.47			
	May	M/F	-	II	-	6.00 ± 1.13	-	cream	cream
	June	-	-	-	-	-	-	-	-
						6.45 ±1.30			
	July	M/F	-	I/III	-	8.00 ± 0.76	-	cream	-
	August	-	M/F	-	III	-	12.00 ±1.00	-	white
						6.07 ± 0.70			
	September	M/F	-	II	-	8.00 ± 0.66	-	white	-
							7.07 ± 1.53		
	October	-	M/F	-	III	-	8.20 ± 0.78	-	yellow
							10.00 ± 1.13		
	November	-	M/F	-	III	-	11.00 ± 0.82	-	cream
	December	M/F	M/F	III	III	5.00 ±0.66	7.13 ±1.46	cream	cream
2002	January	M/F	-	IV	-	not clear	-	transparent	-

Gonad Index (GI) and colours were I (white), II (white), III (cream), and IV (transparent) (Table 3.13). The averages of fecundity from mean eggs per five polyps were 7.00 ±1.07 (single gonad) and 3.00 ± 0.00 with 6.33 ±1.99 (double gonad), which were both to GI I. For GI II, there were 4.29 ± 0.47 with 6.00 ± 1.13 and 6.07 ± 0.70 with 8.00 ± 0.66 (double gonads). GI III was 6.45 ± 1.30 with 8.00 ± 0.76 (double gonad) and 5.00 ± 0.66 (single gonad), and for GI IV was not been clear to monitor.

<u>Setan Island</u>

The average diameter of *A. cerealis* sampled at Setan Island was 21.3 cm. During the first year, gonads were found only in November 2000 (in the beginning rainy season) with GI I, but the fecundity could not be monitored and the colour of gonads was transparent. For the second year, they were obtained in April (GI I with 13.00 ± 0.54), August (12.00 ± 1.00), October (7.07 ± 1.53 with 8.20 ±0.78), November (10.00 ± 1.53 with 11.00 ± 0.82), and December (7.13 ±1.46) 2001. The stage of gonad was at GI III (cream and yellow), which means that this is a potential time of fertilization. It was also recorded in the beginning and at the end of intermediate season II as well as in the beginning and in the middle of the rainy season (Table 3.13).

4. *A. nana*

<u>Pandan Island</u>

A. nana was collected at Pandan Island with an average initial diameter of 23.4 cm. The gonads were found in June, September, December 2000, and January 2001 (the first year), February, June, July, September, November, December 2001 and January 2002 for the second year (Table 3.14).

Based on the season, mature gonads occurred in the middle of the dry season, the intermediate season II, and rainy season as well as at the end of the rainy season (the first year). Whereas during the second year, they appeared in the beginning of intermediate season I, in the middle and at the end of the dry season, in the middle of intermediate season II, and through the whole rainy season.

Gonad Index, fecundity, and colour of gonad of each month are shown in Table 3.14. The possible times of fertilization were recorded in June 2000 and 2001 (in the middle of the dry season) as well as November and December 2001 (in the beginning and the middle of the rainy season).

Table 3.14. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *A. nana*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
						8.13 ± 0.83	8.31 ± 0.64		
	June	M/F	M/F	III	III	8.27 ± 0.60	8.00 ± 0.76	white	white
							10.13 ±0.99		
	July	-	M/F	-	III	-	11.07 ±1.16	-	transparent
	August	-	M/F	-	IV	-	12.07 ±1.03	-	white
						8.00 ± 0.36			
	September	M/F	M/F	II	II	8.00 ± 0.76	12.07 ± 0.59	yellow	yellow to brown
	October	-	-	-	-	-	-	-	-
	November	-	-	-	-	-	-	-	-
							8.13 ± 0.52		
	December	M/F	M/F	II	II	9.13 ± 1.41	10.47 ± 1.30	white	yellow
2001	January	M/F	-	I	-	not clear	-	white	-
	February	M/F	M/F	I	I	9.07 ± 0.70	10.00 ±0.93	transparent	transparent
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	M/F	-	III	-	7.13 ± 0.52	-	cream
	June	M/F	M/F	III	III	11.07 ± 0.59	11.07 ±0.26	white	White
	July	M/F	M/F	IV	III	not clear	17.00 ±0.66	transparent	cream
	August	-	M/F	-	III	-	12.00 ±0.76	transparent	white
						6.07 ± 0.70			
	September	M/F	M/F	II	III	8.00 ± 0.66	17.47 ±0.52	yellow	yellow
							8.00 ± 1.69		
	October	-	M/F	-	IV	-	10.07 ± 1.79	-	cream
	November	M/F	-	III	-	7.00 ± 0.66	-	white	-
	December	M/F	M/F	III	II	6.00 ± 1.31	8.20 ±1.27	brown	cream
2002	January	M/F	-	IV	-	not clear	-	white	-

Setan Island

The average initial diameter of *A. nana* at Setan Island was 26.4 cm. Gonads (male and female) were present in June and July 2000 (in the middle and at the end of the dry season), August and September 2000 (the beginning and the middle of intermediate season II), and

December 2000 (the middle of the rainy season) during the first year. In the second year, they appeared during the interval May to July 2001 (all of the dry season) and the period August to October 2001 (all of intermediate season II) as well as December 2001 (the middle of the rainy season) (Table 3.14).

The possible period of fertilization in the first year was in June and July 2000 (in the middle and at the end of the dry season). For the second year, gonads were found in May, June and July 2001 (all of the dry season), August and September 2001 (the beginning and the middle of intermediate season II).

5. *A. nasuta*

<u>Pandan Island</u>

A. nasuta was taken at Pandan Island with an average initial diameter of 17.8 cm. Gonads of *A. nasuta* appeared only in August 2000 (in the beginning of intermediate season II) for the first year, and in February 2001 (in the beginning of intermediate season I), May 2001 (the beginning of the dry season), in August, and October 2001 (the beginning and the end of intermediate season II) during the second year. The possible time of fertilization seems to be only in February 2001 (in the beginning of intermediate season I) (Table 3.15).

Gonad Index observed each month were I, II, and III (Table 3.15). The average fecundities and colours of gonad were 13.07 ± 0.70 with 14.60 ± 0.70 to GI II (transparent) and 9.00 ± 0.66 with 9.00 ± 0.38 to GI III (yellow), whereas the fecundities of GI I could not be identified.

<u>Setan Island</u>

The average diameter of *A. nasuta* sampled at Setan Island was 20.2 cm. Gonads appeared in July 2000 (at the end of the dry season), during the interval August to October 2000 (all of intermediate season II), and November 2000 (the middle of the rainy season) for the first year. In the second year, it was found in February 2001 (the beginning of intermediate season I), July 2001 (end of the dry season), and in the period August to October 2001 (all of intermediate season II), as well as November 2001 (the middle of the rainy season) (Table 3.15).

Table 3.15. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *A. nasuta*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	M/F	-	III	-	10.00 ± 0.93 12.00 ± 0.85	-	cream
	August	M/F	M/F	I	III	not clear	10.13 ± 0.99 12.07 ± 0.88	transparent	white
	September	-	M/F	-	II	-	4.07 ± 0.59 6.00 ± 0.93	-	yellow
	October	-	M/F	-	II	-	4.13 ± 0.35 12.07 ± 0.88	-	white
	November	-	M/F	-	III	-	4.00 ± 0.00 8.00 ± 0.76	-	white
	December	-	-	-	-	-	-	-	-
2001	January	-	-	-	-	-	-	-	-
	February	M/F	M/F	III	I	9.00 ± 0.66 9.00 ± 0.38	not clear	yellow	white
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	M/F	-	I	-	not clear	-	transparent	-
	June	-	-	-	-	-	-	-	-
	July	-	M/F	-	III	-	12.00 ± 0.93	-	cream
	August	M/F	M/F	I/II	III	13.07 ± 0.70 14.60 ± 1.50	10.00 ± 0.93 12.00 ± 0.46	transparent	white
	September	-	M/F	-	II	-	6.00 ± 0.76 12.20 ± 0.94	-	yellow
	October	M/F	M/F	I	III	not clear	6.13 ± 0.83 9.26 ± 1.16	transparent	yellow
	November	-	M/F	-	III	-	8.67 ± 2.44 10.13 ± 1.46	-	cream
	December	-	-	-	-	-	-	-	-
2002	January	-	-	-	-	-	-	-	-

The possible time of fertilizations during the first year is in July (the end of the dry season), August (the beginning of intermediate season II), and November 2000 (the beginning of the rainy season). For the second year, it was recorded in July (at the end of the dry season), August, and

October (the beginning and the end of intermediate season II), as well as November 2001 (the beginning of the rainy season).

6. ***A. robusta***

<u>Pandan Island</u>

The average diameter of *A. robusta* collected at Pandan Island was 16.4 cm. Gonads of *A. robusta* during the first year were not found. For the second year, samples were obtained in February 2001 (in the beginning of intermediate season I), July 2001 (the middle of the dry season), and September 2001 (the middle of intermediate season II). The possible time of fertilization seems to be in February 2001 (in the beginning of intermediate season I) and July 2001 (the middle of the dry season). The data are shown in Table 3.16.

Table 3.16 also shows that the GI is GI III with fecundity 9.13 ± 0.99 with 9.07 ± 1.62 (double gonad) and 12.00 ± 1.13 (single gonad), as well as GI II with fecundity 5.27 ± 1.91 with 5.13 ± 0.92. The colours of gonad were yellow dark and white to cream and yellow dark for GI III and cream for GI II.

<u>Setan Island</u>

A. robusta was sampled at Setan Island with an average initial diameter of 18.3 cm. The presence of gonads during the first year was recorded only in September 2000 (in the middle of intermediate season II), and in February 2001 (in the beginning of intermediate season I), May 2001 (the beginning of the dry season), September, and October 2001 (the middle and the end of intermediate season II) for the second year (Table 3.16).

Gonad Index (GI), fecundity, and colour of gonads observed are shown in Table 3.16. The possible time of fertilization may be in May 2001 (in the beginning of the dry season) and October 2001 (the end of intermediate season II).

Table 3.16. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *A. robusta*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	-	M/F	-	I	-	not clear	-	transparent
	October	-	-	-	-	-	-	-	-
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2001	January	-	-	-	-	-	-	-	-
	February	M/F	?/F	III	I	9.13 ± 0.99 9.07 ± 1.62	not clear	yellow dark	transparent
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	M/F	-	III	-	8.07 ± 0.96	-	yellow
	June	-	-	-	-	-	-	-	-
	July	M/F	-	III	-	12.00 ± 1.13	-	with to cream	-
	August	-	-	-	-	-	-	-	-
	September	M/F	M/F	II	I	5.27 ± 1.91 5.13 ± 0.92	not clear	cream	transparent
	October	-	M/F	-	III	-	4.00 ± 0.00	-	cream
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2002	January	-	-	-	-	-	-	-	-

7. *A. sarmentosa*

Pandan Island

The average initial diameter of *A. sarmentosa* sampled at Pandan Island was 18.2 cm. During the first year, gonads were present in the period August to September 2000 (in the beginning and the middle of intermediate season II). In the second year, they were found in June 2001 (in the middle dry season), during the interval August to October 2001 (all of intermediate season II). The potential time of fertilization seems to be in September 2001 (in the middle of intermediate season I) (Table 3.17).

Gonad Index (GI) is I, II, III and III (Table 3.17). The average of fecundities and colours of gonads were 14.27 ± 1.10 with 16.00 ± 1.07 and 10.53 ± 2.33 with 13.07 ± 0.70 to GI II (pink and white to pink), as well as 16.00 ± 0.54 to GI III (pink), whereas GI I could not be identified.

Table 3.17. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *A. sarmentosa*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	M/F	-	II	-	16.00 ± 0.00	-	transparent
	May	-	M/F	-	III	-	16.00 ± 0.85	-	orange
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	M/F	M/F	I	III	not clear	10.13 ± 1.13 12.00 ± 1.31	transparent	white
	September	M/F	M/F	II	IV	14.27 ± 1.10 16.00 ± 1.07	not clear	pink	cream
	October	-	-	-	-	-	-	-	-
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2001	January	-	-	-	-	-	-	-	-
	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	M/F	-	II	-	13.00 ± 0.76	-	transparent
	May	-	M/F	-	III	-	18.13 ± 1.41	-	orange
	June	M/F	-	I	-	not clear	-	transparent	-
	July	-	-	-	-	-	-	-	-
	August	M/F	M/F	II	III	10.53 ± 2.33 13.07 ± 0.70	10.00 ± 0.76 12.00 ± 0.38	white to pink	orange
	September	M/F	M/F	III	IV	13.27 ± 1.91 16.00 ± 0.54	12.00 ± 0.00	pink	yellow
	October	M/F	-	IV	-	not clear	-	transparent	cream
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2002	January	-	-	-	-	-	-	-	-

Setan Island

The average diameter of *A. sarmentosa* collected at Setan Island was 20.2 cm. In the first year, presence of gonads was found only in April 2000 (at the end of intermediate season I), in May 2000 (in the beginning of the dry season), August and September 2000 (the beginning and the middle of intermediate season II). For the second year period, there was no change in timing.

Gonad Index (GI), fecundity, and colour of gonads are shown in Table 3.17. The potential time of fertilization seemed to be at the same time in both years, namely: in May (in the beginning of the dry season), and August (the beginning of intermediate season II).

8. *A. verweyi*

Pandan Island

A. verweyi was collected at Pandan Island with an average initial diameter of 13.5 cm. The monthly investigation showed that the presence of gonads *A. verweyi* was recorded only in October 2001 (at the end of intermediate season II). The Gonad Index was GI III with fecundity 10.00 ± 0.93 (yellow colour).

Setan Island

The average diameter of *A. verweyi* sampled at Setan Island was 18.88 cm. Gonads were present during the first year in March 2000 (in the beginning of intermediate season I) with Gonad Index I, in the interval August to October 2000 (all months of intermediate seasons II), and November 2000 (the beginning of the rainy season) with GI III. The average fecundities were between 4.00 ± 0.00 - 13.00 ± 0.00 with 4.00 ± 0.00 - 15.40 ± 2.29 (double gonads) and 4.00 ± 0.00 (single gonad). The colour of gonads were cream and white (Table 3.18).

Table 3.18. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *A. verweyi*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	M/F	-	I	-	not clear	-	white
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	M/F	-	III	-	12.00 ± 0.00	-	white
							10.00 ± 1.41		
	September	-	M/F	-	III	-	15.40 ± 2.29	-	white
							5.07 ± 0.26		
	October	-	M/F	-	III	-	5.27 ± 0.46	-	cream
							4.00 ± 0.00		
	November	-	M/F	-	III	-	4.00 ± 0.00	-	cream
	December	-	-	-	-	-	-	-	-
	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
							4.07 ± 0.70		
	May	-	M/F	-	III	-	4.00 ± 0.00	-	cream
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	M/F	-	III	-	12.07 ± 0.70	-	white
							13.00 ± 0.00		
	September	-	M/F	-	III	-	15.07 ± 0.88	-	white
							10.53 ± 2.33		
	October	M/F	M/F	III	III	10.00 ± 0.93	13.00 ± 0.00	yellow	cream
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2002	January	-	-	-	-	-	-	-	-

9. *Astreopora myriophthalma*

<u>Pandan Island</u>

The average diameter of *Astreopora myriophthalma* collected at Pandan Island was 19.9 cm. The monthly investigation showed that the gonads of *A. myriophthalma* were found in June, September, and November 2000 (the first year), April, May, July, and during the interval September to December 2001 (the second year) (Table 3.19).

Table 3.19. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *A. myriophthalma*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	M/F	-	II	-	7.00 ± 0.66	-	yellow	-
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	M/F	M/F	I/II	I/II	10.27 ± 1.39	10.00 ± 1.13	yellow	yellow
	October	-	-	-	-	-	-	-	-
	November	M/F	-	III	-	not clear	-	brownish	-
	December	-	-	-	-	-	-	-	-
2001	January	-	-	-	-	-	-	-	-
	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	M/F	-	I	-	18.00 ± 1.31	-	transparent	-
	May	M/F	M/F	III	III	10.07 ± 0.88	6.00 ± 0.00	transparent	yellow
	June	-	-	-	-	-	-	-	-
						11.00 ± 0.76			
	July	M/F	-	II	-	12.00 ± 0.54	-	brownish	-
	August	-	-	-	-	-	-	-	-
							12.07 ± 0.70		
	September	M/F	M/F	II	III	8.73 ± 1.53	14.07 ± 0.88	yellow	orange
	October	M/F	M/F	III	II	8.00 ± 0.00	7.13 ± 0.74	yellow dark	cream
						8.00 ± 0.76	8.00 ± 0.85		
	November	M/F	M/F	III	II/III	14.00 ± 1.31	12.00 ± 1.65	orange	yellow dark
	December	M/F	M/F	IV	III	7.00 ± 0.00	8.00 ± 0.93	brown	brownish
2002	January	-	-	-	-	-	-	-	-

Based on the seasons, presences of mature gonads were observed in the middle of the dry season, the middle of intermediate season II, and the beginning of the rainy season (the first year). For the second year, gonads developed at the end of intermediate season I, the beginning and the end of the dry season, the middle and the end of intermediate season II, as well as the beginning and the middle of the rainy season.

Gonad Index (GI), fecundity and colour of gonads are shown in Table 3.19. The possible times of fertilization were in November of both years investigation (the beginning of the rainy season), in May 2001 (in the beginning of the dry season), and in October 2001 (at the end of intermediate season II).

Setan Island

A. myriophthalma was taken at Setan Island with an average initial diameter of 19.8 cm. Gonads were present only in September 2000 (in the middle of intermediate season II) during the first year. For the second year, they appeared in May 2001 (in the beginning of the dry season), in September and October 2001 (in the middle and at the end of intermediate season II), as well as November and December 2001 (the beginning and the middle of the rainy season (Table 3.19).

Gonad Index (GI), fecundity, and colour of gonad are shown in Table 3.19. The potential time of fertilization could be estimated only for the second year, namely: in May 2001 (in the beginning of the dry season), September 2001 (the middle of intermediate season II), as well as November and December 2001 (the beginning and the middle of the rainy season).

B. Family Faviidae

Only one species from family Faviidae was taken to follow their sexual maturation and to investigate the time of reproduction, namely: *Favia speciosa*. This species is a massive coral.

10. *F. speciosa*

Pandan Island

The average diameter of *F. speciosa* collected at Pandan Island was 13.6 cm. The monthly investigation showed that gonads of *F. speciosa* were found in March, July, and September 2000 (the first year), July and September 2001 (the second year).

Based on the seasons, gonads occurred in the middle of intermediate season I, at the end of the dry season, and the middle of intermediate season II (the first year). Whereas during the second year, it occurred at the end of the dry season and in the middle of intermediate season II.

Gonad Index (GI) were I, II, III and IV (Table 3.20). The average fecundities were 12.07 ± 0.10 with 16.13 ± 0.74 between 13.00 ± 0.00 with 15.00 ± 1.25 to GI II, and 16.00 ± 0.66 to GI

III with cream of colouration of both gonads. The fecundities for GI I and GI IV could not be identified.

Setan Island

The average initial diameter of *F. speciosa* at Setan Island was 15.3 cm. Gonads were present only in September 2000 (the middle of intermediate season II) with single gonad (GI I), but it could not be identified during the first year, and in September (GI I) and October or in the middle and at the end of intermediate season II (GI II) for the second year. The data including colour of gonads and fecundity are shown in Table 3.20.

Table 3.20. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *F. speciosa*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	M/F	-	I	-	not clear	-	transparent	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	M/F	-	II	-	12.07 ± 0.10 16.13 ± 0.74	-	cream	-
	August	-	-	-	-	-	-	-	-
	September	M/F	M/F	II	I	13.00 ± 0.00 15.00 ± 1.25	not clear	cream	transparent
	October	-	-	-	-	-	-	-	-
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2001	January	-	-	-	-	-	-	-	-
	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	M/F	-	III	-	16.00 ± 0.66	-	cream	-
	August	-	-	-	-	-	-	-	-
	September	M/F	M/F	IV	I	not clear	not clear	transparent	transparent
	October	-	M/F	-	II	-	13.13 ± 0.35	-	cream
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2002	January	-	-	-	-	-	-	-	-

C. Family Oculinidae

Only one species from the family Oculinidae was sampled to follow sexual maturation and to investigate the time of reproduction, namely: *Galaxea astreata*. This species is a sub massive coral.

11. *G. astreata*

Pandan Island

The average initial diameter of *G. astreata* collected at Pandan Island was 10.1 cm. The monthly sampling showed no gonads present.

Table 3.21. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *G. astreata*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia.

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	M/F	-	II	-	10.27 ± 1.03	-	orange
	August	-	-	-	-	-	-	-	-
	September	-	-	-	-	-	-	-	-
	October	-	-	-	-	-	-	-	-
	November	-	-	-	-	-	-	-	-
	December	-	-	-	-	-	-	-	-
2001	January	-	-	-	-	-	-	-	-
	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	M/F	-	II	-	7.13 ± 0.83	-	brown to yellow
	May	-	-	-	-	-	-	-	-
	June	-	M/F	-	II	-	8.00 ± 1.25	-	brown
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	-	M/F	-	I	-	not clear	-	transparent
	October	-	M/F	-	II	-	8.00 ± 0.00	-	yellow to brown
	November	-	M/F	-	III	-	not clear	-	yellow to brown
	December	-	M/F	-	IV	-	not clear	-	transparent
2002	January	-	-	-	-	-	-	-	-

Setan Island

Before the first collection of tissue samples, the average diameter of *G. astreata* at Setan Island was 16.7 cm. In the first year, gonads developed only in July 2000 or at the end of the dry season with single gonad (10.27 ± 1.03) and Gonad Index II (orange). In the second year, they appeared in April and June 2001 or in the beginning and the end of the dry season (GI II) with fecundity of 7.13 ± 0.83 and 8.00 ± 1.25 and brown to yellow and brown colours of gonads. It was also found during the interval September to December 2001 in GI I, II, III, and IV (Table 3.21). In addition, fertilization is assumed to occur in November (the beginning of the rainy season).

D. Family Merulinidae

Species from the family Merulinidae were taken to follow sexual maturation and to investigate the time of reproduction only in *Hydnopora microconos*. This species is a massive coral.

12. *H. microconos*

Pandan Island

The average diameter of *H. microconos* collected at Pandan Islan was 17.7 cm. The presence of gonads *H. microconos* was recorded in October and December 2000 or at the end of intermediate season II and the beginning of the rainy season (the first year). During this time, Gonad Index (GI) II was found with cream coloured gonads, but fecundity could not be identified. During the second year, they occurred in September and October 2001 (in the middle and the end of intermediate season), in the interval November to December 2001 (the beginning and the middle of the rainy season). Fecundities were found 10.00 ± 1.25 (GI II) and 7.00 ± 1.31 (GI III) with cream and yellow colours of gonads. The potential time of fertilization seemed to be in December (in the middle of the rainy season) (Table 3.22).

Setan Island

The average diameter of *H. microconos* at Setan Island was 16.2 cm. During the first year, gonads were present only in November 2000 (the beginning of the rainy season) with GI I, but the fecundity could not be monitored. For the second year, they appeared in September (GI II with 12.00 ± 1.46), November (GI II with 6.40 ± 1.35), and December (GI III with 7.13 ± 1.46) 2001, when the colour of gonads was cream (Table 3.22).

Table 3.22. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD and colour of gonads of *H. microconos*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia.

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	-	-	-	-	-	-	-	-
	October	M/F	-	II	-	not clear	-	cream	-
	November	M/F	M/F	II	I	not clear	not clear	cream	transparent
	December	-	-	-	-	-	-	-	-
2001	January	-	-	-	-	-	-	-	-
	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	M/F	M/F	I	II	?	12.00 ± 1.46	transparent	cream
	October	M/F	-	II	-	not clear	-	yellow	-
	November	M/F	M/F	II	II	10.00 ± 1.25	6.40 ± 1.35	cream	cream
	December	M/F	M/F	III	III	7.00 ± 1.31	8.13 ± 1.19	cream	cream
2002	January	-	-	-	-	-	-	-	-

E. Family Poritidae

There were two species from family Poritidae sampled to follow their sexual maturation and to investigate the period of reproduction, namely: *Porites lobata* and *P. lutea*. Both forms are massive corals.

13. *P. lobata*

Pandan Island

P. lobata is a massive coral, being adult generally showing yellow dark colours. The average initial diameter of *P. lobata* collected at Pandan Island was 50.6 cm. The presence of gonads *P. lobata* during the first year were recorded in September and October 2000 (in the middle and at end of intermediate season II), and in November 2000 (in the beginning of the rainy season). For the second year, gonads occurred during the interval August to October 2001 (all of intermediate season II), and in November 2001 (in the beginning of the rainy season). The time of fertilization was found to be in November or in the beginning of the rainy season in both years of investigation (Table 3.23).

Table 3.23. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *P. lobata*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colours	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	M/F	-	I	not clear	-	-	cream
							1029 ± 0.47		
	September	M/F	M/F	I/II	II	8.20 ± 0.41	13.00 ± 0.00	yellow	yellow
						10.13 ± 0.74	4.00 ± 0.00		
	October	M/F	M/F	II	III	13.13 ± 0.74	8.00 ± 0.00	yellow	yellow
						10.00 ± 0.00	4.00 ± 0.00		
	November	M/F	M/F	II/III	III	13.00 ± 0.00	8.00 ± 0.00	yellow	yellow
	December	-	M/F	-	IV	-	not clear	-	transparent
2001	January	-	M/F	-	IV	-	not clear	-	transparent
	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
						20.13 ± 1.71			
	August	M/F	-	I/II	-	20.00 ± 0.00	-	cream	-
							12.00 ± 0.00		
	September	M/F	M/F	II	II/III	11.00 ± 1.00	14.00 ± 0.00	yellow	yellow
						8.26 ± 0.96	8.00 ± 1.25		
	October	M/F	M/F	II	III	12.00 ± 0.00	10.00 ± 0.00	yellow	orange
							8.00 ± 0.00		
	November	M/F	M/F	III/IV	III	12.07 ± 0.80	10.00 ± 0.00	yellow	yellow
	December	-	M/F	-	IV	-	5.00 ± 0.00	-	transparent
2002	January	-	-	-	IV	-	not clear	-	transparent

<u>Setan Island</u>

Porites lobata, at Setan Island, was found in many adult colonies with large sizes. Before the first collection of tissue samples the average diameter was 102.4 cm. Gonads were recorded during the interval August to October 2000 (all of intermediate season II) and the interval

November 2000 to January 2001 (all of the rainy season) for the first year, and in the same time span during the second year (Table 3.23).

The explanation of GI, fecundity and colours of gonads are shown in Table 3.23. The possible time of fertilization was estimated to be in October 2000 or at the end of intermediate season II and in November 2000 (in the beginning of the rainy season) for both years of investigation.

14. *P. lutea*

Pandan Island

Like *P. lobata, P. lutea* also is a massive coral, with colours of adult colonies generally being dark yellow and blue to reddish purple. The average diameter of *P. lutea* sampled at Pandan Island was 39.9 cm. The presence of gonads *P. lutea* was found in September (in the middle of intermediate season II) for both years of observation (Table 3.24). The potential time of fertilization was not recorded, because after two years of investigation Gonad Index III never developed.

Setan Island

Before the first collection of tissue samples, the average diameter of *P. lutea* was 63.9 cm. The presence of gonads during the first year was recorded in the interval September to October 2000 (in the middle and the end of intermediate season II) and the interval November to December 2000 (in the beginning and the middle of the rainy season), and in similar times during the second year (Table 3.24).

GI, fecundity, and colours of gonad are shown in Table 3.24. In addition, the time of fertilization during the first year seemed to be in November 2000 (in the beginning of the rainy season) and in December 2001 (in the middle of the rainy season) for the second year.

Table 3.24. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *P. lutea*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	-	-	-	-	-	-	-
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	M/F	M/F	I	I	not clear	not clear	cream	cream
	October	-	M/F	-	II	-	8.00 ± 0.76	-	yellow
	November	-	M/F	-	II	-	9.00 ± 0.66	-	yellow
	December	-	M/F	-	III	-	9.00 ± 0.00	-	yellow
2001	January	-	-	-	-	-	-	-	-
	February	-	-	-	-	-	-	-	-
	March	-	-	-	-	-	-	-	-
	April	-	M/F	-	?	-	?	-	transparent
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-
	September	M/F	M/F	I/II	II	6.07 ± 0.88	13.20 ± 1.01	cream	yellow
	October	-	M/F	-	II	-	7.13 ± 0.83	-	yellow
	November	-	M/F	-	III	-	8.20 ± 0.41	-	yellow
	December	-	-	-	-	-	-	-	-
2002	January	-	-	-	-	-	-	-	-

F. Family Pocilloporidae

Two species from the family Pocilloporidae were collected to follow sexual maturation and to investigate the timing of reproduction, namely: *P. damicornis* and *P. verrucosa*. Both forms are branching coral.

15. *P. damicornis*

Pandan Island

Many colonies of adult *P. damicornis* were found with different colours. The average initial diameter of *P. damicornis* at Pandan Island was 33.5 cm. The gonads in *P. damicornis* were generally found almost every month in both years of observation. Exceptions were May, June 2000 and 2001 as well as July 2001 (dry season) (Table 3.25). Table 3.25 also shows GI, fecundity, and colour of gonads. Reproduction possibly occurred in all seasons.

Setan Island

Similar to Pandan Island, many colonies of adult *P. damicornis* were found with different colours. The average diameter of *P. damicornis* was 38.3 cm. The presences of gonads were more or less the same as at Pandan Island (Table 3.25).

Table 3.25 also show GI, fecundity, and colour of gonads of *P. damicornis*. The possible time of fertilization during the first year appeared to be in April 2000 and in April and December 2001 for the second year.

Table 3.25. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *P. damicornis*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	M/F	M/F	I	II	not clear	7.00 ± 0.00 12.00 ± 0.00	transparent	Cream
	March	M/F	M/F	I	II	not clear	6.00 ± 0.00 8.00 ± 0.00	transparent	Cream
	April	M/F	M/F	III	III	10.00 ± 0.00	12.00 ± 0.00 16.00 ± 0.00	white	White
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
	August	M/F	M/F	II	I	8.00 ± 0.00 11.00 ± 0.00	4.00 ± 0.00 8.00 ± 0.00	white	white
	September	M/F	M/F	II	II	6.00 ± 0.00 10.00 ± 0.00	4.00 ± 0.00 9.00 ± 0.00	white	cream
	October	M/F	M/F	II	I/II	6.00 ± 0.00 8.00 ± 0.00	4.00 ± 0.00 8.00 ± 0.00	white	white
	November	M/F	M/F	III	I	6.00 ± 0.00 8.00 ± 0.00	4.00 ± 0.00 8.00 ± 0.00	white	white
	December	M/F	M/F	IV	II	3.00 ± 0.00 6.00 ± 0.00	9.00 ± 0.00	transparent	transparent
2001	January	-	-	-	-	-	-	-	-
	February	M/F	M/F	II	-	6.00 ± 0.00 12.00 ± 0.00	6.00 ± 0.00 12.00 ± 0.00	cream	cream
	March	M/F	-	I/II	-	many	-	cream	-
	April	M/F	M/F	III	III	6.00 ± 0.00 9.00 ± 0.00	12.00 ± 0.00	white	white
	May	-	M/F	-	IV	-	not clear	-	transparent
	June	-	-	-	-	-	-	-	-
	July	M/F	-	II	-	6.00 ± 0.00 8.00 ± 0.00	-	cream	-
	August	M/F	M/F	II/III	II	11.00 ± 0.00 14.00 ± 0.00	8.00 ± 0.00 14.00 ± 0.00	cream	white
	September	-	M/F	-	II	-	6.00 ± 0.00 12.00 ± 0.00	-	white
	October	M/F	M/F	II	II	6.00 ± 0.00 8.00 ± 0.00	6.00 ± 0.00 12.00 ± 0.00	white	cream
	November	M/F	-	I/II	-	9.00 ± 0.00 12.00 ± 0.00	-	cream	-
	December	M/F	M/F	III	III	5.00 ± 0.00 6.00 ± 0.00	8.00 ± 0.00 12.00 ± 0.00	white	cream
2002	January	-	-	-	-	-	-	-	-

16. *P. verrucosa*

Pandan Island

The average diameter of *P. verrucosa* was 17.5 cm. Gonads were present in March and April 2000 (in the middle and the end of intermediate season I), during the interval August to October 2000 (all of intermediate season II), and the interval November to December 2000 (in the beginning and the middle of the rainy season) for the first year, while during the second year, they occurred in the interval February to March 2001 (in the beginning and the middle of intermediate season I), in July (at the end of the dry season), August 2001 (the beginning of intermediate season II), and December 2001 (the middle of the rainy season).

For further details on GI, fecundity, and colours of gonads see Table 3.26. During the first year, fertilization occurred in April 2000 or at the end of intermediate season I, and in August 2000 (the beginning of intermediate season II). For the second year, it occurred in February 2001 (the beginning of intermediate season I) and December 2001 (the middle of the rainy season).

Setan Island

At Setan Island the average diameter of *P. verrucosa* was 18.2 cm. During both years of investigation gonads were observed almost at the same time as at Pandan Island with only few exceptions (Table 3.26). This table also shows GI, fecundity, and colours of gonads. The possible time of fertilization was in April 2000 or at the end of intermediate season I and in October 2000 (the end of intermediate season II) for the first year and in the same seasons during the second year.

Table 3.26. Presence of Gonads (M= male and F= female), Gonad Index, Fecundity (means ± SD) and colour of gonads of *P. verrucosa*, identified from February 2000 to January 2002 in coral reefs of Pandan and Setan Islands, West Sumatera Indonesia

Years	Months	Presence of Gonad		Gonad Index		Fecundity		Colour	
		Pandan	Setan	Pandan	Setan	Pandan	Setan	Pandan	Setan
2000	February	-	-	-	-	-	-	-	-
						6.00 ± 0.77	8.62 ± 1.27		
	March	M/F	M/F	II	II	6.00 ± 0.00	10.00 ± 0.00	cream	cream
	April	M/F	M/F	III	III	9.00 ± 1.34	10.00 ± 0.00	white	white
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
	July	-	-	-	-	-	-	-	-
						10.00 ± 0.00			
	August	M/F	M/F	III	I	12.00 ± 0.00	not clear	white	white
	September	M/F	M/F	II	I	10.00 ± 0.00	10.00 ± 0.00	white	white
						8.00 ± 0.00			
	October	M/F	M/F-	II	III	10.00 ± 0.00	-	white	white
	November	M/F	M/F	IV	IV	not clear	not clear	transparent	white
						3.52 ± 1.24			
	December	M/F	M/F	I	I/II	6.00 ± 0.00	9.00 ± 0.00	transparent	cream
2001	January	-	-	-	-	-	-	-	-
						7.00 ± 0.00			
	February	M/F	-	III	-	9.00 ± 0.00	-	cream	-
						6.00 ± 0.00			
	March	M/F	M/F	IV	I	6.00 ± 0.00	not clear	transparent	transparent
	April	-	M/F	-	III	-	12.00 ± 0.00	-	white
	May	-	-	-	-	-	-	-	-
	June	-	-	-	-	-	-	-	-
						7.00 ± 0.00			
	July	M/F	M/F	II	I	10.00 ± 0.00	not clear	cream	transparent
						8.00 ± 0.00	10.00 ± 0.00		
	August	M/F	M/F	III	II	16.00 ± 0.00	12.00 ± 0.00	white	white
	September	-	M/F	-	II	-	not clear	-	transparent
	October	-	M/F	-	II	-	7.00 ± 0.00	-	white
	November	-	-	-	-	-	-	-	-
	December	M/F	M/F	III	I/II	10.00 ± 0.00	6.00 ± 0.00	white	transparent
2002	January	-	-	-	-	-	-	-	-

3.3 Plankton samples for eggs and planulae of corals

Due to the difficulties in assigning eggs and planulae to certain coral species, only their presences are recorded. Eggs and planulae of local coral species are shown in Plate 3.14.

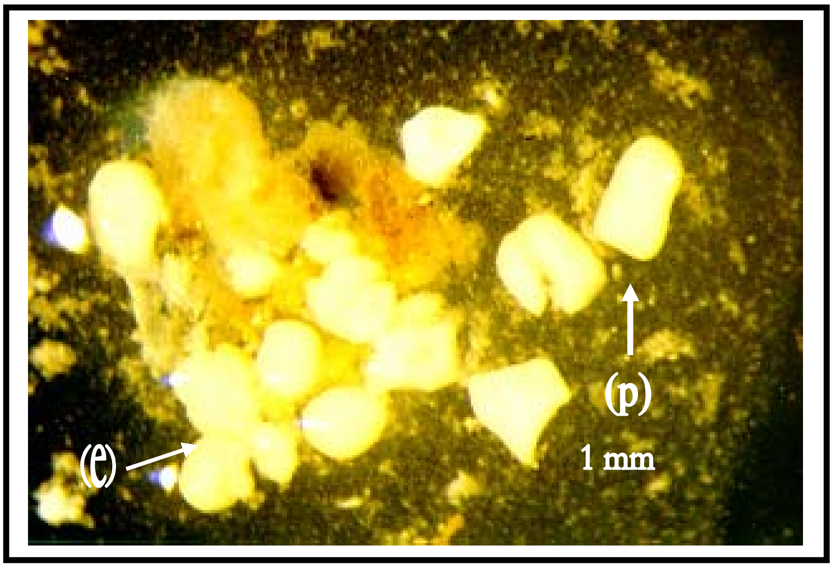


Plate 3.14. Planulae (p) and eggs (e) of corals

The presence of eggs and planulae around Pandan and Setan Islands are shown in Table 3.27. From a total of 24 months of investigation, eggs near Pandan Island were found during18 months (May, June, July, August, September, October, November, December 2000, February, April, May, June, July, August, September, October, November, and December 2001), whereas planulae were obtained during 15 months (June, September, October, November, December 2000, February, April, May, June, July, August, September, October, November, and December 2001). Eggs of corals close to Setan Island occurred as long as 16 months (August, November, December 2000, January, February, March, April, May, June, July, August, September, October, November, December 2001, and January 2002), whereas planuae were found during all months of investigation. It is evident from Table 3.27 that eggs and planulae during the second year of observation in both locations were more numerous.

The total number of eggs at Pandan Island varied between 0 – 79 eggs/liter, and between 0 – 79 eggs/liter at Setan Island (Table 3.27). The highest number at Pandan Island was detected in December 2000 (in the middle of the rainy season), October 2001 (at the end of intermediate season II), and November 2001 (the beginning of the rainy season), while the lowest numbers were found in February, March, April 2000 (during all of intermediate season I), January 2001 and 2002 (the end of the rainy season), and March 2001 (the middle of intermediate season I). At Setan Island, most eggs occurred in December 2000 or in the middle of the rainy season (the first year), in August and September 2001 or in the beginning and middle of intermediate season II (the second year), whereas fewest were obtained during all of months in the first year, except: in August, November, December 2000, and January 2001.

Table 3.27. Total number of Eggs and Planulae of corals (Total number/liter) in water columns of Pandan Island and Setan Island from February 2000 – January 2002

		Pandan Island		Setan Island	
Years	**Months**	**Eggs**	**Planula**	**Eggs**	**Planula**
2000	February	0	0	0	7
	March	0	0	0	5
	April	0	0	0	10
	May	1	0	0	8
	June	8	5	0	2
	July	15	0	0	4
	August	18	0	13	22
	September	3	4	0	14
	October	17	10	0	7
	November	23	11	1	20
	December	59	27	28	43
2001	January	0	0	6	27
	February	7	1	6	21
	March	0	0	2	18
	April	1	4	21	4
	May	3	4	13	21
	June	12	9	38	46
	July	17	11	22	18
	August	13	28	73	71
	September	30	15	79	88
	October	79	39	39	73
	November	68	37	41	89
	December	11	8	23	19
2002	January	0	0	3	2

The total quantity of planulae at Pandan Island ranged between 0 – 37 per liter, whereas at Setan Island, it was between 2 – 89 per liter (Table 3.27). The greatest quantity at Pandan Island was observed in December 2000 (in the middle of the rainy season), October 2001 (at the end of intermediate season II), and November 2001 (the beginning of the rainy season), while the least quantity was found during the interval February to April 2000 (all of intermediate season I), in May and July 2000 (the beginning and the end of the dry season), August 2000 (the beginning of intermediate season II), and in January 2001 and 2002 (the end of the rainy season). For Setan Island, the highest quantity occurred in December 2000 or in the middle of the rainy season, September 2001 or in the middle intermediate season II, and November 2001 or in the beginning of the rainy season, whereas the least numbers were encountered in June 2000 or in the middle of the dry season and in January 2002 or at the end of the rainy season.

3.4 Relationship between reproduction of corals and settlement on the substrates

The relationship between reproduction of corals and settlement on the substrates was estimated by monitoring the coral colonies settlement (every month and three months or seasons) and the presences of gonad (GI II and GIII), eggs, and planulae (every month). As to be expected, coral colonies, which settled on the substrates at Pandan and Setan Islands, were produced by adult corals, which lived in the respective area. In Table 3.28 the presences and absences and their relationship between gonad, eggs, planulae, and coral colonies settlement were marked with + and –, respectively.

Table 3.28. Relationship of presences of gonads, eggs and planulae with coral colonies settlements on the substrates at Pandan Island. +: present, -: absent. C-I: coral colonies settlements every month, C-III: coral colonies settlements every tree months (seasons), P: planulae, E: eggs, 1: *A. cerealis*, 2: *A. donei*, 3: *A. gemnifera*, 4: *A. nana*, 5: *A. nasuta*, 6:*A. robusta*, 7: *A. sarmentosa*, 8: *A. verweyi*, 9: *A. myriophthalma*, 10: *F. speciosa*, 11: *G. astreata*, 12: *H. microconos*, 13: *P. lobata*, 14: *P. lutea*, 15: *P. damicornis* and 16: *P. verrucosa*

Years	Monthly	C-I	C-III	P	E	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2000	Feb	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mar	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
	Ap	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
	May	-		-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	June	-	+	+	+	+	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-
	July	-		-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
	Aug	+		-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
	Sep	+	+	+	+	-	-	-	+	-	-	+	-	+	+	-	-	+	-	+	-
	Oct	+		+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-
	Nov	+		+	+	-	-	-	-	-	-	-	-	+	-	-	+	+	-	+	-
	Dec	+	+	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+
2001	Jan	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Feb	+		+	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-	+	+
	Mar	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
	Ap	-		+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-
	May	+		+	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-
	June	-	+	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
	July	-		+	+	-	-	+	-	-	+	-	-	+	+	-	-	-	-	+	-
	Aug	+		+	+	-	-	-	-	+	-	+	-	-	-	-	-	+	-	+	+
	Sep	+	+	+	+	-	-	+	+	-	+	+	-	+	-	-	-	+	+	-	+
	Oct	+		+	+	+	+	-	-	-	-	-	+	+	-	-	+	+	-	+	+
	Nov	+		+	+	+	-	-	+	-	-	-	-	+	-	-	+	+	-	+	-
	Dec	+	+	+	+	+	-	+	+	-	-	-	-	-	-	-	+	-	-	+	+
2002	Jan	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3.29. Relationship of presences of gonads, eggs, and planulae with coral colonies settlements on the substrates at Setan Island. +: present, -: absent. C-I: coral colonies settlements every month, C-III: coral colonies settlements every tree months (seasons), P: planulae, E: eggs, 1: *A. cerealis*, 2: *A. donei*, 3: *A. gemnifera*, 4: *A. nana*, 5: *A. nasuta*, 6:*A. robusta*, 7: *A. sarmentosa*, 8: *A. verweyi*, 9: *A. myriophthalma*, 10: *F. speciosa*, 11: *G. astreata*, 12: *H. microconos*, 13: *P. lobata*, 14: *P. lutea*, 15: *P. damicornis* and 16: *P. verrucosa*

Years	monthly	C-I	C-III	P	E	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2000	Feb	+		-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-
	Mar	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
	Ap	+		-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	+
	May	+		-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
	June	+	+	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
	July	+		-	+	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-
	Aug	+		+	+	-	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-
	Sep	+	+	-	+	-	-	-	+	+	-	-	+	+	-	-	-	+	-	+	-
	Oct	+		-	+	-	-	-	-	+	-	-	+	-	-	-	-	+	+	+	+
	Nov	+		+	+	-	-	-	-	+	-	-	+	-	-	-	-	+	+	-	-
	Dec	-	+	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+	+
2001	Jan	+		+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Feb	+		+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mar	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ap	-		+	+	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	+
	May	-		+	+	-	-	-	+	-	+	+	+	+	-	-	-	-	-	-	-
	June	+	+	+	+	+	+	-	+	-	-	-	-	-	-	+	-	-	-	-	-
	July	+		+	+	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-
	Aug	+		+	+	-	+	+	+	+	-	+	+	-	-	-	-	-	-	+	+
	Sep	+	+	+	+	+	+	-	+	+	-	-	+	+	-	-	+	+	+	+	+
	Oct	+		+	+	+	+	+	-	+	+	-	+	+	+	+	-	+	+	+	+
	Nov	+		+	+	+	+	+	-	+	-	-	-	+	-	+	+	+	+	-	-
	Dec	+	+	+	+	+	-	+	+	-	-	-	-	+	-	-	+	-	-	+	+
2002	Jan	-		+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

3.5 Oceanographic parameters

In the present study, physical and chemical oceanographic parameters are considered the most important factors governing reproduction and settlements of corals. These are sea surface and bottom temperatures, sedimentation, transparency, pH and salinity.

1. Physically Oceanographic

a. Sea surface and bottom temperatures

Monthly average sea surface and bottom temperatures in both locations during two years investigations (February 2000 – January 2002) displayed similar trends (Figure 3.38 and Table A.3.1 and A.3.3, see Appendix 3).

Sea surface temperatures in both locations fluctuated between 24.0 and 30.0 ^{o}C. For the first year, a maximum of 29.0 ^{o}C was registered at Pandan Island during the interval July to November 2000 (end of the dry season to the middle of the rainy season). At Setan Island, also 29.0^{o}C, occurred in March and July 2000 as well as in the interval September to November 2000. For the second year at Pandan and Setan Islands, the highest of 30.0^{o}C was reached in February and March 2001 (in the beginning and the middle of intermediate season I), and in May 2001 (in the beginning of the dry season) at Pandan Island. In contrast, lowest temperatures were recorded at Pandan Island in April 2001 (at the end of intermediate season I) with 27. 0^{o}C for the first year, and 24.0^{o}C was observed in September 2001 (in the middle of intermediate season II) and November 2001 (in the beginning of the rainy season) (the second year). At Setan Island, 26.7^{o}C was found in December 2000 (in the middle of the rainy season) for the first year, and 24.0^{o}C was registered in November 2001 (in the beginning of the rainy season). The analysis of variance (ANOVA) of sea surface temperature shows highly significant differences in locations, times of sampling, and interactions between locations and times ($F = 4617.84; 71.41; 35.57$, $p < 0.01$) (see Appendix 3, Table A.3.2).

Sea bottom temperatures at Pandan Island varied between 23.0 and 29.0^{o}C and from 23.0 to 29.7 ^{o}C at Setan Island. The maximum of 28.0^{o}C at Pandan and Setan Islands were found in July 2000 or at the end of the dry season during the first year. Furthermore, 29.0^{o}C occurred in the interval February to March 2001, and in July 2001 on Padan Island, and only in February 2001 at Setan Island for the second year. On the other hand, minima were recorded at Pandan Island in February 2000 (24.8^{o}C) and in September 2001 (23.0^{o}C) during both years of investigation. At Setan Island, 26.0^{o}C occurred in October 2000 and 23.0^{o}C in September and October 2001, and January 2002. The ANOVA-test of sea bottom temperatures shows highly significant differences in time of sampling, over a period of the two years investigation, while these is no significant difference in location and interaction between locations and time ($F = 2.83; 53.73; 1.37$, $p > 0.05$; $p < 0.01$; $p > 0.05$) (see Appendix 3, Table A.3.4).

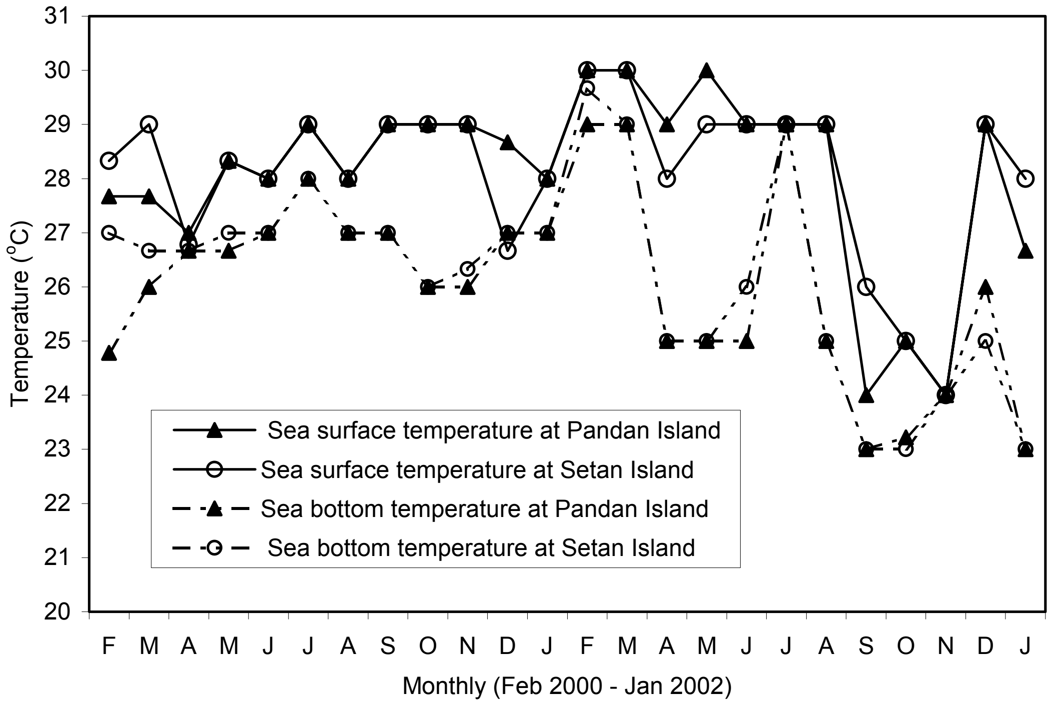


Figure 3.38: Monthly averages of sea surface and bottom temperatures (°C) in both locations during two years of investigation (February 2000 – January 2002)

b. Sedimentation

In the present study, sedimentation is defined as the material (sand, silt, clay, and others), which are present in water column and has settled into the trap. Sedimentation is measured as the mass of sediment in milligram per area of sediment trap (113.04 cm^2) per month. Monthly average values of sedimentation in both locations ranged from 11.80 to 390.42 $mg.cm^{-2}.month^{-1}$ for the first year and 15.95 to 372.73 $mg.cm^{-2}.month^{-1}$ during the second year period (Pandan Island) and 13.74 to 607.45 $mg.cm^{-2}.month^{-1}$ (the first year) as well as 15.95 to 560.72 $mg.cm^{-2}.month^{-1}$ for the second year (Setan Island) (Figure 3.39 and Table A.3.5, see Appendix 3). The highest sedimentation was recorded in similar times during both years of observation for both locations (October 2000 and 2001). The values ranged between 390.42 and 372.73 $mg.cm^{-2}.month^{-1}$ at Pandan Island and 607.45 and 560.72 $mg.cm^{-2}.month^{-1}$ at Setan Island. The lowest sedimentation at Pandan and Setan Islands were 11.80 and 13.74 $g.cm^{-2}.month^{-1}$ in June 2000, and 15.95 and 28.10 $g.cm^{-2}.month^{-1}$ in March 2001, respectively. It is evident from Table A.3.5 (Appendix 3) that the average sedimentation at Setan Island generally was higher than at Pandan Island.

Seasonal fluctuations of sedimentation in both locations during both years were evident. From the beginning of intermediate season I (February – April 2000) to the end of the dry season

(May – July 2000) sedimentation decreased, whereas it increased from the beginning of intermediate season II (August – October 2001) to the end of the rainy season (November 2000 – January 2001) (Figure 3.39). The analysis of variance on sedimentation showed highly significant differences in location, time of sampling, and interaction between locations and time ($F = 56.86; 54.65; 4.14, p < 0.01$) (see Appendix 3, Table A.3.6).

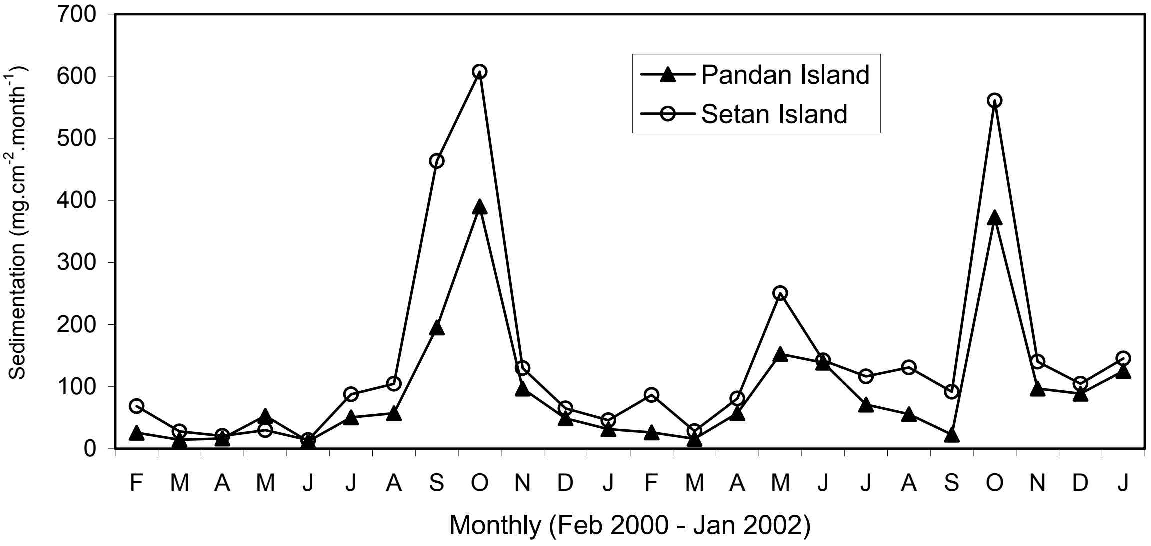


Figure 3.39: Monthly average sedimentation ($mg.cm^{-2}.month^{-1}$) in both locations during two years of investigation (February 2000 – January 2002)

c. Transparency

The average visibility fluctuated between 7.00 - 30.00 m at Pandan Island and 4.00 - 15.00 m at Setan Island (Figure 3.40 and Table A.3.7). Generally the waters around Pandan Island are clearer than near Setan Island. At Pandan Island, the maximum of 30 m occurred in April 2001 (at the end of intermediate season I) and in October 2001 (at the end of intermediate season II). On the other hand, the lowest (7 m) was found in November 2001 (in the beginning of the rainy season). At Setan Island, the highest (15 m) was recorded in April 2001 (in the beginning of intermediate season I), and in December 2001 (in the middle of the rainy season), while the lowest (4 m) was detected in January 2002 (at the end of the rainy season). The ANOVA-test on transparency shows highly significant differences in locations, times of sampling, and interactions between locations and times ($F = 4617.84; 71.41; 35.57, p < 0.01$) (Table A.3.8). Transparency and sedimentation showed inverse relationships in both locations.

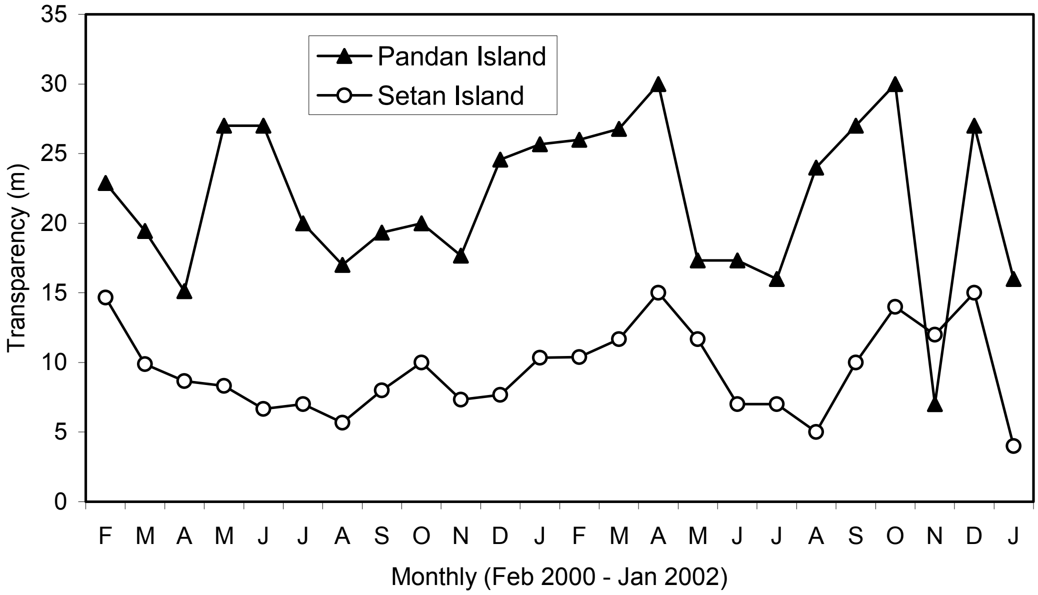


Figure 3.40: Monthly average transparency (m) in both locations during two years of investigation (February 2000 – January 2002)

2. Chemically Oceanographic

a. pH

The pH fluctuated between 7.60 and 9.20 and between 7.63 and 9.00 at Pandan and Setan Islands (Figure 3.41 and Table A.3.9). At Pandan Island, the highest values appeared during the interval June to August 2000 (8.40) for the first year and in August 2001 (9.20) for the second year, whereas the lowest was detected in December 2000 (8.10) (first year) and in November 2001 (7.60) (second year). Furthermore, at Setan Island maxima occurred in March 2000 (8.50) during the first year and in August 2001 (9.00) for the second year. In contrast, the lowest value was measured in October 2000 (7.97) (first year) and in April 2001 (7.63) (second year).

Seasonal fluctuation of pH-values in both locations showed the same trend. During the first year, the pH was relatively stable, while during the second year more fluctuations were encountered. Locations, times of sampling, and interaction between locations and times gave highly significant pH-values (ANOVA; $F = 29.65; 62.95; 15.12$, $P < 0.01$) (see Appendix 3, Table A.3.10).

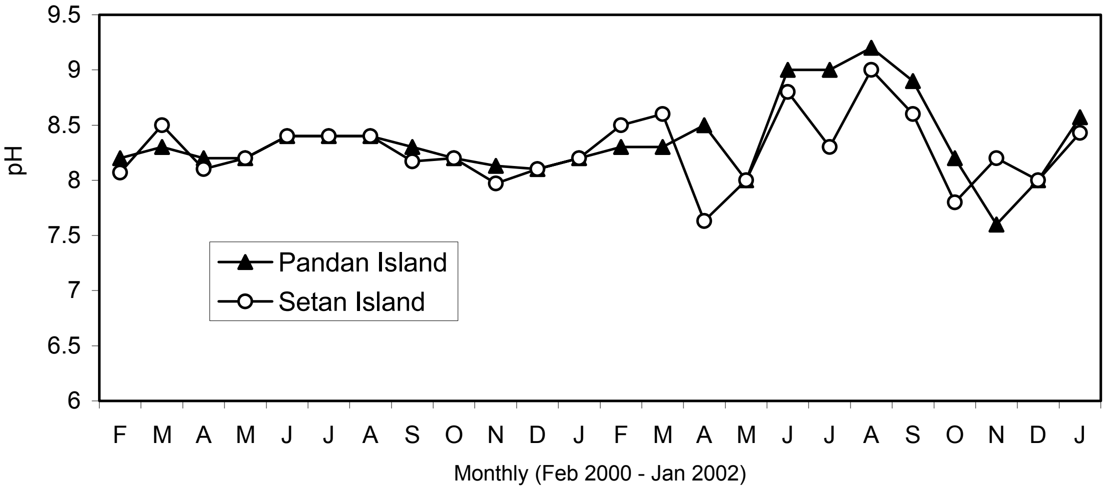


Figure 3.41: Monthly average pH in both locations during two years of investigation (February 2000 – January 2002)

b. Salinity

Monthly average salinities varied between 31.00 – 34.67 and 29.67 – 34.00 at Pandan and Setan Islands with less variability during the first year (Figure 3.42 and Table A.3.11).

Salinities at Setan Island were lower than at Pandan Island. Setan Island is situated close to the Sumatera mainland and therefore more influenced river input by Pisang River (see Figure 2.1).

The analysis of variance on salinity shows highly significant differences in locations, times of sampling and interactions between locations and times ($F = 536.28; 43.70; 29.29$, $p < 0.01$) (Table A.3.12, Appendix 3).

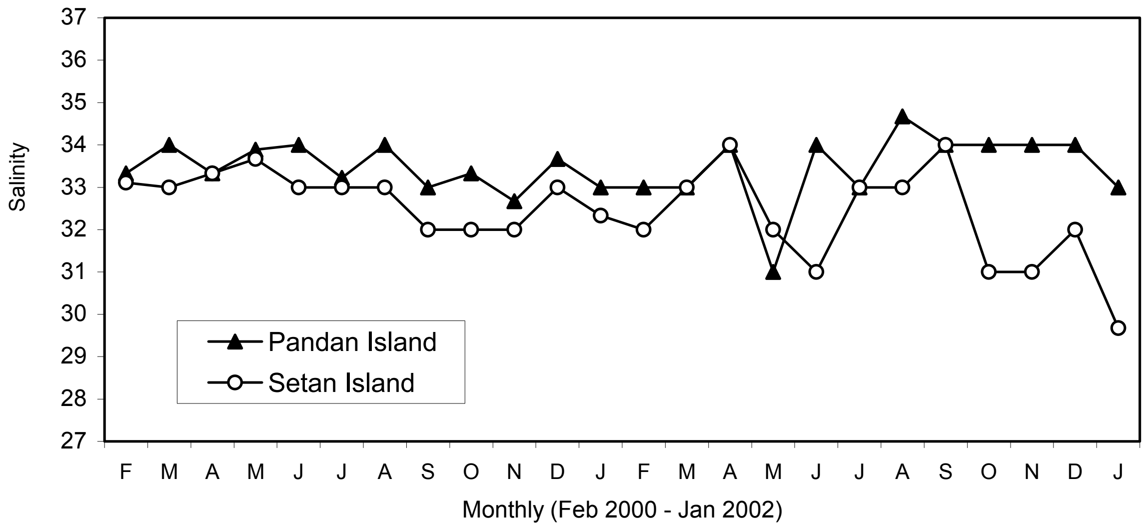


Figure 3.42: Monthly average salinity in both locations during two years of investigation (February 2000– January 2002)

3.6 Rainfall

An additional environmental parameter investigated was the seasonal variation in rainfall, collected in Padang City (ca 10 km from both locations) by Meteorology and Geophysics, Tabing, Padang, West Sumatera, Indonesia. The average monthly rainfall ranged from 2.45 to 26.65 mm (the first year) and from 4.49 to 19.2 mm (the second year) (Figure 3.43). The highest rainfall occurred in November 2000 for the first year and in February 2001 for the second year, whereas the lowest rainfall was in February 2000 and December 2001. The days of rainfall in monthly measurements (from February 2000 to January 2002) is presented in Figure 3.44.

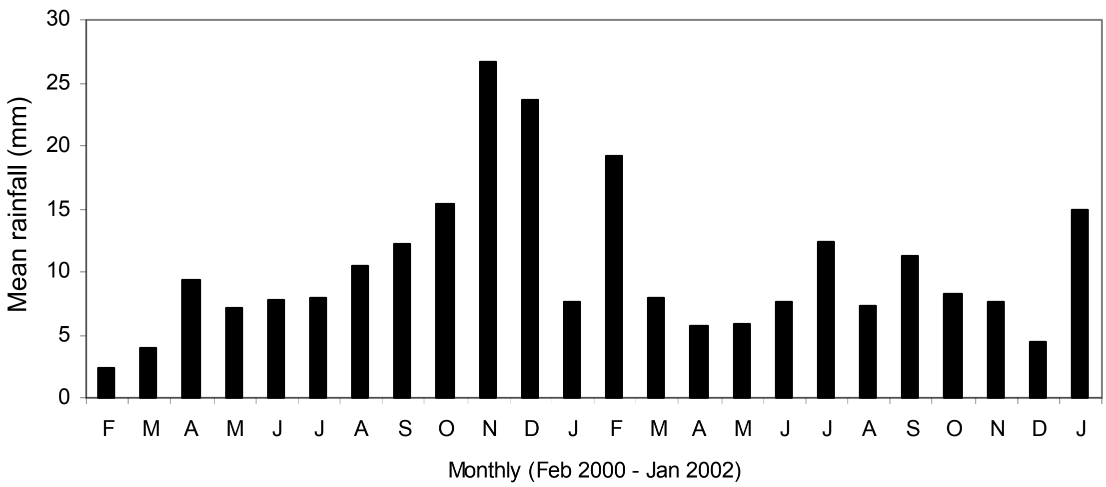


Figure 3.43: Mean monthly rainfall (mm) in Padang City from February 2000 to January 2002) (source from Meteorology and Geophysics, Tabing, Padang, West Sumatera, Indonesia)

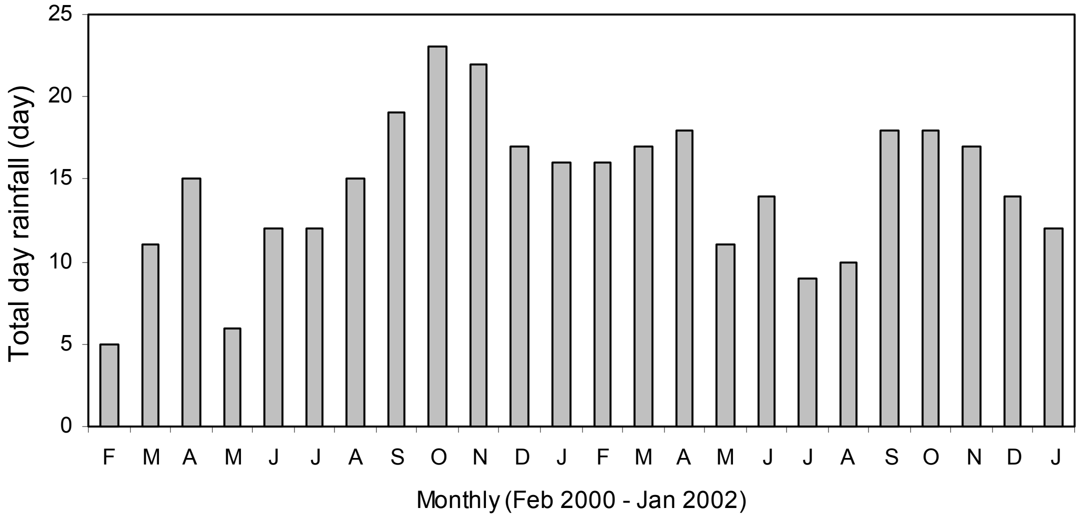


Figure 3.44: Monthly days of rainfall over a taking period of two years (February 2000 to January 2002) in Padang City (source from Meteorology and Geophysics, Tabing, Padang, West Sumatera, Indonesia)

3.7 Relationship between rainfall and oceanographic parameters

Spearman-Rank-correlations were used to test relationships among oceanographic parameters themselves and the relationship between rainfall and oceanographic parameters (Table 3.30 and 3.31). The results show no significant correlation between transparency and sedimentation. However, it is clearly evident from the data that an increase in transparency is followed by a decrease in sedimentation. In addition, pH was negatively correlated with sedimentation but it is a positively associated with transparency, even though, there is no significant correlation among them. Salinity had a negative correlation with sedimentation, surface and sea bottom temperatures, but it was positively correlated with transparency and pH. The overall relationships are significant only between salinity and sea surface temperature, and salinity and rainfall (Table 3.30). Moreover, rainfall was positively correlated with sedimentation, surface and sea bottom temperatures, and pH, whereas it was negatively associated with transparency and salinity.

Table 3.30. Spearman-Rank-correlations among oceanographic parameters themselves and the relationship between rainfalls and oceanographic parameters at Pandan Island. Bold values are statistically significant ($p < 0.05$, $n = 24$)

	Sediment	Transparency	Sea surf. temp.	Sea bott. temp.	pH	Salinity
Transparency	-0.25					
pH	-0.02	0.05				
Salinity	-0.13	0.31	**-0.42**	-0.38	0.15	
Rainfall	0.20	-0.23	0.06	0.30	0.18	**-0.42**

At Setan Island, transparency was negatively associated with sedimentation, but without being significant (Table 3.31). In addition, pH had negative correlations with sedimentation and transparency, but was highly significant with transparency. Salinity was negatively significantly correlated with sedimentation, whereas with transparency, surface and sea bottom temperatures and pH showed a positive correlation (Table 3.31). Moreover, rainfall correlated positively with sedimentation, sea bottom temperature and pH, but had negatively with transparency (highly significant), sea surface temperature and salinity.

Table 3.31. Spearman-Rank-correlations of relationships among oceanographic parameters themselves and the relationship between rainfalls and oceanographic parameters at Setan Island. Bold values are statistically significant ($p < 0.05$, $n = 24$)

	Sediment	**Transparency**	**Sea surf. temp.**	**Sea bott. temp.**	**pH**	**Salinity**
Transparency	-0.02					
PH	-0.15	**-0.52**				
Salinity	**-0.64**	0.03	0.14	0.30	0.03	
Rainfall	0.25	**-0.41**	-0.03	0.18	0.07	-0.25

3.8 Relationship between oceanographic parameters and rainfall with settlements of coral colonies

Multiple regressions between the oceanographic parameters; sea surface and bottom temperatures, transparency, sedimentation, pH, and salinity, and rainfall as the independent variables with total corals colonies which settled on the substrates as the dependent variable at Pandan and Setan Island over a sampling period of two years (February 2000 – January 2002) are presented in Table 3.32. The results showed that the oceanographic parameters and rainfall had a significant influence on the settlements total of coral colonies at Pandan Island ($F = 3.31$, $p < 0.05$, $R^2 = 0.59$). Whereas at Setan Island, contradictory results appeared in which oceanographic parameters and rainfall had no significant contribution to the number of coral colonies settled on the substrates ($F = 1.26$, $p > 0.05$, $R^2 = 0.36$).

Table 3.32. Result of stepwise multiple regression analysis for relationship between oceanographic parameters and rainfall with settlements of coral colonies, *: significant with $p < 0.05$ and ^{ns}: not significant with $p > 0.05$

	Pandan Island		Setan Island	
R^2	0.59		0.36	
ANOVA	3.31*		1.26^{ns}	
	B (coefficients)	**t**	**B (coefficients)**	**t**
Constant	2.79	0.06	114.74	1.02
Sea surface temperature	0.28	0.46	0.26	0.15
Sea bottom temperature	-0.70	-1.25	1.62	1.03
Sedimentation	0.30	0.23	-3.18	-1.25
Transparency	-0.04	-0.32	-0.20	-0.21
PH	-0.37	-0.89	-17.81	-1.96
Salinity	0.28	0.25	-0.70	-0.30
Rainfall	0.55	4.50*	0.10	0.22

Based on the data from Table 3.32, for Pandan Island, only rainfall had a significant positive effect to the settlement of colonies ($t = 4.50$ with $p < 0.05$), while all oceanographic parameters showed no significant influence. At Setan Island neither rainfall nor oceanographic parameters showed significant effects to the establishment of coral colonies.

4. DISCUSSION

4.1 Critical evaluation of methods

4.1.1 Material, characteristics, and position of concrete substrates

Following the recommendations from previous investigations (Van Moorsel, 1988; Fisk and Harriott, 1990; English et al., 1994; Harriott and Banks, 1995; Maida et al., 1995; Abrar, 1997; Oren and Benayahu, 1997), concrete substrates of 20 x 20 x 2 cm size and a rough texture were used in this study for settlement of juvenile corals. The characteristics of the substrates were modified in regard to in size and surface texture. Van Moorsel (1988), Fisk and Harriott (1990), Harriott and Banks (1995), Maida et al. (1995), and Oren and Benayahu (1997) used ceramic tiles for settlement of juvenile corals with sizes between 15 x 15 cm and 20 x 20 cm and smooth surfaces. English et al. (1994) suggested that cement is better than other material used so far. The study from Abrar (1997) using different artificial substrates for settlement of corals resulted in a total of 108 colonies, which settled on the substrates within a five months period. Of those, 59 colonies grew on cement, 29 on tiles, and 20 colonies on iron, respectively. Cement plates are consistent and can not be damaged in the water column. Based on previous research, rough substrates were preferred over smooth ones. Most corals settled at sheltered sections on the substrates with a rough surface texture.

In addition to material and characteristics of the substrates, settlement of juvenile corals also was influenced by the position of the substrate within the water column. In this study, the substrates were placed in a 75^{o} angle in the water column. The substrates were held on metal racks with a size of 50 x 50 cm at the top and 60 x 60 cm at the bottom as well as 50 cm total height. Carleton and Samarco (1987), and Samarco (1991) found a significant correlation between plate angle and coral recruit density, and significantly more recruits than expected on substrates at angles between 61 and 90^{o}. Coral larvae may prefer particular angles within microhabitats at settlements and/or survival of recruits may depend on the angle of the microhabitat. In the present study, the juvenile corals were found on all surfaces of the substrates front backsides and all edges.

4.1.2 Collecting of mature coral tissues

The aim of collecting mature coral tissue in this study is to follow sexual maturation and to investigate periodicity of coral reproduction. Similar procedures were used by Dai et al. (1992), Shlesinger et al. (1998), Kojis (1986a and b), Tomascik and Sander (1987), Tanner (1996), Kruger and Schleyer (1998), and Harii et al. (2001). From branching corals 3 – 5 cm long pieces were collected, and from massive corals live tissue and skeleton of approximately 10 cm^2 in surface area were removed with a hammer and chisel. From each species samples were obtained and preserved in 10% formaldehyde-seawater for at least 24 hours. The tissue samples of adult corals were submerged in 8% formic acid for 48 hours for decalcification. Other authors e.g. Kojis (1986a and b) decalcified their samples in Groding and Stewart`s decalcifying solution of 2.5 M HCL and stored in 10% formaldehyde, Tomascik and Sander (1987b) used a solution of equal parts of 50 % formic acid and 20% sodium citrate, which was changed after 6 hours, and Tanner (1996) decalcified in a solution of 10% hydrochloric acid and 5% formaldehyde for decalcification. After two to three days, when decalcification was complete, samples were preserved in 75% alcohol. In addition, Kruger and Schleyer (1998) used formic-nitric acid solution for decalcification and preserved the samples in 70% ethyl alcohol. The method used in the present study is simpler and less expensive than those reported above.

Almost all studies on sexual reproduction used histological analysis of coral tissues. Because I had limited access to laboratory facilities for histology analysis, I used the developmental stage of the reproductive tissues to describe the Gonad Index and to predict the time of reproduction.

4.2. Discussion of results

4.2.1 Total number of coral colonies and species settled

Coral colonies

The total number of coral colonies settled on the substrates in the monthly samples at Setan Island (218 colonies) is higher than at Pandan Island (83 colonies). This result was more influenced by the islands locations (oceanic area versus land closeness) than by river input and human settlement. Currents, wave action, and wind generally play an important role in influencing the marine ecology around islands. Padan Island is an oceanic island with average oceanic currents of 0.60 m per second (west wind season) and 0.80 m per second (east wind season), wind velocities of 10 knot (wets wind season) and 8 knots (east wind season), whereas at Setan Island (situated in a bay) these respective values were lower (Nasrun, 1999). Areas of high prevailing wave energy and oceanic currents influence the reproductive success and recruitment failure of corals as well as their growth rate (Birkeland, 1997). Studies by Fisk and Harriott (1990), who investigated spatial and temporal variation in coral recruitment on the Great Barrier Reef, showed that the mean density of coral recruits on artificial plates was greater in the fringing reef (81.1 recruits/plate) than in mid-shelf reefs (15.6 recruits/plate).

The lower abundance of coral recruits on the settlement plates at Padan Island compared to Setan Island could result either from lower local availability of larva or from a lower probability that larva settle when present. Local larval availability may be a function of local abundance of adult corals (Bak and Engel, 1979; Van Moorsel, 1989), if reefs are primarily self-seeding (see Balck et al., 1991). Self-seeding is more likely with brooding corals, which release larvae that can settle rapidly (Lewis, 1974; Goreau et al., 1981). In the present study, the most common coral recruits were several species of Pocilloporidae (*Pocillopora damicornis* and *P. verrucosa*) and Acroproridae (*Acropora* sp), all of them brooding species (Birkeland, 1997). Total coral settlement at our study locations was correlated with total adult coral cover at the sites. The areal cover and diversity of corals at Setan Island was (35 %) higher than at Pandan Island (25 %). This implies that coral larva settling was probably higher at Setan Island. Coral settlement rates should be influenced by the local availability of larvae and the probability that larvae settle if suitable substrates are present (Hunte and Wittenberg, 1992). Several studies have suggested that settlement rates are influenced by larval availability and hence by the local abundance of adult corals (e.g. Harriot, 1983b; Van Moorsel, 1989). Furthermore, observations on maturity and size measurements of adult corals showed that those corals, which were ready for reproduction, were more numerous at Setan Island than at Pandan Island. Reasons for these different conditions of the coral reef at Pandan Island were that here the corals were recovering from bleaching in 1997 (Zakaria, 2001). According to Richmond (1993), Hunte and Wittenberg (1992) showed that the successful regeneration of a coral reef depended on the presence of adult corals, which were able to reproduce. In addition, Richmond and Hunter (1990), Stoddarrt and Black (1985), and Wallace (1985 a and b) reported that the first sexual reproduction of corals generally occurs if the diameter of a colony is higher than 10 cm. Tanner (1996) studied *P. damicornis* with 15 to 20 cm in diameter to investigate seasonality and lunar periodicity in the reproduction of Pocilloporid corals. Kojis (1986b) found sexual reproduction in *Acropora* from the Great Barrier Reef and Papua New Guinea with average sizes of colonies between 10 and 30 cm.

Our measurements (see chapter 3.2) showed that the average diameter of reproducing corals from the families Acroporidae (nine species) ranged from18.88 to 37.08 cm at Setan Island (Pandan Island: 13.5 and 23.3 cm). Other species were similar in size (Faviidae) 15.3 cm at Setan Island and 13.6 cm at Pandan Island; Oculinidae 16.7 cm at Setan Island and in 10.1 cm at Pandan Island; Merulinidae in 17.7 cm at Pandan Island and in 16.2 cm at Setan Island; Poritidae 63.9 and 102.4 cm for Setan Island and 39.9 to 50.6 cm for Pandan Island; Pocilloporidae 28.3 for Setan Island, and at Pandan Island, it ranged from 20.5 cm.

The other reason why different numbers of coral colonies settled on the substrates in the monthly sampling between at Setan and Pandan Islands were competition between coral colonies and other species (biotic factor). At Pandan Island, the coral colonies had to compete mainly with coralline algae than algal turfs, barnacles, mussel and other organisms. In contrast, at Setan Island, the coral colonies competed more with algal turfs than coralline algae, barnacles, mussel, and other organisms. Other oceanographic parameters such as transparency and sedimentation were more favourable at Pandan Island than at Setan Island.

Coralline algae are capable of fast growth in waters with high transparency and less sedimentation, because photosynthesis can be optimal (Benayahu and Loya, 1981; McCook, 2001; McCook et al., 2001). They outgrow coral colonies (Lirman, 2001; McCook, 2001; Birkeland, 1997). In addition, coralline algae mainly grow laterally (encrusting) until they enclose juvenile corals and other species, which live around them. On the other hand, high sedimentation will not influence the growth of algal turfs and sponges as well as other benthic species (Brown and Dunne, 1980; Hunte and Wittenberg, 1992; Hodgson, 1990), which may actually benefit from this input.

Coral larvae are sensitive to microhabitats, e.g., substrate composition (Benayahu and Loya, 1984), light conditions, and orientation of substrates (Babcock and Mundy, 1996). Densities and composition of coral recruits also differ among monthly, seasons and between years, often by several orders of magnitude and latitude (e.g., Wallace, 1985a). Different monthly sampling periods over the two years of investigation in both locations showed that the coral colonies did not settle on the substrates during all months. At Setan Island, colonies established themselves during 19 months (of 24), which was higher than at Pandan Island (14 months). Most settlements at Setan Island were found in August 2000 (the beginning of intermediate season II) in the first year and in June 2001 (the middle of the dry season) in the second year, whereas at Pandan Island, the maxima were recorded in November 2000 (the beginning of the rainy season) during the first year and in May (the beginning of the dry season), September (the middle of intermediate season II), and November 2001 (the beginning of the rainy season) for the second year (see Figure 3.1).

The peaks of settlement correlated with the time of adult fertilization in both locations (Pandan and Setan Islands) (see Table 3.28 and 3.29). Results of Tanner (1996), who investigated coral settlement during the period 10th February 1992 to 18th March 1993 at Heron Island in the southern Great Barrier Reef, found from three species of Pocilloporid present in February, March, and April 1992 (intermediate season I), August, September, and October 1992 (intermediate season II) as well as November and December 1992 (rainy season), which are similar with my study. However during the present study more corals inhabited the substrates than Harriott and Bank (1995) and Tanner (1996) reported elsewhere. The cause for this phenomenon may be the different latitudinal location of the study sites. My study was conducted in low latitudes (equatorial region). Pandan is located on 0º 55' 55.51" S and 100º 8' 16.91" E and Setan Island is located at 1º 07' 09.13" S and 100º 22' 51.74" E. The study of Harriott and Bank (1995) has taken place at Solitary Island Marine Reserve, eastern Australia (30º 18' S and 29º 40' S) and the investigation of Tanner (1996) was performed at Heron Island, at the southern part of the Great Barrier Reef, Australia (23º 26 S, 151º 55' E), both at higher latitudinal locations. Islands from low latitudes generally have smaller variations of oceanographic parameters (especially temperature) during the year than islands, which are located at high latitudes). According to Miller (1995), Suharsono (1996), Lalli and Parsons (1997), and Birkeland (1997) coral reefs are generally restricted to seawater with a temperature range between 18º and 36ºC, with an optimal range of 26 – 29ºC. This is expressed in latitudinal patterns of coral reef distribution and diversity.

Water temperature, lunar cycles, salinity, food, day length, moonlight, tidal cycles and daily light /dark cycles (Harrison and Wallace, 1990) have been suggested as mechanisms for synchronizing gamete development within the anthozoa. Experimental studies of the effects of environmental variables on gametogenesis and planulation in *B. elegans* have shown that temperature is the major factor controlling reproductive seasonality (Beauchamp, 1993). Richmond and Hunter (1990) reported that changes of oceanographic parameters could influence the release of planule and such the settlement of juvenile corals on the substrates. These factors and the amount of rainfall (see sub chapter 3.8 and 4.2.5) also influenced the total number of newly settled coral colonies at Pandan and Setan Islands during the different monthly investigations. The oceanographic parameters (temperature, transparency, sedimentation, pH, and salinity) varied with different seasons. Rainfall was positively correlated with sedimentation, surface and sea bottom temperatures, and pH, whereas it was negatively associated with transparency and salinity at Pandan Island. Moreover, at Setan Island, rainfall correlated positively with sedimentation, sea bottom temperature and pH, but was negative with transparency, sea surface temperature and salinity. However, in this case, sedimentation and transparency is more influenced by rainfall. During the rainy season, higher rainfall causes increased sedimentation, and in turn decreased transparency in both locations. In contrary, in the dry period lower rainfall causes decreased sedimentation, and increased transparency.

Sedimentation may damage corals at any stage in their life cycle. Hodgson (1990), Hunte and Wittenberg (1992) noted that coral planulae do not settle on silt-covered surfaces, but prefer clean substrates. Corals and associated zooxanthellae depend on light (high transparency in the water column) for rapid deposition of calcium carbonate (Chalker, 1981), high turbidity can reduce coral growth rates. Growth may also decrease because of the diversion of energy to removal of sediment particles.

Based on three monthly (seasons) investigations, the settlement of corals in both locations generally occurred during all seasons, with the total number being higher at Setan Island than at Pandan Island. During the first year most settlements were found in the intermediate season II, while in the second year a maximum was recorded in the intermediate season I and II at Pandan Island. At Setan Island, settlements also peaked in the intermediate season I during the first year and in the intermediate season I and II in the second year period.

Most coral larvae settled from the plankton predominantly during a restricted period. The result of this seasonal pattern was obviously similar to previous studies conducted in the Great Barrier Reef (Bothwell, 1982; Wallace, 1985a and b). Here remarkably coordinated mass spawning always occurred in late spring-early summer for a large number of coral species from this region (Harrison et al., 1984).

Thus, recruitment from a rich pool of larvae present in the water column (Doherty, 1982) is not equally given year round, it may well exist during the intermediate season I and II in some years. The concentration of large numbers of juveniles of a variety of species during these seasons may result in intense competition amongst young corals. Dense recruitment may also provide escape from predator or from other post settlement effects (Underwood and Denley, 1984).

During the yearly investigation, the total number of coral colonies at Pandan Island was higher than at Setan Island. Furthermore, the investigation of the second year period showed more recruits than during the first year. In addition, the total number of coral settlements after two years of investigation at Setan Island (17 colonies) was greater than at Pandan Island (5 colonies).

Interestingly, the number coral colonies settled during both long periods (every year and after two years) were lower than during short periods (every month and every three months). This difference indicates that longer periods of recording cause a decrease in the number coral colonies settled on the substrates. A reason for this may be competition between corals and coralline algae, algal turfs, barnacles, and mussels, which actually were found on all surfaces of the plates.

As it was mentioned already that competition between coral colonies and other species on the substrates resulted in a different community pattern at Pandan Island than at Setan Island. At

Pandan Island, coralline algae were predominant and followed by other species such as algal turfs, barnacles, and mussels. At Setan Island, the assemblage was dominated by algal turfs.

The reason why coralline algae were dominant at Pandan Island is that the rate of growth of this coralline algae was faster than that of other species. This indicates that the conditions there were qualitatively better in terms of transparency and sedimentation rates, which resulted in high rate of photosynthesis. Meanwhile, at Setan Island, which is dominated by algal turfs, the transparency was poorer, and the levels of sedimentation were higher.

Other factors, which are considered important to influence these differences, may be predation by fish. Species of the families Scaridae and Acanthuridae were observed in both locations and traces of their bites showed on the surfaces of the plates. These bite traces appeared only on the substrates which were exposed in the waters for longer time periods.

Coral species

Corals, which settled on the substrates during the investigation periods (every one month, every three months, every year, and after two years) were generally dominated by species from the families of Pocilloporidae (*Pocillopora damicornis*, *Pocillopora* sp., *P. verrucosa*, *Styllophora* sp., and *Seriatopora* sp.) and Acroporidae (*Acropora* sp., *Montipora aequituberculata*, *Montipora* sp., *A. cerealis*, and *A. verweyi*) as well as unidentified species. Smaller numbers were found of other coral families such as Poritidae (*Porites* sp.), Oculinidae (*Galaxea* sp. and *G. fascicularis*), Merulinidae (*Merulina* sp., and *M. scrabicula*), Faviidae (*Platygyra* sp.), and Agariciidae (*Leptoseris* sp.). Reasons for these conditions are the number of colonies of adult Pocilloporidae and Acroporidae were higher than those of other families in both locations. In addition, all Pocilloporidae and several Acroporidae are brooding species. In brooding species, eggs are fertilized internally, with the embryo developing to the planula stage inside the coral polyp. Brooded larvae contain a set of symbiotic zooxanthellae from the parent colony. It has been demonstrated that zooxanthellae contribute to the larvae, giving them additional energy and thus promote long-distance dispersal and survival (Richmond, 1987, 1988). Nevertheless, the ability to immediately settle results in some brooded planulae attaching to the substrates within centimeters of the parent colony (Birkeland, 1997).

This is in accordance with previous investigations in which also species of the families Pocilloporidae and Acroporidae were most abundant. Dustan and Johnson (1998) found a total of 8627 coral spat on all of their plates over the four years of observation in the southern Great Barrier Reef. The recruits were dominated by individuals of the families Pocilloporidae, which accounted for 80.1% (6921 colonies), while the Acroporidae (excluding the genus *Isopora*) represented only 16.4% (1405 colonies). Representatives of the families (or genera) Poritidae, Faviidae and Isoporan acropoids amounted only to 1.7% (143 colonies), 0.0% (1 colony), and 0.1% (14 colonies), respectively. The rest of the colonies (unidentified colonies), accounted for a total of 1.7% (143 colonies) of all recruits observed.

Records by Harriott and Banks (1995) about the recruitment of scleractinian corals in the Solitary Island Marine Reserve, a high latitude coral dominated community in Eastern Australia showed that from the 391 recruits recorded on all plates in the summer of 1992/93, the most abundant taxa are the families Pocilloporidae (66%), followed by the Poritidae (23%). Only 3 recruits (< 1%) from the family Acroporidae were recorded; 2 at North Solitary Island and 1 at South West Solitary Island.

Harriott and Fisk (1987) studied coral settlement on plates and recruitment of scleractinian corals and found that the families acroporids comprised 32% of the spat in the fore-reef and 63% in the back-reef, while the families pocilloporids comprised 41% of spat in the fore-reef and 21% in the back-reef. Less than 2% of all newly settled corals were species of the family poritids, and more than 1% of them were unidentifiable. Around 19 to 25 % of spat were categorised as unidentified species, because they were too small to identify (< 0.5 mm diameter), partially broken or without distinctive morphological features. Because of their form, the families Pocilloporidae and Acroporidae (branching forms) have higher growth rates than massive corals (Suharsono, 1984).

During the period of this study, it was found that only species from the families Acroporidae (*A. cerealis*, *A. verweyi, Acropora* sp., and *M. aequitubeerculata*), Pocilloporidae (*P. darmicornis* and *P. verrucosa*), Ocullinidae (*Galaxea* sp.), Merulinidae (*Merulina scrabicula*) and Agariciidae (*Leptoseris* sp.), were still alive at the end of the sampling period.

4.2.2 Average growth rates of coral species which settled on the substrates

Coral growth is defined as increase of mass, of volume and of area per unit of time (Buddemeier and Kinzie, 1976; Hughes, 1987). The increase of mass and volume of corals is manifested in addition of calcium carbonate to the skeleton and in a magnification of the number of individuals in the coral colony. The calcification rate (growth) of corals is directly correlated with light intensity. This is clearly seen in the hermatypic corals hosting symbiotic dinoflagellates (zooxanthellae). Corals without zooxanthellae show lower calcification rates compared to those hosting symbionts. Therefore, zooxanthellae play an important role in the process of calcification. Growth also is influenced by lunar periodicity, seasonality, and latitudinal gradients (Johannes et al., 1983; Crossland, 1994; Suharsono, 1984). In addition internal factors (genetics, life form, presence/absence of zooxanthellae) and external factors (nutrients and oceanographic parameters) (Suharsono, 1984; Rogers, 1990; Miller, 1995; Atkinson et al., 1995) also play an important role in growth of juvenile and adult coral.

Because of unpredictable problems such as difficulties in monitoring of coral species in the water column, limitedness of time in using scuba equipment, very small individual coral species settling on the substrates, and that individuals were not found usually during monthly sample collections, the measurements, therefore, were done only after time schedule. In this study, the growth rates of coral species at Pandan Island were higher than at Setan Island. The highest growth rates of coral species occurred generally in the intermediate season I and II and in the dry of season. The reason for this finding may include higher quality of oceanographic parameters, especially transparency and sedimentation at Pandan Island (see Table 3.41 and 3.42).

The growth of a coral is the result of several physiological processes, which may be altered by environmental conditions, namely sedimentation, transparency and light intensity. Because corals and associated zooxanthellae depend on light for rapid deposition of calcium carbonate (Chalker, 1981), high turbidity can reduce coral growth rates. Growth may also decrease because of the diversion of energy to the removal of sediment particles. Dodge et al. (1974) described the inverse correlation between natural sedimentation and *Montastrea annularis* growth rates. Growth rates of this species from the East Flower Garden Bank reef in the Gulf of Mexico were negatively correlated with discharge of sediments and fresh-water from the Atchafalaya River (Dodge and Lang, 1983).

Growth of branching and encrusting species (families Pocilloporidae and Acroporidae) was faster than that of massive and sub massive corals (families Poritidae and Faviidae) (Suharsono, 1984). In addition, metabolism of massive corals e.g. *Goniastrea* also is lower than that of branching corals (Drew, 1973). In this study, we found growth rates in Pocilloporidae of 21.0 mm within one year (1.8 mm/month) and also in Acroporidae with higher growth rates than the massive and sub massive corals (family Occulinidae with species *Galaxea* sp. = 12.0 mm within one year (1.0 mm/month.

4.2.3 Collection of mature coral tissues

Sexual reproduction of corals includes fusion of sperm and eggs. In brooding species, the eggs are fertilized internally and the embryo develops into the planulae stage inside the coral polyp. In this stage it is released into the water column. Spawning species release their eggs and sperm into the water column where subsequently external fertilization and development takes place (Fadlallah, 1983; Ricmond and Hunter, 1990; Kenyon, 1992; Johnson, 1992; Ward, 1992; McGuire, 1998; Tanner, 1996).

Sexual reproduction in corals may occur according to the lunar cycle (Harrigan, 1972; Lewis, 1974; Stimson, 1978; Harriot, 1983 a, b; Jokiel et al., 1985; Szmant-Froelich et al., 1985; Bermas et al.., 1992), monthly (Richmond and Jokiel, 1984; Richmond and Hunter, 1990; Johnson, 1992; Tanner, 1996; Fadlallah, 1983; 1996), seasonally (Rinkevich and Loya 1979a, b; Szmant 1986; Tomascik and Sander, 1987a, b), and yearly (Willis et al., 1985; Babcock et al., 1986). Several internal factors (e.g. genetic and nutrient) status of corals (Rinkevich, 1989; Atkinson et al., 1995; Ward, 1995; Birkeland, 1997) and external factors (e.g. temperature, transparency, sedimentation, light intensity, salinity, wave, and current) (Kojis and Quinn, 1982; Guzman and Holst, 1993; Birkeland, 1997), and latitudes (Kojis, 1986b; Dai et al., 1992; Babcock et al., 1994; Harii et al., 2001) may also play a role in triggering reproduction of corals.

Reproductive periodicity may vary with location, both latitudinal and from reef area to reef area (e.g., Stimson 1978; Rinkevic and Loya 1979b; Richmond and Jokiel, 1984; Kojis, 1986b; Oliver and Willis, 1987; Oliver et al., 1988), and may have an underlying seasonal pattern (Stimson 1978; Harriot 1983; Stoddart and Black 1985).

It is speculated that seasonal changes in water temperature (either increase or decrease) may determine the timing of annual reproductive cycles in corals, while tidal cycles and lunar periodicity may influence the timing of gamete release (review in Richmond and Hunter 1990; also see Szmant, 1991).

Two major conclusions can be draw from this study. First, several species of the families Acroporidae and Pocilloporidae are brooding species, and generally were able to reproduce during the whole period of this study. Secondly, members of Faviidae, Oculinidae, Merulinidae, and Proritidae had ripe gonads during several months or certain seasons.

Seasonal timing and length of reproductive periods in corals are supposed to vary with reproductive modes and with latitude (Harrison and Wallace, 1990). Brooding species tend to breed and planulate throughout extended periods or year-round, while spawning species often have relatively short, distinct annual breeding seasons (Shlesinger and Loya, 1985; Richmond and Hunter, 1990; this study). The four brooding species (*Pocillopora damicornis*, *P. verrucosa*, *Acropora cerealis* and *A. nana*) in both locations in the present study display prolonged reproductive periods in which planulation occurs, most likely, throughout the year. Their reproductive characteristics may account for their wide distribution and abundance on the reefs and new substrates in both locations.

In this study, investigation of 16 species of adult corals from six families in both locations, showed that monthly and seasonally variations in the presence of gonad (male and female), gonad index, fecundity and colour of gonad each of species occurred (see Table 3.18 – 3.33 in chapter 3).

Due to limited reports about timing of reproduction in corals in lower latitudes the following discussion compares the synchrony of spawning and breeding of 16 species of corals species in this study and those, which were investigated at locations at different latitudes. Latitudinal variations in the length and timing of breeding seasons occur in a variety of marine invertebrates (include scleractinian corals) (Giese and Pearse, 1974; Oliver et al., 1988). In the present study *A. cerealis* was ready to reproduce in June (in the middle of dry season), October (at the end of intermediate season II), November and December (the beginning and the middle of rainy season) at Pandan Island, whereas at Setan Island, reproductive activity was recorded in March (the middle of intermediate season I), June and July (the middle and the end of the dry season), September and October (the middle and the end of intermediate season II) as well as November and December (the beginning and the middle of the rainy season). Dai et al. (1992) found that this species usually reproduced in May and June in northern and sourthen Taiwan. Furthermore, Veron and Wallace (1984), Heyward (1989), and Richmond and Hunter (1990) observed reproduction in this species in July and during summer in Central Pacific (Guam, Marshal, Island, and Palau), and also in November in the Great Barrier Reef (Babcock et al., 1986).

Hayashibara et al. (1993) recorded the time of fertilization of *A. donei* in June at Akijima Island, Okinawa, Japan. In my study it occurred in February, April (the beginning and the end of intermediate season I), and October (the rainy season) at Pandan Island and in February (the beginning of intermediate season I), June, and July (the middle and the end of the dry season), during the interval August to October (all of intermediate season II), and November (the beginning of the rainy season) for Setan Island.

The result of previous work at the Great Barrier Reef by Willis et al. (1985), Babcock et al. (1986) showed that *A. gemnifera* spawned in November. We have evidence that it was possible also in May and July (the beginning and the end of the dry season), September (the middle of intermediate season II), and December (the middle of the rainy season) for Pandan Island, whereas at Setan Island, reproduction occurred in August and October (the middle and the end of intermediate season II) as well as in November and December (the beginning and the middle of the rainy season).

For *A. nana,* the time of fertilization was predicted to occur in June (the middle of the dry season), September (the middle of intermediate season II), November, and December (the beginning and the middle of the rainy season) for Pandan Island, whereas at Setan Island, it was recorded in the May to July period (all of the dry season), August and September (the beginning and the middle of intermediate season II) as well as December (the middle of the rainy season). There are only few reports in the literature about the timing of fertilization of *A. nana*. Dai et al. (1992) recorded it in April in Nanwan Bay and in June in sourthen Taiwan.

In the present study *A. nasuta* reproduced in February (the beginning of intermediate season I) and August (the beginning of intermediate season II) at Pandan Island and July (the middle of the dry season), in the interval August to October (all of intermediate season II) as well as in November (the beginning of the rainy season) for Setan Island. Dai et al. (1992) found the timing of fertilization of this species to be in June in sourthen Taiwan. Furthermore, Richmond and Hunter (1990) recorded reproduction in July and during the summer in the Central Pacific (Guam, Marshal, Island, Palau). Furthermore, it was recorded in November in the Great Barrier Reef by Willis et al. (1985) and Babcock et al. (1986) and in May at Akajima Island, Okinawa, Japan (Hayashibara et al., 1993).

A. robusta reproduced in February (the beginning of intermediate season I), July (the end of the dry season), and September (the middle of intermediate season II) at Pandan Island, whereas at Setan Island, it spawned in May (the middle of the dry season) and October (the end of intermediate season II). Bothwell (1981) recorded reproduction during spring until summer at the Great Barrier Reef, whereas Babcock et al. (1986) found in November at the same location.

Willis et al. (1985) reported the timing of fertilization of *A. sarmentosa* at the Great Barrier Reef to be in November, whereas Wallace (1985a) recorded it in February, August, and November from the same location. Meanwhile, in this study, I found ripe gonads in August and September (the beginning and the middle of intermediate season I) for Pandan Island and in April (the end of intermediate season I), May (the beginning of the dry season), and August (the beginning of intermediate season II) for Setan Island.

The possible time of fertilization in *A. verweyi* appeared to be in October (the end of intermediate season II) at Pandan Island, whereas at Setan Island, it may occur in May (the beginning of the dry season), during the interval August to October (all of intermediate season II). According to Hayashibara et al. (1993) the time of spawning in this species was found to be in August at Akajima Island, Okinawa, Japan.

Shlesinger and Loya (1985) recorded reproduction of *A. myriophthalma* during the interval July to September in the Red Sea. Furthermore, Babcock et al. (1986) reported it from the Great Barrier Reef in November, and Bermas et al. (1992), described spawning in the Philippines occurring during spring. In this study, I recorded it from May to July (all of the dry season), September and October (the middle and the end of intermediate season II) for Pandan Island

and in May (the beginning of the dry season), September and October (the middle and the end of intermediate season II), and finally in November and December (the beginning and the middle the rainy season) for Setan Island.

The possible time of reproduction of *P. damicornis* at Pandan Island was found during most of the months during both years of investigation. An exception was the interval May to July or all of the dry season. The same was true at Setan Island. Dai et al. (1992) recorded reproduction during November until March in southern Taiwan and the interval January to April in Nanwan Bay. In addition, Harrigan (1972), Stimson (1978), Richmond and Jokiel (1984) recorded year round spawning in Hawaii and in the Central Pacific (Guam, Marshal, Island, and Palau) as well as in the Great Barrier Reef (Fadlallah, 1983), whereas in the Eastern Pacific, it occurred only during summer (Glynn et al., 1991).

P. verrucosa reproduced in February and April (the beginning and the end of intermediate season I), July (the end of the dry season), August (the beginning of intermediate season II), and December (the middle of the rainy season) at Pandan Island, whereas at Setan Island, spawning occurred in April or at the end of intermediate season I and in October (the end of intermediate season II). Stimson (1978) found year round reproduction in the Central Pacific (Guam, Marshal, Island, and Palau), whereas Shlesinger and Loya (1985) reported spawning during summer in the Red Sea.

According to Dai et al. (1992) the timing of reproduction in *F. speciosa* was in June at northern Bay and May at southern Taiwan. From this study, it was observed in July (the end of the dry season) and September (the middle of intermediate season II) for Pandan Island, whereas for Setan Island, it was recorded in October (the end of intermediate season II).

Fertilization of *G. astreata* was not found at Pandan Island, whereas at Setan Island, it occurred in April (the end of intermediate season I), June and July (the middle and the end of the dry season), October (the end of intermediate season II), and December (the middle of the rainy season). Willis et al. (1985) recorded reproduction in October and November from the Great Barrier Reef, whereas Babcock et al. (1986) observed in November at the same location. Furthermore, Dai et al. (1992) found spawning individuals in April and May on Nanwan Bay, Taiwan.

According to Kojis and Quinn (1981), Babcock et al. (1986), the timing of fertilization of *Porites lobata* at the Great Barrier Reef was in November and December. In addition, Richmond and Hunter (1990) recorded it to be in July in the Central Pacific (Guam, Marshal, Island, and Palau), and in Hawaii, it occurred in August (Hunter, 1988). Dai et al. (1992) reported it for July in northern Taiwan. In this study, ripe individuals were observed during the interval August to

October (all of intermediate season II), and November (the beginning of the rainy season) for Pandan Island, whereas at Setan Island, it was recorded in September, October (the middle and the end of intermediate season II), and November (the beginning of the rainy season).

Finally *P. lutea* reproduced in September (the middle of intermediate season II) at Pandan Island, whereas at Setan Island, it was observed in September and October (the middle and the end of intermediate season II) as well as November and December (the beginning and the middle of the rainy season). Heyward (1989) reported reproduction in this species during summer in the Central Pacific (Guam, Marshal Island, and Palau). Other reports include January (Kojis and Quinn, 1981), November to January (Harriot, 1983a), November (Babcock et al., 1986) at the Great Barrier Reef, and June (Hayashibara et al., 1993) at Akajima Island, Okinawa, Japan.

4.2.4 Plankton samples for eggs and planulae

From a total of 24 months investigation, at Pandan Island the presence of eggs were recorded during 18 months, whereas planulae appeared during 15 months (see sub chapter 3.3). Furthermore, at Setan Island eggs appeared during 16 months, whereas planulae were recorded during all of the 24 months (see sub chapter 3.3). The presence of eggs and planulae was correlated with the timing of reproduction of adult corals (16 species) from both locations (see Table 3.18 until 3.33 with 3.34). Most eggs and planulae at Setan and Pandan Islands were found in the same periods (from August to December; in the beginning of intermediate season II to in the middle of the rainy season).

The total numbers of eggs and planulae at Setan Island were higher than at Pandan Island (see Table 3.34). Reasons for this are based on island locations in an oceanic area (Pandan Island) versus bay area (Setan Island). Areas of high prevailing wave energy and oceanic current influence the reproductive and recruitment success of corals as well as their growth (Birkeland, 1997). Padan Island is an oceanic island which had current speeds of 0.60 m per second (west wind season) and 0.8 m per second (east wind season), wind velocity is of 10 knots (west wind season) and 8 knots (east wind season), whereas at Setan Island lower values are reported (Nasrun, 1999). Furthermore, the higher total numbers of eggs and planulae at Setan Island than at Pandan Island was probably correlated with total adult coral cover. The areal cover and variety of corals at Setan Island (35 %) and the adult corals, which were ready for reproduction was higher than at Pandan Island (25 %). Harriot (1985) and Van Moorsel, (1989) reported that the larval availability was influenced by the local abundance of adult corals.

4.2.5 Oceanographic parameters and rainfall

Due to the limitedness of equipment to measure oceanographic parameters, we only recorded temperature (sea surface and bottom), sedimentation rates, transparency, pH, and salinity and rainfall.

Pandan (0^o 55' 55.51" S and 100^o 8' 16.91" E) and Setan Island (1^o 07' 09.13" S and 100^o 22' 51.74" E) are two islands located near the equator. Oceanographic parameters generally, show small variations annually.

The analysis of variance (ANOVA) of the all oceanographic parameters (five oceanographic parameters) show highly significant differences in locations, months, and interaction between locations and months ($p < 0.01$), except for sea bottom temperature (see Appendix 4).

The average monthly sea surface temperature in both locations during two years investigations (February 2000 – January 2002) had the same values (24.0 – 30.0°C) (see Figure 3.40). These values were similar with data from Johan (2001), who investigated transplantations of corals at Pari Island, the Thousand Islands Indonesia (5^o 52' 205" S and 106^o 35' 759" E) and (5^o 51' 025" S and 106^o 36' 486" E). He found a range of sea surface temperature between 24.0 – 29.5°C, and the highest occurred in May (in the beginning of the dry season), and the minimum during December to February (from the middle of the rainy season to the beginning of intermediate season I). Abrar (1997) reported that sea surface temperatures in coral reefs of Sikuai Island ranged between 27.5 and 29.6°C. Furthermore, Sabater and Yap (2002) found at Quezon Island in the Hundred Islands National Park, northern Philippines (16.22517° N and 120.04535°E) a temperature range of 27.5 to 30.0°C with the highest occurring in June, and the lowest in February.

The average of monthly bottom temperatures in both locations in the present study ranged between 23.0 – 29.0°C at Pandan Island and between 23.0 – 29.7°C at Setan Island. There is no report about sea bottom temperatures, which could be compared with this region.

The temperature in both locations was still reasonable for growth and development of corals. Corals are generally restricted to waters between 18° and 36°C, with an optimal range of 26 – 29°C. This is expressed in latitudinal patterns of coral reef distribution and diversity (Miller, 1995; Suharsono, 1996; Birkeland, 1997). Within this range, certain corals will grow differently fast, depending on the temperature. Drastic thermal shifts can result in reduced coral vitality (e.g., bleaching, reproduction inhibition) or, in extreme instances, total destruction of entire reef systems (Birkeland, 1997).

Pollution of the marine environment by sedimentation is an increasing problem of the tropics that threatens economically important coral reef resources (Bak, 1978; Cortes and Risk, 1985; Hodgson, 1990). Sedimentation may damage corals at any stage in their life cycle. Hodgson (1990), Hunte and Wittenberg (1992) noted that coral planulae do not settle on silt-covered surfaces, but prefer clean substrates.

The four important types of sediment stress are (1) smothering, (2) abrasion, (3) shading, and (4) inhibition of recruitment. Of these three, smothering is the easiest to visualize. Under natural conditions, reefs on the downwind flanks of large carbonate platforms can be buried by sediment derived from the bank top (Hine and Neumann, 1977). Storms, or more recently, dredging of nearby areas can increase the levels of suspended sediment markedly, resulting in intensive damage to reef corals and other sediment-sensitive biota.

During storms, physical abrasion by moving sediment can cause substantial damage to coral tissue (Hubbard, 1986). Although massive corals are more resistant to physical disruption by wave action, their slow growth rate virtually guarantees that wave-induced sediment scour will severely damage or kill a young colony before it can grow above the level of frequent sediment motion (Birkeland, 1997).

While more subtle in its effects than abrasion or smothering, shading is probably the most important of all sediment related effects. The reduced levels of light due to suspended sediment in the water column can reduce coral growth (Hubbard and Scaturo, 1985; Hubard et al., 1986), and induce complete mortality if allowed to persist for an extended period of time.

Excess sedimentation can also reduce settlement of coral larvae. Morelock et al. (1979) discussed the importance of substrate types in larval recruitment in Puerto Rico. Roy and Smith (1971) proposed that on Fanning Island, the increased vulnerability of young corals to sediment damage was a more limiting factor than sediment covering available space.

Monthly average sedimentation in both locations in this study (form February 2000 until January 2002) ranged between 11.80 – 390.42 $mg.cm^{-2}.month^{-1}$ at Pandan Island and between 13.74 – 607.45 $gram.cm^{-2}.month^{-1}$ at Setan Island. Sedimentation at both locations in the present study had low to middle levels of effect to coral communities (1.00 – 50.00 $mg.cm^{-2}.day^{-1}$) (Pastorak and Bilyard, 1985).

Seasonal fluctuations of sedimentation in both locations during both years were evident. From the beginning of intermediate season I (February – April 2000) to the end of the dry season (May – July 2000) sedimentation decreased, whereas it increased from the beginning of intermediate season II (August – October 2001) to the end of the rainy season (November 2000 – January 2001). Nevertheless, the average sedimentation at Setan Island generally was higher than at Pandan Island. The highest sedimentation at Setan Island was caused by river input of Pisang and Sungai Pisang settlement (2000 inhabitants).

In clear water, light intensity decreases exponentially with water depth and the light spectrum shifts rapidly toward its blue end. As a result, photosynthesis and $CaCO_3$ production (which is partly dependent on it) drops off as well. In addition to changes in growth rate, reduced light at greater depths can cause polymorphic corals to change their shape from mounds in shallow water to pates at greater depths. The latter is more efficient for light gathering as it places all the photoreceptors (symbiotic algae within the coral tissue) along vertically facing surfaces (Bikerland, 1997). The average of transparency of Pandan Island generally was higher than Setan Island (see Figure 3.42). Transparency and sedimentation showed inverse relationships in both locations.

There is no report about direct effects of pH to growth of corals. The value of pH in both locations in this study ranged between 7.6 and 9.20 at Pandan Island and between 7.63 and 9.00 at Setan Island.

The average monthly salinity in both locations varied between 31.00 and 34.67 at Pandan Island and from 29.67 until 34.00 at Setan Island (Figure 3.44). The salinity near Setan Island was lower than in waters of Pandan Island. Reasons for this condition was that Setan Island is an island which is situated close to Sumatra mainland and strongly influenced by the Sungai Pisang river. Pandan Island is a more distant island within the Padang archipelago, and therefore less influenced by river discharge and anthropogenic disturbances. The average salinity in both locations in the present study was still reasonable for growth and development of corals. Corals as well as coral reefs are limited to areas of salinities between 32 – 35, although they can also grow at higher levels up to 42 (Birkeland, 1977; Nybakken, 1988)

4.3 Conclusions

- The total number of coral colonies settled on the substrates every month, every three months (seasons), and after two year investigation at Setan Island is greater than at Pandan Island, whereas every year sampling at Pandan Island is higher than Setan Island. The most settlements occurred during the intermediate of season I (February to April) and II (August to October) and in the beginning of the rainy season.

- Coral species, which settled on the substrates during the periods this study, were dominated by species from families of Pocilloporidae (*Pocillopora damicornis*, *Pocillopora* sp., *P. verrucosa*, and *Styllopora* sp.) and Acroporidae *Acropora* sp., *Montipora aequituberculata*, *Montipora* sp., *A. cerealis*, and *A. verweyi*) as well as unidentified species. Other coral families such as Poritidae (*Porites* sp.), Oculinidae (*Galaxea* sp. and *G. fascicularis*), Merulinidae (*Merulina* sp., and *M. scrabicula*), Faviidae (*Platygyra* sp.), and Agariciidae (*Leptoseris* sp.) also occurred but in lower number.

- Generally the average growth rate of coral species, which settled on the substrates at Pandan Island, was higher than at Setan Island.

- The adult corals that lived in each location probably were the source of the coral colonies, which settled on the substrates. In addition settlements occurred in both locations when surrounding corals produced eggs or planulae larvae were found in the water column.

- Oceanographic parameters (sea surface and bottom temperature, transparency, sedimentation, pH, and salinity) and rainfall did not show any extreme values during this study at both locations and generally did not significantly influence the growth of coral communities. Only rainfall had a significant positive on the coral settlement at Pandan Island.

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Appendix 1: Total number of coral colonies settlements

Table A.1.1. Mean, standard deviation (SD), and standard error (SE) of the total number of coral colonies settled on the substrates at Pandan and Setan Islands every year, over a sampling period of two years

Locations	Mean	SD	SE
Pandan Island	2.17	1.65	1.17
Setan Island	1.67	0.94	0.67

Table A.1.2. Mean, standard deviation (SD), and standard error (SE) of the total number of coral colonies settled on the substrates based on different years of investigation, over a sampling period of two years, s: significant

Years	Mean	SD	SE
First Year	1.00	0.33	0.33
Second Year	2.83	0.33	0.33

Table A.1.3. Mean, standard deviation (SD), and standard error (SE) of the total number of coral colonies settled on the substrates of interaction between the island locations and year of observation, over a sampling period of two years

Locations	Years	Mean	SD	SE
Pandan Island	First Year	1.00	0.00	0.00
	Second Year	3.33	0.56	0.33
Setan Island	First Year	1.00	0.00	0.00
	Second Year	2.33	1.53	0.88

Table A.1.4. Independent sample test (t-test for equality of mean) of the total number of colonies settled on the substrates at Pandan and Setand Islands after two years, ns: not significant

	t	df	Sig.	Std. Error Difference
Equal variances assumed	1.488^{ns}	4	0.211	2.687

Table A.1.5. Mean, standard deviation (SD), and standard error (SE) of the total number of coral colonies settled on the substrates at Pandan and Setan Islands after two years

Locations	N	Mean	SD	SE
Setan Island	3	5.67	4.62	2.67
Pandan Island	3	1.67	0.58	0.33

Appendix 2. Average growth rate of coral species

Table A.2.1. Average length (L) and average width (W) in mm as well as total polyp (P) of seven coral species settled on the concrete substrates at Pandan Island after one month as well as monthly (February 2000 – January 2002) settlements, over a sampling period of two years

		F-2000			Mr-2000			Ap-2000			M-2000		
No	**Taxonomy**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**
I	**Pocilloporidae**												
	P.a damicornis	-	-	-	2.00	1.50	3.50	-	-	-	-	-	-
	Pocillopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Stylophora sp.	-	-	-	-	-	-	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	M. aequituberculata	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	-	-	-	-	-	-	-	-	-	-	-	-
IV	**Unidentified family**												
	Unidentified species	-	-	-	-	-	-	-	-	-	-	-	-

Table A.2.1. Continued

		Jn-2000			Jl-2000			Ag-2000			Sp-2000		
No	**Taxonomy**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**
I	**Pocilloporidae**												
	P.a damicornis	-	-	-	-	-	-	2.23	1.70	5.25	1.20	0.60	4.00
	Pocillopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Stylophora sp.	-	-	-	-	-	-	1.60	1.50	1.00	-	-	-
II	**Acroporidae**												
	Acropora sp.	-	-	-	-	-	-	1.60	1.10	4.00	0.30	0.20	1.00
	M. aequituberculata	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	-	-	-	-	-	-	-	-	-	-	-	-
IV	**Unidentified family**												
	Unidentified species	-	-	-	-	-	-	1.60	1.05	2.5	0.30	0.20	1.50

Table A.2.1. Continued

No	Taxonomy	Oc-2000			No-2000			Dec-2000			Ja-2001		
		L	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**
I	**Pocilloporidae**												
	P. damicornis	1.20	0.60	4.00	1.30	0.75	6.75	0.63	0.40	5.75	-	-	-
	Pocillopora sp.	0.30	0.20	1.00	0.30	0.23	3.00	0.29	0.21	3.29	-	-	-
	Stylophora sp.	-	-	-	-	-	-	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	0.80	0.40	3.00	1.70	0.90	3.67	0.60	0.30	2.50	-	-	-
	M. aequituberculata	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	0.35	0.25	1.00	0.70	0.50	1.50	-	-	-	-	-	-
IV	**Unidentified family**												
	Unidentified species	0.30	0.20	1.50	0.20	0.13	1.33	-	-	-	-	-	-

Table A.2.1. Continued

No	Taxonomy	F-2001			Mr-2001			Ap-2001			M-2001		
		L	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**
I	**Pocilloporidae**												
	P. damicornis	2.00	2.00	6.00	2.50	2.00	4.00	-	-	-	-	-	-
	Pocillopora sp.	1.20	1.15	3.00	-	-	-	-	-	-	2.70	2.50	5.00
	Stylophora sp.	-	-	-	-	-	-	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	0.70	0.50	1.00	-	-	-	-	-	-	2.45	1.40	4.00
	M. aequituberculata	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	-	-	-	-	-	-	-	-	-	-	-	-
IV	**Unidentified family**												
	Unidentified species	-	-	-	-	-	-	-	-	-	1.10	0.80	?

Table A.2.1. Continued

No	Taxonomy	Jn-2001 L	Jn-2001 W	Jn-2001 P	Jl-2001 L	Jl-2001 W	Jl-2001 P	Ag-2001 L	Ag-2001 W	Ag-2001 P	Sp-2001 L	Sp-2001 W	Sp-2001 P
I	**Pocilloporidae**												
	P. damicornis	-	-	-	-	-	-	1.27	0.97	5.33	0.80	0.53	1.67
	Pocillopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Stylophora sp.	-	-	-	-	-	-	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	-	-	-	-	-	-	0.80	0.55	3.00	1.50	1.50	1.00
	M. aequituberculata	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	-	-	-	-	-	-	-	-	-	-	-	-
IV	**Unidentified family**												
	Unidentified species	-	-	-	-	-	-	-	-	-	1.30	0.80	1.00

Table A.2.1. Continued

No	Taxonomy	Oc-2001 L	Oc-2001 W	Oc-2001 P	No-2001 L	No-2001 W	No-2001 P	Dec-2001 L	Dec-2001 W	Dec-2001 P	Ja-2002 L	Ja-2002 W	Ja-2002 P
I	**Pocilloporidae**												
	P. damicornis	-	-	-	1.05	0.95	1.00	1.00	0.90	1.00	-	-	-
	Pocillopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Stylophora sp.	-	-	-	1.35	1.05	1.00	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	0.90	0.67	0.27	1.15	0.90	1.00	-	-	-	-	-	-
	M. aequituberculata	-	-	-	-	-	-	21.00	4.00	many	-	-	-
III	**Poritidae**												
	Porites sp.	0.60	0.30	1.00	-	-	-	-	-	-	-	-	-
IV	**Unidentified family**												
	Unidentified species	-	-	-	-	-	-	-	-	-	-	-	-

Table A.2.2. Average length (L) and average width (W) in mm as well as total polyp (P) of eleven coral species settled on the concrete substrates on Setan Island after one month as well as monthly (February 2000 – January 2002) settlements, over a sampling period of two years

		F-2000			Mr-2000			Ap-2000			M-2000		
No	**Taxonomy**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**
I	**Pocilloporidae**												
	P. damicornis	1.90	1.60	4.00	1.90	1.00	4.00	-	-	-	-	-	-
	Pocillopora sp.	-	-	-	-	-	-	1.20	1.00	3.00	-	-	-
	Stylophora sp.	-	-	-	-	-	-	-	-	-	2.10	1.33	1.67
II	**Acroporidae**												
	Acropora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Montipora sp.	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	-	-	-	-	-	-	-	-	-	-	-	-
IV	**Oculinidae**												
	Galaxea sp.	-	-	-	-	-	-	-	-	-	-	-	-
V	**Unidentified family**												
	Unidentified species	0.60	0.35	1.67	0.30	0.20	1.00	1.57	0.70	1.67	?	?	?

Table A.2.2. Continued

		Jn-2000			Jl-2000			Ag-2000			Sp-2000		
No	**Taxonomy**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**
I	**Pocilloporidae**												
	P. damicornis	-	-	-	-	-	-	4.67	3.34	6.10	1.24	1.11	1.00
	Pocillopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Stylophora sp.	-	-	-	-	-	-	4.10	1.80	4.80	1.00	0.85	1.00
II	**Acroporidae**												
	Acropora sp.	1.50	1.00	1.00	1.70	1.50	1.00	2.65	1.75	5.75	1.03	0.82	1.00
	Montipora sp.	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	-	-	-	1.00	1.00	1.00	1.80	1.00	1.00	-	-	-
IV	**Oculinidae**												
	Galaxea sp.	1.30	1.10	1.00	-	-	-	-	-	-	-	-	-
V	**Unidentified family**												
	Unidentified species	-	-	-	-	-	-	1.92	1.64	1.60	2.00	1.00	1.00

Table A.2.2. Continued

No	Taxonomy	Oc-2000 L	Oc-2000 W	Oc-2000 P	No-2000 L	No-2000 W	No-2000 P	Dec-2000 L	Dec-2000 W	Dec-2000 P	Ja-2001 L	Ja-2001 W	Ja-2001 P
I	**Pocilloporidae**												
	Pocillopora damicornis	0.80	0.60	2.00	1.43	0.93	5.00	-	-	-	-	-	-
	Pocillopora sp.	0.70	0.30	1.00	-	-	-	-	-	-	-	-	-
	Stylophora sp.	-	-	-	-	-	-	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	2.15	1.30	4.00	1.40	0.90	5.00	-	-	-	-	-	-
	Montipora sp.	0.70	0.70	1.00	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	0.51	0.49	1.00	0.30	0.25	1.00	-	-	-	-	-	-
IV	**Oculinidae**												
	Galaxea sp.	-	-	-	-	-	-	-	-	-	-	-	-
V	**Unidentified family**												
	Unidentified species	-	-	-	0.23	0.17	1.00	-	-	-	-	-	-

Table A.2.2. Continued

No	Taxonomy	F-2001 L	F-2001 W	F-2001 P	Mr-2001 L	Mr-2001 W	Mr-2001 P	Ap-2001 L	Ap-2001 W	Ap-2001 P	M-2001 L	M-2001 W	M-2001 P
I	**Pocilloporidae**												
	Pocillopora damicornis	0.40	0.30	2.00	-	-	-	-	-	-	-	-	-
	Pocillopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Stylophora sp.	-	-	-	-	-	-	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Montipora sp.	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	-	-	-	-	-	-	-	-	-	-	-	-
IV	**Oculinidae**												
	Galaxea sp.	-	-	-	-	-	-	-	-	-	-	-	-
V	**Unidentified family**												
	Unidentified species	-	-	-	-	-	-	-	-	-	-	-	-

Table A.2.2. Continued

No	Taxonomy	Jn-2001 L	Jn-2001 W	Jn-2001 P	Jl-2001 L	Jl-2001 W	Jl-2001 P	Ag-2001 L	Ag-2001 W	Ag-2001 P	Sp-2001 L	Sp-2001 W	Sp-2001 P
I	**Pocilloporidae**												
	Pocillopora damicornis	1.21	1.13	1.00	-	-	-	2.40	1.83	1.00	1.21	1.11	1.00
	Pocillopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Stylophora sp.	-	-	-	-	-	-	0.90	0.60	1.00	1.00	0.85	1.00
II	**Acroporidae**												
	Acropora sp**.**	1.33	1.13	1.00	3.00	2.10	3.00	3.54	2.38	5.80	1.03	0.82	1.00
	Montipora sp.	0.80	0.70	1.00	-	-	-	1.00	1.00	1.00	-	-	-
III	**Poritidae**												
	Porites sp.	-	-	-	-	-	-	-	-	-	-	-	-
IV	**Oculinidae**												
	Galaxea sp.	1.00	0.08	1.00	3.00	2.00	1.00	1.58	1.39	1.00	-	-	-
	Galaxea fascicularis	-	-	-	-	-	-	2.40	2.40	1.00	-	-	-
V	Merulinidae												
	Merulina sp.	-	-	-	2.00	1.75	1.00	-	-	-	-	-	-
VI	**Faviidae**												
	Platygyra sp.	-	-	-	-	-	-	1.40	1.30	1.00	-	-	-
VII	**Unidentified family**												
	Unidentified species	?	?	1.00	-	-	-	1.90	1.25	1.00	2.00	1.00	1.00

Table A.2.2. Continued

No	Taxonomy	Oc-2001 L	Oc-2001 W	Oc-2001 P	No-2001 L	No-2001 W	No-2001 P	Dec-2001 L	Dec-2001 W	Dec-2001 P	Ja-2002 L	Ja-2002 W	Ja-2002 P
I	**Pocilloporidae**												
	Pocillopora damicornis	3.20	3.00	10.00	1.86	1.59	2.76	1.42	1.30	1.00	-	-	-
	Pocillopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Stylophora sp.	-	-	-	-	-	-	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp**.**	1.00	0.77	1.33	1.72	1.56	1.50	-	-	-	-	-	-
	Montipora sp.	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	0.75	0.65	1.00	-	-	-	-		-	-	-	-
IV	**Oculinidae**												
	Galaxea sp.	-	-	-	-	-	-	1.52	1.45	1.00	-	-	-
	Galaxea fascicularis	-	-	-	-	-	-	-	-	-	-	-	-
V	Merulinidae												
	Merulina sp.	-	-	-	-	-	-	-	-	-	-	-	-
VI	**Faviidae**												
	Platygyra sp.	-	-	-	-	-	-	-	-	-	-	-	-
VII	**Unidentified family**												
	Unidentified species	-	-	-	3.00	2.20	?	-	-	-	-	-	-

Table A.2.3. Average length (L) and average width (W) in mm as well as total polyp (P) of six coral species settled on the concrete substrates on Pandan Island after three months as well as seasonally or every three months (February 2000 – January 2002) settlements, over a sampling period of two years

		IS-I (I)			DS (I)			IS-II (I)			RS (I)		
No	Taxonomy	L	W	P	L	W	P	L	W	P	L	W	P
I	**Pocilloporidae**												
	P. damicornis	-	-	-	2.30	2.00	4.00	4.23	4.00	3.30	0.50	0.37	6.00
	Pocillopora sp.	-	-	-	3.10	3.00	3.00	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	-	-	-	2.10	2.00	2.00	6.54	2.86	7.60	1.05	0.53	5.25
	M. aequituberculata	-	-	-	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	-	-	-	-	-	-	-	-	-	-	-	-
IV	**Unidentified family**												
	Unidentified species	4.00	3.00	4.00	-	-	-	-	-	-	-	-	-

Table A.2.3. Continued

		IS-I (II)			DS (II)			IS-II (II)			RS (II)		
No	Taxonomy	L	W	P	L	W	P	L	W	P	L	W	P
I	**Pocilloporidae**												
	P. damicornis	2.74	2.10	6.14	2.30	2.00	4.00	3.00	2.10	2.00	4.00	1.45	6.00
	Pocillopora sp.	-	-	-	3.10	3.00	3.00	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	3.67	3.00	8.67	2.05	1.40	1.50	4.07	3.00	3.67	11.33	10.00	9.33
	M. aequituberculata	-	-	-	-	-	-	23.33	14.67	many	30.00	20.00	many
III	**Poritidae**												
	Porites sp.	1.20	1.00	1.00	-	-	-	2.00	1.30	1.00	-	-	-
IV	**Unidentified family**												
	Unidentified species	-	-	-	-	-	-	6.50	5.50	?	-	-	-

Table A.2.4. Average length (L) and average width (W) in mm as well as total polyp (P) of eight species settled on the concrete substrates on Setan Island after three months as well as seasonally or every three months (February 2000 – January 2002) settlements, over a sampling period of two years

		IS-I (I)			DS (I)			IS-II (I)			RS (I)		
No	**Taxonomy**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**
I	**Pocilloporidae**												
	Pocillopora damicornis	0.45	0.25	2.00	2.74	2.34	6.60	2.01	1.49	2.001	-	-	-
	Pocillopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Stylophora sp.	0.50	0.30	1.00	1.00	1.00	1.00	0.70	0.57	1.00	-	-	-
	Seriatopora sp.	-	-	-	-	-	-	0.45	0.35	1.00	-	-	-
II	**Acroporidae**												
	Acropora sp.	14.00	9.00	6.00	7.80	5.37	1.00 - many	3.12	2.54	3.60	0.50	0.30	1.00
	Montipora sp.	2.00	0.90	1.00	2.60	2.10	1.00	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	1.40	1.15	1.50	1.40	0.70	1.50	0.75	0.55	> 0.05	0.30	0.20	1.00
IV	**Unidentified family**												
	Unidentified species	5.00	4.36	7.67	-	-	-	1.00	1.00	1.00	-	-	-

Table A.2.4. Continued

		IS-I (II)			DS (II)			IS-II (II)			RS (II)		
No	**Taxonomy**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**	**L**	**W**	**P**
I	**Pocilloporidae**												
	Pocillopora damicornis	2.70	1.84	4.36	1.50	1.00	1.50	2.29	2.04	5.75	3.30	2.00	1.00
	Pocillopora sp.	2.10	0.70	2.00	3.00	2.50	5.00	-	-	-	-	-	-
	Stylophora sp.	1.82	1.38	3.27	1.00	0.90	1.00	1.98	1.53	4.13	-	-	-
	Seriatopora sp.	-	-	-	-	-	-	-	-	-	-	-	-
II	**Acroporidae**												
	Acropora sp.	2.72	2.00	4.42	6.67	5.67	8.33	3.55	2.53	7.67- many	2.30	1.85	3.50
	Montipora sp.	0.58	0.48	1.00	-	-	-	-	-	-	-	-	-
III	**Poritidae**												
	Porites sp.	0.82	0.62	1.17	0.50	0.40	1.00	0.67	0.63	1.00	8.00	3.00	9.00
IV	**Unidentified family**												
	Unidentified species	1.81	1.36	3.18	0.70	0.40	1.00	3.20	2.00	?	-	-	-

Appendix 3: Oceanographic parameters

Table A.3.1. Mean (Average)(^{o}C) and Std. Deviation (±) of monthly sea surface temperature, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, N: number of measurements

		Pandan Island		Setan Island		
Years	**Monthly**	**Mean (m)**	**Std. Deviation (±)**	**Mean (m)**	**Std. Deviation (±)**	**N**
2000	February	27.7	0.5	28.3	0.5	9
	March	27.7	0.5	29.0	0.0	9
	April	27.0	0.0	26.8	0.4	9
	May	28.3	1.0	28.3	1.0	9
	June	28.0	0.0	28.0	0.0	9
	July	29.0	0.0	29.0	0.0	9
	August	28.0	0.0	28.0	0.0	9
	September	29.0	0.0	29.0	0.0	9
	October	29.0	0.0	29.0	0.0	9
	November	29.0	0.0	29.0	0.0	9
	December	28.7	0.5	26.7	0.5	9
2001	January	28.0	0.0	28.0	0.0	9
	February	30.0	0.0	30.0	0.0	9
	March	30.0	0.0	30.0	0.0	9
	April	29.0	0.0	28.0	0.0	9
	May	30.0	0.0	29.0	0.0	9
	June	29.0	0.0	29.0	0.0	9
	July	29.0	0.0	29.0	0.0	9
	August	29.0	0.0	29.0	0.0	9
	September	24.0	0.0	26.0	0.0	9
	October	25.0	0.0	25.0	0.0	9
	November	24.0	0.0	24.0	0.0	9
	December	29.0	0.0	29.0	0.0	9
2002	January	26.7	2.0	28.0	0.0	9
	Mean	28.1	1.6	28.2	1.4	

Table A.3.2. Two-way ANOVA of monthly sea surface temperature, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, **: highly significant differences df: degrees of freedom, SS: sum of squares, MS: mean square, p: probability

Source	**dfSS**		**MS**	**F-value**	**p-value**
Island locations	1	1.82	1.82	11.70**	<0.01
Monthly	23	977.74	42.51	274.10**	<0.01
Island locations * Monthly	23	43.41	1.89	12.18**	<0.01
Error	384	59.56	0.16		
Total	432	343364.00			

Table A.3.3. Mean (Average)(^{o}C) and Std. Deviation (±) of monthly bottom seawater temperature, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, N: number of measurements

		Pandan Island		Setan Island		
Years	**Monthly**	**Mean (m)**	**Std. Deviation (±)**	**Mean (m)**	**Std. Deviation (±)**	**N**
2000	February	24.8	6.7	27.0	0.0	9
	March	26.0	0.0	26.7	0.5	9
	April	26.7	0.5	26.7	0.5	9
	May	26.7	0.9	27.0	1.5	9
	June	27.0	0.0	27.0	0.0	9
	July	28.0	0.0	28.0	0.0	9
	August	27.0	0.0	27.0	0.0	9
	September	27.0	0.0	27.0	0.0	9
	October	26.0	0.0	26.0	0.0	9
	November	26.0	0.8	26.3	1.0	9
	December	27.0	0.0	27.0	0.0	9
2001	January	27.0	0.0	27.0	0.0	9
	February	29.0	0.0	29.7	0.7	9
	March	29.0	0.0	29.0	0.0	9
	April	25.0	0.0	25.0	0.0	9
	May	25.0	0.0	25.0	0.0	9
	June	25.0	0.0	26.0	0.0	9
	July	29.0	0.0	29.0	0.0	9
	August	25.0	0.0	25.0	0.0	9
	September	23.0	0.0	23.0	0.0	9
	October	23.2	0.7	23.0	0.0	9
	November	24.0	0.0	24.0	0.0	9
	December	26.0	0.0	25.0	0.0	9
2002	January	23.0	0.0	23.0	0.0	9
	Mean	26.1	2.2	26.2	1.8	

Table A.3.4. Two-way ANOVA of monthly bottom seawater temperature, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, **: highly significant differences, ns: not significant differences df: degrees of freedom, SS: sum of squares, MS: mean square, p: probability

Source	df	SS	MS	F-value	p-value
Island locations	1	3.00	3.00	2.83^{ns}	>0.05
Monthly	23	1310.11	56.96	53.73**	<0.01
Island locations * Monthly	23	33.44	1.45	1.37^{ns}	>0.05
Error	384	407.11	1.06		
Total	432	296914.00			

Table A.3.5. Mean (Average)(mg.cm^{-2}.month^{-1}) and Std. Deviation (±) of monthly sedimentation, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, N: number of measurements

		Pandan Island		Setan Island		
Years	**Monthly**	**Mean**	**Std. Deviation (±)**	**Mean**	**Std. Deviation (±)**	**N**
2000	February	25.54	7.06	68.41	17.96	3
	March	1.4.54	4.74	27.84	4.74	3
	April	16.34	6.72	20.85	5.34	3
	May	52.87	27.90	30.08	5.65	3
	June	11.80	1.59	13.74	4.57	3
	July	50.72	8.83	87.88	47.37	3
	August	57.33	18.31	104.74	34.64	3
	September	195.30	51.23	463.35	64.70	3
	October	390.42	132.47	607.45	43.10	3
	November	96.72	17.61	129.93	69.58	3
	December	49.13	5.77	65.18	5.71	3
2001	January	31.43	11.00	45.80	7.84	3
	February	26.12	7.50	86.49	22.95	3
	March	15.95	2.50	28.10	9.16	3
	April	57.21	12.04	81.00	23.95	3
	May	152.54	31.86	250.47	46.44	3
	June	138.80	53.40	142.22	30.81	3
	July	71.16	13.58	116.39	78.64	3
	August	55.62	4.03	130.72	55.95	3
	September	22.62	0.91	91.62	54.01	3
	October	372.73	96.00	560.72	90.63	3
	November	96.72	17.61	140.00	84.78	3
	December	88.47	31.58	104.39	73.57	3
2002	January	125.41	29.55	145.26	26.74	3
	Mean	92.31	24.37	147.61	37.87	

Table A.3.6. Two-way ANOVA of monthly sedimentation, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, **: highly significant differences, df: degrees of freedom, SS: sum of squares, MS: mean square, p: probability

Source	df	SS	MS	F-value	p-value
Island locations	1	1372.58	1372.58	56.86**	0.01
Monthly	23	30343.29	1319.27	54.65**	0.01
Island locations*Monthly	23	2297.35	99.89	4.14**	0.01
Error	96	2317.35	24.14		
Total	143	36330.57			

Table A.3.7. Mean (Average)(m) and Std. Deviation (±) of monthly transparency, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, N: number of measurements

		Pandan Island		Setan Island		
Years	**Monthly**	**Mean (m)**	**Std. Deviation (±)**	**Mean (m)**	**Std. Deviation (±)**	**N**
2000	February	22.89	1.83	14.67	3.32	9
	March	19.44	1.24	9.89	1.05	9
	April	15.11	2.42	8.67	0.71	9
	May	27.00	0.00	8.33	2.78	9
	June	27.00	0.00	6.67	0.50	9
	July	20.00	6.06	7.00	0.00	9
	August	17.00	2.29	5.67	1.00	9
	September	19.33	2.18	8.00	1.50	9
	October	20.00	2.60	10.00	1.50	9
	November	17.67	0.50	7.33	1.32	9
	December	24.56	2.01	7.67	1.00	9
2001	January	25.67	1.50	10.33	2.00	9
	February	26.00	1.66	10.39	3.02	9
	March	26.78	1.72	11.67	2.06	9
	April	30.00	2.60	15.00	1.73	9
	May	17.33	2.18	11.67	2.65	9
	June	17.33	2.18	7.00	1.15	9
	July	16.00	0.00	7.00	0.00	9
	August	24.00	0.00	5.00	0.00	9
	September	27.00	1.73	10.00	1.73	9
	October	30.00	0.00	14.00	0.00	9
	November	7.00	0.00	12.00	0.00	9
	December	27.00	1.73	15.00	1.73	9
2002	January	16.00	0.00	4.00	2.29	9
	Mean	21.67	5.90	9.46	3.49	

Table A.3.8. Two-way ANOVA of monthly transparency, over a sampling period of February 2000 – January 2002) at Pandan and Setan Islands, **: highly significant differences, df: degrees of freedom, SS: sum of squares, MS: mean square, p: probability

Source	df	SS	MS	F-value	p-value
Island locations	1	16115.01	16115.01	4617.84**	0.01
Monthly	23	5731.65	249.20	71.41**	0.01
Island locations * Monthly	23	3015.79	131.12	37.57**	0.01
Error	384	1340.06	3.49		
Total	432	130844.75			

Table A.3.9. Mean (Average) and Std. Deviation (±) of monthly pH, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, N: number of measurements

		Pandan Island		Setan Island		
Years	**Monthly**	**Mean**	**Std. Deviation (±)**	**Mean**	**Std. Deviation (±)**	**N**
2000	February	8.20	0.09	8.07	0.005	9
	March	8.30	0.00	8.50	0.15	9
	April	8.20	0.00	8.10	0.00	9
	May	8.20	0.00	8.20	0.00	9
	June	8.40	0.00	8.40	0.00	9
	July	8.40	0.00	8.40	0.00	9
	August	8.40	0.00	8.40	0.00	9
	September	8.30	0.00	8.17	0.10	9
	October	8.20	0.00	8.20	0.00	9
	November	8.13	0.05	7.97	0.05	9
	December	8.10	0.00	8.10	0.00	9
2001	January	8.20	0.00	8.20	0.00	9
	February	8.30	0.00	8.50	0.15	9
	March	8.30	0.00	8.60	0.00	9
	April	8.50	0.00	7.63	0.18	9
	May	8.00	0.00	8.00	0.00	9
	June	9.00	0.00	8.80	0.09	9
	July	9.00	0.00	8.30	0.00	9
	August	9.20	0.00	9.00	0.00	9
	September	8.90	0.00	8.60	0.00	9
	October	8.20	0.00	7.80	0.00	9
	November	7.60	0.00	8.20	0.00	9
	December	8.00	0.00	8.00	0.00	9
2002	January	8.57	0.65	8.43	0.85	9
	Mean	8.36	0.38	8.27	0.35	

Table A.3.10. Two-way ANOVA of monthly pH, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, **: highly significant differences, df: degrees of freedom, SS: sum of squares, MS: mean square, p: probability

Source	df	SS	MS	F-value	p-value
Island locations	1	0.78	0.78	29.65**	0.01
Monthly	23	37.86	1.65	62.95**	0.01
Island locations * Monthly	23	9.09	0.40	15.12**	0.01
Error	384	10.04	0.03		
Total	432	29932.89			

Table A.3.11. Mean (Average) and Std. Deviation (±) of monthly salinity, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, N: number of measurements

		Pandan Island		**Setan Island**		
Years	**Monthly**	**Mean**	**Std. Deviation (±)**	**Mean**	**Std. Deviation (±)**	**N**
2000	February	33.33	0.50	33.11	0.33	9
	March	34.00	0.00	33.00	0.71	9
	April	33.33	0.71	33.33	0.50	9
	May	33.89	0.33	33.67	0.50	9
	June	34.00	0.00	33.00	0.00	9
	July	33.22	0.44	33.00	0.00	9
	August	34.00	0.00	33.00	0.00	9
	September	33.00	0.00	32.00	0.00	9
	October	33.33	0.50	32.00	0.00	9
	November	32.67	0.50	32.00	0.00	9
	December	33.67	0.50	33.00	0.87	9
2001	January	33.00	0.87	32.33	0.50	9
	February	33.00	0.87	32.00	0.00	9
	March	33.00	0.00	33.00	0.00	9
	April	34.00	0.00	34.00	0.00	9
	May	31.00	0.00	32.00	0.00	9
	June	34.00	0.00	31.00	0.00	9
	July	33.00	0.00	33.00	0.00	9
	August	34.67	0.50	33.00	0.00	9
	September	34.00	0.00	34.00	0.00	9
	October	34.00	0.00	31.00	0.00	9
	November	34.00	0.00	31.00	0.00	9
	December	34.00	0.00	32.00	0.00	9
2002	January	33.00	0.00	29.67	2.00	9
	Mean	33.46	0.81	32.46	1.13	

Table A.3.12. Two-way ANOVA of monthly salinity, over a sampling period of two years (February 2000 – January 2002) at Pandan and Setan Islands, **: highly significant differences with p-value < 0.01

Source	**df**	**SS**	**MS**	**F-value**	**p-value**
Island locations	1	108.00	108.00	536.28**	0.01
Monthly	23	202.41	8.80	43.70**	0.01
Island locations * Monthly	23	135.67	5.90	29.29**	0.01
Error	384	77.33	0.20		
Total	432	469916.00			

CURRICULUM VITAE

1	**NAME**	Indra Junaidi Zakaria
2	**DATE OF BIRTH**	8 June 1967
3	**NATIONALITY**	Indonesian
4	**EDUCATION**	1991: Ir. Department: Fisheries Resource Utilization, Bung Hatta University, Padang West Sumatra, Indonesia. Program Study: Fisheries Resource Utilization. 1996: M.Sc. Program Study: Post harvest Technology, Bogor Agricultural University, Bogor West Java, Indonesia. Currently (from 1998): PhD Student at the Institute for Polar Ecology, Christian Albrechts University of Kiel, Germany. Main Subject: Marine Biology, conservation and rehabilitation of coral reefs.
5	**OTHER TRAINING**	12 – 22 December 1995, Training Course Diver and Methodology Evaluating Condition of Coral Reef (Basic Level), in P3O-LIPI, Jakarta, 26 July – 4 August 1996, Training Course Diver and Methodology Evaluating Condition of Coral Reef (advanced Level), in Bung Hatta University cooperation with P3O-LIPI, Jakarta. 22 – 29 November 1996, Training Course Taxonomy Reef in Bung Hatta University cooperation with ZMT, Bremen University, Germany. 3 – 10 March 1997, Training Course GIS for Management of Coastal and Marine West Sumatra in Bung Hatta University cooperation with LIPI-Geotek, Bandung.
6	**LANGUAGE**	• English – good reading, fair writing and speaking • German – good reading and speaking, fair writing • Indonesian – native
7	**MEMBERSHIP OF PROFESIONAL SOCIETIES**	• Minang Bahari Foundation (NGO). • Coral Reef Information and Traning Centre (CRITIC) Region West Sumatra. • Indonesia Assosiation Coral Reef Study (IACRS) Region 1 Sumatra.
8	**COUNTRIES OF WORK EXPERIENCE**	Indonesia, Germany

9 **EMPLOYMENT RECORD**	
FROM: March 1992	To: Present
EMPLOYER	Faculty of Fishery Bung Hatta University, Padang, West Sumatera Indonesia.
POSITION:	Researcher and Lecturer
FROM: June 1996	To: Present
EMPLOYER:	Research and Development Centre Fishery of Bung Hatta University.
POSITION	Specialist Staff Researcher

Erklärung

Hiermit erkläre ich, dass die vorliegende Dissertation nach Inhalt und Form, abgesehen von der Beratung durch meine akademischen Lehrer, meine eigene Arbeit ist. Sie wurde noch keiner anderen Stelle im Rahmen eines Prüfungsverfahrens vorgelegt.
Dies ist meine erster Promotionsversuch.

Kiel, den 16 Dezember 2003

Indra Junaidi Zakaria