D-4.2.5 Land use effect on coral communities(Final Report)

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Abstract

I.Terrestrial area

This research aims at studying the influence of red soil outflow on coral reef. The object region of research is composed of three areas, namely Sesokojima area, Kuroshima area and Amitoriwan area. In investigation, we analyzed land use, average degree of inclination and the distance from river or seashore and studied the degree of danger of red soil outflow.

As a result, it was made clear that the area with the highest degree of danger of red soil outflow was Sesokojima area. The area with the lowest degree of danger was Amitoriwan area. Intermediate degree of danger was shown in Kuroshima area among the above three areas. 32.1% of Sesokojima area was evaluated at "dangerous" land. Three were quarries, land under development, golf links, pineries, etc. in this "dangerous" land. There is scarcely any "dangerous" land in Kuroshima area and Amitoriwan area. 96.6% of Amitoriwan area was evaluated at "safe" and "comparatively safe". This value is about twice the value of Kuroshima area or Sesokojima area. "Safe" or "comparative safe" area is flat forest area or forest area, distant from river or seashore.

II. Marine area

To evaluate the effect of land development on coral communities, we conducted monitoring of coral communities and recorded environmental conditions at 3 study sites in Okinawa Prefecture, Japan, in 1995 and 1996. We selected 5 stations each at (1)

Sesoko Island, (2) Amitori Bay, and (3) Kuroshima Island. The land development is most progressed at (1), negligible at (2), and intermediate at (3). For environmental conditions, we analyzed sediment collected by traps, and water quality (salinity, SS, Total-N, NH_4-N, NO_2-N, NO_3-N, Total-P). We found within-locality variation in the environmental parameters. However, we cannot detect clear trend in among-localities difference. We monitored coral communities in permanent plots, and recorded number of coral recruits onto artificial settlement plates. We detected significant decrease in coral percent cover only at (1). The decrease was mainly due to predation on tabular Acropora by Acanthaster planci at (1). In contrast, coral percent cover tended to increase at (2) and (3). Coral settlement was greater in 1996 than in 1995 at the 3 study sites. Coral settlement tended to be less at (3) than at (1) and (2).

Key Words Coral reef, Coral community, Coral settlement, Land Classification, Land Use, Mesh analysis, Red Soil, Sediment, Water quality

I. Terrestrial area

1. Research Objective

Coral reef in Okinawa is precious internationally. The investigation on decrease in coral reef was already carried out[1]. Further, the load of red soil outflow on coral reef in micro-area was also investigated[2]. However, in these researches, the influence of red soil outflow from macro-area has not been studied so far. Then, the objective of our research is to study the influence of red soil outflow on coral reef, covering wide area. The object region of investigation is composed of three areas, namely Sesokojima area (Fig. 1), Kuroshima area (Fig. 2) and Amitoriwan area (Fig. 3). In investigation, we will analyze land use, average degree of inclination and distance from river or seashore and study the degree of danger of red soil outflow.

2. Research Method

Red soil is distributed in the object region of research and flows out when it rains. Further, the steeper the inclination of terrain becomes, the more rapidly water flows. On the other hand, if there is forest, rain does not beat against red soil. As computed soil-loss per unit of area changes with soil condition, actual survey is necessary. But it is difficult to survey actually and so following universal soil-loss equation is used[3].

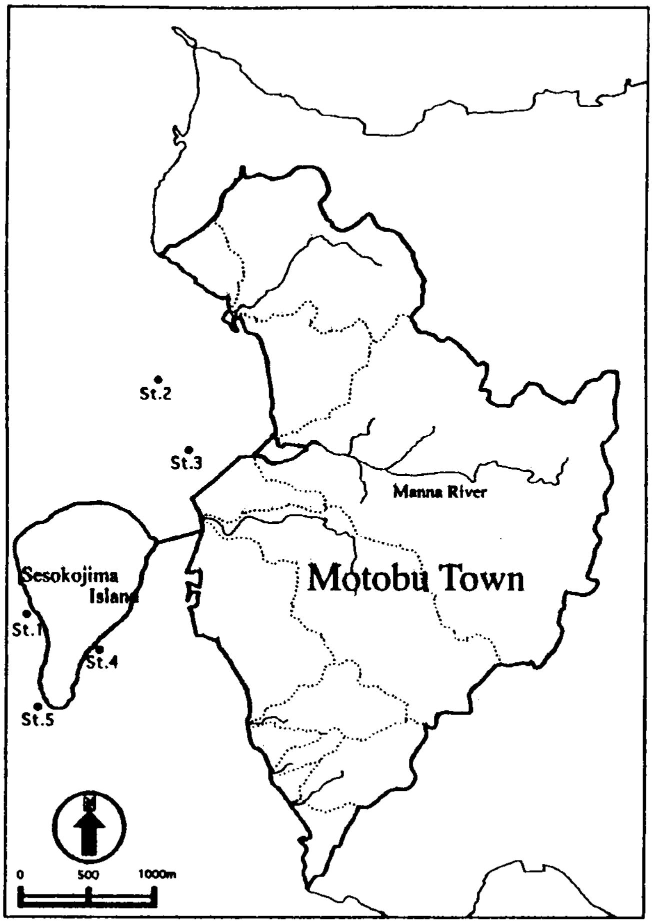

Fig. 1 Sesokojima Area

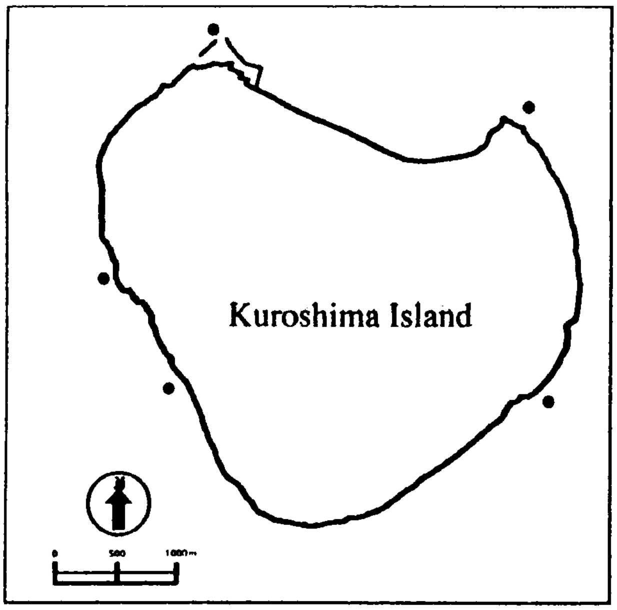

Fig. 2 Kurosima Area

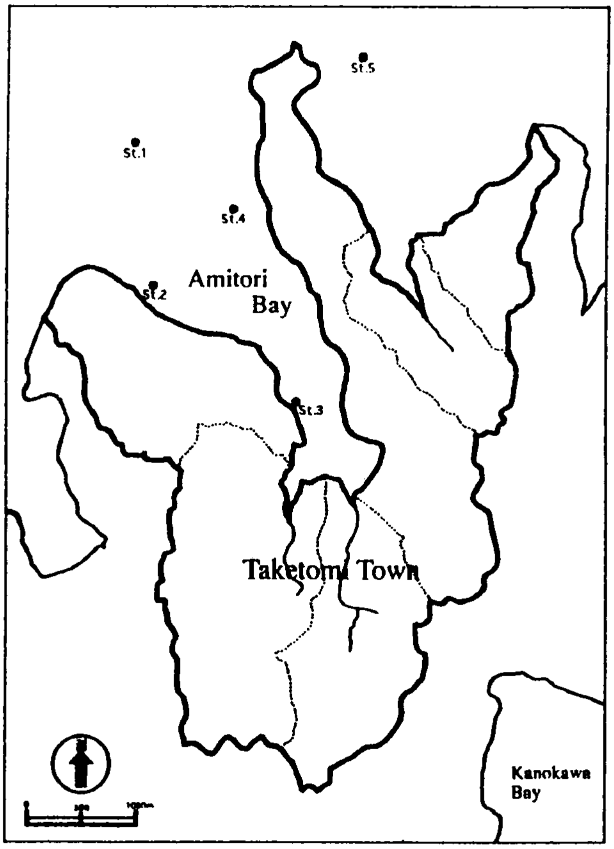

Fig. 3 Amitoriwan Area

A=RKLSCP

Here, A : Computed soil-loss per unit of area

R : Rainfall factor

K : Soil-erodibility factor

L, S : Slope-length factor, slope-steepness factor

C, P : Cropping-management factor, Erosion-control practice factor

This equation is a prediction equation for micro-area, such as farm land, etc. As this research is to be carried out covering macro-area, we have decided to improve this equation. We have much rain in Okinawa. Red soil and jyagaru soil, liable to be eroded, distribute over wide area[4). Therefore, we regarded intensity of rainfall and soil-erodibility as constant. Further, since this study covers wide area, we used factor of average degree of slope-inclination instead of slope-length factor and slope-steepness factor.

And we used land-use factor instead of cropping-management factor and erosion-control practice factor. Moreover, we considered that the danger of red soil outflow becomes higher, if the distance from river or seashore becomes shorter.

Red soil outflow is caused by the inclination of terrain and land use. Further, it is influenced by the distance from river or seashore. We analyzed land use, average degree of terrain-inclination and the distance from river or seashore in three object areas of research, namely Sesokojima area, Kuroshima area and Amitoriwan area. Mesh analysis was used for investigation. Further, degree of danger of surface soil outflow was evaluated, combining three elements. We used topographic maps 1:25,000, published by Geographical Survey Institute, as base maps for analysis. The scale of mesh is square, each side of which has a length of 250m. The area of investigation unit is 6.25ha. The number of set mesh is 1,114 in total :645 in Sesokojima area, 189 in Kuroshima area and 280 in Amitoriwan area.

3. Result

3.1 Land use

Natural forest spreads out in Amitoriwan area. Forest occupies about 40.3% of Sesokojima area. Forest in Sesokojima area distributes mainly in steep sloping land. Forest covers about 13.2% of Kuroshima area. Forest in Kuroshima area distributes along seashore of the island for tide and wind protection. There are many villages and artificial structures in Sesokojima area. Field and grassland occupy about 81.5% of Kuroshima area. Grassland in Kuroshima is cattle pasture. We can learn from these facts that land development is progressing in Sesokojima area, there is scarcely found any artificial land use in Amitoriwan area and farming is flourishing in Kuroshima area.

Table 1 Classification of land use

Land	use	Sesokojima area	Kuroshima area	Amitoriwan area
Forest	broad-leaved forest, needle-leaved forest	40.5%	13.2%	99.2%
Artificial structure, village	village, road, port	8.8%	2.1%	0.4%
Field, glassland	pinery, sugarcane field, fruit field, glassland	44.8%	81.5%	0.0%
Bare ground, wastel	bare ground, quarry, cliff	5.3%	1.6%	0.4%
Other	sand	0.6%	1.6%	0.0%
Total		100.0%	100.0%	100.0%

3.2 Average degree of inclination

As there are mountains, such as Mt. Yaedake (453.5m above sea level), etc., in the eastern part of Sesokojima area, its terrain is complicated and there are several steep sloping lands. There are flat lands along seashore and River Manna. Whole Amitoriwan area consists of steep sloping lands. The largest percentage of steep sloping lands is shown in Amitoriwan area among three areas. Whole Kuroshima area nearly consists of lands.

3.3 The distance to river or seashore

There is no river in Kuroshima area. Rainwater sinks directly into the soil. The percentage of area, less than 500m distant from river or seashore, is 59.5% in Sesokojima area, 51.1% in Amitoriwan area and 48.1% in Kuroshima area respectively. In each area, there are many meshes, located at a very short distance from river or seashore.

Table 2 Classification of average degree of inclination

Degree of inclination	Number of contour line	Condition	Sesokojima area	Kuroshima area	Amitoriwan area
<5°	0 – 2	frat or gently sloping land	27.0%	99.5%	7.5%
5° – 11°	3 – 5	↑	22.9%	0.5%	16.1%
12° – 17°	6 – 8	│	25.6%	0.0%	36.7%
18° – 23°	9 – 11	↓	17.2%	0.0%	26.8%
24° ≦	12 –	steep sloping land	6.7%	0.0%	12.9%
Total			100.0%	100.0%	100.0%

Table 3 Classification of distance from river or seashore

Distance	Number of mesh	Condition	Sesokojima area	Kuroshima area	Amitoriwan area
1500m ≦	6 −	long distance	13.0%	1.6%	6.8%
1000 - 1499m	5 − 6	↑	5.8%	17.5%	16.1%
500 - 999m	3 − 4	↓	1.6%	32.8%	26.1%
< 500m	0 − 2	short distance	59.5%	48.1%	51.1%
Total			100.0%	100.0%	100.0%

4. Discussion

4.1 Influences of red soil outflow

There are the following two kinds of influences of red soil outflow on coral reef[5].

- The influence of direct sedimentation of red soil on coral reef
- The influence of the suspension of red soil particles

The actual condition of these two kinds of influences is not yet made clear. Here, we evaluated degree of danger of red soil outflow, considering that red soil outflow influences coral reef. Practically, evaluation was carried out from the following point of view.

1) Red soil outflow is most influenced by land use among three elements, namely land use, average degree of inclination and the distance from river or seashore.

2) Red soil outflow is proportional to the percentage of bare ground in land use.

3) The steeper inclination becomes, the more earth and sand are liable to flow out[6].

4) The nearer to river or seashore land use comes, the more flowed out soil is liable to run into the sea.

5) In forest area, earth and sand don't flow out easily, because of low percentage of bare ground.

6) In forest of steep sloping land, soil flows out[7].

7) In artificial structure and village a comparatively small amount of soil flows out.

8) Even in gently sloping land, if water beats against soil directly, red soil flows out.

Based on these knowledge, we defined the equation to obtain degree of danger of red soil outflow. Namely, the evaluation made in this research is a relative evaluation.

$$A = RKSUL$$

Here, A: Degree of danger of red soil outflow

R: Intensity of rainfall (Constant)

K: Soil- erodibility (Constant)

S: Average degree of inclination

U: Land use

L: Distance from river or seashore

Each evaluation factor of three elements, namely land use, average degree of inclination and the distance from river or seashore, is shown in Table 4. Each one of rainfall factor and soil-erodibility factor was settled as a constant 1. The degree of danger of red soil outflow was computed using this equation and classified into five classes shown in Table 5.

Table 4 Evaluation factor of red soil outflow

Evaluation factor	Land use	Degree of inclination	Distance
1	forest	<5°	<500m
2	—	5° — 11°	500-999m
3	—	12° — 17°	1000-1499m
4	—	18° — 23°	1500m≦
5	artificial structure ,village , road ,port	24° ≦	—
15	pinery , sugarcane field , fruit field , glassland	—	—
20	bare ground , quarry , cliff	—	—

Table 5 Classification by degree of danger of red soil outflow

Class	Degree of danger	Condition
1	1 — 5	safe
2	6 — 20	comparatively safe
3	21 — 60	comparatively danger
4	61 — 240	danger
5	240 ≦	most dangerous

4.2 Degree of danger of red soil outflow

The result of the classification of degree of danger of red soil outflow into five classes is shown in Fig. 4.

Land with degree of danger 5 are found, only in Sesokojima area. This area consists of quarries and land under development. Lands with degree of danger 4 occupy 32.1% of Sesokojima area. These areas with many steep sloping lands are composed of quarries, golf links, pineries, etc. Lands with degree of danger 3 occupy 50.3% of Kuroshima area and 18.4% of Sesokojima area. In Kuroshima area, about half the lands of island was classified as degree of danger 3. Lands with degree of danger 2 occupy 80.7% of Amitoriwan area, 40.2% of Kuroshima area and 33.2% of Sesokojima area. In Amitoriwan area, as most of the lands are used for forest, there are a lot of lands with degree of danger 2. Lands with degree of danger 1 occupy 18.9% of Amitoriwan area, 15.3% of Sesokojima area and 9.5% of Kuroshima area. Forest in flat land and forest, distant from river or seashore, were classified as degree of danger 1.

As the result of these classification, it was made clear that the highest degree of danger of red soil outflow was shown in Sesokojima area, followed by Kuroshima area and Amitoriwan area in order.

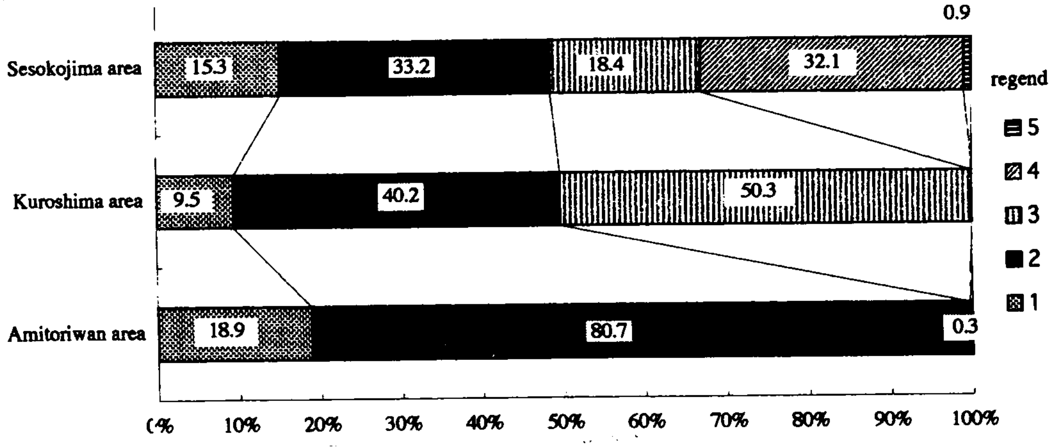

Fig. 4 Compornent of degree of danger

5. Conclusion

In this research, we analyzed land use, average degree of inclination and the distance from river or seashore in three areas, namely Sesokojima, Kuroshima and Amitoriwan. As a result, we could grasp characters of lands in three areas. Based on analyzed data, degree of danger of red soil outflow was classified into five classes. It is necessary to study the relation to research data on coral in this sea area in the future. Further, the research of factors, used in evaluation equation to compute degree of danger of red soil outflow, is also necessary.

II. Marine area

1. Introduction

We conducted the present study to provide baseline data on coral communities and their environment in Japanese coral reefs. Our main objective was to evaluate the effect of land development on coral communities. For this objective, we conducted the study on environmental conditions and coral communities at 3 study sites, which differs in the degree of the land development.

2. Methods

Study sites

We selected 3 study sites, i.e. Sesoko Island, Amitori Bay, and Kuroshima Island, in Okinawa Prefecture, Japan. The development has been most progressed at Sesoko, and is negligible at Amitori, and is moderate at Kuroshima. We established 5 stations in each study site.

Environmental conditions

We collected sediment deposited into three traps (PVC pipe, inner diameter was 9 cm, height was 30 cm), which were set at each station. Dry weight, ash-free dry weigh, and particle size composition of the sediment were determined. The sediment collection was done two or three times at two-month intervals in 1995 and 1996. We collected water samples basically every month from May to November in 1995 and 1996. Salinity, SS, Total-N, NH_4-N, NO_2-N, NO_3-N and Total-P of the collected water was determined. Analyses of the sediment and the water quality were made at Okinawa Environmental Science Center.

Monitoring of coral communities

We randomly established 4 permanent plots at every station, and recorded coral communities in the plots by photography once each in 1995 and 1996. The size of the plots was 1 m^2 at Sesoko and Kuroshima, and 1 m^2 and 4 m^2 at Amitori, where size of coral colonies were large at 3 stations. We recorded percent cover, colony density and genera density of hermatypic corals as parameters of the community. We also recorded coral predators, such as *Acanthaster planci*, if they were present.

Coral settlement

We placed 5 sets of settlement plates (10 X 10 cm, slate) on stainless bolts fixed in the substrate at each station. The set consisted of 2 plates: one was on top of the other with 2 cm distance. At each sample period, settlement plates which had been submerged for 2 months were collected and replaced by fresh plates. The plates were set out in April at Amitori and Kuroshima, where major coral spawning occurs in April, and in May at Sesoko, where it occurs in May, and every month thereafter until September. Coral spat were identified to family level where possible.

3. Results and Discussion

Environmental parameters

Sediment

In total, we collected 165 sediment samples. A preliminary examination on relationship between total dry weight and percentage of silt-clay content showed that percentage of silt-clay was small when the total weight exceeded 30 g. Thus we used the samples whose total weight was less than 30 g (Table 6). Although there was large variation within the study sites, we cannot detect clear trend in the among-sties difference.

Water quality

Concentration of the nutrients was generally low in all the study sites, and there was no clear trend in the among-sites variation (Table 7).

No significant difference in the nutrients concentration was found among the study sites in the present study. If phytoplanktons uptake the nutrients rapidly, biomass of phytoplanktons might be greater at the sites where land development is active. In future study, measurement of chlorophyll concentration of phytoplankton should be included in the sea water analyses.

Table 6. Particle size composition of sediment samples. The samples, whose total dry weight was less than 30 g, were included. Percentage in dry weigh was shown in parentheses.

Station	Number of samples	Total dry weight (g)	Rubble (g)	Coarse sand (g)	Fine sand (g)	Silt (g)	Clay (g)
Amitori St.1	17	9.82	3.37(34.3)	1.93(19.7)	1.74(17.8)	2.42(24.6)	0.36(3.7)
Amitori St.2	6	3.23	0.12(3.6)	0.81(25.2)	0.62(19.0)	1.53(47.3)	0.16(4.9)
Amitori St.3	17	10.55	0.18(1.7)	0.30(2.8)	2.19(20.8)	6.96(66.0)	0.92(8.7)
Amitori St.4	18	2.81	0.10(3.4)	0.32(11.5)	0.54(19.4)	1.53(54.3)	0.32(11.4)
Amitori St.5	18	3.44	0.29(8.5)	0.81(23.6)	1.29(37.6)	0.86(24.9)	0.19(5.5)
Sesoko St.2*	3	3.76	0.19(5.0)	0.56(14.8)	1.44(38.3)	1.20(32.0)	0.37(9.8)
Kuroshima St.1	12	11.36	1.13(10.0)	1.70(15.0)	2.36(20.8)	5.50(48.4)	0.67(5.9)
Kuroshima St.2	9	16.45	0.34(2.0)	0.72(4.4)	2.13(12.9)	11.53(70.1)	1.74(10.6)
Kuroshima St.3	12	7.01	0.75(10.7)	1.55(22.1)	2.54(36.2)	1.86(26.5)	0.32(4.5)
Kuroshima St.4	9	12.54	0.19(1.5)	0.70(5.6)	2.03(16.2)	8.47(67.6)	1.15(9.2)
Kuroshima St.5	5	10.01	0.57(5.7)	1.79(17.9)	4.75(47.5)	2.40(24.0)	0.50(5.0)

*The number of samples at Sesoko was extremely small because the traps were broken by typhoons.

Table 7. Mean values of water quality parameters for 2 years (all in mg/l).

Stations	Salinity	SS	Total-N	NH_4-N	NO_2-N	NO_3-N	Total-P
Amitori 1	34.261	0.0	0.044	0.000	0.0008	0.000	0.0048
Amitori 2	34.284	0.0	0.051	0.003	0.0009	0.000	0.0049
Amitori 3	34.253	0.1	0.045	0.004	0.0011	0.004	0.0054
Amitori 4	34.284	0.0	0.049	0.003	0.0008	0.004	0.0045
Amitori 5	34.208	0.0	0.048	0.000	0.0004	0.000	0.0056
Sesoko 1	34.452	0.0	0.069	0.000	0.0022	0.011	0.0049
Sesoko 2	34.486	0.0	0.049	0.000	0.0016	0.002	0.0051
Sesoko 3	34.488	0.1	0.053	0.000	0.0013	0.002	0.0067
Sesoko 4	34.379	0.2	0.082	0.000	0.0012	0.018	0.0053
Sesoko 5	34.487	0.1	0.099	0.002	0.0010	0.027	0.0049
Kuroshima 1	34.359	0.2	0.070	0.014	0.0012	0.000	0.0044
Kuroshima 2	34.377	0.6	0.072	0.009	0.0011	0.000	0.0048
Kuroshima 3	34.305	0.2	0.060	0.009	0.0021	0.000	0.0043
Kuroshima 4	34.295	0.2	0.066	0.008	0.0027	0.000	0.0046
Kuroshima 5	34.305	0.2	0.080	0.013	0.0019	0.000	0.0049

Coral communities

Overall mean of coral percent cover was 39.7±5.3% (±SE, n=20), 31.2±5.4% (n=20), and 30.1±6.9% (n=20) for Amitori, Sesoko, and Kuroshima, respectively, in 1995.
The overall mean did not differ significantly among the sites ($p>0.05$, nested ANOVA). However, in 1996, the overall mean was 44.9±5.0%, 19.6±3.3%, and 38.9±7.3%, for Amitori, Sesoko, and Kuroshima, respectively. In 1996, the difference was significant ($p<0.001$, nested ANOVA), and the mean was significantly smaller at Sesoko than at Amitori and Kuroshima (both $p<0.001$, Tukey's multiple comparison).
At Amitori, there was no significant difference in mean percent coral cover and mean genera density of the 5 stations between the years ($p>0.05$, two-way ANOVA; Fig. 5). In contrast, mean colony density significantly increased between the year ($p<0.05$, two-way ANOVA), and significant increase was detected at St. 4, where *Acropora* showed good recruitment. Non-significant decrease in mean percent coral cover at St. 3 was due to mortality of some *Acropora* colonies, but no predator, such as *Acanthaster planci*, was found there.

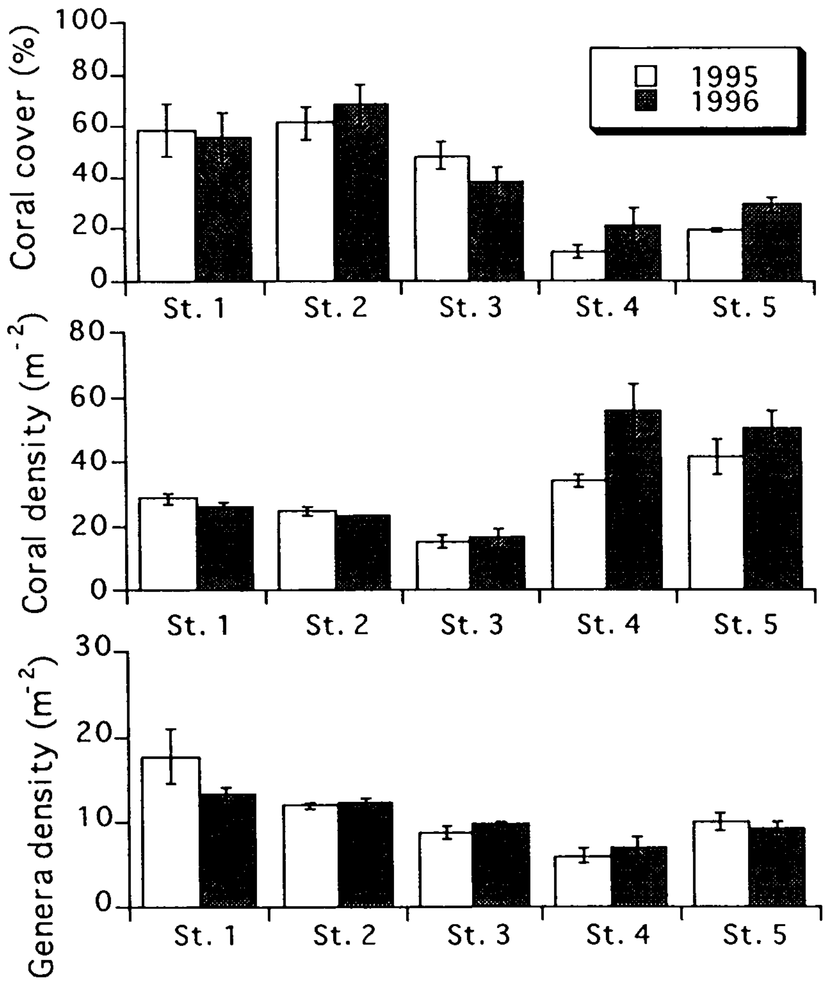

Fig. 5. Coral community parameters at each station in Amitori. Bars are SE.

At Sesoko, the mean percent coral cover decreased significantly between the year ($p<0.01$, two-way ANOVA; Fig. 6), and significant difference was found at St. 2, where *Acanthaster planci* appeared in high density (the highest density was 1.3/10 m^2). In 1995, tabular *Acropora* was dominant there, but almost all the tabular *Acropora* disappeared because of the selective feeding by *A. planci*; mean percent cover of tabular *Acropora* decreased from $38.6\pm9.3\%$ to $1.5\pm0.9\%$ ($n=4$) between the year at this station. The mean of colony density and genera density did not differed significantly between the year ($p>0.05$, two-way ANOVA).

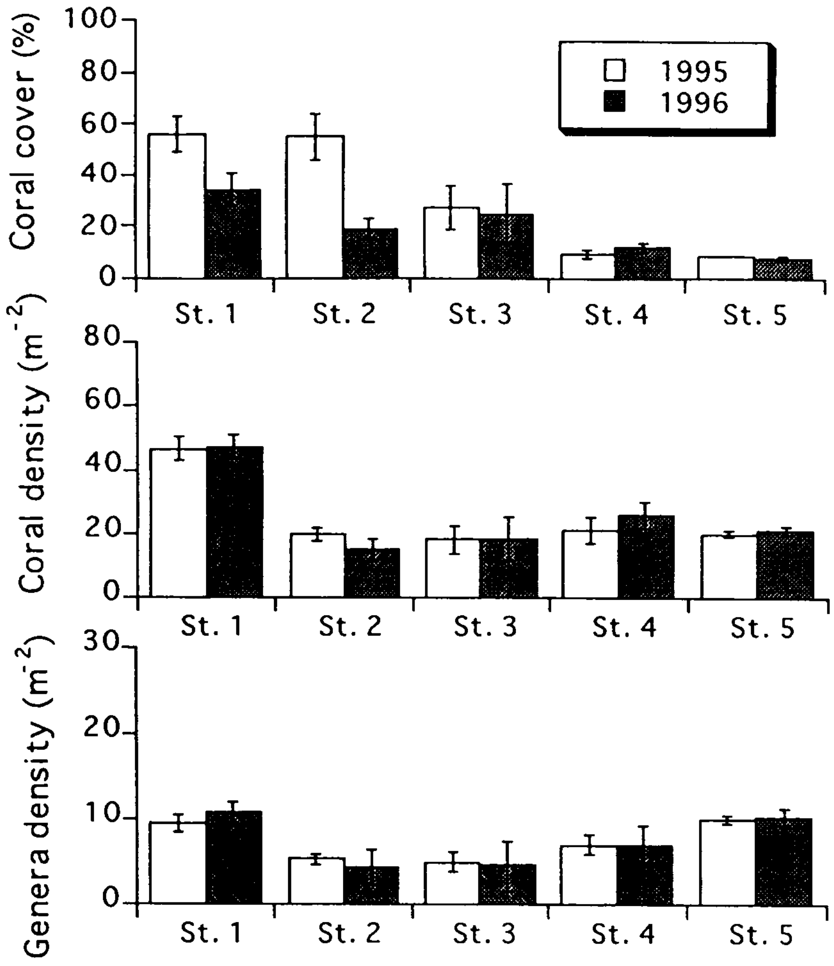

Fig. 6. Coral community parameters at each station in Sesoko. Bars are SE.

At Kuroshima, percent coral cover increased at all the stations, but no significant change was detected in the means of the 3 community parameters ($p>0.05$, two-way ANOVA; Fig. 7).

The present data on coral community might support that land development may cause high density of *Acanthaster planci* due to increased phytoplankton densities[10], and coral communities are devastated in such area.

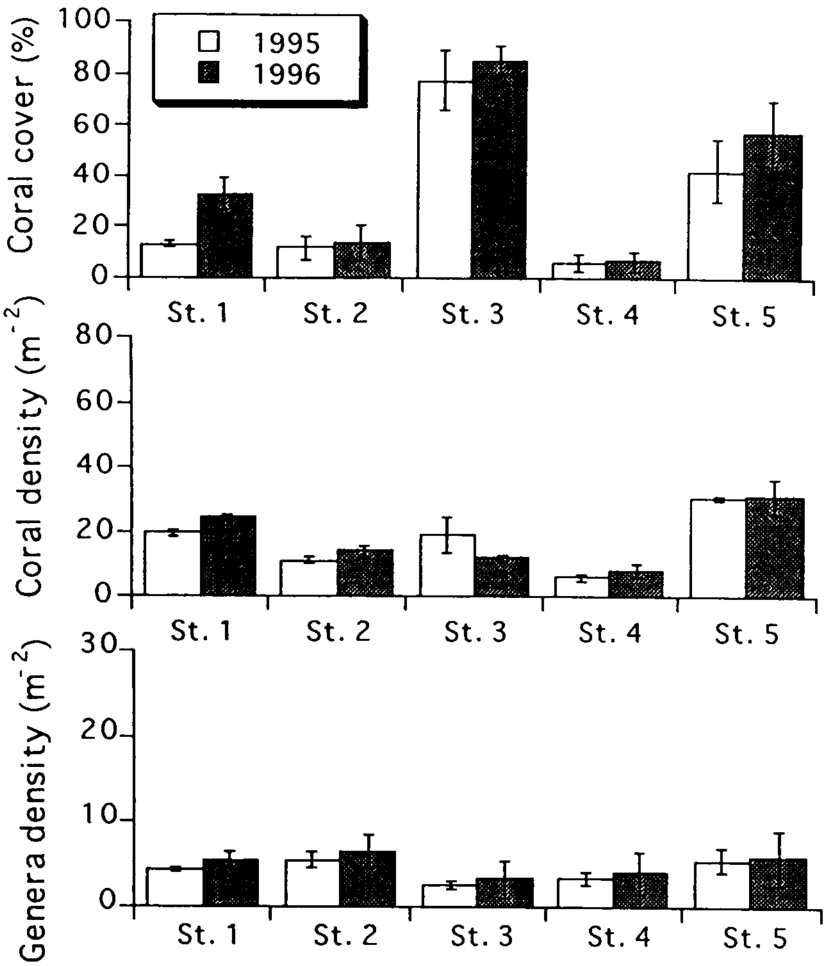

Fig. 7. Coral community parameters at each station in Kuroshima. Bars are SE.

Coral settlement

At Amitori, 71.1% of all the coral settlement was Acroporidae in 1995. Number of the settlement was smallest at St. 3 in 1995 (Fig. 8). In 1996, 75.0% of all the coral settlement was Acroporidae, and number of coral settlement was highest at St. 3.

At Sesoko, 47.0% of all the coral settlement was Acroporidae in 1995, whereas more than 95% was Acroporidae in 1996. Number of the settlement was about 10 times greater in 1996 than in 1995 (Fig. 8). Number of the settlement was largest at St. 1 in 1995.

Unfortunately, all the plates were removed by typhoons at St. 1 in 1996.

At Kuroshima, the settlement tended to be smaller than the other 2 study sites.

The present data on coral settlement suggest that coral recruitment varied greatly between years. Although some plates were lost, heavy settlement at Sesoko in 1996 may suggest that recovery potential of coral community is not poor.

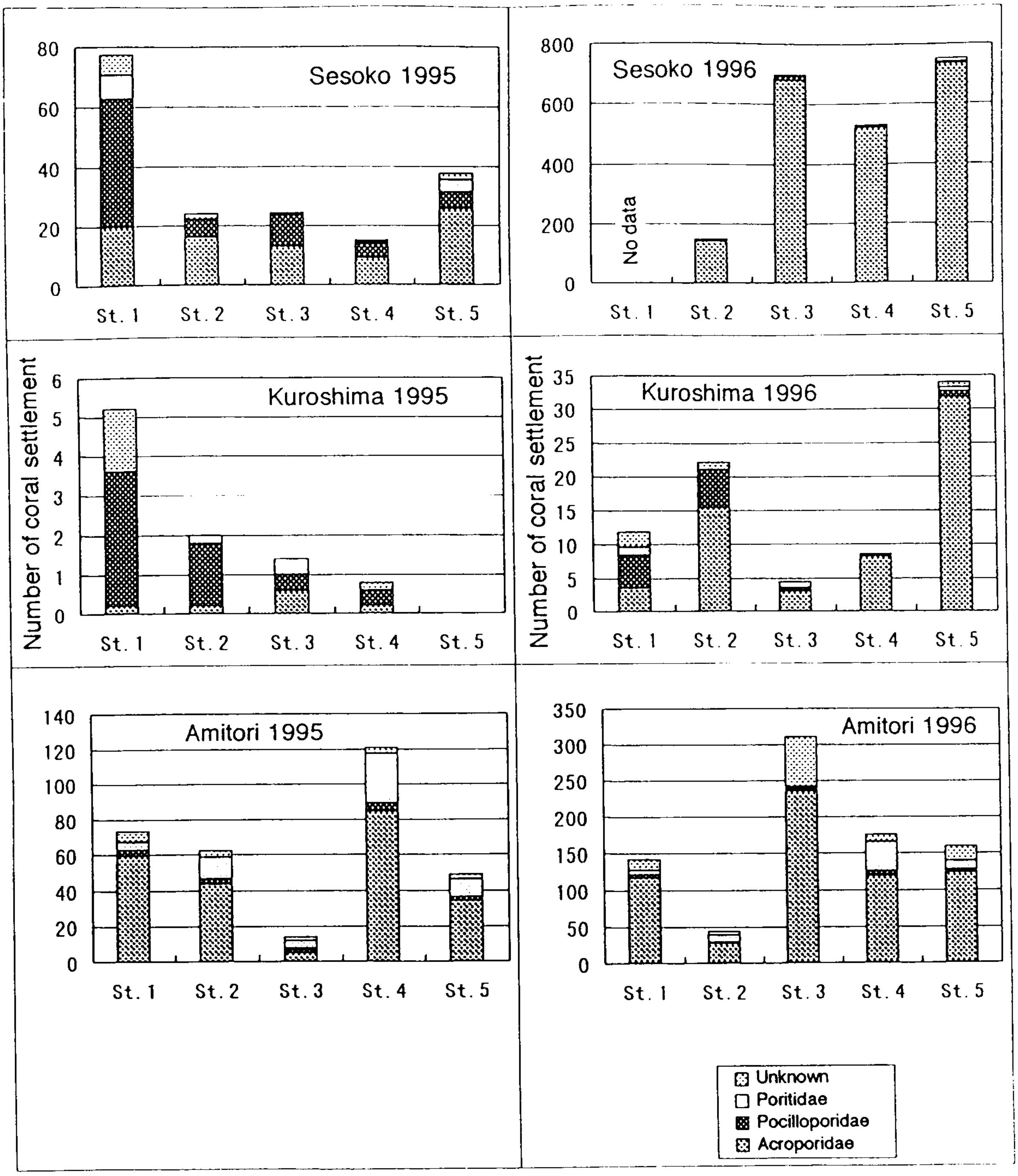

Fig. 8. Sum of the mean number of coral settlement per set for each two-month period at each station.

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