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The Ecology of *Gracilaria verrucosa* (Hudson) Papenfuss [Formerly *G. confervoides* (L.) Greville] in Koddiyar Bay, Trincomalee

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Introduction

The name *Gracilaria verrucosa* (Hudson) Papenfuss was substituted for the name *Gracilaria confervoides* (L) Greville by Papenfuss (1950). However the name *G. verrucosa* has not yet come into general use except among the phycologists and the former name (*Gracilaria confervoides*) will be retained here as it is used commercially. *G. confervoides* shows a wide geographical distribution. May (1948) has shown that it exhibits a wide range in size, colour, anatomy and ecological behaviour in Australian plants of the species. Cotton (1912), Gibb (1939), Humm and Wolf (1946) had observed that *G. confervoides* is conspicuous in the flora of the summer months in Europe. In Ceylon it is most conspicuous during the period of the south-west monsoon at Koddiyar Bay, Trincomalee, in the east coast. *G. confervoides* occurs unmixed unlike *G. lichenoides* found on the Pearl Banks, Silavathurai, Mannar region, Jaffna, and some of the nearby islands where it is found mixed with other algal flora. As it occurs alone, *confervoides* is easily harvested. This investigation was undertaken to study its vegetative growth, morphology, reproduction and regeneration. (See Fig. 1 on page 30.)

The Occurrence of *Gracilaria confervoides* in Koddiyar Bay

Koddiyar Bay (Fig. 1) is situated off the east coast of Ceylon at Trincomalee. The bay has a maximum length of about eight miles from the mouth to the base and a width of about seven miles. The depth of the bay up to a distance of one half mile from the shore varies from 1ft. to 30 fathoms.

The seaweed beds in the bay extends to about five miles off shore and up to a depth of four fathoms. The depth in this region is rather uneven due to the occurrence of sand banks between which channels of water run. The extent, location and amount of seaweed depend on the relatively calm season from May to October. During the months from July to October, *confervoides* is cast at various points on the sand banks and beaches. During storms, it gets buried in the sand. The colour of the *confervoides* varies from red to pale yellow depending on how long it has lain on the beach. Only the red coloured weed should be collected for commerce. The greater portion of the weed collected by the harvesters is found up to a depth of one and a half fathoms although it occurs up to four fathoms. (Using a diver it was found that the maximum depth at which *confervoides* occurred was at four fathoms.)

Since most of the plants found were attached to worm tubes or rooted in the sand, certain shallow areas were dug up from time to time, but no stones or shells were found serving for anchorage of the plants and there was no evidence of attachment discs. In the deeper areas some plants were found attached to shells and stones by attaching discs, but these were very few. In most cases the plants can be said to grow without attachment to any solid substratum.

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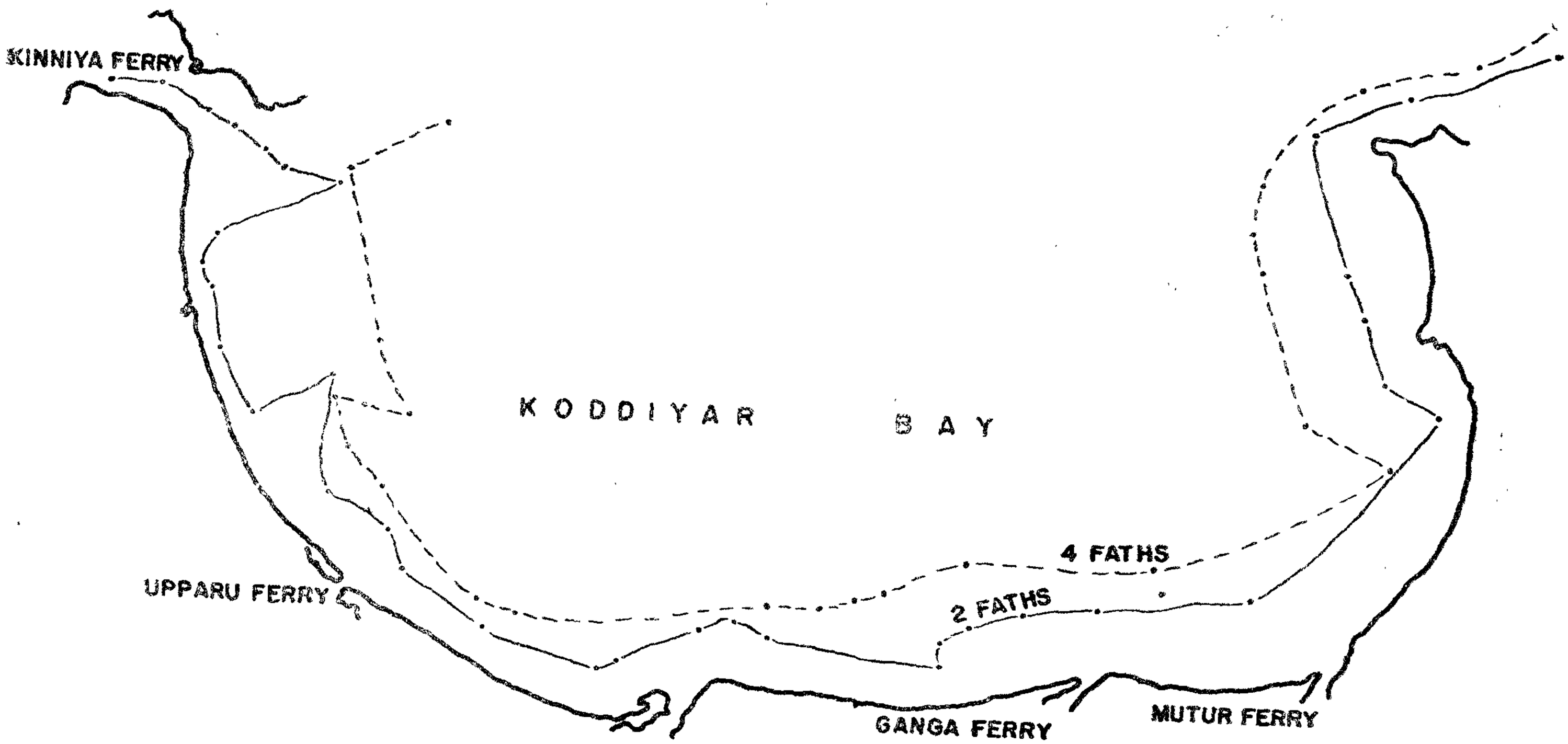

FIG. I. MAP OF KODDIYAR BAY

Vegetative Growth

Experiments on growth were conducted on twenty plants fixed at regular intervals to a one inch mesh nylon net having an area of 9 sq. metres. This net was spread and weighted down on the sandy bottom in a sheltered area close to Ganga ferry at a depth of one meter and distance ten meters from the shore. The selected plants consisted of a single branched axis or clump of axes with a hold-fast. The growth could be judged by measuring the length of the plant since the thallus is cylindrical and the bulk will be proportional to the length. However, to measure the growth of the axes as well as the branches it was decided to record the wet weights of the plants at monthly intervals instead of measuring their length.

Percentage gain per day in fresh weight from 3.7.1964 to 12.8.1964 = 1·275
Percentage gain per day in fresh weight from 12.8.1964 to 12.9.1964 = 3·742
Percentage gain per day in fresh weight from 12.9.1964 to 9.10.1964 = 3·777

Out of the twenty plants attached to the net in July, three were lost in September and only 7 plants survived to October. It will be observed from the table (Table 1) that the percentage gain in weight of the plants per day from 3rd July to 12th August was 1·275. From 12th August to 12th September there was a sudden increase in the percentage gain to 3·742 per day. From 12th September to 9th October the percentage gain increased to 3·777 per day. From these results it is obvious that the period of maximum growth of the plant is from August to October.

TABLE 1

Net Weight in Grammes of Gracilaria confervoides

Plant No.	*3·7 1964*	*12·8 1964*	*% gain*	*12·9 1964*	*% gain*	*9·10 1964*	*% gain*
1	5·5	8·1	47	—	—	—	—
2	4·6	6·8	48	—	—	—	—
3	5·2	8·2	58	—	—	—	—
4	5·8	9·0	55	15·2	162	21·2	266
5	6·4	9·4	50	15·8	147	21·9	242
6	4·9	—	—	—	—	—	—
7	5·4	8·3	54	14·6	170	20·1	272
8	5·6	8·9	59	—	—	—	—
9	6·4	9·8	53	16·0	150	22·1	245
10	7·0	10·0	51	18·1	144	—	—
11	5·8	9·4	62	15·0	159	21·3	267
12	6·3	—	—	—	—	—	—
13	4·8	7·2	50	—	—	—	—
14	5·5	8·4	53	15·8	181	—	—
15	6·2	9·4	52	17·4	180	24·5	295
16	5·6	—	—	—	—	—	—
17	5·5	9·9	62	15·4	180	—	—
18	6·8	10·8	44	18·8	176	26·9	294
19	6·3	10·2	62	18·2	189	—	—
20	4·9	7·4	51	—	—	—	—
		Average	51	—	167	—	269

Morphology and Reproductive Cycles

G. confervoides found at Koddiyar Bay are filiform, terete and grow indefinitely. Branching is irregular, often secund and dichotomous. Branches are more or less uniform, tapering upwards and perceptibly contracted at their bases. The plant varies in colour being purplish-red, red, and

sometimes greenish-yellow but most of the plants in the deep areas are red. The length to which this species grows at Koddiyar Bay varies with the different areas where it occurs. Plants closer to the shore (where the depth of water is less than 1·5 meters) attain a length of 0·3 to 0·5 meters. Plants in the deeper areas grow more luxuriantly and some plants had a length of 2·1 meters at a depth of 6·5 to 7 meters.

There is no difference in the vegetative structure in the male, female and tetrasporic plants except that the male plants are smaller in size. Vegetative growth takes place in early May from the remnants of plants, attached to polychaete tubes, from the previous season.

Tetraspore production begins in June and sporangia are densely scattered at the ends of branches which are swollen. Tetrasporangia are immature in July but by August they reach maturity and the tetraspores are shed, while in some areas maximum production was observed in August and by September or October most of the plants have shed their tetraspores. Empty tetrasporangia were observed in October and November. Tetrasporangia in surface view are rounded in shape and in transverse section are ovoid and surrounded by unmodified cortical cells.

The cystocarpic or mature female plants are characterised by the hemispherical, dome-shaped protuberances scattered on the surface of the frond. The carpogonial branch is two-celled and developed from a primary cortical cell. Numerous nutritive filaments connect the pericarp with the gonimoblast which consists of large vacuolated cells. Capospores are round or ovate and are shed in the cystocarpic cavity within the pericarp and liberated later through the carpostome.

Plants bearing cystocarps were observed in July. Their number increased in August and September during which period the carpospores were shed. Maximum production of carpospores were observed in September and October. Empty cystocarps were found in October and November. By the end of November there were no traces of these plants, the beds being obliterated or buried in sand by the heavy seas during the north-east monsoon.

Male plants are less common throughout the year than plants bearing tetraspores or carpospores. Antheridia are borne in deep pits on the frond surface. In surface view the pits are round or oval in shape and in sectional view they are pocket-like, bordered by unmodified cortical cells. They contain globular spermatia.

The decay of cystocarpic plants takes place when pathogens enter the thalli through the ostioles of the cystocarp after the shedding of the carpospores. In tetrasporic plants decay begins with the damage of branch tips through which loss of material takes place slowly. Pathogens were not observed in the tetrasporangia after the discharge of tetraspores. This is probably due to the small opening left after the discharge of the tetraspores and perhaps also to the absence in the sporangial cavity of such mucilage as found in the cystocarp and which is conducive to the invasion of pathogens.

Regeneration Studies

Regeneration studies on *G. confervoides* were carried out from May to October. It started growing in May. The seaweed beds were dug up in several places and it was found that the plant regenerated vegetatively from the remnants of plants attached to polychaete tubes and buried in the sand by the heavy seas in November of the north-east monsoon. During the first week of July two experimental plots each of 144 square meters were marked. (Table 2.)

(1) The first experimental plot was marked off about twenty meters from the shore with poles at a depth of one meter near the Resthouse, Mutur. At the time of marking the plants had already started growing and had an average height of 20 cms. and an average wet weight of 139·3 grams per square meter.

(2) The second plot was similar to the first and was marked off in a sheltered region near Ganga ferry at a distance of ten meters from the shore at a depth of one meter. Here too the plants had already started growing and reached an average height of 23 cms. and an average wet weight of 161·4 grams per square meter.

EXPERIMENTAL PLOT.

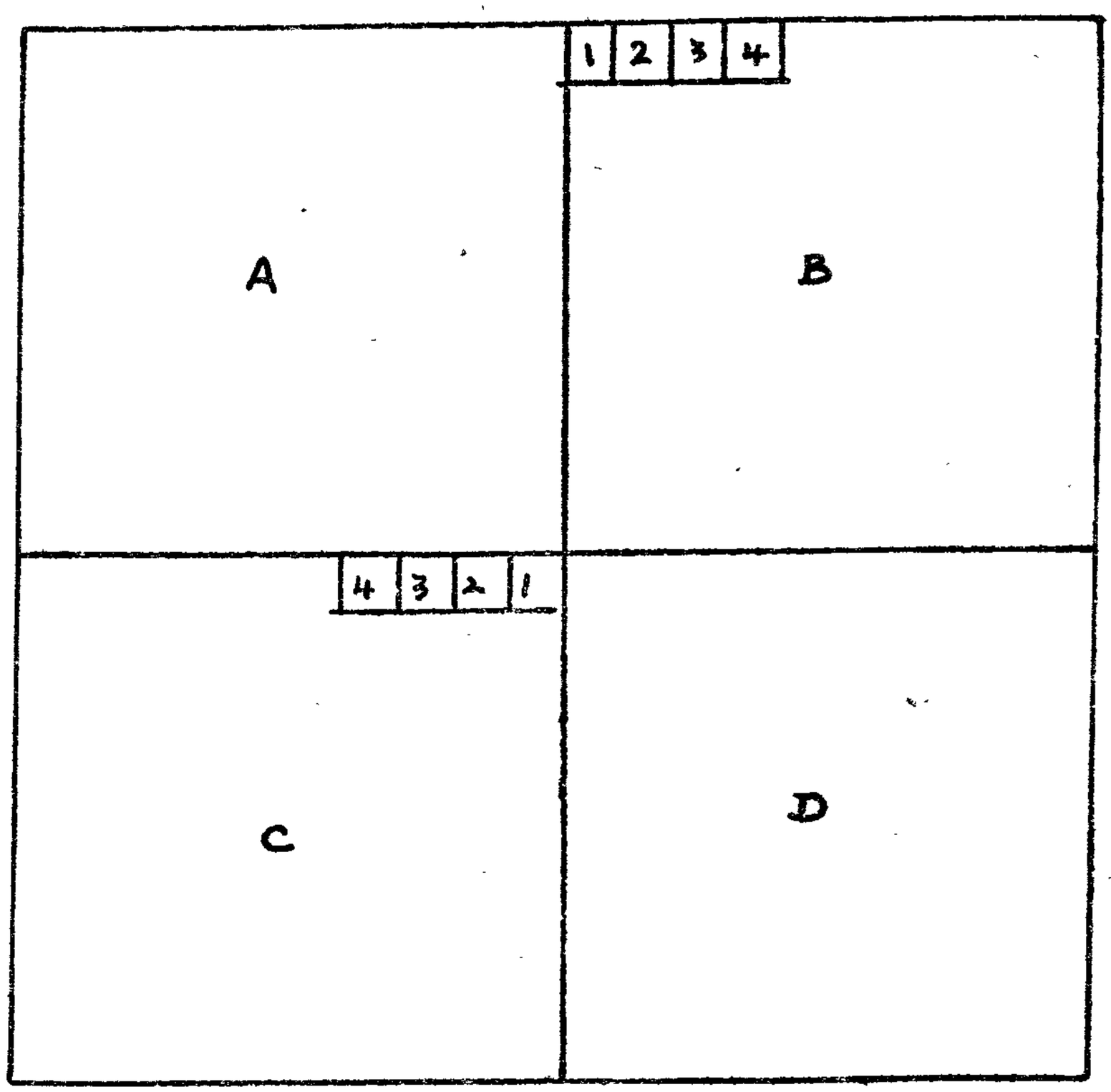

TABLE 2

	Plots not harvested				*Plots harvested by "atanguwa"*			
	Total wet wt. of plants in gms. per sq. meter	*%agar content*	*No. of worm tubes per sq. meter*	*Total wet wt. of worm tubes in gms./ sq. meter*	*Total wet wt. of plants in gms./ sq. meter*	*%agar content*	*No. of worm tubes per sq. meter*	*Total wet wt. of worm tubes in gms. per sq. meter*
Plot No. 1 near Mutur Resthouse								
1st week or July, 1964 ..	139·2	30	16	18·7	143·1	26	15	20·8
2nd week of August, 1964 ..	196·3	31	14	21·5	112·5	33	12	21·7
2nd week of September, 1964	286·8	28·6	16	22·2	198·4	35	15	23·4
2nd week of October, 1964 ..	378·4	40	15	26·1	312·6	42	18	24·7
Plot No. 2 near Ganga Ferry								
1st week of July, 1964 ..	148·6	26	15	19·2	143·6	25	14	20·2
2nd week of August, 1964 ..	201·4	37	14	23·5	109·8	34	13	22·6
2nd week of September, 1964	311·3	40	15	24·8	213·4	36	12	23·9
2nd week of October, 1964 ..	390·5	41	18	25·1	321·4	42	15	28·6

Two diagonal square plots (A, D) in each experimental plot (Fig. 2) were harvested with the traditional " atanguwa " (hand net) during the first week of July while the other two plots (B, C) were not harvested. Subsequently 1 square meter of each diagonal plot (1, 2, 3, etc.) was harvested during the second week of August, September and October and the results are tabulated below. The soil in both experimental plots was sandy and *confervoides* were found growing unattached. When attached plants were found, it was to polychaete worm tubes, and very occasionally to mollusc shells. " Atanguwa " (hand net) harvesting was not harmful as this method left behind remnants of the basal part of the plants. Plants after harvesting by " atanguwa " exhibited vigorous growth.

Summary

1. The growth rate of *Gracilaria confervoides* reached a maximum between the middle of September and the middle of October, the percentage gain in fresh weight being 3·777.

2. Plants were found to grow more luxuriantly in areas deeper than 1·5 meters than in shallower waters.

3. Tetrasporangia began growing in June, continued till August and the spores were shed by September and October. Cystocarpic plants occurred from July and their numbers increased to a maximum in September.

4. With the onset of the north-east monsoon the plants disappeared being obliterated or buried in the sand by the heavy seas.

5. Regeneration took place in May vegetatively from the remnants of plants attached to polychaete worm tubes during the previous season. Subsequently the plants developed tetrasporangia and carposporangia which released tetraspores and carpospores respectively. They, in turn, developed into tetraporic and carposporic plants.

6. Maximum yield of agar from plants was found in September and October.

7. Since tetrasporangia and carposporangia are formed in July and August harvesting should not be done during this period.

8. It is recommended that only plants cast ashore during the months of July and August should be collected. Collection should be done when the plant is still red in colour and not when it is bleached. Actual harvesting by " atanguwa " should be carried out in September and October. These recommendations will serve as conservation measures for *G. confervoides*.

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