Rebuilding the ocean floor – Construction of artificial reefs around the Japanese coast

Japan is one of the most advanced countries in the world in the field of Marine Science. The island nation is made mainly of four major islands, namely Hokkaido, Honshu, Shikoku and Kyusu. Japan has a thick population density, and its land resources are very limited due to heavy urbanization and industrialization. Hence the sea is the ultimate territory left for exploitation and utilization of resources. The Japanese have a long tradition of eating many types of seafoods such as fish,

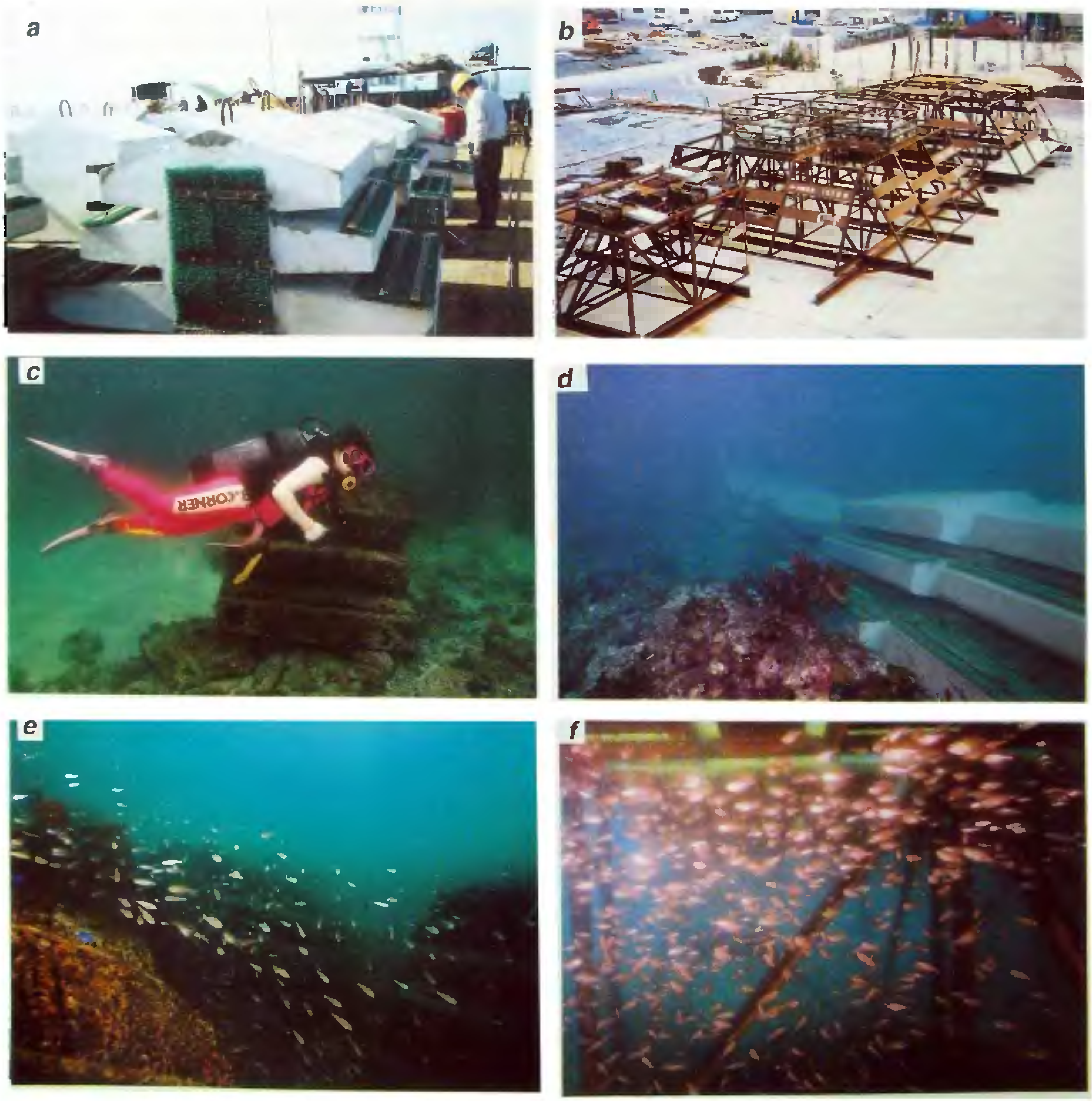

Figure 1. Artificial reef construction. ***a***, Trapezoid-shaped concrete blocks with plastic mats; ***b***, Iron frames of different designs fitted with small concrete structures; ***c***, A SCUBA diver placing blocks at the sea bottom; ***d***, Concrete blocks arranged in a row; and ***e***, ***f***, Varieties of fishes at the artificial reef site.

lobsters, prawns, oysters, abalone, octopus, seashells, seaweeds, etc. In olden days, these seafoods were mainly harvested from natural stocks. But as the demand for seafood increased over a period of time new techniques were devised for higher production. Intensive and semi-intensive aquaculture techniques were practised and seafood production increased many-folds to meet the rising demand. But the story did not end there. Soon the sea surface was overcrowded with floating rafts for fishing and seaweed cultivation. The Japanese had no options left on the sea surface but to go for the ocean floor utilization. Hence the idea of artificial reef construction on the ocean floor developed.

Work on artificial support systems for sessile organisms other than fishes is called 'tsukiiso' in Japanese. Stone mounding works for edible seaweed *Laminaria* (popularly known as Kombu in Japan) have the oldest and the longest history of 'tsukiiso' works in Japan. From 1844 to 1847, groups of fishermen had collected several hundred pieces of stones covered with sprouts of 'Kombu' near Hakodate in Hokkaido Island[1]. Recently, devastation on the coasts giving rise to barren grounds is increasing in many parts of Japan, resulting in heavy loss of natural populations of seaweeds, seagrasses, and sea animals and growth of coralline algae in their place. Consequently, fishery resources such as abalone, lobsters and fishes have become depleted. This has attracted considerable attention in Japan. Thus under-water afforestation using *Laminaria*, *Ecklonia*, *Eisenia* and *Sargassum* was established to serve as a feeding site, nursery and shelter for many marine organisms[2]. Since 1980, many marine scientists tried to create artificial reefs using concrete and iron structures with heavy funding from government and private industries to recover lost seaweed beds.

Concrete blocks and iron structures of different design, size and weight are used for the construction of artificial reefs (Figure 1 *a, b*). Each block weighs between 1 and 4 tons depending on size and design. These structures are usually carried by ships and with the help of heavy-duty cranes placed at the bottom of the sea at different depths ranging from 5 to 10 m. The blocks are placed in a sequencial manner by SCUBA divers (Figure 1 *c, d*). Plastic mats similar to Tarton turf on the sloping sides of the block offer favourable substrata for both seaweeds and attaching animals while the blocks attract a lot of fishes (Figure 1 *e,f*). A mixture of mature seaweed thalli is transplanted to these artificial reefs during the reproductive season using the 'spore bag' technique[2]. Slow-eluting fertilizers in iron containers are placed

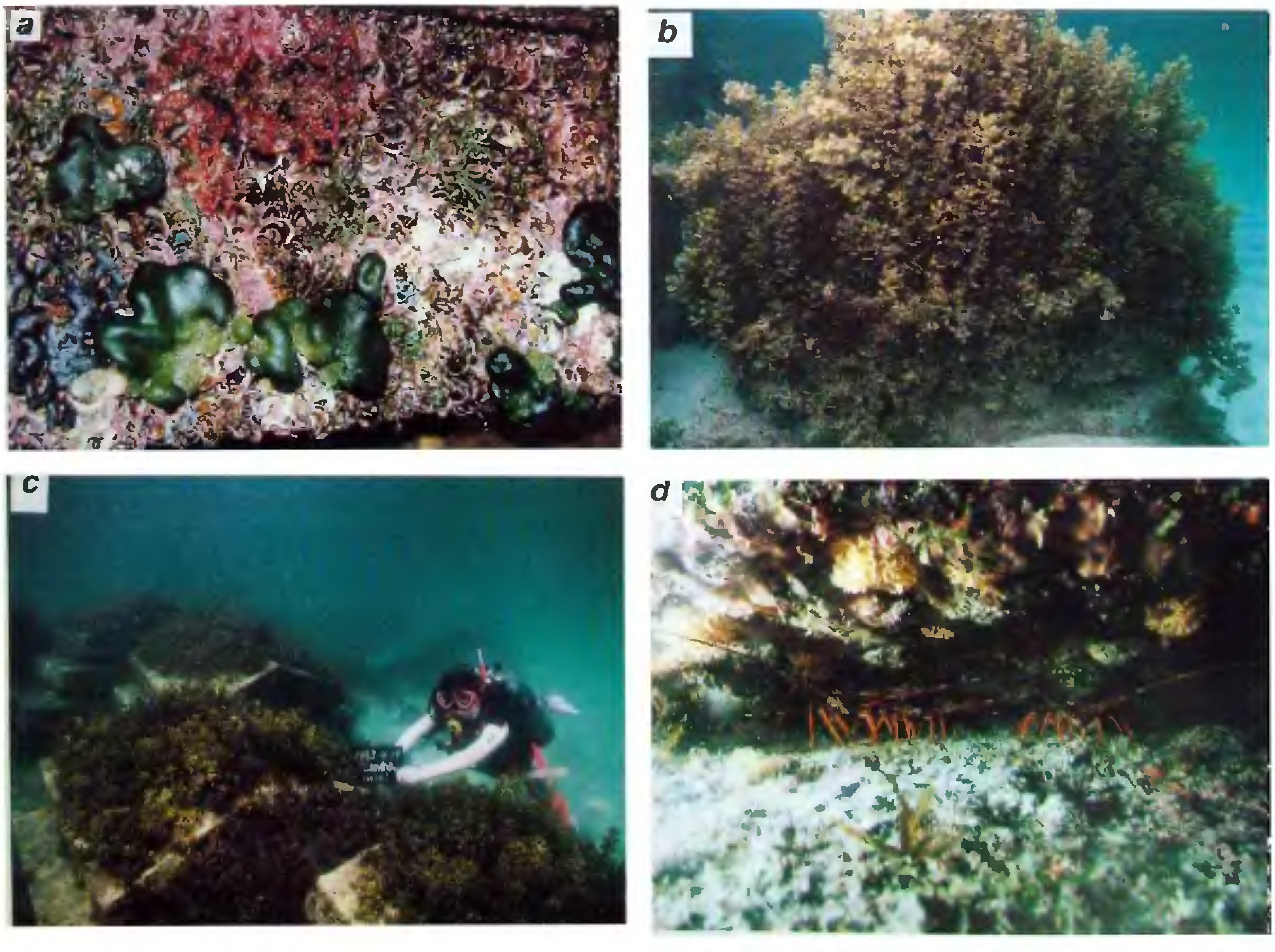

Figure 2. Growth of seaweeds and other animals on artificial reefs. ***a***, *Codium* spp fronds grown on the mats; ***b***, *Sargassum* community on the reefs; ***c***, Blocks showing luxurious growth of seaweeds; and ***d***, Lobsters on artificial reefs.

between the reef units for supporting growth of seaweeds. Over a period of time (usually 1–2 years), a large number of seaweeds, abalone, shellfish, lobsters, etc. colonize on these artificial reefs (Figure 2 *a–d*). The abundance and biomass of these plants and animals are usually more in comparison to the natural substrata. Techniques for the construction of artificial reefs have already been standardized and are in practice, for many years. A large number of concrete-making companies have come up in recent years for this purpose creating more job opportunities. So artificial reef construction is not only economical but also ecological.

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Biological management of patchouli (*Pogostemon cablin*) wilt caused by *Rhizoctonia solani*

Amongst the various fungal diseases of patchouli (*Pogostemon cablin*), wilt caused by *Rhizoctonia solani* is one of the most destructive[1]. Patchouli is one of the most important aromatic plants which yield an essential oil known as patchoulol. This crop has been recently introduced in the Tarai of UP. Wilt incidence has been reported from various fields and accounts for about 1–10% losses. Synthetic chemicals (fungicides) do not provide adequate control of the pathogen, besides being toxic to both human beings and animals. The use of ecofriendly antagonistic biological agents can check the spread of the pathogen and disease effectively[2,3]. Several soil-borne Deuteromycetous fungi including *Trichoderma harzianum* and *Gliocladium virens* are known to inhibit the growth and the sclerotial production of *Rhizoctonia solani*[4]. This phenomenon of antagonism has been exploited to control plant diseases. Several workers have reported the interaction between AM fungi (*Glomus aggregatum*) and soil-borne plant pathogens[5,6]. These AM fungi make the host more resistant to plant pathogens and thus help in biological control of plant diseases[7–9]. In the present work, efficacy of *T. harzianum*, *G. virens* and AM fungi was tested separately and in combination to find out the suitable biological control of *Rhizoctonia* wilt of patchouli.

R. solani, the causal organism of wilt of patchouli, was isolated from infected plants of patchouli in the fields. *T. harzianum* and *G. virens* were tested as biological antagonistic agents to control the wilt of patchouli separately and in combination with AM fungi. The mass inoculum of antagonist, i.e. *T. harzianum*, *G. virens* and the pathogen *R. solani* was prepared on a sand–maize medium (sand and broken maize in 1 : 3 ratio). The medium was sterilized at 15 psi (121°C) for an hour. Pathogens as well as antagonists were inoculated aseptically and were incubated for 21 days at 27 ± 2°C. Colony forming unit (CFU)/g was calculated after 21 days of incubation.

Maize (*Zea mays*) was used as a trap plant for the multiplication of AM fungi in pots (3 kg sandy loam soil, pH 6.8, available phosphorus 10.2 ± 0.64 ppm, available potassium 42.5 ± 0.68 ppm and available nitrogen 39.25 ± 0.86 ppm taken in 20 cm diameter earthen pots). The pot soil was examined after three months for the sufficient AM spores (450/100 g soil).

Antagonistic activity of *T. harzianum* and *G. virens* was tested against *R. solani* by using the dual culture technique[10]. Pathogens as well as antagonists were inoculated at the opposite ends of petri dishes containing potato dextrose agar (PDA). The growth of the pathogen was tested against the antagonist. From the zone of interaction in the dual culture, mycelial fragments were taken periodically and were observed for hyphal interaction[11]. Another *in vitro* test was conducted on the viability of sclerotia of *R. solani* after being subjected to attack by antagonists separately. Ten sclerotia were inoculated in a row at the periphery of petri dishes and the antagonist was

Table 1. Effect of different treatments on the wilt of patchouli

Treatment	Average height of healthy plants (cm)[b]	Average height of diseased plants (cm)	Average shoot fresh weight of healthy plants (g)	Per cent infection
TH + RS	52 ± 2.12 (8.33)[c]	45 ± 2.16 (15.38)	63 ± 1.94 (10.52)	20 (47.36)[a]
GV + RS	54 ± 1.98 (12.5)	46 ± 2.22 (17.94)	66 ± 2.24 (15.78)	16 (57.89)
GA + RS	61 ± 2.16 (27.08)	49 ± 2.34 (25.64)	72 ± 2.38 (26.31)	32 (15.78)
TH + GA + RS	63 ± 2.28 (31.25)	51 ± 1.98 (30.76)	75 ± 2.33 (31.57)	12 (68.42)
GV + GA + RS	65 ± 2.36 (35.41)	54 ± 2.34 (38.46)	78 ± 2.24 (36.84)	9 (76.31)
Control	48 ± 2.24	39 ± 1.82	57 ± 2.16	38

[a]Per cent decrease over control; [b]Average of five replicates; [c]Per cent increase over control; TH, *Trichoderma harzianum*; GV, *Gliocladium virens*; GA, *Glomus aggregatum*; RS, *Rizoctonia solani*; ±, standard error.