# Application of Seaweed Cultivation to the Bioremediation of Nutrient-Rich Effluent

**Article** *in* ALGAE · September 2002

DOI: 10.4490/ALGAE.2002.17.3.187

Algal Biotechnology and Environment
Editors: Dinabandhu Sahoo, B. D. Kaushik (21-33)

3

# Seaweed Community Analysis of a Rocky Shore for the Sustainable Seaweed Integrated Aquaculture System (SSIAS) in Korea

**Ik Kyo Chung*[1], Yun Hee Kang[1], Si Jung Ryu[1], Myung Sook Kim[2], Charles Yarish[3] and Jin Ae Lee[4]**
[1]Department of Marine Science Pusan National University, Busan 609-735, KOREA
[2]Research Institute for Basic Sciences, Pusan National University, Busan 609-735, KOREA
[3]Department of Ecology and Evolutionary Biology, University of Connecticut, Stamford, CT 06901, USA
[4]School of Environmental Science and Engineering, Inje University, Gimhae 621-749, KOREA

**ABSTRACT**

The ecological traits of the intertidal rocky shore seaweed communities were investigated for the site-specific development of the Sustainable Seaweed Integrated Aquaculture System (SSIAS) in Korea. Monthly phenological surveys of the intertidal communities were conducted in 2002 to obtain information on the wild seaweed species for their application to the SSIAS. The changes of the dominant species composition and their fresh weight and coverage were prominent among the seasons and sampling sites. Generally, brown algae, *Laminaria japonica* and *Sargassum* sp., were dominant in the winter; red algae were abundant in the spring and the autumn. Green alga, *Ulva pertusa*, showed the broadest coverage year around. The C/N ratios of seaweeds and the ambient nitrogen concentrations were positively correlated.

**Keywords:** C/N ratio, seaweed, sustainable seaweed integrated aquaculture system.

## INTRODUCTION

Fed mariculture including intensive finfish aquaculture has caused many environmental problems. Modern intensive monoculture requires high levels of inputs such as seawater, feeds, fertilizers, chemicals, and inevitably produces considerable wastes. Therefore, many aquaculture operations put enormous pressure on coastal habitats. To reduce the nutrient burden of the fish farm effluents, the integration of seaweed cultivation with fish aquaculture has been proposed (Neori et al., 2004). The integrated aquaculture system is not a new concept; however, there have been significantly fewer examples of aquatic animals being polycultured with seaweeds than of aquatic animals polycultured with other aquatic animals (Stickney, 2000).

Studies on the methods of treating effluents from enclosed mariculture systems with macroalgae date back to the work of Ryther and colleagues in the mid-1970s, and this approach has gained new interest in the 1990s (Troell et al., 1999). Various strategies for integrating seaweed cultivation with fish culture have been successful (Brzeski and Newkirk, 1997).

Korea has some experience with polyculture. The National Fisheries Research and Development Institute (NFRDI) of Korea has already established guidelines for polyculture (Anonymous, 1994). Examples are *Porphyra tenera* and short necked clams or surf clams; *Hizikia fusiformis* (now considered a species of *Sargassum*) or *Laminaria japonica* and sea squirt; *Undaria pinnatifida* or *L. japonica* and abalone. The NFRDI's previous project did not provide the ecological basis for the present polyculture concept. They were simple combinations of several species with similar culture techniques and facilities or sharing the same space. In any case, based on these results, the legal basis of polyculture licensing was established. Soon after the finfish and shrimp aquacultures increased unexpectedly in the 1990s, a changed concept and strategy of an integrated culture to manage the effluent from these organisms was required. The study of environmentally sound integrated systems has been in progress under the Sustainable Seaweed Integrated Aquaculture System (SSIAS) project to reduce the environmental impact of marine farmed finfish effluent in the coastal zone (Chung et al., 2002). Under the auspices of the SSIAS, we investigated the rocky shore seaweed community to evaluate wild seaweed species as a nutrient sink and, accordingly, as candidates for the SSIAS.

## MATERIALS AND METHODS

An ecological survey on the rocky shore seaweed community was conducted in the Tongyong area, known as 'the Home of Korean Aquaculture', located in the South Sea of Korea (Chung et al., 2002). Three sites were chosen based on the different environmental characteristics. Station (St.) 1 was close to the dock area near the waste treatment plant of Tongyong City, St. 2 was near the public beach area in between St. 1 and St. 3, and St. 3 was facing to the open channel of the South Sea (Fig. 1).

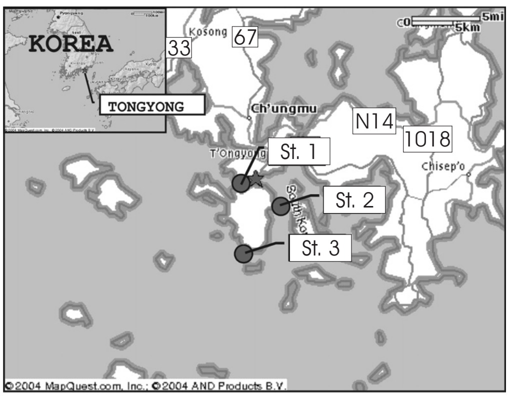


**Fig. 1** Map of the study area (Tongyong area) showing the three study sites.

The basic ecological aspects of seaweed community structure were surveyed on monthly basis using the quadrat method (50 cm × 50 cm). The seawater nutrient contents were analyzed by standard methods (Parsons et al., 1984). The tissue elemental contents were analyzed by a CHNS/O elemental analyzer (Perkin Elmer 2400 Ser. II). Seawater and air temperature were referenced by the NFRDI's statistics for the fixed site observation data (Anonymous, 2002).

## RESULTS AND DISCUSSION

As the aim of this study was to establish the background of the application of wild seaweed species for the SSIAS, for one year, in 2002, the seaweed community was studied using a different methodology from that of the conventional rocky shore ecological studies. Only several factors were considered.

The changes of seawater and air temperatures are shown in Fig. 2. Unusually low temperatures were recorded in May, which may be speculated to be the result of unusual atmospheric cooling. This cooling did not significantly affect the nutrient concentrations. The concentrations of dissolved inorganic nitrogen ($NO_3^-$ and $NH_4^+$) and phosphate ($PO_4^{3-}$) varied among the sampling sites and seasons and did not show any significant seasonal trends. However, spatial variation was prominent; the concentrations of inorganic nutrients were highest at St. 1, second highest at St. 2, and relatively low at St. 3 (Fig. 3). The changes in the fresh weight of the three seaweed groups and dominant intertidal seaweed species at the three rocky shore sites during the study period are shown in Figs. 4 to 9. Generally, the total biomass was highest in late winter and early spring, when brown algae, such as *Undaria pinnatifida* and *Sargassum* sp., were dominant at all three sites. Generally, there were decreasing trends of biomass during late spring and summer.

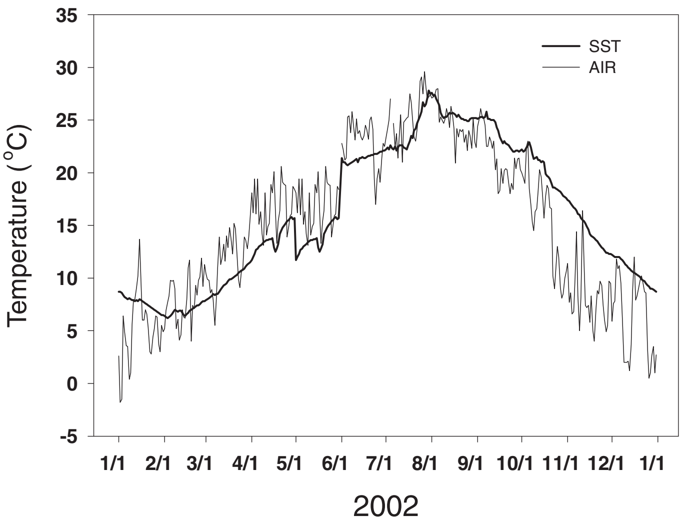


**Fig. 2** Variation of seawater and air temperature at the fixed observation site at Tongyong (Choongmoo) Station in 2002.

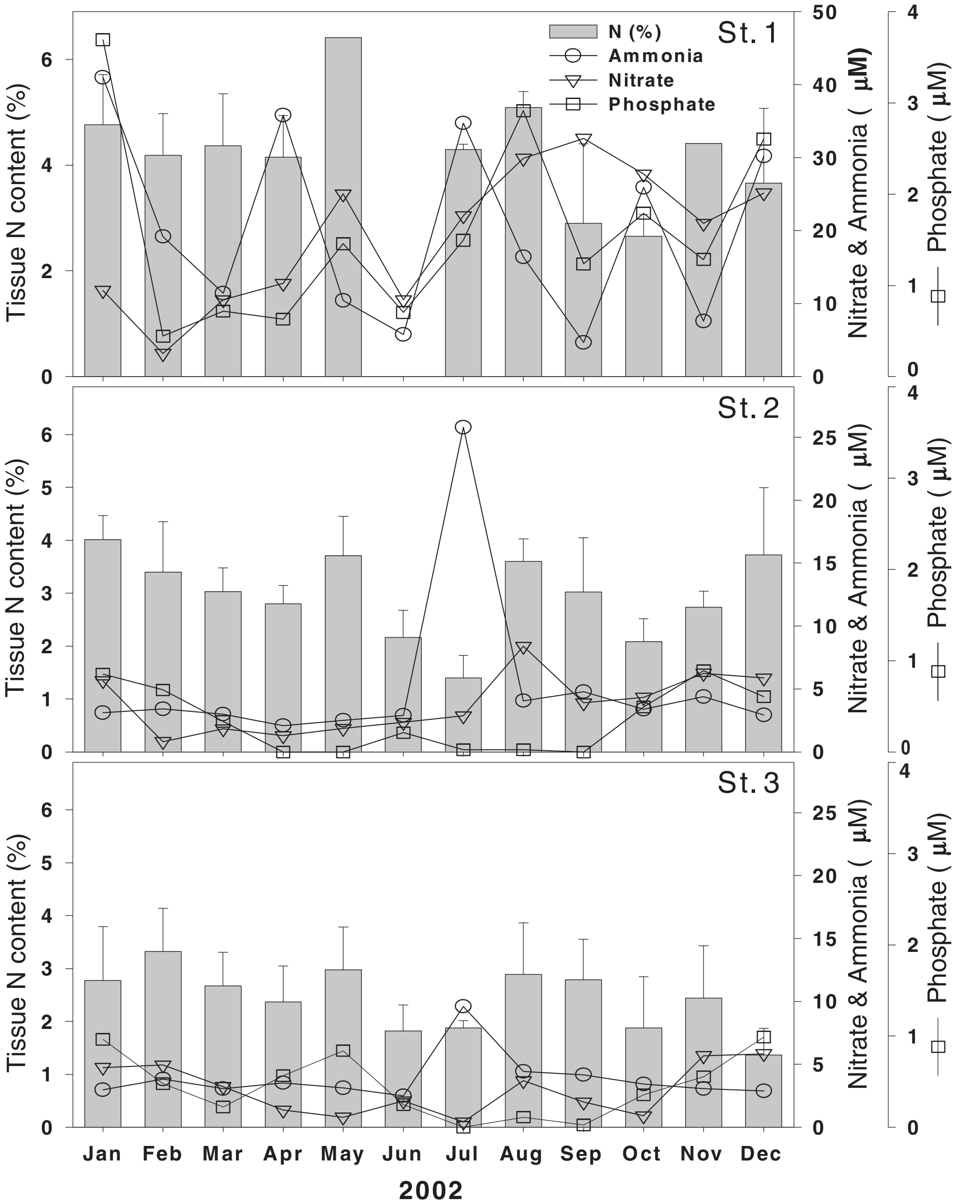


**Fig. 3** The changes of concentrations of the dissolved inorganic nutrients and tissue nitrogen contents (%) in Tongyong area.

The patterns of dominant species composition, in coverage, are drawn in Figs. 10-12. The green alga *Ulva pertusa* showed the highest coverage throughout the whole year at all sites. Four dominant species were recorded at St. 1 and St. 2, but ten species appeared with high coverages at St. 3. At St. 1, other than *U. pertusa*, *Pachymeniopsis*, *Lomentaria catenata* and *Undaria pinnatifida* appeared in the winter and spring seasons only (Fig. 10). At St. 2, P. *elliptica*,

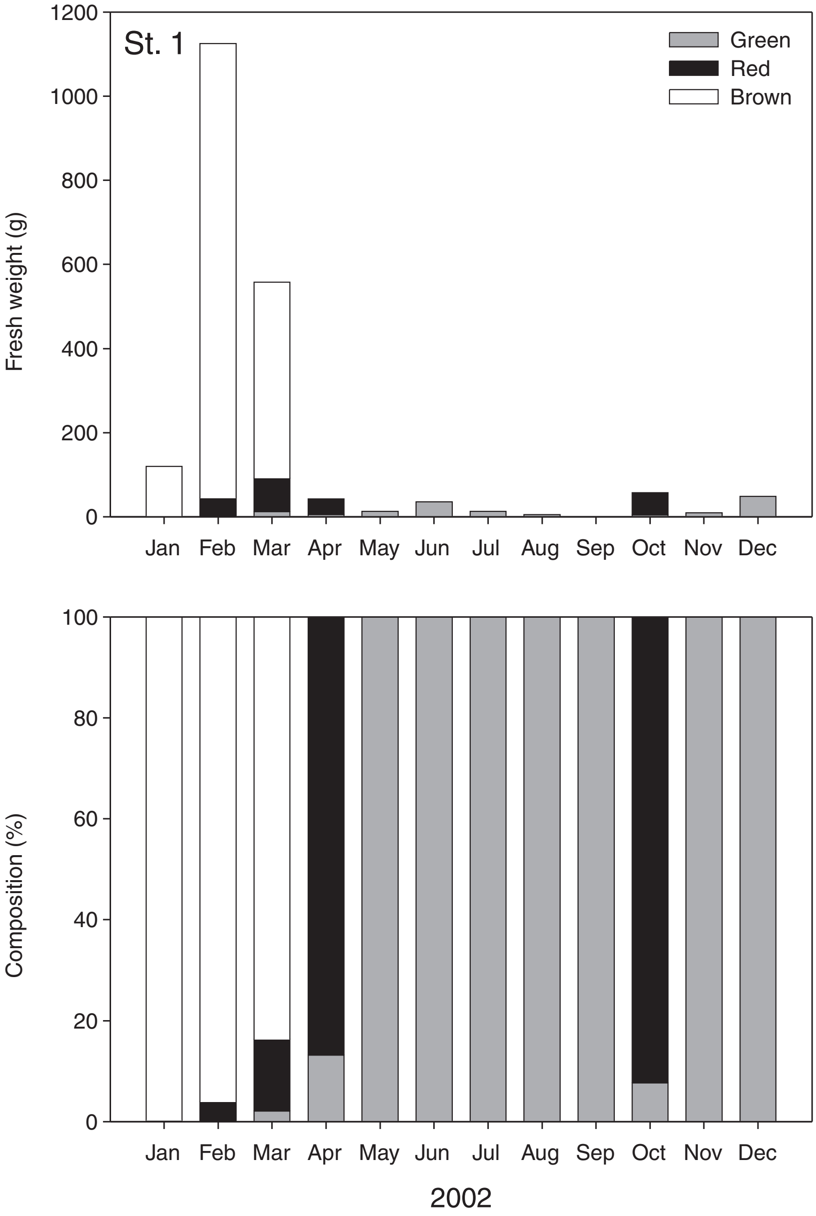


**Fig. 4** The change of fresh weight and algal composition at St. 1 in Tongyong area.

*Sargassum* sp. and *U. pinnatifida* appeared, except in the summer (Fig. 11). There were more diverse species present at St. 3, and they showed species specific coverage patterns throughout the year, which were different from those at other sites (Fig. 12). An unusually high value was recorded at St. 2 in June due to the contribution of *Ulva* sp. and *Codium* sp.

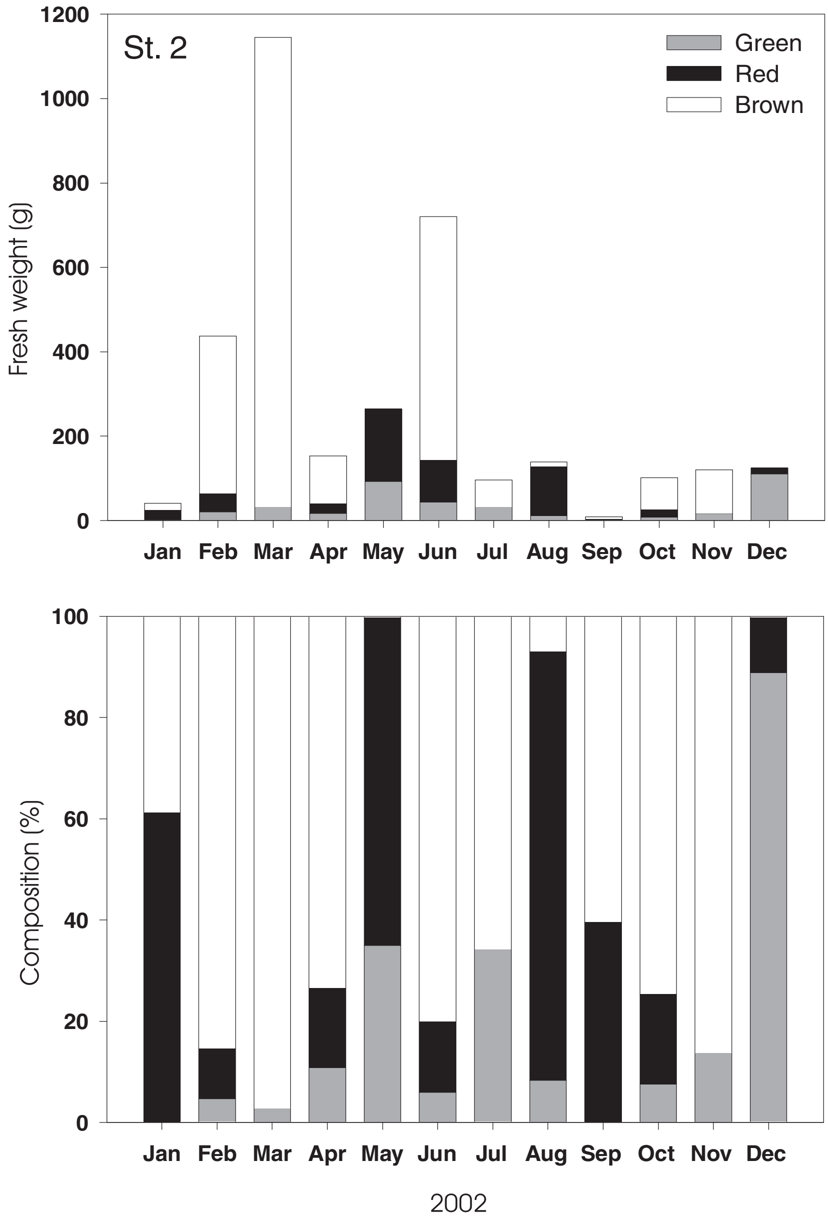


**Fig. 5** The change of fresh weight and algal composition at St. 2 in Tongyong area.

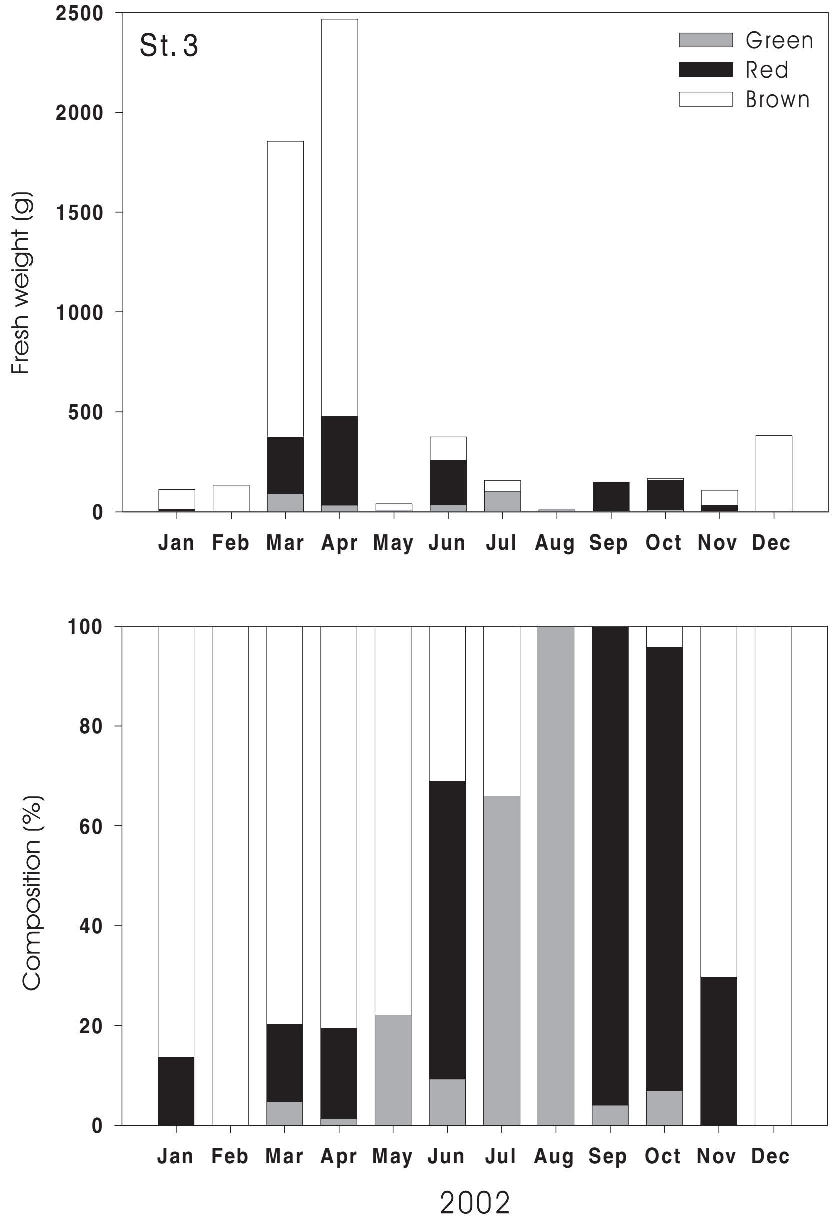


**Fig. 6** The change of fresh weight and algal composition at St. 3 in Tongyong area.

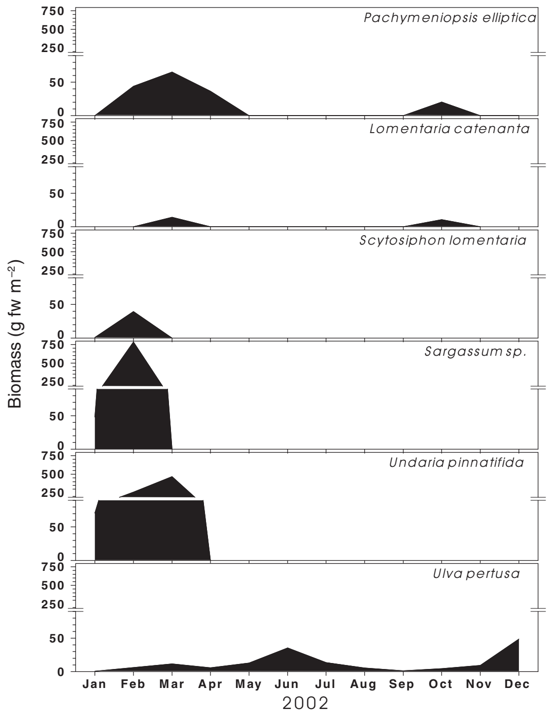


**Fig. 7** The change of fresh weight of dominant intertidal seaweed species at St. 1 in Tongyong area.

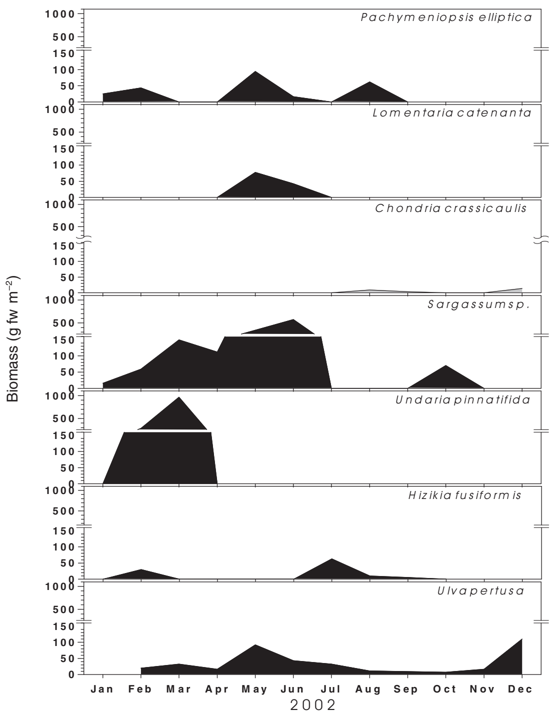


**Fig. 8** The change of fresh weight of dominant intertidal seaweed species at. St. 2 in Tongyong area.

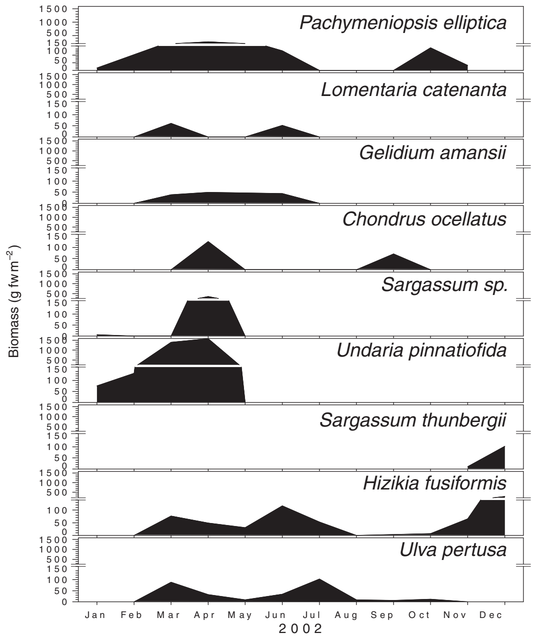


**Fig. 9** The change of fresh weight of dominant intertidal seaweed species at. St. 3 in Tongyong area.

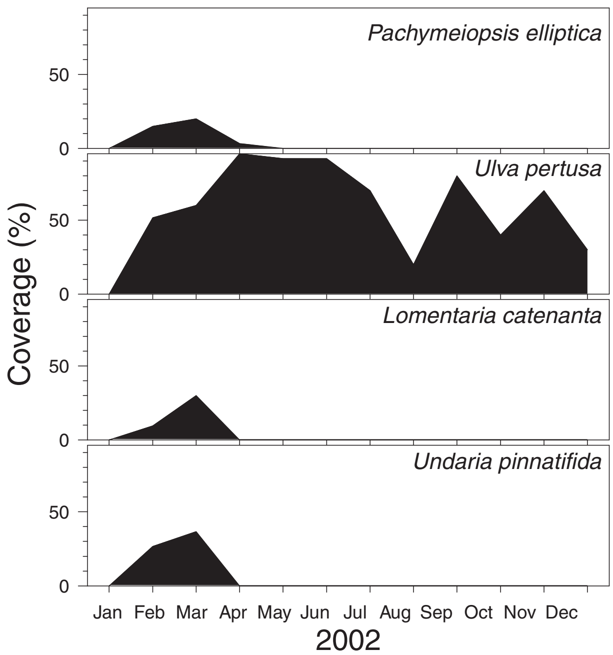


**Fig. 10** The change of coverage of intertidal seaweed species at St. 1 in Tongyong area.

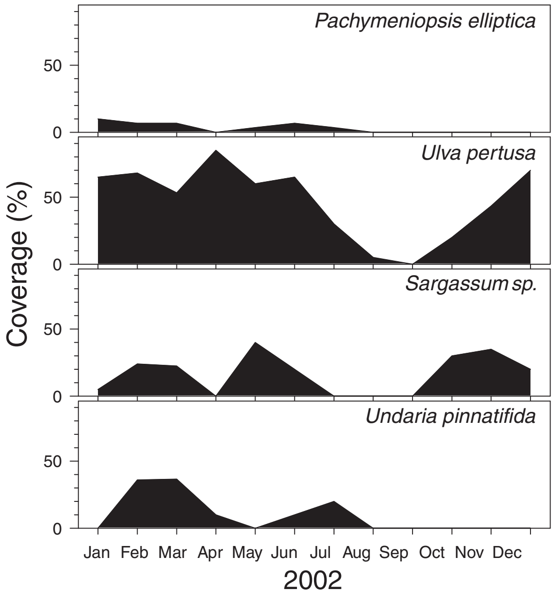


**Fig. 11** The change of coverage of intertidal seaweed species at St. 2 in Tongyong area.

The tissue nitrogen contents of all seaweed species specimens of St. 1, where the amount of ambient inorganic nutrients was highest, were higher, with an average of 4.26% than those at St. 2 and St. 3, which averaged 2.97% and 2.43%, respectively (Fig. 3). The nitrogen contents of green, brown and red algae averaged 3.39%, 2.73% and 3.16%, respectively. The averaged values of tissue nitrogen contents from several species, which showed a coverage greater than 10%, revealed that red algae had higher average tissue nitrogen than brown algae (though the difference was not significant). Although the internal tissue nitrogen contents are thought to be the complex results of the interactions among the external environments, uptake kinetics, assimilation, growth and reproductive processes (Hanisak, 1983), the tissue nitrogen contents increased with increased concentration of dissolved nitrogen in seawater (Fig. 13).

The ultimate goal of this study was to develop a strategy to achieve the sustainability of the coastal ecosystem based on sound ecological and economic principles (Newkirk, 1996). There are many conflicts among the users of coastal waters, and aquaculture should be conducted under an integrated coastal zone management which maintains a balance between 'extractive' and 'fed' aquaculture (McVey et al., 2002; Rawson et al. 2002). Although the present local cultivation seaweed species are very promising (Noori et al., 2004; Chung et al., 2002), the results of this field study could be used as a basis for the management of selected seaweed species, because field phenology and nitrogen contents information on the seaweeds is required to confirm and preserve these seaweeds as probable local candidates for other systems in other locations.

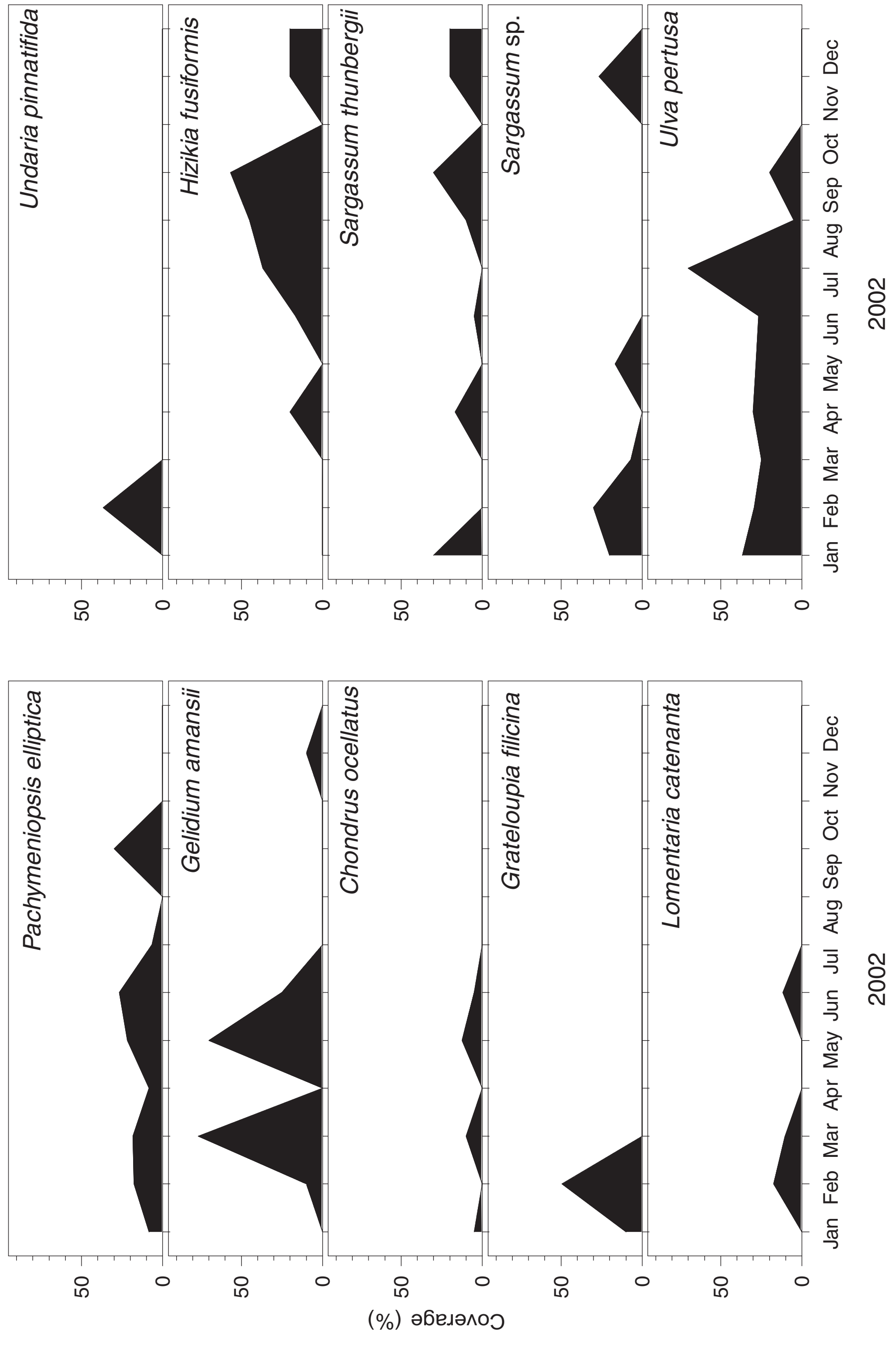


**Fig. 12** The change of coverage of intertidal seaweed species at St. 3 in Tongyong area.

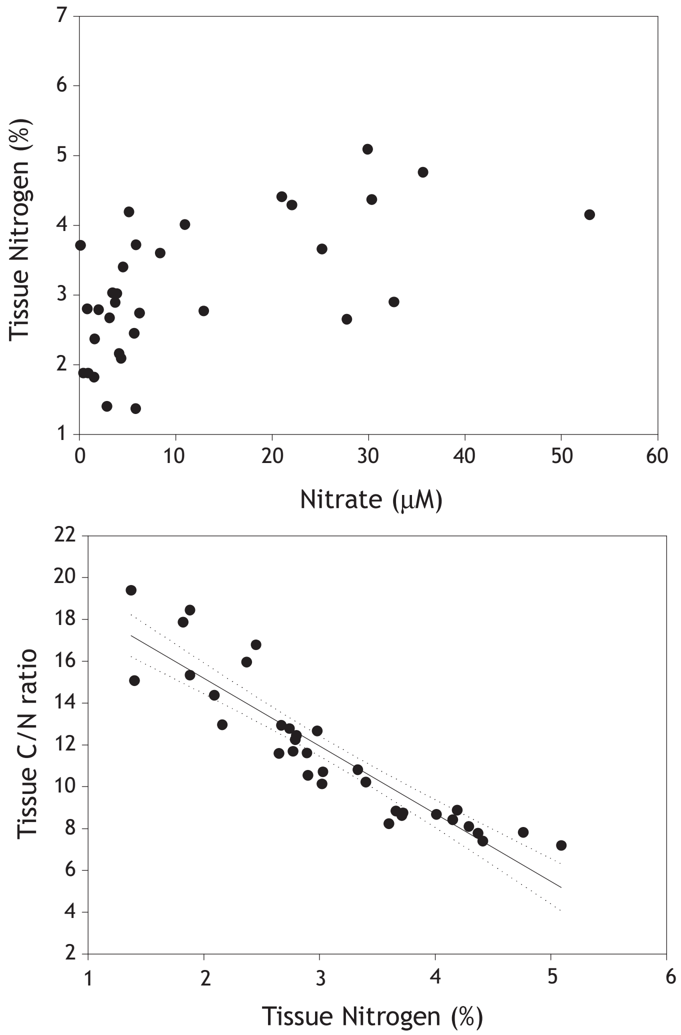


**Fig. 13** A plot of total dissolved inorganic nitrogen vs. tissue nitrogen contents of seaweeds in Tongyong area.

## REFERENCES


Anonymous, 1994. Studies on the development of polyculture system in thee coastal waters of Korea. Final report (National Fisheries Research and Development Institute) (in Korean with English summary).

Anonymous, 2002. National Fisheries Research and Development Institute. (http://www.nfrda.re.kr)

Brzeski, V. and Newkirk, G. 1997. Integrated coastal food production systems: A review of current literature. *Ocean Coastal Management.* 34: 55-71.

Chung, I. K., Kang, Y. H., Yarish, C., Kraemer, G. P. and Lee, J. A. 2002. Application of seaweed cultivation to the bioremediation of nutrient-rich effluent. *Algae.* 17: 187-194.

Hanisak, M. D. 1983. The nitrogen relationships of marine macroalgae, in: *Nitrogen in the marine environment*, edited by E. J. Carpenter and D. G. Capone (Academic Press, London), pp. 699-730.

McVey, J. P., Stickney, R. R., Yarish, C. and Chopin, T. 2002. Aquatic polyculture and balanced ecosystem management: New paradigms for seafood production, in: *Responsible marine aquaculture*, edited by R. R. Stickney and J. P. McVey, (CABI Publishing, New York), pp. 91-104.

Neori, A., Chopin, T., Troell, M., Buschmann, A. H., Kraemer, G. P., Halling, C. M., Shpigel, M. and Yarish, C. 2004. Integrated aquaculture: Rationale, evolution and state-of-the-art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture* 231: 361-391.

Newkirk, G. 1996. Sustainable coastal production systems: A model for integrating aquaculture and fisheries under community management. *Ocean Coastal Management* 32: 69-83.

Parsons, T. R., Maita, Y. and Lalli, C. M. 1984. A manual of chemical and biological methods for seawater analysis, (Pergamon, Oxford).

Rawson, Jr. M. V., Chen, C., Ji, R., Zhu, M., Wang, D., Wang, L., Yarish, C., Sullivan, J. B., Chopin, T. and Carmona, R. 2002. Understanding the interaction of extractive and fed aquaculture using ecosystem modeling, in: *Responsible marine aquaculture*, edited by R. R. Stickney and J. P. McVey, (CABI Publishing, New York), pp. 263-296.

Stickney, R.R. 2000. Polyculture in: *Encyclopedia of aquaculture*. edited by R. R. Stickney (John Wiley & Sons, Inc., New York), pp. 658-660.

Troell, M., Rönnbäck, P., Halling, P., Kautshy, C. and Buschmann, A.H. 1999. Ecological engineering in aquaculture: Use of seaweeds for removing nutrients from intense mariculture. *J. Appl. Phycol.* 11: 89-97.