# Characteristics of the productivity structure in the coastal areas along the Kansai International Airport Island, Japan

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## Abstract

Prior to the second phase of work of the Kansai International Airport Island, areal surveys were conducted in 1998-1999 in the vicinity of the island and the annual production of phytoplankton, zooplankton, seaweed, phytal animals, sedentary animals and benthic animals were examined. Macrobenthic animals ranked first in carbon biomass (18.1 ton C) in the planned reclamation area, followed by seaweed (14.6 ton C) and phytoplankton (14.3 ton C). Annual production of carbon per unit area was highest for phytoplankton (392 gC/m$^2$/year), and then seaweed was 360 gC/m$^2$/year, which was comparable to the phytoplankton production. However, planktonic organisms accounted for 98% of the total production (3227 ton C) when the annual production of phytoplankton, zooplankton, seaweed, phytal animals, sedentary animals and benthic animals at the planned reclamation area were compared. Based on the results of the field surveys, we demonstrate that more attention should be paid to the annual production to evaluate the effects of reclamation on coastal ecosystems.

## 1 Introduction

The Kansai International Airport was constructed ca. 5 km off the coast of Izumisano, southeastern Osaka Bay, Japan during the first phase in 1994, and the second phase work started in July 1999. As during the construction of this airport efforts have been made for environmental protection, a large seaweed forest was artificially formed on the slope mound around the first constructed airport island. Efforts are being made to harmonize coastal development activities with natural environments, and the construction of attractive coastal zones is required which allow the re-establishment of the original ecosystem. The Ministry of the Environment of Japan also showed its new policies in 1994 on the environmental management in which a greater importance was placed on the harmonization between development and environmental protection. Therefore, for instance, it is essential to estimate precisely and evaluate the effects of land reclamation on

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coastal ecosystems before a new project of the reclamation begins. However, little attention has been paid to the analysis of changes in the structure and function of coastal ecosystems when we have to assess the impact of development activities on coastal habitats.

In this study, we regarded the phytoplankton and zooplankton as representative organisms of the pelagic communities around the Kansai International Airport Island, macrobenthos and meiobenthos as those of the benthic communities, and seaweed, phytal animals and sedentary animals as those of the periphytic communities on the slope mound. In addition, we focused our attention on the biological production of the northwest coast of the airport island, which will be reclaimed as the second phase work. Our goal is to compare and evaluate the environmentally negative impacts of the airport construction (e.g. Loss of habitats for infaunas) to positive ones (e.g. Formation of artificial seaweed forests on the slope mound). For this purpose, field investigations were done in the vicinity of the Kansai International Airport Island as advance surveys and the biomass, production and characteristics in the occurrence of plankton, benthos and periphyton were examined.

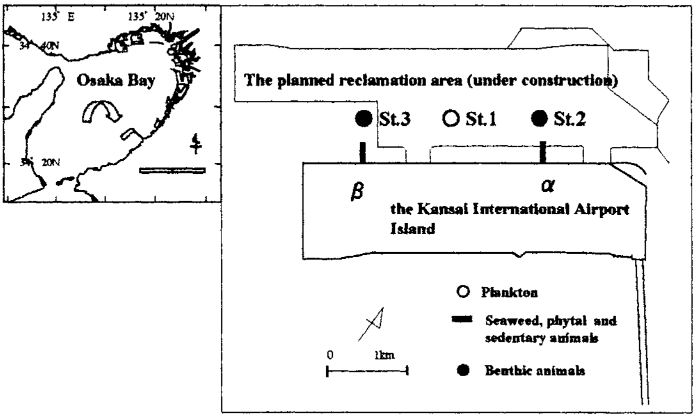


Fig. 1 Sampling stations and survey lines for phytoplankton, zooplankton, seaweed, phytal animals, sedentary animals and benthic animals along the north-western coast of the Kansai International Airport Island.

# 2 Methods

## 2.1 Plankton

Temperature, salinity and chlorophyll a concentration were measured at 0.5-1.0 m intervals from the surface to the bottom of St.1 (Fig.1) in May, August, November 1998 and January 1999. Water samples were also taken on the same day at the surface and at layers of 50%, 25%, 5%, 1 % irradiance of the same site.

They were used for observations of phytoplankton species and their primary production. The primary production was measured following the *in situ* method of Mori et al. [1]. Collection of zooplankton was made by towing more than 4 times from the near bottom to the surface with a Kitahara net with a 0.025 m mouth diameter and 0.1mm mesh opening. Immediately after collection, the samples were preserved in ca. 10% formalin and were used for counting individual numbers and measurements of dry body weight. Production of zooplankton was calculated after Ikeda and Motoda [2].

## 2.2 Benthic animals

Samples were collected at Sts. 2 and 3 (Fig.1) in May, July, September and November 1998 and in January and March 1999 with a 0.002 $m^2$ KK type core sampler for meiobenthos and with a 0.1 $m^2$ Smith-McIntyre grab for macrobenthos. Immediately after collection, the benthic samples were preserved in ca. 10% formalin, and then transferred to the laboratory for counting animal species and numbers. Annual production of benthic animals was estimated based on the mean biomass, number of generations per year and P/B ratios. For simplicity, we regarded the P/B ratio and generation number as 3 and 3, respectively, for the nematodes, and regarded them as 3 and 10 for the Foraminifera and other meiobenthic animals. In the case of macrobenthic animals, we considered the P/B ratio as 3.4 when the wet body weight was less than 0.5g but considered it as 0.6 when the wet body weight exceeded 0.5g. For benthic animals in which P/B ratio was known, we used the reported values [3].

## 2.3 Periphyton

Seaweed, phytal animals and sedentary animals on the slope mound were taken in May, August and November 1998 and March 1999 at lines . and ., (Fig.1). The samples were collected at six depths (0, 2, 4, 6, 8, 12m from the sea surface) with a 1m quadrat and were employed for counting the species, the number of individuals and wet weight for seaweed and sedentary animals. The number of species and dry weight of phytal animals were also examined for *Ecklonia cava*, *Undaria pinnatifida*, *Sargassum muticum* and *Sargassum filicinum*. Annual production was estimated from the maximum value of biomass in one year for seaweeds [4] and in the same manner as macrobenthic animals for phytal animals and sedentary animals. In addition, carbon concentrations of the predominant 48 species of zooplankton, seaweed, macrobenthic animals, phytal animals and sedentary animals were determined using a Yanagimoto CHN analyzer (Type MT-5). The areas, which disappear or receive environmental impacts as part of the second phase work of airport construction, were calculated as $583 \times 10^4$ $m^2$ (reclamation and inner water area) for plankton, $772 \times 10^4$ $m^2$ (reclamation and sand capping area) for benthic animals and 132706 $m^2$ (slope mound: 3860m long x 34.38m wide) for seaweed, phytal animals and sedentary animals.

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## 3 Results and Discussion

Table 1 Primary production of phytoplankton, compensation depth and transparency at St.1 from 26 May 1998 to 27 January 1999.

| Date | Primary production ($gC/m^2/day$) | Compensation depth (m) | Transparency (m) | Most predominant phytoplankton |
|---|---|---|---|---|
| 26 May 1998 | 0.27 | 3.7 | 6.8 | *Skeletonema costatum* |
| 26 August 1998 | 5.5 | >17 | 3.5 | *Rhizosolenia fragilissima* |
| 26 November 1998 | 0.31 | 9.1 | 5.2 | *Cryptomonas* sp. |
| 27 January 1999 | 2.3 | 9.3 | 6.5 | *Eucampia zoodiacus* |

Table 2 Occurrence of zooplankton at St.1 from 26 May 1998 to 27 January 1999.

| Date | Number of species | Number of individuals ($n/m^3$) | Biomass ($mgC/m^3$) | Production ($mgC/m^3/day$) | Predominant zooplankton[1)] |
|---|---|---|---|---|---|
| 26 May 1998 | 30 | 126350 | 62.8 | 20.8 | *Noctiluca scintillans*<br>*Paracalanus* sp. |
| 26 August 1998 | 41 | 50512 | 100.1 | 38.5 | Nauplius stage of copepoda<br>*Oithona* sp.<br>*Euterpina acutifrons* |
| 26 November 1998 | 30 | 120750 | 79.4 | 19.4 | *Noctiluca scintillans* |
| 27 January 1999 | 23 | 34423 | 40.6 | 3.0 | *Noctiluca scintillans*<br>*Paracalanus* sp.<br>*Oikopleura* sp. |
| Average | 31(65)[2)] | 83009 | 70.7 | 20.4 | *Noctiluca scintillans* |

1) Zooplankton species observed at the rate higher than 10% in number of individuals.
2) The number in parenthesis shows the total number of species observed.

### 3.1 Plankton

Temperature changed from 10.1 to 27.9 . and salinity varied from 31.1 to 32.3 psu with almost no difference between the surface and bottom layer except for May 1998. Chlorophyll a concentration exceeded 10.g/l at depths shallower than 8m in August 1998, while all values were less than 3.g/l from the surface to the bottom in May and November 1998. Chlorophyll a concentration was vertically constant and was ca. 5 .g/l in January 1999.

Table 1 shows the primary production of phytoplankton, the compensation depth and transparency at St.1. Net production changed between 0.27 and 5.5 g C/ $m^2$/day with an annual average of 2.1 g C/ $m^2$/day. The compensation depth was from 3.7 to.17 m which were 0.54-4.9 times deeper than the value of transparency. According to Joh [5] and Yamaguchi [6], primary production of phytoplankton in Osaka Bay was at a range of 0.86-4.5 g C/ $m^2$/day. These values are not markedly different from ours.

Occurrence of zooplankton is shown in Table 2. The number of species obtained was 65 and was high in August but low in January. *Noctiluca scintillans* was the most abundant species and accounted for 48-67% of the total individuals.

Carbon biomass and annual production of zooplankton were 40.6-100.1 mgC/$m^3$ (average 70.7 mg C/$m^3$) and 3.0-38.5 mg C /$m^3$/day (average 20.4 mg C /$m^3$/day), respectively. The values of biomass and annual production from the present study were relatively close to those of Joh and Uno [7].

Next, the carbon biomass and annual production of plankton at the planned reclamation area were determined. In this calculation, the biomass of phytoplankton was estimated from the following relationship between the chlorophyll a concentration and the particulate organic carbon (POC) in southeast Osaka Bay [5].

$$\text{POC } (\mu\text{g/l}) = 36.8 \times \text{Chl.a } (\mu\text{g/l}) + 284$$

Further, we used the average of May, November 1998 and January 1999 as the annual average (0.96 g C/ $m^2$/day) since the net production was extremely high on August 26, 1998 compared to other months due to a bloom of *Rhizosolenia fragilissima*. According to data from the Osaka Prefectural Fisheries Experimental Station, this bloom of *Rhizosolenia fragilissima* was reported to continue for only 9 days in August in the vicinity of the Kansai International Airport Island. Therefore, a net production of 5.5 g C/$m^2$/day occurred for 9 days of one year and a value of 0.96 g C/ $m^2$/day was estimated for the rest of the year. As a result, the annual primary production of phytoplankton per unit area was 391 g C/$m^2$/year. Mean biomass and annual net production in the planned reclamation area were 14.3 ton C and 2281 ton C, which was 0.2% of the total net production of the whole of Osaka Bay. In terms of zooplankton, the value was 8.2 ton C for the mean biomass and 869 ton C for the annual production in the planned reclamation area.

### 3.2 Benthic animals

Table 3 shows the number of species and individuals of meiobenthic animals, which are expressed using the amounts from Sts. 2 and 3. The values were 6-8 for the number of species and changed from 300 to 3808 individuals/0.004 $m^2$ for the number of individuals depending on the season. Predominant organisms were nematodes and Foraminifera which occupied more than 85% of the total numbers of the meiobenthic animals. Mean biomass and annual production of carbon per unit area were estimated as 3.47 x $10^{-2}$ g C/$m^2$ and 0.69 g C/$m^2$/day. Hirakawa et al. [8] reported that the annual production of meiobenthic animals in the tidal flat of Mikawa Bay, Japan reached 3.42 g C/$m^2$/day. This is ca. 5 times higher than that of the Kansai International Airport Island.

The occurrence of macrobenthic animals is shown in Table 4. The number of species and individuals varied between 32 and 69 and from 130 to 2059individuals/0.8 $m^2$, showing low values in late summer and autumn but high values in winter and spring. The mean biomass and annual production of macrobenthic animals per unit area were 1.94 g C/$m^2$ and 4.55 g C/$m^2$/year, respectively. According to Tamai [3], the mean annual production of macrobenthic animals in the Seto Inland Sea is 1.9 g C/$m^2$/year, which is ca.

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Table 3 Number of species and individuals and predominant animals in the meiobenthos at Sts. 2 and 3 from 26 May 1998 to 25 March 1999.

| Date | Number of species | Number of individuals ($n/0.004m^2$) | Predominant animal |
|---|---|---|---|
| 6 May 1998 | 7 | 1040 | Nematoda (61.9)<br>Foraminifera(23.8) |
| 22 July 1998 | 6 | 300 | Nematoda (86.7)<br>Foraminifera (5.3) |
| 16 September 1998 | 8 | 3536 | Nematoda (73.2)<br>Foraminifera (23.4) |
| 26 November 1998 | 8 | 3808 | Nematoda (69.2)<br>Foraminifera (21.1)<br>Ciliata (7.2) |
| 27 January 1999 | 7 | 848 | Nematoda (63.2)<br>Foraminifera (24.5) |
| 25 March 1999 | 7 | 3592 | Nematoda (82.0)<br>Foraminifera (11.1) |

* Numbers in parentheses for predominant animals show the percentage of individual number of the predominant animal to the total number of individual meiobenthic animals.
** Each value is expressed as the amount of Sts. 2 and 3.

Table 4 Number of species and individuals and the wet weight in macrobenthos at Sts. 2 and 3 from 26 May 1998 to 25 March 1999.

| Date | Number of species | Number of individuals ($n/0.8m^2$) | Wet weight ($g/0.8m^2$) | Predominant animals |
|---|---|---|---|---|
| 26 May 1998 | 62 | 2059 | 16 | Foramirifera |
| 22 July 1998 | 39 | 342 | 193 | *Lumbrineris longifolia* |
| 16 September 1998 | 35 | 130 | 74 | *Paraprionospio* sp. type B<br>*Theola fragillis* |
| 26 November 1998 | 32 | 265 | 23 | *Alvenius ojianus*<br>*Theola fragillis* |
| 27 January 1999 | 69 | 835 | 161 | *Luidia* spp. |
| 25 March 1999 | 49 | 792 | 64 | *Sigambra tentaculata*<br>*Harpiniopsis* sp.<br>*Nephtys polybranchia* |

* Each value is expressed as the amount of Sts. 2 and 3.

two-fifths of the production of coastal area along the Kansai International Airport Island. However, Hirakawa et al. [8] noted that the production of macrobenthic animals in the tidal flat of Mikawa Bay reached 32.9 g $C/m^2$/year. This is ca. 7 times higher than the production of the Kansai International Airport Island. Such low values in annual production of meiobenthic and macrobenthic animals along the coast of the airport island presumably results from the following reasons: 1) The silt and clay content of bottom sediments exceed 60.6-98.9% in the vicinity of the airport island. This is too fine for the growth and success of interstitial animals. 2) Moderate hypoxia [9] usually occurs in the bottom layer of east Osaka Bay in summer and this may lead to reduced growth and survival of benthic animals in the vicinity of the airport island. The mean biomass and annual production of carbon were calculated as 0.27 ton C and 5.3 ton C/year for meiobenthic animals, and 18.1 ton C and 40.2 ton C/year for macrobenthic animals, respectively.

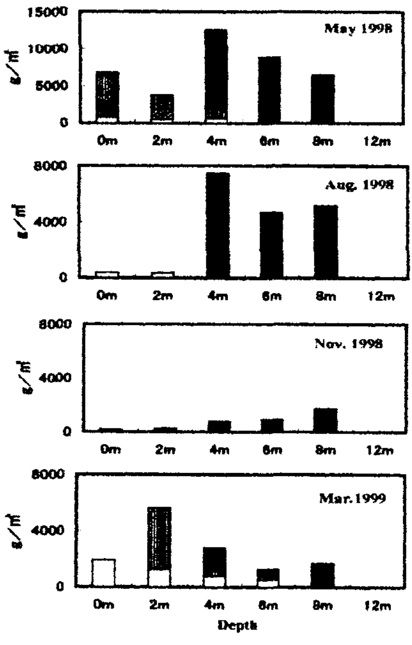


Fig. 2 Biomass of the four predominant species of seaweeds at depths of 0, 2, 4, 6, 8 and 12 m from the sea surface in the vicinity of the Kansai International Airport Island. Each value is expressed as the average of lines $\alpha$ and $\beta$. Symbols: ■; *Ecklonia cava*, ▥; *Undaria pinatifida*, ⊟; *Sargassum muticum*, ▨; *Sargassum filicinum*, □; Others.

### 3.3 Periphyton

Predominant seaweed species varied depending on the water depth. For instance, *Undaria pinnatifida* and *Sargassum muticum* were abundant at a water depth of 0-1 m, *Sargassum filicinum* grew densely at 2-3 m depth and *Ecklonia cava* had a high biomass over a wide range of 4-9m depth on the northeast mound of the airport island. But no predominant seaweed was observed at a depth of 12m. Seasonal changes of the biomass of seaweed at the six sampling depths (0, 2, 4, 6, 8, 12 m depth) are shown in Fig. 2. The average of biomass of the six depths changed from 35.6 to 207.7 g C/m$^2$ and showed a high in spring but a low in autumn. The most predominant seaweed throughout the year was *Ecklonia cava* and its maximum yield attained 658 g C/m$^2$. *Undaria pinnatifida* was the secondmost dominant species, which mainly appeared from winter to spring and its maximum yield was 137 g C/m$^2$. The genus *Sargassum* grew abundantly between autumn and spring. The mean biomass and annual production of seaweed along the northwest mound of the Kansai International Airport Island were 14.6 ton C and 28.6 ton C/m$^2$ and the average annual production of carbon per unit area was 216g C/m$^2$/year. As the production per unit area obtained here included values for deeper than 10 m where no abundant seaweed was observed, a modified production per unit area was calculated for depths less than 10 m. The modified value reached 360 g C/m$^2$/year and was slightly higher than the average production of seaweed on the temperate coasts of western Japan (e.g. 285 g C/m$^2$/year for the Seto Inland Sea, Ninomiya, personal communication).

Table 5 Biomass of phytal animals on four species of seaweeds along lines α and β from May 1998 to March 1999.

| Seaweed | Phytal animals | Wet weight of phytal animals on 1 kg of seaweed (g) | | | |
|---|---|---|---|---|---|
| | | May 1998 | Aug. 1998 | Nov. 1998 | Mar. 1999 |
| *Ecklonia cava* | Annelida | 0.12 | | 0.22 | |
| | Mollusca | 0.11 | 0.17 | | |
| | Arthropoda | 12.2 | 0.22 | 0.28 | 2.21 |
| | Others | 0.02 | 0.04 | 0.03 | |
| *Sargassum muticum* | Annelida | 1.0 | 10.81 | 0.06 | |
| | Mollusca | 16.32 | 0.06 | 0.04 | |
| | Arthropoda | 167.18 | 6.19 | 11.35 | 41.96 |
| | Others | 0.67 | | 1.61 | |
| *Sargassum filicinum* | Annelida | 0.63 | | | |
| | Mollusca | 0.33 | | | 0.32 |
| | Arthropoda | 61.87 | 1.0 | 8.86 | 8.13 |
| | Others | 0.12 | | | |
| *Undaria pinnatifida* | Mollusca | 0.56 | | | |
| | Arthropoda | 1.2 | | | |

* Each value is expressed as the average of line α and line β.

The wet weight of phytal animals on *Ecklonia cava*, *Undaria pinnatifida*, *Sargassum muticum* and *Sargassum filicinum* is shown in Table 5. Predominant animals on the four species of seaweed were Caprellidae and Ischyroceridae for Arthropoda and juvenile mussels for Mollusca, Spirorbidae for Annelida. Biomass of phytal animals was different depending on the seaweed species and the season. For instance, wet weight per 1kg of *Sargassum muticum* was highest in spring being 185 g, while it decreased to 13.1-42.0 g in the other seasons. In contrast, the wet weight was low and was less than 10 g in *Ecklonia cava*, *Undaria pinnatifida* and *Sargassum filicinum* excluding a value of 63.0 g for *Sargassum filicinum* in spring. Biomass and annual production of phytal animals along the northeast mound of the airport island were estimated from the biomass of seaweed, biomass of phytal animals on unit weight of *Ecklonia cava*, *Undaria pinnatifida*, *Sargassum muticum* and *Sargassum filicinum*, carbon concentrations and P/B ratios of phytal animals. Their mean biomass and annual production of carbon were 4.47 kg C and 15.2 kg C/year for Annelida, 7.47 kg C and 25.4 kg C/year for Mollusca, and 151.1 kg C and 513.9 kg C/year for Arthropoda. As a whole, the total biomass and annual production of phytal animals on the northeast mound of the airport island were estimated to be ca. 0.16 ton C and ca. 0.55 ton C/year, respectively.

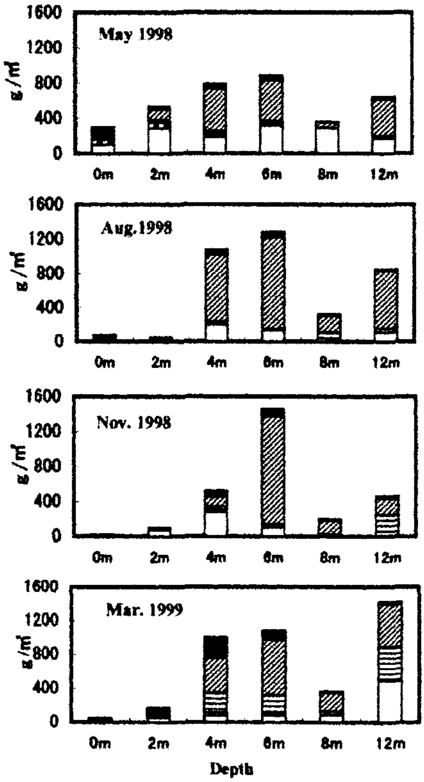


Fig. 3 Biomass of the sedentary animals at depths of 0, 2, 4, 6, 8 and 12 m from the sea surface in the vicinity of the Kansai International Airport Island. Each value is expressed as the average of lines $\alpha$ and $\beta$. Symbols: ■; Gastropoda, ▨; Bivalve, ⊟; Barnacle, ◧; Other crustaceans, ◫; Polychaete, □; Others.

Figure 3 shows the seasonal changes of biomass of sedentary animals in relation to the water depth. Mean wet weight per unit area at the six depths was 461-684 g/m$^2$ with relatively high values at 4, 6 and 12 m. Total wet weight at the six depths was low in autumn but its seasonal variation was small. Predominant animals were *Arca boucardi*, Ostreidae, Gastropoda, *Balanus trigonus*, *Asterina pectinifera*, holothurians and ascidians. As a result, the mean biomass and annual production of sedentary animals along the northwest mound of the airport island were estimated as 2.3 ton C and 3.3 ton C/year, which was calculated from the dry weight, carbon concentration and P/B ratios of the dominant sedentary animals.

Table 6 Biomass and annual production of phytoplankton, zooplankton, seaweed, phytal animals, sedentary animals and benthic animals in the planned reclamation area of the second phase work of the Kansai International Airport Island

| Organism | Biomass (t C) | Annual production (t C/year) | Annual production per unit area (gC/m$^2$/year) |
|---|---|---|---|
| Phytoplankton | 14.3 | 2281 | 391 |
| Zooplankton | 8.2 | 869 | 149 |
| Seaweed | 14.6 | 28.6 | 360 |
| Meiobenthic animals | 0.27 | 5.3 | 0.7 |
| Macrobenthic animals | 18.1 | 40.2 | 5.2 |
| Phytal animals | 0.16 | 0.55 | 6.9 |
| Sedentary animals* | 2.3 | 3.3 | 24.9 |

* Values of sedentary animals include phytal animals.

## 4 Conclusion

The mean biomass and annual production of phytoplankton, zooplankton, seaweed, phytal animals, sedentary animals, and benthic animals in the planned reclamation area are compared in Table 6. Macrobenthic animals were the most abundant organisms in biomass (18.1 ton C), followed by seaweed (14.6 ton C) and phytoplankton (14.3 ton C). Annual production of carbon per unit area was highest in phytoplankton (391 gC/m$^2$/year), then seaweed was 360 g C/year which was almost the same as the phytoplankton production. This means that the construction of an artificial seaweed forest has the potential effectiveness to increase production around the Kansai International Airport Island. However, planktonic organisms accounted for 98% of the total production (3228 ton C) at the planned reclamation area when compared to the annual production of phytoplankton, zooplankton, seaweed, phytal animals, sedentary animals and benthic animals. This characteristic mainly resulted from the water depth and the higher growth rate of phytoplankton and zooplankton, along with their three-dimensional distribution in seawater in contrast to the two-dimensional listribution of seaweed, phytal animals, sedentary animals and benthic animals on he mound or on the bottom sediment. In addition, the present study clarified that mall planktonic organisms play an important role in the biological production at he coast of the Kansai International Airport Island. This will lead to an idea that nore attention should be paid on the annual production to evaluate the effects of eclamation on coastal ecosystems.

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