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Effect of Geological Succession on Macrophyte and Microbiota in Aquifer Ecosystem in Urban Coastal Zone

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ABSTRACT: This study was conducted to investigate the effect of geological succession of sediment on macrophyte and microbiota in aquifer ecosystem. The research field was selected as Yatsu Tidal Flat where located in urban coastal zone in Tokyo Inner Bay. This tidal flat has been registered under Wildlife Protection Area of Japan in 1988 and the Ramsar Convention in 1993, and just as the tidal flat that was left from reclamation of waterfront zone of urban area. It is very important to obtain some information about these ecosystem characteristics of such nature left in urban area, because creation of artificial tidal flat is recognized as one of important enterprises to construct urban ecosystem. In recent years, a large chlorophyceae, *Ulva* spp. (mainly *Ulva pertusa* and *Ulva japonica*) which is recognized as a biotic indicator of eutrophicated sea area, has become observed in Yatsu tidal flat, and it is considered that *Ulva* spp. give a large effect to water quality. *Ulva* spp. has high absorbent potential of nutrient salts at its growth phase, so this macrophyte is considered to place the microbiota such as zooplankton and phytoplankton under its control. In the first place, the geological succession as muddy to sandy occurred because of water quality change as fresh water to sea water. This water change resulted from the decrease of drainage with the sewer system service in basin area, and lead oligotrophication of the sediment. *Ulva* spp. is one of the biological indicater for sea water and sandy sediment and eutrophicated environment. Because of the irregular growth of *Ulva* spp., the quantity of phytoplankton decreased drastically, and the dominant species of phytoplankton and zooplankton transited from ideal to unsuitable food organisms for macrobenthos which is important food for the migratory birds, and the production potential of this aquifer ecosystem became in fragility.

Keywords: Urban coastal zone, Macrobenthos, Macrophyte, Geological succession, Yatsu tidal flat

1. INTRODUCTION

Tidal flat is located in the boundary zone between land and sea area. Therefore, the environmental factors are changing periodically and very rapidly, according to supply of fresh water from river and tide action. On the other hand, the algal production speed and rate, such as diatoms and/or flagellums on surface of sediment that is forming bio-film, is very high, because of much nutrient salts are supplied from both land and sea areas. Unique and precious ecosystem is constituted, and birds and fishes gather to take feed at the same time. Tidal flat is very important place as familiar nature, for not only wild lives in tidal flat but also human in surrounding area. And it is the place where for recreation, and to obtain marine resources [1]. Although the area is decreased by reclamation because of tidal flat is shallow sea and therefore it is easy to reclaim, the importance of wetland including tidal flat is indicated recently, and Ramsaor Convention whose purpose is to protect migratory is adapted at the year 1971. Eleven wetlands are registered for the convention in Japan [2].

Yatsu Tidal flat where is registered under Ramsaor Convention, is reclaimed its circumference, and shut out from Tokyo Inner Bay for over 20 years. And environment of this tidal flat is terrifically changed, for instance decrease of inflow load and pure water originate in domestic wastewater by improvement of public sewerage system. Furthermore, it is recognized apprehensions in recent years that there is possibility to occur the runoff of sediment by tidal current. From analysis for the environmental succession and factors of this unique tidal flat, some essential suggestions for construction artificial tidal flat in urban area is expected to be obtained.

In this paper, the study was conducted to investigate the effect of geological succession of sediment on macrophyte and microbiota in aquifer ecosystem.

2. OUTLINE OF YATSU TIDAL FLAT

In the extreme end of the Tokyo Inner Bay, an un-reclaimed Tideland of 40 ha is left which is now called as Yatsu Tidal Flat (Yatsu Higata) as shown in Fig.1. Sea water comes in and out with the ebb and flow of the bay. Large numbers and different kinds of shorebird and migratory bird come here each season. They are giving tremendous relaxation to the community in the midst of the urban area. Yatsu Tidal Flat was designated as an official site of Ramsar Convention (Convention on Wetlands of International Importance Especially as Waterfowl Habitat) in 1993.

In 1898, it was a shoal beach and was used for salt manufacturing. In 1924, Keisei Rail Road (Keisei Dentetsu) reclaimed the area and made a play land Yatsu Play Land (Yatsu Yu-en). The remaining shore served for swimming and clam fishing. The community had great fun out of it. In 1979, Tokyo Bay Reclamation project encroached the shore and Yatsu Tidal Flat came to be in danger of land development. Groups and community people stood against

for its protection (Fig.2). In 1984, the conservation of the Yatsu Tidal Flat was then included in the construction project of local area public facility. Later in 1988, Yatsu Tidal Flat was designated as the Natural Wildlife Protection Area. In 1982, Yatsu Play Land was closed due to the opening of the Tokyo Disney Land in the nearby town. In 1993, Yatsu Tidal Flat was designated as the Ramsar Site by The 5th Conference of the Contracting Parties to the Convention on Wetlands. In 1994, Observation Center was opened. In 1996, Yatsu Tidal Flat joined to The East Asian and Australasian Shore Bird Reserve Network in The 6th Conference in Brisbane, Australia. In 1997, Narashino City enacted The Day of Yatsu Tidal Flat for celebration of Yatsu Tidal Flat conservation. In 1998, Narashino City and Brisbane City Council agreed to The Affiliation Agreement of their Wetland Conservation.

In Yatsu Tidal Flat, during the flow tide, the tidal flat is in the water (0.8m depth in average), and during ebb tide, the tidal flat appears. The tidal flat is connected to Tokyo Inner Bay through two canals, and the water flows in and out. So many shorebirds gather and feed themselves, and so many creatures are inhibiting such as crabs and invertebrates on which the birds live. Throughout a year, many kinds of birds are seen in Yatsu Tidal Flat. Seasonally there comes huge number of seasonal migratory birds. For the shorebirds flying between Siberia and Australia, Yatsu Tidal Flat is their important intermediate rest place after and before their long journey [3].

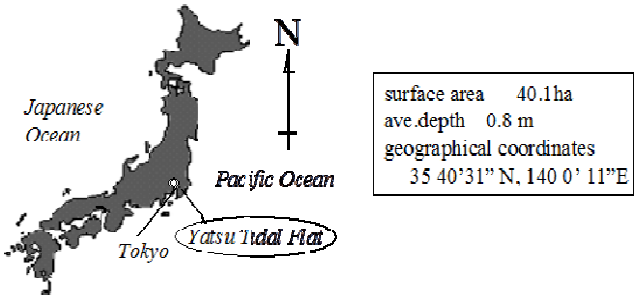

Fig.1 Location of Yatsu Tidal Flat

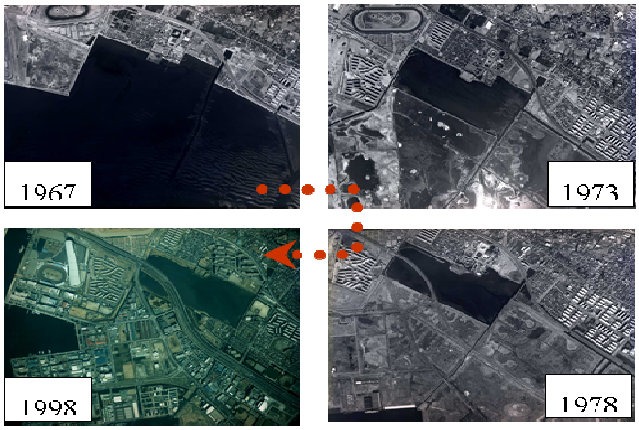

Fig. 2 Succession of environmental condition around Yatsu Tidal Flat

3. RECENT PLOBLEMS IN YATSU TIDAL FLAT

Since 1983, *Ulva* sp., a marine macrophyte (chlorophyceae) which forms the green tide with its irregular growth, has been observed and increased in its individual number. The occupied zone in Yatsu Tidal Flat has expanded, that is, 6.8 ha in 1995, 13 ha in 1993, 20 ha in 2000, and 40 ha (completely occupied) after 2005 (Fig.3) [4]. The main species of *Ulva* spp. was identified as *U.pertusa* and *U.japonica*. The reasons of this phenomenon, an eutrophication of water quality, increasing of seawater supply, and sediment succession from mud to sand have been reported (Fig.4) [5].

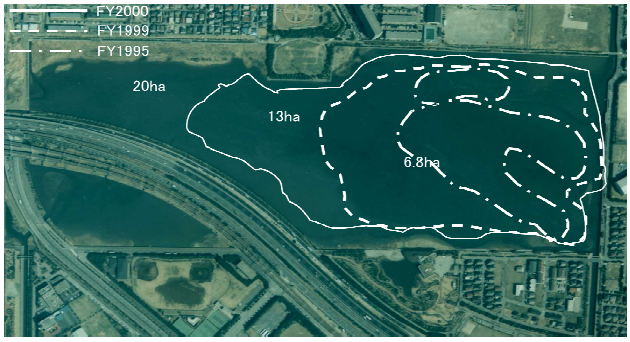

Fig.3 Succession of occupied zone by *Ulva* spp.

Ulva spp. is recognized as one species of large green algae that like sand or sandy-mud sediment condition rather than mud sediment condition [6][7]. That is, it is thought that growth of *Ulva* spp. is brought about by existence of sufficient nutrient salts and progress of chlorinization of water and sandification of sediment in this tidal flat. From these outcomes, the rise of a ratio (sand / mud) and that of (sea water / fresh water) can be considered as one of reasons for the irregular growth of *Ulva* spp..

Sediment condition of the area where *Ulva* spp. is much grown (ORP : -200 ～ -250mV) is presenting the black reduction state compared with the sediment of the area where *Ulva* spp. is not observed (ORP : -50～-100mV). So, in such reduction area, there cannot be observed any macrobenthos that is supporting a tidal flat ecosystem as main predator [8].

Fig.4 *Ulva* spp. multiplicated in Yatsu Tidal Flat

It is considered that *Ulva* spp. decayed and made anaerobic Sediment state after its irregular growth. In comparison with 1984 and 1995, the total species number of macrobenthos has increased from 13 to 39, however, the total individual number has clearly decreased, and no living point was also observed [9]. That is, it is suggested that biological production mechanism has been changing from "large quantity of small species" condition to "small quantity of large species" condition, namely, change to brittle bio- production state.

Thus, a change of phytoplanktonic flora which plays an important role on food chain of the tidal flat ecosystem as the primary producer, and that of zooplanktonic fauna as the primary consumer leads a change of macrobenthic fauna as the food source of the migratory birds. The decrease of migratory birds attracts very few customers who visit to Yatsu Tidal Flat to relax, and this leads decay of recreational function, that is, the ecosystem service.

4. GEOLOGICAL SUCCESSION IN YATSU TIDAL FLAT

In Yatsu Tidal Flat, the mud area has decreased from 20 ha to 15 ha, sandy-mud area has increased from 10 ha to 18 ha, and Ignition Loss (I.L.) of sediment, that indicates the quantity of organic matters in sediment, has also been decreased (Fig.5). Moreover, although the thickness of the mud layer in Yatsu Tidal Flat was 25-200cm in 1984, it is decreased rapidly 0-50cm in 1995. This means sediment condition of Yatsu Tidal Flat is changing from mud to sand, and it was suggested at the same time that flow out of sediment, especially mud layer from this tidal flat to Tokyo Inner Bay.

The amount of inflow load that is flown from its basin area to Yatsu Tidal Flat is decreased 16.8% for these 12 years from 1983 to 1995 (Fig.6), and the diffusion of the sewerage system in basin area is 85.3% in 2010. The decrease is because of the amount of drainage inflow from the household decreased with improvement of public sewerage system of a basin area. Furthermore, improvement of public sewerage is not only reduction of inflow loads, but also brought about the result of reduction of the amount of fresh water supply. Chloride ion concentration in Yatsu-Funadamari located in most inner part of Yatsu Tidal Flat continues rising (Fig.7). This phenomena namely means the water quality in Yatsu Tidal Flat is changing from fresh water to sea water.

At Yatsu Tidal Flat, the inflow loads has decreased as improvement of public sewerage system that is started since 1990. As the result, water quality has changed from fresh water to sea water and sediment condition has also changed from mud to sand, and it is caused the irregular growth of *Ulva* spp., which is the indicator of eutrophicated state. That is, as shown in figure 6, at the first step of succession, a tidal flat just like tideland lake is formed artificially with reclamation and development of its circumference, and the water quality became fresh water and sediment condition became muddy, in gradually. So it is formed ecosystem that has high-bio-production potential. However, in recent years, supply of fresh water and organic matter from land area has

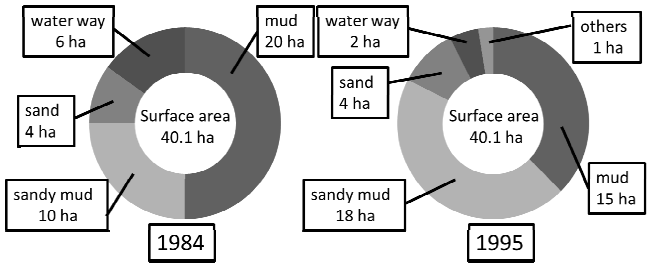

Fig.5 Comparison of sediment quality in 10 years

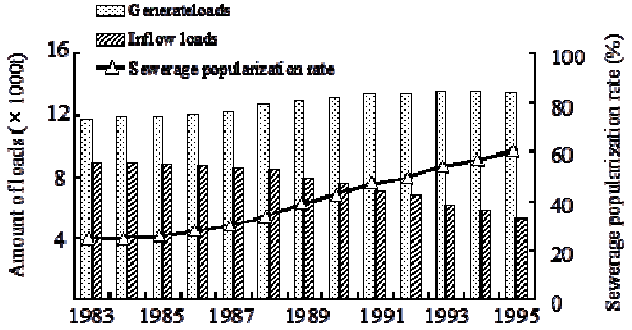

Fig.6 Change of popularization of sewerage and amount of loads

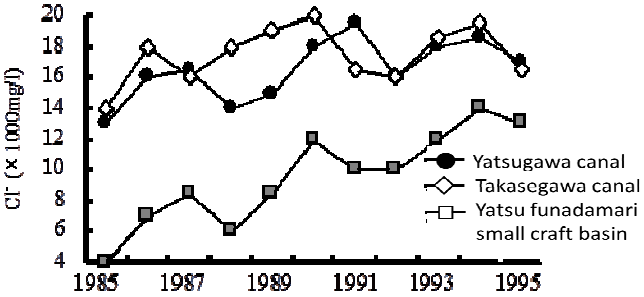

Fig.7 Change of chloride ion concentration

decreased with improvement of public sewerage system, so chloronization of water quality and sandification of sediment condition have progressed, and bio-production potential has reduced. Moreover, tide action becomes more influence, such as flow out of sand from Yatsu Tidal Flat. From these outcomes, it was made clear that Yatsu Tidal Flat has been changing to the foreshore tidal flat again with remaining the topographical characteristics as tideland lake.

5. SUCCESSION OF MICROBIOTA

Regarding to phytoplanktonic flora which plays an important role on the food chain as the primary producer of the tidal flat ecosystem, microscopic observation has been conducted for several years (Fig.8). As results obtained from the observation, the following outcomes were obtained. 1) As

quality of phytoplanktonic flora, seasonal change of species composition of phytoplankton is not so large and its species number was 50-60 species through a year, 2) As quality of phytoplanktonic flora, individual numbers of phytoplankton was larger in summer and smaller in winter, and supplied from Tokyo Inner Bay to Yatsu Tidal Flat throughout two channels, called Yatsu river in the eastern side and Takase river in the western side, with the ebb and flow of the bay, 3) The diversity index, calculated by Shannon Index, of phytoplankton is larger in winter and smaller in summer, and the possibility of simplisation of phytoplanktonic flora was occurred by outflow from Yatsu Tidal Flat to Tokyo Inner Bay, 4) Unique ecosystem has been constructed in this enclosed tidal flat because of its closure circumstance which greatly influencing to phytoplanktonic flora.

The macrobenthos mainly observed in Yatsu Tidal Flat were Cinidaria, Mollusca, Annelida, Arthropoda and Lophophorata. As biotic indicator of organic polluted condition, Annelida was much observed in mud sediment zone. Macrobenthic fauna is considered poor in un-polluted environment and rich in polluted environment in general [10] . But in further polluted environment, the species and individual number of macrobenthos become to decrease, and macrobenthic fauna become poor again as a result. This tendency is not only in case of macrobenthos but also in most of biotic indicator, for example, phytoplankton, water glass, and so on. The wealthy nature means a state that co-exist with many species, many individuals, and without one or some dominant species. Yatsu Tidal Flat was considered to be in the state which environmental condition is shifting from the further polluted condition to the polluted condition with the progress of sandy sediment and seawater. Yatsu Tidal Flat is considered to indicate succession from mud sediment tideland to sandy tideland like other tidal flat in Tokyo Inner Bay. Macrobenthic fauna is very diverse in sand tideland, so the macrobenthic fauna in Yatsu Tidal Flat is considered to become more diverse year by year (Fig.9). On the other hand, *Ulva* spp. has become observed to be growing irregularly. This large green algae is considered to beat macrobenthos such as Annelida because of its large leaf body and sedimentation which leads anaerobic condition. From these phenomena, ecosystem balance is considered to be not in good condition [11].

Increase in the amount of pollutants that flows into Yatsu Tidal Flat has been resulted from the concentration of population, the increase of factories and the expansion of reclaimed land. And water plant and macrobenthos, especially Annelida in tideland is very useful to purify the organic pollutants with their prey-predation interaction [12][13]. It is important to protect macrobenthos from extermination because of its usefulness for purification of organic polluted sediment, especially in tidal flat ecosystem. In addition, Tokyo Inner Bay is recognized as a famous sea area where the Blue Tide (Aoshio, anaerobic water bodies) occurs frequently. In fact, a large scale Aoshio occurred 3 times in summer in 2000. This anaerobic water bodies flew into Yatsu Tidal Flat and influenced greatly not only to macrobenthos but also to other creatures in this enclosed tidal flat. Furthermore, EDCs are also considered to be one of environmental factors that give large effect [14]. So, further study about the effect of environmental factors on macrobenthic fauna is necessary for the environmental

Fig.8 Plankton observed in Yatsu Tidal Flat

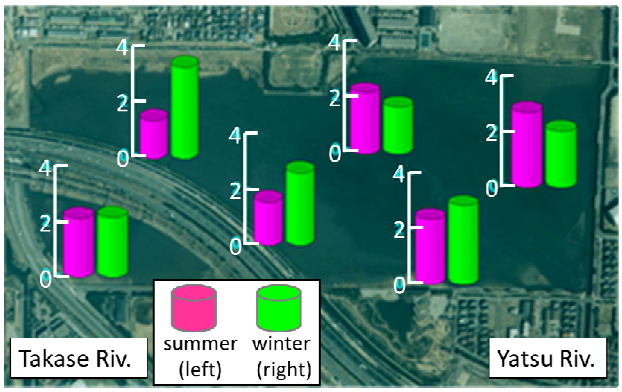

Fig.9 Diversity index (H') of macrobenthos

Fig.10 Sandbank located near the mouth of Yatsu river which disappeared after the Tohoku Region Pacific Coast Earthquake in 11 March 2011.

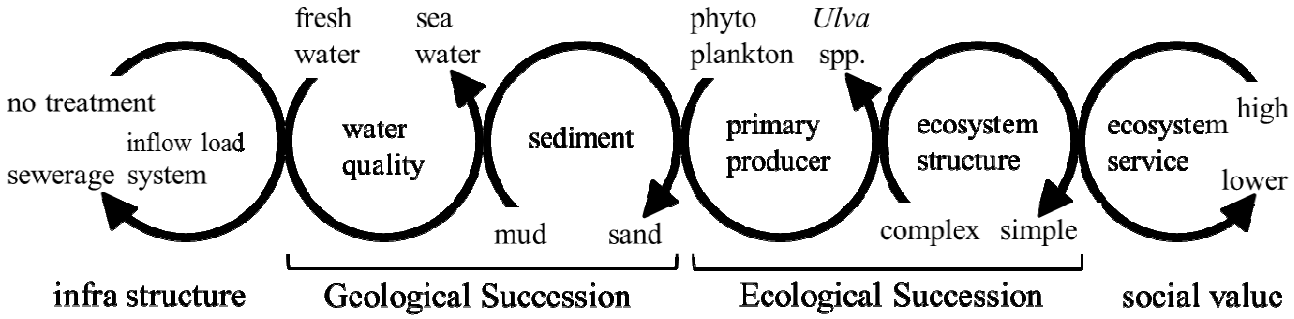

Fig.11 Relationship between geological and ecological succession in Yatsu Tidal Flat

improvement of not only Yatsu Tidal Flat but also any nature left in urban area.

6. EFFECT OF TOHOKU REGION PACIFIC COAST EARTHQUAKE

The Tohoku region Pacific Coast Earthquake which occurred at 11 March 2011 gave large influence not only to the pacific coast but also to the coastal zone of Tokyo Inner Bay. Yatsu Tidal Flat is not exception as same as Sanbanze and Banzu Tidal Flat where also located in Chiba prefecture side of Tokyo Inner Bay. The liquefaction of sediment in Yatsu Tidal Flat was observed. The promenadea walk was damaged and the microtopography of ebb water route in tidal flat was changed with an uplift of sediment. For example, a sandbank located near the mouth of Yatsu river was disappeared after the earthquake (Fig.10). It is considered that micro particle sand was ejected from underground and sedimental condition in the tidal flat became more sandy. However, in Yatsu Tidal Flat, the water flow, especially ebb tide, is very fast (about 2m/s in the canal) [15] and the sand particle was immediately flush out to Tokyo Inner Bay. *Ulva* spp. was also damaged temporary but it grew and occupied the tidal flat surface again. Further continuous investigation should be necessary to estimate the geological succession effect on the tidal flat ecosystem structure and function (Fig.11).

7. CONCLUSIONS

The investigation of the effect of geological succession of sediment on macrophyto and microbiota in aquifer ecosystem was conducted in this study. The results obtained are summarized as follows.

1) As a result of inflow loads has decreased with improvement of public sewerage system, water quality has changed from fresh water to sea water and sediment condition has also changed from mud to sand, and bio-production potential has reduced, in Yatsu Tidal Flat, the artificial tideland lake.

2) There is the inherent clockwise flow occurred by tidal action is made clear, and the relationship between the clockwise flow and sediment condition was suggested.

3) The phenomenon of sand spill is occurred by tide action in the east area of Yatu Tidal Flat was made clear.

4) It is considered that Yatsu Tidal Flat has been changing to the foreshore tidal flat again with remaining the topographical character as tideland lake.

5) Because of the irregular growth of *Ulva* spp., the quantity of phytoplankton decreased drastically, and the dominant species of phytoplankton and zooplankton transited from ideal to unsuitable food organisms for macrobenthos which is important food for the migratory birds, and the production potential of this aquifer ecosystem became in fragility.

6) Further continuous investigation should be necessary to estimate the geological succession effect on the tidal flat ecosystem structure and function.

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