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Ecological Footprint Accounting of "TAKUMI"

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ABSTRACT

An ecological footprint accounting of the prototype ocean nutrient enhancer TAKUMI was performed to assess the sustainability of this type of artificial upwelling technology. The results indicate that the dominant component of the ecological footprint is CO_2 emissions from the combustion of fuel to provide system power. The ecological footprint per unit biomass of fish production by TAKUMI was determined to be about 30% of the value associated with commercial chicken production. The analysis also suggests that renewable energy sources should be employed to operate the system in order to realize sustainable artificial upwelling.

KEY WORDS: Ecological footprint, biocapacity, ocean nutrient enhancer, artificial upwelling, deep ocean water.

INTRODUCTION

World population has increased rapidly following the industrial revolution, reaching 6.5 billion in 2006. Several forecasts estimate that this number will rise to about 8 billion in 2020. The statistical database (http://faostat.fao.org) of the Food and Agriculture Organization (FAO) of the United Nations (UN) reveals serious problems concerning global food supply meeting the needs of this growing population. 800 million people currently suffer hunger, and it is not unreasonable to expect worldwide food shortages in the future. For example, over the past 30 years, world cereal production has approximately doubled; however, since around 1996, production has remained essentially constant at about 2,100 Mt y^{-1}. In the U.S., per capita cereal consumption stands at 800 kg-cereal y^{-1} per person. At this level, current production can only support 2.5 billion people. On the other hand, 10 billion people could be sustained at the African level of 200 kg-cereal y^{-1} per person, although this may negatively impact health and longevity; the average life expectancy in Africa is about 50 years, due in part to compromised nutrition.

Growth in food production has been accomplished through tremendous use of fresh water, chemical fertilizer and fossil fuels. This, in turn, has resulted in depletion of water resources, expanding areas of infertile land, climate change, and so forth. Furthermore, the shift from cereal-dominant diets to meat-dominant ones imposes greater environmental loads, since production of a unit of meat requires several units of cereal. These factors argue for the development of new sustainable technologies to enhance production of food, and animal protein in particular.

One candidate food production technology is ocean fertilization using deep ocean water (DOW). DOW is cold, nutrient-rich and pathogen-free seawater found at depths of several hundred meters or more. DOW has attracted interest as a renewable resource for energy and marine primary production (Otsuka, 2001). Artificial upwelling of DOW may significantly enhance marine primary production (Liu, 1999). Potential benefits of artificial upwelling can be inferred from the results of many studies of natural upwellings, e.g., Ryther's classical report (1969).

The Japanese program Marino-Forum 21 has undertaken an *in-situ* experiment of a prototype ocean nutrient enhancer, named TAKUMI, in Sagami Bay, which aims to confirm the effects on marine primary production and to establish the technology for practical use. It is important, however, to assess such technology from the viewpoint of sustainability, since the goal is to develop sustainable food resources rather than just another means for conventional food protein production. Ecological footprint is a parameter that accounts for resource and energy consumption and waste streams. This indicator can be used to assess the sustainability of human activities from the viewpoint of regenerative natural capacity. In this study, an ecological footprint accounting of TAKUMI is performed to investigate the sustainability of artificial upwelling technology.

OCEAN NUTRIENT ENHANCER "TAKUMI"

A prototype ocean nutrient enhancer named TAKUMI was developed to create new fishery grounds by artificial upwelling. The project was organized by the Marino-Forum 21, a satellite organization under the Fisheries Agency of Japan. The primary feature of TAKUMI is a density current generator to minimize sinking and diffusion of the cold, dense DOW after discharge into the euphotic zone (Ouchi, 2003). The density current generator is applicable in a stratified water column. It draws in both high-density DOW and low-density surface ocean water (SOW), and discharges the medium-density mixed water using a double