Impact of a cage culture system on material cycling

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Introduction

Cage culture systems are used to increase productivity by concentrating energy supply much higher than natural ecosystems. Intensive food supply and excretion disturb the material cycling and distort the local material budget. As a result, the structure of biological communities around the cage changes and anoxic conditions may develop in the vicinity. To understand the impact of cage culture on the material cycles, we studied an experimental cage system located in Tongyoung area in the southern coast of Korea. We estimated annual budget of carbon, nitrogen, and phosphorus at and near the cage culture system by conducting field measurements and using models.

Material and methods

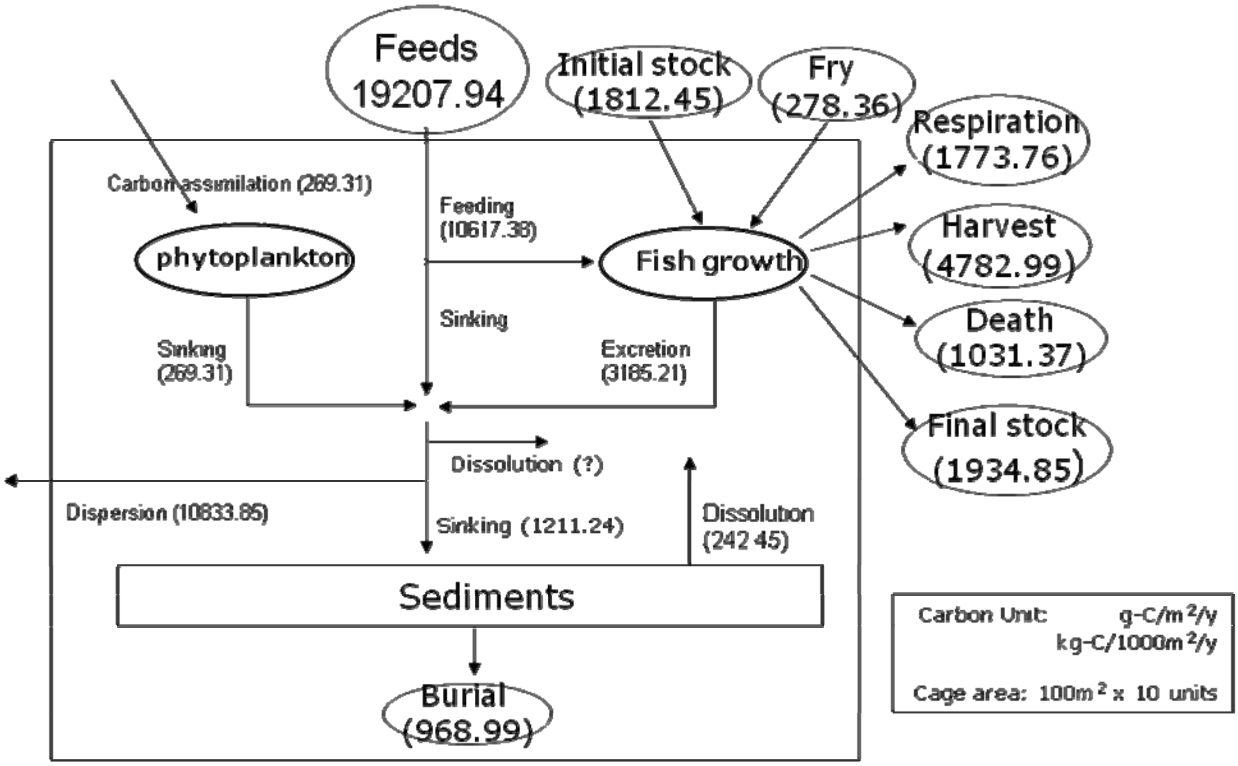
In the conceptual model of the system, phytoplankton production and fish feeds are the two sources and burial in the sediments is the major sink (Fig. 1). Fluxes among the sources and sinks are tracked. Feeding rate of fish within a cage was estimated from a mass-balance equation as follows.

F (Feeding) + (I) initial biomass + B (fry biomass) =
R (respiration) + H (harvest) + D (death) + S (remaining stock) + E (excretion)

I, B, H, D, and S were obtained from observation. R and E were estimated using models (Grant, 1986). Sedimentation rate was measured by sediment traps (diameter 10cm, aspect ratio: 8) hung vertically at the centre and periphery of cages at 15m depth (5m above the bottom). The trap was deployed for Aug 1995~March 1996. To measure the material exchanges across the water-sediment interface, benthic chambers and traps were placed and sediment cores were also taken. Surface chlorophyll-a and nutrient were sampled daily for the period between Jul 1995 and Jan 1996. Primary productivity was measured in Jun and Aug 1995, and Feb 1996, from which annual primary production was estimated. Elemental composition was based on literature (KORDI, 1993).

Results

The carbon budget is shown in Fig. 1. 55.2% of the carbon in the fish feeds was fed by fish. 61.4% of the carbon, which included unfed feeds and excretion, was released to the environment. The released portion was 57.0% for nitrogen and 44.0% for phosphorus. Of these, direct sedimentation underneath the cage was 10%, 5%, and 40% for carbon, nitrogen, and phosphorus, respectively. The estimated sedimentation rate was 10,833 g-C m^{-2} yr^{-1}, 4,043 g-N m^{-2} yr^{-1}, and 130 g-P m^{-2} yr^{-1}. The remainder, about half of the feed input, dispersed out to the ambient environments. The quantity of organic carbon collected in the sediment trap showed a close relationship with fish feed supply. The primary production was 1/100 of the fish feeds. Fish productivity was 100~2,000 times higher than natural ecosystems. Transfer efficiency was about 25%, which would be much lower in reality because ancillary energy was used to maintain the cage systems. Considering the density of similar cage cultures in the region, the annual discharge of carbon from cages to the environment was estimated to be 79,740 kg C/km^2. Similarly, the discharge of nitrogen was 3,436 kg N/km^2, and that of phosphorus was 72.2 kg P/km^2. Such values could be used as a basis to estimate carrying capacity of aquaculture with the consideration of circulation characteristics of the region.



<Fig. 1> Annual budget of carbon in the cage culture system