Dynamic Simulation of a Kelp Raft Culture System under Current

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ABSTRACT
Large-scale kelp raft culture system is under combination action of wind, wave and current. The safety and reliability of the facility directly affect the whole aquaculture production. In this paper, the calculation and analysis are based on hanging culture form of a kelp raft culture system. We developed a coupled dynamic model for the system and established a numerical model to describe the culture line deformation and force. The incorporation of culture line flexibility gives more realistic results that can afford a valuable reference for the practical structure design of the aquaculture facility.

KEY WORDS: Raft culture; Kelp; Current; Dynamic.

INTRODUCTION
With the rapid development and increasing scale of marine culture, the inshore development reaching saturation in terms of space, aesthetics and ecological carrying capacity, future expansion will be offshore (Plew, 2005), which makes the raft culture system exposes to complex sea conditions. The safety and reliability of the facility directly affect the whole aquaculture production. Therefore, it is essential to study on the force analysis, the movement characteristic and the resistance to current, wind and waves of the raft culture system. Study about dynamic of culture system and its hydrodynamic impact on the fluid field is quite necessary.

Marine culture system has been the focus of a number of studies. Plew (2005) studied the hydrodynamic effects of large mussel farms based on observations in and around one of the first large mussel farms in New Zealand. Raman-Nair (2008) and Cui (2012) simulated the dynamic of a mussel longline system involves the coupled dynamics of the main line and the attached buoys and mussel culture. In previous numerical simulation research, hydrodynamic forces generated by the culture line usually neglected (Deng, 2010), or simply modeled as rigid cylinders. There is little work in the existing literature describing the flexibility of the culture line. In this paper, the calculation and analysis are based on a hanging culture form kelp raft culture system as is shown in Fig. 1. Considering the flexibility of the hanging kelp and its large deformation under current, a two-dimensional model for the coupling of flow and flexible culture line with hanging kelp is proposed. Previous model developed by Adelrhman(2007) considered vegetation stiffness to be negligible, which cannot describe the actual situation accurately. Luahr and Nepf (2011) modeled the seagrass blades as isolated, buoyant, inextensible elastic beams. Dijkstra and Uittenbogaard (2010) did consider the interaction between flow and vegetation that both are buoyant and had non-negligible stiffness. Which is similar to our model, yet we conduct a more accurate force and motion analysis.

The purpose of the present study is to develop a numerical model that can simulate large deflection of the culture line with hanging kelp on it. With this model, the deformation and forces can be described accurately. Then establish a coupled dynamic model of the main line, buoys, mooring line and culture line with hanging kelp. We calibrate and test the culture line model with existing data from laboratory experiments and compared with previous numerical results. Using the validated model, the motion equations are formulated for the raft culture system, then the analysis of motion characteristic and mooring line force is conducted.

METHODS

Numerical Model for Culture Line
The mathematical model can be used to simulate the flexible vegetation motion under both steady and time-varying flow. To develop this model, we start with a few simplifying assumptions. First, considering the flexibility of vegetation, we modeled the culture line with hanging kelp on it as a series of rigid segments with rectangular cross-sections attached to the main line. The segments were linked together by hinge joints and springs that can transmit forces and moments. Second, the physical properties were assumed constant along the blade. Third, the