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Sea based container culture (SBCC) hydrodynamic design assessment for European lobsters (*Homarus gammarus*)

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ABSTRACT

The presented work describes the hydrodynamic assessment studies of a much needed technical innovation of Sea Based Container Culture (SBCC) as part of a semi-intensive, passive aquaculture culture system for farming the European lobster (*Homarus gammarus*). Factors that are known to influence growth and survival rates were obtained from previous literature, including flow rate, wave energy and motion characteristics; these factors defined performance criteria for SBCC containers.

The internal flow velocities and external flow patterns for different SBCC container designs were measured and used to inform design decisions. Suitable graphical representations have been developed to assess SBCC containers on specific performance criteria. Oyster SBCC containers were found to provide stable motion characteristics but perform poorly against the lower velocity limit, indicating insufficient supply of Dissolved Oxygen (DO) to allow for optimal growth of European lobsters. Internal flow velocities were also measured on un-fouled and fouled SBCC containers; results showed SBCC 2 would not provide enough DO with 66% biofouling coverage (66% biofouling replicates one year deployment) and triggered a redesign. SBCC 1 at 90° yaw angle of attack demonstrated all round good performance against upper and lower velocity limits and motion characteristics; thus showed greatest promise for cultivation of European Lobster.

1. Introduction

The world's population is forecast to rise by one third between 2009 and 2050 (DESA, U.N., 2013). Due to limited agricultural land and growing pressure on exploited marine livestock, aquaculture could increase productivity and contribute to global food security by providing a sustainable food source to feed the growing population. Between 2006 and 2011, captured fishery production increased by only 0.4%; whereas, aquaculture production grew by 34.5% (Mathiesen, 2012). Many species present potential as candidates for aquaculture that are currently unexploited in the sector, a promising candidate being the European Lobster (*Homarus gammarus*) for the following reasons. The demand for European lobster currently exceeds suppy, resulting in high prices across global markets (Drengstig and Bergheim, 2013). Supply is limited to approximately 5000 t per year coming from capture fisheries based mostly in the UK and Ireland (http://www.fao.org/fishery/species/2648/en), though the majority of this is exported. Currently much of the market deficit for lobsters in Europe is met via the import of live American lobster (*Homarus americanus*) (Davies et al., 2014), though there are growing concerns over the potential invasiveness of escapees and inadvertant releases to damage native ecosystems (Van der Meeren et al., 2000, 2010; Jørstad et al., 2007; Stebbing et al., 2012).

Trials in Norway utilising Recirculating Aquaculture Systems (RAS) have recently illustrated the potential for farming lobster to market size (Drengstig and Bergheim, 2013), but there is still a lack of appropriate technological development in RAS design, married to inappropriate economies of scale. In RAS systems difficulties can arise from; maintaining required water quality (temperature, salinity, ammonia and dissolved oxygen), feeding necessities, high capital investment and the labour intensive nature of such systems (Drengstig and Bergheim, 2013). Due to the cannibalistic nature and slow growth rates exhibited by the species, the lobster demands the use of a rearing system that has; individual compartments, is relatively inexpensive to construct and operate, is simple and inexpensive to maintain, is based on non-anthropogenic food supply, is self-cleaning, allows for sufficient feed and water exchange

Abbreviations: AoA, angle of attack; ADV, acoustic doppler velocimeter; DO, dissolved oxygen; SBCC, sea based container culture.

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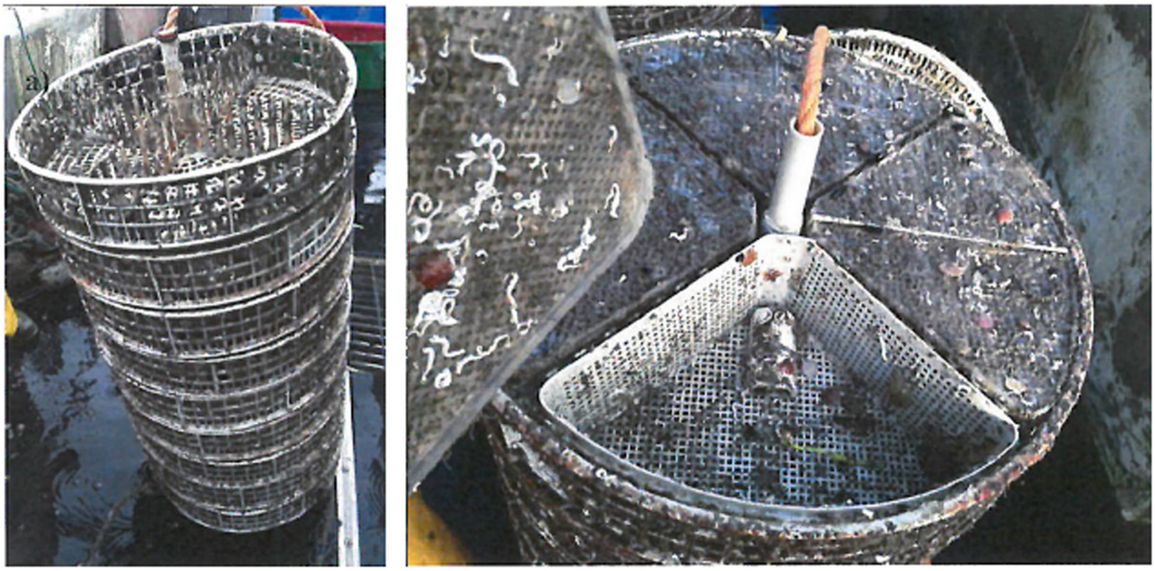

Fig. 1. (A) Stack of Oyster SBCC container tiers. (B) Individual compartments within a given tier.

from naturally occuring sources, enables high stock density production while ensuring optimal growth and survival, and permitting easy access to livestock for inspection (modified from Drengstig and Bergheim, 2013). A potentially viable solution is a Sea Based Container Culture (SBCC) system because water quality and feed is supplied naturally by the sea and, capital investment and labour is minimal in comparison to land based techniques (Uglem et al., 2006; Benavente et al., 2010; Daniels et al., 2015). The feasibility of lobster SBCC systems has been tested using a variety of containers including one originally designed for rearing oyster sprat (Fig. 1; manufactured by Pelegrin Y Manresa, S.L., Alicante, Spain) with good success (Uglem et al., 2006; Benavente et al., 2010; Browne et al., 2011; Daniels et al., 2015). These preliminary studies have established: 1) low energy costs, 2) zero feed costs 3) fixed unit cost of production (compared to an escalating cost against time in land based culture) and 4) good short term survival and growth rates. SBCC systems therefore hold the potential to deliver a low carbon system for sustainable aquaculture, providing a valuable human protein source at minimal unit cost.

A biological literature review, performed prior to this study, identified critical parameters for the growth of the European lobster. The three critical parameters related to the hydrodynamic performance of SBCC systems include (though are not limited to); *flow rate, wave energy* and *motion characteristics* (Burton, 2003; Drengstig and Bergheim, 2013; Galparsoro et al., 2009; Howard and Nunny, 1983; Smith et al., 1999; Uglem et al., 2006). Flow rate is important in providing sufficient oxygen and food as well as removing waste to ensure optimal lobster growth is obtained (Drengstig and Bergheim, 2013, Uglem et al., 2006; Burton, 2003). Flow rates previously reported to be successful for rearing lobster range from 4 L/min (Beal and Chapman, 2001) to 100 L/min (Drengstig and Bergheim, 2013). Wave energy can influence feeding behaviour and growth as well as causing physical damage and potentially mortality (Galparsoro et al., 2009; Howard and Nunny, 1983; Smith et al., 1999). Wave energy sources resulting in velocities in excess of 250 mm/s can inhibit food gathering activity of lobsters and hence should be minimised (Galparsoro et al., 2009). Lobsters also experience stress, or exhibit reduce feeding behaviour if they live in a space that experiences dynamic motion (Galparsoro et al., 2009; Smith et al., 1999).

This paper aims to compare hydrodynamic properties of SBCC designs, to identify the most suitable container for rearing *H. gammarus* based on assessments below:

1a) Measure the internal flow patterns at different flow velocities, angles of attack (AoA) and percentage of biofouling.

1b) Development of a graphical methodology to inform best design configuration, presenting internal flow patterns and, upper and lower velocity limits.

2a) Visualise and assess motion characteristics and severity (only allowing 2D motion; X- and Y-axis) caused by external flow velocities.

2b) Visualise external flow patterns (using dye-tracing method) and identify causes of motion characteristics (visualised in step 2a).

2c) Analyse and rate the SBCC containers based on their motion characteristics towards potential impact of lobster development (from 2a) and recommendation methods to reduce excessive SBCC container motion (from 2b).

2. Materials and methods

The hydrodynamic performance of scaled SBCC containers, designed specifically for lobsters, was evaluated in the current flume based at the University of Exeter, Penryn campus, Cornwall, UK. Scale models were moored in the current flume on a specially designed model-bracket and end plates (Section 2.1). Internal velocities were measured using Acoustic Doppler Velocimetry (ADV) fitted to a traverse system to automate the measurement of flow conditions (Section 2.1.4). 2-D motion characteristics of SBCC containers were visualised by allowing freely rotation in X- and Y-axis coordinates whilst recording the motions (Section 2.1.5). To assess the cause of motion the external flow patterns were visualised using a dye-tracing method (Rathakrishnan, 2007; Section 2.1.5).

2.1. Experimental configuration

2.1.1. Hydrodynamic facility

A hydrodynamic test facility (Fig. 2) comprising of a recirculating water tank (called a current flume) providing controlled input flow velocities was used to measure internal velocities and visualisation external flow patterns. The test section (Fig. 2b) was of 2 m long, 0.6 m wide and 0.6 m deep, with a maximum input flow velocity of