Aquaculture 448 (2015) 186–195

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

Development of sea based container culture for rearing European lobster (*Homarus gammarus*) around South West England

C.L. Daniels [a,*], B. Wills [a,b], M. Ruiz-Perez [a], E. Miles [b], R.W. Wilson [b], D. Boothroyd [a]

[a] The National Lobster Hatchery, Padstow, Cornwall, UK
[b] Biosciences, College of Life and Environmental Sciences, University of Exeter, Exeter, UK

ARTICLE INFO

Article history:
Received 6 October 2014
Received in revised form 18 May 2015
Accepted 19 May 2015
Available online 27 May 2015

Keywords:
Survival
Growth
Environmental factors
Stocking
Aquaculture
South West England

ABSTRACT

This three year field investigation consisted of three discrete experiments, examining six potential sites for rearing the European lobster (*Homarus gammarus*) around the Cornish coast (U.K.). Sea-based container culture (SBCC) systems were deployed, varying site, year, depth, shelter and pre-fouling, to test effects on growth and survival of juvenile *H. gammarus*. Site and depth were examined between May–August 2011 at two sites off the South coast. One estuarine (River Fal: RF) and one sea-based (St. Austell Bay: SA) site were assessed with containers suspended at either 2 or 8 m depth. Greatest survival was found at the SA site (56%) compared to RF (25%), with the greatest growth (specific growth rate: SGR 3%, live weight gain: LWG 0.4 g and carapace length gain: CLG 4.5 mm) also achieved at SA. Depth did not affect juvenile development. Between May and August 2012, one estuarine (Fowey: F) and two sea-based (SA and St. Mawes: SM) sites on the south coast were selected to assess the effect of site and shelter. SM showed the highest survival (93%). Growth and survival were not affected by the presence of a shelter. From August to December 2013, three sites off the north and south coasts were selected to assess the effect of site, depth, pre-fouling and feed availability. Sea-based (Port Quin Bay: PQ, Wave Hub: WH and SA) sites were assessed, with containers submerged at either 3 or 10 m above the sea bed (PQ 7–14 m, WH 42–49 m depth at chart datum). Survival did not significantly differ between sites (61–86%), but growth at the PQ site (LWG 0.7 g; carapace length gain: CLG 6.1 mm) was significantly greater than at all other sites (LWG 0.3–0.4 g; CLG 2.5–3.6 mm). Depth did not affect juvenile development. Pre-fouling reduced growth at all sites. Feed availability varied between sites with PQ showing the greatest taxonomical units. Variations between years were also shown between 2011 and 2013 at the SA site. SBCC systems show potential for culturing *H. gammarus* juveniles compared to hatchery controls (survival ≤46%), acting as a transition step between hatchery rearing and release for stocking purposes. The importance of site selection and between year variations is highlighted as important factors to consider for larger scale assessment of aquaculture potential.

Statement of relevance: This work presents the culmination of three discrete studies between 2011 and 2013 that investigated the use of sea based container culture (SBCC) systems for rearing European lobster (*H. gammarus*) juveniles at various sites around South West England. This is a relatively novel field and the first study of its kind to consider sites around the South West of England and also to quantitatively assess potential feed species. The main findings of this work identify the importance of site selection, deployment and container structure. With an ever increasing demand for protein, there needs to be efforts to relieve pressure on natural fishing stocks. This study not only highlights the potential for SBCC to provide improved stock enhancement processes but also discusses the potential for aquaculture of this currently unexploited species.

Juvenile culture is one of the bottlenecks for the development of lobster culture due to high unit cost of production, high mortality rates due to cannibalism within intensive culture systems and long development times, and as such we feel that this work is extremely timely and relevant. This manuscript will not only contribute to the understanding of how SBCC systems can be employed, but also adds to our understanding of the requirements of the species. Therefore, this work is of significant interest to those involved in the culture of lobsters and marine animals generally.

1. Introduction

The Food and Agriculture Organization of the United Nations (FAO) predicts that the world's human population will increase by 34% by 2050, reaching 9.1 billion (Fisheries and Aquaculture Department, 2010). To feed this increasing population, food production must

Abbreviations: SBCC, Sea Based Container Culture; RF, River Fal; SA, St. Austell; F, Fowey; SM, St. Mawes; PQ, Port Quin Bay; WH, Wave Hub; CL, Carapace Length; LWG, Live Weight Gain; CLG, Carapace Length Gain; SGR, Specific Growth Rate.

* Corresponding author.
E-mail address: carly.daniels@nationallobsterhatchery.co.uk (C.L. Daniels).

http://dx.doi.org/10.1016/j.aquaculture.2015.05.026
0044-8486/

increase by approximately 70% (FAO, 2009). With many capture fisheries under intense pressure and with very little potential for growth, the world must look to aquaculture technologies to help meet the growing global production demands for seafood (World Bank, 2013).

The European lobster, *Homarus gammarus* (L.) is an economically important, high value species with a relatively limited fishery. For many years, lobsters have been reared in hatchery conditions, from larvae through the early juvenile stages of development for stock enhancement, ranching and re-stocking purposes. *H. gammarus* is not currently exploited by the aquaculture sector; and demand exceeds supply, resulting in very high prices across global markets (Drengstig and Bergheim, 2013). Therefore, assessing the potential for commercial scale culture of the species is likely to become an increasingly important priority.

There is currently a lack of appropriate technological development in system design for rearing *H. gammarus*, coupled with inappropriate economies of scale for on-growing economically viable numbers of post-juvenile lobsters in land based systems (Drengstig and Bergheim, 2013). Due to their cannibalistic nature and slow growth rates, the species demands the use of rearing systems that contain individual compartments and maximise production density, that are relatively inexpensive to construct, operate and maintain, and allow for sufficient water exchange and feeding (Drengstig and Bergheim, 2013).

The on-growing of lobsters at sea in individual containers, known as sea-based container culture (SBCC) has produced good survival and growth rates (Beal, 2009, 2012; Beal and Protopopescu, 2012; Beal et al., 2002; Browne et al., 2011; Knudsen and Tveite, 1999; Perez-Benavente et al., 2010). SBCC provides low energy costs, zero feed costs and a fixed unit cost of production (compared to an escalating cost against time in land based culture). Lobsters reared in SBCC systems are likely to receive behavioural enrichment due to variable biological, chemical and physical parameters that they are continuously exposed to. This is particularly important for individuals destined for release as part of stock enhancement, ranching or re-stocking efforts. Preliminary trials have indicated that lobster juveniles cultured in submerged containers in coastal waters are able to utilize naturally occurring organisms growing in/on the containers and zooplankton moving through the containers in order to sustain growth and survival (Beal, 2012; Perez-Benavente et al., 2010). Field experiments using SBCC systems specifically designed to rear oyster spat, have shown potential in lobster rearing trials (Browne et al., 2011; Perez-Benavente et al., 2010; Uglem et al., 2006). Perez-Benavente et al. (2010) deployed oyster spat SBCC systems for 6–14 months off the coast of Spain and at three locations off the Irish coast, using either suspended, or ground based mooring systems. This study reported lobster survival rates of up to 89% in ~6 months and total length (length from the tip of the rostrum to the end of the tail) of 40–50 mm (Perez-Benavente et al., 2010) equivalent to ~10.2–12.8 mm carapace length in ~8 months. Uglem et al. (2006) also reported on the use of oyster spat containers in Galicia, Spain for rearing *H. gammarus* showing survival rates of between 75% and 89% with individuals attaining a total length >40 mm (equivalent to 10.2 mm carapace length) in trials up to 250 days (~8.5 months). Though, it is apparent that variation in the success of SBCC appears site and container specific (Beal and Protopopescu, 2012; Beal et al., 2002).

The present three year study aimed to assess six potential sites for the deployment of SBCC systems around the South West of England, examining different variables at various sites, that may cause disparity in survival and growth of juvenile European lobster. Variables include: depth, temperature, light, feed availability, shelter presence, pre-fouling of containers and mooring systems.

2. Materials and methods

2.1. Rearing stage I larvae–stage V post-larvae

The National Lobster Hatchery (NLH) in Padstow (Cornwall, UK) provided post-larval stage V *H. gammarus* for the trials. Lobsters were collected from a mixed broodstock origin and grown communally, in 80 L conical larval vessels, to stage IV (following Daniels et al., 2010). When lobsters reached stage IV (at approximately 20 days) they were transferred into the juvenile Aquahive™ system (Shellfish aquaculture systems Ltd.). Lobsters were kept in the Aquahive™ until they reached stage V, taking a further 10–14 days. During this period the larvae and post-larvae received a diet of frozen copepod *Calanus* spp. Stage V lobsters were then transferred into SBCC systems when required.

2.2. Hatchery controls

Hatchery control (H) animals ($n = 33$ experiment^{-1}) were held in the individual compartments from the SBCC systems and held in raceways at the NLH. Lobsters were fed daily on a formulated pellet developed specifically for lobsters (National Lobster Hatchery, Cornwall, UK, formula not disclosed).

2.3. Sea based container culture (SBCC) systems

The containers used in this study were oyster spat rearing baskets arranged in tiers (Fig. 1a). Tiers can be stacked as high as desired, though in the present experiment 7–8 tiers were employed (see Table 1 for experiment specifics). Each tier contained four individual compartments with a 2.5×2.5 mm internal mesh size (Fig. 1b). Elastic bands were placed around each compartment to further secure the lid. Each lobster was kept individually within their compartment. Compartments were labelled to allow rapid monitoring of individuals. Tiers were secured together in stacks using bungee cord and rope.

2.4. Mooring system

Three mooring designs, depicted in Fig. 2, were examined for their suitability to either suspend or float SBCC systems from. All systems provided the ability to test positioning (depth) of SBCC within the water column. Mooring system a (Fig. 2a) suspended multiple SBCC systems at a distance of 2 m apart from the pre-existing horizontal ropes (long lines) or structures. Vertical rope and marker buoy systems marked and supported the lone line systems. At sites where no existing structure was available mooring systems b and c were assessed. Mooring system b (Fig. 2b) was designed to allow the suspension of individual stacks, with each mooring being placed approximately 10 m apart to prevent entanglement with each other and other static gear in severe weather. Mooring system c (Fig. 2c) floated multiple SBCC systems at a distance of 20 m apart from a ground line marked by vertical end lines and buoys. Specifics of mooring systems evaluated in individual experiments are detailed in Table 1.

2.5. Site selection

Each site (Fig. 1c) was purposely chosen to investigate the effect that varying environmental conditions may have on the growth and survival of SBCC reared lobsters. Experiments were carried out between 2011 and 2013 (see Table 1 for exact dates).

2.5.1. St. Austell Bay 50° 18.956 N, 4°44.063 W

SBCC systems were suspended (2011–2013) from the pre-existing static mussel ropes owned by Westcountry Mussels of Fowey (using mooring system a — Fig. 2a). St. Austell Bay (SA) is an exposed site approximately two miles offshore from Par docks. The SA site is 16 m deep (chart datum) and has a 4.7 m tidal range.

2.5.2. River Fal 50°12.880 N 5°01.652 W

The River Fal (RF) is a submerged river valley or ria containing deep water channels up to 18 km inland. SBCC systems were suspended (2011) from pre-existing static mussel ropes owned by Westcountry Mussels of Fowey (using mooring system a — Fig. 2a) in the King