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Training camp—A way to improve survival in European lobster juveniles?

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ABSTRACT

A series of experiments was conducted to test if keeping hatchery-produced European lobster juveniles (*Homarus gammarus*) in an enriched environment with substrate and shelter would improve anti-predator behaviour and survival in a competition setting. Newly hatched postlarvae (stage IV) were divided into two treatments. Naïve postlarvae were raised in single compartments, while trained postlarvae were released communally into tanks with substrate and shelter, allowing for developing burrowing and shelter-seeking behaviour and interactions with conspecifics. The duration of the treatment lasted 181 days in 2007/2008 and 226 days in 2008/2009. In the second experiment, 4-mo old juveniles were purchased from a commercial hatchery and divided into the same two treatment groups. The treatments were considerably shorter, lasting 47 days. At the end of the treatment period an equal number of juveniles from each treatment was released into experimental units with substrate and shelter i.e. semi-natural system for a period of 91–145 days. Number of shelters was half the total number of juveniles to induce competition for shelters. In both experiments, trained juveniles occupied more shelters and had higher survival than naïve juveniles. Combining all experiments, average survival was 53% in trained lobsters compared with 18% in the naïve lobsters. These results are the first to demonstrate that enriching the hatchery environment for a period of time (a minimum of 47 days here) while rearing European lobster juveniles increased their shelter occupancy and their survival compared to naïve juveniles the same size and age. Survival rates were 3–4 times higher in trained compared to naïve lobsters after 145 days.

1. Introduction

Efforts to increase recruitment to the fisheries by releasing hatchery-produced juvenile fish or invertebrates have been made for more than 150 years (Munro and Bell, 1997; Nicosia and Lavalli, 1999; Bell et al., 2005). Japan and China have the longest experience, and have to a certain degree also documented success (Uki, 2006; Hamasaki and Kitada, 2006; Wang et al., 2006). In northern Europe, several release programs have focused on the European lobster (*Homarus gammarus*) (Latrouite and Lorec, 1991; Addison and Bannister, 1994; Cook 1995; Agnalt et al., 2004; Schmalenbach et al., 2011). In Norway, hatchery-produced lobster juveniles released over a period of 5 years and monitoring the fishery for 10 years resulted in an overall recapture of 6.2%, ranging from 3.6 to 9.1%, for the various year classes (Agnalt et al., 2004). This is rather high compared with many other release programs, but Borthen et al. (1999) made an economical analysis on these data and concluded that the recapture rate must be higher than 14% to break-even. This is also in accordance with economic estimates by Moksness et al. (1998).

A major limitation in the Norwegian release experiment was predation immediately after release (van der Meeren, 2000), as also reported in other release programs (e.g. Castro et al., 2001; Daly et al., 2013). In the production of lobster for release purposes, the juveniles are reared individually from the time of settling; i.e. stage IV/postlarvae in plastic boxes with perforated floor (Grimsen et al., 1987). These boxes are bare, except for shell parts or coarse-grained sand in stage V–VII to induce claw development (Govind and Pearce, 1989; Korsøen, 1994). The rearing method provides very few environmental stimuluses, and if and how this affects behaviour is still unknown. Rearing lobster communally, i.e. in open tanks in relatively high numbers with a surplus of food and shelter, offers a more complex set of stimuli. A range of bottom substrates have been tested, from cobble of different sizes to oyster shells and PVC tubes (van Olst et al., 1975; Linnane et al., 2000; Jørstad et al., 2001). The most common method is to use one type of substrate,

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while Jørstad et al. (2001) tested a combination of shell sand supplied with a variety of shelters. Stage IV (postlarvae) released into such complex environment reached sizes comparable to individual rearing and with survival rates of 30–60%, after 4–5 months.

Enhancing behaviour skills like shelter seeking and occupancy as well as social interactions in lobster has not yet been fully explored. Berril (1974) found that burrowing behaviour was based on instincts in newly-settled European lobster. Wickins and Barry (1996) found some evidence of learning or behavioural adaptation. More experiments are needed to look specifically at the physical environment in the hatchery, combined with shelter and predator/prey training (Brown and Day, 2002; Svåsand, 2004; Huntingford, 2004). In this study, we aimed to assess if exposure to substrate and shelter, as well as conspecifics, in the nursery phase can enhance the performance of European lobster juveniles ready-to-be released. We predicted that a training period would enhance shelter occupancy, as well as increase survival compared to naïve juveniles.

2. Material and methods

2.1. Training from postlarvae

2.1.1. Production of postlarvae

The experiment took place at the Institute of Marine Research (IMR) field station at Parisvatnet, Øygarden, located outside Bergen (60°37′N, 4°48′E). Ovigerous females were kept in units (70 × 40 × 25 cm) until hatching. Newly hatched larvae were collected every morning, counted and transferred to 40 l upstream incubators (plankton Kreisler, Hughes et al., 1974). The incubators were supplied with aerated sea water at 18–19 °C, 10 l min^{-1}. The larvae were fed daily with frozen *Artemia* sp. and frozen krill (*Euphasiidae* sp.). Maximum density for each incubator was set to 50 larvae l^{-1}. The larvae were staged I–IV, according to Sars (1875). The larval stages I–IV are pelagic, but towards the end of stage IV, the postlarvae larvae will settle, and in the wild find suitable substrate for settling. The larvae reached stage IV after 12–14 days.

2.1.2. Treatment

Postlarvae were separated into two treatment groups. One treatment group was raised individually in single-compartments (Fig. 1a); naïve I. The other treatment group was released into tanks (2 × 2 m) where the bottom was covered with 2–3 cm shell sand and shelters (empty valves of scallop) (Fig. 1b); trained. We defined this as enriched environment. The tanks were supplied with filtered ambient sea water. The water depth in the tanks was approximately one meter. It took a few days after the treatment started before the postlarvae settled in the single compartments and in the tanks. The juveniles were fed frozen krill *Euphausia* spp. The first treatment period started 1.7.2007 and ended 11.2.2008 (226 days) and the second treatment period started 11.8.2008 and ended 7.2.2009 (181 days). At the end of the treatment period, carapace length (CL), measured from the anterior part of the orbit to the posterior part of the carapace, was recorded in all juveniles to closest 0.1 mm below with a calliper. Lobster from the two treatment groups were tagged with visible implant elastomer tags (VIE; Northwest Marine Technology Inc) of different colours. The individuals were kept in single-compartment cells for 1–7 days to check for mortality due to the tagging. No mortality was observed. The temperature during the first treatment period was 13.5 ± 1.5 °C during the first 30 days, thereafter slowly decreasing to 5–6 °C at day 140 and was stable at that temperature towards the end. In the second treatment, average temperature the first 30 days was 16.2 ± 0.5 °C, slowly decreased to 8 °C at day 100 and decreased further to 5 °C, and remained such towards the end.

2.1.3. Test arena

Sheltering was defined as an anti-predator mechanism, hence we chose to let the juveniles compete for shelter in a competition arena. We set up four trials, 1–4. Trial 1–2 after the first treatment period and trial 3–4 after the second. In all trials, the juveniles were released into tanks (2 × 2 m; similar to what was used during training treatment and supplied ambient water), bottom covered with 2–3 cm shell sand and shelters (empty valves of scallop). The juveniles were fed frozen krill *Euphausia* spp in excess. In trial 1–2, 20 juveniles of each treatment group (n = 40) were released with 20 shelters. The experiment started 15.2.2008 and ended 15.5.2008 (91 days). In trial 3–4, 40 juveniles of each treatment group were released (n = 80), competing for 40 shelters. These experiments started 11.2.2009 and ended 18.6.2009 (128 days). At the start of the trials, there were no significant differences in carapace length between the treatment groups in trial 1–2 (ANOVA, $p > 0.05$) and trial 3–4 (ANOVA, $p > 0.05$). Number of juveniles of each treatment group (naïve and trained) that were found outside shelter, and burrowing activity (seen as piles of sand at the entrances to the shelter) were recorded regularly. At the end of the trials, the number of juveniles of each treatment group outside and within shelter was recorded. One juvenile in trial 1–2 and one in trial 3–4 had lost their elastomer tag at the end of experiment. These two could not be allocated to either treatment and were omitted from further analysis.

2.2. Short-term training of juveniles

2.2.1. Treatment

900 ready-to-be-released juveniles were purchased from Norwegian Lobster Farm AS (NLF) at Kvitsøy, Rogaland (59°24′09″N 05°24′09″E) (www.norwegian-lobster-farm.com). The juveniles were approximately four months old, mean CL = 8.93 ± 0.87 mm, n = 155. They were hatched and on-grown at 19–21 °C, in single-celled compartments deprived of stimuli as substrate and shelter. The juveniles were divided into two treatment groups, naïve and trained. About half of the naïve juveniles were kept in single compartments similar to experiments described in Section 2.1, at ambient temperature of 12 °C (naïve I). The other group was kept in their original single compartments, at temperature 19–21 °C (naïve II). The training treatment was made at the site of NLF in eight flow-through tanks (1 × 1 m), with ambient water temperature at about 12 °C. The bottom of the tanks was covered with 2–3 cm shell sand. 56 juveniles were released into each tank, with 56 shelters available (empty valves of scallop and oyster). The juveniles were fed dry pellets patented by NLF, twice a week. The training started 8.10.2009 and ended 23.11.2009 (47 days).

2.2.2. Test arena

For this experiment we decided to move from a tank-system to a semi-natural system in a lobster holding park facility at Kvitsøy, in the vicinity of NLF. Historically, the park was a holding facility for commercially captured lobster, a rectangular building partly submerged in the intertidal zone with water exchange at each short side. Two meshed netting enclosures of 12 m^2 (3 × 4 m) were placed at 2.0–2.5 m depth in the lobster park (Trial 5–6). The netting reached above the water surface and was attached with ropes to the park ceiling. 26 scallop baskets (60 × 60 cm) were set on the bottom of the enclosures, with 2–3 cm shell sand (Boston AS). In each enclosure, 260 shelters (empty valves of great scallop and oyster) were added. The enclosures were set up on 8 October 2009 allowing the system to be established before the experiment started.

In preparation for the experiment, we noted that the juveniles in the naïve II treatment were in general in a poorer condition than naïve I. We decided to treat the two naïve groups as two separate treatments. Naïve II was given two days to acclimatize to the same

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