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A regional development strategy for stock enhancement of clawed lobsters (*Homarus gammarus*)

Development of juvenile lobster production methodologies

Ingebrigt Uglem
Gonzalo Perez Benavente
Ronan Browne

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CONTACT DETAILS

NINA Trondheim
NO-7485 Trondheim
NORWAY
Phone: +47 73 80 14 00
Fax: +47 73 80 14 01

NINA Oslo
Postboks 736 Sentrum
NO-0105 Oslo
NORWAY
Phone:+47 73 80 14 00
Fax: +47 22 33 11 01

NINA Tromsø
Polarmiljøsenteret
NO-9296 Tromsø
NORWAY
Phone: +47 77 75 04 00
Fax: +47 77 75 04 01

NINA Lillehammer
Fakkelgården
NO-2624 Lillehammer
NORWAY
Phone: +47 73 80 14 00
Fax: +47 61 22 22 15

http://www.nina.no

Abstract

Uglem, I., Perez Benavente, G. and Browne R. A regional development strategy for stock enhancement of clawed lobsters (*Homarus gammarus*); development of juvenile lobster production methodologies. NINA Report no. 211, 39 pp.

European lobsters (*Homarus gammarus*) are a highly prized and gastronomically appreciated marine organism. As a result of intense fishing pressure lobster landings have declined considerably in many European regions. This decrease has been particularly dramatic in the southern and northern areas of Europe. Releases of artificially raised lobster juveniles have been shown to have the potential to contribute to re-establishment or enhancement of depleted lobster stocks. However, one of the key problems for successful stock enhancement has been the lack of cost effective methodologies for producing juveniles.

After the planktonic stage of their life cycle, the total length of the European lobster ranges from 1.5 to 2 cm. These small early benthic stage animals are extremely vulnerable to predation if released directly into the sea. For this reason it is thought important to rear the lobsters to a length of at least 4 to 5 cm before they are released into the wild in an effort to increase their chances of survival. The purpose of this project was to develop and improve existing methodologies used to produce viable lobster juveniles that are fit for release into the wild.

This project was a part of the AquaReg programme within the framework of the Community initiative programme INTERREG IIIC and it began in 2004. The methodologies used both in the hatchery setting and field were based on rearing the juveniles from metamorphosis until a suitable size for release either in individual compartments suspended from mussel rafts (sea cages or baskets) or communally in natural seawater. Both of these culture techniques involved the postlarval lobsters feeding on naturally occurring plankton and epibiotic fouling organisms. The results demonstrate that survival to a size suitable for release is high when rearing lobsters in suspended baskets (oyster cages). The lobsters also grew well both in sea cage based culture and in communal rearing, despite the fact that lobsters cultured in submerged cages in the open sea were not fed artificial feed during the course of the study.

The methodologies developed represents a cost-effective way of producing lobster juveniles for re-establishment or enhancement efforts, since labour expense, constructions and feeding costs are minimized and the production efficiency is high.

Ingebrigt Uglem, Norwegian Institute for Nature Reserach, Tungasletta 2, N-7485 Trondheim, Norway. Email: ingebrigt.uglem@nina.no

Gonzalo Pérez Benavente, Instituto Galego de Formación en Acuicultura. Niño do Corvo s/n, 36616 Illa de Arousa, Pontevedra-Spain. Email: gonzalo.perez.benavente@xunta.es

Ronan Browne, MRI Carna Laboratories, National University of Ireland Galway. Currently – Carna Co. Galway. Ireland, Email: browne.ronan@gmail.com

Resumen

Uglem, I., Perez Benavente, G. y Browne R. Estrategia para el desarrollo regional de la repoblación de bogavante (*Homarus gammarus*): desarrollo de la metodología de producción de juveniles. Informe de NINA nº 211, 39 pp.

El bogavante (*Homarus gammarus*) es un organismo marino muy apreciado y gastronómicamente valorado. En las últimas décadas, las capturas de bogavante han disminuido de modo considerable en muchas regiones europeas debido a la fuerte presión pesquera. Esta disminución quizás ha sido especialmente acusada en las zonas del norte y del sur de Europa. Las sueltas de juveniles de bogavante criados en cautividad han mostrado su potencial para potencialmente, contribuir al restablecimiento o mejora de los disminuidos stocks regionales de bogavante. Sin embargo, uno de los problemas clave en este contexto es la falta de una metodología eficaz para la producción de juveniles.

Tras la fase planctónica de su ciclo vital, la longitud total del bogavante oscila entre 1,5 y 2 cm. En su primera fase bentónica, estos pequeños animales son extremadamente vulnerables a la predación si se sueltan directamente al mar. Por ello, si se quiere aumentar sus probabilidades de supervivencia, se cree que es importante criar a los bogavantes hasta que alcancen una longitud de 4-5 cm antes de soltarlos. El propósito de este proyecto ha sido desarrollar y mejorar las metodologías existentes para la producción de juveniles de bogavante viables que sean aptos para su suelta al medio natural.

El proyecto formaba parte del programa AquaReg, dentro del marco del programa de iniciativa comunitaria INTERREG IIIC, y comenzó en el 2004. Las metodologías empleadas, tanto en la instalación del criadero como en el exterior, están basadas en la cría de juveniles desde la metamorfosis hasta una talla adecuada para la suelta, ya sea en compartimentos individuales suspendidos de una batea mejillonera (cajas o cestillos ostrícolas) o comunalmente en agua de mar no tratada. Ambas técnicas de cultivo implicaban la alimentación de la postlarvas de bogavante a partir del plancton natural o de los epibiontes. Los resultados demuestran que cuando los bogavantes se crían en cestillos ostrícolas suspendidos la supervivencia hasta tamaño adecuado para la suelta es elevada. Los bogavantes también crecieron bien tanto cuando se criaron en cajas en el mar como cuando se hizo comunalmente, a pesar de que los bogavantes criados en las cajas sumergidas en el mar no fueron alimentados a lo largo del estudio.

Las metodologías desarrolladas suponen un modo rentable de producir juveniles de bogavante cuando se pretende el restablecimiento o mejora de stocks, ya que se reducen los gastos en mano de obra y los costes de construcción y alimentación, siendo por tanto la eficiencia de producción alta.

Ingebrigt Uglem, Norwegian Institute for Nature Reserach, Tungasletta 2, N-7485 Trondheim, Norway. Email: ingebrigt.uglem@nina.no

Gonzalo Pérez Benavente, Instituto Galego de Formación en Acuicultura. Niño do Corvo s/n, 36616 Illa de Arousa, Pontevedra-Spain. Email: gonzalo.perez.benavente@xunta.es

Ronan Browne, MRI Carna Laboratories, National University of Ireland Galway. Currently - Carna Co. Galway, Ireland. Email: browne.ronan@gmail.com

Contents

Foreword

This report summarises the results from a project under the AquaReg programme within the framework of the Community initiative programme INTERREG IIIC. AquaReg involves a co-operation between the regions of Galicia in Spain represented by the CETMAR Foundation, Border, Midland and Western (BMW) region in Ireland represented by The Marine Institute and Trøndelag in Norway represented by joint forces of the South Trøndelag and North Trøndelag counties. The overall objective of AquaReg was to provide opportunities and design strategies for sustainable development of peripheral coastal communities by promotion of interregional co-operation in aquaculture and fisheries. The rationale behind AquaReg was to make more efficient use of the experience and knowledge of aquaculturists, fishermen and scientists, across regional and national borders. In the current project this has been done to develop cost effective and improved technology for production of lobster juveniles. This will be important for a future activities related to re-establishment of endangered lobster populations and for enhancement of overexploited stocks.

We would like to thank the staff at the three participating institutions and the AquaReg administration for an excellent collaboration during the project. We would also like to acknowledge the staffs at the IGaFA and MRI Carna, which have assisted in establishing the hatcheries and the running of a workshop. In addition we would like to thank the participants at the introductionary planning workshop held in Carna, BMW, Ireland in 2004 for their help in designing the project and developing a functional culture methodology. A special thanks goes to Dr. Brian Beal for valuable comments on the manuscript of this report. Finally, but not least, we would like to thank the regional leaders of AquaReg (Geir Tevassvold, Alan Drum and Gabriel Labra) for their patience and help with the administrative matters of the project.

08.12.06, Illa de Arousa, Galicia, Spain
Gonzalo Perez Benavente
Project leader

Prólogo

Este informe resume los resultados del proyecto realizado bajo el programa AquaReg, dentro del marco del programa de iniciativa comunitaria INTERREG IIIC. AquaReg es una cooperación entre las regiones de Galicia (España), representada por la fundación CETMAR, Border, Midland and Western (BMW, Irlanda), representada por The Marine Institute y Trøndelag (Noruega), representada por la unión de los condados de Trøndelag Sur y Trøndelag Norte. El objetivo global de AquaReg ha sido proporcionar oportunidades y diseñar estrategias para el desarrollo sostenible de las comunidades costeras periféricas mediante la promoción de la cooperación interregional en acuicultura y pesca. La lógica de AquaReg ha sido hacer un uso más eficiente de la experiencia y los conocimientos de los acuicultores, pescadores y científicos, a través de fronteras nacionales y regionales. En este proyecto, esto se ha utilizado para desarrollar una tecnología mejor y más rentable para la producción de juveniles de bogavante. Esto será importante para futuras acciones relacionadas con el restablecimiento de poblaciones de bogavante en peligro y con la mejora de los stocks sobreexplotados.

Nos gustaría dar las gracias al personal de las tres instituciones participantes y de la dirección de Aquareg por su excelente colaboración durante el desarrollo del proyecto. También nos gustaría agradecer al personal del IGaFA y del MRI Carna por su ayuda en la puesta en marcha del criadero y la organización del workshop. Además, nos gustaría agradecer a los participantes en el workshop introductorio de planificación que tuvo lugar en Carna, BMW, Irlanda en el 2004 su ayuda en el diseño del proyecto y en el desarrollo de una metodología de cultivo funcional. Agradecemos especialmente al Dr. Brian Beal sus valiosos comentarios realizados sobre el manuscrito de este informe.El doctor Brian Beal realizó la lectura crítica de este informe y sus comentarios y sugerencias sirvieron para mejorarlo, por lo que le estamos agradecidos. Por último, nos gustaría dar las gracias a los líderes regionales de AquaReg (Geir Tevassvold, Alan Drum y Gabriel de Labra) por su paciencia y ayuda con la parte administrativa del proyecto.

08.12.06, Illa de Arousa, Galicia, España
Gonzalo Pérez Benavente
Coordinador del participante líder del proyecto.

1 Background

The European clawed lobster fishery (*Homarus gammarus*) is a valuable resource for many coastal communities. As a result of the demand for lobsters there has been a prolonged and extensive exploitation of the lobster populations throughout its European distribution. Historically the recorded landings of clawed lobsters have exhibited clear signs of overexploitation with declines in catch per unit effort and reductions in total landings in many European countries. Therefore the fishery management practices employed and their enforcement have not proved to be successful.

During the last few decades considerable work has been carried out in North America and European countries such as, Norway and Ireland, aimed at developing techniques for juvenile production for stock enhancement purposes (reviewed in Nicosia & Lavalli 1999). In Norway this work has demonstrated that restocking through releases of cultured juveniles has the potential to be a viable management option in some locations.

For the purposes of this report it is important to define the terms “reestablishment”, “enhancement” and “sea ranching”. Reestablishment involves that endangered local lobsters populations are restored by releasing artificially produced juveniles in the affected areas. Enhancement involves that overexploited lobster populations are augmented to a self sustaining and economically viable level by releases of hatchery reared lobsters. Finally, sea ranching involves that recapture of hatchery reared juveniles in itself will entail an economic profit. The potential for an economical viable sea ranching of lobsters has been investigated, but hitherto the recapture rates have been too low for development of a commercial sea industry. In the project reported here, the main aim was to develop and establish suitable juvenile production methodologies for reestablishment and enhancement.

A major bottleneck encountered for successful large-scale reestablishment or enhancement of lobster populations is the high production costs of juvenile lobsters. It has been possible to produce large quantities of post-larval (Stage IV) lobsters in a reliable and cost-effective manner (e.g. Browne & Mercer 1998, Beal & Chapman 2001). However, ongrowing from the first post-larval stage (IV) and to a juvenile size which would be optimal for release has involved high costs.

Post-larval (stage V to VI) European lobsters are only 1.5 to 2 cm long and they are extremely vulnerable to predation when released directly into the sea. For this reason it is important to rear the lobsters until a larger size before they are released to increase their chances of survival (Beal et al. 2002).

High juvenile production costs have primarily been caused by the need to culture the lobsters in individual compartments after metamorphosis, as cannibalism is common during this phase. Individual culture of lobster juveniles has typically involved construction of technically advanced land based systems. Such land based lobster hatcheries have involved elaborate technical solutions for keeping the animals in single compartments and for feeding the juveniles in a fast and effective manner (Richards & Wickins 1979, Grimsen et al 1987, Burton 1991, Uglem et al. 1998). In addition, artificial heating of the water has been necessary to achieve high growth rates. All of these capital and labour costs have resulted in high production costs.

Another important impediment for large-scale reestablishment or stock enhancement has been variable recapture rates (Nicosia & Lavalli 1999). In some cases the recorded recaptures have been close to zero, while in other studies the recapture rates have been high (>20%, Uglem personal observation). In a research programme aimed at studying the feasibility of lobster releases for enhancement purposes in Norway the final recapture rate approximately ten years after release was estimated to be around 8% (Agnalt et al., 1999). A critical cause of mortality in released hatchery-reared lobster juveniles is believed to be predation immediately after release to the sea (van der Meeren 2000). Poor survival after release might partly be ascribed to

their sub-optimal anti-predator behaviour. This may be as a result of the normal juvenile behaviour being subdued in artificial rearing conditions (Svåsand et al. 1998). Therefore a reason for the low recapture rates of hatchery-reared lobsters could be that earlier culture efforts have been aimed at production instead of animals “designed” for a life in the sea.

Fishing pressure on lobster populations is unlikely to decrease in the future and there is a need for information on the development of functional mitigation actions to maintain and develop a commercial lobster fishery in Europe. One of the key areas in this context is improvement of the lobster culture methods not only with respect to costs but also with respect to juvenile quality. In this perspective, interregional and international collaboration and technology/knowledge transfer at an operational level are important for success.

2 Objectives and project outline

The lobster population in Galicia is characterised as being depleted. The annual recorded lobster landings are around two metric tons. Fishing is an important indigenous industry in Galicia and re-establishment of a sustainable lobster fishery would be a significant contribution to the local economy. The lobster population in Trøndelag has also experienced a significant decline in recorded lobster catches and the establishment of effective culture methods for juvenile production for restocking purposes is seen as a potentially valuable population management tool. A key policy for the success of this project was the exchange of existing expertise, knowledge and technologies regarding lobster culture/restocking. It is believed that what is learnt will have benefits for the three regions and potentially on a European scale.

A goal of this project was to refine the methods for production of lobster juveniles by an active collaboration between research and training institutions in the regions. This was done by initially establishing a demonstration lobster hatchery at the MRI Carna Laboratory Ireland and the organisation of a workshop to discuss issues related to lobster stack enhancement. Subsequently, a pilot scale lobster production line at IGAFA, with the purpose of refining, improving and adapting the existing techniques for lobster culture, was established. In this report the results and experiences obtained during the course of the project are described. This knowledge has then been used to suggest and to discuss overall guidelines for development of regional lobster restocking strategies. Another objective of this project was to generate a network across the three regions for i) mutual exchange of knowledge and technology, and ii) development of future activities with the objective of restocking depleted populations and establishment of local lobster industries in the three regions.

2.1 Objectives

The main objective of the project was to develop information on improved juvenile production methods with respect to costs and quality of lobsters and to suggest guidelines for development of regional lobster restocking through interregional collaboration, exchange of knowledge and transfer of technology. The sub-goals were:

1. To establish a pilot scale lobster production line at IGaFA, Galicia, for operational transfer of knowledge and technology.
2. To improve and refine ongrowing methods for juvenile lobster.
3. To evaluate and suggest guidelines for development of regional lobster re-establishment and enhancement.
4. To generate an information exchange network across the three regions for i) mutual exchange of knowledge and technology, and ii) development of future activities aimed at restocking depleted populations and establishment of localised lobster industries in the three regions.

3 Construction of a small scale hatchery

In order to efficiently transfer knowledge and expertise between the regions a demonstration hatchery was established at the MRI Carna. Subsequently a small scale lobster hatchery was built at IGaFa, Galicia, Spain to improve on ongrowing methodologies. The hatcheries were constructed for production of post-larval lobsters, i.e. for culturing the lobsters from hatching, through the first three pelagic larval stages and until the first benthic stage (Stage IV). In this section the hatchery system is described and discussed. The larval rearing procedures and the results from the further ongrowing trials will be reported in subsequent sections. The hatchery technology used in the current project was developed in the US and Ireland, and has previously been successfully applied in both countries (Browne & Mercer 1998, Beal & Chapman 2001).

3.1 Hatchery system description

Production of post-larval lobster includes the following steps: 1) storage of egg-bearing females until hatching, 2) hatching of larvae and 3) larval culture.

Storage of egg-bearing females

Egg-bearing female lobsters were purchased from local fishermen and transported to the hatchery in oxygenated transport tanks that were filled with ambient seawater. Upon arrival at the hatchery the lobsters were transferred into indoor storage tanks (60 l) with continuous exchange of water (2 l per min) (Figure 1). The tanks were covered with a mesh which prevented the lobsters from escaping.

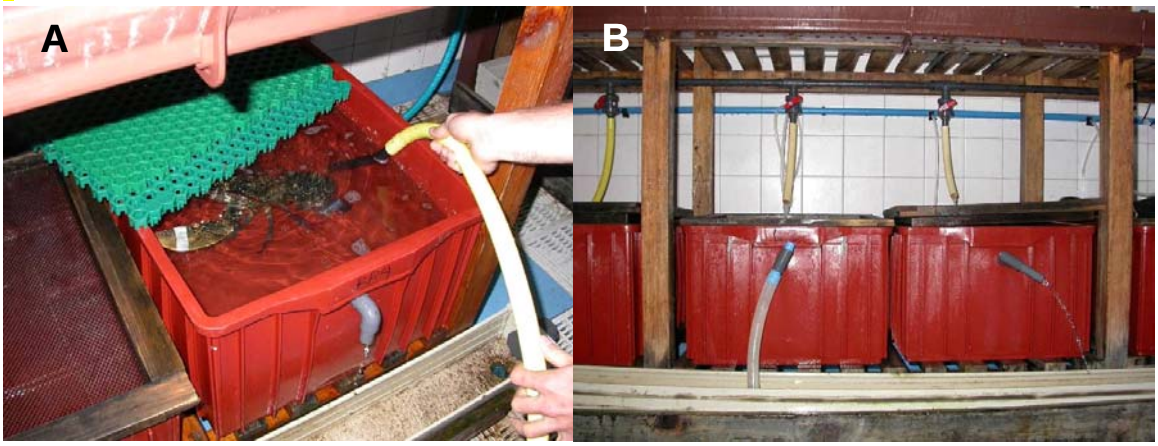

Figure 1. *Storage tanks for egg-bearing females.*

Hatching of larvae

When eggs on the egg-bearing females were adjudged ready to hatch the lobsters were transferred into cylindrical tanks of MDPE (height: 63.6 cm, diameter 53.8 cm, volume 130 l) (Figure 2). The hatching tanks were moderately aerated. Air was supplied to the hatching units from an air blower (low pressure 37 kW blower) and one air hose equipped with a large airstone. The two hatching tanks used in the current project were placed inside the hatchery building (see below).

***Figure 2**. Hatching tank with newly hatched larvae see from above*

Larval culture

Culture of larval lobster requires maintenance of good hygiene and isolation from other aquaculture activities to prevent introduction of pathogens and sub-optimal water quality. For this reason a separate hatchery building (a portable cabin) was established (Figure 3 A & C). The cabin (length: 6 m, width: 2.5 m, height: 2.2 m, area 15 m^2) was equipped with an air condition system (specifications) which was regulated by a thermostat in order to maintain the air temperature between 18 and 20 ºC. The floor of the container consisted of waterproof plywood covered by epoxy paint and it was sloped towards the water outlet which was positioned in one of the corners (Figure 3D).

Air, seawater and freshwater were supplied in separate pipes as indicated in figure 3B. The seawater was mechanically filtered by two cartridge filters (POLYKLEAN 19" nominal filtration 10µm and 5µm positioned on the outside of the hatchery and in addition UV-treated (P2-110W7000-55 Commercial UV Sterilizer) before being used for larvae culture. A working table (Figure 3B) with a sink with a fresh water tap was placed along the hatchery wall. Six cylindro-conical hoppers (volume 90 l, inner upper diameter: 35 cm) were placed on 73 cm high tables, constructed of waterproof plywood, on the other sides of the container (3B). The hoppers were covered by transparent lids (methacrylate) to prevent that water aerosol was transferred between the tanks. Two hatching tanks and one tank for disinfection of equipment were also positioned in the hatchery as indicated in figure 3B. Moreover, two larger polyethylene tanks (height: 102.6 cm, diameter 64.7 cm, volume 320 l) each supplied with a thermostat controlled water heater (titanium, 300 W) was placed adjacent the hoppers for pre-heating the filtered/UV-treated seawater to 18-20 ºC before it was used for larvae culture. A footbath for disinfection of boots when entering the hatchery was positioned in front of the door.

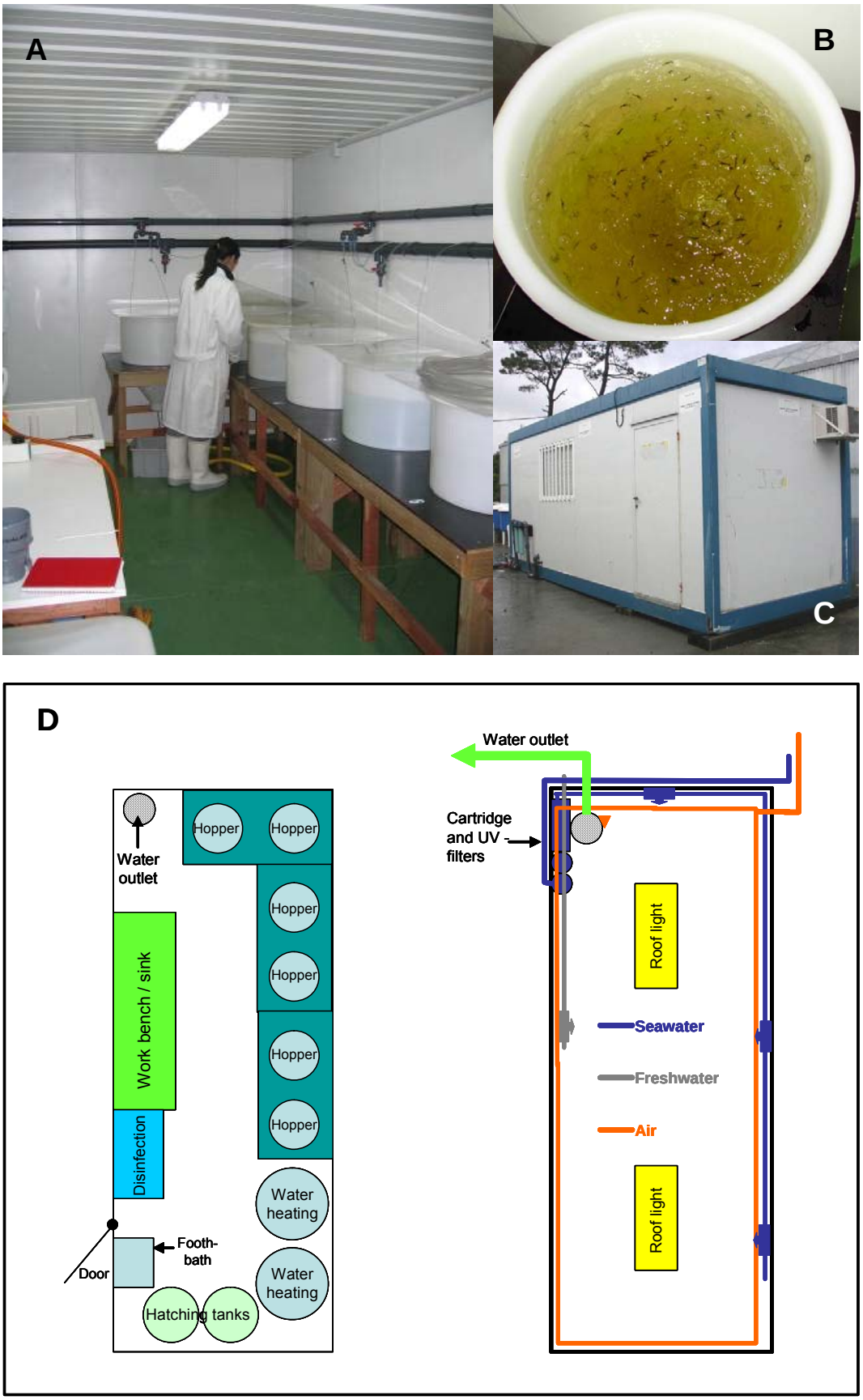

Figure 3. *A) Picture from the inside of the hatchery. B) A larval rearing hopper with algae, Artemia and stage II and IV lobsters. D) Principle sketches of the hatchery seen from above*

3.2 Hatchery design

The hatchery was primarily designed as a small scale demonstration hatchery, but the yearly production capacity could, under optimal conditions, be more than 15000 post larval lobsters. The relatively simple construction and the modest size of the hatchery illustrate that culture of larvae until the first benthic stage does not involve any major investments. In the current project no calculation of the price per produced post larval lobster was performed as the hatchery was designed as a demonstration and experimental facility.

The hatchery technology applied in the current project is in principle the same as has been used in the USA and Ireland for production of post-larval lobsters (Browne & Mercer 1998, Beal & Chapman 2001). The major difference in this project was that the hatchery was constructed in a mobile container. This illustrates the simplicity of this hatchery design and opens for the possibility to build mobile lobster hatcheries. Moreover, the current hatchery design might easily be expanded by using several containers. However, if a large scale hatchery should be built, a permanent insulated building with climate control and parallel water and air supplies would be the best alternative. In the long run this would ensure less maintenance of the hatchery constructions and facilitate a more stable and efficient production since all production steps will be gathered under the same roof.

4 Larval culture

Culture of lobster larvae from hatching and until the first post larval stage was carried out from 2004 to 2006. The hatchery methodology used was similar to that previously used in Ireland and USA. Methodological training was carried out through a practical mini-workshop arranged in Ireland in 2004 and through that the Norwegian and Irish partners visited Galicia and actively took part of the hatchery operation during 2004 - 2005. In this section the applied methodology and the production results will be summarized

4.1 Methods

Broodstock

After the egg-bearing females arrived at the hatchery the lobsters were kept in the storage containers for varying periods depending on the developmental stage of their eggs. The developmental stage was determined by measurement of the eye size of the embryos according to Richards & Wickins 1979. The hatching time could to a certain extent be manipulated by increasing or decreasing the water temperature, since the development rate of lobster embryos is directly related to the water temperature. During the period before hatching the lobsters were fed daily a diet of fresh and frozen mussels and frozen squid.

Hatching

When the lobster eggs showed clear signs of being close to hatching (reddish colour and swelling due to water absorbance) the females were transferred to the hatching containers in the hatchery building. Immediately before transfer, the eggs and lobster exoskeleton were disinfected by gently bathing in Betadine (10 ml/l). Great care was taken to not expose the gills to the disinfectant since iodine is toxic to lobsters, but not to eggs. The water in the hatching containers was continuously aerated and was exchanged every day with clean filtered sea water (see above) to maintain good water quality. The hatching containers were cleaned and disinfected before the water was exchanged. The females were not fed in the hatching containers. Usually the hatched larvae are actively released after dusk when the female performs a fanning behaviour with her pleopodes. To ensure that the larvae did not starve after hatching they were transferred to the larvae culture hoppers late in the evening, usually around two hours after sunset, the same day as the hatching took place. Lobster larvae are photopositive and will

thus actively gather at the top of the water column in the hatching tanks as long as the light source in the compartment is placed above the tank. This made it easy to collect the larvae after hatching by using a fine-meshed hand net. Batches of newly hatched lobster larvae were thereafter weighed to the nearest 0.01 g. Since the variation in individual weight is low for newly hatched lobster larvae the number of individuals in each batch could be estimated by linear regressions developed for previously weighed and counted larvae batches (as previously done in Ireland and the USA). Gentle and fast handling of the lobster larvae ensured that the weighing process did not reduced their subsequent survival.

Larval culture

Each larval hopper was then supplied with 500 to 1000 lobster larvae. The hoppers were filled with pre-heated (18 to 20 ˚C) and filtered seawater (Filtered to 1 micron and UV irradiated) prior to transfer of the larvae. In addition, de-capsulated *Artemia* cysts (6-8 g cyst/hopper) and live microalgae (*Isochrysis galbana* and T-ISO, approximate density: 150 cells/µl) were added to the hopper before larvae transfer. The hoppers were vigorously aerated to distribute the larvae and the feed in the water column. The larvae were cultured in the same hopper for two days, without exchange of water or further feeding. Then the larvae were transferred to a freshly prepared hopper using a fine-meshed hand-net. Usually the first larvae reached the first benthic stage (stage IV) 12-15 days after hatching, while the mean developmental time was approximately 14 - 16 days. During this time the larvae had been transferred seven times among hoppers. When approximately 70% or more of the larvae had reached stage IV the hopper was emptied by a hand-net and the larvae transferred to one of the hatching containers. Typically, stage IV larvae were able to swim in the water column in the tank, while the earlier stages sank to the tank bottom. This enabled an easy and fast separation of stage IV's from earlier stages. Finally, the larvae were counted and transferred to the various ongrowing systems (see below).

Hygiene

The major problem experienced during the larval culture was high mortality that occurred in stage III in some of the hoppers. This was most likely caused by a build-up of an unknown *Vibrio* species. In an effort to prevent mortality caused by pathogens a strict hygiene scheme is followed for this type of hatchery methodology. All berried lobsters that were introduced into the hatchery were disinfected as described in hatchery section. A foot bath with sodium hypochlorite solution ensured disinfection of shoes before entering the hatchery and operators washed their hands before working on each hopper. Great care was taken to avoid transfer of water between the hoppers. The hopper lids were always kept in place unless one of the hoppers was tended. All nets and equipment were disinfected in a solution of Betadine before being used in one of the hoppers. When the hoppers had been emptied they were washed and disinfected by spraying sodium hypochlorite over their inner surface, and then thoroughly rinsed with clean water before the hoppers were restarted. The floor and the hopper tables were washed and disinfected daily. Finally all sea water was UV-treated before entering the hatchery. Initial experiments with a hydrogen peroxide based disinfectant (MCRich-Catvis) which could be used in the hoppers during the culture process were carried out, but the result was increased mortality. This method should be studied further and might reduce the risk for diseases if a treatment schedule that does not inflict mortality can be developed.

Feeding

The lobster larvae were fed decapsulated AF grade *Artemia* cysts (INVE, 6 to 8g. of cysts per hopper). After being de-capsulated the cysts were incubated at 20ºC for 20 hours. Then the combination of decapsulated cysts and nauplii were collected on a 100 µm mesh and rinsed thoroughly with UV treated seawater before they were introduced into the hoppers. *Isocrysis* sp. algae were cultured on a continuous system in transparent LDPE bags of 400l. Artificial light was provided. Pasteurized enriched water was continuously added to each bag. The collection of algae was also on a continuous basis. Algae paste (*Isochrysis* and *Pavlova*) was also tried in initial pilot experiments, but produced significantly lower survival than live algae.

4.2 Results

The survival from hatching until stage IV varied from 2.8 to 93%. The variation in survival might be related to varying egg quality between different females and outbreaks of *Vibrio* infection. In some batches survival was very high until the third larval stage. Typically the mortality increased abruptly immediately before the stage III lobsters moulted to stage IV. This is believed to be a symptom of *Vibrio* infection.

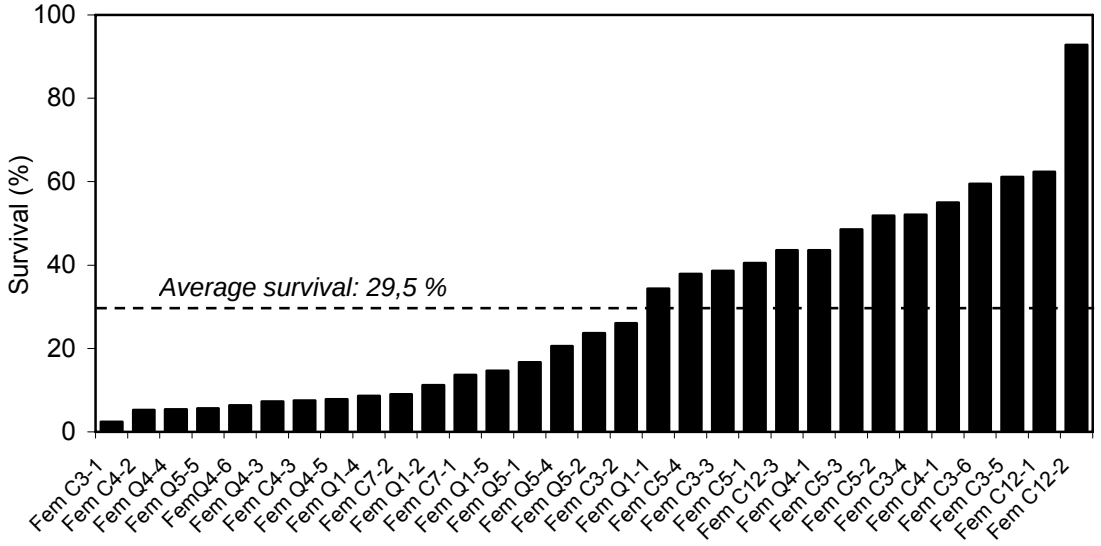

***Figure 4**. Survival of larvae until stage IV for the various batches cultured during the project period. The larvae production was carried out between late autumn 2004 and winter 2006. The mean number of larvae stocked in each hopper was 794 and altogether five females were used as broodstock.*

4.3 Discussion – larval culture methodology

The larval culture activity in the current project had two main goals. The first goal was to train the different participants in the techniques for lobster culture developed in USA and Ireland, while the second goal was to produce a sufficient number of post larvae for the ongrowing trials. Both goals were achieved during the project period. In fact, a higher number of larvae were produced than planned and it was also possible to perform pilot studies aimed at refining the culture technique. The established expertise and the facility will also benefit other ongoing projects in Galicia aimed at re-stocking the local lobster populations. The fact that the results have been variable has also been instructive because it has generated new knowledge about how to overcome problems that might arise when culturing lobster larvae. In conclusion, the results in the current study demonstrate, in concurrence with earlier studies (Browne & Mercer 1998, Nicosia & Lavalli 1999, Beal & Chapman 2001) that culture of lobsters from hatching, through the three pelagic larval stages and until the first post larval stage is not a major bottleneck for developing an efficient technique for producing lobster larvae.

5 Development and improvement of methodology for juvenile culture

Post-larval European lobsters are only 1.5 to 2 cm long and are vulnerable to predation if they are released directly into the sea. For this reason it is important to rear the lobsters until they reach a length of 4-5 cm before they are released to increase their chances of survival. The culture of lobster juveniles until this size has however been difficult due to the need for expensive technology, high amounts of energy for heating of water and the high work load. Furthermore, the earlier intensive juvenile culture techniques also produced lobsters that were exposed to an unnatural environment during the first months, presumably resulting in lobster juveniles that were not fit for the life in the sea. In the current project our aim was to develop a production technology that was both simple and cost effective and that would produce more fit juveniles than earlier intensive culture techniques.

The basic idea behind one of the techniques was that the lobsters should be cultured in cages deployed at sea from the first benthic stages until they reached a size that was assumed to be adequate for release. Our hypothesis was that the naturally occurring plankton and epibiotic organisms that fouled these cages would represent a sufficient source of food for a high survival and growth rate during this culture phase. In addition we wanted to compare communal rearing of lobsters in land-based tanks with sea based culture in individual cages.

The basic principles behind these culture techniques are not new. Both sea-based culture in single cages and communal rearing have been tested in previous studies with variable results (e.g. van Olst & Ford 1976, Uglem et al. 1998, Knutsen & Tveite 1999, Jørstad et al. 2001, Beal et al. 2002). The new aspect in the current study was that we wanted to try these technologies under warmer natural conditions than had been done before for *H. gammarus* and in a region with long traditions and an extensive infrastructure for using the marine areas for raft culture of invertebrates. The relatively warm climate in Galicia and the high productivity of the waters in the area was thought ideal for enhancing growth of lobsters. Furthermore, the existing raft infrastructure is ideal for potential future large scale rearing efforts. In addition, we examined if a brief land based culture phase in single cages would improve the results of sea-based culture of lobsters. The study design was a result of a mini-workshop in BMW arranged in the beginning of the project that gathered lobster researchers from the participating countries and from the US.

5.1 Methods

In the current project our aim was to test two different techniques for ongrowing of lobster juveniles; 1) ongrowing in single cages suspended from mussel rafts and 2) communal rearing.

Single cages suspended from mussel rafts

Two types of single cages were used for the trials. The first type was termed "**sea cages**" and was custom made of rectangular PVC tubes (Figure 5A, height/width: 6.5 cm, length: 15 cm, volume: 634 cm^3), with the ends covered by a mesh screen (mesh size: 1 mm). Each sea cage was supplied with a removable plug on the top side for addition/removal of the lobster. The sea cages were mounted on ropes with one sea cage line consisting of 35 individual cages. These ropes were equipped with a 2.75 kg weight at the end and suspended from a mussel raft. The other type of single cage system tested was commercial **oyster baskets** (Figure 5B), where one lobster was added in each of the single compartments in the basket. The external height of the oyster baskets varied between 40 and 70 cm dependent on the number of floors with single compartments used. Each "floor" within the oyster basket consisted of four approximately triangular single compartments (internal height: 6 cm, radius: 18 cm, internal volume: ~ 1520 cm^3). The baskets were constructed of perforated plastic material (mesh size: 2 x 2 mm). The baskets were equipped with a weight and suspended from the mussel rafts in the same way as

the sea cages. No artificial feed was added into the single cages during the period they were suspended from the mussel rafts.

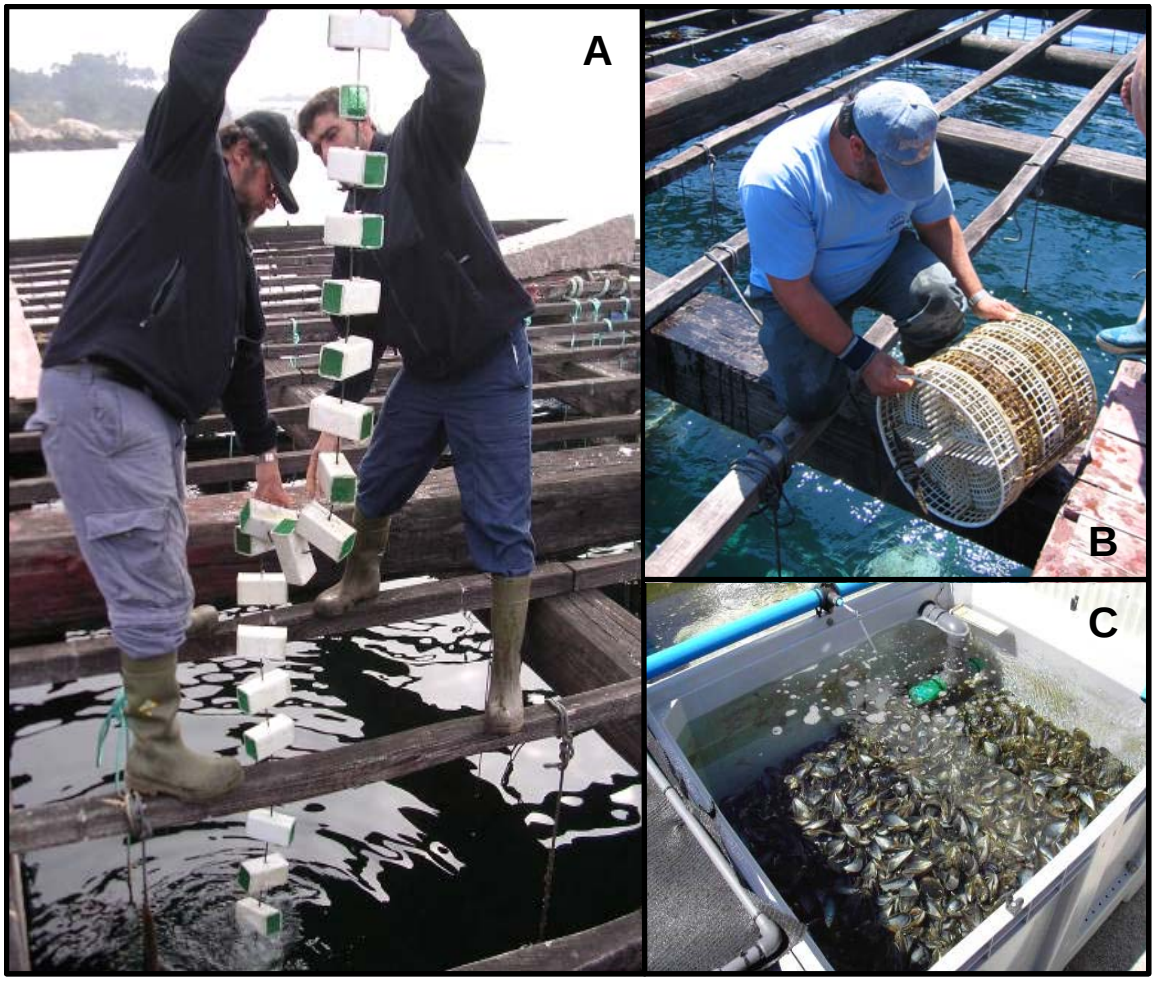

Figure 5. *A) Sea cages being suspended from a raft. B) Oyster basket being tended. C) A communal rearing tank with blue mussel substrate.*

Communal rearing

In the communal rearing trials we used 1 m^2 tanks (n=4) with a bottom substrate consisting blue mussel shells (*Mytilus edulis* or *Mytilius galloprovinciallis*) (Figure 5C). *Ensis siliqua* razor clam shells were also used in one of the experiments. Each of the tanks was initially stocked with between 50 to 100 stage IV lobsters. The water flow was 25 l/min. The communally reared lobsters were fed initially by addition of small amounts of newly hatched Artemia (INVE AF grade cysts) and throughout the trial with shrimp dry pellets (FRIPPAK Raceway, RW+550 and RW+700). However, since the water that was added to the communal rearing tanks was unfiltered a fast growth of natural epibiotic organisms also took place and the lobsters most likely also fed on these organisms.

Control culture under intensive conditions

To compare growth and survival of lobsters reared in sea cages or communally with lobsters cultured from stage IV under traditional intensive conditions control groups were reared in individual compartments under controlled conditions. The individually cultured lobsters were held in a system without recirculation, but with filtered seawater (25 microns) (Figure 5). The single compartments were organized in trays consisting of 22 x 7 compartments (154 cells). The lobsters were fed in excess once per day with frozen mysids, adult frozen Artemia, shrimp pellets

and frozen krill. Each compartment was cleaned for uneaten food the day after feeding. Additional water movement in the compartments was created with tidal siphons (e.g. Richards & Wickins 1979). The water temperature in the compartments was relatively similar (± 2˚C) to the ambient temperature in the sea. However, initial problems with oxygen over-saturation in the water resulted in high mortality during the first two weeks until the lobsters reached stage V. Thereafter, the mortality was low. For that reason we were unable to compare the survival of these control lobsters with the other groups for the trials initiated during spring 2005. However, since the mortality occurred only during the first period after transfer from the hatchery we have compared the growth in the control groups with the growth of the other groups.

The intermediate land based culture period

Pilot-trials were initially carried out by directly transferring the newly hatched stage IV's into cages suspended from rafts. This practice resulted in high mortality, probably as a result of handling stress. For this reason an intermediate or nursery culture phase in land based tanks was introduced in an effort to increase the survival through the first sensitive benthic stage. The intermediate culture phase consisted of stage IV lobsters being transferred into either sea cages or oyster baskets and held in a large land based tank (3000 l.), with unfiltered sea water at ambient temperatures for approximately two weeks (Figure 6). During this time nearly all lobsters reached the second benthic stage (stage V). Newly hatched Artemia and Artemia collected from the lobster larvae hoppers were added into the tank daily. Since Artemia is much smaller than the mesh size in the sea cages and the baskets, the lobsters were able to feed on the planktonic Artemia during this phase. Typically the survival in the intermediate culture phase was >90%. The results presented below are only from experiments which included an intermediate land-based culture phase, since the trials that not included this phase was terminated immediately after the high mortality was discovered. *Hence, one important result from the current project is that an intermediate nursery culture phase seems crucial for ensuring a high survival of lobsters cultured in cages suspended from mussel rafts.*

***Figure 6**. Oyster baskets in the intermediate culture tank.*

5.2 Results

Trials with different ongrowing methods were initiated during the spring and autumn of the year 2005. In the ongrowing trials that began during the spring lobsters were reared in single cages baskets and communally. In the autumn the lobsters were only reared in single cages and baskets. Oyster spat were added to some of the single cages and baskets in the trials initiated during autumn in order to examine if this treatment affected survival and growth. The rationale behind this treatment was that oyster spat may have a beneficial effect by providing a shelter for the juveniles. Moreover, it is well documented that addition of oyster spat in the rearing compartments increases the proportion of lobsters with a natural set of claws (e.g. Wickins 1986). Individual cultivation of lobsters was carried out during both periods.

5.2.1 Survival

Trials initiated during spring

The survival from transfer of stage IV lobsters from the hatchery to oyster baskets and until the end of the trials, was similar for both replicates initiated during spring 2005 (89%) (Figure 7) However, there was a clear variation between the two sea cage trials with survival rates of 85 % and 65% (Figure 7). There was no variation in survival between baskets and sea cages in the first spring replicate 200 days after hatching ($\chi^2 = 0.37$, $p = 0.54$), while the survival in the baskets was significantly higher compared to sea cages in the second spring replicate 190 days after hatching ($\chi^2 = 18.34$, $p < 0.001$) (Figure 7). Most of the mortalities in the second sea cage trial occurred during the first 45 days after transfer to sea cages. The survival in the communal rearing groups was significantly lower than for the other ongrowing groups with 28 % out of the initial number of stage IV lobsters surviving until the end of the trials (Figure 7). The survival rates in the individual rearing trials were low due to gas super saturation effects during the first couple of weeks after transfer from the hatchery and this group was thus not comparable with the other ongrowing trials. Survival in individual land-based culture during the first six months is high under optimal conditions (70-90%) (Reviewed in Nicosia and Lavalli 1999).

Trials initiated during autumn

The survival of lobster juveniles cultured in oyster baskets was significantly higher than the survival recorded for lobsters cultured in sea cages in the 2005 Autumn trials (Figure 8, $\chi^2 = 41.72$, $p < 0.001$). There was no variation in survival between lobsters cultured in oyster baskets without spat (82 %) and with spat (75 %) 250 days after hatching (Figure 8, $\chi^2 = 0.47$, $p = 0.49$). Likewise, there was no variation in survival between lobsters cultured in sea cages without spat (30 %) and with spat (33 %) at the end of the trials (Figure 8, $\chi^2 = 0.07$, $p = 0.78$). As in the trials initiated during spring 2005 the mortality in the sea cage autumn trials occurred during the first two months after transfer to sea cages. The survival in the individual rearing trials (74 %) did not differ from the oyster baskets without spat at the end of the trials (Figure 8, $\chi^2 = 1.52$, $p = 0.22$), but lobsters cultured individually survived better than lobsters reared in single cages ($\chi^2 = 31.39$, $p < 0.001$).

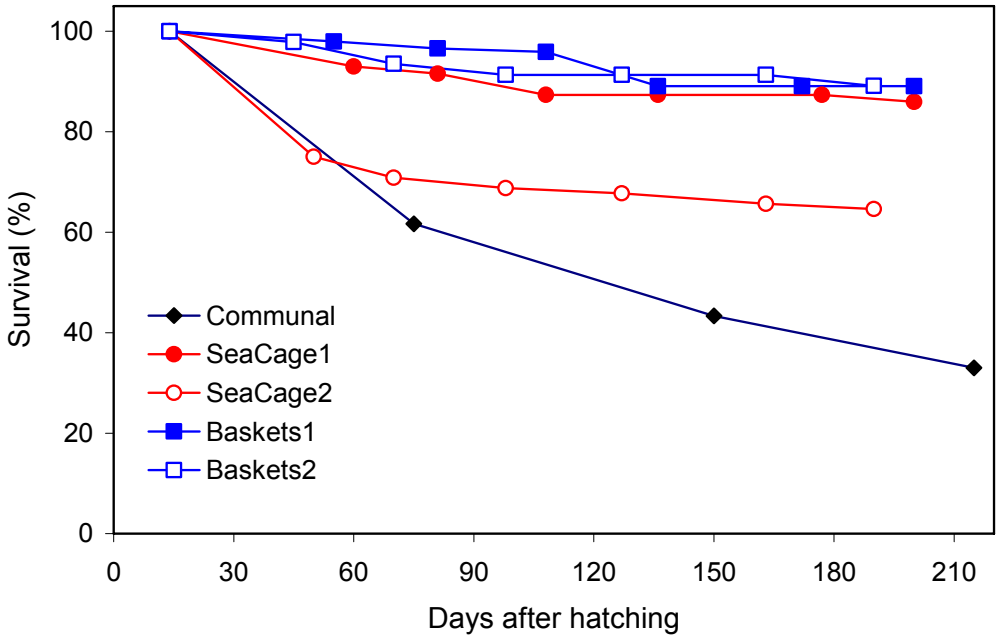

***Figure 7**. Actual survival from stage IV in the spring 2005 ongrowing trials. Survival in the communal rearing trials is based on pooled results from three trials initiated 24.04.05 (n=100), 06.05.05 (n=50) and 08.05.05 (n=150). The survival rates in the sea cage trials are based on trials initiated 18.05.05 for replicate 1 (3 ropes, total initial n=96) and 07.05.05 for replicate 2 (2 ropes, total initial n=71). The survival rates in the oyster baskets were measured in trials initiated 17.05.05 for replicate 1 (2 baskets, initial n=46) and 06.05.05 for replicate 2 (5 baskets, initial n=146). The measurement day varied slightly in the groups within each pooled trial and the number of days after hatching thus has a +/- 2 days variance.*

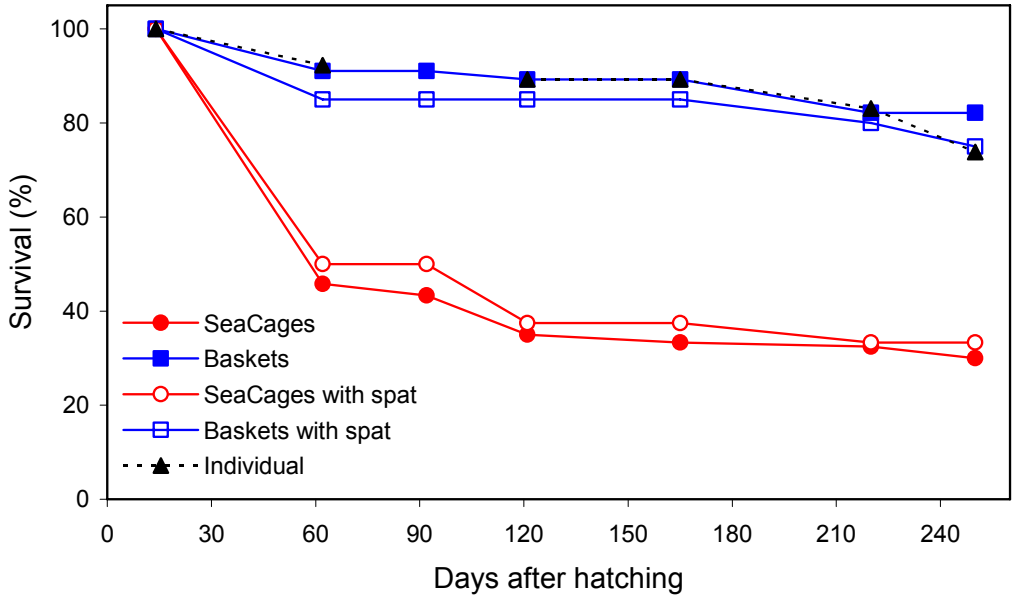

***Figure 8.** Survival in the autumn 2005 trials. The survival rates are based on experiments initiated between 22.09.05 to 24.09.05.The initial sample sizes were 120 and 24 juveniles in the sea cages with and without spat, respectively, while the initial sample sizes in the baskets with and without spat were 56 and 20 juveniles, respectively. In the individual rearing trials the initial sample size was 65 individuals. The day of measurement varied slightly between the different groups and the number of days after hatching thus has a +/- 2 days variance.*

Comparison of survival among spring and autumn trials

As survival of lobsters was measured at different times (days from hatching) comparison of survival among season had to be carried out after calculation of an interpolated survival for the trials initiated in spring 2005. The survival was interpolated to day 220 for the spring trials as this date corresponded to the closest day after hatching that survival was measured in the trials initiated during autumn 2005. The calculation of interpolated survival rates at day 220 was carried out by using linear regressions developed from the last five survival measurements only, as the decrease in survival during this period appeared to be linear. The estimated number of surviving lobsters at day 220 was then rounded to the nearest whole number to allow application of chi-square tests. The interpolated survival at day 220 for lobsters cultured in baskets from spring 2005 did not differ from that measured at day 220 after hatching for lobsters cultured in baskets from autumn 2005 ($\chi^2 = 1.90$, $p = 0.17$). However, the interpolated survival for lobsters cultured in sea cages was higher for both spring replicates compared to the autumn trial (replicate 1 spring vs. autumn: $\chi^2 = 61.02$, $p < 0.001$, replicate 2 spring vs. autumn: $\chi^2 = 20.35$, $p < 0.001$). Even though one of the sea cage groups showed comparable survival to the basket groups, the sea cage culture involved a higher mortality than the basket culture; with most of the mortality occurring during the two first months after the juvenile culture was initiated (Figure 7 & Figure 8). The survival for lobsters cultured individually and communally could not be compared among seasons since comparable trials were not carried out during both seasons.

5.2.2 Growth

Trials initiated during spring

Growth of lobsters was measured at irregular intervals during the ongrowing that began in spring 2005. As a result of this the size of the lobsters not could be compared directly between individual, communal and the sea based culture through statistical analyses for the spring trials. However, the lobsters cultured in individual compartments clearly demonstrated faster growth than the other ongrowing methods, while communally cultured lobsters seemed to grow slower than the other groups (Figure 9, Table 1). Furthermore, lobsters cultured in sea cages grew slower than lobsters cultured in baskets in both replicates (Figure 9, Table 1) (replicate 1: 200 days after hatching, $t = -4.68$, $p < 0.001$, replicate 2: 190 days, $t = -6.26$, $p < 0.001$). The juveniles cultured in baskets, sea cages or communally reached a total length at 4 cm after approximately 160 to 210 days. In order to quantify the extent of the variation in size within each of the different ongrowing trials the coefficients of variation for total length (Figure 10) and for specific growth rate (Table 1) were calculated. Both the coefficients of variation for total length and for specific growth rate indicated that communally cultured lobsters varied considerably more in size than the lobsters reared with the other techniques (Figure 10, Table 1). There were no major differences with respect to intra-treatment variation in size between the other groups but lobsters cultured in baskets appeared to vary more in size than lobsters cultured in sea cages (Figure 10, Table 1).

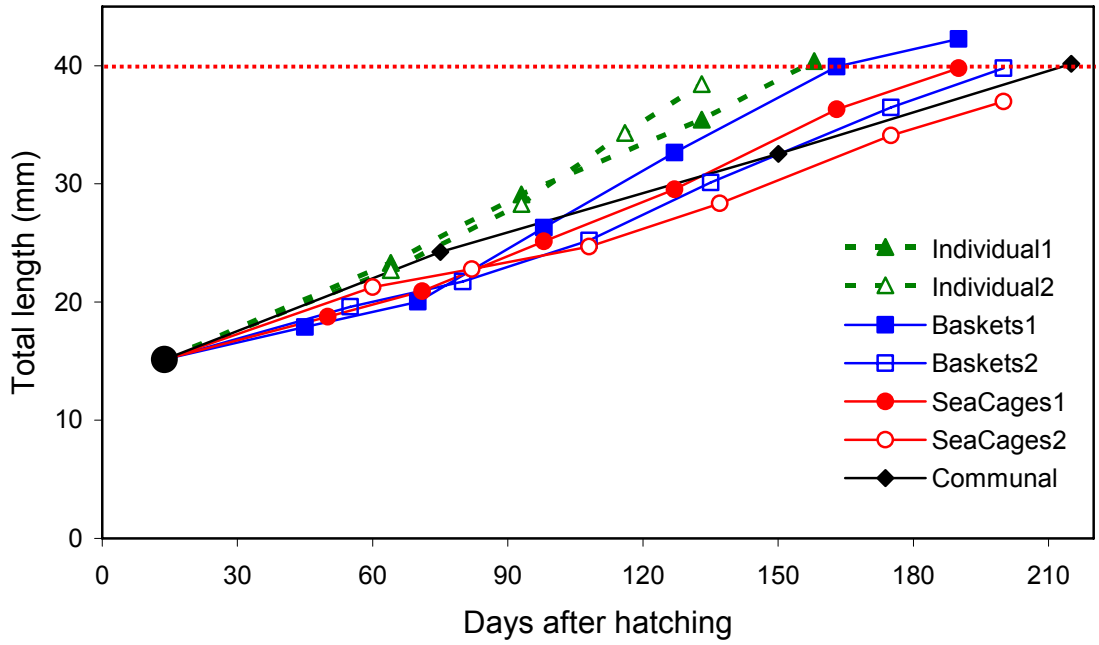

***Figure 9**. The total length in relation to time after hatching for the trials initiated during spring 2005. Initial group compositions and sample sizes are as specified for figure 7. The size at stage IV is calculated as a mean of a larger and independent sample of stage IV's, i.e. the size of the stage IVs were not measured for each group. The reason for this was that measurement of small and fragile stage IV lobster could reduce the subsequent survival.*

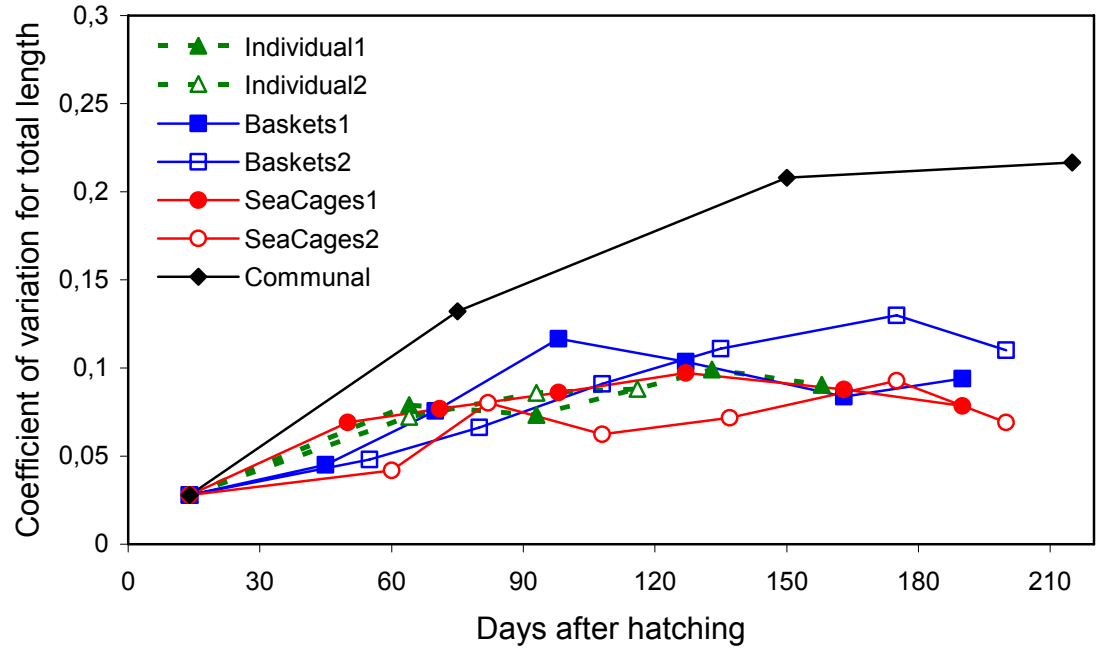

***Figure 10**. The coefficient of variation for total length in relation to time after hatching for the trials initiated during spring 2005. The initial group compositions and sample sizes are as specified for figure 7.*

Table 1. *Average specific growth rates with coefficients of variation for the ongrowing trials initiated during spring 2005. The specific growth rates are calculated for the surviving individuals until the end of the experiments only.*

	Seacages1	Seacages2	Baskets1	Baskets2	Communal	Individual1	Individual2
Termination of trial (days from initiation of ongrowing)	176	186	176	186	201	144	119
N	63	61	41	130	99	71	42
Specific growth rate	0,34	0,32	0,36	0,33	0,30	0,43	0,51
Coefficient of variation	0,048	0,047	0,053	0,069	0,129	0,054	0,067

Trials initiated during autumn

In the trials initiated during autumn 2005, the juveniles reared in baskets grew significantly faster than both the individually reared lobsters and the juveniles reared in sea cages (Table 2). The individually cultured lobsters also grew faster than the lobsters cultured in sea cages (Table 2). At the end of the trials the average total length of lobsters reared in baskets without spat were between 24 % and 16 % longer than lobsters reared in sea cages without spat and individually reared lobsters, respectively (Figure 11). Furthermore, there was no variation in growth rate between lobsters cultured in baskets or sea cages, with or without spat (Figure 11, Table 2). The juveniles cultured in baskets reached a mean total length of approximately 4 cm after 220 days, i.e. a size that might be regarded as suitable for release into the sea. Individually reared lobsters reached a mean length of 4 cm around day 250, while the mean size of lobsters reared in sea cages was less than 4 cm at the end of the trials. As for the trials initiated during spring 2005 the coefficients of variation for total length (Figure 12) and for specific growth rate (Table 2) were used for evaluating the size variation for each of the different ongrowing techniques. Together these two measurements of size variation did not reveal any obvious or major trends with respect to within group variation in size for the different ongrowing techniques.

Table 2*. Average specific growth rates with coefficients of variation for the ongrowing trials initiated during autumn 2005. The specific growth rates are calculated for the surviving individuals until the end of the experiments only. Significant differences are indicated with letters in the table (One-way ANOVA with Tukey post hoc analyses, significance level p < 0.05)*

	Seacages	Seacages with spats	Baskets	Baskets with spats	Individual
Termination of trial (days from initiation of ongrowing)	250	250	250	250	250
N	36	8	46	15	48
Specific growth rate	0,25	0,25	0,29	0,29	0,27
Signifcant variation, specific growth rate	***a***	***a***	***c***	***c***	***b***
Coefficient of variation	0,064	0,050	0,054	0,039	0,043

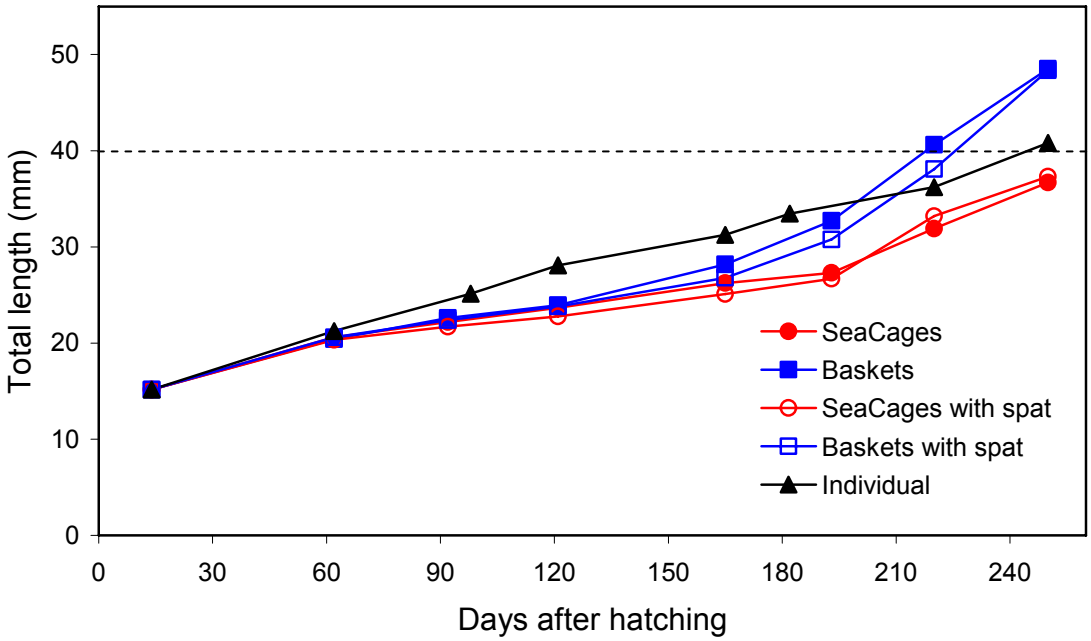

Figure 11. *Total length in relation to time after hatching for the trials initiated during autumn 2005. Initial group compositions and sample sizes are as specified for figure 8. The size at stage IV is calculated as a mean of a larger and independent sample of stage IV's, i.e. the size of the stage IVs was not measured for each group.*

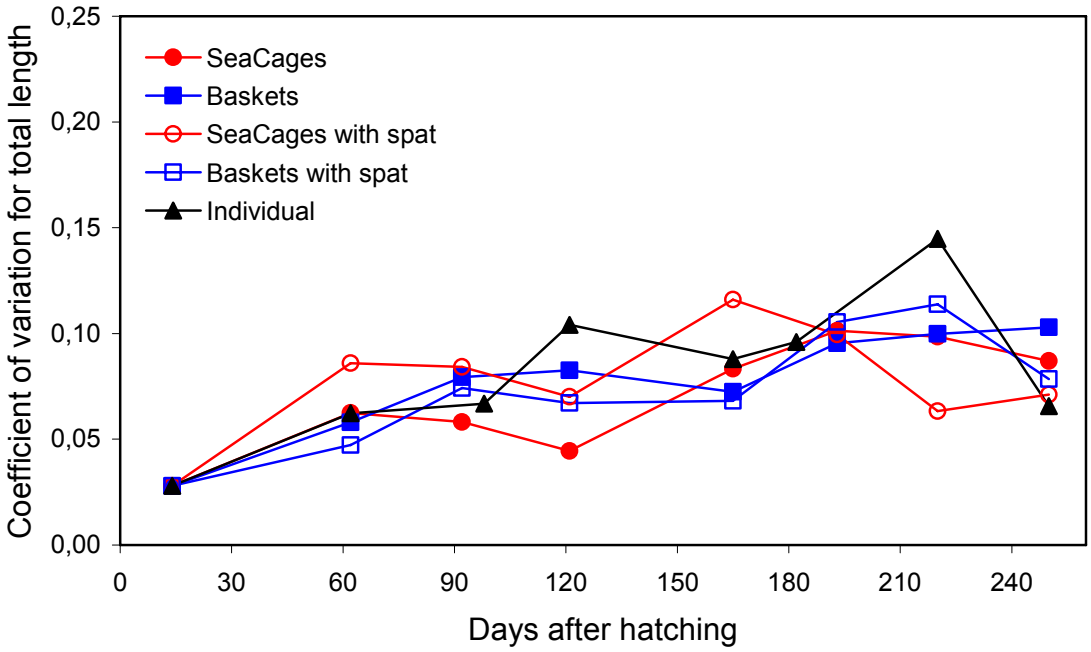

Figure 12. *The coefficient of variation for total length in relation to time after hatching for the trials initiated during autumn 2005. The initial group compositions and sample sizes are as specified for figure 8.*

Comparison of survival among spring and autumn trials

The growth of lobsters is highly dependent on the water temperature (e.g. Nicosia & Lavalli 1999). Since the different ongrowing trials were carried out under varying temperature conditions (Figure 13) this might have caused the observed variations in juvenile total length among the different groups (see above).

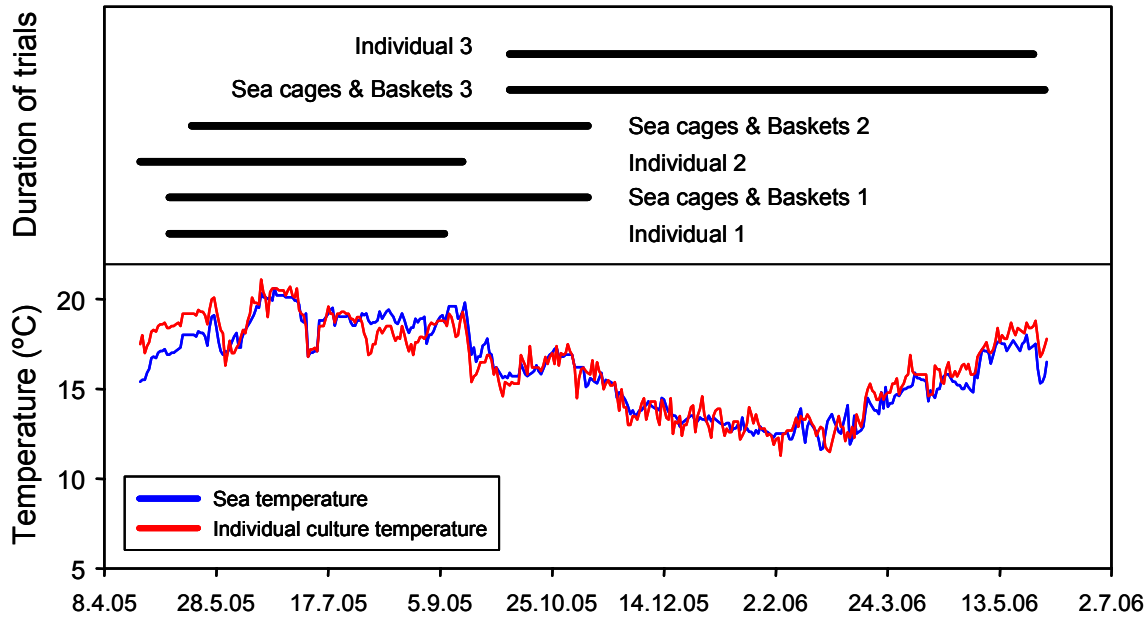

***Figure 13**. Temperature conditions and duration of the different trials*

To be able to compare the different groups independently of water temperature the degree-days at the varying measuring dates were calculated. Since the lobsters were measured at varying dates the size at 3000 degree-days were estimated through back-calculation using linear regressions for each surviving individual to the termination of the trials (Figure 14). This also enabled the different groups to be compared across seasons. The average r^2 for the individual regressions was high (average = 0.95, SD = 0.048) indicating that the back-calculation of the size at 3000 degree-days was relatively accurate. Unfortunately the temperature data for the communal culture was incomplete and this group could not be included in the analyses.

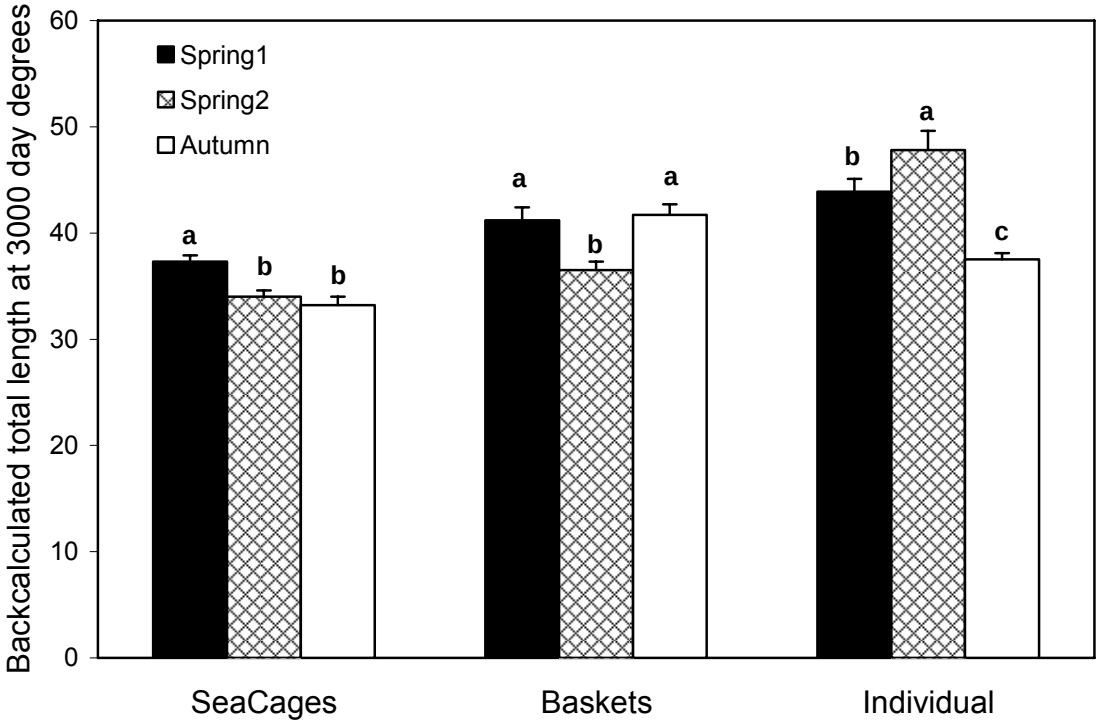

***Figure 14**. The back-calculated total length at 3000 day degrees for lobsters cultured in sea cages, baskets or individually for the varying ongrowing methods and replicates. Significant differences within each ongrowing method are indicated with letters in the table (One-way ANOVA with Tukey post hoc analyses, significance level p < 0.05)*

The back-calculated total length at 3000 degree-days varied significantly between the different replicates for all three ongrowing methods (Sea Cages: One-way ANOVA, $F = 40.11$, $p < 0.001$, Baskets: One-way ANOVA, $F = 42.99$, $p < 0.001$, Individual culture: One-way ANOVA, $F = 64.64$, $p < 0.001$). In the sea cage trials the lobsters in the first spring replicate were significantly larger than the lobsters in the second spring and the autumn replicates at 3000 degree-days (Figure 14). The lobsters cultured in baskets in the second spring replicate were smaller at 3000 degree-days compared to the first spring and the autumn replicates. Furthermore, the individually cultured juveniles in the second spring replicate were larger at 3000 degree-days than the juveniles in the first spring replicate, which in turn were larger that the juveniles in the autumn replicate (Figure 14). If all lobsters produced with each ongrowing method were pooled individually cultured lobsters were larger than basket produced lobsters, which in turn were larger than sea cage produced lobsters (One-Way ANOVA, = 106,23, p<0,001, Tukey Post Hoc tests, p<0,001).

5.2.3 Claw configuration and colouration

The claw configuration and the coloration of the juveniles were estimated for the spring trials only. The results show that the proportions of lobsters with symmetrical claws were relatively low for the lobsters cultured in baskets and sea cages at the end of the experiment (Figure 15). In these groups between 80% and 95% of the juveniles had 1) already developed a natural claw configuration with one crusher and one cutter claw or 2) they would most likely do so in the future, since weakly asymmetrically claws to a large extent tend to develop into a natural claw configuration. When the claw status were divided into either symmetric claws or asymmetric claws (weak + strong asymmetry) there were found a significant heterogeneity between the groups (Chi-square test, p<0.001). However, when the communally reared lobsters were excluded from the analyses there were no heterogeneity between the groups (Chi-square test, p=0.064). This suggest that development of a natural claw configuration is more likely to take place for a higher proportion of lobster cultured in sea cages and oyster baskets compared to

communally cultured lobsters. However, it would be reasonable to assume that a relatively high proportion of the communally cultured lobsters also would develop a natural set of claws.

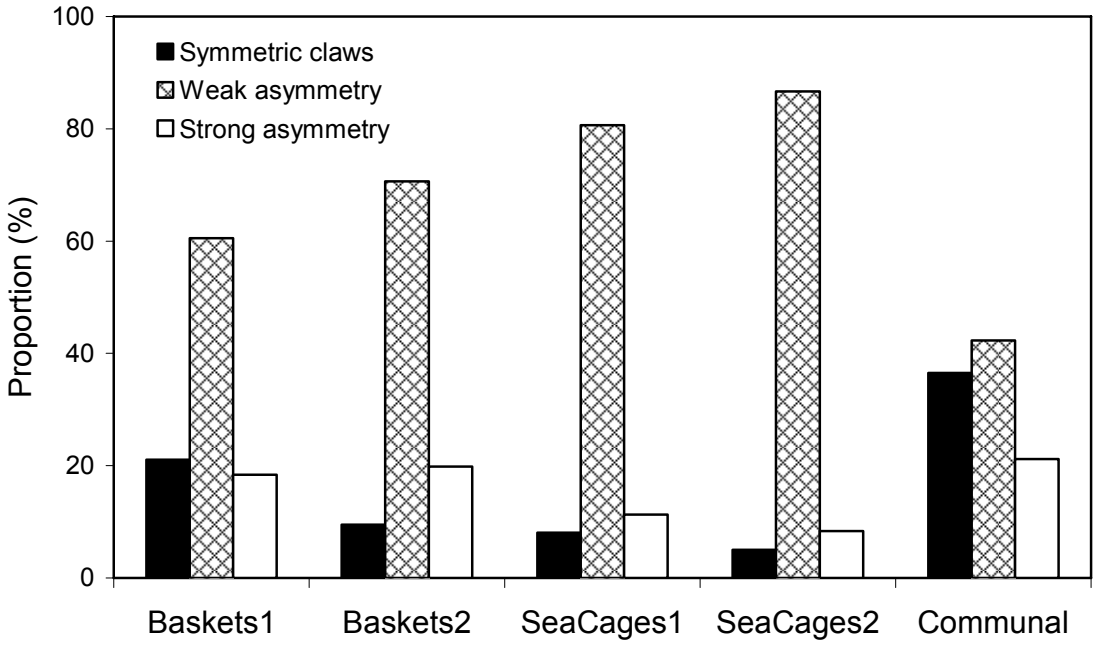

***Figure 15**. The proportions of lobsters with symmetric claws (i.e. two scissor claws), with weak asymmetrical claws (i.e. claws that most likely would develop into a crusher and cutter claw) and with obviously asymmetrical claws (i.e. one cutter and one crusher claw) at day 200 (± 15 days) for the trials initiated during spring 2005 .Sample sizes are the same as indicated in Table 1.*

The coloration of the lobsters varied along a continuous scale and was thus indexed into four major colour categories (black, brown, green and pale) for simplifying the data analyses. Between 25 % and 43 % of the lobsters cultured in sea cages or in baskets were pale, while the rest of the juveniles had colours that are assumed to be more adequate for juveniles of this size (i.e. black, brown or green, Figure 16). For lobsters reared communally only 6 % of the juveniles were pale (Figure 16). Apart from that the variation in colouration seemed to vary relatively inconsistently between the different groups.

When the colouration were divided into either assumed natural coloration (black, brown and green) and assumed unnatural coloration (pale) there were found a significant heterogeneity between the groups (Chi-square test, $p<0.001$). When the communally reared lobsters were excluded from the analyses there were no significant heterogeneity between the groups (Chi-square test, $p=0.052$). However, the lack of heterogeneity was marginally non-significant. These analyses suggest that development of an assumed natural coloration is more likely to take place for a lower proportion of lobster cultured in sea cages and oyster baskets compared to communally cultured lobsters. Nevertheless, a relatively high proportion of the lobsters cultured in sea cages and in oyster baskets also developed an assumed natural coloration.

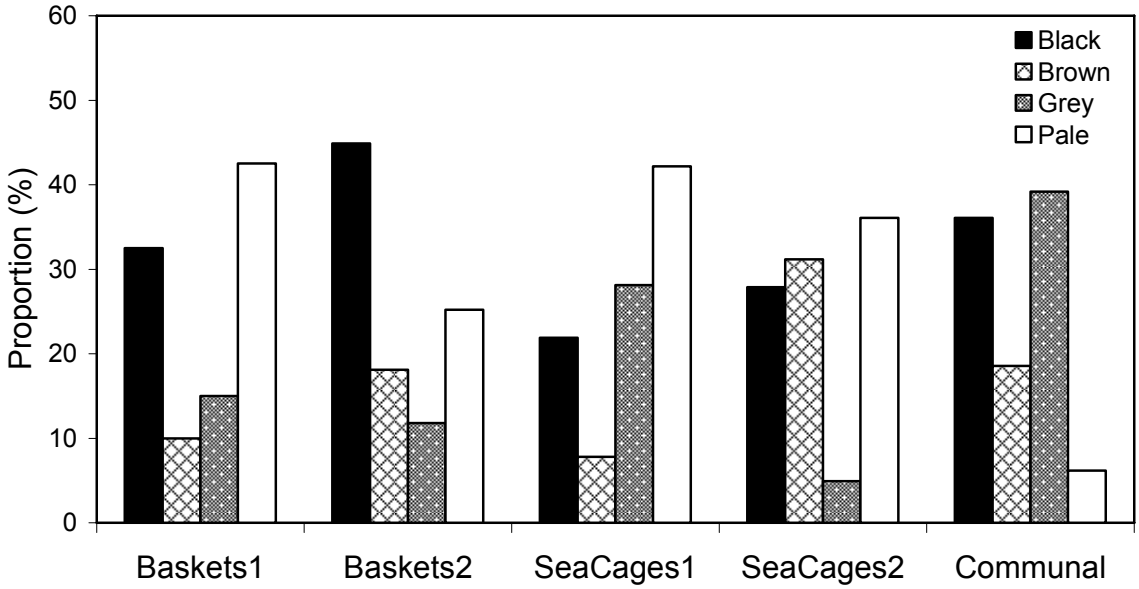

***Figure 16**. The proportions of lobsters in the varying treatements with different colouration at day 200 (± 15 days). Sample sizes are the same as indicated in Table 1.*

5.3 Discussion – ongrowing trials

5.3.1 Survival

The results show that the survival from stage IV and until the juveniles reached a size suitable for release was high (typically > 80%) in sea trials. The survival rates achieved in basket culture in the current study are considered to be excellent, especially since the lobsters were not fed or tended during the course of the study. In other studies where lobster juveniles have been cultured in submerged cages in the sea the survival rates have been lower (Uglem et al. 1998, Knutsen & Tveite 1999, Beal et al. 2002). The survival in earlier intensive culture has also been comparable with the survival in basket culture (reviewed in Nicosia & Lavalli 1999). One difference from this study and earlier studies is that the lobsters were cultured to stage V under controlled conditions before transfer to the sea cages. This might have lead to an increased tolerance to environmental stresses during and after transfer to the sea and thus also a higher survival. Another difference between this study and other studies is that the lobsters were cultured in cages suspended in open water and not in cages near or at the bottom. Whether this affected the survival is difficult to assess, but it shows that culture of lobsters in submerged cages can be carried out in an easier way than done before and that earlier problems with cages filled by sediments can be avoided (Knutsen pers comm.)

The survival in the sea cage trials was less than in the basket trials in two of the replicates, with the bulk of the mortality occurring during the two first months after transfer to the sea cages. Since the mortality in the intermediate culture phase was low (Perez Benavente pers. obs) and the survival after two months in the sea was high, the mortality in the sea cages might be related to unfavourable handling during transfer of the sea cages to the mussel raft. The handling procedures did, however, not vary between the sea cage replicate with the highest survival and the two replicates with higher mortality. It is unlikely that the differences in survival among basket and sea cage cultured lobsters were related to differences in volume of the single compartments or varying water circulation rates, since the high mortalities in the sea cage trials occurred when the lobsters were relatively small. Mortality caused by small compartment size or low water circulation rates would most likely occur at larger juvenile sizes.

The trials initiated during spring 2005 showed that the mortality in the communal rearing trial was considerably higher than when culturing lobsters in either sea cages or in oyster baskets. The survival at the end was 28%, which is comparable to findings from earlier communal culture studies for *H. gammarus* (Jørstad et al. 2001, Browne pers obs.). However, communal culture of lobster juveniles has yielded higher survival than those observed in this study (Jørstad et al. 2001, Browne pers obs). Whether the survival rate in communal rearing is acceptable for a viable large scale culture of lobster juveniles for release purposes depends on the availability of stage IV lobsters. If high numbers of stage IV lobsters are available a survival rate of about 30-40 % might be acceptable since the culture technique involves less investments and workload than earlier used intensive and land-based culture methods (e.g. Grimsen at al 1987, Burton 1992).

The survival of individually cultured lobsters was variable in this current study. This was most likely a result of periodic gas super saturation in the culture system. This is a problem that is relatively easy to overcome by installing de-saturation units in the culture system. During autumn 2005 a simple system for de-saturation was installed with following increased survival.

5.3.2 Growth

The results of the trials show that lobsters cultured in baskets and sea cages grow well compared to intensively grown lobsters, even though they were not fed during the sea based phase of the culture. The lobsters cultured intensively grew faster than basket cultured lobsters, which again grew faster than sea cage cultured animals. The finding that individually cultured lobsters grew fastest was not surprising since these animals were fed in excess. The variation among basket and sea cage cultured lobsters might be related to that the area available in baskets were larger that in sea cages. Larger compartments would probably lead to higher food abundance due to that the available area for growth of fouling organisms will increase with the size of the inner surface of single compartments. Furthermore, the water circulation was probably greater in the baskets since the perforated area was larger compared to sea cages, and a higher water circulation rate would increase the availability of planktonic organisms and probably also a better water quality.

Nevertheless, the growth differences between the different treatments were not substantial and may not be significant for the outcome of a large scale juvenile production activity. These results indicate that lobster juveniles cultured in submerged cages in the sea are able to utilize fouling organisms on the cages and/or planktonic organisms as food to such an extent that they are able to make use of most of their growth potential during this phase. This finding is supported by findings for *H. americanus* which are able to survive and grow well through the juvenile stages on diet consisting natural plankton only (Barshaw 1989). The growth in the sea based culture in the current study was higher or comparable to what has been found in earlier studies, where lobster juveniles have been cultured in submerged cages close to or at the sea floor without artificial feeding (Knutsen & Tveite 1999, Beal et al. 2002) and also with earlier intensive land-based culture (e.g. Uglem et al. 1995, Burton 1992). For instance, lobsters cultured in near bottom single cages without artificial feeding at the Irish west coast from September 2000 until June 2001 were approximately 2.2 cm (corresponds to a carapace length around 0.9 cm) in total length at the end of the study (Beal et al. 2002). Therefore the lobsters cultured in Galicia during winter time grew approximately twice as fast at lobsters cultured with a similar technology in Ireland during wither time. Even though the study carried out by Beal et al. (2002) studies is not directly comparable with the current study it appears that the conditions in Galicia during winter time are more favourable for sea based lobster culture than Ireland.

The growth rate of lobsters cultured in the sea varied with season and the specific growth rates were systematically higher for the trials initiated during the spring compared to the trials initiated during the autumn. This could be an effect of varying abundance of feed organisms at different times of the year or a result of the juveniles from the autumn trials experiencing a lower temperature than the juveniles from the spring trials. To control for the temperature variation over time the juvenile size at 3000 degree-days was estimated by back-calculation. Analyses

of the back-calculated data showed that there was a variation in growth among seasons, but that there was no evident seasonal pattern. Both in basket and sea cage culture the juveniles in the autumn trial were smaller at 3000 degree-days than in one of the spring trials, while they were similar in size with the second spring trial. Thus, it is reasonable to assume that variation in temperature explains a higher proportion of the growth variation than variability in feed availability or other variables among seasons. Furthermore, this indicates that the feed availability in Galicia during winter is sufficient for supporting an adequate growth and survival.

The growth rate in communal culture was comparable with the sea based cage culture, but less than found in individual compartmentalised land based culture where lobsters were fed by hand to excess. Moreover, the growth in communal culture was more variable compared to individual culture (both sea based and land based). This finding concurs with those of Jørstad et al. (2001) results on communal culture of *H. gammarus* and is most likely a result of inter-individual competition. The claw loss rate was high (51 %) for lobsters reared communally (Perez Benavente pers. obs) suggesting agonistic interactions, which might be related to the observed growth variation.

5.3.3 Claw configuration and coloration

In early culture of lobsters for release into the sea a high proportion of the animals developed a symmetrical and unnatural set of claws (Wickins 1986). This could result in those lobsters being less adapted to the life in the sea. In addition, an unnatural claw configuration could also reduce the market value of the lobsters. The problem with development of symmetrical claws has been solved by adding either oyster spat or small pieces of mussels to the culture compartments (Wickins et al. 1986). In this way more than two thirds of the cultured lobsters developed a natural claw configuration with a scissor claw and a larger crusher claw. The results from this study show that a relatively high proportion of the lobsters cultured in baskets and sea cages will probably develop a set of claws that will be similar to their wild counterparts. The majority of communally cultured lobsters developed a natural claw set. The trials in the current study were terminated before a conclusion could be made on the proportion of lobster cultured in sea cages or baskets that will possess natural claws as adults.

The natural coloration of lobster juveniles is unknown since *H. gammarus* juveniles of the size produced in these type of trials have not been found in the wild (Linnane et al. 2001). However, it is reasonable to assume that a pale colouration is not natural, as wild juvenile lobsters that are slightly larger than the juveniles produced in the current study exclusively have a darkish colouration. The results from this study show that a minority of the cultured lobsters have a pale colouration and that the communally produced lobsters were darker than the lobsters cultured in sea cages and baskets. The importance of this finding is difficult to assess, but it can be assumed that a darker colouration will be advantageous in terms of avoiding predation in the wild. The colour variation found in the current study would probably not affect the coloration of adults as lobsters are able to develop a darker coloration if given a natural feed with the required pigments and since the released lobster will find adequate food after being released.

5.3.4 Culture with spat in the culture compartments

The use of oyster spat in compartments did not affect the survival or the growth of the juveniles. This might indicate that the lobsters find adequate shelter in the sea cages and the baskets and that they avoid possibly energetic costly shelter seeking behaviour during the culture period. Claw configuration was not determined during these trials for the lobsters cultured with spat in the compartments, but earlier studies have demonstrated that addition of a substrate that the lobsters can handle during the first benthic stages results in a majority of juveniles that develop a natural claw configuration (Wickins 1986, Uglem et al. 1995). Therefore, the use of oyster spat or a similar substrate is recommended for future culture of lobster juveniles in submerged single compartments, as long as the proportion of lobsters with a natural set of claws at an adult age is unknown for these culture methods.

5.3.5 Were the methods adequate for mass production of lobster juveniles?

The results from the current study show that all three experimental ongrowing techniques could be used successfully to produce lobsters juveniles to reestablish endangered local populations or to augment seriously depleted stocks. The culture of lobsters in oyster cages was significantly more efficient than communal rearing or sea cage culture. On the basis of this study juvenile culture in oyster baskets would be the first choice of ongrowing methodology, but communal culture might also be carried out in cases where stage IV's are produced in excess. Nevertheless, both large scale communal culture and culture in single compartment structures in the sea depends on that suitable and cost-effective technology for large scale production can be developed. In the current study the different methods have been tested in small scale and under controlled conditions and up-scaling of the production might introduce hitherto unknown problems and challenges.

Oyster basket culture

The results in this study suggest that culture of lobsters in oyster baskets or some kind of similar structure in the sea would give better results than communal culture. In addition, the need for investments and for developing new technology for up-scaling might also be less when culturing lobsters in single-compartments in the sea compared to communal culture. The availability of structures for suspending compartments will probably not be a major limiting factor since rafts or long-line culture facilities for mussels can be used and since commercial mussel farming is widespread in most European coastal areas. However, the oyster baskets used in the current study needs customisation. A suggestion would be to develop a special basket for the culture of lobsters with a higher number of smaller compartments than in oyster baskets. Moreover, it would be an advantage if "lobster baskets" could be constructed from a lighter material than oyster baskets. A "higher" basket of thinner plastic material, with lids on the side of the basket such that the lobsters can be introduced or removed without demounting the basket, would increase the capacity per basket and decrease the labour demand considerably. A design that should be tested further is disposable baskets, from a similar material as used in baskets for berries, surrounded by a supporting non-corrosive netting tube. One of the greatest advantages with disposable baskets is that time-consuming cleaning is avoided. The experiences from the current project suggest that there could be massive amounts of epibiotic organisms on the baskets at termination of the culture and that these organisms can be hard to remove before re-use of the baskets. In an environmental context it would also be advantageous that disposable lobster baskets are produced from a material that can be recycled. However, a cost-effective construction of disposable baskets for lobster production would require that a large amount of baskets are produced industrially.

Even though the results from the current study are very positive for the culture of lobsters in baskets it is important to consider that the results are obtained on one location only. The water temperatures and the fauna vary greatly along the European coast and it might be reasonable to assume that the production efficiency could vary likewise. The water temperature in Galicia is, for instance, much higher and more stable than for instance in Norway. Thus longer production periods might be expected in more northerly regions as indicated by Beal et al. (2002).

Communal culture

Communal culture might be an alternative if production of stage IV lobsters if excessive amounts of stage IV are produced in a hatchery. However, whether or not communal production of lobsters is feasible also depends on local conditions. In more southern regions, large shallow outdoor ponds for communal rearing can easily be constructed. Given that it will be possible to produce 30 juveniles per m^2, a pond that is, for instance,30 cm deep, 10 m wide and 50 m long (500 m^2), would have a production capacity of 15 000 juveniles. Compared to earlier used land based techniques for production of lobster juveniles a structure like this will be technologically simple and considerably less costly to construct. However, in northerly regions with harsh weather conditions this type of culture will require the construction of buildings. Furthermore, even though the amount of work needed for tending the lobsters is minor in communal rearing, the collection of lobsters once they have reached a size suitable for release

is time consuming and ineffective when using mussel shells as a substrate. This means that there is a need for developing an artificial substrate that enables a faster collection of juveniles if communal rearing should be scaled up for production of large numbers of lobsters to reestablish or augment stocks. An artificial substrate may for instance be constructed as a coherent “mat” with adequate holes or crevices. A “mat-like” substrate might be removed from the communal culture pond in one operation and might thus simplify the collection of juveniles substantially. Obviously, there are still a range of unanswered questions regarding the technical feasibility of large-scale communal culture of lobster juveniles that need to be tested in future studies.

5.3.6 Costs of production

The costs for large-scale production of lobsters for re-establishment or stock enhancement are difficult to estimate at the present stage, since technology for large scale production is still not developed and tested. However, it is reasonable to believe that the costs for future juvenile production, either in single-compartment structures in the sea or communally, would be considerably less than for earlier used large scale production methodology. Firstly, the current project has demonstrated that lobster juveniles can be successfully produced with minimal artificial feeding and tending compared to other culture techniques for lobsters. Secondly, the need for artificial heating will be minimal since the lobster juveniles can be cultured either in unfiltered sea water at ambient temperatures or in the sea. Thirdly, the need for large onshore buildings is also minimized since the juvenile ongrowing could take place in the sea or in shallow onshore ponds in more southern regions in Europe. However, the costs would vary depending on the country where the production takes place. For instance, the costs for labour is considerably higher in Norway compared to Spain. Furthermore, the harsh climate in Norway might also involve that sea based culture requires more costly constructions than in southern Europe. Finally, since the temperature and the growth season decrease with increasing northerly latitude one should also expect that the production efficiency would decrease in more northern regions compared to southern regions. Nevertheless, the methods tested in the current study would most likely be transferable between different regions with minor adaptations.

6 How can the results be used in future regional reestablishment activities?

The current project has demonstrated that lobster juveniles can be cultured successfully in more cost-efficient and less technology demanding ways compared to those previously used. The aim of this chapter is first to suggest how the methodologies applied in the current project can be used in a regional plan for producing lobsters for re-establishment and enhancement purposes. Emphasis is made on designing a production plan that is compatible for the different regions participating in the AquaReg programme with relatively minor modifications. It is however important to bear in mind that the experimental activity in the current project has been carried out in Galicia and that application of the described techniques not necessarily will produce the same results in all regions.

The second goal of this chapter is to point out in which areas more work and development needs to be done. Even though the results from the current project are positive and indicate that it might be possible to culture lobster juveniles in a better and more efficient way compared to earlier large scale culture efforts, there is still a range of questions that needs to be answered before a large scale production line for lobster juveniles and a successful restocking/enhancement activity can be established. For instance, a successful up-scaling of the juvenile production methodology and a satisfactorily survival of the juveniles after release are both central assumptions for the feasibility of reestablishment or enhancement activities.

6.1 A regional plan for production of lobster juveniles

Hatching of eggs, larval rearing and culture of early benthic phase lobsters

The first step in production of lobster juveniles involves hatching of eggs, rearing of pelagic larvae until the first benthic stage and possibly an intermediate land based culture phase before the lobsters either are transferred to a communal rearing facility or to sea based single compartment culture. However, establishment of new hatcheries for production of lobster larvae and early benthic stage juveniles requires relatively large investments. Thus, collaboration with existing aquaculture of other marine species might be a good alternative. *Hatcheries for marine fish species like Atlantic cod, sea bass and sea bream do, for instance, use the same type of food sources as required for culture of lobster larvae and the water treatment systems at such farms will also be suitable for lobster farming*. Hatcheries for various species of marine finfish exist in all three regions participating in the AquaReg programme and also in other regions in Europe. Establishment of a lobster hatchery could accordingly either be based on modification of existing fish farms or construction of customised hatcheries connected to already existing hatcheries for other marine species. Establishment of new and independent lobster hatcheries is of course also an alternative, but collaboration with existing hatcheries for other marine species would be highly beneficial.

Culture of early benthic phase lobsters until an adequate size for release

In this project we have tested and developed two methods for culture of lobster juveniles. Until more precise information about production costs can be estimated, our suggestion is to *combine the communal and sea based juvenile culture methods in a future regional culture strategy* because this will increase the production stability simultaneously as it will not represent any major additional investments. However, culture in oyster baskets should be prioritized before communal rearing. An obvious requirement for successful up-scaling of these methods is development of a customised, functional and cost effective “lobster basket” and a functional artificial substrate for communal rearing. In addition, communal rearing in outdoor ponds might be more adequate in more southern regions compared to northern regions.

All regions participating in the AquaReg programme have commercial shellfish industries. In Spain mussel rafts dominate and long-line mussel culture is the norm in Ireland and Norway. Even though the sea based culture of lobsters in the current project was carried out under mussel rafts there is no obvious reason why lobster baskets not could be suspended from other facilities for mussel culture. Moreover, the production outcome of both communal and sea based juvenile culture will obviously vary with respect to the seasonal variation in temperature and the abundance of planktonic and epibiotic organisms. Although we have not carried out any trials with cultured lobsters in ambient and unfiltered sea water in Norway and Ireland our prediction is that the lower temperatures during winter in these two countries will involve a considerable slower growth than during winter time in Galicia. This is supported by the findings by Beal et al. (2002). *Thus, we suggest that sea based culture in Norway and Ireland should be initiated during spring only, while a year-round production could take place in Spain and that a combination of communal culture could be an adequate methodology for Ireland and Spain, while sea based culture could be the best solution in Norway. However, culture of juvenile lobsters in single compartments in the sea during winter should not be ruled out as an alternative for Norway and Ireland without further testing.*

A regionally adapted infrastructure

Culture of lobsters for re-establishment or stock enhancement should be organized on a regional level. The collection of broodstock should optimally take place in the same areas were the lobster juveniles later will be released to avoid affecting the local genotypes in an unwanted manner. However, in cases were the lobster stocks are seriously depleted and local broodstock is unavailable, collection of broodstock from neighbouring areas might be the only alternative. A suggestion is to use local fishermen to collect the broodstock. Thereafter the broodstock should be transferred to a centrally placed common hatchery. In the further culture of larvae and juveniles the different origins should be separated. After the intermediate culture

phase the lobsters could be transported to rafts or other types of mussel farms preferable in the areas were the re-establishment or enhancement activities will take place. A simple plan for production and release of lobster juveniles is suggested in figure 17.

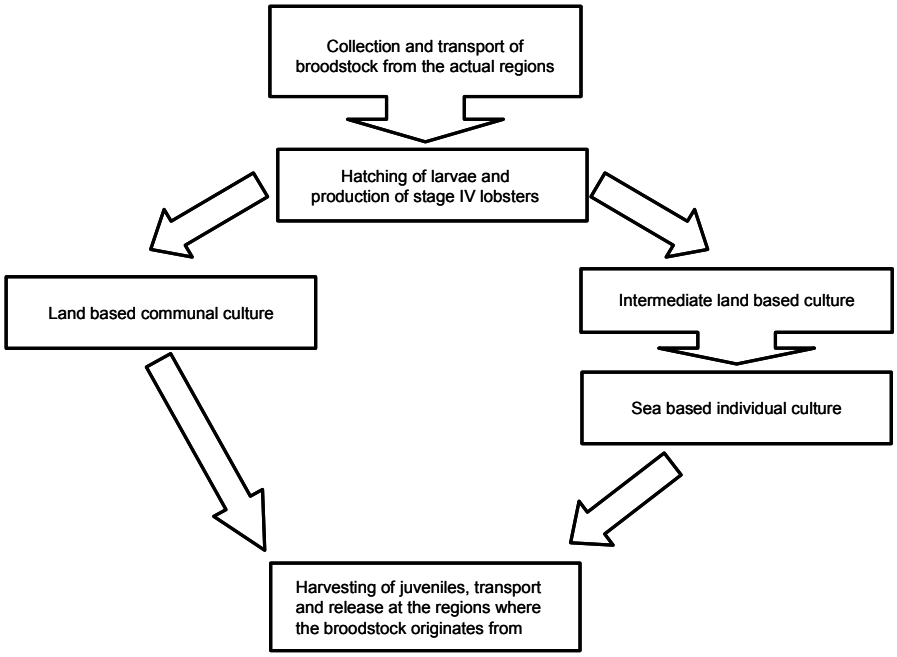

Figure 17. *A suggested plan for production of lobster juveniles for re-establishment or enhancement*

6.2 Suggestions for future research and development

Larval rearing: The larval rearing methodology that was used in the current project is based on methodology that is developed and thoroughly tested in the US and in Ireland. Event though this methodology worked satisfactorily also in the current project there is still compartment for improvement and modifications. Results from standardized experiments aimed at testing pre-decapsulated Artemia cyst, algae paste and various disinfectants could improve the production efficiency. The overall goal in this context should be to increase the stability of the production by eliminating the occasional problems with Vibrio infections and also to further increase larvae survival and to shorten the developmental time until stage IV.

Communal culture of juveniles: So far only small scale tests have been performed on communal culture of lobster juveniles. Large scale test needs to be done in order to estimate the actual production capacity and the costs related to labour and investment. A large scale test of communal lobster culture could, for instance, be carried out in a large sectioned outdoor pond at the existing lobster hatchery in Galicia. There is also a need for practical experience with the operation of a large communal rearing facility before operational costs can be estimated. As mentioned above an artificial and functional bottom substrate needs to be developed and tested.

Sea based culture of juveniles: Large scale culture of lobster juveniles in single compartment in the sea depends on development of a customized lobster basket as suggested above. In this context, experiments to determine the optimal design, including material type, compartment size and amount of compartments, are required. This could be done in a range of small scale tests, preferably in different regions and at different times of the year.

Transportation, release methods, juvenile quality and monitoring of growth and survival after release: The current project has dealt with refinement and development of production methodology. The next step of the project would be to release the lobsters into the sea and to monitor the growth and survival for a relatively long period after release (6-10 years). In this context, there is a need for establishing routines for transport and release of the lobsters that are adapted to this particular production methodology. Furthermore, there would be a need for studying the performance, in terms of ability to seek shelter, avoidance of predators and foraging, for lobsters produced with the different techniques. Finally, a long term monitoring programme with tagged and released lobsters is needed for estimating the potential for re-establishing endangered populations or for enhancing depleted stocks.

6.3 Feasibility of reestablishment or enhancement by releases of cultured juveniles

The keystone issues for successful re-establishment or enhancement activities are 1) stable and predictable production of high quality and inexpensive lobster juveniles and 2) a satisfactorily survival in the sea of the released juveniles. The current project has demonstrated that development of a cost-effective and efficient production of lobster juveniles is realistic. Whether or not the survival of the lobsters after release will be sufficient to find a basis for reestablishment or enhancement is difficult to assess. This can only be answered through long-term monitoring programmes. However, re-establishment and enhancement have different demands with respect to survival of the released lobsters. Re-establishment involves that a sufficient number of individuals survive to reproduction such that these lobsters are able to create a founder population than in the long run will become self-sustainable. Enhancement of stocks requires that the survival of the released lobsters will be high enough for supporting an economical viable regional lobster fishery based on a combination of wild recruited and hatchery reared lobsters. Hence, stock enhancement requires a considerably higher recapture rate compared to reestablishment. These break even survival rates are, however, difficult to assess at the time being and will obviously vary between regions and countries

.

It is also crucial to understand that re-establishment and stock enhancement are different from a sea ranching concept, which assumes that the recaptures of released lobsters will entail an economical profit in itself. Earlier studies have demonstrated that the recaptures of released lobsters most likely will be to low to support an economical viable sea ranching industry. Moreover, the sea ranching concept also involves major legislation difficulties concerning the ownership of the released lobsters.

An extremely crucial assumption for successful reestablishment or enhancement activities is that such activities are backed up with a regionally adapted management plan. Reestablishment or enhancement will be pointless if the released lobsters are not protected from over-fishing. Thus, it is imperative that any activity involving release of lobster juveniles into sea is accompanied with a sustainable and strictly enforced management scheme. Finally, releases of hatchery reared lobster juveniles is only one of several tools in the ”tools box” available for reestablishment or enhancement activities and other management schemes that for instance conserve and protect egg-bearing females should also be considered.

7 Conclusions

- The overall objective of the project was to provide information for improvement of lobster juvenile production methods with respect to costs and quality of animals and to suggest guidelines for development of regional lobster restocking through interregional collaboration, exchange of knowledge and transfer of technology

- The sub-goals of this project were to establish a pilot scale lobster production line at IGaFA, Galicia, for operational transfer of knowledge and technology, to improve and refine ongrowing methods for juvenile lobster and to evaluate and suggest guidelines for development of regional lobster re-establishment and enhancement. In addition we wanted to generate a network across the three regions for i) mutual exchange of knowledge and technology, and ii) development of future activities aimed at restocking depleted populations and establishment of localised lobster industries in the three regions

- A pilot scale hatchery for culture of lobsters from eggs to settlement (stage IV) was established at IGaFA during 2004. The hatchery has operated successfully until the end of the project with an average larval survival at 29.5 %. The hatchery is constructed in a portable container and is thus the first mobile lobster hatchery ever constructed.

- Four different ongrowing techniques for culture of lobsters from stage IV and until a size suitable for release (approximate 4 cm total length) have been examined and tested. Two techniques are based on culture of lobsters in single cages submerged under mussel rafts. In one of the techniques the lobsters were cultured in oyster **baskets**, while lobsters where cultured in specially designed **sea cages** in the second technique. Before the lobsters were transferred to baskets or sea cages they were cultured to stage V under controlled conditions. In the sea based phase the lobsters were not fed. The third tested technique involved juveniles cultured from stage IV and reared **communally** in tanks receiving ambient, flow-through seawater and containing mussels as a bottom substrate. The fourth technique was indoor **individually** culture with intensive feeding resembling the most common used method for culture of lobster juveniles in the past.

- The results from the ongrowing trials show that culture in baskets gave higher survival (> 80%) and growth (> 4 cm total length in approximate 180-210 days) than culture in sea cages. Communal culture resulted in a lower survival than these two methods, but comparable, though more variable, growth. Individually reared lobsters were significantly larger than lobsters cultured in baskets, sea cages or communally. However the growth differences were not large in relation to the basket and sea cage cultured lobsters that were not fed and communally reared lobsters that received only minor amounts of food. Thus, the results show that lobster juveniles cultured in single compartments under mussel rafts are able to utilize naturally occurring food in the sea and that this food source supports a sufficient growth and survival to culture lobster juveniles for re-establishment or enhancement purposes. The methodology developed would represent a cost-effective way of producing lobster juveniles for re-establishment or enhancement efforts, since expenses to labour, constructions and feeding is minimized and since the production efficiency is high.

- The results from the current project have been used to evaluate and suggest guidelines to develop a regional lobster reestablishment or enhancement programme. Emphasis has been made to suggest guidelines that are compatible with the infrastructures of management, fishery and aquaculture of the different participating regions in AquaReg. Furthermore, suggestions concerning required developmental work and research for scaling up the varying culture methods for mass production of lobster juveniles are presented and discussed. Even though the results from the current project are positive and indicate that it might be possible to culture lobster juveniles in a better and more efficient way compared to earlier large scale culture efforts, there is still a range of unanswered questions before a large scale production line for lobster juveniles and a successful restocking/enhancement activity can be established

8 Conclusiones

- El objetivo global del proyecto ha sido proporcionar conocimientos para la mejora de los métodos de producción de juveniles de bogavante en lo que atañe a los costes y a la calidad de los animales y proponer pautas para el desarrollo de la repoblación regional de bogavantes mediante la colaboración interregional, el intercambio de conocimientos y la transferencia de tecnología

- Los sub-objetivos han sido poner en marcha una línea de producción de bogavantes a escala piloto en el IGaFA (Galicia) para la trasferencia operativa de conocimientos y de tecnología, mejorar y afinar los métodos de pre-engorde de juveniles de bogavante y evaluar y proponer pautas para el desarrollo regional del restablecimiento y mejora de las poblaciones de bogavante. Además, hemos pretendido crear una red entre las tres regiones para i) el intercambio mutuo de conocimiento y tecnología, y ii) el desarrollo de actividades futuras que tengan como objetivo la repoblación de poblaciones que se hayan visto reducidas y el establecimiento en las tres regiones de actividades empresariales locales relacionadas con el bogavante

- Durante el 2004 se puso en marcha en el IGaFA un criadero a escala piloto para la cría de bogavantes desde el huevo hasta la post-metamorfosis (stage IV). El criadero ha funcionado con buenos resultados hasta el final del proyecto resultando una supervivencia larvaria media de 29,5%. El criadero fue construido utilizando una caseta de obra portátil, siendo el primer criadero de bogavante portátil que se haya construido.

- Se estudiaron y probaron cuatro técnicas diferentes de pre-engorde para la cría de bogavantes desde la fase IV hasta una talla adecuada para la suelta (aproximadamente 4 cm de longitud total). Dos técnicas se basan en la cría de bogavantes en cajas individuales sumergidas bajo bateas mejilloneras. En una de las técnicas, los bogavantes se criaron en **cestillos** ostrícolas mientras que en la segunda técnica los bogavantes se criaron en **cajas** diseñadas *ex-profeso*. Antes de ser trasladados a los cestillos o a las cajas, se criaron en condiciones controladas hasta la fase V. En la fase de cría en el mar no se alimentaba a los bogavantes. La tercera técnica ensayada consistía en la cría **comunal** de juveniles, desde la fase IV, en tanques que recibían agua de mar en flujo abierto y sin tratar y que tenían un substrato formado por conchas de mejillón. La cuarta técnica era la cría **individualizada,** bajo techo, con alimentación intensiva, semejante a los métodos más comúnmente empleados en el pasado para la cría de juveniles de bogavante.

- Los resultados de las pruebas de pre-engorde muestran que la cría en cestillos produce supervivencias más altas (> 80%) y mejor crecimiento (> 4 cm de longitud total en aproximadamente 180-210 días) que la cría en cajas. La cría comunal da como resultado una supervivencia menor que con estos dos métodos, aunque los resultados de crecimiento son comparables pero más variables. Los bogavantes criados individualmente eran significativamente más grandes que los criados en cestillos, cajas o comunalmente pero las diferencias de crecimiento no eran grandes si se comparan con los bogavantes criados en cestillos o cajas que no fueron alimentados y con los bogavantes criados comunalmente que recibieron sólo cantidades limitadas de alimento. Por lo tanto, los resultados demuestran que los juveniles de bogavante criados en compartimentos individuales bajo bateas mejilloneras son capaces de utilizar como alimento los organismos que se encuentran de forma natural en el mar y que esta fuente de alimento sostiene un crecimiento y supervivencia suficientes para la cría de bogavantes destinados al restablecimiento o mejora de poblaciones. La metodología desarrollada supondría una manera rentable de producir juveniles de bogavante para acciones de restablecimiento o mejora, ya que los costes de mano de obra, instalaciones y alimentación se minimizan y la eficacia productiva es alta.

- Los resultados de este proyecto se han empleado para evaluar y sugerir pautas para desarrollar un programa regional de restablecimiento o mejora de poblaciones de bogavante. Se ha puesto énfasis en sugerir pautas que sean compatibles con las infraestructuras de gestión, pesca y acuicultura de las regiones participantes en AquaReg. Además, se presentan y estudian sugerencias sobre el trabajo de investigación y desarrollo que se necesitaría para aumentar la escala de los diferentes métodos de cría, con objeto de alcanzar la producción a gran escala de juveniles de bogavante. Aunque los resultados de este proyecto son positivos e indican que podría ser posible la cría de juveniles de bogavante de forma más eficiente que con los anteriores intentos para la cría a gran escala, todavía hay un campo de preguntas, por el momento sin respuesta, antes de que puedan ser establecidas una línea de producción a gran escala de juveniles de bogavante y una actividad de repoblación que tenga éxito

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Norsk Institute for Nature Research
NINA Head Office
Postal address: NO-7485 Trondheim, NORWAY
Visiting address: Tungasletta 2, NO-7047 Trondheim, NORWAY
Phone: + 47 73 80 14 00
Fax: + 47 73 80 14 01
Organisationsnumber: 9500 37 687

http://www.nina.no

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