Preliminary Investigations into the Feasibility of Small Scale, Commercial Aquaculture of *Panulirus argus*, Based on Collection of Pueruli from the Wild

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ABSTRACT

Settlement of Caribbean spiny lobster (*Panulirus argus*) pueruli on a variety of collection devices was studied during April - July 2002 and May – September 2003 in the British Virgin Islands. Collectors were tested for efficiency relative to size and the most efficient collector was selected for subsequent use. Periodicity and catch rates were compared with results from similar studies. Settlement rates were highest during the new moon to first quarter, as found in other studies.

Post-pueruli collected in 2002 were reared at 667/m^2 for 30 days on diets of live brine shrimp nauplii, light-attracted plankton, and frozen coquina (*Donax variabilis or D. denticulatus*) or dwarf herring (*Jenkensia lamprotaenia).* Subsequently, the juveniles were transferred to static, aerated, 70 L tanks at initial densities of 330/m^2 and were fed either dwarf herring or coquina. Growth and survival rates were similar.

Juveniles (15 - 22 mm CL), were caught in seagrass beds and reared in 60 l tanks on mixed diets of squid flesh, dwarf herring and coquina, to estimate growth rates and rearing times to marketable sizes. A small number of post-pueruli were reared to >60 mm CL in under 10 months.

Throughout the trials, all mortality appeared to coincide with molting. Dead lobsters were rapidly consumed but cannibalism of live, molting, lobsters was not observed. Deaths are believed to be related to inadequate feeds or to physiological factors.

KEY WORDS: Aquaculture, spiny lobster, *Panulirus argus*

Investigaciones Preliminares en la Viabilidad de Escala Pequeña Aquaculture Comercial de *Panulirus argus*, Basó en la Colección de Pueruli del Salvaje

Asentamiento de puérulos de langosta espinosa caribeña (*Panulirus argus*)

en una variedad de dispositivos de la colección se estudió durante marzo – julio 2002 en las Islas de la Virgen británicas. Se probaron coleccionistas para eficiencia relativo a la dimensión y el coleccionista más eficaz se seleccionó para el uso subsecuente. Se compararon periodicidad y proporciones de la captura con resultados de los estudios similares. Las frecuencias del asentamiento eran más altas durante la nueva luna a primero cuarto de luna, como encontró en otros estudios.

Post-puérulos coleccionó en 2002 se crió a las 667/m^2 durante 30 días las dietas encendidas de nauplii de *Artemia* vivo, plancton luz-atraído, y el coquina helado (*Donax variabilis*), manjúa (*Jenkensia lamprotaenia*) y calamar. Como consecuencia, los juveniles se transfirieron a la estática, aireó, 60 L tanques a las densidades iniciales de 330/m^2 y o se alimentó manjúa o coquina. El crecimiento y proporciones de supervivencia eran similares.

Se realizaron experimentos criando adicionales sin los 30 días de inicial criar, a empezar densidades de 560/m^2. Post-puérulos se alimentó exclusivamente con coquina triturado o con manjúa. Las proporciones de mortalidad eran altas y aquéllos alimentaron en manjúa había impedido el crecimiento de crecimiento que persistió a pesar de la manipulación dietética más tarde.

Juveniles (15-22 mm CL), se cogió en pastos marinos y se crió en 60 L tanques en las dietas mixtas de carne del calamar, manjúa y coquina, estimar crecimiento tasa y criando tiempos a los tamaños comerciables.

Post-puérulos, coleccionó en 2003, se crió a las densidades de 55/m^2 en jaulas triangulares pequeñas puestas en tanques de 1200 L, con agua del mar corriente. Medio se crió en las dietas de coquina helado y manjúa mientras el remanente tenía la misma dieta complementada por un alimento comercial especialmente formulado. El crecimiento y proporciones de supervivencia eran buenas.

Durante los ensayos, toda la mortalidad parecía coincidir con mudar. Se consumieron langostas muertas rápidamente pero el grado al que el canibalismo de mudar langostas contribuyó a la muerte era incierto.

PALABRAS CLAVES: Aquicultura, langosta, *Panulirus argus*

INTRODUCTION

Spiny lobsters, of the family Palinuridae, are amongst the most valuable of all fishery resources. The global annual harvest is about 77,000 metric tons valued at US$500 million (Jeffs and Davis 2003). A large part of global production of spiny lobsters is exported to Japan and the U.S.A. and this is a very valuable source of foreign exchange.

The cultivation of spiny lobsters, based on the capture of post-larvae or juveniles, has become an important activity in Vietnam, where annual exports of cultivated lobsters have reached a value of US$ 25 million in seven years (Anon. 2000, Tuan et al. 2000, Hair et al. 2002). Their cultivation arose as an adjunct to the cultivation of groupers and with very little scientific input. The lobsters are reared in seabed enclosures or submerged cages and attain 1 kg in 2 years, with mortality rates reported to not exceed 10% per year (Hair et al. 2002). They are fed on trash fish that are available from the trawling industry

and a variety of shellfish (Tuan et al. 2000).

The larval life of all palinurids is six to nine months. The phyllosoma larvae are very widely dispersed and pass through many stages in the pelagic environment before they transform into post-larval pueruli that settle on the seabed. Juveniles of the most important tropical species inhabit shallow lagoons, mangroves and seagrass beds and move to deeper water as they mature.

Because of the lengthy larval life spiny lobsters are very difficult to rear from eggs. However, a variety of fairly inexpensive devices are known to attract settling pueruli, some of which have been designed specifically for this purpose. These include various assemblages of trays, fibrous mats, tiles or mats of plastic strands, suspended 0 - 3 m below the water surface. The pueruli of some species can also be caught in nets. Catch rates of pueruli are variable, depending on site and season.

As with other marine benthic organisms that have a planktonic or pelagic larval phase, the pueruli are subjected to extremely high predation rates during and immediately after settlement. In excess of 95 % of the settling organisms are consumed by predators (Hair et al. 2002, Acosta and Butler 1999), and the settled juveniles also have extremely high mortality rates. Consequently, it is highly likely that no more than one puerulus in 1,000 survives the first year of life on the seabed. Because of these high mortality rates at settlement, the capture of pre-settlement pueruli is expected to have no effect whatever on recruitment rates to the settled populations and the release of a single year-old reared lobster probably would be sufficient to offset the capture of 1000 pueruli.

In contrast to the capture of pre-settlement pueruli, the capture of settled juveniles will have an impact on the wild stocks and will reduce recruitment to the fishery and, eventually, the spawning stock biomass. It appears that juvenile lobsters are taken in Vietnam, and such practices are to be avoided if lobster cultivation starts elsewhere. Because of the long larval life, the larvae are probably widely distributed and the management of stocks of most species is an international issue.

It seems likely that development of cost effective harvest methods and low cost grow out systems might pave the way for sustainable lobster farming industries in many developing countries. The economic returns from such industries could be substantial and this may lead to an increased interest in marine conservation and sustainable use of fisheries resources, in general.

This project was undertaken with the main objectives of:

i) Identifying an economical, robust and effective method for collecting large numbers of the pueruli of the Caribbean spiny lobster, Panulirus argus, which might be applied at a fishery level by low income communities;
ii) Testing the scope for using locally available feeds to rear pueruli to market size, using a low-cost flowing sea water tank system;
iii) Determining the rearing period to reach minimum market size.

Other topics that are currently being investigated include the potential use of commercially available shrimp feeds for application in lobster culture,

observing feeding and molting behavior to avoid molt death or cannibalism, and examining the use of simple refuge structures that are scaled for single lobster occupancy.

COLLECTION OF PUERULI

Previous Studies

Many studies of the settlement of *P. argus* have been conducted in the Caribbean (Bannerot et al.. 1988, Gutierrez-Carbonell et al.. 1988, Ward 1989, Briones-Fourzan and Gutierrez-Carbonell 1988, Young 1991, Conceição et al. 1996, Quinn and Kojis 1997, Arango Lopez and Manrique Sierra n.d.). Most of these have focused on the collection of pueruli with specially designed collectors. Most collection devices are variations of the classic "Witham collector" (Witham et al. 1968). These have generally been made of closely spaced sheets of air-conditioner filter material suspended vertically from a float, to form a 30 cm (1-foot) cube. Other collectors include the Phillips collector and variants such as the GuSi collectors (Phillips and Booth 1994, Phillips 1995). These are either triangular or round in cross-section and covered with strands of synthetic material. Where these simple collectors have been used, comparisons can be made between different studies. However, very large variations can be found in settlement rates between consecutive years, between sites within years and seasonally within a single year. Rates of >50 pueruli/collector/month have been reported for individual sites (Briones-Fourzan and Gutierrez-Carbonell 1988, Quinn and Kojis 1997) while other studies have reported average monthly catch rates of <10 pueruli/collector/ month. The most comprehensive study to date was that of Bannerot et al. (1988) who obtained an average of 30 pueruli/collector/month in a year long study around Antigua.

Methods

Studies of puerulus collection techniques started in early 2002. A variety of devices, including mop heads, bundles of netting, containers of red algae, stacks of small PVC tubes and Witham-style collectors were tested. Only the Witham collectors were successful and subsequent puerulus collection effort used six large Witham collectors, 40 x 40 x 40 cm in size, each made of 10 sheets of settlement material. Filters are no longer used in most air conditioners. Instead, black aquaculture filter material (Enkemat, supplied by Aquatic Ecosystems Ltd, Apopka, FL, USA) was used. Additionally, an array of six small collectors was made from large (15 x 23 cm) green domestic scouring pads (produced by Sysco Ltd) threaded onto lengths of plastic coated wire and suspended from half a fishing float 0.2 m below the surface; three with five sheets per collector and three with 10 sheets. These collectors were deployed along the south-west coast of Beef Island, BVI, close to the Hans Creek channel, from February to July 2002. All collectors were checked weekly during this period and pueruli were removed for use in rearing experiments. Losses of collectors were high.

After a break in August, collection of pueruli resumed in early September.

A set of six new collectors, each made with six sections of Astroturf (23 cm x 15 cm) were tested along with the remaining collectors, increasing the number to 12. Astroturf is cheap and robust and sufficient material for a collector costs less than US$3.00. Fibres of similar texture to Astroturf, but longer, have proved effective for collection of pueruli (Gutierrez-Carbonell et al. 1988, Phillips 1972).

Collectors were deployed in water 3 - 5 m deep along the south coast of Tortola, at Paraquita Bay, Hodges Creek and Buck Island. The collectors were checked regularly throughout September, October and November 2002. Unfortunately, most disappeared over the course of these three months.

New collectors were made in 2003 from six rectangles of Astroturf (15 x 25 cm), spaced roughly 1 cm apart, by folding over the top 2 cm and threading this end of the section onto two U shaped lengths of plastic coated wire. This wire harness was then fitted with half a normal fishing float and a wire painter (20 cm). The wire painter could be snapped onto a wire hoop, on the string between marker flags, by means of a standard snap clip (used by most long-lining vessels to attach bait lines). Thirty collectors were divided into six strings of five collectors, with 2 m between collectors.

Three strings of collectors were deployed on the southwest side of Buck Island and three on the southwest side of Beef Island. At each site the collector strings were placed so that they were diagonally aligned with the shoreline and roughly facing the prevailing wave direction. One string at each site was positioned close to the headland, so that some of the wave energy from the rough conditions on the windward side would still reach it. The other two strings at each site were placed at equal distances between the headland and likely settlement habitats, in proportion to the geography of each site.

Commencing in April 2003, 40 additional collectors were constructed, each composed of six heavy-duty green scouring pads (15 cm x 23 cm). The end of each scouring pad was set into a square section of molten polypropylene (plastic bread board, 11 cm x 11 cm), which was then fitted with half a standard fishing float and a plastic coated wire painter as before. This cheap and fast new method of construction provides a very robust collector. These collectors were divided into eight strings of five collectors, spaced 2 m apart, and deployed close to channels through the fringing reefs that protect mangrove and sea grass beds. Collectors were checked once a week, where possible, and more often during high settlement periods.

Results

Mean monthly catches for each collector type were calculated from the individual catches at each haul (Table 1). For the 2002 sampling period catch rates were also converted to a function of surface area for each collector to examine their relative efficiencies.

The catch rates on the various collectors during 2002 are shown in Figure 1. A strong lunar periodicity is evident from the pronounced peaks in settlement. The Enkemat filter material collectors caught more pueruli during the April new moon peak, but otherwise catches do not appear to be significantly different. During the largest settlement event of the year, 217 pueruli were collected from the array of collectors at Beef Island. The largest individual

catches were consistently taken from collectors placed at the edges of channels through the fringing reef. A total of 405 pueruli were harvested from 10 collectors in three months of sampling. The smaller scouring pad collectors caught many more pueruli per cm^2 than the Enkemat collectors (Figure 2).

Table 1. Calculated mean monthly catch rates for each type of collector tested during 2002 and 2003.

	Black Witham	Scour pad		Astro turf	Scour pad
Apr-02	8.31	1.60	**May-03**	0.20	0.40
May-02	12.56	7.94	**Jun-03**	0.06	0.50
Jun-02	4.50	3.36	**Jul-03**	0.10	0.90
Jul-02	4.33	1.20	**Aug-03**	0.27	1.16
			Sep-03	0.70	3.60
Range	**4.33-12.56**	**1.20-7.94**	**Range**	**0.06-0.70**	**0.40-3.60**

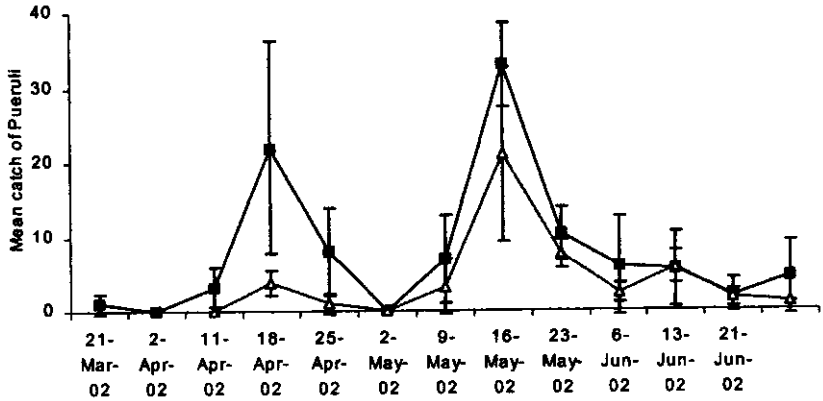

Figure1. Mean catches of pueruli/collector during weekly hauls at Beef Island in 2002. Black squares represent the Enkemat filter material Witham collectors (+/- SD). Open triangles represent the two sizes of scouring pad collectors (+/- SD). The x-axis dates approximate the new moon period of each calendar month.

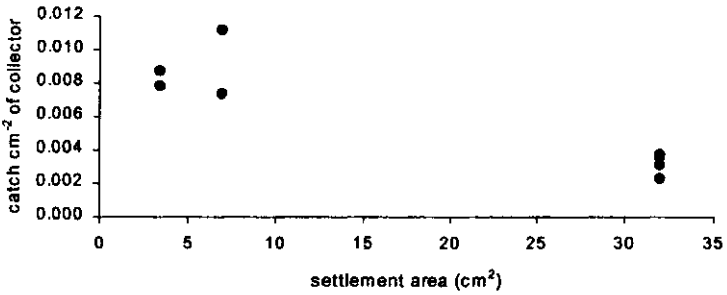

Figure 2. Mean catch rates per cm^2 of total collector surface area for 40 x 40 cm, 10-leaf Witham collectors and 15 cm x 23 cm 5-leaf and 10-leaf scouring pad collectors.

The large Enkemat Witham collectors became very heavy as they fouled and were difficult to handle in rough conditions. The plywood base was colonized and burrowed into by a variety of organisms and eventually destroyed. The two sizes of scouring pad collector were much more easily checked, but lasted less than six months in the water as wave action on the fouled surfaces pulled the material apart at the wire fastenings. The larger 10-leaf collectors caught somewhat more pueruli than the 5-leaf collectors, but the differences were not significant (Figure 2).

Settlement of pueruli to the Astroturf collectors in 2003 was very sparse. Only 99 pueruli were collected from a total of 960 hauls. In contrast, 369 pueruli were collected from 315 hauls of the scouring pad collectors. Most pueruli were collected between 15 and 20 days after the full moon (Figure 3). The catches on scouring pad collectors steadily increased between May and September 2003 with larger numbers of pueruli settling on heavily fouled collectors and those collectors positioned close to channels through the fore reef. Distribution of pueruli within each string of collectors, and indeed on each collector, was not uniform and pueruli appeared to aggregate. Groups of up to eight pueruli were regularly found on one or two of the five collectors in each string and were grouped on apparently random leaves of these collectors.

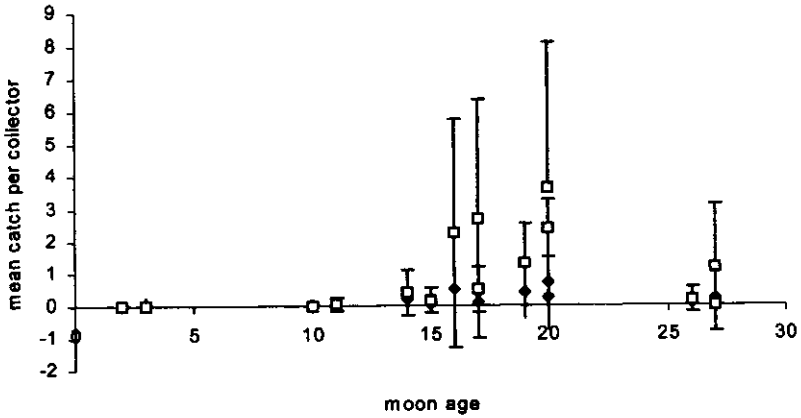

Figure 3. Catch rates on 6-leaved Astroturf collectors (closed diamonds) and 6-leaved scouring pad collectors (open squares) (+/- S.D.) relative to moon age during 2003

Discussion

The magnitude of catches of the larger Enkemat Witham collectors suggests that the size of collector may be important in attracting pueruli. However, the lack of correlation between catch and collector surface area, indicates that the size of the collector profile may be important. The aggregation of pueruli on one or two collectors within groups of collectors suggests that there may be a behavioral explanation for the observed settlement patterns. Audio communication or olfactory cues might be important, as has been shown for settling reef fish (Altema et al. 2002).

Catche rates on the Astroturf collectors were far too low for a commercial growout operation. Scouring pad collectors were more efficient and are cheap, easily made, robust and easily checked. It appears that numbers of pueruli per collector increased steadily over the collection period, suggesting that there was either a gradual increase in numbers of settling pueruli or the collectors become more efficient as they mature. At the collection rates reported, 920 scouring pad collectors would be required to provide 30,000 pueruli per year (the figure that we consider to be the minimum for an economically viable, individually-operated grow-out system). At less than US$ 6,000, the cost of this many collectors is not prohibitively expensive, but the time taken to check all the collectors would be a major expense. It is possible for one person to check over 100 collectors in a day. With a nine-day collection period spanning the first quarter moon of each month, it would be possible for one person in a small craft to carry out this scale of collection effort. However, deployment of so many collectors may create conflicts with other resource users. We were unable to secure supplies of uncut rolls of scouring pad material direct from primary manufacturers. If this were possible it would substantially reduce the cost.

REARING EXPERIMENTS

Feeds and Methods

One of the objectives of the project is to identify a cheap and acceptable feed that may be used to sustainably farm lobsters throughout the Caribbean. The dwarf herring, *Jenkensia lamprotaenia*, are abundant at certain times of the year, as are several other species of clupeids and engraulids. These species are occasionally harvested for bait but are not otherwise used. Additionally, the coquina (*Donax sp.*, either *D. variabilis* or *D. denticulatus*), are found on beaches throughout the Caribbean and coquina are known to be an ideal food for spiny lobsters (Ting 1973). They can be harvested relatively easily by a sand rake.

From December 2001 to August 2002, lobsters were maintained in static seawater in a set of nine 70 L tanks or in small aquaria, with aeration and under-gravel filters. Water was changed weekly. Subsequently, a flowing seawater system became available together with three 1,200 L tanks.

Seventeen small juvenile lobsters captured in sea grass beds in December 2001 and January 2002 were individually tagged with paper numbers stuck onto the carapace with "superglue". The lobsters were measured (carapace length), weighed and re-tagged after each molt. They were fed on diets of fish, coquina and squid, in combination or alone, twice per day, every day.

Additionally, 15 post-pueruli, caught in October 2002, were reared in 70 L tanks on a diet of coquina and fish. Water was changed twice a week and the under gravel filter was renewed every four weeks. Mean water temperature in the tank was 26°C. In May 2003 these lobsters were transferred to the flowing sea water system where mean water temperature was 29°C.

Post-pueruli taken from puerulus collectors were transported to the laboratory in aerated 19 L (5 gallon) bottles. Clumps of fresh red algae were provided as shelter and these will also have contained micro-fauna. After 24 hours they were transferred to small tubs or aquaria where they remained, usually, for 30 days. Thereafter they were transferred to 70 L tanks or enclosures within the 1,200 L tanks for feeding and survival experiments.

For the 30-day post-puerulus nursery stage, the lobsters were stocked at 667/m^2 and fed on a mixed diet of *Artemia* nauplii, amphipods, live plankton and crushed coquina. Three specific feeding experiments were undertaken. In the first experiment, a comparison was made of growth and survival on diets of crushed coquina or fish. All lobsters were measured at weekly intervals for 60 days but this was discontinued in later work to minimize disturbance. Secondly, crushed coquina or *Artemia* nauplii or live plankton were compared. In the third experiment, the lobsters were fed exclusively on coquina or on a mixture of *Artemia* nauplii and live plankton, with three replicate of each treatment.

After the nursery stage, lobsters were stocked in 70 L tanks at 330 m^2 and fed twice a day. Each day the tanks were scanned for fresh molts, the lengths of the molted carapaces were measured and the numbers of surviving lobsters counted. From May to August 2002, lobsters were reared either on diets of dwarf herring alone or a mixed diet of coquina, dwarf herring and squid.

In 2003, the 1,200 L tanks in the flowing seawater system were stocked at a density of 550/m^2 with post-pueruli, 10 days post settlement. The lobsters were given a diet either of coquina and fish or a diet of coquina, fish and pellets made from agar and commercial *Penaeus monodon* feed (Zeigler Bros. Aquastable). These experiments are continuing and the results will be reported elsewhere.

Results

The length-weight relationship of juvenile lobsters can be described as $W = 0.0016CL^{2.5738}$, when weight (W) is measured in g and carapace length (CL) in mm. There was no discernable difference between males and females in the size range studied.

The 17 tagged juvenile lobsters were reared for up to 96 days. All showed substantial growth at successive molts but with much variability in the increment in carapace length and weight. Lobsters were generally fed on a mixed diet of coquina and dwarf herring and a basic diet of dwarf herring supplemented by coquina appears to be adequate although, no doubt, better diets will be found or formulated.

Growth increment data were analyzed using the method of (Munro 1982). There was much variation in the size of increments. With the asymptotic carapace length (L_{inf}) set at 174 mm for females and 190 mm for males, the average growth coefficients were 0.29 for females and 0.24 for males, values that conform well with the general range of values found in the literature (Baisre 2000). At these rates of growth, males would reach a CL of 65 mm and a weight of 250 g in about 21 months and a female the same size in about 2 years. Water temperatures were 26-27 °C, whereas optimum growth rates are reported to be achieved at 30°C (Lellis and Russell 1990). In practice, it is also possible that poor-growing individuals, particularly females, would be culled and released, provided that numbers were not sufficiently large to affect local genotypes.

Newly settled pueruli, reared at a high density and fed crushed coquina, grew significantly faster than pueruli fed with chopped frozen fish (Figure 4). However, the lowest mortality rate was achieved by rearing newly settled pueruli with frozen fish.

Post-pueruli that were reared on a diet of crushed coquina molted more frequently, were larger and the cohort attained a larger biomass than those fed on brine shrimp nauplii or on plankton (Table 2). P revious investigators have used adult brine shrimp as feeds for post-pueruli with satisfactory results (Pardee and Foster 1999).

In the third experiment, 10 post-pueruli were reared for 30 days in floating 1.0 L tubs and fed either crushed coquina or a mixture of brine shrimp larvae and plankton. Table 3 shows that the post-pueruli generally survived and grew better on the clam diet. Additionally, survival in "clams tub 1" was exceptionally low, and if this tub can be discounted the final biomass attained on the coquina diet would be markedly superior.

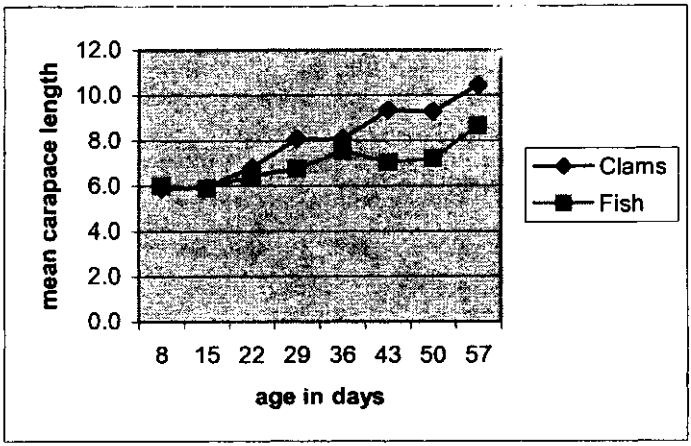

Figure 4. Comparative growth rates of newly settled pueruli fed with crushed coquina and with chopped dwarf herring.

Table 2. Survival and biomass of 15 post-pueruli reared for 30 days in 7.5 L enclosures and fed on chopped coquina, Artemia nauplii and plankton.

Feeds	Clam 1	Clam 2	Artemia	Plankton
Number or post-pueruli	15	15	15	15
Total No. Molts	26	19	16	18
Molts per day	0.84	0.61	0.52	0.58
Molts per day per lobster	0.056	0.041	0.034	0.039
Survival	0.93	0.87	0.87	0.87
Mean CL of survivors	7.9	8.2	7.9	6.7
Mean wt of survivors	0.7	0.8	0.6	0.4
Surviving biomass	10.2	10.1	7.3	4.9

Table 3. Survival and biomass attained by 10 post-pueruli reared for 30 days in 1.0 L floating tubs and fed on chopped coquina clams or *Artemia* nauplii and plankton (a & p).

Feeds	Clams 1	Clams 2	Clams 3	Average clams	a&p 1	a&p 2	a&p 3	Average a&p
Number of post-pueruli	10	10	10	10	10	10	10	10
Total No.of molts	9	20	7	12	6	5	7	6
Molts per day	0.29	0.65	0.23	0.39	0.19	0.16	0.23	0.19
Survival	0.3	0.9	0.8	0.67	0.8	0.7	0.9	0.80
Mean CL of survivors	6.5	7	7.6	7	5.8	6.4	6.1	6.1
Mean wt of survivors (g)	0.4	0.5	0.6	0.5	0.3	0.5	0.3	0.4
Surviving biomass (g)	1.2	4.3	5.3	3.6	2.4	3.3	3.1	2.9

Early juvenile lobsters that were reared in tanks from age 30 - 90 days on diets of fish or coquina showed no differences in growth rate (Figure 5). When early juvenile (>30 days old) lobsters were reared in tanks, survival rates were generally poor. In a number of cases this appeared to be attributable to cannibalism of newly molted individuals, but it is not entirely clear that the individuals that died were killed by other lobsters or were consumed after they had died as a result of the molting death syndrome that has been reported by other investigators (Lellis 1991).

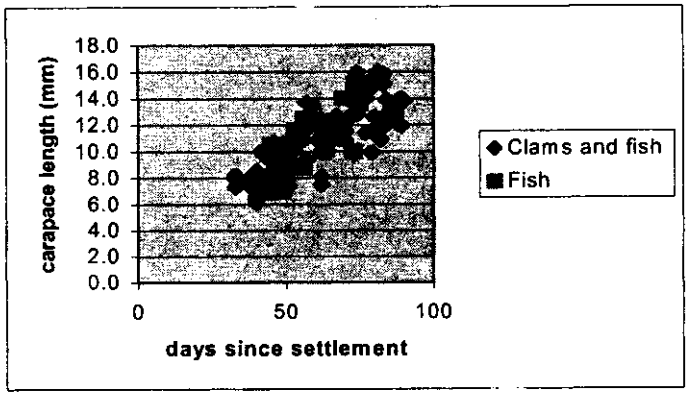

Figure 5. Comparative growth rates of 31-90 day-old lobsters fed exclusively on coquina or fish, after rearing in nursery tanks for 30 days post-settlement

Lobsters collected as pueruli in October 2002 and reared in 70 L tanks for six months before being transferred to the flowing sea water system reached >60 mm CL by July and August 2003. The diet consisted of 50 % fish and 50 % frozen clam with occasional supplements of goose barnacles (*Lepas anatifera*). Of 15 pueruli stocked in the tank in October 2002, only seven remained after six months. Mortality was entirely associated with overnight power failures.

Discussion

Newly-settled pueruli can be reared on crushed coquinas with great success. High early survival rates have been achieved by supplying pueruli with high concentrations of amphipods, but the convenience of coquinas is unsurpassed so far. Dwarf herring are particularly useful for the larger lobsters, between three and nine months post-settlement. Lobsters will readily take this feed and appear to do well on it when they are larger (Figure 5).

Survival in general was too low for immediate commercial application. Regular grading of lobsters as well as provision of plentiful hiding places, suitable for single occupancy, may help to reduce aggressive interactions.

CONCLUSIONS

The investigations have shown that scouring pad material is an effective and inexpensive settlement surface for pueruli and that collectors with reduced dimensions and settlement surfaces give higher rates of settlement per unit of settlement area. No work was done with Phillips or Gusi collectors (Phillips 1972, Gutierrez- Carbonell et al. 1988) because the settlement materials used (Filastica and Tanikalon) are expensive or difficult to purchase. Some of the designs that have been tested in Australia (Phillips et al. 2003) are very expensive and their possible loss would constitute a serious financial risk to small-scale operators. No particular collector has yet been shown to be optimal for small-scale operations and comparative trials are needed to resolve this issue.

Lobsters should be graded according to size, regularly (once a month is recommended), and sufficient shelters of the appropriate size (sufficient for single occupancy) may be advantageous.

Post-pueruli were raised from 6 mm CL to >60 mm CL in nine to ten months. The importance of temperature on growth rates is well reported (Lellis and Russell 1990, Lellis 1991, Jeffs and Davis, 2002). With constant water temperatures of around 30°C, a well-designed tank and seawater system and a diet of coquina and fish, it is likely that pueruli could be reared to 250 g within 12 months.

The cause of deaths at molting remains a major unsolved problem.

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