Journal of Shellfish Research, Vol. 18, No. 2, 451–458, 1999.

GROWOUT OF BLACKLIP PEARL OYSTERS, *PINCTADA MARGARITIFERA*, ON CHAPLETS IN SUSPENDED CULTURE IN SOLOMON ISLANDS

KIM J. FRIEDMAN[1,2]* AND PAUL C. SOUTHGATE[1]
[1]*James Cook University*
Townsville
Queensland 4811, Australia
[2]*ICLARM Coastal Aquaculture Centre,*
P.O. Box 438
Honiara
Solomon Islands

ABSTRACT This study, conducted in the "open" reef systems of Solomon Islands, assessed growth and survival of blacklip pearl oysters (*Pinctada margaritifera*, L.) on chaplets in suspended culture. Oysters were robust and mortalities after handling and drilling were low (<0.6 %). Survival of an initial batch of *P. margaritifera* was 87% after 1 year. Groups of oysters with mean dorsoventral measurements (DVM) of 63 and 71 mm showed mean (± SE) annual growth rates of 64 ± 2 and 60 ± 1 mm, respectively. Growth rates compared favorably with those reported for *P. margaritifera* in Polynesia and indicate that oysters caught as spat (approx. 11 mm, DVM) would reach acceptable size for "seeding" (110 mm DVM) in around 16 months. Oysters on chaplets were subject to significant fouling by algae, however, survival of oysters cleaned every 2, 3, 4, and 6 weeks was 96–97% over a 7-month period. Growth of oysters cleaned every 3 weeks was significantly greater than those cleaned every 2 or 6 weeks. Oysters became detached from chaplets (through drill-hole breakage) in significant numbers; this problem was greater for smaller oysters. When oysters were attached singly on chaplets, approximately 54% made byssal attachments to the rope; however, 90% of oysters held in pairs on chaplets made byssal attachments to each other. Although paired oysters could be cleaned more rapidly than oysters hung singly, shell growth (DVM) of paired oysters was significantly reduced.

KEY WORDS: pearl oyster, *Pinctada*, growth, survival, chaplets, suspended culture, open reefs

INTRODUCTION

Production of cultured black pearls from *Pinctada margaritifera* is seen as an appropriate, sustainable industry for remote regions of the Pacific (Lucas et al. 1995), and has expanded rapidly in eastern Polynesia over the last decade (Fassler 1995). French Polynesia has been at the forefront of this development and currently earns approximately US $145 million annually from the sale of black pearls (Remoissenet 1996, Doubilet 1997). This success has not gone unnoticed by other small island nations in the region (Lucas et al. 1995). Historically, these nations have relied on more modest incomes from the sale of *P. margaritifera* shell for its nacre or "mother-of-pearl" (MOP) (Gervis and Sims 1992, Richards et al. 1994). In Cook Islands, pearl culture started with one family in 1982 (Sims 1993a), and, by 1994, pearl sales generated an annual income of US$ 4.5 million (Fassler 1995). At present, black pearl culture is also underway, being attempted or assessed in Japan (Lintilhac 1987), Marshall Islands (Sims pers comm. 1998), China (Meng and Xing 1991), Vanuatu (Anon 1996), Fiji (Ward 1995, Mercier and Hamel 1998), and Solomon Islands (Friedman et al. 1996, Mercier and Hamel 1998, Friedman et al, 1998).

In the atolls of Polynesia, *P. margaritifera* are generally harvested from collectors as spat and cultured on dropper ropes or "chaplets" (see Fig. 1) when their dorsoventral measurement (DVM, Nicholls 1931) reaches 65–90 mm (AQUACOP 1982, Preston 1990). This method is also widely used for scallops in Japan (Ventilla 1982). Oysters are drilled through the base of the shell (dorsal posterior region) and attached to chaplets with wire or monofilament fishing line. Oysters are grown on chaplets for the rest of their time in culture, only being removed temporarily when they reach 110 mm DVM, to be "seeded" for pearl production (Lintilhac 1987).

Oysters large enough to be held on chaplets have "size refuge" from all but the largest fish and invertebrate predators (Coeroli et al. 1984), and, because longlines are set in relatively deep water, they are isolated from predators associated with reefs (Swift 1985, Sims and Sarver 1995). However, survival and growth of pearl oysters in suspended culture is also influenced by fouling (Alagarswami and Chellam 1976, Mohammad 1976, Doroudi 1996, Taylor et al. 1997). In Cook Islands, chaplets are removed from the water once a year for washing with pressure hoses. At this time, algae ("soft" fouling) and such organisms as cementing bivalves and tubular polychaetes ("hard" fouling) are removed. Before oysters are returned to the water, the fastening of the oyster to the chaplet is checked for wear, and the oyster is re-drilled if necessary (J. Lyons, pers comm. 1997).

Oysters are sometimes lost from chaplets when drill holes break, and oysters fall to the bottom. In Cook Islands, farmers lose ~5% of stock in this way (R. Newnham, pers comm. 1995); however, because atoll lagoons generally have a hard substrate (Sims 1992, Coeroli et al. 1984), a large percentage of these oysters can be recovered (J. Lyons, pers comm. 1997).

Recently, experiments were conducted in Solomon Islands to determine whether collections of wild spat and culture of juvenile oysters would be successful in the "open" reef systems that are characteristic of that region (Friedman and Bell 1996, Friedman et al. 1996, Friedman et al. 1998, Friedman 1998). However, there is a paucity of published information on growth of *P. margaritifera* held on chaplets for open reef systems of the Pacific. This paper describes growth and survival of *P. margaritifera* held on chaplets in Solomon Islands. In addition, experiments were conducted to: (1) determine a cleaning regime that optimizes growth of oysters held on chaplets; and (2) assess the rate of oyster losses from chaplets because of failure of drill holes.

*Corresponding address: P.O. Box 20, North Beach, Western Australia 6020. E-mail: kfriedman@fish.wa.gov.au

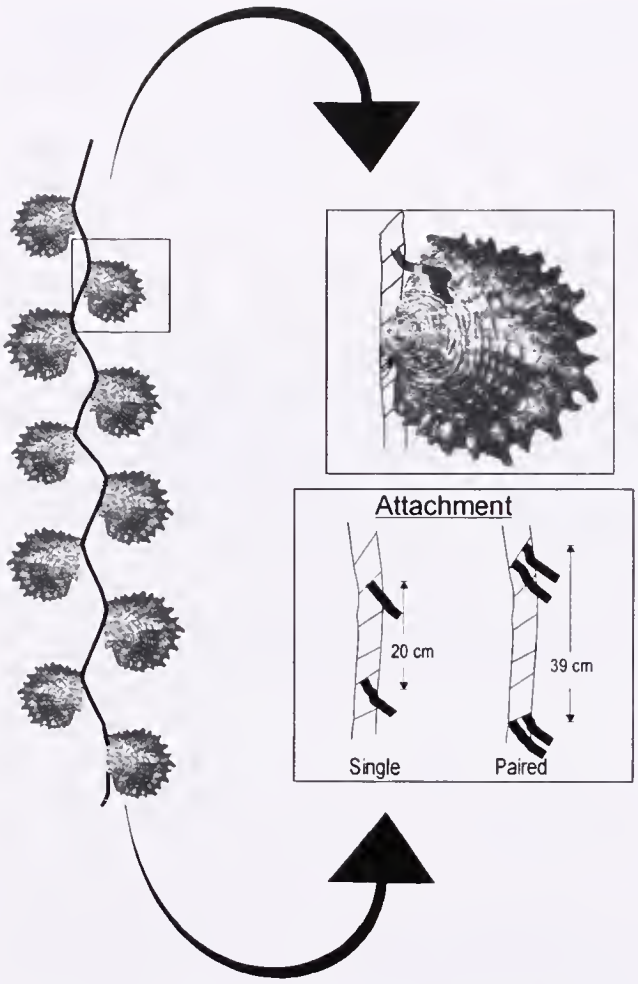

Figure 1. Chaplet system for culturing *P. margaritifera*.

MATERIALS AND METHODS

Growout of *P. margaritifera* on chaplets was carried out within Gizo lagoon in the Western Province of Solomon Islands (Fig. 2). The section of the lagoon chosen for oyster culture was approximately 1 km across with a mean depth of ~40 m, and numerous passages and sections of submerged reef linking the lagoon to the open ocean. Currents in this area measured over a representative tidal cycle with a Schiltknecht Mini Air 20 current meter ranged between 0.0–0.15 m s^{-1}.

P. margaritifera with a DVM of ~65 mm were drilled (2-mm drill bit) and tied to 4-mm polypropylene rope chaplets using monofilament fishing line (37 kg breaking strain) of a similar width to the drill hole (Fig. 1). All oysters were threaded onto single pieces of monofilament and tied so that the flatter of the two valves lay against the chaplet rope (Fig. 1). Oysters tied singly, were attached at ~20 cm intervals, when attached singly along the chaplet and 40 cm apart when in pairs (Fig. 1). Chaplets held 10 single oysters (or five pairs) and were attached to submerged longlines at 1.5-m intervals. The 100-m longlines (Fig. 3) were held at a depth of approximately 9 m and sited at least 50 m clear of fringing reef, over a sandy substrate. During the growth trials, oysters were brushed *in situ* by divers using SCUBA, to remove fouling on a monthly basis. Oysters that became detached from chaplets during the trials were re-drilled and replaced in their original position on the chaplet.

Growth and Survival of Oysters on Chaplets

A trial group of 90 oysters were drilled and hung singly on chaplets at the end of August 1996. These oysters were divided into two size classes: 58–65 mm and 66–78 mm DVM, with a mean (± SE) of 63 ± 0.3 mm (n = 51) and 71 ± 0.7 mm (n = 39), respectively. These oysters were removed from the water and measured every 3 months. A second group of 1,440 oysters with a mean (SE) DVM of 66 ± 0.3 mm, were drilled and hung singly on chaplets between 11 November 1996 and 5 December 1996. These oysters were removed from the water and measured in February and again in September 1997.

At the end of these trials (September 1997), oysters from experiments were measured for wet weight and shell thickness (Gervis and Sims 1992), as well as DVM. Additional data from pearl oysters grown on chaplets under similar conditions, but not included in experiments, where collated with data from experimental animals and used for analysis of morphometric relationships. Morphometric analyses of pearl oysters were conducted on both experimental animals and other oysters grown under similar conditions.

Modifying Cleaning Regimes of Oysters on Chaplets

To identify a cleaning regime that provided satisfactory growth and survival, with acceptable labor input, 100 oysters that were hung singly on 10 replicate chaplets were cleaned every 2, 3, 4, or 6 weeks, for 7 months (20 February to 22 September 1997). At the start and end of this experiment, all oysters were measured (DVM). The mean DVM at the start of the experiment was 85 ± 0.4 mm (n = 400). Fouling algae were saved from 25% of the oysters from each cleaning treatment in June 1997, at the time when oysters were scheduled for cleaning. Algae from individual oysters were placed into individual fine-meshed bags and rinsed to removed fine particulate matter (silt) and contaminants (e.g., shell, crabs) before being sun dried for up to a week. The samples were then oven dried for 24 h at 65 °C and weighed.

Retention of Oysters on Chaplets

Chaplets made up in November to December 1996 (n = 1440) and immersed for 7 months were assessed to determine any relationship between the size of oysters at drilling and their retention on chaplets. All data used in this assessment were from chaplets where oysters had been hung singly.

Strong byssal attachment reduces the chance of oysters being lost from chaplets. Observations that oysters readily made attachments to other oysters prompted an experiment to monitor byssal production and attachment of oysters hung in pairs and oysters hung singly. In April 1997, eight replicate chaplets (10 individuals per chaplet) for each treatment were deployed on longlines. The mean (±SE) DVM at the start of the experiment was 67 ± 0.5 mm (n = 160). At the end of 4 months immersion, retention of oysters, byssal attachment, and growth (DVM and wet weight) of oysters were recorded. Chaplets holding "paired" and "single" oysters were cleaned monthly, and the time required for cleaning was determined. Following this experiment, byssal threads of all oysters were severed, and re-attachment was examined by SCUBA divers after 1, 2, 7, 14, and 21 days.

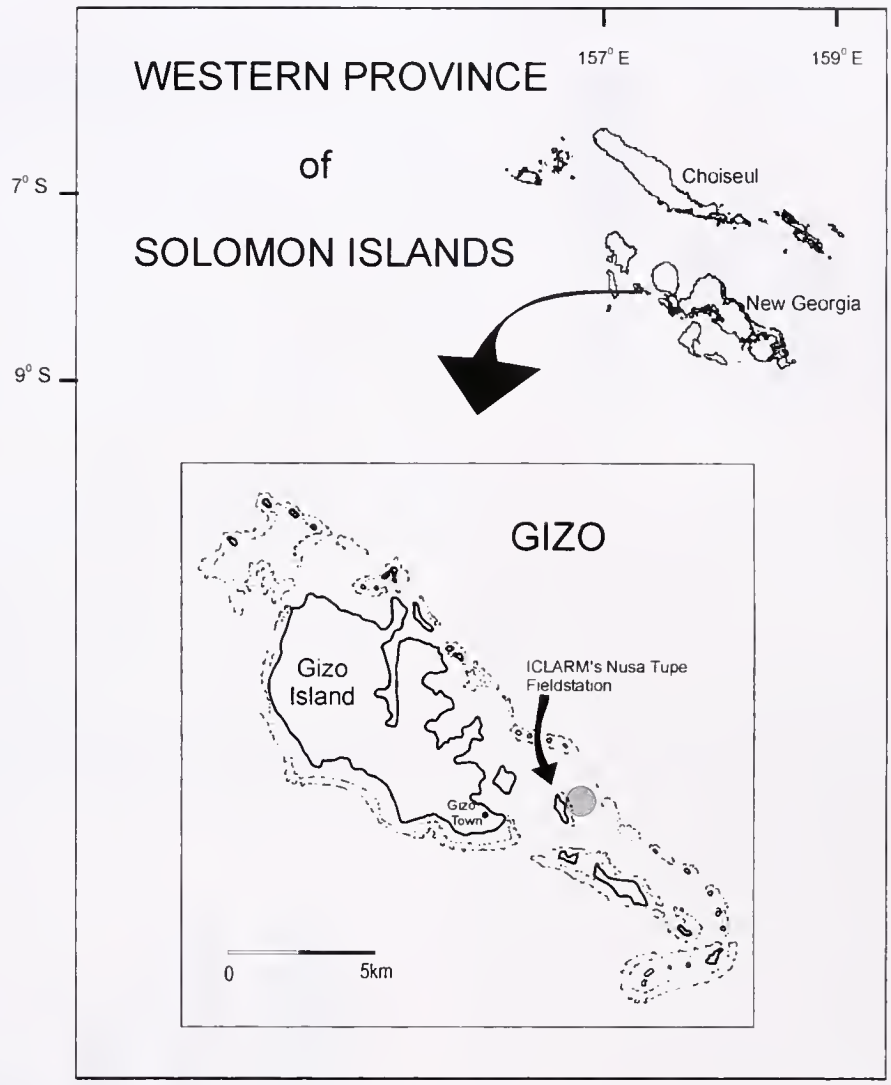

Figure 2. Gizo Lagoon in the Western Province of Solomon Islands. *P. margaritifera* were held in suspended culture east of Nusa Tupe Island (circled area).

Data Analysis

To examine differences in oyster growth (mm DVM) among cleaning regimes, a nested analysis of variance (ANOVA), (cleaning schedule × chaplet [cs]) was used with data from six oysters per chaplet. To examine differences in dry weights of algae among cleaning regimes, a similar analysis was conducted using algal weights from five oysters from four chaplets within each treatment.

To compare byssal attachment between oysters hung singly and in pairs, the number of oysters on each chaplet forming attachments with each other, or the rope, were compared for each treatment using a t-test. Growth (mm DVM and g wet weight) of oysters in each treatment were analyzed using t-tests. To analyze variation in the time taken to brush all oysters on a chaplet for each treatment, a two-way ANOVA, (method of attachment × diver) was used for two divers each cleaning four chaplets within each treatment.

Before t-tests or ANOVA, data were checked for homogeneity of variance using Levene's or Cochran's test, respectively, and transformed to $\log_{10}(x + 1)$ to meet this assumption where necessary. Significant differences among means were identified using Tukey's HSD test.

RESULTS

Growth and Survival of Oysters on Chaplets

From the initial batch of 90 oysters, 78 (87%) were alive 1 year later. For the 12 oysters that were lost, only two dead shells were found attached to chaplets. The two subgroups drilled at sizes between 58–65 mm and 66–78 mm, had a mean (± SE) annual growth rate of 64 ± 1.9 mm and 60 ± 1.4 mm DVM, respectively (Fig. 4). Two of the oysters from each of these subgroups showed very low growth rates (<39 mm y^{-1} DVM).

Of the 1,440 oysters drilled and hung in November to December 1996, 1,342 (93.2%) were live in September 1997. Of the 98 that were lost, only eight dead shells were found on chaplets. Growth of these oysters is represented in Figure 4, by four subgroups of oysters, delineated by their mean (± SE) sizes at drilling

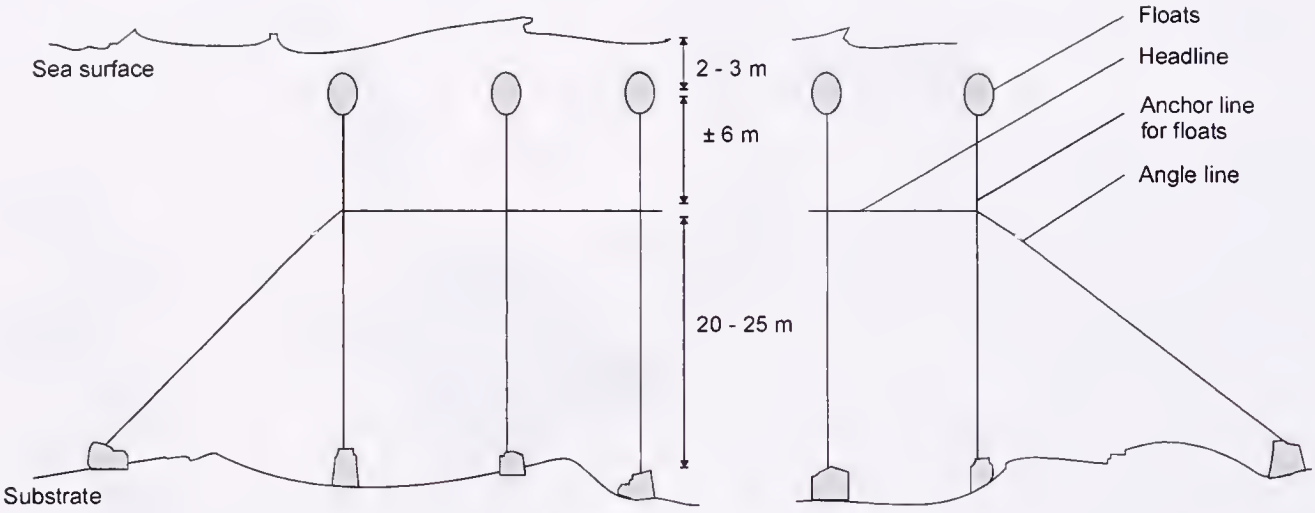

Figure 3. Diagram of longline system for suspended culture of *P. margaritifera* on chaplets.

(DVM): 52 ± 0.2 mm (n = 64); 60 ± 0.2 mm (n = 225); 69 ± 0.2 mm (n = 206); and 78 ± 0.3 mm (n = 63). Growth of these oysters was not as fast as the 90 oysters drilled in August 1996 (Fig. 4). Those hung on chaplets at a size of approximately 65 mm DVM attained 110 mm DVM, the size required for seeding, in 8 months. When oysters were attached to chaplets at a size of 77.8 mm DVM, they were large enough to seed in 6.5 months (Fig. 4).

Morphometric relationships between wet weight and DVM and shell thickness and DVM are shown in Fig. 5 a & b. Graph a) is useful to farmers of *P. margaritifera*, because it allows for comparisons of size/weight ratios between stocks of oysters grown in Solomon Islands and those grown elsewhere. The graph can also help farmers of *P. margaritifera* in Solomon Islands who want to calculate flotation needs for longline culture. Graph b) is added for general reference and will be of value should a relationship be established between shell thickness and the capacity for oysters of greater thickness to accept and retain larger nuclei.

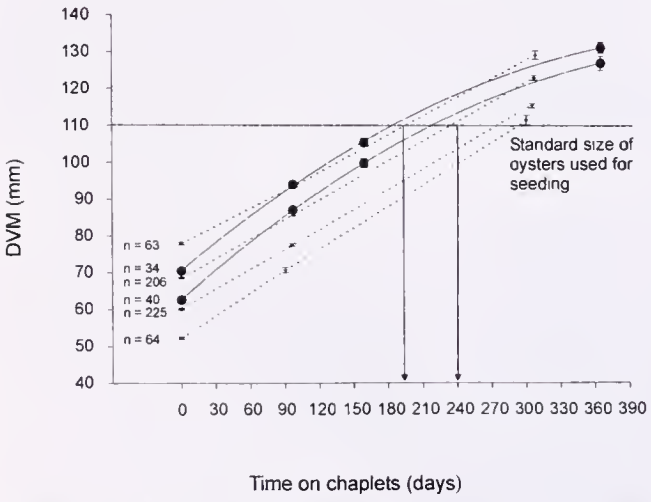

Figure 4. Growth (DVM SE) trajectories for subgroups of *P. margaritifera* of different sizes placed on chaplets for growout. The two long-dash lines depict growth of the 90 oysters drilled and hung on chaplets in August 1996, and the four dotted lines are from the bulk of oysters drilled and hung on chaplets in November to December 1996.

Modifying Cleaning Regimes of Oysters on Chaplets

Survival of oysters cleaned every 2, 3, 4, and 6 weeks was 96, 96, 96, and 97%, respectively, despite the fact that algae grew heavily on oysters, sometimes covering them completely. Analysis of dry weight of algae on oysters cleaned every 2, 3, 4, or 6 weeks showed a progressive increase in weight of algae from 2 to 4 weeks, but no significant increase in weight between 4 and 6

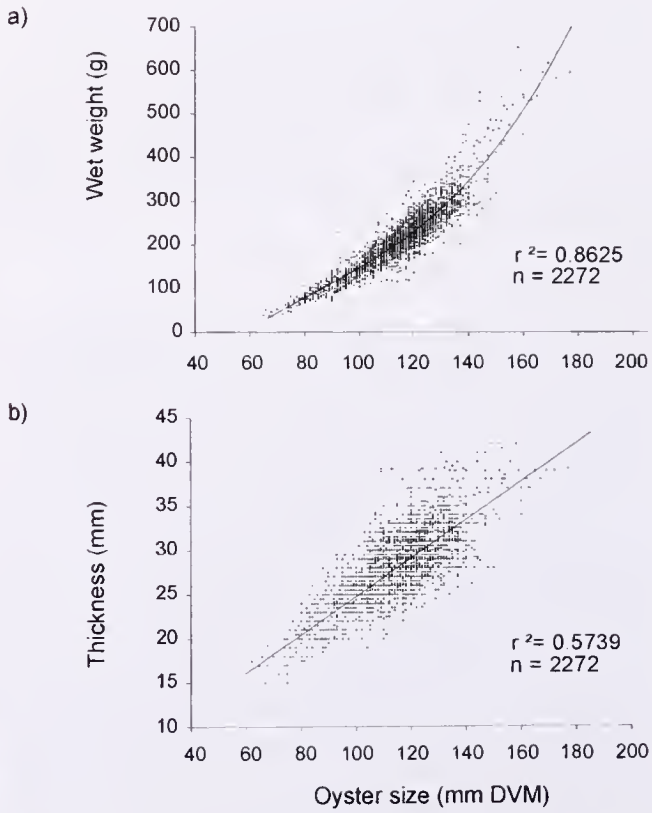

Figure 5. Size of *P. margaritifera* (DVM) relative to: a) wet weight; and b) thickness.

TABLE 1.

Results of the nested ANOVA for effects of cleaning schedule (fixed factor) and chaplet (random factor) on a) dry weight of algae on collectors, and b) growth of *P. margaritifera* (DVM).

Source of Variation	df	MS	F	P
a) Dry weight of algae				
Cleaning schedule	3	1.270	82.452	0.0000
Chaplet [clean schedule]	12	0.015	7.630	0.0000
Residual	64	0.015		
b) Growth of oysters				
Cleaning schedule	3	100.117	3.182	0.0354
Chaplet [clean schedule]	36	31.468	1.048	0.4037
Residual	200	31.468		

weeks (Table 1, Fig. 6a). The average mass of algae on oysters not cleaned for 6 weeks was 7.8 ± 0.8 SE g per oyster.

The growth increment of oysters among the four cleaning treatments differed significantly (Table 1), with oysters cleaned every 3 weeks growing significantly faster ($p < .05$) than those cleaned on a 2- or 6-week schedule (Fig. 6b).

Retention of Oysters on Chaplets

Mortalities of oysters after handling and drilling were low (< 0.6%). However, greater proportions of smaller oysters were lost

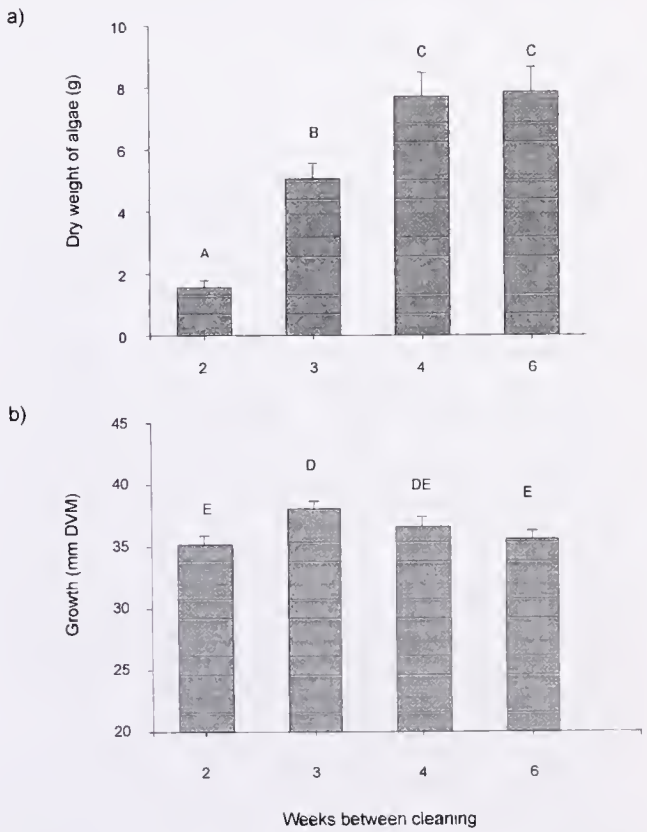

Figure 6. Variation in: a) mean (±SE) dry weight of algae removed from *P. margaritifera*; and b) growth of *P. margaritifera* (mean DVM ±SE) cleaned at 2, 3, 4, and 6 week frequencies. Means with different superscripts were significantly different ($p < .05$).

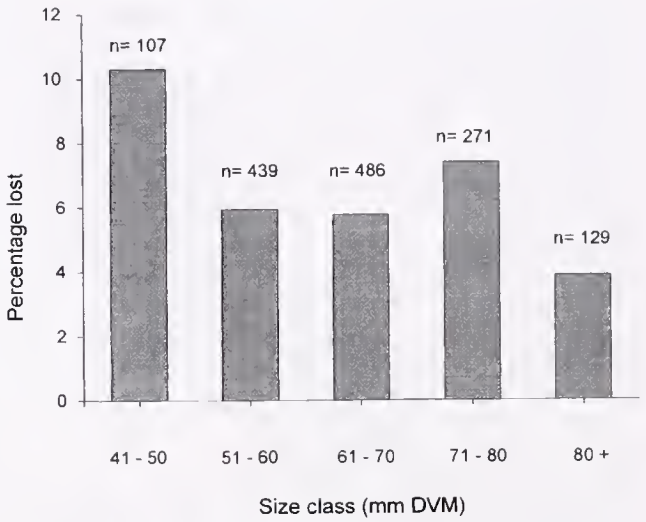

Figure 7. Percentage of *P. margaritifera* drilled at different sizes (November to December 1996) lost from chaplets by September 1997. Of the 1,440 oysters drilled and hung on chaplets, only eight dead oyster shells were recovered.

from chaplets (Fig. 7). In the experiment comparing losses of oysters held singly and in pairs, no oysters were lost through failure of the drill hole during the 4-month experiment. Oysters held on chaplets in pairs made byssal attachments to each other in 90% ± 3.0 SE of cases. In contrast, significantly fewer (df 14, t = 6.085, $p < .001$) oysters held singly on chaplets made byssal attachments to the rope (54% ± 5.0 SE). Not only were oysters more likely to make byssal attachments to other oysters than to rope, but attachments to other oysters were more secure (15.8 ± 0.7 SE byssal threads, $n = 72$ oysters) than those of single oysters to rope (4.3 ± 0.5 SE byssal threads, $n = 43$ oysters).

Another advantage of attaching oysters in pairs was that one valve of each oyster remained relatively free of fouling. As a result, mean cleaning times were significantly shorter ($F_{1, 12} = 8.678$, $p < .05$) for chaplets holding pairs of oysters (105 ± 7 SE s^{-1}, $n = 8$ chaplets) than for chaplets where oysters were hung singly (127 ± 7 SE s^{-1}, $n = 8$ chaplets). A disadvantage of attaching oysters in pairs was that growth was significantly reduced ($p < .01$) by an average of 2 mm DVM over a period of 4 months (Table 2). There was no significant difference ($p = .13$) in

TABLE 2.

Results of t-tests for effects on growth (DVM and wet weight) of *P. margaritifera* attached singly or in pairs to chaplets for four months. Mean growth (DVM and wet weight) is shown at the bottom of the table. Means with different superscripts are significantly different (P < 0.05).

Source of Variation	df	t value	P
DVM	158	2.986	0.0033
Wet Weight	158	1.538	0.1261

Attachment	Single	Pairs
Mean DVM (mm ± SE)	23.1^{a} ± 0.50	20.85^{b} ± 0.56
Mean wet weight (g ± SE)	67.7^{a} ± 2.0	62.9^{a} ± 2.4

changes in wet weight of oysters between the two treatments over the 4 months (Table 2).

After byssal threads had been severed, paired oysters re-made attachments in 96% ± 2 SE of the cases after 3 weeks; whereas, only 21% ± 4 SE of single oysters made connections with the rope (Fig. 8). Again, attachments made by single oysters were composed of relatively small numbers of threads (2.5 ± 0.4 SE byssal threads, $n = 17$) as compared to attachments made by oysters held in pairs (11.3 ± 0.6 SE byssal threads, $n = 76$). Interestingly, oysters hung singly produced byssal threads that were seen floating, without making an attachment. The number of oysters found producing such threads was greatest ($n = 22$ oysters, mean = 7.4 ± 1.0 SE byssal threads floating) 2 days after the byssal threads had been severed and decreased as the experiment progressed.

DISCUSSION

P. margaritifera cultured in the "open" reef systems of Solomon Islands were shown to be robust to the rigors of drilling, and growth of oysters on chaplets compared favorably with rates reported from the "closed" and semiclosed atoll lagoons of Polynesia. Sims (1993b) presented size at age data for *P. margaritifera* from Manihiki atoll, Cook Islands that showed that 9-month-old oysters (~81 mm DVM) were 38 mm (DVM) smaller than 2-year-old oysters (~119 mm DVM). This suggests that the mean annual growth increment for oysters of 81 mm DVM is < 38 mm DVM. Similarly, Coeroli et al. (1984) reported a growth rate of 35 mm y^{-1} for *P. margaritifera* of 70–80 mm DVM in French Polynesia. In contrast, oysters from the "open" reefs of Solomon Islands with a mean DVM of 78.7 mm grew a mean of 51 mm in 306 days (~10 months); whereas, oysters drilled at 70.4 mm DVM grew an average of 60.3 mm DVM in a year. *P. margaritifera* caught as spat (~11 mm DVM) in Solomon Islands need to be reared in intermediate culture (Friedman 1998, Friedman and Southgate 1999) and then on chaplets, for a total of ~16 months to reach 110 mm DVM; the size reported by Lintilhac (1987) and Gervis and Sims (1992) to be suitable for seeding.

Although the growout system for *P. margaritifera* in Solomon Islands resembles closely the one used in the atoll lagoons of Polynesia, the conditions found in the open reefs of Solomon Islands have more in common with those found on pearl farms cultivating *P. maxima* in Indonesia and Australia. Whereas atoll lagoons in Polynesia are surrounded by a low-lying carbonate island (atoll) and are relatively nutrient poor (Littler et al. 1991), open reef systems are generally bordered by high islands that are the source of nutrient inputs from fresh water runoff (Chellam et al. 1987). The higher nutrient load in the lagoons of Solomon Islands may have been a factor in the good growth rates recorded in this study. Yukihira (1998), showed that increases in food availability produced increased growth rates in *P. margaritifera* up to an optimum of 1–2 mg L^{-1} (ca. 10,000–20,000 cells mL^{-1}). In the Cook Islands, Ponia (1997) found that water movement on a farm of 50,000 oysters needed to be > 0.01 m s^{-1} to avoid 98% removal of microalgae by oysters hung on chaplets. His recordings of water movement in Manihiki lagoon in the Cook Islands ranged between 0–0.06 m s^{-1}. In French Polynesia, surface water movement in Takapoto atoll (closed atoll) is 0.03 m s^{-1} (Salvat 1981). In Solomon Islands, tidal water flow is greater (0–0.15 m s^{-1}), ensuring replenishment of food to culture areas. Although measurements of food abundance were not taken in this study, we suggest that the greater nutrient loading and relatively high water movement in Solomon Islands was likely to have stimulated greater pearl oyster growth (Chellam et al. 1987).

Additional anecdotal evidence for the greater levels of nutrients in Solomon Islands than Polynesia is the fact that growth of algae on oysters and chaplet ropes was more of a problem in Solomon Islands than in the atoll lagoons of Polynesia. The noticeable difference in the level of algal fouling may have been influenced by differences in the numbers of grazers between these two regions, although this is unlikely, because there was no observable evidence that fish or invertebrate grazers were less common in Solomon Islands than Polynesia. Despite oysters in Solomon Islands becoming completely covered with algae, observations *in situ* revealed that even heavily fouled oysters were able to open their valves normally. Although oysters required regular cleaning, there was relatively little fouling by cementing organisms such as bivalves and polychaetes ("hard" fouling), which are more difficult to remove than algae. In addition, hard fouling and other byssally attached bivalves have been shown to cause shell deformity of other pearl oyster species during culture (Dharmaraj et al. 1987, Doumenge et al. 1991, Taylor et al. 1997). Such fouling may render oysters vulnerable to attack from predators such as small fish and crabs (J. Taylor, pers comm. 1998) and, in the worst cases, result in mortality (Dharmaraj et al. 1987). Hard fouling organisms present a greater problem than algal fouling, because they also compete directly with oysters for food and space (Ponia 1997). In Cook Islands, settlement of the pest species *P. maculata*, can cause longlines to sink to the substrate. This species is the dominant bivalve at pearl farms in Cook Islands, often comprising > 90% of the total tissue biomass on culture equipment. Management of this fouling organism places a considerable burden on farm husbandry (Ponia 1997). In Solomon Islands, there was no evidence that algal fouling presented any risk of mortality to oysters. In fact, the presence of an algal covering on shell valves may have prevented successful settlement and growth of hard fouling.

Although survival was not threatened by algal fouling, growth of oysters was significantly greater when algae were brushed from chaplets on a 3–4 week cycle. This time interval is similar to that adopted for *P. maxima* culture in Indonesia and Australia (Gervis and Sims 1992, McGuinness 1994, Taylor et al. 1997), but shorter than that practiced by farmers in the atoll lagoons of Polynesia for *P. margaritifera* (J. Lyons, pers comm. 1999). Surprisingly, oysters cleaned on a 2-week schedule had some of the lowest growth

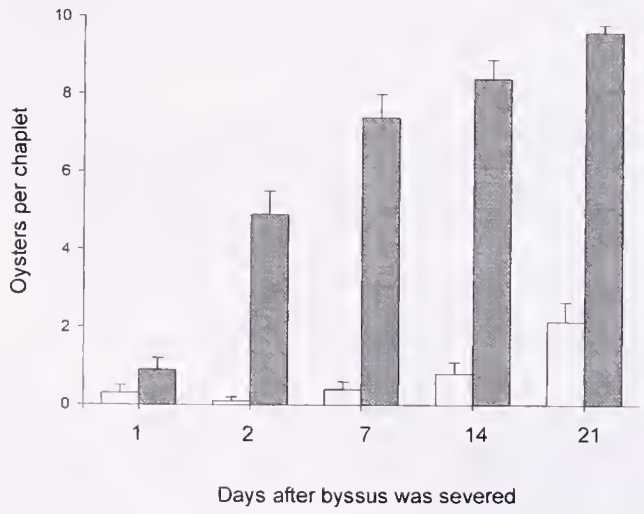

Figure 8. Mean (±SE) number of single (blank) and paired (solid) *P. margaritifera* per chaplet that made re-attachments after byssal threads had been severed.

rates. In addition, oysters from this treatment required re-drilling more often than oysters cleaned less frequently (K. Friedman, unpublished data 1997). In contrast, Taylor et al. (1997) showed that survival and growth of *P. maxima* in Indonesia did not differ significantly when cleaned at 2 or 4 week intervals; whereas, repeated handling results in increased mortality of scallops (Ventilla 1982, Parsons and Dadswell 1992). Anecdotal accounts suggest that the lower growth rates at more frequent cleanings in Solomon islands are attributable to "stressing" of the oysters, although the precise causes are unclear.

The number of oysters that became detached from chaplets was a concern, because the deep water (40 m) did not allow easy retrieval of lost oysters, and the sandy substrates in Gizo lagoon made the oysters difficult to find. Another notable difference between atoll lagoons and the open reefs in Solomon Islands was the presence of relatively fast water movement in the growout area (up to 0.15 m s^{-1}). Pearl oyster culture in this relatively high energy environment and regular brushing of chaplets to remove algae may have exacerbated losses from chaplets. Also, smaller sized (< 51 mm DVM) oysters with thinner shells detached from chaplets in greater numbers than larger, thicker shelled oysters.

Oysters tied to chaplets in pairs made strong byssal attachments to one another, as is their habit in the wild (Herdman 1903, Gervis and Sims 1992). This behavior secures oysters to the chaplet even if one oyster becomes detached from the monofilament line. *Pinctada margaritifera* differ from their close relative *P. maxima* in this regard, because byssal attachment persists in adults (Doumenge et al. 1991). Examination of re-attachment after byssal threads were severed showed that oysters attempted to make attachments even when hung singly, but that successful connections to polypropylene chaplet rope were less common than to other oysters. Because there was evidence that attaching oysters in pairs affected growth negatively, further experiments to find an alternative material for chaplet rope, which is both hard wearing and suitable for byssal attachment, would allow oysters hung singly to make attachments to the rope.

In conclusion:

1. Few mortalities resulted from drilling and attaching *P. margaritifera* to chaplets.
2. Growth of *P. margaritifera* in Solomon Islands compared well to that reported from lagoons in Polynesia; oysters caught as spat (±11 mm DVM) reached acceptable size for seeding in 16 months.
3. Oysters on chaplets were fouled quickly by algae. However, the algae did not cause mortalities and may have been advantageous in preventing fouling by cementing bivalves and tubular polychaetes. A 3–4 week cleaning cycle resulted in significantly greater growth of oysters than more or less frequent cleaning regimes.
4. Oysters detached from chaplets in significant numbers; this problem was greatest for the smallest oysters drilled.

ACKNOWLEDGMENTS

We thank Gideon Tiroba and Ruth and Barley White Dunne for their assistance with experiments. Johann Bell, Sandra Shumway, and an unknown reviewer provided helpful comments on the draft manuscript. This research was conducted as part of the project entitled "Development of Small-Scale Village Farms for Blacklip Pearl Oysters in Solomon Islands Using Wild Spat" funded by the Australian Centre for International Agricultural Research (ACIAR). This is ICLARM Contribution Number: 1476.

LITERATURE CITED

Alagarswami, K. & A. Chellam. 1976. On fouling and boring organisms and mortality of pearl oysters in the farm at Veppaloidai, Gulf of Mannar. *Indian J. Fish.* 23 (1-2):1–22.

Anon. 1996. Production of black pearls in Vanuatu commences. *South Pacific Comm. Pearl Oyster Bull.* 9:40.

AQUACOP. 1982. French Polynesia—Country Report. pp. 31–33. *In:* F. B. Davy and M. Graham (eds.). Bivalve Culture in Asia and the Pacific. Proceedings of workshop held in Singapore, 16–19 February 1982. International Development Research Centre, Ottowa, Ontario, Canada.

Chellam, A., T. S. Velayudhan & A. C. C. Victor. 1987. pp. 72–77. *In:* K. Alagarswami (ed.). Pearl Culture Bulletin. Cent. Mar. Fish. Res. Inst. No. 39. Central Marine Fisheries Research Institute, Cochin, India.

Coeroli, M., D. De Gaillande, J. P. Landret & AQUACOP (D. Coatanea). 1984. Recent innovations in cultivation of mollusks in French Polynesia. *Aquaculture* 39:45–67.

Dharmaraj, S. K., A. Chellam & T. S. Velayudhan. 1987. Biofouling, boring, and predation of pearl oyster. pp. 92–97. *In:* K. Alagarswami (ed.). Pearl Culture Bulletin. Cent. Mar. Fish. Res. Inst. No. 39. Central Marine Fisheries Research Institute, Cochin, India.

Doroudi, M. S. 1996. Infestation of pearl oysters by boring and fouling organisms in the northern Persian Gulf. *Indian J. Mar. Sci.* 25:168–169.

Doubilet, D. 1997. Black pearls of French Polynesia. *Natl Geograph* 191(6):30–37.

Doumenge, F., A. Toulemont & J. Branellec. 1991. The South Sea Pearl. The Philippine Golden Pearl. Musee Oceanographique, Monaco. 54 pp.

Fassler, C. R. 1995. New developments in pearl farming. *World Aquacult.* 26 (3):5–10.

Freidman, K. J. & P. C. Southgate. 1999. Growout of blacklip pearl oysters, *Pinctada margaritifera*, collected as wild spat in Solomon Islands. *J. Shellfish Res.* 18:159–167.

Friedman, K. J. 1998. Black pearl farms in the Pacific. The "open" reef systems of the Solomon Islands. *Austasia Aquacult.* 12(3):3–9.

Friedman, K. J. & J. D. Bell. 1996. Effects of different substrata and protective mesh bags on collection of spat of the pearl oysters, *Pinctada margaritifera* (Linnaeus, 1758) and *Pinctada maculata* (Gould, 1850). *J. Shellfish Res.* 15(3):535–541.

Friedman, K. J., J. D. Bell, M. Gervis & G. Tiroba. 1996. Progress on research on the potential of farming blacklip pearl oysters in Solomon Islands. *South Pacific Comm. Pearl Oyster Inf. Bull.* 9:11–13.

Friedman, K. J., J. D. Bell & G. Tiroba. 1998. Availability of wild spat of the blacklip pearl oyster, *Pinctada margaritifera*, from "open" reef systems in Solomon Islands. *Aquaculture* 167:283–299.

Gervis, M. H. & N. A. Sims. 1992. The biology and culture of pearl oysters (Bivalva: Pteriidae). *ICLARM Stud. Rev.* 21, 49 pp.

Herdman, W. A. 1903. Report to the Government of Ceylon on the Pearl Oyster Fisheries of the Gulf of Manaar. Part I. The Royal Society of London. 146 pp.

Lintilhac, J. 1987. Black Pearls of Tahiti. Royal Tahitian Black Pearl Book, Papeete, Tahite. 53 pp.

Littler, M. M., D. S. Littler & E. A. Titlyanov. 1991. Comparisons of N- and P- limited productivity between high islands versus low carbonate atolls in Seychelles Archipelago: a test of the relative-dominance paradigm. *Coral Reefs* 10:199–209.

Lucas, J. S., M. Ito, M. Kamatie, J. R. Norton, P. C. Southgate, B. Tioti & J. R. Whitford. 1995. Pacific Island Pearl Oyster Resource Development Project. pp. 112–115. *In:* Y. Zhoa, F. Hu, H. Zhou, H. Cui, C. Yao, F. Din, and Y. Lu. (eds.). *Proc. 4th Asian Fisheries Forum.* Asian Fisheries Society. Manila.

McGuinness, R. 1994. Australia's giant pearls. *Australian Geographic* July–September 1994, 35:40–61.

Meng, Z. & K. Xing. 1991. The effects of various factors on the nucleus-insertion of the black lipped pearl oysters *Pinctada margaritifera* Linnaeus. *Oceanologia et Limnologia Sinica,* 22:8–13.

Mercier, A. & J. F. Hamel. 1998. Pearls in the making. *Island Business* April:16–17.

Mohammad, M. B. M. 1976. Relationship between biofouling and growth of the pearl oyster, *Pinctada fucata* (Gould) in Kuwait, Arabian Gulf. *Hydrobiologica* 51 (2):129–138.

Nicholls, A.G. 1931. On breeding and growth rate of the black-lip pearl oyster (*Pinctada margaritifera*). *Report for Great Barrier Reef Commission* 3:26–31.

Parsons, G. J. & M. J. Dadswell. 1992. Effect of stocking density on growth, production, and survival of the giant scallop, *Placopecten magellanicus*, held in intermediate suspension culture in Passamaquoddy Bay, New Brunswick. *Aquaculture* 103:291–309.

Ponia, B. 1997. Feeding models and chlorophyll levels at black pearl farms in the Cook Islands: implications for management. M.Sc. thesis, James Cook University of North Queensland.

Preston, G. 1990. Pearl culture in three French Polynesian atolls 1986–1987. *South Pacific Commission Pearl Oyster Information Bulletin* 1:10–12.

Remoissenet, G. 1996. From the emergence of mortalities and diseases on *Pinctada margaritifera* to the effects on the pearling industry. pp. 371–386. *In:* Present and Future of Aquaculture Research and Development in the Pacific Island Countries. Proceedings of the International Workshop held from 20–24 November 1995 at Ministry of Fisheries, Tonga. JICA.

Richards, A. H., L. J. Bell & J. D. Bell. 1994. Inshore fisheries resources of Solomon Islands. *Mar. Poll. Bull.* 29(1–3):90–98.

Salvat, B. 1981. Geomorphology and marine ecology of the Takapoto atoll (Tuamotu archipeligo) Proceedings of the 4th International Coral Reef Symposium, Manila, Philippines. Vol. 1. pp. 505–509.

Sims, N. A. 1992. Abundance and distribution of the black-lip pearl oyster, *Pinctada margaritifera* (L.), in Cook Islands, South Pacific. *Aust. J. Mar. Freshwater Res.* 43:1409–1421.

Sims, N. A. 1993a. Pearl oysters. pp. 409–430. *In:* A Wright (ed.). Nearshore Resources of the South Pacific. IPS, Suva. 710 pp.

Sims, N.A. 1993b. Size, age, and growth of the black-lip pearl oyster, *Pinctada margaritifera* (L.), (Bivalvia; Pteriidae). *J. Shellfish Res.* 12(2):223–228.

Sims, N.A. & D. J. Sarver. 1995. Feasibility of commercial black pearl culture in Namrick Atoll, Marshall Islands. Final report for Saltonstall–Kennedy Grant Program, 24 pp.

Swift, D. R. 1985. Training Manual Aquaculture. Fishing News Books. 135 pp.

Taylor, J. J., P. C. Southgate & R. A. Rose. 1997. Fouling animals and their effect on the growth of silver-lip pearl oyster, *Pinctada maxima* (Jameson). *Aquaculture* 153:31–40.

Ventilla, R. F. 1982. The scallop industry in Japan. *Adv. Mar. Biol.* 20: 310–381.

Ward, F. 1995. Pearls. Gem Book Series, 64 pp.

Yukihira, H. 1998. Feeding, energy budgets, and nutritional ecology of the pearl oysters, *Pinctada margaritifera* (Linnaeus) and *P. maxima* Jameson. Ph.D. thesis, James Cook University, Australia. 177 pp.