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PRELIMINARY OBSERVATIONS ON OYSTER PEARL NET CULTIVATION IN COASTAL GEORGIA

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ABSTRACT: This work reports on survivorship and growth rates attained by a transplanted northern stock of *Crassostrea virginica* ($\bar{x}$ = 15 mm) tested at various densities in pearl nets in sheltered and exposed sites in coastal Georgia (October 1985 - August 1986). Monthly growth increments ranged from 4.5 to 5.1 mm (shell height). One hundred oysters per net was the optimum stocking density. One hundred percent mortality was suffered at both sites during June - August (probably due to *Perkinsus marinus*). Current growth rates indicate a growth to market size time of 18 months or less for 15 mm seed grown in pearl nets. However, pearl net cultivation is shown to have serious drawbacks as an oyster grow-out system for coastal Georgia and alternative systems are discussed.

Key words: Oysters, *Crassostrea virginica*, Growth, Survival, Mortality, Density, Pearl Nets.

The American oyster, *Crassostrea virginica* (Gmelin, 1789), constitutes an important fishery for the coastal United States. In 1908, the state of Georgia led the country in oyster landings; but today the oyster industry in Georgia is virtually non-existent. In 1987, only 9,080 pounds of oyster meats valued at $17,889 were reported landed in Georgia (Georgia Department of Natural Resources, 1988).

Oyster harvesting in Georgia is now limited to manual gathering from intertidal beds. Blue crab fishermen, operating during slack periods of their principal fishery are, nevertheless, one of the major suppliers of oysters at present. The inefficiency and infrequency of current harvesting techniques result in the existence of an, as yet, unrealized potential for oyster production in Georgia waters. This precludes the availability of sufficient oyster supplies to support a processing industry in Georgia. In addition, most beds were not managed in the past, resulting in overharvesting and the decline in the industry. Now most beds are dominated by "coon " oysters, *i.e.*, densely packed and stunted oysters.

One method of increasing shellfish production is to develop mariculture techniques for the oyster. Georgia has a considerable expanse (450,000 acres) of essentially unpopulated and unpolluted coastal marsh. Undoubtedly, a substantial portion of it offers the requisite optimal salinity, temperature and turbidity regimes conducive to shellfish culture.

As part of the ongoing mariculture development program at The University of Georgia's Marine Extension Service on Skidaway Island, Georgia, a wide range of shellfish are being investigated as potential mariculture candidates. Studies with the American oyster (*Crassostrea virginica*) include experimentation with transplanted northern strains, with the hope of gaining a markedly faster growth to market size for singles (reported herein), and a variety of

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tests with the native stocks. The purpose of this work was to determine (1) the biological feasibility of oyster pearl net cultivation in Georgia, (2) the influence of density levels on growth and survival rates, and (3) the influence of site location on growth and survival rates.

MATERIALS AND METHODS

Oysters used in this study were shipped from the Aquaculture Research Corporation in Dennis, Massachusetts. An exposed site (Priest Landing) and sheltered site (House Creek) were selected for the placement of rafts from which pearl nets (6 mm mesh) were suspended (Fig. 1). Upon arrival (October 9, 1985), the majority of oysters were transplanted to 3 rafts at Priest Landing where they were to be held in pearl nets until raft construction at the sheltered site was completed. Several hundred oysters were maintained as "reserves" at the Shellfish Laboratory on Skidaway Island. Unfortunately, two of the three rafts at Priest Landing were destroyed during a severe storm, resulting in a one month delay in the commencement (Nov. 10, 1985) of House Creek trials. Oysters from the Shellfish Laboratory were used to stock the House Creek test. A total of 2,400 oysters were placed in pearl nets at the two locations. Due to storm induced losses, the House Creek experiment was more limited in scope than

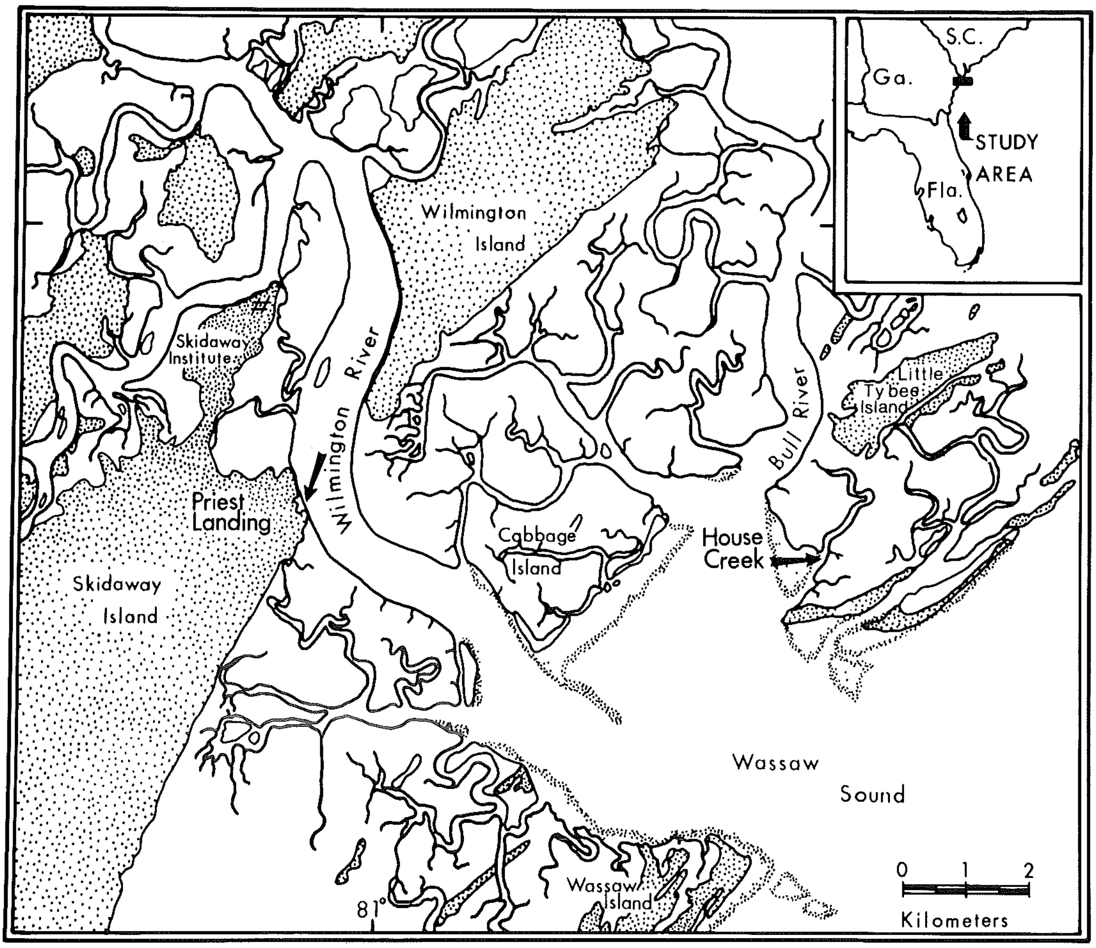

Figure 1. Map of the study area showing the exposed site (Priest Landing) and sheltered site (House Creek) where the raft culture experiments were carried out.

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Table 1. The experimental design employed to test the influence of density levels on growth and survival rates of *Crassostrea virginica*.

Trials	Dates and Duration of Trials (Days)	Density Tested	Replicates
Exposed Site			
Priest Landing	9 October 1985 — 4 July 1986 (238)	50	3
		100	3
		200	3
		300	3
Sheltered Site			
House Creek	10 November 1985 — 5 July 1986 (207)	50	3
		100	2
		200	1*

*Due to storm losses, there were insufficient numbers for another replicate.

originally planned, with fewer replicates of the density tests (Table 1), and the original experimental design had to be changed. The site comparison aspects originally planned were no longer feasible after the storm induced delay in establishing the House Creek trial.

Oysters were set up in pearl net replicates and all nets (0.3 m × 0.3 m) were suspended at a depth of *ca.* 0.3 m (*i.e.*, from water surface to top of net) from the raft at each site. Labels ensured the proper identification of each replicate during sampling sessions and original positioning on the raft and reallocation following sampling were random. Nets were separated from one another by *ca.* 0.5 m in a grid-like layout employed from the raft. Four stocking densities were tested; 50, 100, 200 and 300 oysters per net (Table 1). Initial mean size at the commencement of site experiments was 15 mm (± 0.03 mm S.E.) at Priest Landing and 15.4 mm (± 0.41 mm S.E.) at House Creek. The reserve oysters maintained on a flow through raceway system from October 9 - November 10, 1985, and later employed in the House Creek trials, exhibited little growth during this period (the sand and gravel filtration systems employed in our laboratory are known to remove the vast majority of molluscan food material from the seawater supply). Survival and growth rates were examined on January 14, March 31 - April 1, June 4 - 5, and August 5, 1985. Shell height (*i.e.*, longest possible measurement from hinge to lip) was recorded to the nearest 0.1 mm for 50 specimens per net using vernier calipers. Fouling organisms were removed from nets using a scrub brush at each sampling session.

Statistical analyses of the density effects on growth and survival were evaluated within sites only by comparing the mean size attained (2 Factor ANOVA and the Student-Newman-Keuls (SNK) multiple range tests) and percent survival (Kruskal-Wallis one way ANOVA by rank). Storm damage enforced alterations to the original experimental design rendered a statistical comparison of results among the two test sites invalid. All statistical analyses were carried out according to Sokal and Rohlf (1981), using SPSS/PC software.

RESULTS

By January 1986, oysters at Priest Landing (exposed site) ranged from 33.6 mm to 36.3 mm in height, but there were no significant differences in size attained among density levels, as deter-

Table 2. *Crassostrea virginica* pearl net culture experiment 1985-86.

Area/Initiation Date	Density	Size (mm)(SE)	14 Jan. 1986 N	14 Jan. 1986 Mean Size(mm)(SE)	31 March 1986 N	31 March 1986 Mean Size(mm)(SE)	4 June 1986 N	4 June 1986 Mean Size(mm)(SE)
Priest Landing 9 Oct. 1985	50	15.0(.03)	48	34.7(0.67)	48	44.8(1.15)	48	54.4(1.53)
	50	15.0(.03)	48	34.2(0.86)	*		*	
	50	15.0(.03)	51 +	36.2(0.81)	49	45.9(0.92)	50	56.0(1.55)
	100	15.0(.03)	91	34.2(0.97)	89	45.2(0.87)	91 +	56.2(1.06)
	100	15.0(.03)	94	36.3(0.76)	92	49.2(0.88)	92	56.1(1.08)
	100	15.0(.03)	*		*		*	
	200	15.0(.03)	202 +	33.6(1.06)	*		*	
	200	15.0(.03)	190	36.0(1.11)	*		*	
	200	15.0(.03)	196	35.9(1.19)	*		*	
	300	15.0(.03)	294	33.8(1.08)	*		*	
	300	15.0(.03)	296	35.7(1.07)	296	42.2(1.13)	294	51.4(1.36)
	300	15.0(.03)	276	34.3(0.91)	251	44.0(0.68)	222	52.8(1.37)
			15 Jan. 1986		1 April 1986		5 June 1986	
	Density	Size (mm)(SE)	N	Mean Size(mm)(SE)	N	Mean Size(mm)(SE)	N	Mean Size(mm)(SE)
House Creek 10 Nov. 1985	50	15.4(.41)	49	18.4(0.36)	50	32.9(0.71)	49	48.2(1.23)
	50	15.4(.41)	49	19.9(0.37)	39	34.1(0.61)	39	51.1(1.11)
	50	15.4(.41)	51 +	19.4(0.37)	51	35.6(0.62)	50	51.8(1.34)
	100	15.4(.41)	100	19.8(0.44)	101 +	32.0(0.95)	100	50.7(1.53)
	100	15.4(.41)	100	19.3(0.47)	100	34.2(0.80)	96	48.1(1.55)
	200	15.4(.41)	199	21.0(0.51)	200 +	32.3(0.96)	199	45.6(1.74)

* Samples lost.
\+ Unexplained gain in number.

mined by a factorial ANOVA examining the effects of density and replicates on size (Tables 2 and 3). At House Creek, replicate mean sizes ranged from 18.4 - 21 mm (Table 2). At this site, there were highly significant differences, as determined by a factorial ANOVA and SNK multiple range test (P = .0026) between mean size attained by oysters stocked at the 200/net level (21 mm) and those at the 50/net (19.3 mm) and 100/net (19.6 mm) levels, with both of the latter growing more slowly than the former (Table 3). Statistical analyses are outlined in Tables 4 and 5. There was no significant difference between the size attained by oysters stocked at 50/net and 100/net (Table 5a). A factorial ANOVA showed no significant difference among all density replicates within each site (Table 4). However, a one way analysis of variance of replicates within each site-date revealed significant differences among the replicates of House Creek 50/net (January and April) and Priest Landing 100/net (March) (Table 5b). Although the likelihood of committing a type 1 error is increased by carrying out multiple comparisons of the effect of replicates within site-date, the levels of significance (P = 0.018) and the focus upon a single date with its limited size class argue in favor of real differences. On January 15 the A (18.4 mm) replicate of 50 oysters/net was significantly (P = 0.018) different from the other two replicates, which were not significantly different from one another. In April it was the C (35.6 mm) replicate

Table 3. Mean shell height values of *Crassostrea virginica* at various stocking densities (N = number measured) (represents pooled replicate data).

Area	Density	14 Jan. 1986 mm (SE) -N	31 Mar. 1986 mm (SE) -N	4 June 1986 mm (SE) -N
Priest Landing	50	35.1(0.82)-147	45.3(0.92)- 97	55.2(1.55)-102
	100	35.3(0.50)-100	47.2(1.09)-181	56.2(1.08)-183
	200	35.2(0.66)-150	---	---
	300	34.5(0.71)-200	42.8(3.18)-261	52.1(1.37)-199
Area	**Density**	**15 Jan. 1986 mm (SE) -N**	**1 April 1986 mm (SE) -N**	**5 June 1986 mm (SE) -N**
House Creek	50	19.3(0.22)-149	34.3(0.62)-140	50.3(1.34)-138
	100	19.6(0.49)-100	33.1(0.80)-100	49.4(1.55)-100
	200	21.0(0.51)- 50	32.3(0.96)- 50	45.6(1.74)- 50

Table 4. Statistical analyses of oyster pearl net trials at House Creek and Priest Landing using a factorial ANOVA.

Trial - Date	Factors Tested	F-Ratio	(D.F.)	Probability
House Creek - January	Density	7.198	2	0.001
	Replicates	1.190	2	0.306 (NS)
Priest Landing - March	Density	12.481	2	0.000
	Replicates	0.510	2	0.601 (NS)
House Creek - June	Density	4.381	2	0.013
	Replicates	2.597	2	0.076 (NS)
Priest Landing - June	Density	5.721	2	0.004
	Replicates	0.398	2	0.672 (NS)

Table 5.
(a). Further statistical analyses of oyster pearl net density treatments at House Creek and Priest Landing shown in Table 4 (Student-Newman-Keuls Multiple Range Test). Separation in bars signify significantly different data sets.

Trial - Date	ANOVA: F Ratio	Probability	S-N-K Multiple Range (Density Levels) 50	100	200	300
House Creek - January	6.0573	0.0026	———	———	———	
Priest Landing - March	12.4809	0.0000	———	———		———
House Creek - June	4.0138	0.0191	———	———		
Priest Landing - June	6.0940	0.0024	———	———		———

Table 5.
(b). Replicates of the House Creek 50/net and Priest Landing 100/net (March only) treatment displayed significant differences and are revealed by the Student-Newman-Keuls Multiple Range Test.

	Probability	50 per Net Density Replicates		
		A(18.4 mm)	B(19.5 mm)	C(19.9 mm)
House Creek - January	0.0180	———	———	———
		A(32.9 mm)	B(34.1 mm)	C(35.6 mm)
House Creek - April	0.0139	———	———	———
		100 per Net Density Replicates		
		A(45.2 mm)	B(49.7 mm)	
Priest Landing - March	0.0013	———	———	

which differed significantly from A and B (P = 0.0139), which were not significantly different from one another (Table 5b). On March 31 the A (45.2 mm) and B (49.2 mm) replicates of 100 oysters per net at Priest Landing were significantly different (P = 0.001) from one another (Table 5b). However, despite the differences among replicates, all were lumped for further analyses on the grounds that replicates are designed to show the variation that can occur within a treatment.

There were also highly significant differences in mean size attained by March 31 at the Priest Landing site between the 50/net (45.3 mm) and 300/net (42.8 mm) densities (P < 0.001) as well as between the 100/net (47.2 mm) and 300/net densities (P < 0.001) (Tables 3, 4, and 5a). The difference in size attained between the 50/net and 100/net density levels was not significant. At House Creek, on April 1, mean sizes ranged from 32.3 mm (200/net) to 34.3 mm (50/net), but there were no significant differences (one way ANOVA) in mean size attained among the different densities (P = 0.86) (Tables 2 and 3).

On June 4, 1986 there were highly significant (P = 0.004) differences found among density treatments at Priest Landing (Table 4). The 50/net (55.2 mm) and 300/net (52.1 mm), as well as the 100/net (56.2 mm) and 300/net (52.1 mm) treatments, displayed significant differences in oyster growth on the basis of SNK multiple range test (Table 5a). There were no significant differences in size attained between densities of 50/net and 100/net (Table 5a). Density mean sizes ranged from 45.6 mm (200/net) to 50.3 mm (50/net) at House Creek by June 5th (Table 3). A factorial ANOVA, replicates × density, revealed that there were significant differences among densities (= 0.013; Table 4). However, SNK multiple range test indicated that only the differences between densities of 50/net (50.3 mm) and the 200/net (45.6 mm) were significant (P = 0.010; Table 5a). Mean size of 100/net oysters (49.4 mm) was intermediate between and not significantly different from either of the other two.

Table 6 illustrates the between sampling growth increments of oysters, inferred from size data, at each stocking density over the duration of the study at Priest Landing (9 Oct. 1985 - 4 June 1986) and House Creek (10 Nov. 1985 - 5 June 1986). Estimated mean daily growth increments varied from 0.16 mm (300/net)

Table 6. Mean growth increments of *Crassostrea virginica* at various stocking densities for the periods indicated. Based on data in Table 3.

Area	Density	9 Oct. 1985 - 14 Jan. 1986 mm (Days)	14 January - 31 March 1986 mm (Days)	31 March - 4 June 1986 mm (Days)
Priest Landing	50	20.1 (97)	10.2 (76)	9.9 (65)
	100	20.3 (97)	11.9 (76)	9.0 (65)
	200	20.2 (97)	---	---
	300	19.5 (97)	8.3 (76)	9.3 (65)

Area	Density	10 Nov. 1985 - 15 Jan. 1986 mm (Days)	15 January - 1 April 1986 mm (Days)	1 April - 5 June 1986 mm (Days)
House Creek	50	3.9 (66)	15.0 (76)	16.0 (65)
	100	4.2 (66)	13.5 (76)	16.3 (65)
	200	6.6 (66)	11.3 (76)	13.3 (65)

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Table 7. Mean daily growth increments of *Crassostrea virginica* calculated from data presented in Table 6.

Area	Density	9 Oct. 1985 - 14 Jan. 1986 mm/day	14 January - 31 March 1986 mm/day	31 March - 4 June 1986 mm/day	9 Oct. 1985 - 4 June 1986 mm/day
Priest Landing	50	0.21	0.13	0.15	0.17
	100	0.21	0.16	0.14	0.17
	200	0.21	----	----	0.16
	300	0.20	0.11	0.14	0.16
Area	**Density**	**10 Nov. 1985 - 15 Jan. 1986 mm/day**	**15 January - 1 April 1986 mm/day**	**1 April - 5 June 1986 mm/day**	**10 Nov. 1985 - 5 June 1986 mm/day**
House Creek	50	0.06	0.20	0.25	0.17
	100	0.06	0.18	0.25	0.16
	200	0.09	0.15	0.21	0.15

to 0.17 mm (50/net and 100/net) at Priest Landing while those at House Creek varied from 0.15 mm (200/net) to 0.17 mm (50/net) (Table 7). These figures indicate a monthly incremental growth of between 4.5 - 5.1 mm (30 days). Figure 2 illustrates growth patterns for each density treatment at both sites throughout the study. Growth appeared to commence more rapidly at Priest Landing (October - January) with House Creek oysters growing considerably more rapidly than those at Priest Landing from April to June.

Mean survivorship levels ranged from 86% to 100 % up until June 1986 (Tables 2 and 8). There were no significant differences detected among density levels in terms of survival (%) either between sampling dates or over the entire study period, as determined by the Kruskal-Wallis one way analysis of variance by rank.

DISCUSSION

Density induced effects on growth of oysters were detected at both sites. At Priest Landing, oysters grown at densities up to 100/net exhibited significantly greater size attained than those at 300/net. Similar results at House Creek showed 50/net and 100/net treatments exhibiting significantly greater oyster growth than the 200/net treatment. It would appear that at the sheltered and exposed sites, oysters can be grown at densities up to 100/net (*i.e.*, 1,111 per m^2) without a significant density induced reduction in growth.

Over the entire duration of the study, the daily incremental size increase data are similar for both the sheltered and exposed sites at similar density levels (Table 7) in spite of considerable differences during specific periods. However, due to storm damage enforced alterations in experimental design, this statement must remain a casual observation and cannot be supported by statistical analyses. The growth at both sites does, however, meet the requirements for a commercial operation, providing, of course, the catastrophic mortality levels can be overcome (see below). Ecological conditions in southern latitudes of the eastern United States apparently support greater instantaneous growth rates for oysters than in more northern areas (Dame, 1972). Recent studies in Georgia using transplanted northern surf clam seed also displayed markedly increased growth rates in the southern habitat (Walker *et al.*, 1988). The results reported herein show continuous oyster growth

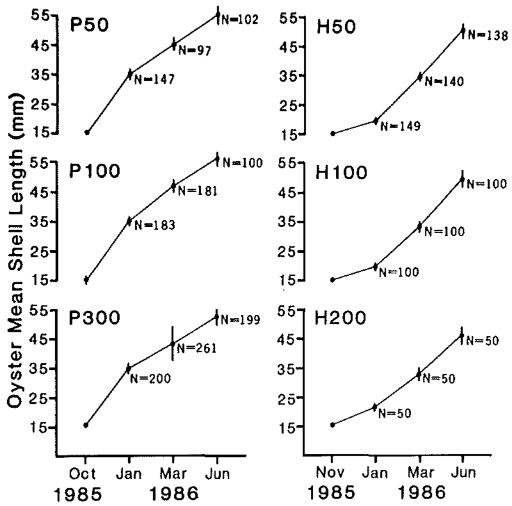

Figure 2. Mean shell height values computed from pooled replicate data for each density treatment. N = number of oysters measured. P 100 = Priest Landing, 100 per net treatment; H 100 = House Creek, 100 per net treatment, etc. Vertical bars represent 2 standard errors about the mean.

throughout the winter months when the northern stock would normally show no growth in their native habitats (*e.g.*, Beaven, 1953; Shaw 1960, 1968; Mattiessen and Toner, 1966). The current growth observations using northern oyster seed indicate substantially less time required to grow oysters to market size (76.2 mm) in Georgia (*ca.* 18 months) using standard mariculture systems and density levels. The mean 30-day shell height increment of 5.1 mm observed during the first eight months in the field would give a market size oyster in approximately 12 months using 15 mm seed and assuming adequate survival and maintenance of the observed growth rate. Allowing for a gradual slowing of growth with size, one can reasonably postulate an 18 month growth period for such market size oysters in Georgia. Comparative systems in northern areas require from 2.5 years (Chatham, Massachusetts - Shaw, 1960, 1968) to 3 years (Martha's Vineyard, Massachusetts - Mattiesen and Toner, 1966 and in Maryland - Beaven, 1953). Monthly growth increments similar to those reported here have been reported for tray-cultivated oysters (with lower densities, 320/m^2) grown in South Carolina (3.8 mm per month - Burrell *et al.*, 1981 and 3.5 mm per month - Manzi *et al.*, 1977).

The growth patterns observed at the two sites studied were markedly different (Fig. 2) and we would offer two hypotheses to explain this. One, the earlier deployment of the Priest Landing trial exposed those oysters to a month of warmer water temperatures during which period the majority of the growth detected for the October - January period was laid down. Presumably, by the time the House Creek oysters were in place, ambient temperatures were supporting a lower instantaneous growth rate at both sites. Two, assuming temperature levels during November - January were still supporting substantial daily growth rates, as would appear likely given the detected growth through January - March, then one may postulate a stress factor for the House Creek oysters. Because of their virtual starvation, due to the negligible food quality of the water supply in the shellfish laboratory where these oysters were held for a month, they may have been considerably stressed at their time of deployment. Thus, they may have required a period of acclimation causing a reduction in growth. It would appear that the House Creek oysters had caught up, so to speak, by April and that from that time, on, they apparently exhibited a greater growth rate (Fig. 2), possibly due to some benefit derived from the sheltered habitat.

Density levels were shown to have no significant effect on survivorship at both the sheltered and exposed trial sites throughout this study. However, the catastrophic mortalities observed during June - August 1986 pose a serious problem for oyster mariculture in Georgia.

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Table 8. Mean percentage survival data for oysters at various density levels calculated from N values shown in Table 2.

Area	Density	9 Oct. 1985 - 14 Jan. 1986	14 January - 31 March 1986	31 March - 4 June 1986	9 Oct. 1985 - 4 June 1986
Priest Landing	50	96.2	77.2	100	98.0
	100	92.5	97.7	100	90.5
	200	97	----	---	----
	300	96.2	95.5	85	86.0
Area	**Density**	**10 Nov. 1985 - 15 Jan. 1986**	**15 January - 1 April 1986**	**1 April - 5 June 1986**	**10 Nov. 1985 - 5 June 1986**
House Creek	50	98.7	92.7	100	92.0
	100	100	100	98.1	98.0
	200	99.3	100	100	99.5

The pattern and intensity of the kill are not indicative of predator pressure, as predator induced mortalities have been shown to decrease with age and size (Wayne and Davies, 1977). Furthermore the pearl nets used in this investigation are known to be efficient in excluding the major oyster predators, mud and blue crabs, oyster drills and starfish, while *Cliona* infestations were not detected at any stage. However, an epizootic of Dermo (*Perkinsus marinus*) was detected in many areas of coastal Georgia during summer and fall 1986 (Dr. S. Stevens, Georgia Department of Natural Resources, personal communication), and is strongly suspected as the causitive agent in the observed oyster mortalities in our pearl net trials. The 100% level of mortality, found at both sites in our study, is commonly associated with Dermo, and the crowded nature of oyster grow out systems, such as pearl net and tray cultivation, have been related to increased rates of transmission and mortality due to this pathogen (Andrews, 1967; 1979). Furthermore, similar pearl net trials in 1984 (R. Walker, personal observation) using native oysters met with a similar fate. Heat stress is another possible cause for the observed mortalities. However, considering the mortalities experienced by native oyster populations (1985 - 86), and those grown in pearl nets in 1984 (R. Walker, personal observation), disease is more strongly suspected as the causative agent.

Considering the threat of disease and the enormous fouling problems associated with the tremendous natural oyster spat fall, the future for a mariculture based single oyster industry in Georgia is far from assured. There may be, however, considerable promise for a shucked oyster product using native stocks. Production of such a product could be achieved in approximately 12 to 18 months under the growing conditions in Georgia as shown in the current study. The advantages for such a commodity are twofold; firstly, a reduced time to market will hopefully alleviate disease threats somewhat by reduced exposure (with only one season of high risk as opposed to 2 - 3 for a single oyster). It may be possible to plant seed in late spring or early summer to avail of the demonstrated "refractive" qualities to *Perkinsus marinus* infections (Ray, 1953) of oysters under 4 months of age and have them harvested before the major danger period (summer and fall) the next year; secondly, fouling due to oyster spat will not seriously disadvantage the marketability of the shucked oyster. If the initial trials with a shucked oyster product prove encouraging, genetic selection programs for disease resistance and increased growth rates can be initiated to heighten the advantages of this industry. The labor intensity required to maintain pearl nets in a relatively unfouled state effectively rules out this system for coastal Georgia. We are currently investigating intertidal placement of cage and rack culture systems with a view to optimizing the advantages of exposure as an antifouling device while still maintaining as close to optimal growth rates as possible. From the results of the current study, it would appear that such grow out systems might be stocked at up to *ca.* 1000 - 1100 per m^2 without density retardation of growth. The necessity for constant monitoring for disease incidence among mariculture stocks to enable diversionary activity, *e.g.*, transplanting to lower salinity waters in times of danger, cannot be overemphasized if such systems are to be successful.

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