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GROWTH AND SURVIVAL IN THE SCALLOP *NODIPECTEN NODOSUS* AS RELATED TO SELF-FERTILIZATION AND SHELL COLOUR.

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ABSTRACT: The purpose of this study was to find out the effects of inbreeding on the growth and survival of the scallop *Nodipecten nodosus*. For this, we used self-fertilized and cross offspring and we compared their growth and survival, and the wet, dry and ash-free mass of certain tissues. Also, we compared orange and brown individuals from both self-fertilized and cross offspring. The study suggests that the consanguinity adversely affects survival but not growth. Self-fertilized offspring showed higher values than cross offspring and seem to be more sensible to the environmental changes, at least during the first months, since the situation changes later. Length and height values were higher in self-fertilized offspring than in cross offspring, and, for both types, in orange individuals than in brown individuals.

RESUMEN: El presente trabajo se realizó con la finalidad de conocer los efectos de la consanguinidad sobre el crecimiento y la supervivencia en la vieira *Nodipecten nodosus*. Para esto se compararon progenies autofecundas y cruzadas en cuanto a talla, supervivencia, masa húmeda, seca y libre de cenizas de algunos tejidos. Además, se compararon individuos de color anaranjado y marrones de las progenies de ambos tipos de cruce. El estudio sugiere que la consanguinidad afecta adversamente la supervivencia pero no el crecimiento. Los individuos producto de autofecundación mostraron mayores valores que los provenientes de cruce y parecen ser más sensibles a los cambios ambientales al menos durante los primeros meses, ya que luego la situación se revierte. En cuanto a longitud y altura, fueron mayores los descendientes de la autofecundación que los de cruce y los individuos anaranjados máyores que los marrones, en ambos tipos de cruce.

INTRODUCTION

In many animals, intensive rearing combined with artificial selection leads to increased inbreeding and consequently decreased fitness due to the expression of previously masked deleterious genes (LYNCH, 1989). In contrast, genetic distance typically increases fitness, even though matings between genetically differentiated populations of certain sessile plants and marine invertebrates may produce progeny with lower fitness due to outbreeding depression (PUSEY & WOLF, 1996).

Inbreeding depression has been extensively documented. In bivalves, LONGWELL & STILES (1973) showed that crosses between brothers in *Crassostrea virginica* exhibited low larval growth and survival in the first filial generation. MALLET & HALLEY (1983) pointed out growth inhibition by consanguinity in *C. virginica*. WADA (1984) found a very high death-rate in consanguinity lines of *Pinctada furcata martensii*. BEATTIE *et al.* (1987) observed smaller shell size and tissue mass (wet and dry) in control individuals in *C. gigas* in the first filial generation. However, IMAI & SAKAI (1961) showed that growth in Pacific oysters, *Crassostrea gigas*, was not reduced after four generations of consanguineous crosses and viability was low. LANNAN (1980) showed that consanguinity does not reduce larval survival in *C. gigas*. WILBUR & GAFFNEY (1991) did not find consanguinity depression in *Argopecten irradians*. MALLET & HALLEY (1983) found high larval survival in a consanguineous family of the American oyster and no depression of survival or shell size in juveniles and adults.

This paper examines the consequences of consanguineous crosses on growth and survival of the scallop *Nodipecten nodosus*, as well as the relationship between shell color and growth.

MATERIALS AND METHODS

Scallops used as progenitors were collected at Chacopatica, Gulf of Cariaco, Venezuela (10° 30´10" Lat N; 64° 13´ 6" Long W) and transported to the Turpialito Research Station (Universidad de Oriente), near Cumaná. They were acclimated to 21°C and subsequently induced to spawn by thermal shock, transferring then to water at 28 °C (VELEZ *et al.*, 1988). Self-fertilization of an orange individual and a cross between the same orange scallop and a brown one were made using a factorial 2 x 2 design. In all cases, gametes were mixed for 15 min and excess sperm was discarded using nets. As oocytes of *Nodipecten nodosus* were released, they were surrounded by spermatozoa in a quiescent state, and fertilization occurred immediately, and prior to self-fertilization. In this species, sperm activation occurs 6 min after oocyte release.

Zygotes were placed in 400 l conical culture tanks and maintained at a density of 3 larvae/ml during the first week and 2 larvae/ml during a second week. A mixture of 1:1 *Chaetoceros gracilis* and *Isochrysis aff galbana* was supplied at 30 cell ul^{-1} day^{-1} as a food source for the larvae.

Larval setting was made in a vertical-flow seawater circling hatching tray. Postlarvae food was 1:1:1 *Chaetoceros gracilis, Isochrysis aff galbana* and *Tetraselmis chuii*. Individuals two millimeters in size were placed in round plastic cages and suspended at 20 m depth from long line in the natural environment at Turpialito.

The density was progressively reduced so that the scallops covered about 30% of culture surface throughout the culture study.

Once a month, the scallops were cleaned and counted, and height–length measurements were made for one sample of 80 individuals from each cross type and shell colour group, to permit making comparisons of length-height relationship. Survival rates were also calculated monthly for each group.

Total, wet, dry and ash free mass were determined for each group at one year of age. Dry mass was measured after drying the tissues at 80°C for 24 h and ash free mass was determined after combusting dry tissues at 400°C for 2 h.

Growth was compared at one year of age using the following procedures:

a.- Two-factor analysis of variance (ANOVA) to test for differences in length and height in respect to cross type and shell colour groups.

b.- Analysis of covariance to compare linear regressions describing length-height and length-weight relationships.

A Student´s t-test was applied to examine differences in survival between groups, and also to evaluate differences in wet, dry and ash free mass of different tissues (muscle, gonad, gills, digestive gland and remaining tissues) for cross and self-fertilization groups. Arcsine transform-ations was used of survival proportions.

Statistical analyses, tests for assumptions in ANOVA as normality and homosedasticity were done according to Zar (1984) using a computational program "Statgraphics plus 7.0".

RESULTS

The number of postlarvae obtained from cross-fertilized scallops was twice that of the self-fertilized scallops even up to one year of age, whereas survival was similar in both groups ($ts = 0.71$ $P > 0.05$) (Fig. 1).

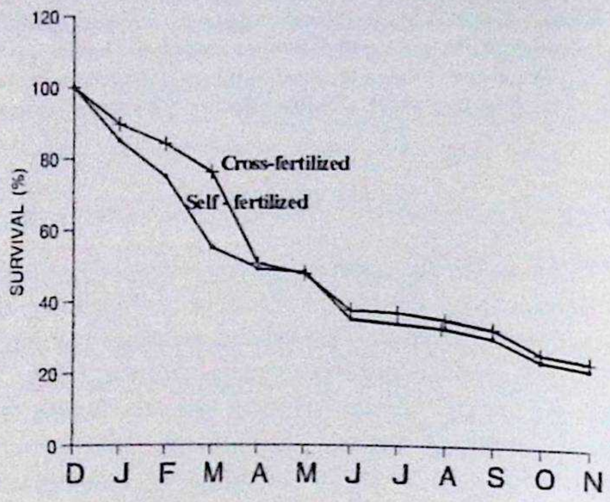

Fig. 1.- A comparison of survival in self-fertilized and cross-fertilized offspring of *Nodipecten nodosus* over the period December 1994 to November 1995. Each value represents the mean of 80 individuals.

At one year of age the ratio of orange to brown offspring in cross-fertilized and self-fertilized groups was 2:1 and 3:1, respectively. Both mean height and length of orange offspring were greater in both cross type groups. Because previous analysis did not show significant differences between either both groups of self-fertilized offspring or both groups of control offspring; they were considered as replicas. ANOVAS showed differences in length and height between cross type groups (length: Fs= 154.70 $P < 0.001$, height: Fs= 149.60 $P < 0.001$) and between shell colour groups (length: Fs= 27.81 $P < 0.001$, height: Fs=23.99 $P < 0.001$). Figure 2 compares shell length in self-fertilized and cross-fertilized offspring from December 1994 to November 1995.

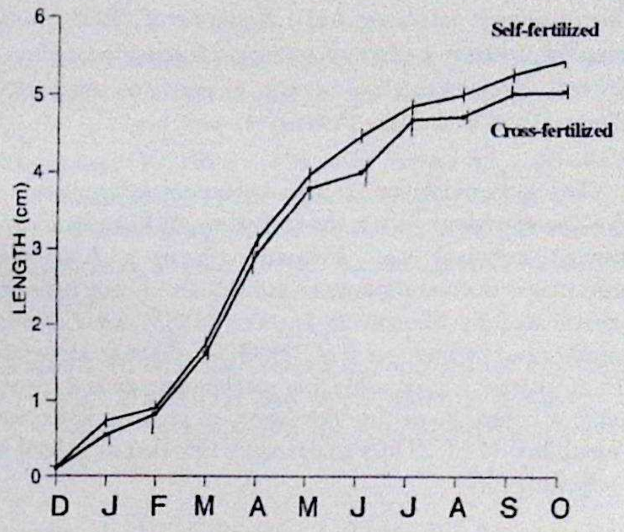

Fig. 2.- Length of self-fertilized and cross-fertilized offspring of *Nodipecten nodosus* over the period of December 1994 to November 1995. Each value represents the mean of 80 individuals.

Shell growth and shape as indicated by height-length relationships were not different in the cross and shell color type groups, either in comparisons of slopes (Fs=0.0134 $P > 0.05$) or of intercept points by pairs ($P > 0.05$). The common equation was:

height = 0.0361 + 0.9943 x length (r=0.991).

Length-weight relationships showed significant differences (t= 0.22314 $P < 0.05$) between cross types. The equations were as follows:

self-fertilization: Ln weight = Ln (-0.819)+ 2.540 x Ln (length) (r = 0.93)

cross fertilized: Ln weight = Ln (2.270) + 0.719 x Ln (length) (r = 0.85)

Significant differences were not observed in final total mass (ts= 1.6620; $P > 0.05$). However, self-fertilized offspring showed significantly higher shell mass and wet and dry digestive gland mass. Total mass, wet muscle mass, the wet and dry mass of the gills, and the dry and wet mass of the remaining tissues also tended to be higher, but not significantty so (Table 1).

TABLE 1: MEAN TOTAL LENGTH(cm), HEIGHT (cm), TOTAL WEIGHT (g), AND WET, DRY AND ASH FREE DRY MASS (g) OF THE MUSCLE, GONAD, GILLS, DIGESTIVE GLAND AND REMAINING TISSUES IN SELF-FERTILIZATION AND CROSS OFFSPRING OF *Nodipecten nodosus.* AFTER BEING REARED FROM DEC. 1994 TO NOV. 1995

	SELF-FERTILIZED		CROSS-FERTILIZED		
	MEAN	SD	MEAN	SD	
LENGTH	5.58	0.44	5.21	0.64	P<0.001
HEIGHT	.61	0.46	5.25	0.62	P<0.001
TOTAL MASS	35.33	8.30	31.17	7.32	P<0.05
SHELL MASS	25.41	6.26	21.88	5.95	P<0.05
		MUSCLE			
WET	3.47	0.85	3.18	0.91	P<0.05
DRY	1.14	0.61	1.28	0.88	P<0.05
ASH FREE	0.13	0.04	0.14	0.05	P<0.05
		GONAD			
WET	0.76	0.26	0.77	0.30	P<0.5
DRY	0.13	0.06	0.13	0.06	P<0.05
ASH FREE	0.03	0.01	0.04	0.02	P<0.05
		GILS			
		0.45	1.37	0.46	P<0.05
WET	1.42	0.20	0.18	0.10	P<0.05
DRY	0.25	0.01	0.05,	0.01	P<0.05
ASH FREE	0.05	DIGESTIVE GLAND			
WET	1.02	0.25	0.87	0.18	P<0.05
DRY	0.26	0.17	0.19	0.06	P<0.05
ASH FREE	0.05	0.02	0.05	0.03	P<0.05
		REMAINING TISSUES			
WET	3.23	0.79	0.08	0.78	P<0.05
DRY	0.50	0.49	0.44	0.28	P<0.05
ASH FREE	0.08	0.03	0.09	0.02	P<0.05

Growth rates for each group (orange and brown offspring from self-fertilization and orange and brown offspring from cross fertilized) showed a tendency to increase during the first six months and then to decrease until they became stable (Fig. 3) coinciding with gonad development which began in the sixth month.

DISCUSSION

This study suggests that consanguinity adversely affects survival but favourably affects growth. Low survival of offspring in consanguineous crosses has been detected in several species of mollusk bivalves: *Crassostrea virginica* (LONGWELL & STILES,1973) , *Pinctada furcata martensii* (WADA,1984) and *Mytilus galloprovincialis* (BEAUMONT & ABDULMATIN,1994). Larger size in self-fertilized *Euvola ziczac* offspring was reported by Betancourt *et al.*, (1995) even though results were not statistically significant.

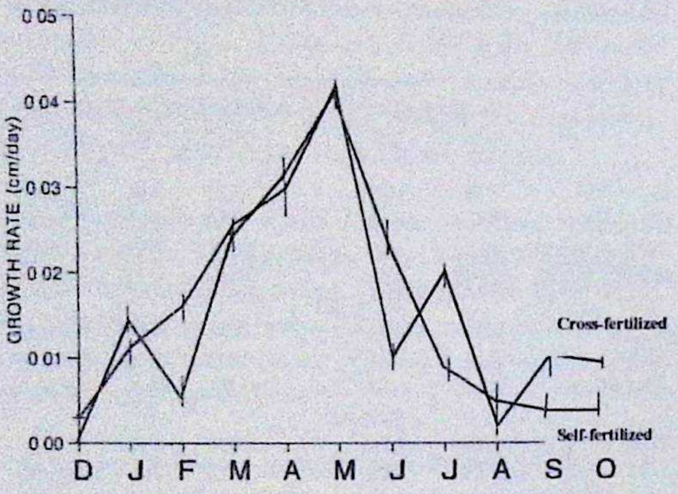

Fig. 3.- Growth rate of self-fertilized and cross fertilized offspring of *Nodipecten nodosus* from December 1994 to November 1995. Each value represents the mean of 80 individuals

Length and height were greater in orange offspring than brown offspring from both cross-type groups. WOLF & GARRIDO (1991) found lower growth and survival in the yellow morph of *Argopecten purpuratus* than in the brown morph, and growth in the yellow morphs was more variable and responded differently to temperature changes than other colored scallops.

Similar length-height relationships in spite of consanguinity and shell color are an indicator of similar shell growth and shape in all groups.

Wet mass, dry mass and ash-free mass were greater in several tissues of the self-fertilization group. BETANCOURT *et al.* (1995) did not find statistical differences in wet and dry mussel mass between self-fertilized and cross-fertilized offspring of *E. ziczac*. However, BEATTIE *et al.*, (1987) found low values of wet and dry soft tissue mass in consanguineous crosses of *Crassostrea gigas*.

Growth rate fluctuations during the first six months indicated that self-fertilized *Nodipecten nodosus* offspring seem to be more sensitive to environmental changes than cross-fertilized offspring, but the reverse was true for organisms over gonad development (Fig.3). Temperature and food availability are considered important environmental factors affecting bivalve growth. For example, BEUKEMA & CADEE (1991) pointed out that growth rate fluctuations parallel to phytoplankton variations, and LODEIROS *et al.*, (1998) showed that there exists a phytoplanktonic biomass influence on growth. *Nodipecten nodosus* is more sensitive to temperature than to food availability (VÉLEZ, A. *pers. com).*

The only indicative of consanguineous depression for *Nodipecten nodosus* was a lower (although not significantly lower) survival rate. Growth appears to have some advantages in consanguineous individuals. These have been mentioned by MALLET & HALLEY (1983) for *Crassostrea virginica* and by DURANT *et al.*, (1993) for *Pinctada margaritifera*. In *N. nodosus*, it is possible that mechanisms exist to protect against consanguineous depression to prevent low genetic variability (1 of 25 loci analyzed by FERNÁNDEZ (1995) was polymorphic) .

It is possible that the organism that selects for self-fertilization has some genetic characteristics which enhances growth. A study of growth heritability is needed to test this hypothesis.

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