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SIZE AND AGE AT SEXUAL MATURITY OF OCEAN QUAHOGS *ARCTICA ISLANDICA* LINNÉ, FROM A DEEP OCEANIC SITE

by

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ABSTRACT

Gonadal tissues and shells of small ocean quahogs, *Arctica islandica*, were collected during summer of 1978 from off Long Island, New York, to determine sexual maturity and age. The quahogs ranged from 19 to 60 mm ($\bar{x}$ = 39.2 mm) in shell length. Undifferentiated and differentiated gonadal development was found, but many in the latter condition were in an intermediate state and were separated into two groups based on tubule development and germinal cell production. Attainment of sexual maturity was variable with respect to size and age. The sex ratio was imbalanced in favor of males and was most unequal in quahogs in intermediate stages of gonadal development, probably because females initiated maturation at somewhat larger sizes and older ages than males.

RÉSUMÉ

Des tissus gonadal et des coquilles de petites "quahogs" d'océan *Arctica islandica*, furent rassemblées pendant l'été de 1978, au large de Long Island, New York, pour la détermination d'âge et maturité sexuelle. La longueur des coquilles des "quahogs" s'étendaient de 19 à 60 mm ($\bar{x}$ = 39.2 mm). Développement gonadal indifférentié et différentié furent trouvées, mais plusieurs dans la condition derniere nommée étaient dans une étage intermédiaire et ont été séparé dans deux groupes basé sur le dévelopment de tubule et la production de cellule germinale. Réalisation de maturité sexuel était variable quant à taille et âge. La proportion sexuelle était déséquilibré en faveur des mâles et était le plus inégale dans les "quahogs" dans les étages de développement gonadal intermédiaires, en toute probabilité parce que les femelles commencaient maturation aux tailles plus grandes et âges plus avancé que les mâles.

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INTRODUCTION

Most bivalves lack external sexual characteristics that may be used to determine maturity and internal characteristics are usually limited to the seasonal production of male and female germinal cells. This is the case for the ocean quahog, *Arctica islandica*, a species that has become an increasingly important fisheries resource in the United States since the mid-1970's (Ropes, 1979a; Murawski and Serchuk, 1979). Procedures for examining gonadal tissues, differentiating the sex of minute germinal cells, and determining sexual maturity have been reported for the surf clam, *Spisula solidissima*, by Ropes (1979b). As is the case for other bivalves, sexual maturity occurs at a young age and small size, but species differences occur (Altman and Dittmer, 1972).

Our knowledge of maturation in ocean quahogs is incomplete. Thompson et al. (In press, a and b) observed that the quahog is a slow growing, long-lived species which exhibits considerable variability in maturation with respect to size and age. The latter conclusion was based on examinations of 39 specimens, 87% of which were 40 mm long or larger in shell length. The samples were collected in April-May, 3-4 months before the spawning period reported for this species by Loosanoff (1953). It seemed reasonable to assume that mature, older quahogs in the sample would produce large numbers of sex cells, but it was not possible to determine whether many gonads in the sample containing only a few differentiated sex cells would do likewise. Their contribution to the reproductive potential of the species was an enigma.

In late July and early August 1978, the National Marine Fisheries Service organized an effort to mark large numbers of ocean quahogs at one location sampled in the study of sexual maturity reported by Thompson et al. (In press,b). This was an opportunity to collect specimens for a re-examination of gonadal condition at about the time of maximum ripeness, as Loosanoff (1953) had reported finding many ocean quahogs in the partial spawning condition in mid-August. The time of collection, then, seemed favorable for obtaining sexually mature quahogs with fully developed, ripe gonads that could be clearly separated from immature quahogs with undifferentiated sex cells in the gonads.

METHODS

A commercial clam dredger was chartered for the marking project during 25 July to 5 August 1978. The hydraulic dredge was modified by lining the inner surfaces with 12.7 mm^2 mesh hardware cloth to retain small clams.

The collection site was at 53-55 m depths 48 km SSE of Shinnecock Inlet, Long Island, New York.

Small quahogs were sorted from the catch during the marking operation. The soft bodies of 133 quahogs were immediately removed from the shells and preserved in Bouin's fixative; shells were saved and coded for reference to corresponding tissues. Further details relative to the sampling scheme and analysis for age and growth studies are reported by Murawski et al. (1980).

The gonadal tissues were processed into slides for microscopic examination using standard histological techniques at the NMFS Oxford, Maryland laboratory. Sections of imbedded tissues 6 µm thick were stained in Harris' hematoxylin, and eosin. Recognition of gametogenic stages was based on previous studies of bivalve reproduction by Ropes and Stickney (1965); Ropes (1968 a and b; 1971; 1979b); and Loosanoff (1953). Shell length measurements to 0.1 mm were made with calipers.

RESULTS

Observations of Gonadal Condition

Of the 133 gonadal tissues, 36 were found to be in an undifferentiated condition (Table 1). Gonadal tubules were of small diameter and few in number within abundant loose vesicular connective tissue. Gonia embedded in the germinal epithelium lacked cellular structures which could be used for sex determinations. The lumina of tubules were empty.

Sex determinations were possible for 97 quahogs but in most (69) the gonads appeared to be in an intermediate stage and not fully developed. These latter tissues were separated into two categories: those with sparse tubule development and those with moderate tubule development.

A limited number of tubules and gametogenic cells were typical conditions in differentiated gonads with sparse tubule development: the 16 male tissues examined were producing a few sperm; the 4 female tissues examined contained a few oocytes. Abundant loose vesicular connective tissue occurred between the widely spaced gonadal tubules. In males, spermatogenic cells at the germinal epithelium were about one layer thick, but were absent in portions of the epithelium. Some sperm were in close contact with the spermatogenic cells and a few were scattered in the lumina of tubules. In females, the few small oocytes occurred at the germinal epithelium, none were in the tubule lumina, and all were in an early developmental stage.

Table 1. Gonadal condition, age and size of ocean quahogs, *Arctica islandica*, from off Long Island, N.Y., in late July to early August 1978.

AGE	N	Number and (Percent)						
		Undifferentiated	Differentiated					
			Sparse		Moderate		Mature	
			Males	Females	Males	Females	Males	Females
2	1	1(0.8)						
3	8	4(3.0)	2(1.5)		2(1.5)			
4	14	7(5.3)	5(3.8)		2(1.5)			
5	25	10(7.5)	4(3.0)	1(0.8)	9(6.8)		1(0.8)	
6	28	10(7.5)	3(2.3)	2(1.5)	10(7.5)		2(1.5)	1(0.8)
7	29	3(2.3)	2(1.5)	1(0.8)	12(9.0)	9(6.8)	2(1.5)	
8	10	1(0.8)			3(2.3)	1(0.8)	5(3.8)	
9	1						1(0.8)	
10	3				1(0.8)		2(1.5)	
11	2						1(0.8)	1(0.8)
12	3						1(0.8)	2(1.5)
13	1						1(0.8)	
14	2						1(0.8)	1(0.8)
15								
16	4							4(3.0)
17								
18	2						2(1.5)	
N	133	36(27.1)	16(12.0)	4(3.0)	39(29.3)	10(7.5)	19(14.3)	9(6.8)
$\bar{x}$ years		5.0	5.1		6.3		10.9	
$\bar{x}$ size		34.4	34.7		38.2		49.7	
Size range		19-46	21-44		20-48		36-60	

For differentiated gonads with moderate tubule development, 39 males examined were producing sperm, while all 10 females examined were producing oocytes. The gonadal tubules were more numerous than in those of the sparse condition and some exhibited an expanded alveolar condition, but loose vesicular connective tissue also clearly separated the tubules. In males, several layers of spermatocytes proliferated from the germinal epithelium with some sperm forming a fringe extending toward the empty lumina; however, portions of the germinal epithelium in some tubules again lacked obvious spermatogenic cells. Oocytes in females were at the same stage of development as seen for females with sparse gonadal tubules, but more were growing from the germinal epithelium. As with males, some portions of the germinal epithelium again lacked obvious oogenic cells.

The sexually mature condition was found in 19 males and 9 females. In these quahogs, the tubules were greatly expanded and filled the gonadal area; little connective tissue occurred between adjacent tubules. Developmental stages similar to those described for other bivalves by Ropes and Stickney (1965); Ropes (1968a and b; 1971; 1979b) and for ocean quahogs by Loosanoff (1953) were recognized. Two males and one female were in an early gonadal condition. Spermatogenesis and oogenesis had the same cellular characteristics as in gonads of moderate tubule development. Six males were in a late gonadal condition.. Primary and secondary spermatocytes and spermatids were proliferating from the germinal epithelium, filling about half of the tubules and sperm crowded into the lumina. No females were found in the late gonadal condition, but 11 males and 2 females were in an advanced late stage. In males, spermatocytes and spermatids proliferated from the germinal epithelium, but sperm predominated in the lumina of the tubules. In females, oocytes crowded into the lumina of tubules and a few seemed to be attached to the germinal epithelium. Six ripe females with numerous oocytes crowding into the tubules were found, but no ripe males. The potential for developing large numbers of germinal cells was most evident and indicative of full sexual maturity in all of these quahogs.

Gonadal Condition vs. Size and Age

In an analysis of gonadal condition relative to size and age, quahogs in the undifferentiated, immature condition ranged from 2 to 8 years old, averaged 5.0 years old, and were from 19 to 46 mm long and averaged 34.4 mm (Table 1). This condition was found in 27% of the gonads in the sample.

For the three types of differentiated gonads, quahogs with sparse tubule development comprised 15% of the samples. They ranged from 3 to 7 years old, averaged 5.1 years old, and were from 21 to 44 mm long and averaged 34.7 mm. This category contained the smallest and youngest female in the sample. It was 38 mm long and 5 years old. Quahogs with moderate tubule development comprised 37% of the sample, ranged from 3 to 10 years old, averaged 6.3 years old, and were from 20 to 48 mm long and averaged 38.2 mm. This category contained the smallest and youngest male in the sample. It was 20 mm long and 3 years old. Sexually mature quahogs comprised 21% of the sample, ranged from 5 to 18 years old, averaged 10.9 years old, and were from 36 to 60 mm long, and averaged 49.7 mm. The smallest mature quahog found was a male 36 mm long and 6 years old, although a 5-year-old, 41 mm long male was also mature; the smallest and youngest mature female found was 41 mm long, and 6 years old.

None of the gonads contained germinal cells suggestive of ambisexuality. This is consistent with the conclusion of Loosanoff (1953) that the sexes are separate. The sex ratio, however, was particularly imbalanced in favor of males. In the 69 quahogs considered less than fully mature, 55 were males and 14 were females, while in the 28 sexually mature specimens, 19 were males and 9 were females; the observed ratios were 4:1 and 2:1, respectively. The data were subjected to goodness of fit tests under the hypothesis of a 1:1 ratio between the sexes; results indicated a highly significant ($P < 0.01$) and a significant ($P < 0.05$) difference, respectively.

DISCUSSION

The time of sampling, sample size, and capture of small quahogs provided a basis for detection of the differentiated and sexually mature stage at younger ages and smaller sizes as compared to the study of Thompson et al. (In press, b). In the present study, 5- and 6-year-old quahogs 41 and 36 mm long, respectively, were considered sexually mature; the youngest mature quahog reported by Thompson et al. (In press, b) was a 42 mm individual 11 years old. The intermediate gonadal condition was found to occur at lower ages and smaller sizes than by Thompson et al. (In press, b) and slightly smaller sizes were found for sexually mature quahogs. Variability in attainment of sexual maturity at age/size was observed in both studies.

For the 69 gonads containing sexually differentiated germinal cells and sparse to moderate tubule development, some morphologically ripe sperm were present, but oogenesis never exceeded an early developmental state. The sperm may be spawned, but the fate of the oocytes remains an enigma. In oysters, <u>Crassostrea virginica</u>, germinal cells remaining in the gonads after spawning are reabsorbed (Galtsoff, 1964), but viable, nearly ripe or ripe germinal cells may be retained by hard clams, <u>Mercenaria mercenaria</u>, for some time after the spawning season (Loosanoff and Davis, 1951). Thus, bivalves appear to differ greatly in this respect. No conclusion can be drawn relative to retention of germinal cells after spawning for ocean quahogs which were intermediate between the immature and mature condition in the absence of collected data or for other reasons.

A disparity in the initiation of gametogenesis was observed between the sexes. Male quahogs began producing germinal cells at a smaller size and younger age than females. This suggests that females require a longer period of development and growth. The latent expression of female sexuality is a probable explanation for the highly significant difference obtained in tests of the sex ratio of quahogs in the intermediate gonadal condition. The significant difference observed for fully mature quahogs may be due to the small number in the sample (Dixon and Massey, 1957), but Jones (1980) observed a similar disparity ($P < 0.05$) for quahogs larger than 75 mm from offshore New Jersey. In his collections 184 were males and 136 were females, a ratio of 1.35:1.

Pelseneer (1926) investigated the sex ratio of several mollusk species, including lamellibranchs. He found more females in the older individuals of some populations and the converse among younger individuals. Coe (1936) recognized the existence of such disparities in mollusks and proposed the following hypotheses as possible explanations: (1) that males have a shorter longevity than females, because of a differential mortality rate or less resistance to unfavorable environmental conditions; (2) that the development of alternative sexual conditions are environmentally determined; and (3) that sex change may occur. Loosanoff (1953), von Oertzen (1972), Thompson et al. (In press, b) and Jones (1980) all considered the species to be strictly dioecious. Sex reversal in some mollusks has been linked with castration from parasites invading the gonads, but evidence of causality was considered inconclusive by Noble and Noble (1961) and Malek and Cheng (1974). Except for the occurrence of the commensal nemertean, *Malacobdella grossa*, in ocean quahogs (Gibson, 1967; Jones, 1979), parasites in the species have not been reported (Ropes and Lang, 1975). Data for older ocean quahogs than were included in the present study are needed to investigate the age/sex relationship, since a disparity in favor of females in older segments of the Middle Atlantic Bight population may have important implications for management.

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