THE GAMETOGENIC CYCLE OF *Drupella cornus* (RÖDING, 1798) AT NINGALOO AND ABROLHOS REEFS.

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ABSTRACT

The gametogenesis of *Drupella cornus* populations from the Ningaloo Reef Tract and Houtman Abrolhos Islands, Western Australia was assessed from qualitative descriptions of the gross gonad condition, change in morphology of the penis and the histological examination of gonads of both sexes. Gametogenesis is continuous, with evidence of spermatogenesis in the males and the initial stages of oogenesis in the females, in all gonads sectioned. Mature gametes were present in both sexes throughout the study except for periods after spawning when the early and late recovery stages of gametogenesis predominated. Two synchronized spawning peaks were recorded at Coral Bay (Ningaloo Reef Tract), in late spring and early summer of 1989 and 1990. These spawning episodes correlated with a steep rise in seawater temperature. A population from the Houtman Abrolhos Islands to the south spawned at similar times but only 20% of specimens shed their gametes entirely. Reduced spawning episodes were also recorded sporadically throughout the study from both geographic locations, suggesting *Drupella cornus* populations will spawn more than once throughout an extended breeding season.

INTRODUCTION

Since the early 1980's there has been a steady stream of literature documenting the feeding of the Muricid genus *Drupella* on scleractinian (stony) corals. *Drupella cornus* is carnivorous, feeding extensively but probably not exclusively on coral (Robertson, 1970). The feeding structure or radula in *Drupella cornus* is unlike that of other muricids as it is long, slender and equipped with denticulate lateral teeth armed with bifid tips (Arakawa, 1958). It is therefore well adapted to the removal of coral polyps from their surrounding protective calcareous theca. Removal of coral polyps leaves a bare, white patch of calcified skeleton (the feeding scar) which is soon invaded by filamentous algae.
The first population explosion of *Drupella spp* with associated widespread coral destruction was reported by Moyer, Emerson and Ross (1982), at Miyake-jima, Japan by *Drupella fragum* and at Mactan Island, Cebu in the Philippines by *Drupella rugosa*. Reports of damage to coral along the Ningaloo Reef Tract first began to appear in the early 1980's (Stoddart, 1989).

For *Drupella spp* outbreaks to occur, a favourable combination of environmental, exogenous and endogenous factors must have occurred at a stage during their life cycle causing them to reproduce successfully in large numbers. Therefore, knowledge of the reproductive cycles of *Drupella spp* will assist in understanding some of the reasons for these outbreaking populations.

MATERIAL AND METHODS

Samples of the *Drupella cornus* were collected from two coral reef systems along the Western Australian coastline between June 1989 and November 1990.
Site 1 - Coral Bay situated towards the southern end of the Ningaloo Reef Tract, approximately 1100kms north of Perth. (23° 06S, 113° 30'E)
Site 2 - Big Rat Island situated in the Easter Group of the Houtman Abrolhos Islands, approximately 60kms west of Geraldton on Western Australia's mid-west coastline (28° 43's, 113° 47'E).

Monthly sampling was conducted during the day at both sites. Infested coral colonies were located and *Drupella cornus* were collected hapazardly from one or more coral colonies until a sample size of approximately 100 snails was obtained, for later processing.

The specimens were narcotised using 0.35M magnesium chloride until they no longer responded to touch, then measured to the nearest 0.1mm using Vernier callipers. Twelve females and five males were randomly selected, re-measured and cracked along the spire of the shell above the aperture, using a claw hammer.

The shell was eased open exposing the visceral mass of the animal and a portion of the distal end of the gonad and digestive gland tissue was excised, and preserved in formalin-seawater (10:90) for later histology. All specimens were examined in order to determine sex ratios in the populations. Any variation from a 1:1 sex ratio was tested using a chi-squared analysis, ($p>0.05$).

The criterion for determining the sex of *Drupella cornus* was the presence or absence of a penis. In males, morphological changes to the distal end of the penis were recorded from December 1989 to November 1990 for both sites.

Qualitative observations made on the gross gonad condition of usually 5 males and 12 females per month from each study site were described using the following criteria:

a) The visual percentage estimates of the volume occupied by the gonad in the coil of digestive gland/gonad tissue was assessed against the volume a ripe gonad would encompass; close to 50%

b) Gonad colouration in each sex.

c) The external appearance of the gonad was described as taut, granulated, streaked, containing hollow areas or hydrated and flaccid, depending on the stage of development of the gametogenic cycle.

d) A tentative staging for gametogenesis was assigned to each specimen to be compared with later histological staging.

The preserved gonad tissue was dehydrated in an alcohol series, embedded in paraffin wax and sectioned at 6 µm. The sections were routinely stained in Erlich's Haemotoxylin and Eosin.

Five stages were used to assess the gametogenic cycle for *Drupella cornus*. An early and late developmental stage, a ripe stage, partially spent and spent stages. These were adapted from Wells and Keesing (1989), used for the abalone *Haliotis roei*, modified from a method used by Wilson and Hodgkin (1967) for mytilid bivalves.

Surface seawater temperatures were taken opportunistically using a hand held thermometer. All seawater temperature data were collected from depths less than three metres.

RESULTS

Sex Ratios in Populations of *Drupella cornus*

Drupella cornus is gonochoristic in populations from the Ningaloo Reef Tract and Houtman Abrolhos Islands. During this study, no hermophrodites were identified and sex differentiation was evident in all animals examined. Departures from a 1:1 sex ratio were tested and showed no significant differences between months or sites (using chi-squared test, $p>0.05$).

Gross Morphology of the Penis

The morphology of the penis in male *Drupella cornus* specimens changes during the reproductive cycle. The shaft of the penis has a distal swelling, known as the penial papilla (Dr W. Ponder, 1989 pers comm), which appeared to increase and decrease in size in relation to the development of the testis. Males were recorded as:

(i) Developed Penial Papillae (DPP)
(ii) Reduced Penial Papillae (RPP)
(iii) Absent Penial Papillae (APP)

Gross Morphology of the Gonad Tissue

In general, the male gonads are an ochre/orange colour in the early/late developmental stages, a golden colour when ripe, orange/brown and tinged with green when partially spent and brown with visible white streaks when fully spent. The female gonads are a cream/pale yellow colour in the early/late developmental stages, cream when ripe, pale yellow and tinged with green when partially spent and brown with visible white streaks when fully spent.

Besides colour, the external appearance changes noticeably from being taut and exhibiting a distinct scalloped edge along the margin with the digestive gland in the ripe condition, while early/late stages have some hollow areas present and appear slightly granulated and streaked. The partially spent stage exhibits obvious hollow areas and is heavily granulated with visible streaking. The spent gonad is flaccid, watery and contains numerous white streaks which may run towards the digestive gland.
Visual estimates of the volume occupied by the gonad in the visceral coil were recorded. Ripe gonads occupied 35% to 50% of the coil volume, early/late and partially spent gonads varied between 20% and 35%, whilst the spent gonads were less than 20% of the total volume.

TABLE 1

Criteria Used to Assess Stages of the Gametogenic Cycle in Adult *Drupella cornus*

STAGE	MALE	FEMALE
EARLY DEVELOPMENT	Large numbers of spermatogonia and spermatocytes present around tubules. Thin layer of spermatids and spermatozoa present.	All cell stages present with large portion of oogonia and primary oocytes. Some stalked oocytes present.
LATE DEVELOPMENT	Gonad lumen moderately packed with spermatozoa. Layers of spermatocytes and spermatids occupy up to half of the gonad lumen.	Moderate numbers of oogonia and primary oocytes still present. Large proportion of cells are stalked oocytes. Yolk granules and lipid droplets beginning to appear.
RIPE	Gonad lumen densely packed with spermatozoa. Few spermatocytes and spermatids present around tubules.	Gonad lumen densely packed with mature oocytes free from trabeculae. Very few stalked oocytes present. Obvious vitelline membrane enclosing densely packed yolk granules and lipid droplets in the cytoplasm.
PARTIALLY SPENT	Gonad lumen partially collapsed in places. Obvious spaces around tubules vacated by sperm. Other areas appear ripe, packed densely with spermatozoa. Spermatocytes and spermatids still present.	Gonad lumen partially collapsed with trabeculae folded. Obvious hollow areas between moderate numbers of mature oocytes present. Some areas remain densely packed. Yolk granules and lipid droplets still enclosed by the vitelline membrane. Very few oocytes present.
SPENT	Gonad lumen collapsed. Few or no spermatogonia or spermatocytes present. Some spermatozoa still present.	Gonad lumen collapsed with trabeculae folded. A few unspawned mature oocytes may be present. Oogonia and early oocytes beginning to appear.

Staging Sequences for the Gametogenic Cycle

The five stages used to assess the gametogenic cycle for both male and female *Drupella cornus*, are summarised in Table 1.

The Gametogenic Cycle of *Drupella cornus*

Histological examination of the gonad sections of each sex of *Drupella cornus*, from both study sites, revealed a similar pattern of reproduction. Gametogenesis is continuous with spermatogenesis in the males and the initial stages of oogenesis in the females present in all gonad sections. Populations from Coral Bay displayed mature gametes nearly all year round except for late summer and early autumn. During this period, early and late developmental stages predominated. This suggested a late spring mating and subsequent spawning period. During late autumn and early winter 1990, individual specimens were recorded at different stages of the gametogenic cycle.

The Big Rat Island population recorded mature gametes in the gonad sections for both sexes throughout the study. The pattern of reproductive activity for the *Drupella cornus* population from Big Rat Island is not as clearly defined as for the Coral Bay population. The partially spent stage was evident in samples throughout the study with other stages being recorded for individuals, inconsistently.

Seawater Temperature

Although seawater temperatures varied at both sites from year to year, both exhibited maximal temperatures between January and March (24°C-26°C) and minimal temperatures (18.9°C-21°C) in July through August .

DISCUSSION

The techniques used to determine the gametogenic cycle for *Drupella cornus* were the histological assessment and gross gonad condition of males and females, and observations on the change in morphology of the penis.

Although no sexual dimorphism could be detected in *Drupella cornus* on the basis of shell shape and size, sexes could be distinguished easily because males bear a conspicuous penis. Sex ratio data for populations of *Drupella cornus* from the Ningaloo Reef Tract and the Houtman Abrolhos Islands showed that ratios of males:females was very close to 1:1. The distal end of the penis of *Drupella cornus* is known as the penial papilla. The penial papillae of males undergoes seasonal resorption after the breeding season and then re-develops. The penis itself is not shed.

The gametogenic cycle for *Drupella cornus* is continuous (Nardi 1991, in prep) and therefore unlike some molluscs where a resting stage occurs Tranter (1958), Wilson and Hodgkin (1967). After a spawning episode, eg. late spring and early summer in Coral Bay 1989, the gonads were in the early and late recovery stages of gametogenesis by late summer, with ripe and partially spent stages evident by mid autumn.

TABLE 2

Male and Female Gonad Stages of *Drupella cornus* from Coral Bay - Ningaloo Reef Tract - August 1989 to November 1990

DATE	SAMPLE SIZE	EARLY DEV.	LATE DEV.	RIPE	PARTIALLY SPENT	SPENT
04.08.89	4(11)				4(10)	
12.09.89	6(11)				6(10)	(1)
07.10.89	4(11)				1(10)	3(1)
13.11.89	5(12)					5(12)
15.12.89	6(13)				1(1)	5(12)
25.01.90	-	-	-	-		
25.02.90	5(12)	3(11)	2(1)			
22.03.90	7(10)	2(7)	4(3)		1	
05.04.90	4(12)		(4)	4(2)	(6)	
10.05.90	5(12)	(3)			5(9)	
21.06.90	5(12)			(7)	5(5)	
26.07.90	-	-	-	-	-	-
14.08.90	5(12)				5(12)	
13.09.90	5(12)	(1)		(1)	4(10)	1
17.10.90	6(12)	(1)			6(11)	
15.11.90	5(12)				1(6)	4(6)

Male and Female Gonad Stages of *Drupella cornus* from Big Rat Island - Houtman Abrolhos Islands - June 1989 to November 1990

DATE	SAMPLE SIZE	EARLY DEV.	LATE DEV.	RIPE	PARTIALLY SPENT	SPENT
26.06.89	6(11)	(1)	(2)	1	5(8)	
15.09.89	5(12)				5(11)	(1)
17.10.89	5(13)				5(13)	
26.11.89	5(12)		(2)		5(10)	
19.12.89	6(12)		(4)	4	2(7)	(1)
24.01.90	7(12)		(2)		6(10)	1
09.02.90	5(11)			1	3(11)	1
11.03.90	6(11)	(1)		2	4(10)	
23.04.90	5(12)		(9)		5(3)	
18.05.90	6(10)			4(6)	2(4)	
20.06.90	5(11)				5(11)	
05.08.90	-	-	-	-	-	-
08.09.90	5(12)	3	(1)		2(8)	
07.10.90	5(12)		(2)		5(10)	
02.11.90	5(12)				4(11)	1(1)

Key: - no data collected
females in parentheses

The histological data and gross gonadal condition of both sexes, confirmed the presence of mature gametes from mid autumn to early summer for Coral Bay samples and throughout the year for the Big Rat Island population. The high proportion of individuals per sample from both study sites in the partially spent stage indicated a prolonged breeding season. Tavera and Faustina (1933) cited by Giese (1959), suggest that in warm seas the tendency is towards continuous breeding but with more intensive activity during some seasons.

Egg laying was not observed in the field. The histological evidence, gross gonadal condition and penial papillae data for Coral Bay populations in November and December, 1989 and November 1990 are consistent with the view that major spawning episodes for *Drupella cornus* occurred between 13 November and 15 December 1989 and commenced approximately 15 November 1990. Nearly all the specimens examined from both sexes were spent at this time in 1989 and either spent or in the latter phases of the partially spent stage in November 1990. These were the only two occasions from either study site that major spawning episodes were detected. Sporadic spawning episodes involving low numbers of snails in the population from Coral Bay occurred during the study. This pattern of sporadic spawning was also prevalent for the Big Rat Island population.

Seasonal fluctuations in seawater temperature have been correlated with the onset of gametogenesis and subsequent spawning episodes for marine invertebrates, eg. Wilson and Hodgkin (1967), Underwood (1974), Joll (1980) and Byrne (1990). A distinction has been drawn between the season of gametogenic activity and the much narrower season of actual spawning, Wilson and Hodgkin (1967). Seawater temperatures recorded from shallow reef areas may be subject to localised weather conditions. Simpson and Masini (1986) found that seawater temperatures in the lagoonal areas of the Ningaloo Reef Tract to be highly variable, spatially and temporally. This is also the case for the Houtman Abrolhos Islands, (A. Pearce 1990 pers. comm). A similar seawater temperature pattern was recorded for both geographical sites which are affected by the warm Leeuwin Current which flows south from the tropics, usually between the months of March and August each year. A sudden steep rise in seawater temperature appears to be a contributing factor towards the syncronized spawning peaks recorded at Coral Bay. The steady rise of seawater temperature recorded at Big Rat Island resulted in a reduced spawning episode during a similar period.

This raises the question of other environmental and exogenous factors being implicated in triggering spawning episodes for *Drupella cornus*. Some of these factors may include; resource partitioning, the occurrence of rough weather, phytoplankton availability, tidal range, and photoperiod. The possibility that pheremones or gametes in the water and endogenous factors may also play a role, Fox (1924), Himmelmann (1975), Minchen (1987), McEuen (1988), Pearse et al (1988), cited by Byrne (1990) should not be discounted.

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