Predation On Single Spat Oysters Crassostrea Virginica (Gmelin) By Blue Crabs Callinectes sapidus Rathbun And Mud Crabs Panopeus herbstii Milne-Edwards

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PREDATION ON SINGLE SPAT OYSTERS *CRASSOSTREA VIRGINICA* (GMELIN) BY BLUE CRABS *CALLINECTES SAPIDUS* RATHBUN AND MUD CRABS *PANOPEUS HERBSTII* MILNE-EDWARDS

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ABSTRACT Single spat oysters *Crassostrea virginica* of four size classes (3.4–24.6 mm mean shell heights [SH]) were offered to six size classes of blue crabs *Callinectes sapidus* (9.3–85.5 mm mean carapace width [CW]) and five size classes of mud crabs *Panopeus herbstii* (7.1–34.4 mm mean CW) for 48 hr. Predation rate, recorded as the number of dead oyster spat/crab/day, was directly proportional to crab size and inversely proportional to oyster size. Mud crabs of 34.4 mm CW and blue crabs of 85.5 mm CW had predation rates of 22.5 and 16.7 spat/crab/day on oyster spat of 24.6 and 24.4 mm SH, respectively. Larger sized spat could be more readily preyed upon by mud crabs than by blue crabs of similar size. Mud crabs of 7.1 and 25.2 mm CW caused significant mortalities to oyster spat of 8.1 and 24.6 mm SH, respectively. Blue crabs of 9.3, 24.5 and 85.5 mm CW caused significant mortalities to oyster spat of 3.4, 13.9 and 24.6 mm SH, respectively.

KEY WORDS: Predation, single spat oysters, *Crassostrea virginica*, crabs, *Callinectes sapidus*, *Panopeus herbstii*

INTRODUCTION

Predation on juvenile American oysters *Crassostrea virginica* by portunid and xanthid crabs is an important cause of oyster mortality (Luntz 1947, Menzel and Hopkins 1956, McDermott 1960, Krantz and Chamberlin 1978, MacKenzie 1981, Elner and Lavoie 1983). Blue crabs *Callinectes sapidus* prey on cultchless oysters up to 40 mm in shell length (Krantz and Chamberlin 1978). Mud crabs *Panopeus herbstii* with carapace widths of 28.0 to 35.5 mm will attack oysters 17 to 54 mm length (McDermott and Flower 1952). MacKenzie (1981) found that adult mud crabs consumed attached oyster spat 10 mm long or less and single oyster spat up to 25 mm long. Estimated predation rates vary from 0.4 to 19.0 spat per crab per day (Menzel and Hopkins 1956, McDermott 1960, Dare et al. 1983, Elner and Lavoie 1983). Larger crabs exposed to smaller single or cultchless spat at near optimum temperatures typically cause higher oyster mortality.

Nursery growout of spat to a larger size less susceptible to predators and the use of predator-exclusion devices such as netting are techniques used to reduce the effects of crab predation (Walne and Davies 1977). Determination of the effects of crab size and oyster spat size on survival is necessary before predator exclusion can be planned for in field growout. This study examines size interactions influencing predation rates of *Callinectes sapidus* and *Panopeus herbstii* on single spat of *Crassostrea virginica* in the laboratory.

MATERIALS AND METHODS

Laboratory experiments were conducted from August to December 1985 using single *C. virginica* spat, set on small pieces of crushed oyster shell. The spat were graded into four size classes 1–5, 6–10, 11–20 and 21–30 mm shell height (SH), measured from umbo to greatest height (Galtsoff 1964), and held in flowing seawater, *Callinectes sapidus* and *P. herbstii* were collected locally, held in flowing seawater and starved for at least 24 hours prior to use. Six size classes of blue crab 7–10, 13–20, 21–26, 30–34, 35–45, 70–100 mm carapace widths (CW) (Table 1), and five size classes of mud crab 6–8, 10–15, 16–20, 22–27, 31–40 mm CW (Table 2) were tested. All the experimental crabs appeared to be healthy and intact. Crabs that lost appendages, molted or died during the experiment were replaced.

Experiments were conducted at the Virginia Institute of Marine Science in Wachapreague, Virginia. Seawater was pumped onto a seawater table holding 24 experimental containers 29 × 18 × 12 cm arranged in two rows. Holes in the sides of each container permitted an exchange of seawater. Water level was maintained at a depth of 7 cm and a cover was placed over the containers to prevent escape of crabs. Temperature and salinity were measured daily and ranged from 20 to 28°C and 24 to 35 ppt, respectively.

Each test consisted of exposing one size class of crabs to four size classes of spat for 48 hr. A crab was placed in a container with fifty spat of one size. Control containers held only spat. Tests were run in triplicate, requiring six containers (3 test replicates + 3 control replicates) for each of the four spat sizes. Placement of spat and crabs was random. Oyster mortality was recorded after 24 hours. Dead spat were replaced with live spat of the same size class and the test continued for a second 24 hours.

Fifty spat were randomly selected from each size class and shell heights measured to the nearest 0.1 mm prior to each experiment. Carapace width of each crab was mea-

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TABLE 1.

Shell heights in the four size classes of oysters (*Crassostrea virginica*) exposed to blue crabs (*Callinectes sapidus*) and carapace widths in the six blue crab size classes.

Oyster size class	Shell Height (mm) Mean ± SD	Range	N
1	3.4 ± 0.84	1.6–5.4	300
2	7.6 ± 1.56	4.8–11.0	300
3	13.9 ± 2.84	8.8–20.1	300
4	24.4 ± 2.93	19.3–31.4	300
Blue crab size class	**Carapace Width (mm) Mean ± SD**	**Range**	
1	9.3 ± 0.65	7.8–9.8	12
2	17.2 ± 2.16	13.3–20.4	12
3	24.5 ± 1.00	23.1–26.0	12
4	31.7 ± 1.04	30.5–33.9	12
5	39.2 ± 3.20	34.9–45.7	12
6	85.5 ± 8.50	73.2–96.4	12

sured to the nearest 0.1 mm at the beginning of each experiment. Shell height and CW data were analyzed using analysis of variance. Predation rates were recorded as the number of dead spat per crab per day and compared using analysis of variance after log (x + 1) transformation of data (Sokal and Rohlf 1981).

A maximum successful predator ratio (Whetstone and Eversole 1981) for crab size classes with mean CW less than or equal to 25.2 mm was determined by dividing the mean SH of the largest spat size class which was significantly ($p < 0.05$) preyed upon by the mean CW. A maximum successful predator ratio for each crab species was also estimated by averaging the ratios.

Although actual predator exclusion tests were not conducted in this study, the authors suggest proper net mesh sizes which should prevent crab entrance. This determination was first made by estimating the carapace lengths (CL)

TABLE 2.

Shell heights in the four size classes of oysters (*Crassostrea virginica*) exposed to mud crabs (*Panopeus herbstii*) and carapace widths in the five mud crab size classes.

Oyster size class	Shell Height (mm) Mean ± SD	Range	N
1	3.7 ± 1.19	1.2–6.8	250
2	8.1 ± 1.60	4.2–13.7	250
3	15.1 ± 3.03	8.3–22.6	250
4	24.6 ± 3.07	19.4–39.9	250
Mud crab size class	**Carapace Width (mm) Mean ± SD**	**Range**	
1	7.1 ± 0.48	6.3–7.9	12
2	13.0 ± 1.26	10.7–14.6	12
3	17.8 ± 1.20	16.4–19.9	12
4	25.2 ± 1.09	22.9–27.0	12
5	34.4 ± 2.18	31.3–39.1	12

according to the ratios described by Williams (1965). The proper net mesh sizes which should prevent crab entrance were then determined.

RESULTS

Mortality of spat in the controls averaged less than 0.3% (max. 0.8%) for all experiments. Crab mortality and shedding was normally less than 5.0% (max. 20.0%) for all experiments. Most oysters were crushed or chipped and tissues removed in the manner described by Krantz and Chamberlin (1978) and Elner and Lavoie (1983). Some spat were crushed but not consumed.

Predation rates are shown in Table 3. Significant differences ($p < 0.01$) in predation were associated with crab-spat size interactions, but there were no differences ($p < 0.01$) in predation rates between the two sampling periods. Predation rates increased as oyster size decreased or crab size increased. Mud crabs caused higher mortalities than blue crabs of similar size. Mud crabs with mean CW of 34.4 mm had a higher predation rate than blue crabs with mean CW of 85.5 mm. Both predators caused significant ($p < 0.01$) mortalities on spat with mean SH of 24 mm. Total mean predation including all spat and crab sizes for blue crabs and mud crabs were 17.4 and 21.5 spat/crab/day, respectively.

Maximum successful predator ratios are shown in Table 4. Mean ratios for blue crabs and mud crabs were 0.42 and 1.03, respectively. Net mesh sizes with the diagonal dimension less than the carapace length of a selected crab size are shown in Table 5.

DISCUSSION

The increase in predation found when spat size decreases or crab size increases has been reported by other crab-bivalve interaction studies (Whetstone and Eversole 1981, Dare et al. 1983, Gibbons 1984). High predation rates of the larger crabs on even the smallest spat suggests an opportunistic feeding behavior. Although tests on prey size preference were not conducted, Seed (1980) concluded that the preferred size is below the maximum size the crabs can consume. Mean predation rates greater than 50 spat/crab/day were probable as some crabs preyed on all fifty spat offered.

Panopeus herbstii, having higher predation rates than *C. sapidus* of similar size, may be more efficient at spat predation. Elner and Lavoie (1983) reported that mud crabs *Neopanope sayi* had predation rates on attached spat similar to that of rock crabs *C. irroratus* twice their size.

Panopeous herbstii had a higher maximum successful predator ratio than did *C. sapidus*. McDermott (1960) found that *P. herbstii* of 30 mm CW could kill oysters of 33 to 35 mm length. This indicated a maximum successful predator ratio of 1.13 which is close to that of 1.03 found herein. Ogle (1978) estimated a maximum successful predator ratio of 0.40 for *C. sapidus*—*C. virginica* interactions, which is very similar to 0.42 calculated in this study.

TABLE 3.

Predation rate (arithmetic mean and range; n = 3), # dead spat/crab/day on four size classes of oysters (*Crassostrea virginica*) exposed to six size classes of blue crabs (*Callinectes sapidus*) and five size classes of mud crabs (*Panopeus herbstii*).

Carapace width (mm)	Oyster Shell Height 3.4 mm	7.6 mm	13.9 mm	24.4 mm	$\bar{x}$ predation for each crab size
Blue crab					
9.3 mm	17.8(11–26)*,**	0.8(0–3)	0.0	0.0	4.6
17.2	36.7(18–50)**	3.0(0–8)***,****	0.3(0–1)	0.2(0–1)	10.0
24.5	49.8(49–50)**	10.3(3–15)*,**	1.8(0–4)**	0.0	15.5
31.7	49.2(47–50)**	28.0(18–33)**	0.8(0–3)***	0.3(0–1)	19.6
39.2	49.5(49–50)	39.2(11–50)****	12.5(0–31)****	0.8(0–4)*	25.5
85.5	41.5(6–50)	49.7(49–50)**	9.7(1–30)	16.7(3–39)	29.4
$\bar{x}$ predation rate for each spat size	40.8	21.8	4.2	3.0	17.4 Total predation
	3.7 mm	8.1 mm	15.1 mm	24.6 mm	
Mud crab					
7.1 mm	19.7(8–30)*,**	3.0(0–6)****	0.0 ***	0.0	5.7
13.0	47.5(42–50)	21.0(0–36)	2.2(0–8)*	1.0(0–3)	17.9
17.8	47.8(47–50)**	22.8(6–43)*,**	8.8(5–12)**	0.5(0–1)*	20.0
25.2	44.3(30–49)	43.5(29–50)**	10.3(5–21)**	7.8(5–12)*	26.5
34.4	46.8(43–49)	48.2(47–49)**	31.7(21–46)	22.5(10–38)	37.3
$\bar{x}$ predation rate for each spat size	41.2	27.7	10.6	6.4	21.5 Total predation

* = significantly different from predation below (p = 0.01).
** = significantly different from predation to the right (p = 0.01).
*** = significantly different from predation below (p = 0.05).
**** = significantly different from predation to the right (p = 0.05).
$\underline{x}$ = significantly different from control (p = 0.01).
$\underline{x}$ (dotted) = significantly different from control (p = 0.05).

Whetstone and Eversole (1981) reported maximum successful predator ratios for *P. herbstii—Mercenaria mercenaria* interactions of 0.65. Predator ratios for *C. sapidus, Cancer irroratus, Carcinus maenas, Neopanope sayi* and *Ovalipes ocellatus* preying on *M. mercenaria* are estimated to be 0.30 (Walne 1974, Mackenzie 1977, Castagna and Kraeuter 1981, Whetstone and Eversole 1981, Gibbons 1984). The data of the authors and others suggest that *P. herbstii* can cause mortalities to juvenile clams and oysters which are more than twice the size of those affected by other crabs of similar size. The presence of a large molariform tooth on the crushing edge of the dactyl of the major claw in *P. herbstii* gives it a distinct mechanical advantage at crushing bivalve shells (Vermeij 1977).

Blue crabs support a major commercial and recreational fishery on the Atlantic and Gulf coasts but population densities are hard to determine. Wells (1961) estimated four blue crabs to every 6 m of reef edge, while Larson (1974) found blue crab densities ranging up to 13 m-2. Estimated population densities of *P. herbstii* on oyster reefs range up to 103 m-2 with highest densities during the summer (Bahr

TABLE 4.

Maximum successful predator ratios for blue crabs (*Callinectes sapidus*) and mud crabs (*Panopeus herbstii*) preying on single spat oysters (*Crassostrea virginica*).

	CW mm	Ratios
Blue crab	9.3	0.37
	17.2	0.44
	24.5	0.44
		0.42 $\bar{x}$
Mud crab	7.1	1.14
	13.0	1.16
	17.8	0.85
	25.2	0.98
		1.03 $\bar{x}$

TABLE 5.

Carapace widths (CW) and estimated carapace lengths (CL) in mm of blue crabs (*Callinectes sapidus*) and mud crabs (*Panopeus herbstii*) and net mesh dimensions which should exclude crabs.

	CW	CL	Net mesh square mm
Blue crab	9.3	3.7	2.6
	17.2	6.9	4.9
	24.5	9.8	6.9
	31.7	12.7	9.0
	39.2	15.7	11.1
	85.5	34.2	24.8
Mud crab	7.1	4.8	3.4
	13.0	8.7	6.2
	17.8	11.9	8.4
	25.2	16.9	12.0
	34.4	23.0	16.3

1974, Larson 1974, Dame 1979, Dame and Vernberg 1982). *Panopeus herbstii* is the largest (43 mm CW) xanthid crab present in Maryland and Virginia waters and is found in salinities of 10 to 34 ppt (Schwartz and Cargo 1960). McDermott and Flower (1952) also found it to be the largest and dominant xanthid species in the Delaware Bay, as well as the most destructive to oysters (McDermott 1960). *Callinectes sapidus* ceases activity at 13°C whereas *P. herbstii* is still active at temperatures below 12°C (Williams 1965, Van Den Avyle 1984). Mud crabs, tending to be less migratory than blue crabs, are usually present within the oyster reef most of their life (Bahr and Lanier 1981). Thus, *Panopeus herbstii* potentially may be a more dangerous predator than *C. sapidus* of single oyster spat in high salinity waters.

Oyster culturists may reduce crab predation on spat by using plastic mesh netting for predator exclusion. Although not tested, the net mesh sizes presented in Table 5 should prevent crab entrance. Crabs smaller than the net meshes can enter the nets and grow to sizes which may cause some spat mortality if not eliminated by constant monitoring or addition of a biological control such as the toadfish (Gibbons and Castagna 1985).

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