A Survey for Prevalence of *Paramoeba* spp. in Blue Crabs along the Atlantic and Gulf Coasts

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Abstract: Paramoeba perniciosa is a parasite that has been found in blue crabs *Callinectes sapidus* from coastal embayments from Florida to Connecticut and has been associated with mortalities in crab shedding facilities in coastal bays of Maryland and Virginia. Hemolymph samples from more than 7300 crabs over a 9-year period from the Gulf (N = 228) and Atlantic (N = 7167) coasts of the United States revealed 0.5% of crabs assayed to be infected by *P. perniciosa*. Infections were limited to crabs collected from Virginia to New Jersey; Rehoboth Bay, Delaware, had a considerably higher prevalence than other sites sampled. Infections were not present or detected in Gulf coast crabs. Areas reported with *P. perniciosa* in blue crabs overlap areas reported with paramoeba-like infections in the American lobster *Homarus americanus* and rock crabs *Cancer irroratus*. One lesser blue crab *Callinectes similis* sampled from a Maryland coastal bay was infected by a *Paramoeba* sp. morphologically similar to *P. perniciosa* in the blue crab. Actual prevalence of *Paramoeba* spp. in *Callinectes* spp. crabs may be higher than reported here due to assay methods. Parasites can cause mortalities in crab populations to the extent that numbers are significantly reduced and therefore disease may need to be considered in fishery models.

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Paramoeba perniciosa (Sprague et a1. 1969), a parasite of the blue crab (*Callinectes sapidus* Rathbun, 1896), was first reported to cause 20%–30% mortalities in crab shedding facilities in coastal bays of Maryland and Virginia (Sprague and Beckett 1966, 1968; Sprague et al. 1969). Blue crabs infected with *P. perniciosa* have been reported from coastal bays from Maryland to Florida (Sprague and Beckett 1966, Newman and Ward 1973, Campbell 1984); infections have also been reported in crabs from Sandy Hook, New Jersey, and Long Island Sound, Connecticut (Johnson 1977). Paramoebiasis has not been detected in blue crabs from the Gulf coast (Overstreet 1978, Couch and Martin 1982, Millikin and Williams 1984). A *Paramoeba* sp. has been detected in rock crabs (*Cancer irroratus* Say, 1817) (Sawyer 1976, Sawyer and MacLean 1978, Campbell 1984). Paramoeba (Sawyer 1976, Sawyer and MacLean 1978) and paramoeba-like (Russell et al. 2000) infections have been identified in lobsters (*Homarus americanus* H. Milne Edwards, 1837).

A histological survey of crabs sampled from July 1974 through June 1975 from

Chincoteague Bay found *P. perniciosa* in tissues of blue crabs each month surveyed (Johnson 1977). Prevalence was highest in July at 57% and varied from 6% to 22% during other months sampled. Another study of blue crabs sampled in 1981 and 1982 from Chincoteague and Chesapeake bays found prevalence peaked in May (8%) and June (12.8%) (Campbell 1984). *P. perniciosa* is usually found in connective tissues and hemal spaces and does not invade the circulating hemolymph within blood vessels until infections are terminal (Johnson 1977). Epizootics are marked by the appearance of amoebae in the circulating hemolymph (Johnson 1977). This paper reports the prevalence and locality of *P. perniciosa* infections in blue crabs surveyed along the Atlantic and Gulf coasts from 1991 through 1997 and documents an additional decapod species, the lesser blue crab (*Callinectes similis* Williams, 1966) with a *Paramoeba* sp. infection.

The following agencies helped collect crabs: Delaware Division of Fish and Wildlife; Maryland Department of Natural Resources; University of Maryland Eastern Shore; National Ocean Service - Cooperative Oxford Laboratory; Virginia Institute of Marine Science Trawl and Dredge Surveys; Louisiana Department of Wildlife and Fisheries; Texas Parks and Wildlife; Georgia Department of Natural Resources; Skidaway Oceanographic Institute, Georgia; National Marine Fisheries Service Beaufort Laboratory; Elaine Andersen of New Jersey; South Carolina Marine Fisheries Division; North Carolina Division of Marine Fisheries; Mississippi Department of Marine Resources; and Gulf Coast Research Laboratory - University of Southern Mississippi. The following people processed samples: C. McCollough, S. Tyler, C. Gieseker, J. Clemmer, and D. Howard of the Cooperative Oxford Laboratory. This work was partially supported by Md. Dept. Natural Resources.

Methods

Crabs were sampled from various sites along the Atlantic and Gulf coasts. In Maryland, blue crabs were collected semi-monthly from 1991 through 1997 from 21 stations within coastal bays, including Isle of Wight, Assawoman, Sinepuxent, Newport, and Chincoteague, in conjunction with the Maryland Department of Natural Resources Coastal Bay Fisheries Project. Crabs from coastal bays of Virginia near Wachapreague and within Chincoteague Bay were sampled in October 1992, October 1993, and June through October 1995. Sites within Chesapeake Bay near Occahannock and Cape Charles, Virginia, were sampled monthly from July through November 1994 and 1995. Crabs were collected in the spring and summer months from 1994 to 1997 in Delaware in conjunction with the Delaware Division of Fish and Wildlife Blue Crab Survey; sample sites included Indian River, Rehoboth Bay, and Delaware Bay. One or more blue crab samples were assayed from coastal bays or tributaries of New Jersey, North Carolina, South Carolina, Georgia, Florida, Mississippi, Louisiana, Texas, and the Atlantic Ocean off Maryland from 1995-1999. Crabs were examined for *P. perniciosa* to obtain supplemental data during a survey for *Hematodinium* sp. in blue crab populations from coastal embayments along the At-

lantic and Gulf coasts (Messick and Shields 2000). Lesser blue crabs collected during this survey ($N = 143$) were also assayed for disease.

Crabs were collected by dredge, trawl, traps, or pots. Water salinity and temperature were recorded when provided. Carapace width (CW) was measured as the longest distance between epibranchial spines. Males <90 mm CW were considered immature (Millikin and Williams 1984); apron shape identified maturity of females. Molt stage was not identified. Hemolymph was sampled by bleeding crabs from arthrodial membranes using a 1-cc insulin syringe with a 1.0-cm, 28-g needle and smearing a drop of hemolymph on acid-cleaned, 0.1% w/v poly-L-lysine-coated microscope slides (Messick 1995). Smears were fixed in Bouin's fluid and stained with Mayer's hematoxylin and eosin (H&E) (Luna 1968). No tissues were processed for histology due to the prohibitive time and financial expense this assay method requires. *P. perniciosa* ranges in size from 3–25 μm, has a round to elongate shape, a well-defined nucleus with a large central endosome, plus a morphologically distinct secondary nucleus-like body in the cytoplasm (Sprague and Beckett 1966, 1968; Sprague et al. 1969). This basophilic secondary body is a major diagnostic characteristic.

Mean intensity and prevalence are defined in Margolis et al. (1982). Briefly, intensity is the number of individuals of a particular parasite species in each infected host. We estimated intensity in crabs by counting at least 300 cells per hemolymph preparation, divided the number of individual parasites by the total number of cells (parasites + hemocytes) counted, and multiplied by 100. Prevalence was determined as the number of infected crabs divided by the total number of crabs sampled and expressed as a percentage.

Results

Hemolymph from more than 7300 blue crabs collected from the Atlantic and Gulf coasts was assayed over a 9-year period. The parasite was detected in 0.49% ($N = 36$) of the 7221 blue crabs assayed from the Atlantic coast and 0% of the 174 assayed from the Gulf coast. Water salinity and temperature where infections occurred ranged from 16–33 ppt and 16–30C (Table 1). The prevalence of infection in females was 0.4% with 13 of 3417 infected; 0.5%, or 2 of 522, mature females were infected. The prevalence in males was 0.6% with 22 of 3726 infected; 1.2%, or 15 of 1289, mature males were infected. Sex was not distinguished for some crabs; therefore, numbers of males and females do not equal the total number of crabs assayed in this study. The average size of infected crabs was 99 mm CW; size of infected crabs ranged from 24–140 mm CW whereas the mean CW of all crabs assayed was 70 mm and size ranged from 4–185 mm. Infection prevalence by month for all samples was 1% in June with 8 of 829, 1% in July with 13 of 1200, 0.7% in September with 10 of 1393, and 0.3% in October with 4 of 1180 infected. All other months had 0% prevalence. Parasite intensity in individual infected crabs varied from 0.8% to 99.5%. Average intensity of infected crabs was 32% in June, 27% in July, 36% in September,

Table 1. Site, prevalence, water salinity, water temperature, collection date, and average intensity of *Paramoeba perniciosa* infections in blue crabs *Callinectes sapidus* collected along the Atlantic and Gulf coasts.

State or area	Site	*N* Sampled	% Prevalence	ppt	°C	Collection date[a]	Average intensity[c]
Atlantic Coast							
New Jersey	Stone Harbor	34	5.9	32	28	15 Sep 1998	97.0
Delaware	Delaware Bay	140	1.4	na[b]	na	11 Sep 1996	73.5
.	Rehoboth Bay	244	8.6	29	19	17 Sep 1994	2.7
				25	16	20 Sep 1994	96.0
				32	27	20 Jul 1995	25.4
				32	27	30 Jul 1996	73.5
				26	21	28 Jul 1997	18.0
	Indian River	310	1.3	na	na	20 Jul 1995	12.0
				22	30	19 Jul 1995	2.1
				16	17	23 Oct 1995	1.0
Atlantic Ocean	Near Ocean City, Md.	25	4.0	33	na	22 Oct 1996	97.0
Chesapeake	Tangier Sound, Md.	68					
Bay	Nanticoke River, Md.	117					
	Cape Charles, Va.	419	0.2	22	30	13 Jul 1995	42
	Occahannock, Va.	315					
	Kiptopeke State Park, Va.	20					
Maryland	Coastal bays	4079	0.1	27	26	22 Jun 1994	7
				29	28	20 Jul 1995	95
				22	16	18 Oct 1995	20
				27	21	23 Sep 1996	96
Virginia	Chincoteague Bay	265		21–33	26		
North Carolina	Albemarle Sound	33					
	Roanoke Sound	24		20	26		
	Pamlico Sound	63					
	Core Sound	214		33	27		
	Newport River	47		25	31		
South Carolina	Bulls Bay	25		22	31		
	Charleston	110		26	13–30		
Georgia	Savannah	91		20–33	various		
	St. Simons to Cumberland	524		various	various		
Florida	Indian River	54		20–30	33–39		
Gulf Coast Subtotal		7221					
Louisiana	Caillou Lake	30		25	23		
	Grand Isle	31		23	32		
Mississippi	Ocean Springs	32		18	27		
Texas	Aransas Bay	81		30	na		
		174					
Total		7395	0.49% mean				

a. Dates listed are dates infected crabs were collected.

b. na = not available.

c. Average intensity is the average of all infected crabs from that sample.

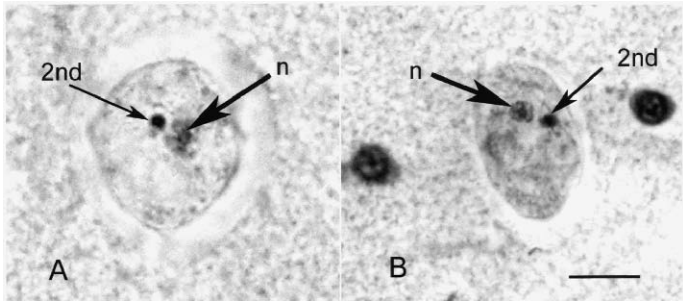

Figure 1. (A) *Paramoeba* spp. in *Callinectes similis*. (B) *Paramoeba perniciosa* in *Callinectes sapidus*. Note similarities in size, morphology, nucleus (n), and secondary nucleus-like body (2nd). Bar = 14 μm.

and 33% in October. Prevalence varied by location from 0 to 8.6% in combined samples (Table 1). More than half of all infected crabs were from Rehoboth Bay, Delaware (Table 1). No infections were found south of Virginia. Statistical analysis of the variation in prevalence of *P. perniciosa* could not be completed due to limited seasonal, temporal, or spatial sampling.

Paramoeba sp. was detected in 1 lesser blue crab from a Maryland coastal bay out of 139 sampled (0.7%) from Maryland, Virginia, and North Carolina. Infection intensity was light based on intensity classification established by Messick and Shields (2000) for *Hematodinium* sp. in blue crabs with 1 *Paramoeba* sp. parasite out of 337 cells in the hemolymph, or 0.30%. The morphology of the parasite found in the lesser blue crab was very similar to *P. perniciosa* in blue crabs. The parasite was round to oval on stained smears, averaging 18 × 14 μm (N = 15, range = 12–27 × 9–18 μm), had a defined nucleus with a central endosome, and a morphologically different secondary nucleus-like body in the cytoplasm (Fig. 1).

Discussion

Disease caused by *P. perniciosa* has been implicated as a factor in annual winter and late spring mortalities of blue crabs and the cause of chronic low-level mortalities in late spring of non-epizootic years in coastal embayments of Maryland and Virginia (Newman and Ward 1973, Couch 1983). Crab mortalities of 20%–30% have been reported in shedding tanks on the lower Eastern Shore of Maryland and Delaware (Sprague and Beckett 1966). Although this study found a relatively low prevalence of *P. perniciosa* infections in blue crabs along the Atlantic coast, prevalence was likely considerably higher: in a previous study, *P. perniciosa* was not detected in hemal sinuses of organs such as gills or hepatopancreas unless infections were heavy to medium in intensity (Johnson 1977). Since our study assayed hemolymph, light to moderate infections were likely missed. Our study detected 1% or less prevalence in July, August, September, and October using the hemolymph assay technique. In comparison, except for 57% in July, 6% to 22% were detected year round in crabs from Chincoteague Bay using histological techniques (Johnson 1977).

Since the appearance of amoebae in circulating hemolymph may indicate epizootics (Johnson 1977), it may be that samples in this study with infections were collected during or soon after an epizootic. Additionally, crab populations and other marine invertebrates may carry chronic parasite infections that occasionally become epizootic, perhaps due to biological stressors such as temperature (Scheibling and Hennigar 1997), season (Newman and Ward 1973), or hydrographic conditions (Sloan 1984; Meyers et al. 1987, 1990; Kuris et al. 1991; Field et al. 1992).

This study found that prevalence varied by location (Table 1). Indian River and Rehoboth Bay, Delaware, are connected via a waterway. Despite this connection, there was considerably higher prevalence of the parasite in Rehoboth Bay than in Indian River. Indian River is classified as an estuary and is phosphate limited in the spring and nitrate limited in late summer (Ullman et al. 1993). Rehoboth Bay is classified as a lagoon, is nitrate limited, and has less flushing and greater turbidity than Indian River (Ullman et al. 1993). Hydrographic features such as reduced water flow or freshwater input may increase prevalence of other parasite infections by allowing infectious stages of parasites to concentrate in shallow, high salinity lagoons (Shields 1994, Messick and Shields 2000). Hydrographic conditions have been implicated in epizootics of crustacean parasites (Sloan 1984, Meyers et al. 1990, Kuris et al. 1991). Many coastal bays have relatively high salinity, little water exchange, moderate to high temperatures, and seasonal hypoxia, which may be conditions that are conducive to parasite proliferation.

This study corroborates other reports that *P. perniciosa* has not been detected in blue crabs assayed from the Gulf coast. Overstreet (1978) suggested that *P. perniciosa* may be present but not yet detected in Gulf coast waters due to limited examination of crabs for parasites; or that geographic, biological, or environmental parameters prevent the introduction of this detrimental parasite into Gulf coast blue crab populations. Although this study found no infected crabs south of Virginia, infections have been found in North Carolina, Georgia, and Florida (Newman and Ward 1973).

The presence of *P. perniciosa* in a lesser blue crab from Maryland is significant. The infected crab was found near its northernmost range (Williams 1984) and the prevalence of this parasite in lesser blue crabs may be considerably higher than reported here since few lesser blue crabs have been investigated in this or other surveys. It is unknown without further investigation how closely related the *Paramoeba* sp. found in the lesser blue crab is to that found in the blue crab. The lesser blue crab occurs with regularity in the same range along the Carolina-Florida coast and is often found associated in large numbers with the blue crab (Williams 1984). Likewise, the geographic distribution of the lesser blue crab overlaps in northern areas with the distribution of the American lobster and rock crabs. American lobsters from Long Island Sound were recently found to harbor a paramoeba-like protozoan parasite in nerve tissue (Russell et al. 2000). This is of particular interest to crustacean biologists, commercial fishermen, and fishery managers due to the association of heavy mortalities in Long Island Sound lobsters with paramoeba-like infections. Additionally, the pathogenic amoebae *P. invadens* (Jones 1985) is found in the green sea urchin (*Strongylocentrotus droebachiensis* Miller, 1776) in eastern Canada (Jones 1985,

Miller 1985). This parasite caused massive mortalities in stocks from 1980–1983 (Miller and Colodey 1983) and again in 1995. Some natural predators of the green sea urchin include lobsters and crabs (Himmelman and Steele 1971). It is currently unknown whether infections can be transferred among host species or whether *P. perniciosa* in the blue crab may be related to *Paramoeba* sp. in lesser blue crabs, paramoeba-like parasites in the American lobster, or *P. invadens* in the green sea urchin. Additional biochemical and molecular analysis would provide valuable information on similarities and differences among *Paramoeba* spp. and paramoeba-like parasites infecting various marine invertebrates.

Although this ancillary study which assayed only hemolymph did not reveal a high prevalence of *P. perniciosa* in blue crabs, the parasite is likely more prevalent in crabs from coastal embayments than reported here. Since Newman and Ward (1973) surmised that 100% of infected crabs die, *P. perniciosa* is a potential cause for blue crab mortalities in shallow coastal bays along the Atlantic coast. Although mass mortalities of blue crabs attributable to *P. perniciosa* are not detected every year, the blue crab fishery can expect periodic losses of crabs due to the disease (Couch 1983). In addition to *P. perniciosa,* there are numerous disease agents such as parasitic viruses, a parasitic dinoflagellate, and microsporidans that affect the blue crab and can be attributed to population mortalities (Millikin and Williams 1984, Messick and Sindermann 1992). Additional research and experimentation is needed to examine how disease affects population numbers and future fishery stocks.

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