Preliminary Review of Life History and Abundance of the Atlantic Rangia (*Rangia cuneata*) with Implications for Management in Galveston Bay, Texas

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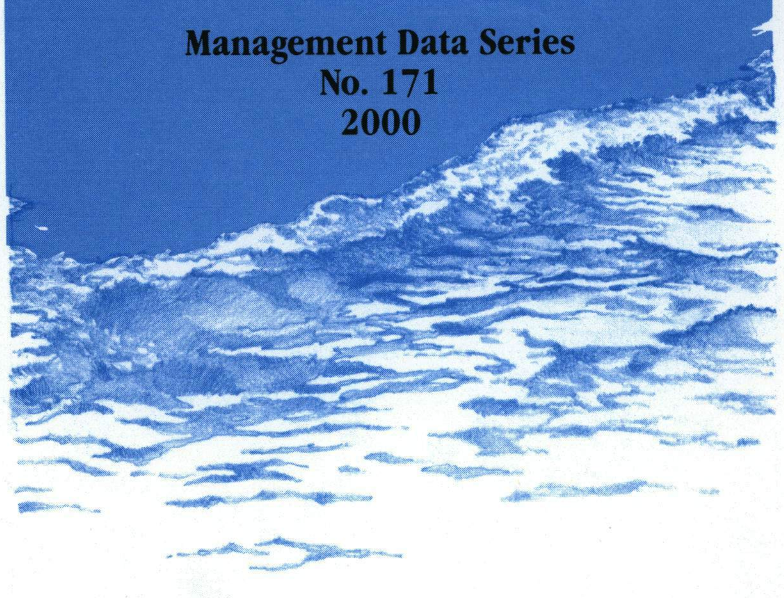

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PRELIMINARY REVIEW OF LIFE HISTORY AND ABUNDANCE OF THE ATLANTIC RANGIA (*Rangia cuneata*) WITH IMPLICATIONS FOR MANAGEMENT IN GALVESTON BAY, TEXAS

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ABSTRACT

This report provides a preliminary assessment of the Atlantic rangia (*Rangia cuneata*), in Galveston Bay, Texas. A review of the biology and life history found environmental conditions within the Galveston Bay system support Atlantic rangia growth and reproduction. Texas Parks and Wildlife (TPW) data on mean size and catch rates from sampling surveys conducted from 1986-1998 were analyzed. Atlantic rangia was found primarily in Trinity Bay and many were of commercial size (~50 mm). A decline in trawl CPUE (127 rangia/sample to 5 rangia/sample) coupled with a slight increase in mean size (29 mm to 36 mm) over the sampling period was observed. An 80% decline in trawl CPUE was observed following record cold episodes and the subsequent freeze of Galveston Bay in 1989. No established fishery for the Atlantic rangia currently exists in the U.S. In many areas efforts to develop a commercial fishery were hindered, primarily because of health issues associated with high coliform counts. Consequently, few guidelines exist for management of the species. In Galveston Bay, the highest densities (53 rangia/sample) of Atlantic rangia were found in current restricted shellfish harvest waters. Therefore, if Atlantic rangia was harvested from these areas it would have to go through depuration. The TPW commission is authorized to establish bag and size limits and to regulate the means and methods by which the Atlantic rangia can be taken. Current regulations allow for harvest by hand, clam tongs, or with special permission, by dredge. Harvesters also have a daily bag limit of 11.4 kg. Local dealers state that the dredge is the more efficient gear and the daily bag limit is not sufficient to recoup the cost of a fishing trip. With limited information available on the species in Galveston Bay, attempts to develop a commercial fishery should be accompanied by studies aimed at determining stock abundance, recruitment and habitat impacts. A limited entry program should be implemented before any commercial fishery is allowed to proceed. Such a program will allow managers to regulate fishing effort and prevent overexploitation of the stock.

INTRODUCTION

Atlantic rangia (*Rangia cuneata)* is an estuarine bivalve (clam) distributed along the Atlantic coast from Maryland to Florida and along the Gulf of Mexico from Northwest Florida to Veracruz, Mexico (LaSalle & de la Cruz, 1985, Instituto Nacional De La Pesca, 1994). Atlantic rangia is resident typically in areas of low salinities (<5 ppt) and can also be found in areas exhibiting fluctuating salinities (Harrel, 1993). In Texas, *Rangia* spp. are reported to be found in less saline, upper portions of bays. The two most common species found in Galveston Bay are *Rangia cuneata* (Sowerby) and the less common brown rangia, *Rangia flexuosa* (Conrad).

Adult Atlantic rangia range in size from 25 - 60 mm total length and have valves that are thick, heavy, and obliquely ovate (La Salle and de la Cruz 1985). The exterior of the shell is rather smooth with color ranging from light brown to grayish brown to black (La Salle and de la Cruz 1985). The umbo is prominent and situated near its anterior end. The shell's interior is glossy white with a blue-gray tinge (La Salle and de la Cruz 1985).

Very little information exists on rangia fisheries. Mexico is the only country with a sustained (> 10 years) fishery for Atlantic rangia and reports suggest the fishery is highly exploited (Instituto Nacional De La Pesca 1994, Alvarez-Legorreta et.al 1994). In the U.S., several states attempted, with limited success, to harvest Atlantic rangia for human consumption. Use of fossil shells for road building material as well as for use in manufacturing, as a source of calcium carbonate, appear to have the greatest commercial value (LaSalle & de la Cruz 1985). However, shells are no longer required for construction or manufacturing purposes and are not exploited.

This review provides a preliminary assessment of the Atlantic rangia focusing on the biology and life history of the species, and distribution and relative abundance in Galveston Bay, Texas. A review of commercial fisheries and markets, as well as the management of Atlantic rangia is presented. This overview is in response to queries made to Texas Parks and Wildlife (TPW) on the feasibility of commencing a fishery for the Atlantic rangia in Galveston Bay.

Life History and Environmental Associations

Salinity

Atlantic rangia is able to tolerate salinities ranging from 0-25 ppt due to its unique utilization of osmoregulatory mechanisms employed by both stenohaline and oligohaline bivalves (Otto and Pierce 1981). At nonlethal salinities > 10 ppt, Atlantic rangia, like many marine organisms, is an osmoconformer (Otto and Pierce 1981). At salinities ≤ 4 ppt Atlantic rangia is an osmoregulator that not only survives, but also thrives in fresh water (Hopkins 1970, Otto and Pierce 1981).

Despite its tolerance to higher salinity levels, Atlantic rangia is generally established only in regions of estuaries where salinity varies from 0-15 ppt (Hopkins 1970, Swingle and Bland 1974, Cain 1975, Jovanovich and Marion 1989, Harrel 1993, Alvarez-Legorreta et al. 1994). Swingle and Bland (1974) found the highest concentrations of clams at the mouths of rivers flowing into Mobile and Perdido Bays, Alabama. Harrel (1993) found live Atlantic rangia beds with a mean density of 238 clams/m^2 in the Neches River, Texas, as far as 57 km upstream from its junction with Sabine Lake. Both Swingle and Bland (1974) and Harrel (1993) show that populations of Atlantic rangia in waters that remain fresh for extended periods of time are comprised of clams with mean shell lengths greater than those in more variable salinity regimes; they also exhibit fewer age classes. Reproductive studies conducted by Cain (1975) suggest Atlantic rangia do not spawn when salinity consistently remains close to 0 ppt. Cain (1975) also found embryos and larvae are intolerant of freshwater and survive best at salinities between 0 - 10 ppt. Campos and Mann (1988) show that swimming larvae exhibit preferences for salinities $\leq$ 10 ppt.

Depth and Substrate

In their comprehensive literature review, La Salle and de la Cruz (1985) cite research indicating highest densities of Atlantic rangia occur at depths < 6 m. Studies by Cain (1975), who collected specimens at depths of 3-4 m in the James River, Virginia, support this finding. Laguna de Pom, a shallow estuary in Mexico, has a mean depth of 1.5 m and supported a rangia fishery for more than twenty years (Alvarez-Legorreta et al. 1994, Ortega Sala Armando Adolfo, Universidad Nacional Autonoma de México (UNAM), pers. comm.).

Laboratory studies conducted by Sundberg and Kennedy (1993) demonstrate Atlantic rangia prefer to settle on sediments rather than hard substrate, with sandy sediments preferred over silt-clay substrates. The researchers also found substrate choice involves biological as well as grain size preference; larvae chose natural sediments over those that had been treated to remove organic content or bacteria. Similarly, Tenore et al. (1968) report Atlantic rangia growth is favored by placement in coarser grained sediments high in organic content, whereas organically-rich, but fine-grained, clay-silt sediments are unfavorable. However, distributions of natural populations are not always similar to those reported for laboratory studies. Cain (1975) found "thriving" Atlantic rangia populations established on predominately silt-clay substrates in the James River, Virginia. The Neches River, Texas, sediments underlying clam beds studied by Harrel (1993) are described as mixtures of sand, silty clay and detritus. Dense beds of Atlantic rangia were found predominately on sandy clay sediments in Alabama (Swingle and Bland 1974). Swingle and Bland (1974) note, however, when Atlantic rangia was found in areas of extremely soft sediments, they occurred more frequently among vegetation root systems than on unvegetated sediments.

Oxygen Requirements

Little information was found on the oxygen requirements of Atlantic rangia. Harrel (1993) states that at least one established population in the Neches River appeared to thrive despite sustained dissolved oxygen levels < 2.0 mg/l. However, Henry and Magnum (1980) note oxygen uptake by Atlantic rangia increases as the animal adjusts to declining salinity, and that, regardless of salinity, a hyperosmotic blood condition is manifest in response to hypoxia. These researchers also state while Atlantic rangia is able to osmotically adjust to rising salinity under anaerobic conditions, oxygen is critical to surviving such fluxes (Henry et al. 1980).

Temperature

Atlantic rangia populations occur from the upper East Coast Atlantic Ocean estuaries of New Jersey to the Gulf of Mexico estuaries of Mexico, suggesting a broad range of water temperatures is tolerated. Cain (1975) recorded seasonal water temperature variations from 2 C - 30 C in a James River, Virginia study. Temperature along the Dog River, Alabama, also varied seasonally from 10 C - 32 C (Jovanovich and Marion 1989). Laguna de Pom, Mexico, exhibits much less variation, with average water temperatures ranging from 25 C - 31 C (Alvarez-Legorreta et al. 1994). Cain (1975) states Atlantic rangia eggs survive and develop well at ambient temperatures as low as 15 C, and that larvae survive even lower fall/early winter temperatures, but exhibit slower growth and delayed metamorphosis. Below-freezing water temperatures apparently limit Atlantic rangia's distribution and range (LaSalle and de la Cruz 1985). Harrel (1993) found significant decreases in densities of Neches River, Texas, Atlantic rangia beds following record cold episodes associated with frontal systems in 1983 and 1989 that resulted in extremely low tides and caused shoreline waters to freeze. However, whether the decline was due to exposure to freezing water temperatures or to air alone is not clear.

Trophic Niche

Olsen (1976) classifies Atlantic rangia as a non-selective filter feeder, based on clams collected from the Ochlockonee River estuary, Florida. He identified 48 species of phytoplankton, including algae and diatoms, in the stomach contents of Atlantic rangia, as well as high percentages of unidentifiable detritus (46-51% at low tide; up to 81% at high tide) (Olsen 1976). Tenore et al. (1968) suggest Atlantic rangia may also ingest organic material directly from sediment, or obtain particulate matter by consuming bacteria. Atlantic rangia, therefore, are primary consumers and ecologically important links in estuarine food webs.

Predators and Parasites

Atlantic rangia are preyed on by a variety of secondary and tertiary detrivores and carnivores. Darnel (1958) found Atlantic rangia in the stomachs of many inhabitants of Lake Pontchartrain, Louisiana, including: Atlantic stingray (*Dasyatis sabina*), gar (*Leisosteus osseus, L. oculatus, L. spatula*), catfish (*Ictalurus furcatus, Arius felis*), sand trout (*Cynoscion arenarius*), spot (*Leiostomus xanthurus*), croaker (*Micropogonias undulatus*), black drum (*Pogonias cromis*), sheepshead (*Archosargus probatocephalus*), pin fish (*Lagodon rhomboides*), flounder (*Paralichthys lethostigma*), gizzard shad (*Dorosoma cepedianum*), bay anchovy (*Anchoa mitchilli*), white shrimp (*Penaeus setiferus*), and blue crabs (*Callinectes sapidus*). LaSalle and de la Cruz (1985) add other estuarine predators including: lesser and greater scaup ducks (*Aythya spp.*), ring-necked duck (*Aythya collaris*), American black duck (*Anas ubripes*), mallard duck (*Anas platyrhynchos*), ruddy duck (*Oxyura jamaicensis*), mud crab (*Rhithropanopeus harrisii*), oyster drill (*Thais haemastoma*), moon shell (*Polonices spp.*) and comb jellies (*Mnemioposis spp.*). Most of these species prey preferentially on juvenile clams. However, some gastropods, along with blue crabs, black drum and sheepshead, prey upon clams as large as 40mm in length (LaSalle and de la Cruz 1985, Darnell 1958). In addition, herring gulls (*Larus argentatus*) have been documented as Atlantic rangia predators, dropping the shells on hard surfaces to obtain the meat (Cristol 1997).

Wardle (1983) discovered a trichocercous cercariae stage of trematode (Family Fellodistomidae) in Galveston Bay, Texas, Atlantic rangia. According to Wardle (1983), sporocysts of the trematode cause castration of the Atlantic rangia host, impacting reproduction.

Gametogenic Cycle

Comparisons of reproductive cycles of Atlantic rangia in three different estuaries indicate similar periods of gamete development and spawning. Differences may be attributed to varying biotic and abiotic parameters (Jovanovich and Marion 1989), physiological differences in populations from different geographic areas (Cain 1975), or both.

Histological examination of individual Atlantic rangia in the James River estuary, Virginia, revealed onset of the early active phase of gonadal development when water temperatures reached ~ 15 C, generally in April to early May (Cain 1975). This was followed by ripening and a light spawn in early summer, as evidenced by clams in spent condition (Cain 1975). All phases of gonadal tissue development were observed throughout summer in what the researcher suggests is a continuation of gamete development, rather than a second cycle. Major spawns of the James River populations occurred in mid-October to late November, when water temperatures were seasonally decreasing and ranged from 22 C to 13 C. Spawning occurred in close conjunction with a flux in salinity, either increasing or decreasing 5-10 ppt. In the second year of the study, one population failed to spawn, although gametes were observed to be ripe from August through November. Cain (1975) notes the salinity at the site remained near 0 ppt for the entire year. As temperatures decreased to 17 C that fall, egg cytolysis occurred. Cain (1975) concludes that, while increasing temperatures stimulate gametogenesis, spawning is initiated primarily by salinity flux.

A study cited by Cain (1975), LaSalle and de la Cruz (1985) and Jovanovich and Marion (1989), found Lake Pontchartrain Atlantic rangia to be in a ripe condition from March through May, and then again from late summer to November, with what appeared to be a postspawning resting stage in summer. Cain (1975) suggests earlier warming could account for the earlier stimulus of gametogenesis than he found in Virginia, and also postulates higher summer water temperatures (near 33 C) could inhibit continual gametogenesis.

Jovanovich and Marion (1989) found a slightly different gametogenic cycle among Atlantic rangia populations in the Dog River, Alabama. Early phase gonadal development occurred in February and March, when water temperatures rose to 15 C. By July, and through September, most clams were in ripe condition. However, unlike the Virginia and Louisiana populations, few Atlantic rangia displayed partially- spawned or spent conditions during summer. Instead, major spawning was found to begin in August, with individuals predominately spent by early November. Jovanovich and Marion (1989) state they are unable to relate spawning to salinity due to highly variable and infrequent measurements, but note that maximum temperatures (32 C) coincide with increased spawning rates. However, graphed data indicate a drop in salinity, followed by a rise, in the August-September period of both study years (Jovanovich and Marion, 1989).

All studies indicate that Atlantic rangia remain reproductively inactive throughout the winter months (Cain 1975, LaSalle and de la Cruz 1985, Jovanovich and Marion 1989). Jovanovich and Marion (1989) attribute the approximate one month difference observed in the onset and completion of reproduction in the geographically separated populations to differences in the interaction of temperature, salinity and nutrient availability.

Larval Development and Recruitment

Mature gametes are released directly into the water, with fertilization occurring thereafter. Sundberg and Kennedy (1993) demonstrate larval development of Atlantic rangia under ideal temperature (23-26 C) and salinity (8-10 ppt) conditions. In the laboratory, juvenile Atlantic rangia were fully formed and possessed functional inhalant siphons within 50 days after fertilization (Sundberg and Kennedy 1993). However, development does not necessarily occur in nature as quickly as it does under optimal laboratory conditions (Cain, 1975).

As discussed previously, settling Atlantic rangia larvae show sediment and salinity preferences that may affect recruitment. Cain (1975) suggests Atlantic rangia may disperse into previously uninhabited regions either by swimming or by passive transport in a tidal salinity wedge during low stream flow regimes. This hypothesis is supported by distribution of Atlantic rangia beds studied by Harrel (1993) and Swingle and Bland (1974), each of whom found densities of clams comprised of one or two age classes in sites not conducive to reproduction. Cain (1975) discovered the most consistent and abundant settling of larvae generally occurred at his mid-upstream site, where variations in salinity were less extreme, but sufficient to stimulate spawning. He postulates interspecies competition and increased larval and juvenile predation may limit recruitment into more saline downstream sites (Cain 1975).

MATERIALS AND METHODS

Atlantic rangia in Galveston Bay were taken during routine TPW Coastal Fisheries Division oyster dredge and trawl sampling (1986-1998). Sampling sites throughout the bay are chosen randomly and sampling done in a standardized manner. Dredges were used to sample known mapped oyster reefs and, for a limited time (1986-1989), samples were taken from the remaining bay bottom. Trawls are rigged to fish along the bottom with the lead line dragging through the first few centimeters of substrate. Total lengths were taken from up to 19 individuals in each sample. For each gear, mean length was calculated from individuals measured in each sample weighted by catch rates. Sample CPUE was calculated as total number of individuals captured per sample. For each gear mean CPUE was determined by year and area. SAS Analysis of Variance was used to determine differences in CPUE's by gear and area (SAS 1987). ArcView GIS software was used to plot distribution and CPUE's of Atlantic rangia in Galveston Bay (Environmenal Systems Research Institute 1999). A complete description of sampling methodology can be found in Hensley and Fuls (1998) and Texas Parks and Wildlife (1999).

RESULTS

Age, Growth and Size

Accepted growth models for Atlantic rangia have been developed by Wolfe and Petteway (1968) who employed the von Bertalanffy growth curve after calculating population parameters of average maximum length and catabolic rate. According to the model, one-year-old clams would be ~ 16 mm, two-year-old clams ~ 28 mm, three-year-old clams ~ 38 mm and four-year-old clams ~ 45 mm. They found Atlantic rangia exceeding 70 mm total length are rare and would be approximately 12 years old (Wolfe and Petteway 1968). LaSalle and de la Cruz (1985) cited studies that estimated age of maturation at 2 - 3 years. Cain (1975) found gonads in clams 14 mm long. A length estimated to be reached at the end of year one.

Annual mean size of Atlantic rangia in Galveston Bay ranged from 26-59 mm, indicating these clams are at least two years old and have the potential for reproductive activity (Table 1). A slight increase in mean sizes of clams over the 13-year period was observed. A significant difference was found in the size of clams selected by each gear with the oyster dredge selecting for larger clams (SAS ANOVA, $F=1413.79$, $P<0.0001$) (SAS 1987). Spacing between the teeth of the oyster dredge, 51 mm center to center, probably excluded smaller sizes from collections. Mean sizes of Atlantic rangia caught by the oyster dredge was similar to lengths reported in Mexico (mean = 50 mm, maximum = 70 mm) for exploited rangias (Instituto Nacional De La Pesca 1994).

Growth rates of Atlantic rangia and even entire populations vary greatly, likely due to variations in temperature, salinity and available food supply. A study of growth in one-year-old Atlantic rangia from an upper Chesapeake Bay population demonstrated an average length increase of 20-22 mm within 15 months with the most rapid growth seen in summer (Klein 1981). Conversely, a growth study of marked Potomac River Atlantic rangia revealed most recovered clams grew very little, whereas a few increased in size up to 78% above the original weight (Andersen and Bilger 1977).

Abundance and Distribution

The most abundant populations of Atlantic rangia in the U.S. are along the Louisiana coast (range: 24 – 48 billion clams, Hoese 1973). In Texas, historical estimates of Atlantic rangia abundance have varied from 16 - 665 clams/m^2 in the Neches River (Harrel 1993). Recent estimates along the Neches River reveal dramatic decreases in density, with ranges from 42 - <1 clams/m^2 (Harrel 1993). The decrease has been attributed to extreme cold fronts and lack of recruitment, due to changes in the river discharge patterns which reduced salt water intrusion into the river, prohibiting spawning and survival of young (Harrel 1993). Published data on abundance estimates of Atlantic rangia in Galveston Bay are not available.

Atlantic rangia is found primarily in Trinity Bay which had the greatest catch per unit of effort (CPUE) (rangia / sample), all other minor bays exhibited lower CPUE's (Table 2). This concurs with anecdotal information suggesting that *Rangia* spp. beds are abundant in Trinity Bay and particularly within the delta area (K. Schlicht, TPW, Seabrook, TX; A. Roco, Texas Natural Resource Conservation Commission, Houston, TX pers. comm.). Mean CPUE was calculated for many of the minor bays (Figure 1 and 2). CPUEs ranged from <1 – 26 rangia/sample (Table 2).

A difference in CPUE by gear was found, with trawls catching more rangia/sample than in oyster dredges (SAS ANOVA, F=50.79, P=0.0000) (Table 3). Trawl samples in the late 1980's yielded significantly higher catch rates of Atlantic rangia than in the 1990's (SAS ANOVA, F=3.189, P=0.0003). This difference, however, was not observed oyster dredge CPUE (SAS ANOVA, F=1.117, P=0.3587).

Mean CPUE was also determined in "approved" and "restricted harvest" waters within the bay, as defined by the Texas Department of Health (TDH) (Fig. 1 and 2). Mean CPUE's of Atlantic rangia were significantly higher in areas of "restricted harvest" compared to areas of "approved harvest" (Table 4). Depuration rates and water quality on potential clam leases must be determined by the TDH, Seafood Safety Division before any commercial operation can be undertaken.

Commercial Harvest and Regulations from U. S. Atlantic and Gulf States and Mexico

All states contacted for this review had, or have, a constituent interest in commercial harvest of rangia clams. Most states do not allow *Rangia* spp. to be harvested because they occur mostly in closed or polluted waters. Most states have some regulations pertaining to the methods and harvest of *Rangia* spp. The taste of *Rangia* spp. was of concern in some of the states, but most stated that after depuration *Rangia* spp. were consumable and in some cases tasted "good".

Alabama

Alabama does not allow harvest of *Rangia* spp. *Rangia* spp. only occur in "closed waters", and Alabama will not allow moving of any shellfish for depuration purposes. Alabama has some interest in a commercial fishery for *Rangia* spp. but they continue to discourage it due to pollution and bioaccumulation of bacteria and contaminates. (Contact: Steve Heath, Dolphin Island Marine Resource Department, (334) 861-2882.)

Florida

Florida does not allow a *Rangia* spp. commercial harvest because they only occur in "closed waters". They do not allow depuration and discourage a commercial industry for *Rangia* spp. Florida's Department of Health conducted studies on the bioaccumulation in *Rangia* spp. and deemed them unsafe to consume due to high standard plate counts of bacteria and contamination from chemical manufacturing byproducts. (Contact: Mark Berrigan, Florida Fish and Game, (850) 488-6058)

Louisiana

Louisiana had a large constituent interest in the harvest of *Rangia* spp. in Lake Pontchartrain during the 1970's and 1980's. The commercial fishery did not continue because of "off-flavor" of the meats and the closing of Lake Pontchartrain's waters due to environmental factors. Louisiana State University, Food Science Division, studied the reason for the "off-flavor" and determined it to be caused by geosmin, a by-product of blue-green algae. They also found the geosmin could be eliminated by depuration in higher salinity waters. The fishery was not financially feasible because the cost of harvesting, moving, and re-harvesting the clams exceeded profits. The commercial harvest of *Rangia* spp. continued until the early 1990's and ended as profits fell. (Contact: Ron Dugas, Louisiana Department of Wildlife and Fisheries, (504) 568-5685).

Mississippi

Mississippi does not have a commercial *Rangia* spp. harvest. There was an interest in a commercial fishery in the early 1980's, but most *Rangia* spp. occur in "closed waters". Mississippi does not allow moving of shellfish for depuration purposes. During the late 1970's and early 1980's a commercial harvest was allowed only for the shell which was used for road surfacing. The commercial harvest ended when hydraulic dredges where banned due to the extensive bottom damage they caused. (Contact: Scott Gordon, Mississippi Marine Resources Department, (228)-374-5000).

North Carolina

North Carolina is the only state with specific regulations for rangia clams. It is unlawful to take *Rangia* spp. in "closed" or "open" waters without a permit from the Fisheries Director (Appendix A: North Carolina Regulations, Permit and Permit Conditions). Attempts were made to harvest from open, non-polluted waters in the 1960's for sale in New York. However, the market closed in the 1970's as the clams were found to have high bacteria counts, although the bacteria was not pathogenic to people. In the 1980's a fishery for *Rangia* spp. shell existed. Shells were used for culinary purposed, to hold a "deviled" clam mixture of other species. Meats were not consumed and were disposed of. Currently *Rangia* spp. are not harvested in North Carolina. The only reported landings were in 1972, 1994, and 1995 (Table 5). (Contacts: David Taylor, Trish Murphy, North Carolina Marine Fisheries, (252) 726-7021, Sheryl Phillips).

Texas

Some seafood dealers in Texas harvested and sold *Rangia* spp. in 1996 and 1997 (Table 6). Harvest stopped because the gear used was inadequate for a commercial operation and areas where *Rangia* spp. were abundant were "closed". TPW only allows harvest by hand or clam tongs, or with special permission, by dredge. Dealers indicated the best way to harvest *Rangia* spp. was with an oyster dredge with a smaller mesh size than currently legal. Ideal dredge tow times were estimated at 15-20 minutes and yielded an estimated 65 – 151 kg. live weight. In most cases, the legal bag limit for a week could be reached in one day. Dealers also stated that the amount of *Rangia* spp. allowed per day was not enough to recoup the cost of a trip. They believe a commercial fishery would be profitable if regulations were changed to accommodate a more liberal harvest. A limited attempt was made to determine the market demand for Atlantic rangia within the Houston area. Contact with local Houston Asian food markets in May 1999 found the markets were not selling Atlantic rangia. However, a seasonal market may exist as Atlantic rangia are sometimes seen in local seafood markets. A discussion with a Texas Seafood Dealer who marketed Atlantic rangia in the mid-1990's had a market primarily among the local Houston Asian-American community. The dealer found Atlantic rangia needed to be depurated and specially flavored or seasoned to be palatable. Average price paid by the consumer was $1.98/kg; ideal market size was 18 – 26 clams/kg.

Mexico

Fisheries for the Atlantic rangia have been reported in the Mexican Gulf States, primarily Campeche and Veracruz (Instituto Nacional De La Pesca 1994). The species have been harvested by divers, waders (hand picked), with the use of rakes and clam nets (Alvarez-Legorreta et al. 1994, Instituto Nacional De La Pesca 1994). Regulations allow for the commercial harvest of this species year-round (Instituto Nacional De La Pesca 1994). Catches in excess of 1500 mt/year were reported in the 1980's, however with the introduction of the clam net, the fishery was considered highly exploited and catches collapsed to less than 400 mt/year in the early 1990's (Alvarez-Legorreta et al. 1994). Mexico no longer has commercial fishery for Atlantic rangia (Ortega Sala Armando Adolfo, UNAM, pers. comm).

DISCUSSION

Our review lists the parameter ranges acceptable for reproduction, settlement and growth of Atlantic rangia. In most cases environmental conditions in Galveston Bay fall within acceptable limits for these ranges. Acceptable parameter ranges are loosely defined as: salinity: 0- 15 ppt, with salinity fluxes; depth: <6m; temperature: ~ 2 – 32^{o} C; oxygen: can tolerate low dissolved oxygen levels <2.0mg/l; and substrate: sandy sediments and/ silt-clay sediments. The review also cites a study that found a trichocerous cercariae stage of trematode that inhibits reproduction in Atlantic rangia in Galveston Bay. Effects of this parasite on the stock is unknown.

Atlantic rangia can be found throughout the Galveston Bay ecosystem, however, its distribution is predominantly within Trinity Bay and associated delta areas. Atlantic rangia of commercial sizes were found in Trinity Bay, but CPUE appeared low in comparison to published density estimates from other areas (Louisiana; Neches River, Texas). Low CPUE's are attributed to the gear and methodology used by TPW sampling which did not target rangia beds. Therefore, declines in CPUE cannot necessarily be attributed to declines in rangia population (Ricker 1975). Harrel (1993) reported a decline in Atlantic rangia density in the Neches River, Texas in 1990, which he attributed to the cold fronts and subsequent freeze of 1989. A decline in Atlantic rangia CPUE in Trinity Bay was also observed in 1990.

Based on the literature, Atlantic rangia in Galveston Bay were at least two years old and capable of gonad development. However, no data were available to determine if clams were reproductively active. An increase in mean size during the sampling period was observed and may be indicative of changes in juvenile recruitment. Studies aimed at determining size/age distribution, reproductive activity and rates of recruitment are needed to better understand the life history of Atlantic rangia in Galveston Bay.

Despite several attempts to develop a fishery for *Rangia* spp. by many states, no long-term fishery has been developed. In many cases, efforts to develop a fishery were not possible due to human health issues. As a result, there are few guidelines regarding exploitation of this species on a sustainable basis. A fishery was established in the Mexican Gulf States of Campeche and Veracruz and catches in excess of 1500mt/year were reported from these combined areas in the 1980's. This fishery was heavily exploited and is no longer commercially viable (Ortega Sala Armando Adolfo, UNAM, pers. comm).

Current TPW Statutes and Proclamations provide the Department with the authority to regulate a fishery for Atlantic rangia (Appendix B). A license must be obtained to commercially harvest the species. Current regulations allow for year-a-round harvesting within daily legal fishing times as well as requiring a daily bag limit. Currently, Atlantic rangia can only be harvested by hand or, with special permission, by dredge. The TPW Commission can make changes in gear, fishing seasons, bag-limits, and fishing times.

The authors tried to determine a market for Atlantic rangia. A seasonal market may exist as Atlantic rangia are sometimes seen in local seafood markets. However, the main impediment to developing a market is the taste and quality of the product. Atlantic rangia have been shown to be bioaccumulators of hydrocarbons and some bacteria. In Galveston Bay, high densities of Atlantic rangia were found in "restricted harvest" waters. Therefore, harvest from "restricted waters" would have to go through a process of depuration, such as that used in the Texas oyster lease industry or through TDH approved land depuration facilities, before the product could be marketed. If authorized for transplant, TDH must determine appropriate depuration rates for Atlantic rangia based on criteria established by the National Shellfish Sanitation Program. Regulations and issues related to shellfish leases are specific to the commercial harvest of oysters and the transplant of rangia clams to leases would require legislative changes to this statute.

Given their slow growth rates (2-3 years for maturation) and limited available data on the stock, a conservative approach to management in Texas is recommended. Information on stock biomass, growth and maturation, specific to the Galveston Bay ecosystem, would be required to determine appropriate bag and size limits and fishing seasons for the stock. Also, commercial sectors interested in developing a commercial rangia clam fishery have recommended a gear not currently legal be used for commercial harvest. If invasive gears are recommended, areas with submerged aquatic vegetation must be avoided. It is recommended that any commercial activity that commences be monitored to determine size structure, habitat impacts, catch rates and fishing effort. Additionally a limited entry program must be implemented before a commercial fishery is allowed to proceed. Such a program will allow managers to regulate fishing effort and prevent overexploitation of the stock.

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Table 1. Annual mean length (mm) of Atlantic rangia caught in TPW samples from Galveston Bay using trawls and oyster dredges, 1986-1998.

Year	Trawls		Non-reef Dredge		Reef Dredge	
	Length (mm)	N	Length (mm)	N	Length (mm)	N
1986	28.9	157	53.5	6	49.2	5
1987	32.4	153	53.4	63	45.4	11
1988	26.6	113	58.8	15	42.6	11
1989	29.5	359	36.7	71	40.2	37
1990	25.9	142	-		43.3	23
1991	33.2	64	-		41.2	41
1992	34.6	88	-		51.4	25
1993	34.4	104	-		48.4	50
1994	35.0	125	-		51.4	34
1995	32.1	193	-		53.1	35
1996	35.8	190	-		53.7	28
1997	31.5	124	-		52.0	41
1998	36.5	125	-		49.4	42
Overall	30.7	1937	46.3	155	47.8	383

Table 2. Mean catch rate (rangia/sample/bay) by gear, TPW data, 1986-98 for Galveston Bay.

Bay	Trawls		Non-reef Dredge		Reef Dredge	
	Catch rate	N	Catch rate	N	Catch rate	N
Burnett Bay	2.8	3				
Clear Lake			1.0	1		
Dollar Bay	26.0	1				
East Bay	1.0	5			0.4	79
Galveston Bay	0.3	27	1.1	12	3.8	146
Tabb's Bay	2.5	2				
San. Jacinto Bay	0.5	2				
Scott Bay	0.5	2				
Trinity Bay	44.4	313	3.8	39	1.4	249
West Bay	1.2	3				
Overall	39.9	358	3.2	52	2.0	474

Table 3. Mean annual catch rate (rangia/sample) by gear, TPW data, 1986-98 for Trinity Bay.

Year	Trawls		Non-reef Dredge		Reef Dredge	
	Catch rate	N	Catch rate	N	Catch rate	N
1986	127.5	23	0.8	4	0.2	11
1987	109.8	20	4.2	15	0.3	11
1988	15.4	22	2.4	6	0.4	28
1989	165.3	28	4.8	14	0.5	37
1990	31.8	22			0.6	30
1991	6.1	24			1.2	22
1992	7.8	12			2.5	11
1993	5.6	24			1.9	17
1994	4.8	34			1.6	16
1995	18.5	21			1.3	18
1996	40.4	30			0.8	16
1997	13.4	19			1.4	17
1998	5.5	34			5.4	15
Overall	44.4	313	3.8	39	1.4	249

Table 4. Mean catch rates (rangia/sample) by gear for "unrestricted" vs. "restricted harvest" areas within Galveston Bay, 1986-1998.

Sampling Strata	Trawl	N	Dredge	N
Sample strata in unrestricted harvest waters	4.2	62	0.8	217
Sample strata mostly in unrestricted harvest waters	22.5	41	2.2	36
Sample strata in restricted harvest waters	53.3	236	3.4	235
Sample strata mostly in restricted harvest waters	5.7	20	2.2	38

Table 5.0 Kilograms and ex-vessel value of *Rangia* spp. shell in North Carolina for 1972, 1994-1995.

Year	Estimated kg. of shell	Value
1972	3,847	$1,009
1994	109	$77
1995	1,759	$1,443

Table 6. Kilograms and ex-vessel value of *Rangia* spp. harvested in Texas (TPW unpublished data).

Year	Estimated kg. Of live weight	Ex-vessel value
1996	15,184	$16,067
1997	2,063	$2,727

Figure 1. Map of Galveston Bay showing "restricted" and "unrestricted" harvest areas, distribution and catch rates of *Rangia cuneata* collected with otter trawls.

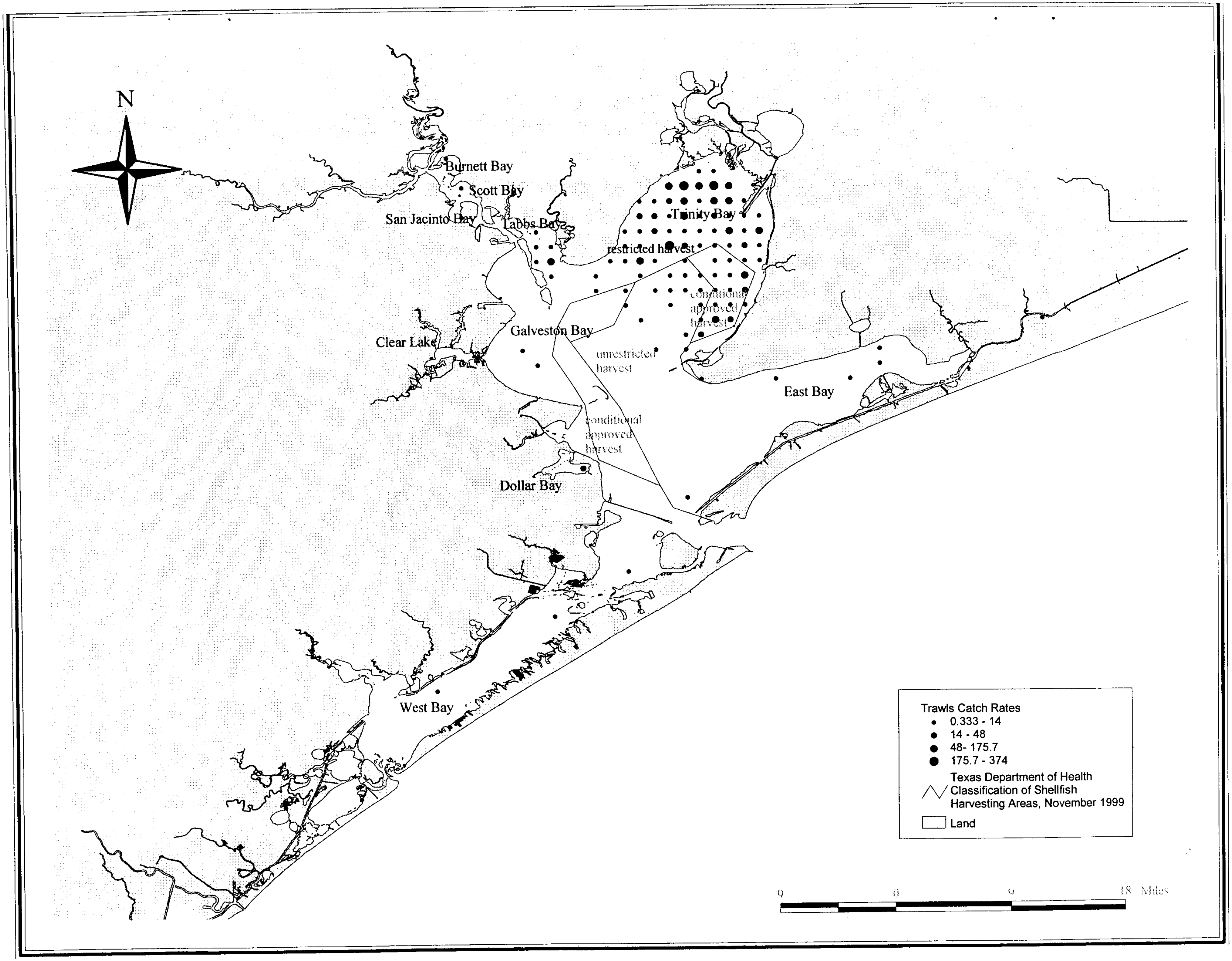
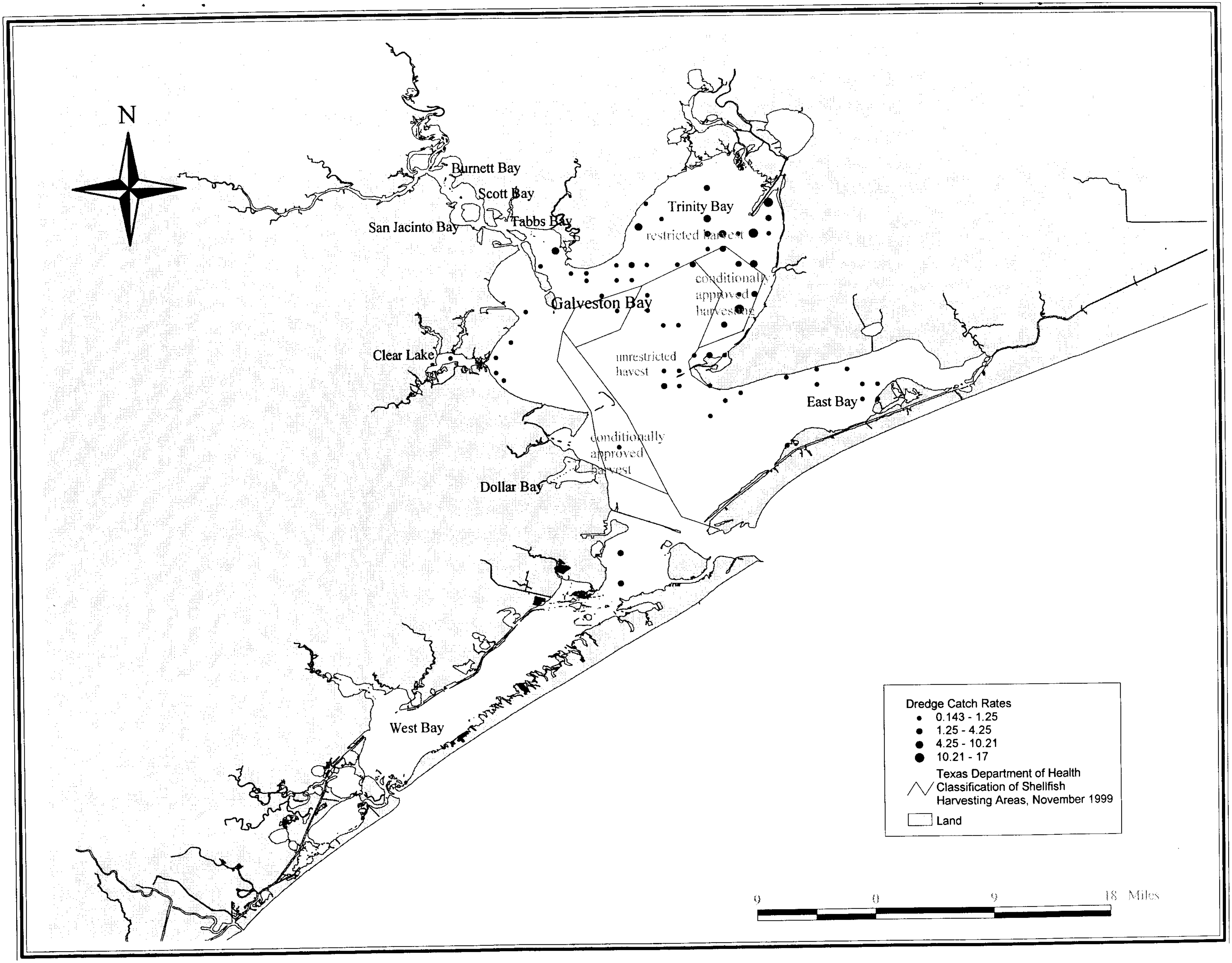

N
Burnett Bay
Scott Bay
San Jacinto Bay
Tabbs Bay
Trinity Bay
restricted harvest
conditional approved harvest
Galveston Bay
Clear Lake
unrestricted harvest
East Bay
conditional approved harvest
Dollar Bay
West Bay
Trawls Catch Rates
0.333 - 14
14 - 48
48- 175.7
175.7 - 374
Texas Department of Health Classification of Shellfish Harvesting Areas, November 1999
Land
0
0
0
18 Miles

Figure 2. Map of Galveston Bay showing "restricted" and "unrestricted" harvest areas, distribution and catch rates of *Rangia cuneata* collected with oyster dredges.


N
Burnett Bay
Scott Bay
San Jacinto Bay
Tabbs Bay
Trinity Bay
restricted harvest
Galveston Bay
conditionally approved harvesting
Clear Lake
unrestricted havest
East Bay
conditionally approved harvest
Dollar Bay
West Bay
Dredge Catch Rates
0.143 - 1.25
1.25 - 4.25
4.25 - 10.21
10.21 - 17
Texas Department of Health Classification of Shellfish Harvesting Areas, November 1999
Land
9
0
9
18 Miles

Appendix A: North Carolina Regulations, Permit and Permit Conditions

SECTION .0400 - RANGIA CLAMS

.0401 PERMIT REQUIREMENT

It is unlawful to take Rangia clams by mechanical methods from all waters, or by any method from polluted waters, without first securing a permit from the Fisheries Director. The permit shall be issued to the boat owner/operator, shall list all crew members involved in the operation, and must accompany the vessel at all times. Such permit shall designate the area and time(s) in which Rangia clams may be taken.

History Note: *Statutory Authority G.S. 113-134; 113-201; 113-202; 143B-289.4;*
Eff. January 1, 1991.

.0402 SEASON, SIZE AND HARVEST LIMITS

Season, size, and harvest limits applicable to hard clams in Section 15A NCAC 3K .0300 do not apply to Rangia clams.

History Note: *Statutory Authority G.S. 113-134; 113-201; 113-202; 143B-289.4;*
Eff. January 1, 1991.

.0403 DISPOSITION OF MEATS

All meats from clams taken from polluted waters shall be disposed of in a manner (other than for human consumption) acceptable to the North Carolina Divisions of Marine Fisheries and Environmental Health.

History Note: *Statutory Authority G.S. 113-134; 113-201; 113-202; 143B-289.4;*
Eff. January 1, 1991.

Appendix B: Texas legislative authority for harvesting rangia.

Chapters 78 of Texas Parks and Wildlife (TPW) Statute and 57 of TPW Proclamation provide the Department with the authority to regulate any future *Rangia spp.* clam fishery in Texas. Chapter 78.006 authorizes the TPW commission to regulate, by proclamation, the taking, possession, purchase, and sale of mussels and clams. Further, this section authorizes the TPW Commission to establish bag and size limits and to regulate the means and methods by which mussels and clams may be taken (§78.006.c). Though not mentioned by species, *Rangia spp.* clams fall under the definition provided in §78.001 for mussels and clams.

I. Harvest

License

Current regulations require that a license be obtained to commercially harvest mussels or clams from the public waters of the state (§78.002). This license must include the specific body of water in which the licensee may operate. The current price for this license is $30 (resident) and $800 (non-resident). A recreational fishing license and saltwater stamp are needed to harvest Rangia clams from the coastal waters of Texas.

Season

Mussels and clams may be harvested year-round in Texas (§57.158.d). Legal fishing times are from 30 minutes before sunrise to 30 minutes after sunset of each day (§57.158.d.1). All public waters of the state are open to mussel and clam harvest except for those identified in 57.158.d.2.A-U.

Means and methods

Mussels and clams may be taken only by hand (§57.158.c.2). However, §78.002.e in statute provides for the use of a dredge in a designated area with permission granted by the Department. This section also provides for the establishment of a gear fee (in addition to the license fee) of $30 or an amount set by the Commission, whichever is larger.

Size and bag limits

There is no size limit specified for *Rangia spp.* clams (§57.158.b). Bag limits for commercial harvest are currently set at 75 pounds per person, per day of whole mussels and clams including their shells (§57.158.b.2.A). Chapter 78.005 establishes statutory authority for the harvest from public waters of the state, for personal use and consumption only, not more than 25 pounds a day of whole mussels and clams, including shell and soft tissue, or 12 pounds a day of mussel and clam shells.

II. Mussel and Clam Dealer

License

A Shell Buyer's license is required in order to purchase mussel and clam shells that have been commercially harvested from Texas public waters (§78.003). The amount of this license can be set by the commission and is currently $100 (resident) and $1,500 (non-resident). §78.003.e specifies that the holder of this license must file a report of activities performed under this license to the department. The Commercial

Landings Program (Monthly Aquatic Product Report), established under §66.019 in Texas Parks and Wildlife Statues, should be appropriate in meeting this requirement.

Other

Chapter 78.004 authorizes the Commission to charge an export fee for mussels or clams or mussel or clam shells harvested from state waters and shipped out-of-state. The fee is currently set at $0.03 per pound but may be set at a higher level by the Commission. Funds generated from this export fee must be used for research, mitigation, or management activities associated with mussels and clams.

PWD RP V3400-661 (11/00)