Bay Scallops, *Argopecten irradians*, in the Northwestern Gulf of Mexico (Alabama, Mississippi, Louisiana, and Texas)

KIM WITHERS and MATT HUBNER

Introduction

Two subspecies of bay scallops inhabit the northwestern Gulf of Mexico coast: *Argopecten irradians concentricus* on the west coast of Florida to the Chandeleur Islands, Lousiana, and *A. i. amplicostatus* from Galveston Bay, Texas, south to northern Mexico. Abundance of bay scallops in the northwestern Gulf is typically much lower than on the west coast of Florida and the Atlantic coast. Alabama, Mississippi, and Louisiana have not reported a commercial scallop catch since harvest statistics began being published in 1950.[1] Texas reported its only commercial catches (since 1895) in 1984 and 1985 (Culbertson et al., 2004). The landings for both years combined were 2.4 metric tons (t) with a market value of $2,746.00. In the same years, 13,437 t of bay scallops with a total value of $35,842.00 were landed in Florida.[1] Texas is the only state in the northwestern Gulf that regulates recreational harvesting of scallops (TPWD, 2002, 2006). Scallops can only be harvested from waters approved by the Texas Department of Health. They can be taken year-round by hand, using dip nets, rakes, or dredging and there are no size or bag limits.

Since there is no fishery on the northwestern Gulf of Mexico, this paper will focus on what is known about past and present bay scallop distribution and abundance in the northwestern Gulf (primarily Texas, Fig. 1) and the reasons why a commercial fishery is unlikely to develop.

Kim Withers and Matt Hubner are with the Center for Coastal Studies, Texas A&M University-Corpus Christi, 6300 Ocean Dr., Unit 5866, Corpus Christi, TX 78412 (email: Kim.Withers@tamucc.edu).

ABSTRACT—There is no evidence that a commercial bay scallop fishery exists anywhere in the northwestern Gulf of Mexico. No data concerning scallop abundance or distribution was found for Alabama, Mississippi, and Louisiana. Texas is the only state west of Florida where bay scallop populations have been documented. These records come from a variety of literature sources and the fisheries-independent data collected by Texas Parks and Wildlife Department (1982–2005). Although common in the diet of prehistoric peoples living on the Texas coast, recent (last ~50 years) bay scallop population densities tend to be low and exhibit "boom–bust" cycles of about 10–15 years. The Laguna Madre, is the only place on the Texas coast where scallops are relatively abundant; this is likely due to extensive seagrasses cover (>70%) and salinities that typically exceed 35 psu. The lack of bay scallop fishery development in the northwestern Gulf of Mexico is probably due to variable but generally low densities of the species combined with a limited amount of suitable (i.e. seagrass) habitat.

Prehistoric Scallop Usage

Shell middens composed primarily of eastern oyster, *Crassostrea virginica*, or rangia, *Rangia cuneata* and/or *R. flexuosus*, shells are common along much of the northwestern Gulf of Mexico coast. The predominant species depends on whether they were deposited in low salinity areas near river deltas and bay heads (rangia), or in areas of higher salinity closer to the Gulf along bay margins and barrier islands (oysters). Texas shell middens usually represent sites of repeated seasonal occupation (Ricklis, 1995), but on the Louisiana Chenier plain, middens can be difficult to separate from natural accumulations of shell (Henderson et al., 2002).

Scallops do not appear in middens from Louisiana (e.g. Poverty Point Site; Gagliano and Saucier, 1963) but they are a common component of middens in northwestern Florida (Russo and Quitmyer, 1996) and Texas (Table 1). We could find no record of marine/estuarine shell middens or bay scallop artifacts in either Mississippi or Alabama. Rangia or freshwater forms dominate the few middens in Louisiana that have been studied (Henderson et al., 2002), suggesting that estuarine salinities may have been too low outside of Texas and Florida to support large prehistoric scallop populations.

Bay scallops are one of five species of marine/estuarine mollusks that were exploited by prehistoric inhabitants of the Texas coastline. Their shells are often co-dominant with oyster shells (Ricklis, 1995), but they are not usually associated with middens dominated by rangia shells. Bay scallops are infrequently found in middens on the upper Texas coast and are much more abundant from Matagorda Bay southward (Steele, 1987; Table 1). The majority of bay scallop shells found in archeological sites are unmodified, even articulated, and in large enough quantities to suggest they were a significant and integral food source (Steele, 1987; Ricklis, 1996). Scallops were apparently not used for tools or ornaments since possibly modified shells were only found at two sites (Steele, 1987).

Bay scallops are most abundant in middens that date to the early Archaic period (~7500–4500 YBP). At that

[1] Landings statistics have been published by the National Marine Fisheries Service, NOAA, in various issues of the Current Fisheries Statistics series

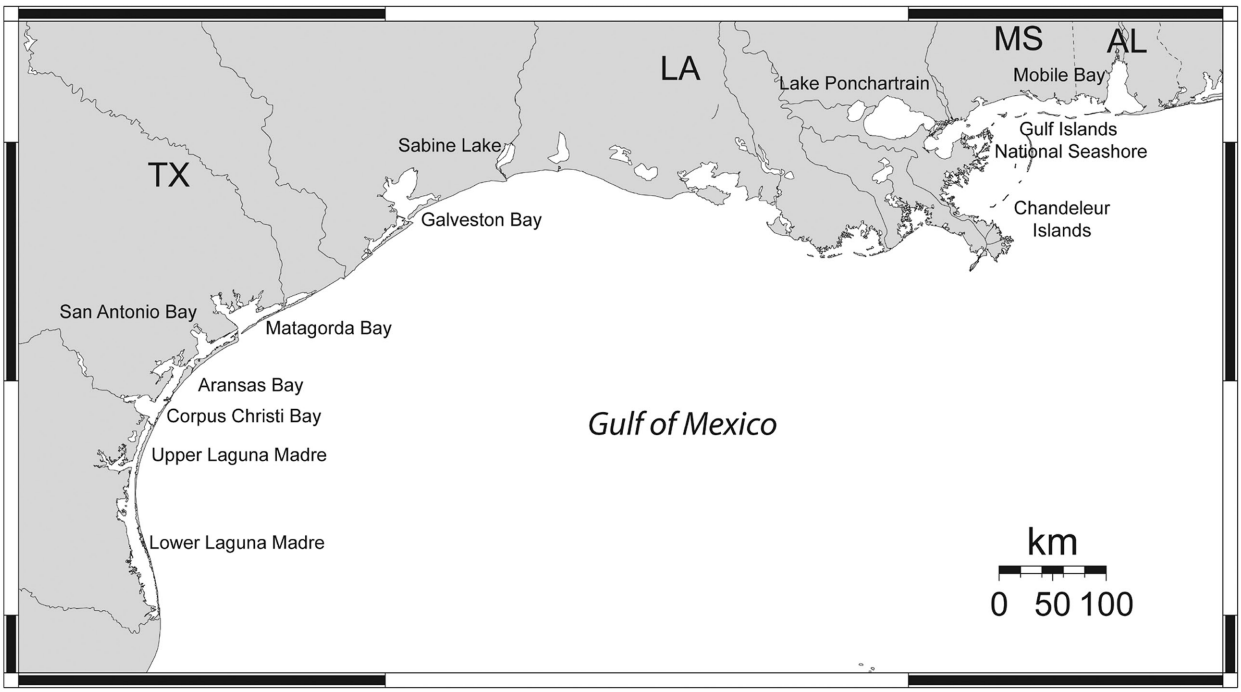

Figure 1.—Map of the Gulf States west of Florida, showing bay systems and other locations mentioned in the text.

Table 1.—Occurrences of bay scallops in archeological contexts on the Texas Gulf Coast.

Bay	Site Name or Number	Date	Remarks	Source
Galveston Bay	Multiple	Not available	Bay scallop present in middens, but not abundant	Steele, 1987
Lavaca Bay	Multiple	Not available	Bay scallop present in middens	Steele, 1987
Matagorda Bay	Multiple	Not available	Bay scallop absent from middens	Steele, 1987
Copano Bay	41AS5	2740–2500 YBP[1]	Bay scallops present in midden	Ricklis and Albert, 2005
	41AS15	Archaic–prehistoric	Bay scallops were ~2% of 183 kg of shell	Prewitt and Paine, 1987
	41AS3	2764–2727 YBP[1]	Bay scallops common	Ricklis, 1995
Aransas Bay	Johnson Site	Archaic	Bay scallops common	Shafer and Bond, 1985; Campbell, 1947
Nueces Bay	41SP15	5257–4875 YBP[1]	Dense oyster & bay scallop	Ricklis and Cox, 1991
	41SP153 Unit 1	7509–9857 YBP[1]	Dense oyster & scallop	Ricklis, 1993
	41SP153 Area 2	5888–4568 YBP[1]	Dense oyster & bay scallop	Ricklis, 1993
	41SP156	5592–4614 YBP[1]	Dense oyster & bay scallop	Ricklis, 1993
	41SP177	3156–2873 YBP[1]	Moderate oyster, some bay scallop	Ricklis, 1993
Corpus Christi Bay	41SP120 South Block	1161–730 YBP[1]	Dense mixed shell midden (oyster, bay scallop, quahog, whelk, others)	Ricklis and Cox, 1991
	41SP120 North Block	1338–741 YBP[1]	Dense mixed shell midden (oyster, bay scallop, whelk, quahog, others)	Ricklis, 1993
	41SP11	626–533 YBP[1]	Scattered shell, including bay scallop	Ricklis, 2006
	41NU65	Archaic–prehistoric	2 bay scallop shells recovered	Steele and Mokry, 1985
	41NU101	Archaic–prehistoric	2 bay scallop shells recovered	Steele and Mokry, 1985
	41SP43/120	Archaic	2,000 fragments, bay scallop 2nd to oyster in abundance	Ricklis, 1987
Laguna Madre	Multiple sites	Not available	Bay scallop present	Steele, 1987
Baffin Bay	41KL13	Archaic–prehistoric	Bay scallop and other shell present on surface	Hester, 1971
	41KL71	4552±60 YBP[2]	Midden contained oyster, whelk, tulip shell, and bay scallop	Smith, 1986
	41KL37	Archaic	Whelk, oyster, bay scallop, and tulip shell scatter	Smith, 1986

[1] These dates represent age before present (YBP) calibrated 1-sigma age ranges (Ricklis, 1995).
[2] This date is an uncorrected radiocarbon date on charcoal from the site (Smith, 1986).

time, barrier islands had not yet formed off the Texas coast, and estuaries were open with unrestricted exchange with the Gulf of Mexico. Shellfish were a seasonally (fall, winter, early spring) important source of both calories and protein, and exploitation was fairly intense. At the Holmes Site on Corpus Christi Bay, scallop shells dominated the deposit and were abundant enough to have yielded an estimated 15,750 g of meat (Ricklis, 1996).

After the barrier islands formed (~4000 YBP), fish and mammal remains dominate midden assemblages. Shellfish

Table 2.—Occurrences and estimated abundance of bay scallops in bays along the Texas Gulf Coast compiled from various published and unpublished sources.

	Bay Scallop Occurrence/Estimated Abundance by Bay												
Year	SL	GB	MB	ES	SA	AB	CB	RB	CC	NB	ULM	LLM	Sources
1894		D							P				Evermann and Kendall, 1894
1940						C							Ladd, 1951
1951–58				R		VA		R				VA	Parker, 1959
1959–60		R											Shidler, 1960
1967								A[1]					Zimmerman and Chaney, 1969
1968								R					Zimmerman and Chaney, 1969
1971–73					0						0		Harper, 1973a, 1973b; Hildebrand and King, 1973
1973–74						P	P		0				Hildebrand and King, 1974; Holland et al., 1974
1974–75								R–C	0		0		Hildebrand and King, 1975; Rickner, 1975
1975–76							D		0		VA		Hildebrand and King, 1976; Calnan, 1980
1976–77	0	D	D	D	D	R	D	D	D	0	0–VA	0	Hildebrand and King, 1977; Circé, 1979; White et al., 1985, 1986a, 1986b, 1987, 1989a, 1989b
1977–78									0		R–C	P	Hildebrand and King, 1979; Rickner, 1979; Williamson, 1980; Brock, 1983
1980											D		Wilhite et al., 1982
1981–82									R		R		Powell et al., 1982; Castiglione, 1983
1984											D	D	Smith, 1985
1986–87										F	C		Chaney, 1988; Drumright, 1989
1989–90										0	0	0	Ruth, 1991; Hicks, 1993; Hicks et al., 1998
1992–93									0		0		Montagna, 1993; Martin, 1994; Montagna and Martin, 1994
2001–02								R			0		Davidson, 2002; Pearce, 2003
2004											A		Withers, K, pers. observ.
2005											C–A	C	Withers, K, pers. observ.; Hicks, D. W., Univ. Texas-Brownsville, pers. commun.
2006											R		Hubner, 2007

[1] Scallops were freshly dead with tissues still attached.

Bay abbreviations:
SL = Sabine Lake
GB = Galveston Bay system, including Trinity Bay
MB = Matagorda Bay system, including Lavaca Bay
ES = Espiritu Santo Bay
SA = San Antonio Bay system, including Hynes and Mesquite bays
AB = Aransas Bay, including St. Charles Bay
CB = Copano Bay; RB = Redfish Bay
CC = Corpus Christi Bay, including Oso Bay
NB = Nueces Bay
ULM = Upper Laguna Madre
LLM = Lower Laguna Madre, including South Bay

Abundance rankings use the author's terminology or were determined as follows:
D = dead only
P = present in a species checklist, but no abundance data provided
0 = none collected
R = rare: less than 5% of total collection.
F = few: 6–10% of collection
C = common: 15–40% of collection or 40–50% of sites
A = abundant: 41–60% of collection or 51–75% of sites
VA = very abundant: numerically dominant and present in most sites sampled

remains are much less abundant in middens deposited after ~3000 YBP (late Archaic). Changing salinities in the newly enclosed bays, concomitant changes in shellfish species composition and abundance, technological advancements, and increasing human populations probably all contributed to reduced importance of shellfish exploitation in the estuaries and greater reliance on fishing and hunting. However, shellfish remained a part of the diet of the native peoples up through historic times. Cabeza de Vaca (early 1500's) and De Bellisle (early 1700's), two early explorers of the Texas Coast, observed opportunistic and deliberate harvest of shellfish, including scallops (Newcomb, 1961).

Recent Abundance and Distribution

Our review of the literature turned up no mentions of living or dead bay scallops in Louisiana, Mississippi, or Alabama. Queries to fishing guides in the Chandeleur Islands area of Louisiana yielded sightings of bay scallop shells, but no reports of live scallops. In Texas, two sources of data for scallop abundance and distribution are available for evaluation: a variety of published and unpublished literature and reports (1894–2006) and quantitative, coastwide fisheries independent monitoring data collected by the Texas Parks and Wildlife Department (TPWD) for 1982–2005.

Literature Records

An exhaustive review of the literature for Texas turned up 40 sources with references to bay scallop distribution and abundance (Table 2). These ranged from reports or counts of dead shell in samples (Powell et al., 1982; Smith, 1985; White et al., 1985–89), and mentions in species checklists (Evermann and Kendall, 1894; Holland et al., 1974), to more quantitative studies that provide a qualitative estimate of abundance (Ladd, 1951), data that allows a reasonable estimation of local abundance, frequency, or both (Hildebrand and King, 1973–79) or samples were taken such that scallops could or should have been collected, but were not (Calnan, 1980; White et al., 1985–89).

Most records represent collections at only one or a few sites within a single bay system. The only comprehensive studies were those by the Bureau of Economic Geology in the mid to late 1970's. Composition and abundance of benthic fauna were included in comprehensive studies of the bottoms on "submerged lands" of the bays and inner shelf of the Texas coast (White et al., 1985–89). Studies focused on shoalgrass, *Halodule wrightii,* beds

(Corpus Christi Bay, Laguna Madre), and turtlegrass, *Thalassia testudinum,* beds (Redfish Bay) yielded the majority of scallop records.

The upper Laguna Madre has been studied more than the other bays and has a more complete record of when scallops have been present. During 1976–77 when all bays were sampled, live scallops were only found in Aransas Bay and upper Laguna Madre. Scallops were abundant in areas of Aransas Bay and lower Laguna Madre in the 1950's, and in parts of upper Laguna Madre in 1975–77 and 2004–05.

TPWD Independent Fisheries Data

Since 1982, nekton have been sampled in each Texas bay system using bag seines and trawls. Both of these gears will also capture bay scallops and, when collected, their numbers and sizes have been recorded. Bay systems are divided into grids, grids are stratified by depth (trawls vs. bag seines), and 20 grids are randomly chosen from each stratum prior to each sampling event. A sampling station within the grid is randomly chosen. No grid can be sampled more than once per month with the same gear. We obtained bag seine and trawl data for 1982–2005 from the Texas Parks and Wildlife's Coastal Fisheries Division, as described in Martinez-Andrade et al. (2005).

Very few scallops were collected in bag seines in any bay (Table 3). Scallops were not collected from Sabine Lake or the Galveston Bay system in either bag seines or trawls. The majority of scallops were collected in trawls in the upper Laguna Madre (Table 4). Trawls outside the Laguna Madre yielded few scallops and from 1991–98 no scallops were collected in trawls from any bay except lower Laguna Madre. Scallops were most abundant in 1987–88 and 2004; more than 95% of these were trawled from the upper Laguna Madre.

Scallops collected in bag seines were largest (mean length 43.4 mm) in Corpus Christi Bay and smallest (mean length 27.9 mm) in upper Laguna Madre (Table 5). Scallops trawled from Aransas and San Antonio bay systems were generally larger than those from other bay systems (Table 6). Average length (San Antonio Bay = 39.9 mm; Aransas Bay = 43.3 mm) of scallops in these two systems was larger than on the rest of the coast and was slightly larger than seined scallops in the same bays. Average shell lengths of scallops trawled from Corpus Christi Bay and the Laguna Madre were smaller than the average of seined specimens.

During 2004, shell length, width, and dry weight as well as scallop body dry weight were determined on a sample

Table 3.—Total numbers of bay scallops collected in bag seines 1982–2005. Data provided by Texas Parks and Wildlife Department.

Year	Matagorda Bay	San Antonio Bay	Aransas Bay	Corpus Christi Bay	Upper Laguna Madre	Lower Laguna Madre
1982						
1983						
1984						
1985				3		
1986						
1987						
1988				2	8	
1989		4	1	1		
1990		4		3	1	
1991		1		2		3
1992						
1993				1		
1994						
1995		1		3		
1996	1	5	2	5		
1997	1	1	2			
1998					1	
1999						
2000				1		2
2001			1			
2002						
2003					1	
2004					6	
2005					1	
Total	2	16	6	21	18	5

Table 4.—Total numbers of scallops collected in trawls 1982–2005. Data provided by Texas Parks and Wildlife Department.

Year	Matagorda Bay	San Antonio Bay	Aransas Bay	Corpus Christi Bay	Upper Laguna Madre	Lower Laguna Madre
1982					10	
1983					25	
1984					12	
1985					9	
1986					10	
1987					385	9
1988		3		7	395	7
1989	1	6	4		2	8
1990		1	1		1	8
1991						2
1992						33
1993						1
1994						1
1995						10
1996						1
1997		1		2		
1998			1		4	1
1999					1	9
2000					1	58
2001	5					5
2002			1			2
2003					26	3
2004					938	16
2005					3	1
Total	6	11	7	9	1,822	175

of 10 bay scallops collected from Bird Island Basin in upper Laguna Madre.[2] These scallops were collected during November from shoalgrass in water about 1.25 m deep. Average shell length was 53.9 mm (SD=7.2), average width was 55.2 mm (SD=7.7), and average dry weight was 23.5 g (SD=6.1). Average length of this collection was nearly double the average length of scallops in TPWD trawls during the same year. Average body dry weight was 23.5 g (SD=6.1).

[2]Hubner, M., and K. Withers. Texas A&M University-Corpus Christi, 6300 Ocean Dr., Unit 5866, Corpus Christi, TX. Unpubl. data on file at the Center for Coastal Studies.

Table 5.—Average length (mm) of bay scallops collected in bag seines 1982–2005 with standard deviation in parenthesis (when more than 1 bay scallop was collected or measured). Data provided by Texas Parks and Wildlife Department. Asterisk (*) indicates that scallops were collected but not measured.

Year	Matagorda Bay	San Antonio Bay	Aransas Bay	Corpus Christi Bay	Upper Laguna Madre	Lower Laguna Madre
1982						
1983						
1984						
1985				*		
1986						
1987						
1988				46.0 (1.4)	31.9 (9.3)	
1989		43.3 (16.9)	50.0	35.0		
1990		47.8 (22.6)		46.7 (9.1)	36.0	
1991		14.0		57.5 (0.7)		34.8 (2.5)
1992						
1993				35.0		
1994						
1995		11.0		42.5 (12.0)		
1996	26.0	38.5 (12.2)	29.0	40.8 (21.4)		
1997	39.0	7.0	40.5			
1998					38.0	
1999						
2000				32.0		51.0 (9.9)
2001			38.0			
2002						
2003					17	
2004					23.8 (8.4)	
2005					21	
Overall	32.5 (9.2)	35.9 (19.5)	39.4 (8.6)	43.4 (13.4)	27.9 (9.3)	42.9 (11.1)

Table 6.—Average length (mm) of bay scallops collected in trawls 1982–2005 with standard deviation in parentheses (when more than 1 bay scallop was collected or measured). Data provided by Texas Parks and Wildlife Department. Asterisk (*) indicates that scallops were collected but not measured.

Year	Matagorda Bay	San Antonio Bay	Aransas Bay	Corpus Christi Bay	Upper Laguna Madre	Lower Laguna Madre
1982					*	
1983					22.4 (11.2)	
1984					20.2 (1.0)	
1985					21.3 (15.9)	
1986					19.0 (8.8)	
1987					25.9 (17.6)	37.1 (16.8)
1988		32.3		30.2 (6.5)	29.0 (13.4)	23.1 (3.5)
1989	8.0	44.0 (1.4)	47.5 (10.2)		25.5 (14.8)	32.2 (26.8)
1990		57.0	40.0		26	18.3 (6.3)
1991						18.0
1992						23.3 (6.3)
1993						15.0
1994						26.0
1995						18.1 (6.6)
1996						29.0
1997		22.0		29.5 (2.1)		
1998			28.0		18.5	35.0
1999					27.0	22.5 (10.4)
2000					10.0	21.2 (0.22)
2001	*					23.3 (13.1)
2002			45.0			39.0 (21.2)
2003					20.8 (9.9)	23.3 (2.5)
2004					18.4 (13.4)	25.7 (10.1)
2005					14.7	25.0
Overall		39.9 (13.3)	43.3 (10.3)	29.9 (4.7)	23.5 (14.1)	25.5 (13.3)

Based on TPWD trawl data, scallop distribution and abundance on the Texas coast appears linked to salinity and fluctuations in salinity. Virtually all scallops were collected from waters of at least 20 psu (Fig. 2). The vast majority of scallops were collected in the hypersaline Laguna Madre (Fig. 3), especially the upper lagoon, which tends to exhibit higher salinities than the lower lagoon. When all data from coastal bays were analyzed using Spearman's rho there was a significant positive correlation between salinity and scallop abundance (correlation coefficient = 0.073; p = 0.0001; n = 22,998). However, the same analysis using data only from Laguna Madre yielded a negative correlation (correlation coefficient = -0.035; p = 0.009; n = 5,682). Boom years in the upper Laguna Madre generally followed years when mean annual salinity dropped to around 30 psu (Fig. 4, top). During the 1990's, a persistent brown tide in the upper Laguna Madre may have prevented a boom year following the 1992–93 salinity declines or salinities may have declined below the threshold for recruitment. In the lower Laguna Madre, scallop abundance is low but the population appears to be more consistent than in the upper lagoon (Fig. 4, bottom). "Boom" abundances (e.g. 1992, 2000) are less than 10% of boom abundances in the upper lagoon, and the pattern of increasing abundance following declining salinity is not clear.

Discussion

We were unable to find any records of abundance or distribution of scallops in the northwestern Gulf of Mexico outside of Texas. Fisheries-independent trawl/bag seine data and other records from Texas show that scallops appear to "boom" from Aransas Bay south at intervals of about 10–15 years (i.e. 1950's, Aransas Bay; 1967, Redfish Bay; 1976–78, 1987–1988, and 2004, upper Laguna Madre). In lower Laguna Madre, scallop populations have peri-

odically boomed (i.e. 1950's) but they may be present in low numbers more consistently than in other bays. The only year between 1987–2005 that no scallops were trawled from the lower Laguna Madre was 1997. Recruitment limitations may be responsible for "boom–bust" cycles of abundance in bay scallops (Peterson and Summerson, 1992). A recruitment study in the upper Laguna Madre during 2005–06, the year after a boom, yielded no scallop spat from 28 stations and only three adults (Hubner, 2007) suggesting that this is case in the upper Laguna Madre.

The lack of bay scallop fishery development in the northwestern Gulf of Mexico is doubtless due to variable but generally low densities of the species combined with a limited amount of suitable (i.e. seagrass) habitat. Bay scallop distribution is closely tied to seagrass distribution (Gutsell, 1930; Marshall, 1947; Eckman, 1987; Ambrose and Irlandi, 1992) and the majority of seagrasses in the northwestern Gulf are found in Texas (Table 7). Seagrass cover in Texas is inversely related to freshwater inflow and increases from north to south. The majority of Texas seagrasses (~79%) are found in the semi-arid and hypersaline Laguna Madre, with over 75,000 ha (Pulich, 1999) and greater than 70% overall coverage (Onuf, 1995). Shoalgrass is the dominant species but turtlegrass, manatee grass, *Cymodocea filiforme*, and small amounts of clover grass, *Halophila engelmannii,* and widgeon grass, *Ruppia maritima*, are also found in the system. Seagrasses fringe the shorelines of other bays (e.g. Corpus Christi Bay, Aransas Bay). Galveston Bay was the only other bay on the Texas coast where seagrasses had been fairly extensive, but by 1989 very little remained (Pulich, 1999). Recent reintroduction of seagrasses into the bay may reverse this trend.

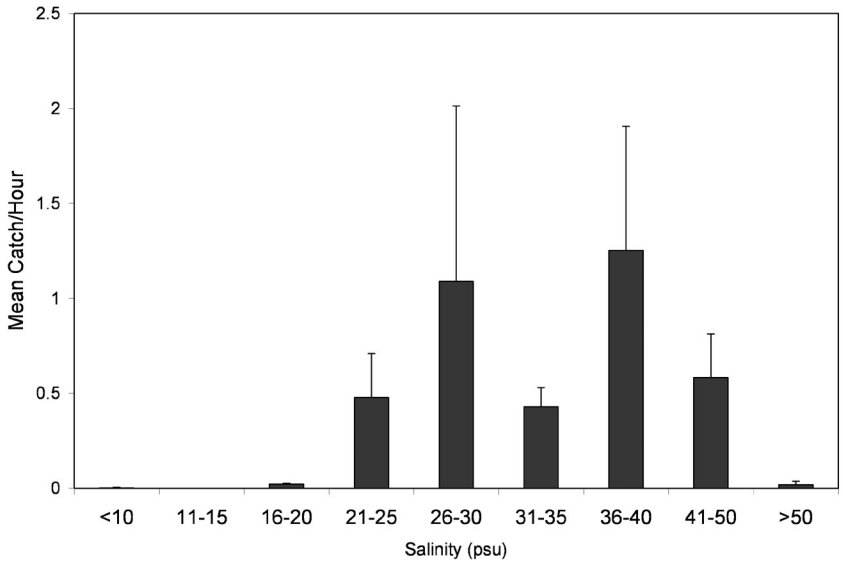

Fig. 2.—Mean abundance and standard deviation of bay scallops in Texas by salinity. Trawl and salinity data from Texas Parks and Wildlife fishery independent monitoring program, 1982–2005.

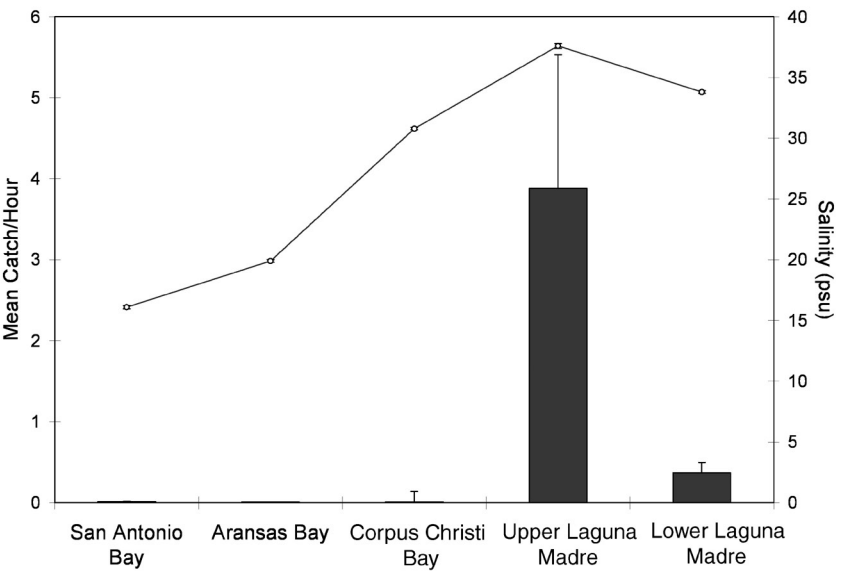

Figure 3.—Mean abundance and standard deviation of bay scallops in central and southern bay systems with overall mean salinity of each bay (line). Trawl and salinity data from Texas Parks and Wildlife fishery independent monitoring program, 1982–2005.

Submerged aquatic vegetation is found in the bays and sounds of the northern Gulf (e.g. Mobile Bay, Mississippi Sound, Lake Ponchartrain), but is often dominated by freshwater species such as wild celery, *Valisnera*, and widgeon grass. Never widespread, where shoalgrass is currently present in Alabama, coverage is much reduced from historic levels (Barry Vittor and Associates, Inc., 2005). Small amounts of seagrasses (primarily shoalgrass and manatee grass) are found on the northern sides of barrier islands in Mississippi (Handley, 1995). Losses were estimated at more than 66% from 1956 to 1992.

In Louisiana, seagrasses have been completely lost in the Mississippi Delta, behind the south coast barrier islands, and in the coastal lakes. Chandeleur Sound, an area that is mostly unaffected by human impacts, is the only part of Louisiana where seagrasses are still present. The lack of seagrasses over

Table 7.—Seagrass cover in the northwestern Gulf of Mexico.

State	Year	Area (ha)	Trends	Source
Alabama (Mobile Bay area)[1]	2002	349	↓ 55–88%	Barry Vittor and Associates, Inc., 2005
Mississippi (Gulf Islands National Seashore)	1992	140	↓ 66%	Handley, 1995
Lousiana (Chandeleur Islands)	1989	5,657	↓ 12%	Handley, 1995
Texas (entire coast)	1994	~94,409		Pulich, 1999
Galveston Bay system		113	↓ 90+%	
Matagorda Bay system		1,551	Unknown	
San Antonio Bay system		4,293	Fluctuates	
Aransas Bay system		3,240	Unknown	
Corpus Christi Bay system (including Redfish Bay)		9,963	Stable	
Laguna Madre system		75,409	Slight decrease	

[1] Includes all submerged aquatic vegetation; seagrasses were not separable, but they represented only a small percentage of all submerged vegetation mapped in the study (Barry Vittor and Associates, Inc. 2005)

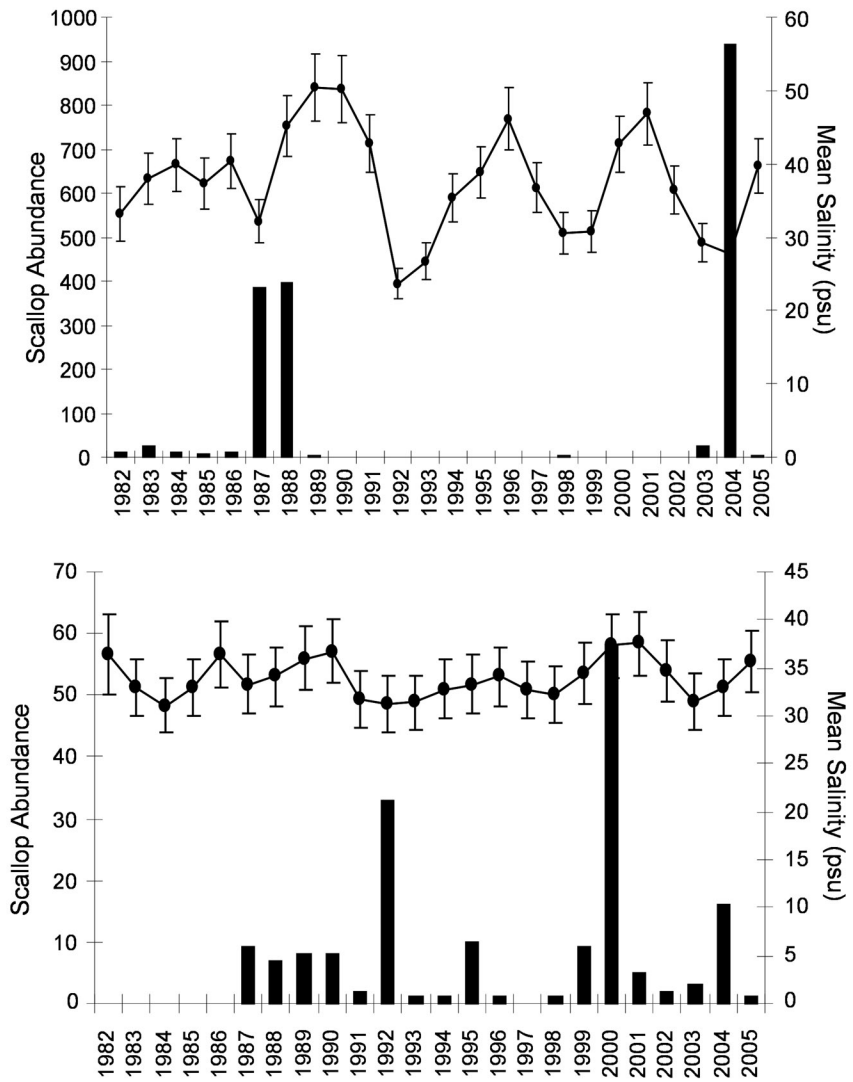

Figure 4.—Overall abundance of bay scallops and mean annual salinity (line) in upper Laguna Madre (top) and lower Laguna Madre (bottom). Trawl and salinity data from Texas Parks and Wildlife fishery independent monitoring program, 1982–2005.

much of the northwestern Gulf, due largely to low average salinities and high turbidity (Handley, 1995), accounts for the lack of scallop records north of Matagorda Bay, Texas.

Another component to add to the complexity of bay scallop abundance patterns in Texas was the persistent and continuous brown-tide bloom in the upper Laguna Madre from 1990–98 (Montagna et al., 1993). The freeze of 1989 and subsequent brown tide have been anecdotally blamed for the absence of bay scallops in the upper Laguna Madre throughout much of the 1990's. Brown tides have plagued New England estuarine complexes since the 1970's and have been implicated in decline of bivalve populations, including the bay scallop (Bricelj and Lonsdale, 1997). The algal blooms affect scallop populations by: 1) reducing the efficiency of filter feeding in adults (Cosper et al., 1989); 2) limiting food sources for larval scallops (Gallager et al., 1989); 3) gamete resorption in reproductive adults (Tracey, 1988); and 4) habitat loss due to increased turbidities (Tettelbach and Wenczel, 1993). Light attenuation from the Texas brown tide had caused a loss of ~940 ha of seagrass cover in the upper Laguna Madre by 1995 (Onuf, 1996) and the bloom continued unabated for another 3 years. Feeding by adult grazers, such as dwarf surfclam, *Mulinia lateralis,* was apparently unaffected by the bloom (Montagna et al., 1993). However, both growth rates and swimming speed were reduced in the larvae of the polychaete *Streblospio benedicti* supporting the hypothesis that reduced populations of benthic organisms were caused by sublethal effects on larvae (Ward et al., 2000).

Although the brown tide may have impacted bay scallop populations in the upper Laguna Madre, they were also absent from other bays that did not experience brown tides during the same period of time (e.g. Corpus Christi Bay, Aransas Bay). In addition, scallops were present in the lower Laguna Madre during nearly every year of the 1990's. It seems just as likely that the absence of bay scallops in the upper Laguna Madre 1991–97 was due to natural variability,

rather than the direct or indirect impacts of the brown tide.

In conclusion, the low and variable abundance of bay scallops in Texas coastal bays and their apparent rarity in the bays along the rest of the northwestern Gulf precludes development of a fishery. In Texas, scallops are most abundant in the Laguna Madre, where seagrass cover is extensive and where salinities generally exceed 35 psu. Boom–bust population cycles are the norm in most bays, but especially in upper Laguna Madre, with booms occurring at intervals of 10–15 years over the last 60 years, based on the available data. This pattern suggests that Texas bay scallops are recruitment limited and that exogenous larval inputs must be very low.

Acknowledgments

We appreciate Clyde MacKenzie's invitation to write this paper, and his willingness to spearhead the effort to thoroughly review the status and trends of bay scallops in North America. Thanks to Jim Tolan of Texas Parks and Wildlife for providing the fisheries-independent data we analyzed for this paper. Wes Tunnell reviewed an early version of the manuscript and his comments helped improve the final product. Clyde MacKenzie and Willis Hobart also provided constructive reviews. The Center for Coastal Studies at Texas A&M University-Corpus Christi provided support to the senior author during the preparation of this manuscript.

Literature Cited

Ambrose, W. G., and E. A. Irlandi. 1992. Height of attachment on seagrass leads to trade-off between growth and survival in the bay scallop *Argopecten irradians*. Mar. Ecol. Prog. Ser. 90:45–51.

Barry Vittor and Associates, Inc. 2005. Historical SAV distribution in the Mobile Bay National Estuary Program area and ranking analysis of potential SAV restoration sites. Mobile Bay Natl. Estuary Prog., Mobile, 13 p.

Bricelj, V. M., and D. J. Lonsdale. 1997. *Aureococcus anophagefferns*: causes and ecological consequences of brown tides in U.S. mid-Atlantic coastal waters. Limnol. Oceanogr. 42:1,023–1,038.

Brock, D. B. 1983. Primary and secondary bay production. *In* L. Byrd and C. Chandler (Editors), Laguna Madre Estuary: a study of the influence of freshwater inflows, chapter VII, p. VII-1–VII-28. Rep. LP-182, Tex. Dep. Water Res., Austin.

Calnan, T. R. 1980. Molluscan distribution in Copano Bay, Texas. Rep. Invest. 103, Bur. Econ. Geol., Univ. Tex., Austin, 71 p.

Campbell, T. N. 1947. The Johnson Site: type site of the Aransas focus of the Texas Coast. Bull. Tex. Archeol. Paleo. Soc. 18:40–75.

Castiglione, M. C. 1983. The distribution and ecology of the molluscs of Corpus Christi Bay, Texas. M.S. thesis, Corpus Christi State Univ., Corpus Christi, 97 p.

Chaney, A. H. 1988. An analysis of nekton and plankton around a shoalgrass bed in the Laguna Madre of Texas. Padre Island Natl. Seashore, Contract # PX7490-7-0009, Corpus Christi, 156 p.

Circé, R. 1979. A seasonal study of seagrass colonization at a dredged material disposal site in upper Laguna Madre, Texas. M.S. thesis, Corpus Christi State Univ., Corpus Christi, 61 p.

Cosper, E. M., E. J. Carpenter, and M. Cottrell. 1989. Primary productivity and growth dynamics of the "brown tide" in Long Island embayments. *In* E. M. Cosper, E. J. Carpenter, and M. Bricelj (Editors), Novel phytoplankton blooms: causes and impacts of recurrent brown tides and other unusual blooms, p. 139–158. Springer Verl., N.Y.

Culbertson, J., L. Robinson, P. Campbell, and L. Butler. 2004. Trends in Texas commercial fishery landings, 1981–2001. Tex. Parks Wild. Dep. Manage. Data Ser. 224, 140 p.

Davidson, J. E. 2002. Effects of propeller scarring on molluscan community structure in seagrass meadows of Redfish Bay, Texas. M.S. thesis, Texas A&M Univ.-Corpus Christi, Corpus Christi, 167 p.

Drumright, A. 1989. Seasonal variation in diversity and abundance of faunal associates of two oyster reefs within a south Texas estuarine complex. M.S. thesis, Corpus Christi State Univ., Corpus Christi, 150 p.

Eckman, J. E. 1987. The role of hydrodynamics in recruitment, growth, and survival in *Argopecten irradians* (Lamark) and *Anomia simplex* (D'Orbigny) within eelgrass meadows. J. Exp. Mar. Biol. Ecol. 106:165–191.

Evermann, B. W., and W. C. Kendall. 1894. The fishes of Texas and the Rio Grande Basin, considered chiefly with reference to their geographic distribution. Bull. U.S. Fish Comm. 12:57–126.

Gagliano, S. M., and R. T. Saucier. 1963. Poverty Point sites in southeastern Louisiana. Am. Antiq. 28:320–327.

Gallager, S. M., D. K. Stoecker, and V. M. Bricelj. 1989. Effects of the brown tide alga on growth, feeding physiology and locomotory behavior of scallop larvae (*Argopecten irradians*). *In* E. M. Cosper, E. J. Carpenter, and M. Bricelj (Editors), Novel phytoplankton blooms: causes and impacts of recurrent brown tides and other unusual blooms, p. 511–541. Springer Verl., N.Y.

Gutsell, J. S. 1930. Natural history of the bay scallop. Bull. U.S. Bur. Fish. 46:569–632.

Handley, L. R. 1995. Seagrass distribution in the northern Gulf of Mexico. *In* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac (Editors), Our living resources: a report to the nation on the distribution, abundance and health of U.S. plants, animals and ecosystems, p. 273–275. U.S. Dep. Inter., Natl. Biol. Serv., Wash., D.C.

Harper, D. E., Jr. 1973a. Fauna of the margins of the Aransas National Wildlife Refuge. *In* Environmental impact assessment of shell dredging in San Antonio Bay, Texas, vol. 5, app, C3-A, p. 43–108. Texas A&M Res. Found., College Station.

_____ . 1973b. The distribution of benthic and nektonic organisms in undredged control areas. *In* Environmental impact assessment of shell dredging in San Antonio Bay, Texas, vol. 3, app, B10-A, p. 1–157. Texas A&M Res. Found., College Station.

Henderson, W. G., L. C. Anderson, and C. R. McGimsey. 2002. Distinguishing natural and archaeological deposits: stratigraphy, taxonomy and taphonomy of Holocene shell-rich accumulations from the Louisiana Chenier Plain. Palaios 17:195–205.

Hester, T. R. 1971. Loyola Beach: an example of aboriginal adaptation to the maritime environment on the lower Texas Coast. Fla. Anthropol. 24(3):91–106.

Hicks, D. 1993. Effects of the December 1989 freeze on seagrasses and associated bivalve mollusca in Laguna Madre. M.S. thesis, Texas A&M Univ.-Corpus Christi, Corpus Christi, 58 p.

Hicks, D. W., C. P. Onuf, and J. W. Tunnell, Jr. 1998. Response of shoal grass, *Halodule wrightii*, to extreme winter conditions in the Lower Laguna Madre, Texas. Aquat. Bot. 62:107–114.

Hildebrand, H., and D. King. 1973. A preliminary biological study of the Cayo del Oso and the Pita Island area of the Laguna Madre: annual report before power plant operation 1972–73. Central Power Light Co., Corpus Christi, Tex., 333 p.

_____ and _____ . 1974. A biological study of the Cayo del Oso and Pita Island area of the Laguna Madre: annual report 1973–74. Central Power Light Co., Corpus Christi, Tex., 233 p.

_____ and _____ . 1975. A biological study of the Cayo del Oso and Pita Island area of the Laguna Madre: annual report 1974–75. Central Power Light Co., Corpus Christi, Tex., unpagin.

_____ and _____ . 1976. A biological study of the Cayo del Oso and Pita Island area of the Laguna Madre: annual report 1975–76. Central Power Light Co., Corpus Christi, Tex., no sequential pg. no.

_____ and _____ . 1977. A biological study of the Cayo del Oso and Pita Island area of the Laguna Madre: annual report 1976–77. Central Power Light Co., Corpus Christi, Tex., no sequential page numbers.

_____ and _____ . 1979. A biological study of the Cayo del Oso and Pita Isalnd area of the Laguna Madre: final report 1972–78. Central Power Light Co., Corpus Christi, Tex., no sequential page numbers.

Holland, J. S., N. J. Maciolek, R. D. Kalke, and C. H. Oppenheimer. 1974. A benthos and plankton study of the Corpus Christi, Copano and Aransas bay systems II; report on data collected during the period July 1973–April 1974. Univ. Tex. Mar. Sci. Inst., Port Aransas, 121 p.

Hubner, M. W. 2007. Recruitment of bay scallops (*Argopecten irradians*) and other byssate bivalves in the upper Laguna Madre, Texas. M.S. thesis, Texas A&M Univ.-Corpus Christi, Corpus Christi, 64 p.

Ladd, H. S. 1951. Brackish-water and marine assemblages of the Texas coast, with special reference to mollusks. Publ. Inst. Mar. Sci., Univ. Tex. 2(1):127–164.

Marshall, N. 1947. An abundance of bay scallops in the absence of eelgrass. Ecology 28:321–322.

Martin, C. 1994. Corpus Christi Bay and La Quinta Channel: a comparison of benthic diversity. M.S. thesis, Texas A&M Univ.-Corpus Christi, Corpus Christi, 81 p.

Martinez-Andrade, F., P. Campbell, and B. Fuls. 2005. Trends in relative abundance and size of selected finfishes and shellfishes along the Texas coast: November 1975–December 2003. Tex. Parks Wild. Dep. Manage. Data Ser. No. 232, Austin, 128 p.

Montagna, P. A. 1993. Comparison of ecosystem structure and function of created and natural seagrass habitats in Laguna Madre, Texas. Univ. Tex. Mar. Sci. Inst. Tech. Rep., TR/93-007, Port Aransas, 72 p.

_____ and C. Martin. 1994. La Quinta Channel environmental monitoring project: benthic diversity. Univ. Tex. Mar. Sci. Inst. Tech. Rep., TR/94-003, Port Aransas, 142 p.

_____ , D. A. Stockwell, and R. D. Kalke. 1993. Dwarf surfclam *Mulinia lateralis* (Say, 1822) populations and feeding during the Texas brown tide event. J. Shellfish Res. 12:433–442.

Newcomb, W. W. 1961. The indians of Texas: from prehistoric to modern times. Univ. Tex. Press, Austin, 440 p.

Onuf, C. P. 1995. Seagrass meadows of the Laguna Madre of Texas. *In* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran and M. J. Mac (Editors), Our living resources: a report to the nation on the distribution, abundance and health of U.S. plants, animals and ecosystems, p. 275–277. U.S. Dep. Inter., Natl. Biol. Serv., Wash., D.C.

_____ . 1996. Seagrass responses to long-term light reduction by brown tide in upper Laguna Madre, Texas: distribution and biomass patterns. Mar. Ecol. Prog. Ser. 138:219–231.

Parker, R. H. 1959. Macro-invertebrate assemblages of central Texas coastal bays and Laguna Madre. Bull. Am. Assoc. Pet. Geol. 43:2100–2166.

Pearce, J. J. 2003. Benthic community relationship to seagrass cover, upper Laguna Madre and Baffin Bay, Texas. M.S. thesis, Texas A&M Univ.-Corpus Christi, Corpus Christi, 131 p.

Peterson, C. H., and H. C. Summerson. 1992. Basin-scale coherence of population dynamics of an exploited marine invertebrate, the bay scallop: implications of recruitment limitation. Mar. Ecol. Prog. Ser. 90:257–272.

Powell, E. N., R. J. Stanton, Jr., H. Cummins, and G. Staff. 1982. Temporal fluctuations in bay enviroments: the death assemblage as a key to the past. *In* J. R. Davis (Editor), Proceedings of the symposium on recent benthological investigations in Texas and adjacent states, p. 203–232. Tex. Acad. Sci., Austin.

Prewitt, E. R., and J. G. Paine. 1987. The Swan Lake Site (41AS16) on Copano Bay, Aransas County, Texas: settlement, subsistence and sea level. Bull. Tex. Arch. Soc. 58:147–174.

Pulich, W., Jr. 1999. Introduction. *In* Seagrass conservation plan for Texas, p. 14–25. Tex. Parks Wild. Dep., PWD BK R0400-041 (4/99), Austin.

Ricklis, R. A. 1987. Archeological investigations at the McKinzie Site (41NU221), Nueces County, Texas: description and contextual interpretations. Bull. Tex. Archeol. Soc. 58: 1–76

_____ . 1993. A model of environmental and human adaptive change on the central Texas coast: geoarchaeological investigations at White's Point, Nueces Bay and surrounding area. Coastal Archaeological Studies, Inc., Corpus Christi.

_____ . 1995. Prehistoric occupation of the central and lower Texas coast: a regional overview. Bull. Tex. Archeol. Soc. 66:265–300

_____ . 1996. The Karankawa Indians of Texas. Univ. Tex. Press, Austin, 222 p.

_____ . 2006. Archeological testing at the McGloin Bluff Site, 41SP11, San Patricio County, Texas. Curr. Archaeol. Tex. 8(1):9–17.

_____ and B. M Albert. 2005. Testing at 41AS5 on Swan Lake, central Texas Coast: a summary of the human-ecological implications. Curr. Archaeol. Tex. 7(1):12–17

_____ and K. A. Cox. 1991. Toward a chronology of adaptive change during the Archaic of the Texas Coastal Bend. La Tierra 18(2):13–31.

Rickner, J. A. 1975. Seasonal variation of selected marine macro-fauna in a seagrass community bordering Stedman Island, Redfish Bay, Texas. M.S. thesis, Texas A&I Univ., Kingsville, 107 p.

_____ . 1979. The influence of dredged material islands in upper Laguna Madre, Texas, on selected seagrasses and macro-benthos. Ph.D. diss., Texas A&M Univ., College Station, 57 p.

Russo, M., and I. R. Quitmyer. 1996. Sedentism in coastal Populations of south Florida. *In* E.J. Reitz, L.A. Newsom, and S.J. Scudder (Editors), Case studies of environmental archaeology, p. 127–147. Plenum Press, N.Y.

Ruth, B. F. 1991. Establishment of estuarine faunal use in a salt marsh creation project, Nueces River Delta, Texas. M.S. thesis, Corpus Christi State Univ., Corpus Christi, 80 p.

Shafer, J. J., and C. L. Bond. 1985 (for 1983). An archeological review of the central Texas coast. Bull. Tex. Archeol. Soc. 54:271–286.

Shidler, J. K. 1960. Preliminary survey of invertebrate species. Tex. Game Fish Comm., Mar. Fish. Div. Job Rept., Proj. MO-1-R-2, Oyster Investigations, Area MO-1, Job B-2b, Austin, 15 p.

Smith, E. J. 1985. Paleoecologic aspects of modern macroinvertebrate communities of southern Laguna Madre, Texas. M. S. thesis, Stephen F. Austin Univ., Nacogdoches, 77 p.

Smith, H. A. 1986. Prehistoric settlement and subsistence patterns of the Baffin Bay area of the lower Texas coast. Ph.D. diss., South. Meth. Univ., Dallas, 173 p.

Steele, D. G. 1987. Utilization of marine mollusks by inhabitants of the Texas coast. Bull. Tex. Archeol. Soc. 58:215–248.

_____ and E. R. Mokry, Jr. 1985 (for 1983). Archeological investigations of seven prehistoric sites along Oso Creek, Nueces County, Texas. Bull. Tex. Archeol. Soc. 54:287–308.

Tettlebach, S. T., and P. Wenczel. 1993. Reseeding efforts and the status of bay scallop *Argopecten irradians* (Lamarck, 1819) populations in New York following the occurrence of "brown tide" algal blooms. J. Shellfish Res. 12:423–431.

TPWD. 2002. Atlantic bay scallop: *Argopecten irradians amplicostatus* fact sheet. Tex. Parks Wild. Dep., Austin, 2 p.

_____ . 2006. Texas Parks and Wildlife outdoor annual hunting and fishing regulations, 2006–2007. Tex. Parks Wild. Dep., Austin, 112 p.

Tracey, G. A. 1988. Feeding reduction, reproductive failure, and mortality in *Mytilus edulis* during the 1985 "brown tide" in Narragansett Bay, Rhode Island. Mar. Ecol. Prog. Ser. 50:73–81.

Ward, L. A., P. A. Montagna, R. D. Kalke, and E. J. Buskey. 2000. Sublethal effects of Texas brown tide on Streblospio benedicti (Polychaeta) larvae. J. Exp. Mar. Biol. Ecol. 248:121–129.

White, W. A., T. R. Calnan, R. A. Morton, R. S. Kimble, T. G. Littleton, J. H. McGowen, and H. S. Nance. 1987. Submerged lands of Texas, Beaumont-Port Arthur area: sediments, geochemistry, benthic macroinvertebrates and associated wetlands. Bur. Econ. Geol., Univ. Tex., Austin, 110 p.

_____ , _____ , _____ , _____ , _____ , _____ , and _____ . 1989a. Submerged lands of Texas, Port Lavaca area: sediments, geochemistry, benthic macroinvertebrates and associated wetlands. Bur. Econ. Geol., Univ. Tex., Austin, 165 p.

_____ , _____ , _____ , _____ , _____ , _____ , and _____ . 1989b. Submerged lands of Texas, Kingsville area: sediments, geochemistry, benthic macroinvertebrates and associated wetlands. Bur. Econ. Geol., Univ. Tex., Austin, 137 p.

_____ , _____ , _____ , _____ , _____ , _____ , _____ , and K. E. Schmedes. 1985. Submerged lands of Texas, Galveston–Houston area: sediments, geochemistry, benthic macroinvertebrates and associated wetlands. Bur. Econ. Geol., Univ. Tex., Austin, 145 p.

_____ , _____ , _____ , _____ , _____ , _____ , and _____ . 1986a. Submerged lands of Texas, Corpus Christi area: sediments, geochemistry, benthic macroinvertebrates and associated wetlands. Bur. Econ. Geol., Univ. Tex., Austin, 154 p.

_____ , _____ , _____ , _____ , _____ , _____ , and _____ . 1986b. Submerged lands of Texas, Brownsville–Harlingen area: sediments, geochemistry, benthic macroinvertebrates and associated wetlands. Bur. Econ. Geol., Univ. Tex., Austin, 138 p.

Wilhite, H. S., T. C. Allison, and J. A. Rickner. 1982. The diversity and distribution of living molluscs in the lower Laguna Madre of Texas. *In* J. R. Davis (Editor), Proceedings of the symposium on recent benthological investigations in Texas and adjacent states, p. 233–247. Tex. Acad. Sci., Austin.

Williamson, C. J. 1980. Population dynamics of molluscs in a seagrass bed surrounding a dredged material island, upper Laguna Madre, Texas. M.S. thesis, Corpus Christi State Univ., Corpus Christi, 81 p.

Zimmerman, R. J., and A. H. Chaney. 1969. Salinity decrease as an affecter of molluscan density levels in a turtle Grass (*Thalassia testudinum* König) bed in Redfish Bay, Texas. TAIUS 2(1):5–10.