**Supporting Information in Support of SI Table 1: Bays and Lagoons**

Most datasets were generated by original authors using either Van Veen grabs or suction excavation of subtidal sediment. Number of stations, samples per station, sedimentary volume per sample, and mesh-size used to extract live and dead individuals varies among authors, as does the number of individuals recovered. However, collection and processing methods were consistent within each study by an author. Most authors provide information on sediment grains size and other physical environmental characteristics for the study area in their published reports, but in most instances raw per-station counts of individuals are unpublished data made available by the author and are used with their permission.

For each study area, station-level data were pooled (aggregated) into habitat-level datasets on the basis of similarity in sediment grain size and presence of vegetation (for categories, see caption 2). This contrasts in many cases with the original authors, who are more like to have grouped stations according to similarity in the living fauna (biofacies), conducted a gradient analysis, or treated the entire area as a unit of analysis.

Human impact was judged from independent (non-molluscan) information discovered in the scientific literature, governmental and non-governmental reports (EPA, UNESCO, environmental impact reports contracted by states, announcements of closures or changes in regulations), and "casual" accounts of environmental conditions and history (fieldcourse descriptions, sport-fishery and boating newsletters, and the web-sites of non-profit interest groups. However, in instances of discrepancy, the expert knowledge of authors of the live-dead data was always deferred to, whenever available via the original report or interview. In instances of discrepancy (rare), inference from the literature tended to underestimate AE relative to expert knowledge by 0.5 or 1 units on the AE scale.

**General information, especially for the Gulf of Mexico:**


Wakida-Kusunoki, A.t. and C.L. MacKenzie, Jr., 2004. *Rangia* and marsh clams, *Rangia cuneata, R. flexuosa*, and *Polymesoda caroliniana*, in Eastern Mexico: distribution, biology and ecoogy, and historical fisheries. Marine Fisheries Review 66 (3): 13-xx [Alvarado]

MacKenzie, C.L, Jr,, and A.T. Wakida-Kusunoki, 1997. The oyster industry of eastern Mexico. Marine Fisheries Review 59(3): xx-xx

Contreras-Espinosa, F. and BG Warner, 2004. Ecosystem characteristics and management considerations for coastal wetlands in Mexico. Hydrobiologia 511:233-245.

Pulich, Jr., W. (ed.). 1999. <u>Seagrass Conservation Plan for Texas</u>. Publ. by Resource Protection Division, Texas Parks & Wildlife Dept., Austin, TX with Texas Natural Resources Conservation Commission and Texas General Land Office. 79 p. (AKA = Pulich, Jr. W., Dunton, K. H., Roberts, L. R., Calnan, T., Lester, J., and McKinney, L. D. 1999. Seagrass conservation plan for Texas. Austin, Texas, Texas Parks and Wildlife.)


**Study areas are organized by AE score per SI Table 1:**

- Study area, date of sampling, and AE score by SK (S. Kidwell)
- L-D data = source of raw data on live and dead numerical abundances of species
- Sed facies data = source of sediment grain size and seafloor vegetation data
- Full citation of published sources
- Enviro = General characterization of study area; based on sources used for L-D and sediment data unless otherwise noted.

**Study areas scored AE 0 (AE absent or negligible, none suspected; "pristine"):**

**Mugu Lagoon in mid-late 1960s = AE0, none other**

L-D & sed facies data = Warme 1971; Peterson 1972, 1976


Warme, J.E., 1971, Paleoecological aspects of a modern coastal lagoon: University of California Publications in Geological Sciences, v. 87, p. 1-110.

Peterson, C.H., 1972, Species diversity, disturbance and time in the bivalve communities of some California lagoons [Ph.D. thesis]: Santa Barbara, University of California, 230 p.

Peterson, C.H., 1976, Relative abundance of living and dead molluscs in two California lagoons: Lethaia, v. 9, p. 137-148.

Enviro =Protected as a natural area by the US Navy, and characterized explicitly as pristine by Peterson (1972) and by JE Warme pers comm. May 2007. Surrounding agriculture at that time was commercial but relatively small-scale compared to the present day.

**Islas Cancun and Contoy, NE Yucatan in 1971 = AE0, none other**

L-D & sed facies data = Ekdale 1972 for quant data table, 1974, 1976, 1977; Warme et al. 1976

Ekdale, A.A., 1972, Ecology and paleoecology of marine invertebrate communities in calcareous substrates, northeast Quintana Roo, Mexico [M.S. thesis]: Houston, Rice University, 159 p.

Ekdale, A.A., 1977, Quantitative paleoecological aspects of modern marine mollusk distribution, northeast Yucatan coast, Mexico: in Frost, S.H., Weiss, M.P., and Sauders, J.B., eds., American Association of Petroleum Geologists, Studies in Geology, v. 4, p. 195-207.

Ekdale, A. A. 1974. Marine molluscs from shallow water environments (0 to 60 metres) off the northeast Yucatan coast, Mexico. Bulletin of Marine Science 24:638-668.

Warme, J.E., Ekdale, A.A., Ekdale, S.R. and Peterson, C.H., 1976, Raw material of the fossil record, p. 143-169 in Structure and Classification of Paleocommunities, R. Scott and R. West (eds.): Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, 291 p.

Enviro =Mangrove rimmed very shallow lagoons behind sandy barrier beaches close to mainland Yucatan peninsula (Cancun) and on the lee-side of a mid-shelfxx island (Contoy). Both areas were very isolated at the time of sampling, with few residents, no tourists, and only a few fishermen ever seen, using artisanal methods (pers comm. A.A. Ekdale 2006).

**Mannin Bay in 1972 = AE0, none other**

L-D data = Bosence 1979b sample by sample rel abund data available from British Library as Brit. Lib. SUP Publ no. 14012 (supplementary material to Bosence 1979 article in Palaeontology, cited in Bosence 1979a; based on 1976 dissertation Univ Reading (not examined))

Sed facies data = Bosence 1979 a for facies assignments of samples; Gunatilaka 1977 for physical environment & lithologic data, broader perspective; Bosence 1978

Bosence, D.W.J., 1979a, Live and dead faunas from coralline algal gravels, Co. Galway, Eire: Palaeontology, v. 22, p. 449-478.

Bosence, D.W.J., 1979b, Supplemental Publication No. SUP 14012 (1979), British Library, Boston Spa, Wetherby, Yorkshire, LS23 7BQ, U.K.

Gunatilaka, A., 1977. Recent carbonate sedimentation in Connemara, western Ireland. Estuarine and Coastal Marine Science 5: 609-629.

Comment by Bosence & Reply by Gunatilaka in 1978 Est. Coatal Mar Sci 7: 303-306.

Enviro =V-shaped re-entrant of the rocky western coast of Ireland, protected from prevailing waves & currents by rocky reefs; bay floored by banks and meadows of red-algae and seagrass, with areas of algal-gravelly sands and muddy gravels; innermost reaches muddy. Low dispersed human population, subsistence or local-market agriculture and fishing at the time. Still a quite pristine drainage area now, but bay used for (organic) salmon aquaculture (web 2007).

**Doboy Sound in 1977-78 = AE0, SFm**

L-D & sed facies data = Henderson & Frey 1986, Appendix I

Henderson, S.W., and Frey, R.W., 1986, Taphonomic redistribution of mollusk shells in a tidal inlet channel, Sapelo Island, Georgia: Palaios, v. 1, p. 3-16.

Enviro =Intense shrimp-trawling on adjacent shelf (NRC 2002) and in the Sound itself but not in the narrow inlet channel where samples were taken (SW Henderson May 2007). Sound was a major lumber port in the $19^{th}$ century; ballast rocks along the channel plus oyster reefs that are are probably produced by boat wake (Henderson pers comm. May 2007). No major towns or coastal industry now to increase nutrient runoff significantly.

**Laguna LaMancha in 1978 = AE0, SFa**

L-D data = Reguero 1994

Sed facies data = Flores-Andolais et al. 1988

Reguero Reza, M.M., 1994, Estructura de la comunidad de moluscos en lagunas costeras de Veracruz y Tabasco, Mexico [PhD. Thesis]: Ciudad Universitaria, Universidad Nacional Autonoma de Mexico, 280 p.
Flores-Andolais, F., Garcia-Cubas, A., and Toledano-Granados, A., 1988, Sistematica y algunos aspectos ecologicos de los moluscos de la Laguna de la Mancha, Veracruz, Mexico: Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, v. 15(2) , p. 235-258.

Enviro =No major towns or cities, no petrochemical extraction or processing, not used as port ( www.gulfbase.org/bay/view.php?bid=lpv); subsistence (non-commercial) agriculture, and artisanal fishing for local markets. Site of an OTS course owing to biodiversity and relatively undisturbed nature (www.ecologia.edu.mx/ots/OT52003/contenido.pdf).
M. Reguero Pers. Comm. May 2007 = significant coliform bacteria now, but very clear when sampled; AE0

**Smuggler's Bay in 1979-1980** = AE0, none
L-D & sed facies data = Miller 1988, and data in unpublished MS thesis 1981; details on timing of sampling/censuses per email exchange with AI Miller July 5-2002
Miller, A.I., 1988, Spatial resolution in subfossil molluscan remains: implications for paleobiological analyses: Paleobiology, v. 14, p. 91-103.
Miller, A.I., 1981, Gradients in nearshore marine mollsucan assemblages: Smuggler's Cove, St. Croix, U.S. Virgin Islands [M.S. thesis]: Blacksburg, Virginia Polytechnic Institute and State University, 156 p.

Enviro =Back-reef area of dense seagrass declining in density landward into non-vegetated silty sand. Site at the time of sampling of a university research station and scattered vacation/retirees homes, and thus fairly pristine, but subject to decadal scale variations in precipitation and runoff which might result in variations in sediment/nutrient input or even salinity (AI Miller pers comm. May 2007). Like other Caribbean islands, large-fish stocks were almost certainly strongly depleted by this time (Jackson et al. 2001).

**Laguna Madre, Texas in early 1980s = AE0, Dr, Sal**
L-D & sed facies data = sampling of facies throughout the Laguna = Smith M.S. thesis Stephen Austin State Univesity, 1985; pers comms 2000; repeated sampling of single station = Staff et al. 1985, 1986; Diss has full data
Sed facies data = Brown et al. 1977, 1980 for enviro descriptions
Smith, E.J., 1985, Paleoecologic aspects of modern macroinvertebrate communities of southern Laguna Madre, Texas [M.S. thesis]: Nacogdoches, Texas, Stephen F. Austin State University, 79 p.
Staff, George M. 1983. The nature of information loss in the paleoecological reconstruction of benthic macrofaunal communities using faunal assemblages from the recent Texas coastal environment. Thesis (Ph. D.; Geology)--Texas A&M University, 211 p.
Staff, G.M., Stanton, R.J., Jr., Powell, E.N., and Cummins, H., 1986, Time averaging, taphonomy and their impact on paleeocommunity reconstruction: death assemblages in Texas bays: Geological Society of America Bulletin, v. 97, p. 428-443.

Enviro =Back-barrier lagoon in arid-subarid setting, with only low-level animal husbandry and small dispersed human population. Northern and southern halves of the lagoon were connected by dredging a channel across the "Land Cut" for the intracoastal waterway , completed in 1950. Salinity has been stabilized since, but the northern half still tends to hypersalinity. Biennial dredging of the Intracoastal waterway results in local dumping of spoils, keeping mud in suspension almost continuously. Both Smith and Staff took care to sample away from spoil-dumping areas. Nutrient runoff from urban and industrial sources has become a problem in the southern end of the Laguna near the international border, as have reductions in seagrass cover and change in grass species throughout the Laguna (non-specified cause: Onuf web biology.usgs.gov/s+t/noframe/m4145.htm#21543), but this was not a notable issue in the early 1980s. Seagrass subject to major fluctuations: seagrass area has mostly increased in the northern LM because less problem with hypersalinity, and has decreased in southern LM from dredging (bareground increased 280% from 1967 to 1988; Quammen and Onuf 1993, Pulich 1999).
Quammen, ML and CP Onuf, 1993. Laguna Madre: seagrass changes continue decades after salinity reduction. Estuaries 16: 302-310.
Pulich chapter in Pulich, Jr., W. (ed.). 1999. *Seagrass Conservation Plan for Texas*. Publ. by Resource Protection Division, Texas Parks & Wildlife Dept., Austin, TX with Texas Natural Resources Conservation Commission and Texas General Land Office. 79 p.

**Mljet Island in 1990s = AE0, none**

L-D & sed facies data = M. Peharda, MS thesis 2000; data actually acquired from pers comm. ms in review Peharda et al.

Peharda, M., 2000, Bivalves (Mollusca, Bivalvia) in Malo jezero on island of Mljet [M.Sc. thesis]: University of Zagreb, Croatia, 87 p.

Peharda M, Hrs-Brenko M, Bogner D, Lucic D, Onofri V, Benovic A 2002. Spatial distribution of live and dead bivalves in saltwater lake Malo jezero (Mljet National park). Periodicum Biologorum 104 (2): 115-122

Enviro =saline "lake" connected to the Adriatic Sea via a narrow inlet, enclosed by a national park; small dispersed human population, no major industry along shore

**Study areas scored AE 0.5 (mild AE suspected given conditions in drainage area):**

**Tomales Bay in 1959 = AE0.5, SFm (oysters), Tox**

L-D & sed facies data = Johnson 1965 J Paleo; Johnson 1965 unpub AEC report for Time station data; Smith undated data sheets for 1957-1959 stations (spp abund's); Juskevice 1969 diss for general info; SK interview of Ed Smith @ Cal Academy Dec 2000

Johnson, R.G.,1965, Pelecypod death assemblages in Tomales Bay, California: Journal Paleontology, v. 39, p. 80-85.

Johnson, R.G., unpublished data for 1959 sampling program in Tomales Bay. "Smith, E.H., no date. 1959 Samples, Tomales Bay, 1-59 and 2-59 Compiled Data. Univ of Pacific, Pacific Marine Station." Archived by Department of Invertebrate Zoology and Geology, California Academy of Sciences.

Juskevice, J.A., 1969, Interspecific correlation and association in benthic marine communities [Ph.D. thesis]: Chicago, University of Chicago, 87 p.

Enviro =In the late 19th century, the town of Tomales grew to a population of 2,000 with extensive potato farming and silting of the lagoon; dairies operated in the immediate drainage area up through the time of sampling; mercury ore mining further upstream . However, the Bay had healthy (commercially exploited) oysters and extensive seagrass beds when sampled for live-dead by Johnson, suggesting that any AE was at most boosting the productivity of existing communities.

http://www.tomalesbaywatershed.org/stewardship_framework.pdf
www.nps.gov/pore/historyculture/people_ranching.htm
http://cemarin.ucdavis.edu/newsletterfiles/Grown_in_Marin_Newsletters8379.pdf

**Tijuana Slough in 1969-71** = AE0.5, SFa (bait)

L-D & sed facies data = Peterson 1972, 1976

Peterson, C.H., 1972, Species diversity, disturbance and time in the bivalve communities of some California lagoons [Ph.D. thesis]: Santa Barbara, University of California, 230 p.

Peterson, C.H., 1976, Relative abundance of living and dead molluscs in two California lagoons: Lethaia, v. 9, p. 137-148.

Enviro =Peterson did not mention nutrient enrichment problems in his dissertation, but this small lagoon receives runoff from San Diego suburb and thus some AE possible. Subject to intense bait-hunting at the time (for bivalve *Cryptomya*) by people walking out onto the flats.

**Study areas scored AE 1 (definitely AE but diffuse or mild; study area not adjacent to a significant point source):**

**Hamana Lake in 1956 = AE1.5, Sal, SFa**

L-D & sed facies data = Tsuchi 1957

Tsuchi, R., 1957, Molluscs and shell remains in the brackish Lake Hamana, the Pacific coast of central Japan: Reports of Liberal Arts and Science Faculty, Shizuoka University (Natural Science), v. 2, no. 1, p. 29-37.

Enviro =shallow lagoon connected to the Pacific Ocean via a narrow sandy inlet owing to a tsunami in the 16th century (www.jnto.go.jp/eng/location/regional/shizuoka/hamanako.html). In 1956 when sampled by Tsuchi (1957), inlet was still natural and characterized by sand-bars; the deepest (12 m) most-inland reaches were floored with seasonally anoxic black muds, and the shallower sandy southern areas only 1-3m deep. Sedimentary core analysis by Itoh et al (2003) indicates that anoxia has existed in the lake over at least the last 250 years (210-Pb dating), but the productivity increased after 1860 (SK=significant AE); trends changed significantly in the 1950s after training walls were built at the inlet (1954-56) to the Pacific Ocean to increase flow into the lake, improving circulation (reducing anoxia) and increasing salinity. Tsuchi sampled in 1956 when this major change would have been underway , but he neither mentions nor illustrates these walls and environmental changes (or ongoing construction) in his report. Anoxia is now much shallower (Itoh et al. 2003) and the eastern part is a resort opened in the mid-20$^{th}$ century (www.jnto.go.jp/eng/location/regional/shizuoka/hamanako.html). Waters now clear (op cit), but long history as fishing aera; 30% drainage area was agricultural (oranges, stock) and 20% was residential in1972 (www.ilec.or.jp/database/asi/asi-44.html)

Itoh, N. Y. Tani, T. Nagatani, and M Soma, 2003. Photorophic activity and redox condition in Lake Hamana, Japan, indiated by sedimentary photosynthetic pigments and molybdenum over the last ~250 years. J Paleolimnology 29: 403-422.

SK Note = thus long-standing AE at the time of Tsuchi's sampling in 1956, but new anthropogenic modification of salinity. The black muds from the heads of the 2 arms of the lake, and the sands at the mouth of the Lake, both show high Jaccard-Chao (0.7) and positive Spearman rho values (0.1, 0.3); these species lists show no evidence of mixing of salinity. Intervening muddy sand facies where condensation of low- and high-salinity faunas might occur is too small to include in the analysis (live N =18) but has J-C =0.2 and rho = -0.06; the living community does include (saline) *Anadara* and *Fabulina* whichare absent from the death assemblage.

**Chesapeake Bay in 1966** = AE1, SFm (oysters)

L-D & sed facies data = Jackson 1968

Jackson, J.B.C., 1968, Neontological and paleontological study of the autecology and synecology of the molluscan fauna of Fleets Bay, Virginia [M.S. thesis]: Washington, D.C., George Washington University, 111p.

Enviro =Sampling was during early stage of post-WWII ramp-up of fertlizer runoff to the Bay and increasing sediment TOC, but AE present for 150-200 years (Kemp et al. 2005) and commercial oyster fishing had crashed in the 1920s (Rothschild et al. 1994, Kirby 2004, Kirby and Miller 2005). Eelgrass was still a significant habitat, at least in the sandy nearshore area of shallow Fleets Bay (Virginia) when sampled by Jackson, although generally seagrass started becoming severely depleted in the 1950s (Kemp et al. 2005).

Kemp WM, Boynton WR, Adolf JE, Boesch DF, Boicourt WC, Brush G, Cornwell JC, Fisher TR, Glibert PM, Hagy JD, Harding LW, Houde ED, Kimmel DG, Miller WD, Newell RIE, Roman MR, Smith EM, Stevenson JC, 2005. Eutrophication of Chesapeake Bay: historical trends and ecological interactions. Mar Ecol Prog Ser 303: 1-29

Kirby MX 2004. Fishing down the coast: Historical expansion and collapse of oyster fisheries along continental margins. Proc. Nat. Acad. Sci. U.S.A. 101 (35): 13096-13099.

Kirby MX, Miller HM (2005) Response of a benthic suspension feeder (Crassostrea virginica Gmelin) to three centuries of anthropogenic eutrophication in Chesapeake Bay. Estuar Coast Shelf Sci 62:679–689

Rothschild BJ, Ault JS, Goulletquer P, Heral M (1994) Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing. Mar Ecol Prog Ser 111:29–39

**Chesapeake Bay in 2003 = AE1, SFm (oysters)**

SK Note = The Chesapeake Bay study of Lockwood and Chastant (2006) is too new to be included in this meta-analysis (raw data are not yet released for re-analysis). Their similarity measures were "% live species also present dead" and "% dead species also present alive", which are uncorrected for sample-size differences and cannot be directly compared to J-C used here. They compared species rank-order abundance using Spearman tests, as here. However, their comparison of the 2002 death assemblage with the 2002 living community is based on pooling live and dead individuals from four stations that span a range of sediment types (2 sites contain >92% mud ("mud" here), whereas 2 sites contain <2% mud but unspecified dominant grain size) and salinity regimes. This pooling procedure is not comparable to other datasets included here. Live-dead agreement, however, is clearly very good, qualitatively, for an AE1 setting, probably because of the long-standing anthropogenic modification in the estuary (their published Spearman rho = 0.68). Hypoxia became chronic and seagrass depletion severe in the Chesapeake Bay ~50 years ago, following depletion of the oyster shellfishery and a marked rise in anthropogenic nutrient input, and AE became detectable ~200 years ago (Kemp et al. 2005, Rothschild et al. 1994, Kirby 2004, Kirby and Miller 2005).

Lockwood, R. and L.R. Chastant, 2006 Quantifying taphonomic bias of fompositional fidelity, species richness, and rank abundance in molluscan death assemblages from the upper Chesapeake Bay. Palaios 21 (4): 376-383.
Kemp WM, Boynton WR, Adolf JE, Boesch DF, Boicourt WC, Brush G, Cornwell JC, Fisher TR, Glibert PM, Hagy JD, Harding LW, Houde ED, Kimmel DG, Miller WD, Newell RIE, Roman MR, Smith EM, Stevenson JC, 2005. Eutrophication of Chesapeake Bay: historical trends and ecological interactions. Mar Ecol Prog Ser 303: 1-29
Kirby MX 2004. Fishing down the coast: Historical expansion and collapse of oyster fisheries along continental margins. Proc. Nat. Acad. Sci. U.S.A. 101 (35): 13096-13099.
Kirby MX, Miller HM (2005) Response of a benthic suspension feeder (Crassostrea virginica Gmelin) to three centuries of anthropogenic eutrophication in Chesapeake Bay. Estuar Coast Shelf Sci 62:679–689
Rothschild BJ, Ault JS, Goulletquer P, Heral M (1994) Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing. Mar Ecol Prog Ser 111:29–39

**West Bay in the mid 1970s = AE1, Dr, (no SFm (oysters)?)**

L-D & sed facies data = White et al. 1985, unpublished lab sheets for by-station live and dead counts

White, W.A., Calnan, T.R., Morton, R.A., Kimble, R.S., Littleton, T.G., McGowen, J.H., Nance, H.S., and Schmedes, K.E.,1985, Submerged lands of Texas, Galveston-Houston area : sediments, geochemistry, benthic macroinvertebrates, and associated wetlands. Austin, Texas: Bureau of Economic Geology, University of Texas at Austin

Enviro =Immediate drainage area was increasingly developed for residential use, but West Bay has good exchange with the Gulf of Mexico and known for being grassier than other bays in the Galveston complex (White et al. 1985, others). However, mixed beds of shoalgrass (Halodule wrightii) and widgeongrass (Ruppia maritima) have declined steadily in West Bay since the 1950's and by 1987 major beds were no longer present (Pulich and White 1991). In the western portion of the Galveston Bay Estuary, seagrass acreage declined from 2200 acres in 1956 to zero in 1989. Most of these seagrass meadows, primarily *Halodule wrightii*, grew along the barrier island edges of western West Bay often supporting faunal densities much greater than those found in bare sand or mud habitats. The only remaining seagrass beds, about 89 acres still in existence, are found in Christmas Bay, a partially isolated embayment adjoining the western end of West Bay. Seagrass loss in this region has been attributed primarily to dredging channels through the beds to waterfront properties and disposal of the dredged material either on or near adjacent beds (http://www.coastalamerica.gov/text/pubs/techtransfer/crp_s2d.html). Oyster production has been limited since at least the 1920s, apparently, owing to restricted flow (construction of the Texas City Dike at thte eastern end (discussion in Powell et al. 1995).

Powell, E. N., J. Song, M. S. Ellis & E. A. Wilson-Ormond. 1995. The status and long-term trends of oyster reefs in Galveston Bay, Texas. J. Shellfish Res. 14:439-457.
Pulich, Jr., W. M. and William A. White. 1991. Decline of submerged vegetation in the Galveston Bay system: Chronology and relationships to physical processes. Journal of Coastal Research 7 (4): 1125-1138.

**Copano Bay in 1976-82 = AE1 (initially scored as AE 1.5 due to reports of oil-soaked sediment in western Bay, but changed to AE1 because of discovery that the State of Texas continued to permit oyster harvesting), SFm (oysters), Tox**

L-D & sed facies data = sampling of many stations and habitats throughout Bay by Calnan, TR 1980; repeated sampling of single station by Staff 1983, Staff et al 1986

Sed facies data = supplemented with Ladd et al. 1957

Calnan, T.R., 1980, Molluscan distribution in Copano Bay, Texas: University of Texas at Austin, Bureau Econonomic Geology, Report Investigations No. 103, 71 p.
Ladd, H.S., Hedgpeth, J.W, and Post, R., 1957, Environments and facies of existing bays on the central Texas coast: Geological Society of America Memoir, No. 67, p. 599-640.
Staff, George M. 1983. The nature of information loss in the paleoecological reconstruction of benthic macrofaunal communities using faunal assemblages from the recent Texas coastal environment. Thesis (Ph. D.; Geology)--Texas A&M University, 211 p.
Staff, G.M., Stanton, R.J., Jr., Powell, E.N., and Cummins, H., 1986, Time averaging, taphonomy and their impact on paleocommunity reconstruction: death assemblages in Texas bays: Geological Society of America Bulletin, v. 97, p. 428-443.

Enviro =Reports in the 1960s that sediment was soaked with oil from local refineries (http://coastal.tamug.edu/CoastalFisheries/1961-1962/CoastalFisheries1961-1962-Spears06.pdf); Ladd et al. 1957 indicate oil drilling operations began between their faunal sampling in 1940 and the 1957 publication and have quite possibly changed the fauna. Calnan 1980 summarizes older literature reporting higher (normal marine) salinities in the 1940s and 1950s with Ostrea equestris alive in the Bay, although in the 1970s only *Crassostrea virginica* occupied the Bay (natural salinity changes of natural origin, linked to precipitation patterns). Copano is considered to be among the middle-upper coast Texas bays that in general tend to have scarce seagrass owing to high precipitation, resulting low salinity intervals, plus turbidity (unattributed cause of turbidity); lack *Thalassia*, tend to have annual widgeongrass *Ruppia maritima* and perennial *Halodule* shoalgrass (Pulich in Pulich 1999).

Pulich, Jr., W. (ed.). 1999. *Seagrass Conservation Plan for Texas*. Publ. by Resource Protection Division, Texas Parks & Wildlife Dept., Austin, TX with Texas Natural Resources Conservation Commission and Texas General Land Office. 79 p.

**Lagunas Carmen and Machona in 1979 = AE1, Sal, SFa (mollusks), Tox, Dr**

L-D data =Reguero 1994

Sed facies data = original total & sed map from Antoli & Garcia Cubas 1985, who cite Gutierrez-Estrada & Galaviz Solis, 1983 for original sed data

Reguero Reza, M.M., 1994, Estructura de la comunidad de moluscos en lagunas costeras de Veracruz y Tabasco, Mexico [PhD. Thesis]: Ciudad Universitaria, Universidad Nacional Autonoma de Mexico, 280 p.

Antoli, V., and Garcia Cubas, A., 1985, Sistematica y ecologia de moluscos en las lagunas coasteras Carmen y Machona, Tabasco, Mexico: Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, v. 12(1), p. 145-198.

Enviro =(based on citations below): Opening of the artificial inlet between Machona and the Gulf is the focus of greatest concern by environmental groups (including litigation): opened to improve the salinity for a declining oyster fishery, the initial opening expanded under natural processes to become 1 km wide within a few years, causing salinization of former pasturelands around Carmen and transformation to unusable mangrove forests. A great deal of dredging associated with PEMEX operations between 1965 and 1972 http://archive.greenpeace.org/comms/mexico/rwlagoon.html). Botello et al. (1983) say that despite industry, hydrocarbon values in the sediments are not above what would be considered unpolluted; attribute this to a high rate of natural weathering [oxidation], owing to dynamic hydrology.

However, M. Reguero Pers. Comm. May & June 2007 says it is not completely free of organic contaminants, with organic rubbish, black water and runoff from fertilized areas during rains, plus heavy metal toxins, and thus considers it to be AE1. Also, although the opening of the artificial inlet acted against eutrophication, there remains a great quantity of suspended material from dredging, which also existed at the time of sampling.

October 2006 http://www.gulfbase.org/bay/view.php?bid=laguna4

Bottello, AV, EF Mandelli, S Macko, and PL Parker, 1980. Organic carbon isotope ratios of Recent sediments from coastal lagoons of the Gulf of Mexico, Mexico. Geochimica et cosmochimica Acta 44: 557-559.

Archive.greenpeace.org/comms/mexico/rwlagoon.html → salinization due to Panteones sandbar; plus much dredging by PEMEX and petrochemical pollution

A. V. Botello, J. A. Goñi and S. A. Castro, 1983. Levels of organic pollution in coastal lagoons of Tabasco state, Mexico; I: Petroleum hydrocarbons. Bulletin of Environmental Contamination and Toxicology 31 93): 271-277.

Mercury citations from M. Reguero Pers. Comm. = (Botello *et. al*., 1976; Hicks, 1976; INGGO, 1980; Pérez-Zapata, 1981; Rosas, 1983).

BOTELLO V., A., CASTRO A., S., y DE LA TORRE P., A., 1981.Niveles actuales de hidrocarburos disueltos en los sistemas lagunares del estado de Tabasco, México. Informe final. ICMyL, UNAM. México, 20 p.

**Laguna Mandinga-Larga in 1980 = AE1 (SK initially assumed AE0), SFa, Tox**

L-D & sed facies data = Reguero & Cubas-Garcia 1993(1994)

Reguero, M., and Garcia-Cubas, A., 1993 (1994), Moluscos del complejo lagunar Larga-Redonda-Mandinga, Veracruz, Mexico: sistematica y ecologia: Hidrobiologica (Revista del Departamento de Hidrobiologia, Univ. Autonoma Metropolitana-Iztapalapa), v. 3 (1-2), p. 41-70.

Enviro = www.gulfbase.org/bay/view.php?bid=lpv → no information re possible AE.

M. Reguero Pers. Comm. May 2007 = associated with the Rio Jamapa, which receives input from 3 other rivers and the port of Veracruz; very serious problem with the quantity of rubbish from surrounding settlements, with tourist activity increasing. These were not serious factors at the time of sampling, but the lagoon was still significantly influenced then by domestic organics and coliform bacteria, thus AE1. Elevated Mercury from industries along Blanco and Jamapa rivers were also a factor at the time of sampling (Botello et. al., 1976; Hicks, 1976; Pérez-Zapata, 1981; Villanueva y Botello, 1998. Metal pollution in coastal areas of Mexico. *Rev. Environ. Contam. Toxicol, 157*: 53-94).

**Laguna Sontecomapan in 1980** = AE1 (SK initially scored as AE0), SFa (mollusks)
L-D data = Garcia-Cubas & Reguero 1995
Sed facies data = De la Cruz & Franco 1981; plus Reguero & Garcia-Cubas pers comm Jan 2001
Garcia-Cubas, A, and M Reguero, 1995. Moluscos de la laguna de Sontecomapan, Veracruz, Mexico: sistematica y ecologia. Hidrobiologica (Revista del Departamento de Hidrobiologia, Univ. Autonoma Metropolitana-Iztapalapa) 5(1-2): 1-24.
De la Cruz & Franco 1981 xx

Enviro = "The area is free of oil exploitation complexes, chemical plants or industrial operations. In the seventies, the Sontecomapan was considered one of the richest mangrove vegetation zones in the country and a highly productive lagoon." October 2006 http://www.gulfbase.org/bay/view.php?bid=laguna9 → thus not AE2

M. Reguero Pers. Comm. May 2007 = elevated levels of heavy metals now (Enrique Portilla Ochoa, Instituto de Investigaciones Biológicas, Universidad Veracruzana, *Conferencia "Lagunas costeras de Veracruz"*, 2005. pdf), but not at the time of sampling. Lagoon had high productivity and clear waters at the time of sampling, but received considerable organic debris and thus would consider it AE1.

**Laguna Chica-Grande in 1980 = AE1, SFa (mollusks)**
L-D data = Garcia-Cubas et al. 1992
Sed facies data = Reguero & Garcia-Cubas pers comm Jan 2001
Garcia-Cubas, A., Reguero, M., and Elizarraras, R., 1992, Moluscos del sistema lagunar Chica-Grande, Veracruz, Mexico: sistematica y ecologia: Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, v. 19(1), p. 1-121.

Enviro = M. Reguero Pers. Comm. May 2007 = no formal study of contamination, supports a high diversity of fish and crustacean, but receives human and animal wastes from surrounding settlements, so would consider to be AE1.

**Laguna Camaronera in 1980 = AE1, SFa (mollusks)**
L-D data = Reguero & Garcia Cubas, 1991
Sed facies data = Rosales-Hoz et al. 1986 on sed/hydrography; also Reguero & Garcia-Cubas 1989, Raz-Guzman et al. 1992 sed/hydro
Reguero, M and A Garcia-Cubas, 1991. Moluscos de la Laguna Camaronera, Veracruz, Mexico: sistematica y ecologia. Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, 18(1): 1-23.
Regeuero, M, and A Garcia-Cubas, 1989. Moluscos de la Laguna de Alvarado, Veracruz: sistematica y ecologia. Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, 16(2): 279-306.
Raz-Guzman, A., G. de la Lanza, and LA Soto, 1992. Caracterizacion ambiental y 13C del sedimiento, detrito y vegetacion del sistema lagunar de Alvarado, Veracruz, Mexico. Revista de Biologia Tropical 40(2): 25-225.

Enviro = "scarce waste management" per www.gulfbase.org/bay/view.php?bid=lpv . According to Botello et al. (1980), Alvarado [by which Camaronero connects to the Gulf] has "normal C isotopes", contrary to Pueblo Viejo & Tampamachoco.

M. Reguero Pers. Comm. May 2007 = part of a large complex lagoon influenced by the Río Papaloapan. Areas most affected by human pollution are around the Port and city of Alvarado, at the mouth of the complex. Camaronera is a cul-de-sac of this system, registers pesticides and coliform bacteria, considers to be AE1.

Bottello, AV, EF Mandelli, S Macko, and PL Parker, 1980. Organic carbon isotope ratios of Recent sediments from coastal lagoons of the Gulf of Mexico, Mexico. Geochimica et cosmochimica Acta 44: 557-559

**Study areas scored AE 1.5 (definitely mild AE, and severe AE suspected):**

**East and Galveston Bays in 1976 = AE1.5, Tox, SFm (oysters), Dr**

L-D & sed facies data = White et al. 1985, unpublished lab sheets with by-station raw counts of live and dead

White, W.A., Calnan, T.R., Morton, R.A., Kimble, R.S., Littleton, T.G., McGowen, J.H., Nance, H.S., and Schmedes, K.E. 1985, Submerged lands of Texas, Galveston-Houston area : sediments, geochemistry, benthic macroinvertebrates, and associated wetlands. Austin, Texas: Bureau of Economic Geology, University of Texas at Austin

Enviro =Galveston Bay certainly mildly AE (AE1) but possibly severely AE in the mid-1970s (surveys of White et al.), given urbanization and petrochemical industry in the immediate drainage area (Houston, Galveston, Texas City). The estuary has been a port for 150 years and area of petrochemical refining for 100 years (http://www.houstonhistory.com). East Bay probably in better shape than Galveston Bay sensu stricto, given greater proximity to opening to Gulf, but owing to lack of obvious natural break point between the two areas and the sampling grid of White et al., stations in the two regions were pooled into single set of habitat-level datasets (versus West Bay, which was kept distinct; has an additional opening to the Gulf and is not an active port). Pulich chapter in Pulich 1999 = seagrasses in upper-coast bays of Texas tend to have scarce seagrass owing to high precipitation, resulting low salinity intervals, plus turbidity (unattributed cause of turbidity); lack *Thalassia*, tend to have annual widgeongrass *Ruppia maritima* and perennial *Halodule* shoalgrass. In Galveston Bay, practically all grass has been lost since the late 1970s, based on 40-50 years of historical data and aerial photography, but anecdotal reports that it was more abundant ~1900. These declines have been attributed to subsidence from groundwater extraction, hurricanes, dredging, and, by Pulich & White 1991, nutrients. Also Leslie Williams –Restoration SpecialistGalveston Bay Foundation (http://www.galvbay.org/resources/upload/Seagrass.pdf) = approximately 70 – 86 % of seagrass in Galveston Bay has been lost since the 1980's (GBNEP 1994); only 700 acres remain, almost half of which are in Christmas Bay. Long history of bottom dredging for shells (http://gbic.tamug.edu/gbeppubs/28/gbnep_28_07-10.pdf) in the Galveston system, which apparently ceased in the early 1970s (implication of Powell et al. 1995); dumping of shells to mitigate for this has created artificial oyster reefs in Trinitiy Bay (Powell et al. 1995). Commercial oystering in the Galveston-East Bay system has a long history, with the first laws regulating it in the 1950s (Kirby 2004). Commercial activity increased in the 1950s owing to improvements in circulation caused by deepening of the Houston Ship Channel, which allowed the 15‰ isohaline to penetrate much further up-estuary, and reef area has increased since 1970 in the upper estuary on spoil heaps along the improved flow of this artificial channel (Powell et al. 1995). However, landings peaked in 1983, followed by rapid decline (attributed to over-exploitation, Kirby 2004).

Study of the Oyster Population on Public Reefs in Galveston Bay during 1966 Project: MO-R-8 (R. P. Hofstetter) http://coastal.tamug.edu/CoastalFisheries/1966/CoastalFisheries1966-pg069.pdf = East, Trinity and Galveston bay have public-access oyster-dredging; problems with dermo, and with spring-runoff freshening in Trinity bay. No mention of public health issues

Kirby MX 2004. Fishing down the coast: Historical expansion and collapse of oyster fisheries along continental margins. Proc. Nat. Acad. Sci. U.S.A. 101 (35): 13096-13099.

Powell, E. N., J. Song, M. S. Ellis & E. A. Wilson-Ormond. 1995. The status and long-term trends of oyster reefs in Galveston Bay, Texas. J. Shellfish Res. 14:439-457.

Pulich, Jr., W. M. and William A. White. 1991. Decline of submerged vegetation in the Galveston Bay system: Chronology and relationships to physical processes. Journal of Coastal Research 7 (4): 1125-1138.

Pulich, Jr., W. (ed.). 1999. *Seagrass Conservation Plan for Texas*. Publ. by Resource Protection Division, Texas Parks & Wildlife Dept., Austin, TX with Texas Natural Resources ConservationCommission and Texas General Land Office. 79 p.

**Trinity Bay in 1976** = AE1.5, Tox, SFm (oysters)

L-D & sed facies data = White et al. 1985, unpublished lab sheets with by-station raw counts of live and dead

White, W.A., Calnan, T.R., Morton, R.A., Kimble, R.S., Littleton, T.G., McGowen, J.H., Nance, H.S., and Schmedes, K.E.,1985, Submerged lands of Texas, Galveston-Houston area : sediments, geochemistry, benthic macroinvertebrates, and associated wetlands. Austin, Texas: Bureau of Economic Geology, University of Texas at Austin

Enviro =Not a port, but tertiary bay in system with resulting lower circulation with clean Gulf waters and so categorized as the same AE conditions as Galveston-East Bay, especially given greater influence by fresh runoff with agricultural nutrients

**Study areas scored AE 2 (severe AE, one or more serious point sources):**

**Laguna Mecoacan in 1979 = AE2, SFa (mollusks), Tox**

L-D data = Reguero 1994

Sed facies data = Galaviz-Solis et al. 1987 for aug sed data)

Reguero Reza, M.M., 1994, Estructura de la comunidad de moluscos en lagunas costeras de Veracruz y Tabasco, Mexico [PhD. Thesis]: Ciudad Universitaria, Universidad Nacional Autonoma de Mexico, 280 p.

Galaviz-Solis, A., Gutierrez-Estrada, M., and Castro del Rio, A., 1987, Morfologia, sedimentos e hidrodinamica de las lagunas dos Bocas y Mecoacan, Tabasco, Mexico: Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, v. 14(2), p. 109-124.

Enviro = Botello et al. (1983) say that despite industry, hydrocarbon values in the sediments are not above what would be considered unpolluted; attribute this to a high rate of natural weathering [oxidation], owing to dynamic hydrology.

However, M. Reguero Pers. Comm. May 2007 agrees with GulfBase etc that AE2, plus metal contaminants, very high concentrations of hydrocarbons in sediments around refineries, chronic condition (Botello et al. 1981).

October 2006 http://www.gulfbase.org/bay/view.php?bid=laguna5

Perez Sanchez, E, JF Muir, and LG Ross, 2002. Coastal aquaculture and sustainable livelihoods in Mecoacan, Tabasco, Mexico. Universidad y Ciencia 18 (35): 42-52.

A. V. Botello, J. A. Goñi and S. A. Castro, 1983. Levels of organic pollution in coastal lagoons of Tabasco state, Mexico; I: Petroleum hydrocarbons. Bulletin of Environmental Contamination and Toxicology 31 93): 271-277.

BOTELLO V., A., CASTRO A., S., y DE LA TORRE P., A., 1981. Niveles actuales de hidrocarburos disueltos en los sistemas lagunares del estado de Tabasco, México. Informe final. ICMyL, UNAM. México, 20 p.

**Laguna Alvarado in 1980 = AE2 (SK initially had scored as AE1), SFa (mollusks), Sol, Tox**

L-D data = Reguero & Garcia Cubas, 1989 for total counts of mollusks, Reguero and Garcia-Cubas pers comm. Jan 2001 for live data

Sed facies data = Rosales-Hoz et al. 1986 on sed/hydrography; Raz-Guzman et al. 1992 on salinity and sed grain sizes

Regeuero, M, and A Garcia-Cubas, 1989. Moluscos de la Laguna de Alvarado, Veracruz: sistematica y ecologia. Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, 16(2): 279-306.

Raz-Guzman, A., G. de la Lanza, and LA Soto, 1992. Caracterizacion ambiental y 13C del sedimiento, detrito y vegetacion del sistema lagunar de Alvarado, Veracruz, Mexico. Revista de Biologia Tropical 40(2): 25-225.

Rosales-Hoz, L, A Carranza-Edwards, and U Alvarez-Rivera, 1986. Sedimentological and chemical studies in sediments from Alvarado lagoon system, Veracruz, Mexico. Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, 13(3): 19-28.

Enviro = "scarce waste management" per www.gulfbase.org/bay/view.php?bid=lpv . According to Botello et al. (1980), Alvarado has "normal C isotopes", contrary to Pueblo Viejo & Tampamachoco.

M. Reguero Pers. Comm. May 2007 = part of a large complex lagoon influenced by the Río Papaloapan. Areas most affected by human pollution are around the Port and city of Alvarado, at the mouth of the complex, considers it to be AE2: the rivers Papaloapan and Blanco are very contaminated, including heavy metals, and Alvarado is a city of 200,000 with a large fishing port, especially for shrimp; anthropogenically contaminated at the time of sampling. Has consistently had patches of *Ruppia* (widgeongrass), however, during and since sampling, and during the wet season floating mats of water hyacinth Eichornia crassipes.

Rocha-Ramirez et al. (2006 Aquatic Ecology) report extensive widgeon grass *Ruppia maritima*, and also extensive floating mats of water hyacinth *Eichhornia crassipes* throughout the year with attached *Neverita* gastropods.

Bottello, AV, EF Mandelli, S Macko, and PL Parker, 1980. Organic carbon isotope ratios of Recent sediments from coastal lagoons of the Gulf of Mexico, Mexico. Geochimica et cosmochimica Acta 44: 557-559
Rocha-Ramirez, A., A. Ramirez-Rojas, R Chavez-Lopez, and J Alcocer, 2006. Invertebrate assemblages associated with root masses of Eichhornia crassipes (Mart.) Solms-Laubach 1883 in the Alvarado lagoonal system, Veracruz. Mexico. Aquatic Ecology (in press).

**Laguna Pueblo Viejo in 1980 = AE2, SFa (mollusks), Tox, Sol**
L-D data = Reguero & Garcia-Cubas, 1993)
Sed facies data = pers comm Reguero & Garcia-Cubas (Jan 2001)
Reguero, M and A Garcia-Cubas, 1993. Moluscos de la Laguna Pueblo Viejo, Veracruz, Mexico: sistematica y ecologia. Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, 20(1): 77-104.

Enviro = Pueblo Vieja shows anomalously low isotopic values probably due to the presence of organic carbon from anthropogenic sources owing to city of Tampico, plus industrial and sewage wastes from the contaminated river Panuco (Bottello et al. 1980; plus web www.invdes…).

M. Reguero Pers. Comm. May 2007 says would consider it AE2: high aromatic hydrocarbons in the outflow of Rio Panuco and the Tampico industrial corridor (citing Botello and Calva, 1998).
Botello and Calva, 1998. *Bulletin Environmental Contamination and Toxicology* , plus human originated contamination (Barrera-Escorcia *et. al*., 1998.).
Bottello, AV, EF Mandelli, S Macko, and PL Parker, 1980. Organic carbon isotope ratios of Recent sediments from coastal lagoons of the Gulf of Mexico, Mexico. Geochimica et cosmochimica Acta 44: 557-559.
www.invdes.com.mx/anteriores/Julio2000/htm/conthidr.html -- Contaminacion por hidrocarburos en la zona costera de Veracruz
www.gulfbase.org/bay/view.php?bid=lpv
Barrera-Escorcia *et. al*., 1998.) Estudio preliminar de contaminación bacteriológica en la Laguna Pueblo Viejo, Veracruz, México. *Rev. Int. Contam. Ambient., 14* (2): 63-68

**Laguna Tampamachoco in 1980 = AE2, SFa (mollusks), Tox**
L-D data = Reguero, M, A Garcia-Cubas, and G Zuniga, 1991
Sed facies data = pers comm Reguero & Garcia-Cubas (Jan 2001) using Mercado 1980 unpub thesis
Reguero, M, A Garcia-Cubas, G Zuniga, 1991. Moluscos de la Laguna Tampamachoco, Veracruz, Mexico: sistematica y ecologia. Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, 18 (2): 289-328.

Enviro = 10x increase in productivty from fertilizer runoff between 1979 and 1989 (Contreras-Espinosa & G Warner 2004). Botello et al. (1980) report abnormal C isotopes like thoseof Laguna Pueblo Viejo from petrochemical pollution. Web www.invdes… cites as most contaminated in Veracruz.

M. Reguero Pers. Comm. May 2007 = elevated aromatic hydrocarbons from thermoelectrical plant and industrial discharges from the Río Tuxpan, considers it to be AE2.
www.gulfbase.org/bay/view.php?bid=lpv
Bottello, AV, EF Mandelli, S Macko, and PL Parker, 1980. Organic carbon isotope ratios of Recent sediments from coastal lagoons of the Gulf of Mexico, Mexico. Geochimica et cosmochimica Acta 44: 557-559.
www.invdes.com.mx/anteriores/Julio2000/htm/conthidr.html -- Contaminacion por hidrocarburos en la zona costera de Veracruz

**Laguna Tupilco-Ostion in 1980 = AE2, SFa (mollusks), Tox, Sal**
L-D data = Garcia-Cubas & Reguero 1990
Sed facies data = pers comm Reguero & Garcia-Cubas (Jan 2001)
Garcia-Cubas A and M Reguero, 1990. Moluscos del sistema lagunar Tupilco-Ostion, Tabasco, Mexico: sistematica y ecologia. Anales del Instituto de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico, 17: 309-343.

Enviro = no mention of anthropogenic modification by GulfBase (October 2006 http://www.gulfbase.org/bay/view.php?bid=ldo1). However, Greenpeace reported that the opening of a new inlet thru sandbar by PEMEX (late 60's, early 70s?) increased salinity and led to salinization of agricultural lands (http://archive.greenpeace.org/comms/mexico/rwlagoon.html).

M. Reguero Pers. Comm. May 2007 considered it to AE2 at the time of live-dead sampling, having a serious problem with contamination from fecal material during Dec 1980 and in April and Sept 1981 when examined by Banuelos 1982.

Bañuelos, R., I. S.Ñ, 1982. (Variación estacional de la contaminación bacteriana coliforme en tres lagunas costeras del estado de Tabasco, México. Tesis profesional. Fac. Ciencias. UNAM. 34 p.)

**Uncertain AE**

**Heta Bay in 1950s = AE uncertain, along with other impacts**

L-D & sed facies data = Tsuchi 1959

Tsuchi, R., 1959. Molluscs and shell remains in Arari Bay and Heta Bay, the west coast of the Izu Peninsula. Reports of Liberal Arts and Science Faculty, Shizuoka University (Natural Science), vol. 2, no. 5, p. 217-228.

**Arari Bay in 1950s = AE uncertain, along with other impacts**

L-D & sed facies data = Tsuchi 1959

Tsuchi, R., 1959. Molluscs and shell remains in Arari Bay and Heta Bay, the west coast of the Izu Peninsula. Reports of Liberal Arts and Science Faculty, Shizuoka University (Natural Science), vol. 2, no. 5, p. 217-228.

## Supplementary Information in support of Text-Figure 3: Seagrass analysis

Excellent species-level information on substratum preferences and feeding methods for the Gulf of Mexico mollusks is available from the monographs of Andrews (1977) and Morton and Britton (1989), supplemented with Humfrey (1975).

The following molluscan taxa were considered to prefer seagrass or other subaquatic vegetation:

| | |
|---|---|
| *Anadara floridana* | *Cerithiopsis greeni* |
| *Chione cancellata* | *Cingula (= misident. Vitrinella) floridana* |
| *Codakia orbiculata* (Yucatan) | *Crassispira leucocyma* (Yucatan) |
| *Laevicardium mortoni* | *Cyclostremiscus suppressus* |
| *Modiolus americanus* (Yucatan) | *Fasciolarria tulipa* (Yucatan) |
| *Mytilopsis leucophaeata* | *Litiopa melanostoma* (Yucatan) |
| *Anachis semiplicata* | *Littorina brevicula* |
| *Anachis pulchella* | *Mitrella lunata* |
| *Assiminea (=Haminoea) succinea* | *Modulus modulus* (Yucatan) |
| *Assiminea (=Haminoea) antillarum* | *Nassarius acutus* |
| *Astraea phoebia* (Yucatan) | *Neritina reclivata* |
| *Atys caribaea* (Yucatan) | *Neritina virginea* |
| *Atys guildinga* (Yucatan) | *Retusa bullata* (Yucatan) |
| *Bittium (=Diastoma = Bittolium) varium* | *Rissoina bryerea* (Yucatan) |
| *Bulla striata* (Yucatan) | *Rissoina cancellata* (Yucatan) |
| *Cerithium eberneum* | *Rissoina decussata* (Yucatan) |
| *Cerithium litteratum* (Yucatan) | *Pyrgocythara plicosa* |
| *Cerithium lutosum* | *Strombus gigas* (Yucatan) |
| *Cerithium muscarum* | *Strombus raninus (*Yucatan) |
| *Cerithium variabile* (Yucatan) | *Tricolia affinis* |
| *Cerithidea pliculosa (macroalgae)* | *Turbo castanea* (Yucatan) |
| | *Zebina browniana* |

**NOTES**

AE2 datasets of the Gulf of Mexico (GOM) are exclusively coarse-mesh (1.5 mm) and from Tabasco and Veracruz, Mexico. They were thus compared only with coarse-mesh datasets (≥1.5 mm) from AE0 and AE1 lagoons in the same Gulf of Mexico region.

<u>AE 2 lagoons of the GOM</u> = Lagunas Tupilco-Ostion, Mecoacan, Tampamachoco, Pueblo Viejo, and Alvarado. The most abundant species alive in AE2 lagoons are either the gastropods *Littoridina sphinctostoma* (deposit-feeder) and *Acteocina caniculata* (predatory; Lagunas Tupilco-Ostion and Mecoacan), or the suspension-feeding infaunal bivalves *Mulinia lateralis* (opportunist; Laguna Tampamachoco), which is sometimes accompanied by abundant live *Cyrenoida floridana* (oligohaline; Laguna Pueblo Viejo). All of these species are also among the most abundant species in the death assemblage. Live-dead discordance owes to the absence or rarity alive of other species that are abundant in the death assemblage, especially grass-dwellers.

<u>AE0 lagoons of the GOM</u> = datasets from Laguna LaMancha (1.5 mm mesh data of Reguero), Laguna Madre of Texas (5 mm mesh data of Smith), and northeastYucatan (3mm data of Ekdale), which is technically Caribbean but shares many species with the Gulf.

<u>AE1 lagoons of the GOM</u> = remaining lagoons of Reguero dissertation, all 1.5 mm = Lagunas Camaronera, Carmen-Machona, Grande, Sontecomapan, and Mandinga

<u>Fine-mesh datasets</u> from the Gulf of Mexico region are from northern Texas bays and lagoons that are definitely AE, with one exception (= Staff's fine-mesh dataset from the AE0 Laguna Madre; excluded from this analysis because singleton category).

Copano Bay (Calnan data; AE1): in both the marginal sand and muddy sand habitats, grass-dwellers constitute 26% of the death assemblages whereas the local living community contains only ~5-6%, suggesting loss of grass within the last few decades before sampling in 1976.

Copano Bay (Staff data; AE1): in this marginal muddy-sandy habitat, grass-dwellers constitute 38% of the death assemblage and 1% of the living community (Census 1, which has the largest live N of all 17 censuses), suggesting loss of grass within the decades before sampling in 1981-82. Very consistent with Calnan's datasets, which are based on a single census but a much larger number of stations per habitat

West Bay (White et al. Data; AE1): all five sampled habitats have only trace numbers of grass-dwellers either live or dead (0-2% alive; 1-8% dead); grassbeds have been in decline in this Bay since the 1950s, and extensive grassbeds were virtually gone by the late 1980s; none of the remaining beds were sampled by White et al. during their survey. The trace quantities of grass-dwelling specimens in the death assemblages indicates little post-mortem transportation of grass-dwelling species out of the few remaining grassbeds at that time

Galveston-East and Trinity Bays (White et al. Data; AE1.5): no grassbeds sampled, virtually none available to sample then; only trace numbers of grass-dwellers either alive or dead (0-6%, five datasets)

## REFERENCES

Andrews, J., 1977. Shells and shores of Texas. Austin, University of Texas Press, 365 p.

Britton, J.C., and B. Morton, 1989. Shore Ecology of the Gulf of Mexico. Austin, University of Texas Press, 387 p.

Humfrey, M., 1975. Sea shells of the West Indies. New York, Taplinger Pub. Co, 351 p.

## Supporting Information in Support of SI Table 2: Open Shelves

**Shelf health.—**Human modification of benthic conditions has taken two forms. One is the increasingly intense and global *bottom-fishing of the seafloor* for commercial fin- and shellfish since WWII and especially since the early 1970s (e.g., use of trawls, dredges, and other mobile gear, here referred to as "trawling"), which increases the frequency of seafloor disturbance and generally decreases the diversity and abundance of shelly taxa and especially attached epifauna (Kaiser 1998, Thrush et al. 1998, Collie et al. 2000, Kaiser et al. 2000, NRC 2002). Mobile sands where native taxa are adapted to disturbance and where attached epifauna are sparse even under natural conditions tend to recover rapidly, and communities on muds commonly have few epifauna to lose, but shellgravels and rocky bottoms are known to suffer large declines expected to require decades to centuries to recover (e.g., Collie et al. 2000). Live-dead datasets collected from areas subject to significant trawling are thus expected to show lower live-dead agreement overall and, in particular, considerable excess dead richness and abundance of attached epifauna in the death assemblage, especially in gravel substrata.

A second form of human impact is anthropogenic *eutrophication* of shelves (AE) owing to run-off of nutrient-rich waters from deforestation, industrial farming and livestock operations, coastal development, and general population growth (Nixon 1995, Rabalais & Turner 2001, Cloern 2001, Weijerman et al. 2005). Small additions of nutrients simply increase the productivity of the existing macrobenthic community, but with increasingly high nutrient loads, the community will acquire the taxonomic composition and trophic structure of mesotrophic and eutrophic conditions, favoring deposit-feeders and other detritivores, chemosymbiotic taxa, and taxa tolerant of dysoxia or intermittent anoxia (Diaz and Rosenberg 1995). Benthic communities in shelf habitats undergoing AE are thus expected to diverge from the time-averaged death assemblage, which will have formed under earlier community states. The result should be lower live-dead agreement than on shelves experiencing natural nutrient regimes. Live-dead discrepancies created by AE should be smallest in muddy seafloors where even natural organic input is generally higher (because dead organic carbon flocs with clays) and greatest in sands and gravels. Estuaries began to show signs of stress of anthropogenic eutrophication starting especially in the 1950's, worldwide (e.g., Lötze et al. 2006), and dead zones (bottom hypoxia or anoxia) began to appear on open shelves in the early 1970s (e.g., Rabalais & Turner 2001).

**Nutrient level.—**Nutrient regime itself—i.e., whether the setting is oligotrophic, mesotrophic, or eutrophic – may matter more than whether the regime has shifted significantly under stress, either natural or anthropogenic. For example, naturally eutrophic conditions created by upwelling are typically highly dynamic spatially and temporally, characterized by cells that shift positions and strength seasonally as well as decadally, causing strong fluctuations in water-column productivity and thus in organic rain-out and dysoxia the seafloor. The highly variable conditions experienced at any given spot on the seafloor, with local death assemblages receiving hardparts from a series of successive community states, should produce low live-dead agreement when live data are based on a single census. Thus, from the perspective of the time-averaged death assemblage, fluctuations in organic rain-out within a natural system might not be substantively different from a steady increase in nutrient supply exerted anthropogenically over several decades, such as occurring in many systems worldwide since the 1950s (Cloern 2001, Rabalais & Turner 2001, Druon et al. 2004, Osterman et al. 2005, Weijerman et al. 2005). Naturally oligotrophic and mesotrophic regimes, on the other hand, if fundamentally more steady than naturally eutrophic settings over these time-scales, should be characterized by higher live-dead agreement.

### CATEGORIZATION OF SHELF STUDY AREAS

Shelves were characterized based on interviewing authors and searching the oceanographic and fisheries literatures.

### Trawling

Nine habitat-level datasets are considered to be from shelves that were suffering little direct impact from trawling at the time of sampling:

Yucatan shelf (Cancun area) = 2 datasets collected in 1971; according to A.A. Ekdale (pers. comm. 2005), only a few local fishing boats, located offshore of sampling areas, were observed during fieldwork; study period predates commercial tourism in area

Amazon shelf = 3 datasets collected in 1989-91; commercial fishing of the Brazilian shelf is presently limited to long-line and bottom gillnets, although mid-column trawling is likely in the future (FAO 2002)

Sapelo shelf = 2 datasets collected before 1986; still a major commercial nearshore shrimping industry along the Georgia coast in the 1990s (NRC 2002), but live-dead samples were collected from within a few tens of meters of the shoreline and thus judged unlikely to have been directly affected

Cholla Bay shoreface (not used in final version of *Lethaia* 2007 because data for rare species are missing) = 1 subtidal dataset collected in 1985-86; commercial fishing and shrimping supported 80% of the local economy in the early 1980's, crashed from overfishing by dragnets and disease in the late 1980s, and since 1994 the entire northern Gulf of California has been part of an International Biosphere Reserve that is off-limits to commercial take; the live-dead dataset was collected from water only a few meters deep and thus judged unlikely to have been directly affected.

San Juan Channel (Friday Harbor) = 1 subtidal dataset collected in July 2002; a commercial sea cucumber fishery exists in the general area of the San Juan Islands, but the study area of Kowalewski et al. (2003) has not been trawled except for research purposes by the Friday Harbor Laboratories, University of Washington (D. Duggins, pers. comm.. 2006).

*Commercial harvesting of bottom fauna* is assumed for:

Patagonian shelf and, less confidently, for the Beagle Channel (55°S; sampled in 1994). The southwest Atlantic is one of the most extensive shelf areas in the world, with takes increasing strongly in the 1970s but collapsing in the 1990s by a combination of intense international and Argentinian fishing (most notably the bottom-trawled hake; Bakun 1993; Garibaldi & Limongelli 2002, Dans et al. 2003 and references therein).

All of the Japanese shelves (Chihama; Tago-no-ura and Oi River in the Suruga Gulf) are likely to have been at least moderately impacted in the 1950s when they were sampled. Coastal Japanese fishing has operated under a strict licensing system (pertaining both to areas and target taxa) since the 1600's and has been managed in some form for 2 millennia (Ruddle 1987). Although the methods would not have been industrial or even mechanized in the late 1950s, fishing had been commercial (i.e., not for local consumption alone) for centuries.

All Mediterranean study areas (Sicily, Tuscany, Rhodes ) are categorized, conservatively, as moderately impacted owing to the historical duration of managed fisheries and commercial activities in the region (dating to Etruscan and Roman times; Zugarramurdi et al. 1995).

Open shelf seafloors of the English Channel (Eddystone, Stoke Point), outer Plymouth Sound, and North Sea (the live-dead datasets of Cadée 1984 for the Oyster Ground are not used here or in other live-dead meta-analyses because data no longer exist for rare species) have commercial trawling histories dating back to the 19$^{th}$ century, with bottom fisheries a subject of concern by the early 1900s (e.g. reports by the Danish and British federal fisheries services on benthic "fish food", such as the series initiated with Petersen & Jensen 1911 and Davis 1923).

Trawling in the Gulf of Mexico, including the Texas shelf, has declined in past decades but remains one of the most intensely trawled areas of the U.S. (NRC 2002). Shrimp trawling is in both shallow and mid-shelf areas, overlapping with the Corpus Christi and Galveston study areas used here (White et al. 1983, 1985; Staff & Powell 1999).

**Anthropogenic Eutrophication**

20 of the 38 open shelf datasets are considered to have had "natural" nutrient regimes at the time of sampling, with natural states ranging from oligotrophic to eutrophic based on pigment (chlorophyll-a) concentrations in surface waters or flux of organic carbon. Confidently included among these are the:

Beagle Channel = 1 dataset collected in 1994. >4 µg/l chlorophyll-a was reported by Hamamé & Antezana (1999)

Patagonian shelf = 2 datasets collected in 1994. Area is influenced by intense western boundary currents and wind- and tide-driven upwelling, resulting in high productivity (Bakun 1993; NOAA 2002); considered naturally eutrophic due to seasonal upwelling, with up to 10 µg/l chlorophyll-a seasonally

Amazon shelf = 3 datasets collected in 1989-91. Persistent upwelling with 5µg/l chlorophyll-a observed on coast in 2000 (Fratantoni & Glickson, 2002); considered to be high-productivity area (Garibaldi & Limongelli 2002, NOAA 2002). Organic matter in the study area is primarily from marine plankton rather than terrestrial runoff (Aller et al. 1996), fed by upwelling, which was observed during each of the 4 cruises (Geyer et al. 1996).

Yucatan shelf (Cancun area) = 2 datasets collected in 1971. This a classic oligotrophic reefal area, fed by waters from the low-productivity Caribbean Sea (150-300 gC/m2-yr; NOAA 2002); the earliest report found ≤0.1 µg/l in summer 1980 (ImaRS 2006).

Corpus Christi shelf, southwestern Texas = 4 datasets collected in 1976-77 by White et al., plus 1 dataset collected in 1986 by Staff and Powell. ≤~2µg/l was observed in summer 1980 (ImaRS 2006). This area is relatively distant from the Dead Zone off the Mississippi River and is adjacent to a semi-arid landmass, unlike the

Galveston shelf of eastern humid-climate Texas, and thus is assumed to be relatively natural in nutrient regime. The Gulf is overall considered to be moderately productive (150-300 gC/m2-yr; NOAA 2002).

Chihama shelf = 1 dataset collected in 1958. No local data found, but area is presumed natural owing to its completely open Pacific facing, swept by the warm (non-upwelling) Kuroshio Current which is only moderately high in productivity (150-300 gC/m2-yr; NOAA 2002). The area was also distant from major urban areas at the time of live-dead sampling.

San Juan Channel = 1 dataset collected in 2002. The San Juan Archipelago receives large volumes of freshwater input from the mainland coast of Washington and British Columbia, which includes timber and other agricultural activities and urban areas, but this constitutes only a (ephemeral) surface lens in the study area near Friday Harbor. There, bottom waters are fully marine, well-aerated, and supplied by Pacific waters having natural nutrient levels. Human populationss on the San Juan Islands themselves are small and low-density, and run-off regulations strictly enforced.

Less confidently included as natural are:

3 datasets collected in 1931 from around the Eddystone light in the English Channel (Smith 1931). Although domestic sewage treatment then would have been virtually nonexistent, population sizes would have been much smaller and commercial fertilizer use on land modest at most. Delivery of significant anthropognic nutrients to the seafloor of the well-mixed Channel waters around Eddystone is thus judged relatively unlikely, in contrast to the situation in the 1980s (Carthew-Bosence datasets, see above).

Sapelo Island, Georgia, USA (2 small datasets from early 1980s. This area shows a narrow coastal band of moderately high chlorophyll-a concentrations in summer 1980 (2-5 µg/l; ImaRS 2006). The adjacent DoboySound was a major timber port in the 19th century (S.Henderson, pers comm. 2007). However, gricultural intensity has generally declined along the Atlantic seaboard over the last ~100 years, compared for example to the U.S. area drained by the Gulf of Mexico, so that current conditions are probably not far from truly natural. The southeastern US Atlantic region is considered moderately productive overall (150-300 gC/m2-yr; NOAA 2002).

Cholla Bay in the northern Gulf of California (1 dataset collected in 1985; not used in meta-analysis because data for rare species are missing) presents a unique situation. Local chlorophyll data for the sampling period (1985) are lacking. At that time, no local agriculture or significant coastal development existed to elevate local run-off of nutrients. However, since the initial damming of the Colorado River in the 1930s, silt and nutrient input to the northern Gulf has been progressively strangled, leading perhaps to an anthropogenic *lowering* of nutrient levels: by the late 1990s, high-nutrient waters >4 mg/m3 stimulated by River input were limited to the delta edge and Cholla Bay itself saw ENSO maxima of ≤5 mg/m3 (Kahru et al. 2004). Thus, although the Gulf is generally classified as highly productive (>300 gC/m2-y; NOAA 2002) due to seasonal upwelling, the Cholla Bay dataset is categorized as anthropogenically "non-eutrophied" and thus is combined with the natural shelves.

Nutrient regimes of the remaining shelves were judged to be elevated above normal levels to some degree, regardless of whether chlorophyll data for surface waters indicated high productivity.

The Galveston shelf is suspected to suffer from significant anthropogenic nutrient input: it receives drainage from an adjacent area of humid agricultural land, has considerable urban centers and coastal industry (petroleum, chemical, and shrimp processing), and is immediately downshore of the growing Dead Zone off the Mississippi-Atchafalaya Delta in the Gulf of Mexico (Rabalais & Turner 2001; NOAA 2002); this part of the Texas shelf was characterized by moderately high chlorophyll-a concentrations in summer 1980 (2-5 µg/l; ImaRS 2006).

The western English Channel (2 datasets from the Eddystone Light and Stoke Point areas), Plymouth Sound (1 dataset), and the coastal Oyster Ground of the North Sea (2 datasets of Cadée 1984), all sampled in the early 1980s, are categorized as impacted given the prolonged cultural history of surrounding lands and ecological reports. Reported chlorophyll levels indicate meso- rather than eutrophic conditions (~1-3 mg/m3; various sources including Aertebjerg & Carstensen 2003, Micheli 1999; but see NOAA (2002) characterization of both the North and Celtic Sea marine areas as highly productive with 150-300 gC/m2-yr).

All of the Mediterranean shelves are considered to be impacted owing to increasing population sizes and coastal development in the 20th C plus atmospheric deposition (see NOAA 2002), with increasing fish landings arguably symptomatic of diffuse fertilization of the marine system (Caddy et al. 1995). However, among these, the shelf in the Gulf of Catania (Sicily) and off the northeastern coast of Rhodes Island (Greece) were judged to be AE1.5 and AE2 respectively owing to the proximity of major towns and polluted harbors.

Similarly, the Tago-no-ura and Oi River shelves from the Suruga Gulf of Japan are located immediately offshore and a few km alongshore from a then-active active pulp mill (1950s) and were thus almost certainly affected by unnatural nutrient levels (scored AE2 and AE1.5, respectively).

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