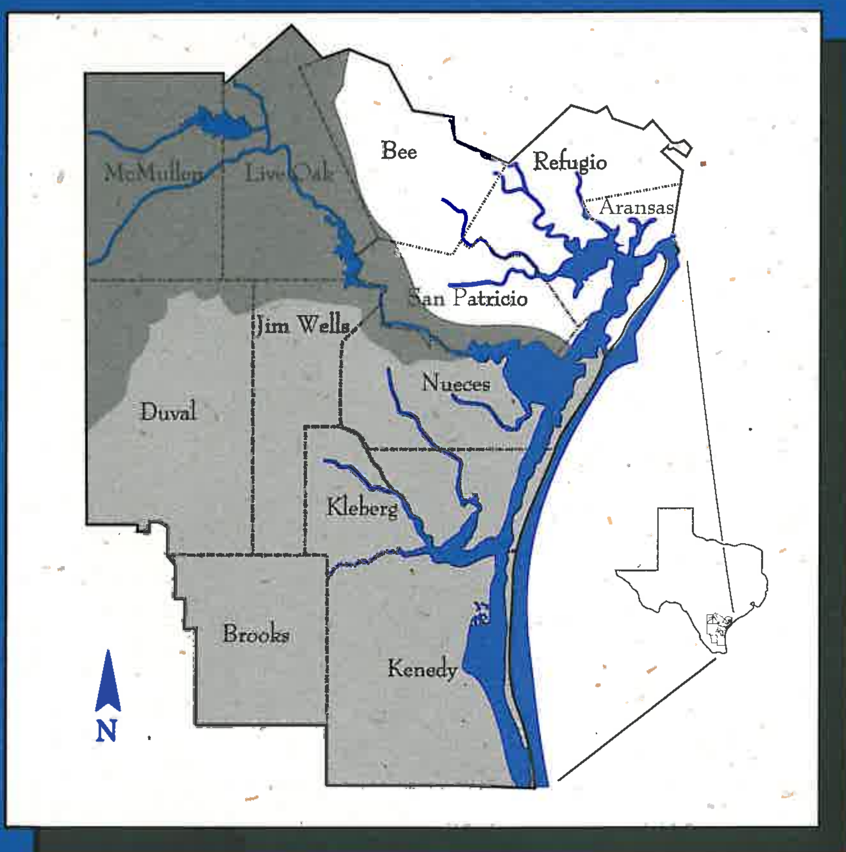
Current Status and Historical Trends in the Incidence of Marine/Bay Debris in the CCBNEP Study Area

Publication CCBNEP – 12
January 1997

Anthony F. Amos
University of Texas Marine Science Institute

Submitted to:
Coastal Bend Bays & Estuaries Program
1305 N. Shoreline Blvd. Ste 205
Corpus Christi, Texas 78401

Current Status and Historical Trends in the Incidence of Marine/Bay Debris in the Corpus Christi Bay National Estuary Program Study Area



Corpus Christi Bay National Estuary Program

CCBNEP - 12 • January 1997

This project has been funded in part by the United States Environmental Protection Agency under assistance agreement #CE-9963-01-2 to the Texas Natural Resource Conservation Commission. The contents of this document do not necessarily represent the views of the United States Environmental Protection Agency or the Texas Natural Resource Conservation Commission, nor do the contents of this document necessarily constitute the views or policy of the Corpus Christi Bay National Estuary Program Management Conference or its members. The information presented is intended to provide background information, including the professional opinion of the authors, for Management Conference deliberations while drafting official policy in the Comprehensive Conservation and Management Plan (CCMP). The mention of trade names or commercial products does not in any way constitute an endorsement or recommendation for use.

Current Status and Historical Trends in the Incidence of Marine/Bay Debris in the CCBNEP Study Area

Anthony F. Amos
Principal Investigator

Contributors
Ms. Andrea R. Wickham
Ms. Kimberly C. Keplar

University of Texas at Austin
Marine Science Institute
750 Channelview Drive
Port Aransas, Texas 78373-5015
512/749-6720
512/749-6777 Fax

Publication CCBNEP - 12
January 1997

Policy Committee

Commissioner John Baker
Policy Committee Chair
Texas Natural Resource Conservation Commission

Ms. Jane Saginaw
Policy Committee Vice-Chair
Regional Administrator, EPA Region 6

The Honorable Vilma Luna
State Representative

Commissioner John Clymer
Texas Parks and Wildlife Department

The Honorable Carlos Truan
Texas Senator

Commissioner Garry Mauro
Texas General Land Office

The Honorable Josephine Miller
County Judge, San Patricio County

Commissioner Noe Fernandez
Texas Water Development Board

The Honorable Mary Rhodes
Mayor, City of Corpus Christi

Mr. Ray Allen
Coastal Citizen

Mr. Bernard Paulson
Coastal Citizen

Management Committee

Mr. Randall B. Wilburn, Co-Chair

Mr. William H. Hathaway, Co-Chair

Local Governments Advisory Committee

Commissioner Gordon Porter, Chair

Mr. James Dodson, Vice-Chair

Scientific/Technical Advisory Committee

Dr. Terry Whitledge, Chair

Dr. Wes Tunnell, Vice-Chair

Citizens Advisory Committee

Mr. Jay Reining, Chair

Financial Planning Advisory Committee

Dr. Joe Moseley, Chair

Program Director

Mr. Richard Volk

Natural Resources Center, Suite 3300, TAMU-CC • 6300 Ocean Drive • Corpus Christi, TX 78412
512/980-3420 • FAX 512/980-3437 • CCBNEP home page: //www.sci.tamucc.edu/ccbnep

TNRCC

Barry R. McBee, *Chairman*
R. B. Ralph Marquez, *Commissioner*
John M. Baker, *Commissioner*

Dan Pearson, *Executive Director*

Published and distributed
by the
Texas Natural Resource Conservation Commission
Post Office Box 13087
Austin, Texas 78711-3087

CORPUS CHRISTI BAY NATIONAL ESTUARY PROGRAM

The Corpus Christi Bay National Estuary Program (CCBNEP) is a four-year, community based effort to identify the problems facing the bays and estuaries of the Coastal Bend, and to develop a long-range, Comprehensive Conservation and Management Plan. The Program's fundamental purpose is to protect, restore, or enhance the quality of water, sediments, and living resources found within the 600 square mile estuarine portion of the study area.

The Coastal Bend bay system is one of 28 estuaries that have been designated as an **Estuary of National Significance** under a program established by the United States Congress through the Water Quality Act of 1987. This bay system was so designated in 1992 because of its benefits to Texas and the nation. For example:

- Corpus Christi Bay is the gateway to the nation's seventh largest port, and home to the third largest refinery and petrochemical complex. The Port generates over $1 billion of revenue for related businesses, more than $60 million in state and local taxes, and more than 31,000 jobs for Coastal Bend residents.
- The bays and estuaries are famous for their recreational and commercial fisheries production. A study by Texas Agricultural Experiment Station in 1987 found that these industries, along with other recreational activities, contributed nearly $760 million to the local economy, with a statewide impact of $1.3 billion, that year.
- Of the approximately 100 estuaries around the nation, the Coastal Bend ranks fourth in agricultural acreage. Row crops -- cotton, sorghum, and corn -- and livestock generated $480 million in 1994 with a statewide economic impact of $1.6 billion.
- There are over 2600 documented species of plants and animals in the Coastal Bend, including several species that are classified as endangered or threatened. Over 400 bird species live in or pass through the region every year, making the Coastal Bend one of the premier bird watching spots in the world.

The CCBNEP is gathering new and historical data to understand environmental status and trends in the bay ecosystem, determine sources of pollution, causes of habitat declines and risks to human health, and to identify specific management actions to be implemented over the course of several years. The 'priority problems' under investigation include:

- altered freshwater inflow into bays and estuaries
- loss of wetlands and estuarine habitats
- declines in living resources
- degradation of water quality
- altered estuarine circulation
- bay debris
- selected public health issues

The **COASTAL BEND BAYS PLAN** that will result from these efforts will be the beginning of a well-coordinated and goal-directed future for this regional resource.

STUDY AREA DESCRIPTION

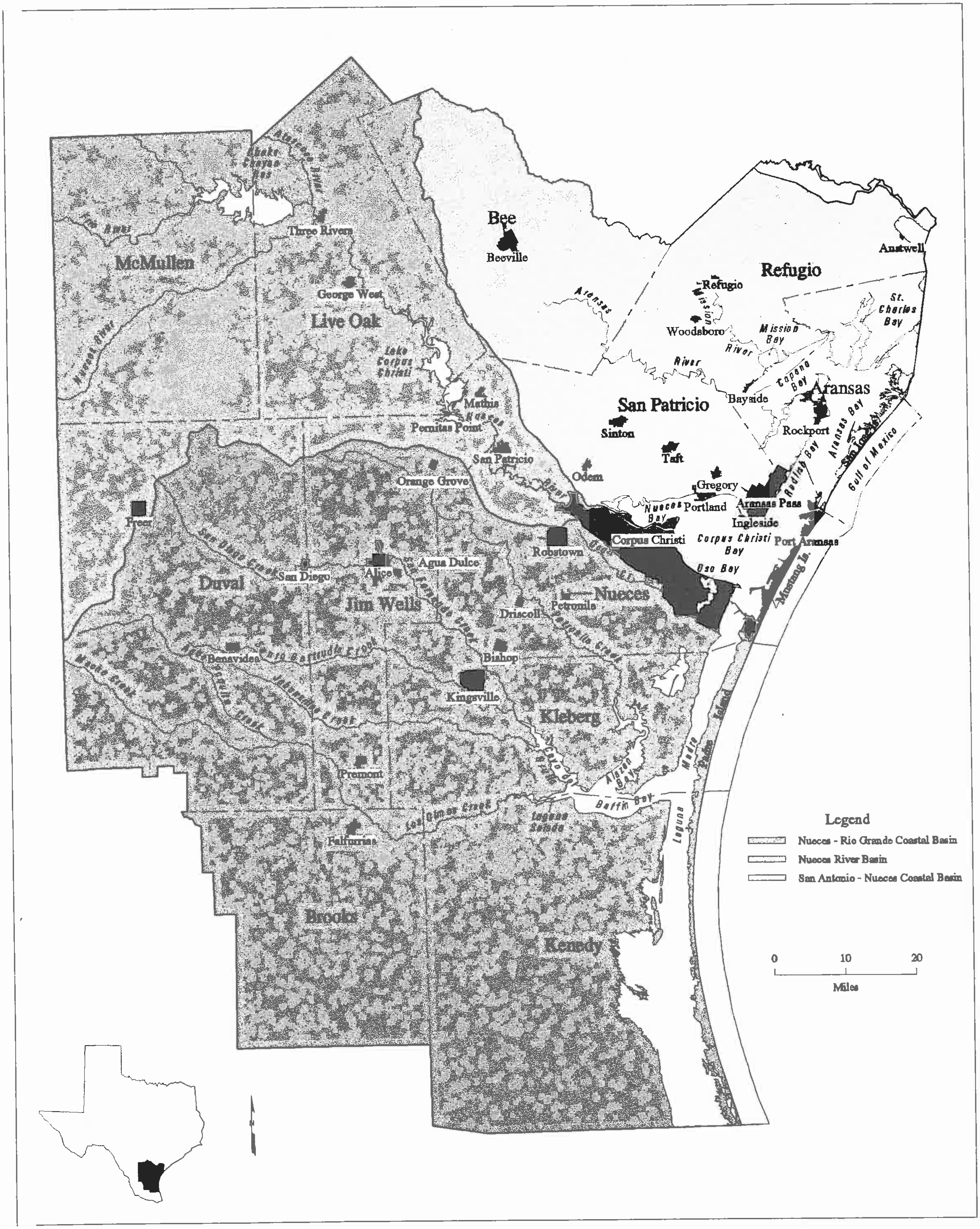
The CCBNEP study area includes three of the seven major estuary systems of the Texas Gulf Coast. These estuaries, the Aransas, Corpus Christi, and Upper Laguna Madre are shallow and biologically productive. Although connected, the estuaries are biogeographically distinct and increase in salinity from north to south. The Laguna Madre is unusual in being only one of three hypersaline lagoon systems in the world. The study area is bounded on its eastern edge by a series of barrier islands, including the world's longest -- Padre Island.

Recognizing that successful management of coastal waters requires an ecosystems approach and careful consideration of all sources of pollutants, the CCBNEP study area includes the 12 counties of the Coastal Bend: Refugio, Aransas, Nueces, San Patricio, Kleberg, Kenedy, Bee, Live Oak, McMullen, Duval, Jim Wells, and Brooks.

This region is part of the Gulf Coast and South Texas Plain which are characterized by gently sloping plains. Soils are generally clay to sandy loams. There are three major rivers (Aransas, Mission, and Nueces), few natural lakes, and two reservoirs (Lake Corpus Christi and Choke Canyon Reservoir) in the region. The natural vegetation is a mixture of coastal prairie and mesquite chaparral savanna. Land use is largely devoted to rangeland (61%), with cropland and pastureland (27%) and other mixed uses (12%)

The region is semi-arid with a subtropical climate (average annual rainfall varies from 25 to 38 inches); rainfall is highly variable from year to year. Summers are hot and humid, while winters are generally mild with occasional freezes. Hurricanes and tropical storms periodically affect the region.

On the following page is a regional map showing the three bay systems that comprise the CCBNEP study area.



Corpus Christi Bay National Estuary Program Study Area

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

This work was made possible by a contract from the Corpus Christi Bay National Estuary Program, Texas Natural Resources Conservation Commission, No.52-000000-07.
The authors would also like to thank the University of Texas at Austin Marine Science Institute for its support in many of the unfunded projects done previously, from which sections of this work are drawn.

The authors extend thanks to the following people for their contributions to the completion of this project. For their help in the arduous and often thankless task of counting and sorting garbage: Pam Plotkin and Chuck Rowe. For their cooperation in sending the information needed: the Center for Marine Conservation's Linda Marannis, Kathy O'Hara, Joan Boomsma, and Laurie Halperin; the Texas General Land Office's Roxanne Rouse and Sheryl McBride. Also, Karen Carnahan, Commissioner Waymon Hallmark, Commissioner Mark Huddleston, Rachel Flippo, Dr. Dan Golden, Holly LaChance, Charles Moss, Billie Clays, Toni Allen, Jane Gilmer, Jake Colville, Leigh Pohlmeir, Don and Wendy Flint, Pam Greene, Kristey Bosworth and Maggie Galvan for the information they gave as coordinators of the beach clean-ups along the coastline. To Carol Cervenka of Ingleside-on-the-Bay, and Mark Smith, René Garza and Sisu Morris of the Corpus Christi Marina for taking time out of their busy schedules to show what they have done to eliminate bay debris. Also to Judge Robert Blackmon for giving his time to contribute information on his efforts in the area.

Current Status and Historical Trends in the Incidence of Marine/Bay Debris in the Corpus Christi Bay National Estuarine Program (CCBNEP) Study Area.

by
Anthony F. Amos,
Andrea R. Wickham and Kimberly C. Keplar
The University of Texas at Austin, Marine Science Institute
Port Aransas, Texas 78373-5015

1 EXECUTIVE SUMMARY

The objectives of this study were to "identify the sources, type, and relative occurrence of floating, submerged, and shoreline debris in the Corpus Christi Bay National Estuary Program (CCBNEP) study area." The major tasks were to: (a) "survey the available literature pertaining to marine/bay debris, both published and unpublished, in the CCBNEP study area" (**Literature Review**); (b) acquire "appropriate data sets..." which describe the current status and historical trends of the incidence of marine/bay debris within the CCBNEP study area (**Data Acquisition**); (c) "compile data on the incidence of marine/bay debris" from sources suggested by CCBNEP, categorizing debris in material types such as plastics, metal, wood, etc. (**Data Compilation**); (d) analyze selected data sets "to determine the current status and historical spatial and temporal trends in the incidence of marine/bay debris" (**Data Analysis and Trend Determination**); (e) "identify specific sources and types of marine/bay debris that are of special concern from an environmental management perspective" (**Identification of Areas of Concern**); (f) "highlight any gaps or inadequacies in existing monitoring programs" (**Identification of Data and Information Gaps**).

a) Few of the literature citations reviewed (Appendix A) pertained to the bays and bay shorelines of the CCBNEP study area; most dealt with debris found on Texas gulf beaches. There is only a small body of literature in the refereed journals. We included many local reports and articles appearing in newsletters, newspapers and magazines, several by the PI, who has written extensively on the subject in the popular press. A section on audio-visual recordings is included. Many of the papers refer to methods used in surveying for debris, a subject we consider important for the CCBNEP, even though most pertain to studies done outside the study area.

b) Data sets were acquired from the Center for Marine Conservation (CMC) from volunteer beach cleanups done since 1986 for all regions in the CCBNEP, as well as from a limited number of volunteer cleanups done by the Texas General Land Office (TGLO). Only two bay sites exist: Port Lavaca, which is just outside the CCBNEP area, and Rockport. Both were used in our analysis, as was the Port Aransas site which has had continuous coverage since 1986. The PI's past and ongoing marine debris data sets from the University of Texas Marine Science Institute (UTMSI) were also used. One part of the UTMSI study was a MARPOL (the international Marine Pollution Agreement, Annex V—regulating the dumping of garbage at sea) assessment. Raw data were not obtained from the third major investigation done in the CCBNEP study region, the Padre Island National Seashore (PINS). Our discussion on this effort is based upon published reports. These three were the only data sets which met any of the criteria pertaining to status and trends.

c) We compiled the CMC data into material categories for Port Lavaca, Rockport, and Port Aransas by item count. Materials are plastics, metal, rubber, glass, paper, cloth, wood, tarballs, and medical waste. The major difference between the first two (bay) sites is that the percentage of plastic is less (61%) compared to the gulf site (78%), while the proportion of glass (9%), metal (13%), and paper (10%) is greater on bay shorelines compared to the Gulf beaches (4% glass, 9% metal, and 5% paper). This is due to the greater quantity of packaged food and drink items used in the bay compared to the beach and offshore environs. We caution, however, that the CMC data has a considerable uncertainty in that it is difficult to reduce it to a common basis for comparison (e.g., items per unit areas surveyed). The MARPOL study showed a breakdown of plastic (80%), glass (3%), metal (3%), paper (5%), and wood (9%). Wood averages 2% on all three CMC sites. Tarballs are not surveyed by the volunteer beach cleanup participants and are treated separately using data collected by the PI on a Gulf beach. Tarballs from unknown sources have generally decreased as a beach debris item but their presence following major spills is still a serious environmental hazard. Medical waste has been found on Gulf beaches sporadically, yet cause much public anxiety when they do. Some frequently found non-medical items (rubber gloves, light sticks) are often mistakenly identified as being medical waste.

d) CMC reports its data for the three sites as numbers of *items counted per location* (the "raw" data). However, because the physical size of the locations (e.g., Rockport, Port Aransas, etc.) varies considerably, we reduced the data to a common base of numbers of *items per kilometer* of shoreline or beach (the "reduced" data). This makes for a more meaningful comparison between one location and another. It was not always possible to determine from the data cards the extent of beach covered and we had to estimate in most cases. For comparison between the widely reported total numbers of items per location and the more precise number of items per kilometer, we performed statistical analyses by regression on both the raw and the reduced data. Correlation coefficients were low and trends so-calculated, inconsistent. No reliable information on trends can be gleaned from these data and the statistics are not included in this report. A detailed analysis of the UTMSI results showed an overall decrease in the standing stock of five targeted items on Mustang Island Gulf beach. Difficulty in assessing trends in the source of these items has resulted from an increase in beach cleaning on the study site by county and city beach workers. An overall decrease was detected in beach debris during the MARPOL study which took place before and after MARPOL was ratified by the U.S. Congress.

e) Types of marine and bay debris of particular concern are as follows, not in order of importance, as this is a subjective concept; monofilament line, six-pack rings, onion sacks, netting, polypropylene ropes, plastic bags, plastic fiber strapping bands (entanglement of marine animals), small plastic and styrofoam pieces, plastic pellets, platic bags, "peanut" packing material (ingestion by marine animals), large plastic sheeting, large appliances (covering of bottom sediments, affecting benthic animals and sea grasses), chemical containers with contents intact, or residue of contents, often unlabelled or mislabelled, medical waste, glass items (hazardous to people and marine animals), and all items of litter and garbage on shorelines or floating (aesthetically displeasing, affecting the economic well-being of a community with a substantial tourist industry).

f) We recognized that information on debris in the bay areas of the CCBNEP study areas is sparse indeed, and that data meeting the quality necessary for trend analysis is non-existent. Consequently, much of this report is devoted to the marine area of marine/bay debris. We expended considerable effort to attempt statistical analyses on all the data acquired but reviewers of the draft final report suggested that the regression analysis not be incorporated in the revision. So that our effort not be closed to scrutiny, we include in the literature citations a report which includes our original analyses and discussion (Amos et al., 1996, deposited in the UTMSI Library). We recommend that the National Marine Debris Monitoring Program, now well-established in the CCBNEP area, with two gulf beach sites, be encouraged to start one or more bay sites to characterize status and trends of bay debris in our area. A complete inventory of sites of potential input of debris to the bays should be compiled in one place, an effort started here with a review of boat ramps, and some industrial and residential complexes. The list should include sewer and storm-drain outfalls, creeks and streams, waterside parks, and roadways bordering waterways and bays, and should be put in both tabular and GIS formats.

Criticism here of any of the efforts at assessing marine debris in the CCBNEP area (including our own) are based on scientific considerations and are not meant to detract from the considerable effort and usefulness of these programs in public outreach and education. Our objective was to answer the question: "Can existing data provide reliable information on (a) current status and (b) historical trends in the incidence of marine/bay debris in the Corpus Christi Bay National Estuary Program (CCBNEP) study area? The answer to the first (a) is a qualified "Yes"; to the second (b), almost certainly, "No".

2 INTRODUCTION

From here we went across Harbor Bridge to the Nueces Bay Causeway, on the south side, at the water's edge. There was garbage everywhere; garbage bags left full of trash, many bottles, food wrappers, ice bags, diapers, cardboard, lure packages, monofilament, covering approximately 45 percent of the area. [From an interview with Mark Smith, Corpus Christi Harbor Master, 21 September 1995].

It takes but a casual observation to realize that our urban and suburban lands are littered with the solid waste products of modern society with its emphasis on consumerism, long-lasting, lightweight materials, attractive, secure, and hygienic packaging, convenience and advertizing. While it might be almost expected that cities are so littered, it is less expected to find high concentrations of such litter and garbage on remote beaches bordering the oceans, lakes, rivers, bays and estuaries, and floating or submerged in many of our coastal waters. Yet this is the case, and the public who visit these places in pursuit of leisure in increasing numbers are also aware of this form of pollution because it is so visible. The Corpus Christi Bay National Estuary (CCBNEP) study area is no exception; in fact, this region is noted as having some of the most littered ocean-side (Gulf of Mexico) beaches in the world. Collectively this litter is known as **marine debris**. Most of the research on marine debris has been done on beaches bordering oceans or in the oceans themselves. To assess the magnitude of the problem in the CCBNEP study area, **bay debris**, man-made litter in the bays, estuaries, lagunas and rivers must be considered to be of prime importance. Debris originating on bay shorelines and urban areas can be transported to the Gulf, and vice-versa. For this study we included the region from San Antonio Bay and Pass Cavallo in the north, to Baffin Bay and the Land Cut in the south (Fig. 1). We looked at the current status and historical trends in the incidence of **marine/bay debris** in the CCBNEP study area by examining existing literature and data. Included in the category of marine debris are **"tarballs"**, which may be of anthropogenic origin, but not natural debris such as seaweeds, driftwood, etc.

The litter observed by Mark Smith along the bay shoreline, at each of the city storm sewer outfalls, and in the Corpus Christi City Marina, is typical of the makeup of bay debris, mostly packaging from items of everyday use discarded by city residents and visitors, but also including larger items from deliberate dumping activity and a certain amount of industrial materials. The problem we encountered in preparing this report was finding any organized surveys of bay debris to assess the magnitude and trend of this material. An increasing number of volunteer cleanups of different areas around the bay are beginning to redress this lack, but information is largely anecdotal at this time. Hence, a disproportionate part of this report is largely about marine debris, as several organized surveys have been done on Gulf of Mexico shorelines.

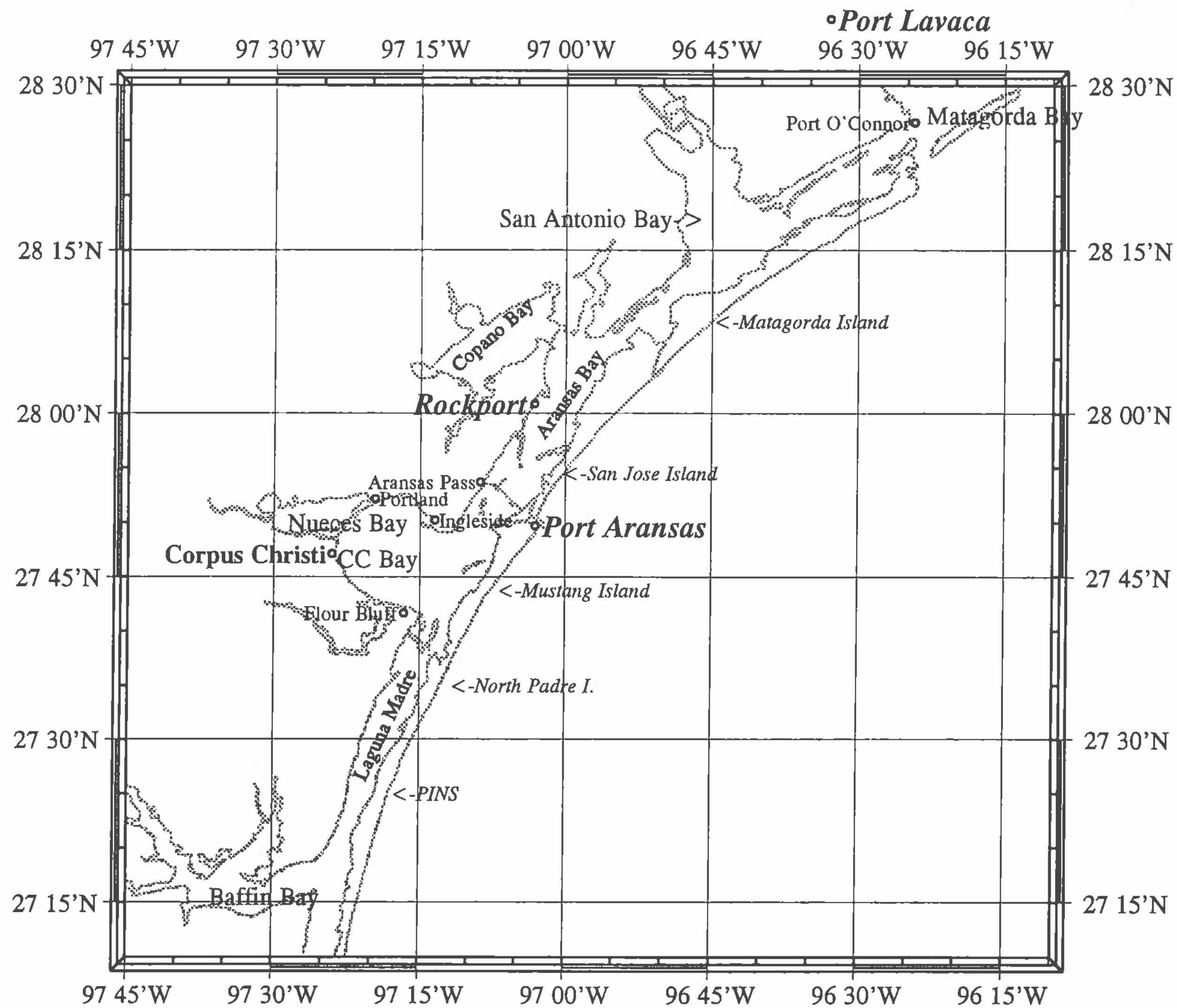


Figure 1 CCBNEP Marine/Bay Debris study area.
The three sites used in study of CMC/TGLO Beach Cleanup data sets
are shown italicized and in bold (Port Lavaca outside CCBNEP area).

We found the shore for many miles strewed with fragments of wrecks, and boxes, and bales of goods, which had been thrown into the sea from vessels... We frequently found, as we walked along the edge of the surf, fresh cocoa-nuts, Brazil-nuts, and other fruits and plants of more southern latitudes, which, no doubt, had made the voyage from the rivers of the southern continent, on the gulf stream, flowing from that direction, to unite with the other, or more northern branch of it. We observed entire sycamores, and other trees from the forests of the north, which, coming down the Mississippi, and being carried to sea, were also deposited on this shore by the same current. Large logs of mahogany, cut in the forests of Honduras, were strewn along the shore. Quantities of pumice-stone and lumps of pure bitumen lay here and there upon the sand. From whence these substances came, we could not then determine: particularly the pumice-stone. That bitumen was abundant in the Caribbean Islands, I was aware; and the pumice-stones may have been washed by tropical rains from the base of some extinguished volcano of Central America, and, carried upon the bosom of some river, been thrown out upon the Gulf waters. Sea-shells and other marine objects, many of rare and beautiful varieties, were abundantly strewn along the water-line of the beach. Of these we would almost involuntarily load ourselves, and as often cast them from us, for others of more beautiful coloring and texture, or of rarer species. The clouds, in the mean time, indicated the approach of a norther. Rapidly the dark scowling vapors crept up from the northern horizon; then a hissing sound came over the waters, followed immediately by a freezing wind that cut to the bone, whirling the sand about like drifting snow. The sharp crystals cut like needles, as they were blown with force against our persons.

The narrator of this quote was S. Compton Smith, M.D. (Smith, 1857), acting surgeon with General (later President) Zachary Taylor's division in Mexico and he was describing events following the wreck of the *Rosella* on Padre Island in the spring of 1846 — one of the earliest descriptions of the island. It illustrates several points about the present-day problem of marine debris:

- South Texas' barrier island beaches have long been strewn with man-made debris.
- Materials, including natural debris (e.g. driftwood), arrive on gulf beaches via river discharges.
- The existence of bitumen (tarballs?) on beaches is not a new phenomenon.
- People then, as now, enjoyed beach combing and appreciate the aesthetic beauty of the beach.
- Our weather, currents, and tides are factors in redistributing materials on the beach.

Now, however, the boxes and bales of goods have been replaced by plastic pails, metal drums and bags of garbage; the trees still come from the Mississippi, mahogany can occasionally still be found; shells still litter the shoreline, although not species as rare and beautiful as then; pumice seldom comes ashore, and tarballs now may also emanate from the offshore exploration for, and transportation of, oil. The public is now well aware of the problem of marine debris in Texas. What do we know, however, of the history of man-made debris in the CCBNEP study area? Is there a body of literature on the subject? What do we know about the origin, quantity, types, distribution, and trends in the amount of debris in the estuary? To answer these questions, we searched through the existing literature and data as recommended in the Scope of Work drawn up by the CCBNEP Scientific and Technical Advisory Committee and approved by the Management Committee. Once the work started, however, we realized that there was a paucity of literature, especially in the refereed journals, and also in the data, particularly about debris inside the estuary itself. Almost all the information gathered to date has been devoted to debris occurring on beaches bordering oceans, in this case, the Gulf of Mexico.

In light of the above, the literature search includes mostly papers written on the general subject of solid waste in the marine environment, followed by articles in newspapers, the popular press, newsletters, and audio-visual material. Most of the non-refereed material does pertain to Texas, and much of it to the CCBNEP study area. The data comes from three sources: firstly, data collected by thousands of volunteers participating in the annual beach-cleanups, one done each September, organized by the Center for Marine Education, and the other done each April, organized by the Texas General Land Office (the CMC/TGLO data); secondly, data collected over the years by the PI (the UTMSI data); and finally, data acquired by the Padre Island National Seashore (the PINS data). The utility of these data sets was examined and analysis of two of them was carried out to see if there were trends detectable. We present here the analytical methods and the results of our analysis in graphical form. The actual data are provided on diskettes accompanying this report. In the **Sources** section we report on the results of our interviews with various individuals and organizations on sources of debris, in particular, bay debris. We identify the gaps in our present knowledge of debris in the CCBNEP study area and include some recommendations on how we feel the CCBNEP should proceed in assessing the magnitude and trends of marine/bay debris as the presently available information is not adequate to the task.

3 LITERATURE REVIEW

June 4, 1965 at 0°41.2'S; 93°26.5'E. Indian Ocean aboard R/V *Robert D. Conrad*, 300 km from the coast of Sumatra. *A large quantity of debris, presumably land-based in origin, and floating in the frontal zone, consisted of coconut shells, small pieces of planking, sticks, leaves, a wine bottle, Coca-Cola bottle, and a glass fisherman's float*. [From Amos et al., 1972].

References in the oceanographic literature to floating debris in the oceans are sparse, but there is a body of literature on the phenomena of fronts, slicks, windrows, Langmuir circulation and convergence zones, and the concentrations of both natural and man-made debris associated with these features (often recognized by fishing vessels as productive catch areas). Forty years prior to the observation of the front above, William Beebe devoted a whole chapter in his book, *The Arcturus Adventure* (Beebe, 1926) to an almost identical front in the Pacific Ocean. He made no mention of any man-made debris. Neuston nets have been towed in pelagic waters to collect and analyze debris in the oceans (e.g., Battelle Ocean Sciences, 1992), and much work has been done on the stomach contents of oceanic birds which consume plastic pellets floating thousands of miles from inhabited land (e.g., Bourne and Imber, 1982). In Galveston Bay, bag seines were used to characterize near-shore floating debris (GBNEP, 1993). Little has been written about submerged debris, but Goldberg (1996) believes it to be a significant ecological hazard. There is some literature on what happens to flotsam when it becomes jetsam on a beach. Perhaps the first paper is that of Cooke and Dixon (1977) who tallied containers on an English beach. Since then the literature on beach debris has been mainly confined to reports and published workshop symposia.

3.1 Methods

For the literature review (Appendix A) we did standard library research for journal articles and reports, and compiled the PI's collection of various reports, newsletters, magazine and newspaper articles. In particular, the PI has written extensively for the popular press as well as given numerous talks and testimonies at hearings and public meetings. The bibliography has been split into sections separating the more "legitimate" publications (including "gray" literature) from the newspaper and magazine articles. Within these categories we have separated items by general marine debris subjects, including those on tarballs. A section on audio-visual publications has also been included. A body of information of more local import exists in the minutes of various committees, such as the EPA's Gulf of Mexico Program Subcommittee on Marine Debris, CMC Workshops, the Minerals Management Service (MMS) Information Transfer Meeting Proceedings and Environmental Impact Statements on offshore oil exploration and production leases. There have been three International Conferences on Marine Debris which published proceedings.

3.2 Results

Rather than produce an exhaustive bibliography of all marine debris literature, we have limited our entries to those we feel more pertinent to the CCBNEP and its special concern for bay debris. However, it is obvious that the great majority of this literature base concentrates on the problems associated with debris floating at sea and ocean-side beach debris, i.e., marine debris. There is very little on bay debris alone. We compensated for this lack by conducting a limited search into the local sources and potential sources of bay debris, presented in the **Sources** (4.2.4). We append (electronically) to this report the PI's previously unpublished notes on beach debris which could double as both literature and data. See the section **Historical Data Review** (4.0).

We include separate sections on the local literature on tarballs. This presented us with a dilemma. The literature on oil spills and oil pollution is huge and we felt it was outside the scope of this study. However, tarballs themselves, often the weathered result of oil spills, are a part of the marine debris, especially on gulf beaches. The region has seen several major oil spills which resulted in persistent tarballs on the beach (IXTOC I in 1979 and 1980, *Burmah Agate* in 1979, *Alvinas* in 1983, and the two Buffalo Barge spills, in 1995 and 1996, for example). We have limited our literature search here to the IXTOC I event and its consequences and the PI's subsequent long-term study of the persistence of tarballs from that spill on Mustang Island beach. Again, there have been few papers on tarballs in the CCBNEP area. We do present some tarball data analysis **Results** (4.2), on the analysis of **UTMSI Data** (4.2.2), and append (electronically) to this report the PI's previously unpublished notes on tarballs.

4 HISTORICAL DATA REVIEW

June 1970 in the mid-Atlantic Ocean aboard *RA II*. *The Atlantic was no longer blue but gray-green and opaque, covered with clots of oil ranging from pin-head size to the dimensions of the average sandwich. Plastic bottles floated among the waste. We might have been in a squalid city port. I had seen nothing like this when I spent 101 days with my nose at water level on board the **Kon Tiki*** [1947]... *We must make an outcry about this to everyone who would listen.* [Thor Heyerdahl, from *The RA Expeditions*, Doubleday, Garden City, New York, p.209.]

Heyerdahl's sighting of floating tarballs and plastic in the middle of a vast ocean is something seen by countless other mariners, but measured by few. Potentially, this material could become beach debris on any coastline, on remote islands, or even the Texas shore. We discovered that finding early data on marine debris in the CCBNEP study area was even more difficult than finding early literature on the subject. One of the first attempts to numerically document South Texas beach debris was done by the PI in November 1979, counting one-gallon plastic milk jugs on the beach (61 in 6.05 statute miles of Mustang Island Gulf beach). The PI has kept notes on beach debris and tarball concentrations since 1978 and started an index system to estimate both natural and man-made debris in 1983.

Most of the efforts at documenting marine debris quantitatively started around 1986 with the first volunteer Texas Beach Cleanup in September of that year, and organized by the Center for Environmental Education (CEE 1986). The credit for this must go to Linda Marannis of CEE who was the director of the CEE branch office in Austin. It was Linda's idea to glean some information on the nature of Texas' beach debris problem by asking the volunteers to fill out data forms as well as removing trash from the beach. The latest version of these forms is reproduced herein as Figure 2. This was followed in 1987 with the first Spring Beach Cleanup organized by the Texas General Land Office (TGLO) under the direction of Commissioner Gary Mauro. Commissioner Mauro and his staff have been active in the campaigns to keep Texas beaches clean. They started the Adopt-A-Beach program, along the lines of the Keep America Beautiful (KAB) Adopt-A Highway campaigns. Locally, the PI started assessing marine debris in earnest in 1987 (Amos, 1993), and the Padre Island National Seashore began their monitoring programs in 1989 (Cole et al., 1990).

4.1 Methods

4.1.1 CMC/TGLO Data

One of the major data archives acquired for this project was that collected by the Center for Marine Conservation, or CMC (originally Center for Environmental Education, or CEE), during the annual volunteer beach cleanups which were started in Texas in 1986. These cleanups are done on the same September Saturday morning throughout Texas and the nation, from 9 am until noon, local time. Although Texas data has been compiled each year by CMC

ITEMS COLLECTED

You may find it helpful to work with a buddy as you clean the area, one of you picking up trash and the other taking notes. An easy way to keep track of the items you find is by making tick marks. The box is for total items; see sample below.

Example:

	TOTAL		TOTAL
egg cartons ~~||||~~ ~~||||~~ ~~||||~~ |	16	cups ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ||	22

PLASTIC

	Total number of items		Total number of items
bags:		fishing nets	
food bags/wrappers		hard hats	
salt		light sticks	
trash		pieces	
other bags		pipe thread protector	
bottles:		rope	
beverage, soda		sheeting	
bleach, cleaner		longer than 2 feet	
milk/water gal. jugs		2 feet or shorter	
oil, lube		6-pack holders	
other bottles		strapping bands	
buckets		straws	
caps, lids		syringes	
cigarette butts		tampon applicators	
cigarette lighters		toys	
cups, utensils		vegetable sacks	
diapers		"write protection" rings	
fishing line		other plastic (specify)	
fishing lures, floats			

FOAMED PLASTIC

buoys		packaging material	
cups		pieces	
egg cartons		plates	
fast food containers		other foamed plastic (specify)	
meat trays			

FOLD ALONG THIS LINE

GLASS

bottles/jars:		fluorescent light tubes	
beverage bottles		light bulbs	
food jars		pieces	
other bottles/jars		other glass (specify)	

RUBBER

balloons		tires	
condoms		other rubber (specify)	
gloves			

METAL

bottle caps		55 gallon drums:	
cans:		rusty	
aerosol		new	
beverage		pieces	
food		pull tabs	
other		wire	
crab/lobster traps		other metal (specify)	

PAPER

bags		newspapers/magazines	
cardboard		pieces	
cartons		plates	
cups		other paper (specify)	

WOOD

(leave driftwood on the beach)

crab/lobster traps		pallets	
crates		other woods (specify)	
lumber pieces			

CLOTH

clothing/pieces

Remember to turn the card over and fill out your name and address and to record sources and entangled wildlife!

Figure 2 Data card used by CMC/TGLO beach cleanup volunteers.

for inclusion in its annual reports (CEE, 1986 through 1988; CMC 1989 through 1995), no analysis has been done specifically for our state, and especially not for the CCBNEP study area. Data from the cards filled in by the volunteers are sent by regional coordinators to CMC in Washington, where the data are entered into spreadsheets. Nine separate areas are listed as being in the CCBNEP study area. From north-to-south, they are Port Lavaca, Matagorda Island, Rockport, San Jose Island, Port Aransas, Mustang Island, Corpus Christi, North Padre Island, and the Padre Island National Seashore. Port Lavaca is in the San Antonio/ Guadalupe Estuary. It is thought that more bay-type debris is found on the beaches cleaned there and we include it in the analysis. There is inconsistency in the naming of these sub-regions and before we could begin the analysis we had to decide where each named region was (see the individual site descriptions below). Table 1 lists the nine locations used by CMC. The two bay sites and one Gulf beach site used in the data analysis here are shaded. Mustang Island was not listed until 1992 and subsequent to that, was listed instead of Corpus Christi. We believe that the Corpus Christi count area, which is on the southern half of Mustang Island, should be part of the Corpus Christi data but may have been listed separately when the city limits were changed. Consequently, we have combined the Mustang Island and Corpus Christi count totals for 1992 and called the Mustang Island count "Corpus Christi" for 1993 and 1994. This is but one of the problems with the CMC data consistency. Our data base for the CCBNEP study region contains eight, not nine, sub-regions. Items from the data sheets are totaled in each of the categories of marine debris, which, in turn, are grouped by material type.

Table 1. Sites of CMC volunteer cleanups (1986-1994) in the CCBNEP study area, and years when cleanups were done (*). Data analyzed for this report come from years and locations indicated by shading. PL=Port Lavaca, MAT=Matagorda Beach, SJI=San Jose Island, ROCK=Rockport, PA=Port Aransas, MI=Mustang Island, CC=Corpus Christi, NPI=North Padre Island, PINS=Padre Island National Seashore.

YEAR	PL	MAT	SJI	ROCK	PA	MI	CC	NPI	PINS
86		*	*		*		*		*
87		*			*		*		*
88		*	*		*		*		*
89	*	*	*	*	*		*		*
90	*	*	*	*	*		*		*
91	*	*	*	*	*		*	*	*
92	*	*	*	*	*	*	*	*	*
93		*	*	*	*	*		*	
94	*	*		*	*	*		*	*

Another problem arises in the identification of debris items. The original list has been modified over the years as it became obvious that some items were difficult for volunteers to identify or were poorly defined at the outset. We identified 79 items out of the original list on the data cards (Table 2, Fig. 2). Spreadsheets were constructed which have 79 rows of item types and, in the CCBNEP area, eight columns, one for each location. Some of the data was acquired from CMC on disc and others in the form of printouts which were entered into spreadsheets. We did not get to see the original data cards, except for the 1995 Great Texas Trashoff sheets which are discussed later. Identification of debris items was marked by some confusion. For example, plastic soda bottles were re-categorized from "Bottles, Soda" to "Bottles, Beverage" in 1989. The infamous one-gallon milk jugs have been variously called "Bottles, Gallon", "Milk Jugs", and "Milk/Waterjugs". "Cups/Utensils" became "Cups/Straws" in 1989, a designation which is most confusing. CMC has clarified the categories with illustrated data sheets and their publication on how to do a beach cleanup (Marannis, 1989). Amos (1993b) discusses some of the problems found in dealing with entries in the data cards, transcribing to the computer, and interpretation of items found. Using Quattro Pro we have stored all these data on 150-MB Bernoulli cartridges for the purpose of analysis, and on diskette for inclusion with this report as an archive. Because some of our analysis is done using programs written by the PI, we also include ASCII files.

Statistical analyses were performed on subsets of the data, one file for each category, to facilitate the data manipulation (these subsets are also included in the overall data disks accompanying the report). Additional sets by material type (plastic, glass, rubber, metal, paper, wood, and cloth) were also constructed for analysis. CMC includes another material type, foamed plastic, or Styrofoam, which we include under plastic here. The material type "tarballs", while often mentioned by CMC volunteers, are not tallied on the cards. The UTMSI data includes tarballs. Items were grouped both by count region for all years and by year for each region. In addition, we show the raw count data and also analyze by items per unit distance (kilometer). Standard first-order linear regression was used on the data sets and a coefficient of variance computed.

Amos (1993b) found errors in the way the data were compiled and even in how the debris was perceived by the volunteers. Therefore, to evaluate the methods used in this major volunteer effort, we further investigated techniques, specifically for this report. We did this by conducting interviews with the coordinators for each region and also by observing the September 16, 1995 cleanup. The interviews were conducted mostly by KCK with contributions by AFA. The narrative has been edited for clarity but left mainly in the words of the interview participants because the comments add to the understanding of the role volunteers play in the question of marine debris studies. Two special interviews were conducted separate from the Beach Cleanup coordinators: Carol Cervenka in Ingleside-on-the-Bay, and Mark Smith of the City of Corpus Christi Marina. Ideally, for intercomparison of data from each location, cleanups should include information additional to that listed on the CMC data cards. We interviewed cleanup coordinators from all Texas coastal areas, asking these specific questions:

Table 2. Debris categories used in the analysis of the CMC volunteer beach cleanup data. A numerical designation and four-letter code was devised for each item to facilitate computer identification and sorting.

#	CODE	Description	#	CODE	Description
	PLASTIC			**GLASS**	
1	FBAG	Plastic food bags	43	GBEV	Glass beverage bottles
2	TBAG	Plastic trash bags	44	GFBT	Glass food bottles
3	SBAG	Plastic salt bags	45	OBEV	Glass other bottles
4	OBAG	Other plastic bags	46	FLUO	Fluorescent light tubes
5	BBOT	Plastic beverage bottles	47	BULB	Light bulbs
6	BLCH	Plastic bleach bottles	48	GPCS	Glass Pieces
7	MILK	Plastic milk jugs	49	OGLA	Other glass
8	LUBE	Plastic oil/lube bottles		**RUBBER**	
9	OBOT	Other plastic bottles	50	BALO	Balloons
10	BUCK	Plastic buckets	51	COND	Condoms
11	LIDS	Plastic caps/lids	52	GLOV	Gloves
12	BUTS	Cigarette butts	53	TIRE	Tires
13	LGHT	Cigarette lighters	54	ORUB	Other rubber
14	PCUP	Plastic cups/utensils		**METAL**	
15	DIAP	Diapers	55	MCAP	Metal bottle caps
16	LINE	Fishing line	56	SPRY	Metal aerosol cans
17	NETS	Fishing nets	57	BEVG	Metal beverage cans
18	FLOT	Plastic floats/lures	58	FCAN	Metal food cans
19	HARD	Hard hats	59	OCAN	Other metal
20	STIK	Light sticks	60	MTRP	Metal crab/fish traps
21	PPCS	Plastic pieces	61	DRUM	55 gallon drums
22	TPRO	Pipe thread protectors	62	MPCS	Metal pieces
23	ROPE	Rope	63	PTAB	Pull tabs
24	PSHT	Plastic sheeting	64	WIRE	Wire
25	SXPK	Six-pack holders	65	OMTL	Other metal container
26	STRP	Strapping bands		**PAPER**	
27	STRW	Plastic straws	66	PBAG	Paper bags
28	SYRG	Syringes	67	CARD	Cardboard
29	TAMP	Tampon applicator	68	CART	Cardboard cartons
30	TOYS	Toys	69	PCUP	Paper cups
31	SACK	Vegetable sacks	70	NEWS	Newspapers
32	WPRT	Write protect rings	71	PPCS	Pieces of paper
33	OPLA	Other plastic	72	PPLA	Paper plates
34	BUOY	Styrofoam buoys	73	OPAP	Other paper
35	SCUP	Styrofoam cups		**WOOD**	
36	EGGC	Styrofoam egg carton	74	WTRP	Wooden crab/lobster pots
37	FFCN	Styrofoam fast food cont.	75	WCRT	Wooden crates
38	TRAY	Styrofoam meat trays	76	DRFT	Lumber
39	PCKG	Styrofoam packaging	77	PALL	Wooden pallets
40	SPCS	Styrofoam pieces	78	OWOD	Other wood
41	SPLT	Styrofoam plates		**CLOTH**	
42	OSTY	Other Styrofoam	79	CLTH	Cloth

1) What was the exact location and length of the beach cleaned in your area?
2) How many volunteers were involved?
3) Do you have records archived from previous years clean-ups? If so, are they your own set of records, or are they copies of the standard CMC data cards? May I come to your location and view these records?
4) How many years have you been coordinator of your area?
5) Was anyone else involved before you?

We were mainly interested in the cleanups conducted in the CCBNEP study area, but as the response to our initial telephone enquiries was mixed, we included all the Texas coordinators who were interviewed, especially as some outside the area provided more detail. Only responses from sites in the CCBNEP study area are given here. The full responses are found in Amos et al. (1996). Some coordinators did not respond and some we were unable to contact. Responses to the numbered questions are given below, with additional notes.

PORT LAVACA/MATAGORDA:

A. *Toni Allen (512-552-9242)*

1) On the bay shores, about 4.5 miles of Magnolia Beach (about 10 miles from Port Lavaca) and Indianola Beach are cleaned. On Matagorda Island Beach, about 2.5 miles are covered. Transportation from Port O'Conner to the island is provided by ferry.
2) About 70 volunteers have registered for the island this year [1995]. Normally about 400 volunteers take part in the cleanup of the bay shores.
3) Yes, I can come to see the data.
4) Toni has been involved for about five years.
5) Marlene Paul was the previous coordinator; she is now the county clerk.

NOTES: The cleanup portion on Matagorda Island is coordinated by Terri Austin. Lunch and T-shirts are provided by various donations from Days Inn, HEB, Formosa Plastics (T-shirts) and Union Carbide (work gloves). Toni mentioned that there was not much change in the amount of trash found on the beach in the last few years. She thought that the reason for this was that although a landfill was only 15 miles away, many people dump their trash on the beach. Because of this, mostly household trash is found. Toni also noted that even though trash receptacles were provided, visitors throw trash in the "general direction" of the barrel, but do not bother to throw it in the barrel, thus leaving the wind to spread it around. On Matagorda Island, she said that the trash mainly consisted of industrial trash from ships and rigs. When I asked her about any bay cleanup efforts, she said not really, but the city comes down now and then to clean the park on the bay. She did mention an incident where a scout troop was having a function at the park the same day as the beach cleanup and wanted to know if it was OK to clean the bay area. Toni told them to call the city to ask and she would give them some bags to do so. The scout leader mentioned that the city was hesitant and not very happy about the idea of these kids coming down to clean the area.

SAN JOSE ISLAND:

A. *Pam Greene (512-749-4735)*

1) About 1.1 miles from North Jetty of the Aransas Pass to the Private Property fence-line.
2) Around 50-75 volunteers.

3) Yes, we may look at the records (we have done so in the past and for this report). All records go to the CMC.
4) Pam has coordinated this region since 1991.
5) Chris Sandstrom did the job before then, and Russ Miget before her.

NOTE: This was the subject of our detailed study of volunteer beach cleaning in 1992 (Amos, 1993b).

ROCKPORT/FULTON:

A. *Jane Gimler (512-729-6445)*

1) 1 mile on the beach and the 4 miles between Water Street and Fulton Street.
2) In the Fall, about 100-125 participate. In the spring, about 50-60 are involved.
3) No answer.
4) Jane has been involved for about 2 years.
5) Stephanie Brand was the previous coordinator for about 2 years also; she is now in Minnesota.

B. *Jake Colville (512-729-1160)(Fax 512-729-8835)*

Aransas County Clean Team (new president is Steve Long), P.O. Box 111 Fulton, TX. 78358 (512-729-9991)

1) About 9 miles are covered, including Little Bay and Fulton Beach Rd., and the beach (about 1 mile).
2) Last year a total of about 220 people (the September and April cleanups combined). Girl Scouts, 4-H, etc. also got involved with the clean-up.
3) Possibly. Little Bay Clean Team—citizens adopt a section of shoreline of Little Bay, consists of about 10 groups.
4) She has been involved for about 4 years.
5) No one preceded her, there were trash clean-ups going on, but they were uncoordinated.

PORT ARANSAS:

A. *Pam Greene (512-749-4735)*

1) From the South Jetty of the Aransas Pass to the Nueces County marker 13 (near the southern Port Aransas city limits, halfway between Access Roads #1 and #2). Total distance, 7 miles. Also includes the part of the South Jetty bordering Mustang Island Gulf beach (both channel and sea sides), a very difficult and trashed-out half-mile.

NOTE: For the past two years, a section of "Charlie's Pasture" has been included. This is on the west side of Mustang Island, bordering the Corpus Christi Ship Channel. It is important because it is one of the few areas on the bay in the CCBNEP study area.

2) From 250 to 550 volunteers; less for the April cleanups.
3) Yes, we obtained the 1995 September results and sent them on to CMC.

NOTE: The region includes some sections of beach which have been adopted by the Texas Adopt-A-Beach program. These are cleaned by the adopters separately from Pam's volunteers (it is the same with other sections of the beach). The distances are from a half-mile to 2 miles. These data sheets are sent to the GLO.

4) Pam has coordinated this region since 1991.
5) Chris Sandstrom did the job before then, and Russ Miget before her.

CORPUS CHRISTI/MUSTANG ISLAND:

A. *Leigh Pohlmeir (512-881-1248—TX. St. Aquarium)*

1) An approximate 12-mile stretch is cleaned, covering the Nueces County area from Bob Hall Pier to Mustang Island.
2) 750 to 900 volunteers.
3) No. All records go to Texas General Land Office or the Center for Marine Conservation.
4) Leigh has been coordinating since 1994; this clean-up coming up is her fourth coordination effort (both April and September).
5) Kate Brown used to coordinate, but she is no longer with the Texas State Aquarium.

NOTES: Leigh noted that more people from other cities are coming down to participate in the clean-ups. Students from UTSA, Trinity, etc. are volunteering. Also, people from Dallas, San Antonio and out-of-town companies are sending groups to volunteer.

NORTH PADRE ISLAND AT CORPUS CHRISTI:

A. *Don and Wendy Flint (512-857-8765, days; 512-949-8984, evenings and weekends)*

1) The area cleaned is about 8 miles, from Kleberg County line to Padre Island National Seashore. About one-half of this area is adopted by groups which are responsible for the clean-up in that area (Texas Adopt-A-Beach program).
2) The most is about 300 to 400 people. Last year about 200 participated.
3) No. All the information goes to Texas General Land Office.
4) They have been involved since 1986.
5) No. Don and Wendy started the program.

NOTES: Mr. Flint did a report in 1985 discussing an informal experiment he conducted where he roped off a one-half mile section of beach. One-half of this section was cleaned, and the other half was left uncleaned. Due to this report, Gary Mauro asked him to head the clean-up for his area. Don mentioned that he doesn't think anything has changed. He said the trash looked mostly Mexican or from small shrimp boats. Mr. Flint did note that he thought there was not as much industrial waste seen (recently).

PADRE ISLAND NATIONAL SEASHORE

A. *Kristey Bosworth (512-949-8068)*

1) In the spring, 10 miles were covered near the visitors center and 13 miles were covered at Big Shell (a special cleanup, the first ever organized for this remote beach famous for its fishing and trash).
2) No answer.
3) No answer.
4) Ms. Bosworth has been involved for about four years.
5) No answer.

NOTES: The interviewer reported a reluctance to respond to these questions and therefore we have limited information on this area.

1995 NATIONAL BEACH CLEANUP:

We observed the 1995 National Beach Cleanup at three locations in the CCBNEP area to glean first-hand methods and techniques used by the coordinator and the volunteers. Our observation of the 1995 Beach Cleanup was split between the authors as follows. From north-to-south, Rockport-KCK, San Jose Island-AFA (assisted by Chuck Rowe [CR]), Port Aransas and Mustang Island-ARW.

ROCKPORT CLEANUP—16 SEPT 1995 (KCK):

I attended the Rockport Cleanup on September 16. The areas covered in Rockport were Bird Island at the Connie Hagar Sanctuary on Little Bay, Little Bay in general, the Rockport City Beach, along the Aransas Bay along Water Street and the Fulton Beach Road to Kon Tiki along the bay. The area I visited was the Bird Island cleanup coordinated by Bob Austin. Jane Gilmer was at the Water Street/Fulton Beach Road area. Bird Island is a long, narrow island at 28°02.85N, 97°03.52W in the middle of Little Bay, Aransas County. The island itself has a normal bay vegetation. Close to the water was *Sporophola*, then *Salicornia virginica*, and *Machaeranthera*, then *Disticlis* and *Spartina*, then at the crest was domestic grasses, sunflowers, and prickly pear cacti mixed with brush. This island is a big nesting area for shore birds. Lots of nests with egg-shell fragments, there were some nests that had bits of Styrofoam or plastic in the nest site as if it were being used as nesting material. There were also several carcasses in the area, all but one I saw were skeletal, and none had any evidence of monofilament entanglement or ingestion of plastic or Styrofoam. I saw two roseate spoonbill bodies and several juvenile laughing gull bodies and a few adults. The trash on the island looked mainly as if it came from private fishing boats of the area. There were beverage cans and bottles, ice bags, Styrofoam cups and cooler/bait bucket lids, a few shoes and hats, and some food wrappers. Since this was the first time this island had been thoroughly cleaned, there were some very old beer cans with the peel-back openers and made of a much heavier grade of metal than the modern ones. Bob Austin said that most of the trash is between the grass and the water line, however that day's high tides kept the shoreline submersed, making it hard to get to. The Coast Guard Auxiliary boated us back and forth across the bay to the Island. The group I went with was the Rockport/Fulton Junior High Honor Society. There were 26 of us all together. Other groups that helped in other areas were the Girl Scout Troop 803, Probates from the local facility, and lots of private citizens. At the end, about 110 to 125 people were served hot dogs and refreshments.

SAN JOSE ISLAND CLEANUP—16 SEPT 1995 (AFA and CR):

San Jose Island is accessible only by boat. Volunteers use the Jetty Boat which leaves Port Aransas at two-hour intervals beginning at 6 am. They do not go beyond the fence line, 1.1 miles to the north of the jetty, beyond which is private property. We were able to observe during our regular San Jose Island Turtle/Trash Survey, which is done at eight-day intervals. We had intended to do a before-and-after count of trash on the section of beach cleaned by the volunteers. However, by the time we got to the North Jetty at 0903, the cleanup was well under way and we had to delay our counting until after we had surveyed the entire island and the volunteers had gone. We saw about a dozen volunteers collecting trash and some were entering data into the tally cards. Others were hefting full bags back to the landing site for pickup. At 1505, we observed the beach to be almost spotlessly clean of man-made trash for the first half-mile north of the jetty. From the first fence line to the jetty, we counted only 20 beverage cans, 4 light bulbs, and one 5-gallon pail. Compare this to the 570 beverage cans, 232 light bulbs, 256 5-gallon pails, 69 plastic crates, 17 shrimp baskets, 134 rubber gloves, 91 floats, 31 hard hats, 353 1-gallon milk jugs, 146 egg cartons, and 114 green bleach bottles from Mexico counted on the rest of the island's beach (we count only these targeted items).

MUSTANG ISLAND/NORTH PADRE ISLAND BEACH CLEANUP—16 SEPT 1995 (ARW):

I began at 9:00 in the morning with the goal of driving the entire length of Mustang Island, on to Padre Island, and ending at the PINS (Padre Island National Seashore). I wanted to observe the cleanup and talk with the coordinators of the different areas. In Port Aransas, I spoke with Pam Green. She was instructing the volunteers on how to fill out the forms and what areas of the beach to clean. I was told that she had around 300 volunteers who would be cleaning the Port Aransas gulf beach, the South Jetty of the Aransas Pass, San Jose Island and Charlie's Pasture. I left there and proceeded south on Mustang Island gulf beach. I drove to the Fish Pass jetties, turned around and came out onto the Island Road at Access Road 2. As it was so soon after the beginning of the cleanup, there were not many people out cleaning; of those that I did see, the following is what I observed:

The entire beach had been scraped by the City of Port Aransas and by Nueces County and what trash there was had been dumped on the dunes with the sand that had been scraped up. As I moved on down the beach, I only saw a few people with bags, and most of them did not have tally cards. [Volunteers were] putting trash in bags but not recording [on data sheets], and picking trash out of the piles at the dune line.

I proceeded to go out to the Island Road to Gulf Beach Access Road 3. When I reached the beach, I drove north to the southern boundary of the Mustang Island State Park. I then turned around and drove south along the Gulf beach. I encountered one group of 30 high school children cleaning the beach just north of Access Road 3. I spoke with the principal; who said that he brought these children each year and that he would turn his cards in at 12:00 at the Holiday Inn. This is where the GLO would collect all cards, unless other arrangements had been made. I was not able to establish under what region these would be recorded. The principal said that he wrote "Padre Island" on the back of the cards as the location cleaned.

I then continued on south, observing many people with bags but few with tally cards. They were simply putting the trash in the bags and not recording the information. I got off the beach at the sea wall and drove to the Holiday Inn. There, I spoke with a teacher from Corpus Christi who said that he had 75 volunteers who were cleaning from JP Luby Surfing Pier to Bob Hall Pier. Again, it was not clear where (what section of the beach) these tally cards would be recorded.

I then got back on the beach just past the sea wall and drove past Bob Hall Pier. I came across many people cleaning the beach and many people just fishing and playing. By this time it was almost 11:00 and much of the cleaning had been completed. It was impossible to count the people cleaning or even the bags that had been filled. Trucks were passing me constantly filled with bags of trash.

There were many groups. Coast Guard, Rotary Club, and a large group from the General

Land Office. When I spotted what looked like a central gathering point of these groups, I would stop and speak with the coordinator. One group had conducted their cleanup (tallying) in an interesting way. After all volunteers had finished picking up trash in their assigned areas, they would gather around the coordinator and he would call out each item on the list. If a volunteer had picked up that particular piece of trash, that person would raise his/her hand. The coordinator would then tally all trash picked up by the entire group on one card. There were about 50 people included in this group. Another group had fifteen people (adults and children). They were asked to pick up as much trash as they could in 30 minutes, record what they found, and come back for barbeque and swimming.

4.1.2 UTMSI Data

Since 1978, notes on marine debris were made during regular beach surveys made by the PI on Mustang Island Gulf beach. Starting in 1983, a subjective estimate was made of the quantity of 40 categories of both natural and anthropogenic beach debris. At the least, this effort which continues to this day, provides information on when these items wash ashore throughout the year. At the best, its 0-to-5 index provides a more quantitative record which, for some categories, has been regressed against numerical data. We present box diagrams showing the results of these estimates in section (4.2.2). In the ongoing long-term survey of Mustang Island beach, the PI has made numerous notes on debris on the beach. These notes have been coded so that they can be sorted by subject matter. The data (not including pre-1984 notes, which are still being transcribed from the hand-written log sheets) are included in the data bank appended to this report. A list of codes is given in Table 3.

Table 3. Description of codes pertinent to CCBNEP marine debris study, used in Mustang Island beach survey.

CODE	DESCRIPTION
GARB	General note on garbage (marine debris). Often specifically includes details container of household and other products.
CHEM	Specific details of large-volume containers (e.g., 5- and 55-gallon pails and drums) which contain chemicals or oils.
TARB	References to tarballs, oil spills, etc.

Table 4 shows a typical arrangement of the notes under the first two of these codes. Under CHEM, every container found during regular beach surveys has been cataloged and described. Codes within the notes allow for further sorting by content, size, container material and type of container. Later, in an attempt to inform the public about the quantity of marine debris washing ashore locally, the PI published the "Milk Jug Index" in a weekly column for the *South Jetty* newspaper (from 20 December 1988 through 24 December 1989—see **3.0 Literature Review**) which tabulated the number of certain common items recorded on

Table 4. Format of notes made during survey of an 11.8 km stretch of Mustang Island gulf beach. DIST is the distance in meters from the transect starting point, SIZE is the volume of the container, followed by a single letter code for quantity of material in the container when found (E=Empty, F=Full, P=Partly full), and a double-letter code for type of container (first letter; P=P, M=Metal, G=Glass; second letter, P=Pail, D=Drum, C=Carboy, B=Bottle). NOTES contain a description of the container and details of any label. Clock refers to the time-stamp on many containers showing the date of manufacture.

Representative section of BEACHobs notes for code CHEM for 1992

DATE	TIME	DIST	SIZE			NOTES
92/01/19	08:33:44	5001.3	55gal	E	MD	Empty r sty metal drum. Roped off by Nueces Co. Another was back a mile or so.
92/02/02	09:01:23	9211.8	5gal	E	PP	Empty yelow plastic pail with red lid. Golden West HYD OIL. Warnings about petroleum product, flammability, etc. Clock 3/89.
92/02/12	08:16:56	3150.7	5gal	E	PP	Empty white plastic pail with lid. "RIG Wash " in stencil on side. Clock 1/91.
92/05/12	06:59:42	3567.4	50Kg	E	PB	Empty plastic woven bag (several?) CRISOTILA. oduto da mina de Cana Brava, Minacu Brasil. These sacks are half buried in wet sand at S/L. stretching 6.2m. They could all be sewn together as the capacity of this sack is far greater than 50Kg.
92/05/12	08:48:01	10840.4	4.5Kg	E	PP	Empty yellow plastic pail with lid.Bardahl Grasa. Mexico (grease).
92/05/14	07:04:31	4404.8	55gal	P	MD	Partly full rusty metal drum. No label. fragment of reddish paint and legend on top. "205 L.." (205 liters).
92/05/14	07:07:52	4669.8	2l?	E	PB	Empty blue plastic bottle with handle. All legend in Japanese. Bleach.
92/05/14	07:38:59	6230.4	55gal	E	MD	Empty rusty metal drum. Some yellow paint on side. Only fragment of legend. ...ERSOL. 615....-28
92/05/14	08:20:33	10563.1	5gal	E	PP	Empty red plastic pail. No lid. Yellow label. RIGVIS-L Liquid HEC Viscosifier. RIG-CHEM Inc, Houston, New Orleans,"Mix 5 gal to 20 barrels of fluid to obtain funnel viscosity of 35-40."Warning ls.

Representative section of BEACHobs notes for code GARB for 1994

DATE	TIME	DIST	SIZE			NOTES
94/06/24	07:42:11	5899.6				Plastic yellow soft-drink crate."Costemar" printed sides.
94/06/24	08:01:43	6182.4	6.75oz	E	PB	Empty opaque plastic bottle "Great Bluedini" Kool-Aid Burts soft drink. I see more & more ofthese kid's drink bottles on beach.
94/07/02	06:53:07	2360.7				Blue hardhat in good shape. No logos. Kept.
94/07/02	08:10:56	11812.3				Site of fireworks show. Fireworks with names like "Bumper Harvest", "Happy New Year", "Fireworks Friendship" (these made China), and "Big Tex Cone" (this made in Roswell, NM).
94/07/04	06:47:49	399.2				Site of party. 15 Budweiser cans & cardboard carton, plastic bag.
94/07/04	06:50:13	471.6				Site of party. 14 bud cans, towell, aluminum, plastic.
94/07/04	07:03:04	1078.2				One of the nastiest party site. 24 beer cans, Full plastic garbage bags, newspaper, plastic, fire remains. A hole dug contains garbage bags, glass beer bottles.
94/07/04	07:12:49	1552.7				GARB Long-billed curlew among garbage
94/07/04	07:45:54	5827.5				Site of party.16 beer cans plus fire site & other garbage.
94/07/14	08:29:34	8259.8				Less garbage today.
94/07/14	08:49:21	11517.2				More garbage here. Shrimp basket, milk jugs, big light bulbs, gloves, beverage cans, 2-stroke (Mexican) motor oil

the beach during each week (milk jugs, egg cartons, chemical pails and drums, green [Mexican] bleach bottles, and beverage cans).

The main body of work was done from 1987 through 1992. The techniques used have been detailed in Amos (1993a, 1993b) and are only briefly reviewed here. The goal was to document trends in the **standing stock** of debris on a Texas barrier island Gulf beach. A hiatus in the project occurred in 1990 with few surveys being done, but in 1991 and 1992, following the ratification of MARPOL Annex V, the survey was re-established. Some 175 surveys of an 11.8-km stretch of Mustang Island Gulf beach were done at an eight-day sampling interval. A vehicle was driven slowly along the beach and counts were made of 84 types of debris, including a few countable natural items. Items had to be large enough to permit a reasonably accurate count. Data were entered directly into a computer by the vehicle operator. Items counted were not removed from the beach. Simultaneously, the smaller pieces of debris, including many natural items, were collected from three 10-m wide swaths of beach along the transect. This was called the "micro-trash" survey and items were recorded by weight rather than number. It was most useful in quantifying the uncountable debris such as tarballs. For this report, the data has been reprocessed to produce monthly averages for each of the debris items. Files of these averages are provided in the data diskettes.

4.1.3 PINS Data

We were unable to acquire the actual data from the Padre Island National Seashore (PINS) marine debris surveys. Their published reports were used to glean what information we could. Of two main efforts, summaries of the "Quarterly Surveys" (done from 1988 to 1993) have been published in Cole et al. (1990), Manski et al. (1991), and Cole et al. (1995). Surveys are done in December of one year, and March, June, and September of the following year. The project was done in 1988/89, 1989/90, 1990/91, 1991/92, and 1992/93 in coordination with seven other National Parks and Seashores.

It was immediately recognized that PINS is anomalously high in the quantity of marine debris compared to that at the other national sites. The results of PINS surveys have been excluded from the general analysis of this data set by Manski et al. (1991). Results of the surveys at other parks have been used to analyze the statistics of trend analysis in marine debris monitoring projects by the CMC-sponsored National Marine Debris Project (CMC, 1996) for which the first author is a workshop participant. We used none of the data in this report. There is some contention on the usefulness of this method and the data set (Miller et al., 1995). PINS has continued monitoring marine debris on the National Seashore and has tried various techniques, varying the length of beach, the frequency of surveys, and the lateral extent of the beach surveyed. Since March 1994 they have done daily surveys of a 16-mile stretch of beach, the results from the first year being published in a data report (Miller et al., 1995). We did not get the raw data from PINS, but have used the information from Miller et al. (1995) to study the published numbers and do some additional analysis and comparison with our other data sets within the limits of the information in the report.

4.2 Results

4.2.1 CMC/TGLO Data

This is the only substantial data set which includes a site on the bay, as opposed to the Gulf shorelines. Hence we attempt to analyze the bay sites, which are few, but of greater interest to the CCBNEP, in comparison to the Gulf sites, which are many and also include other data sets. For the analysis of the data presented in this report we chose three of the debris items examined in the UTMSI data, one-gallon milk jugs, metal beverage cans, and 5-gallon pails and carboys. They represent three potentially different sources of debris: shrimping, beach-going/land-based sources, and offshore oil and gas industry, respectively, although not exclusively. On the bay sites, one would expect that beverage cans to be a dominant item and the other two less-so if their source is strictly marine. We plotted annual histograms (e.g. Fig. 3) of these three items by location and year from 1986 to 1994, the latest year for which data was available, pie-diagrams showing relative percentages of these material types by location and year (e.g. Fig. 9), trends in the material makeup of debris with time (e.g. Fig. 11), and histograms by location and year of the distribution of debris classed by material type (e.g. Fig. 13). Only data from the September cleanups are included.

First we examine the totals counted for these three items by location as a function of year, hence we can examine the data for temporal trends at each site. The diagrams (e.g. Fig. 3) have nine bar-graph panels, one for each of the eight locations analyzed, and one which shows the means of all locations. The X-axis is years from 1986 through 1994 with the mean of **all** years on the right. To aid in comparison, the same vertical scale is used for each location, except for the ninth graph, labeled "ALL CCBNEP." Statistical information is shown to the right of each panel. Listed are the **n**umber of observations, the **Tot**als, **Max**ima, and **Means**. Where no data was collected for that year, an **n** appears in the place of the bar. In all these diagrams, the two bay sites and the Port Aransas (Mustang Island Gulf beach) site are highlighted. We present the data in two ways: diagrams (a) are the numbers as reported on the data sheets, while diagrams (b) are normalized to numbers per unit distance (per kilometer), using the best estimate of distances covered by the volunteers gleaned from our interviews and observations.

Next, we look at the same data plotted by year as a function of location (e.g. Fig. 4) to examine for geographic variations. Ten bar-graph panels are presented, one for each year from 1986 through 1994, and one, the mean of the nine years of data analyzed. As above, diagrams (a) are totals counted, while diagrams (b) are plotted as density of items per kilometer.

Numbers of **one-gallon plastic milk (and water) jugs** (Fig. 3a) are few in Port Lavaca and Rockport. They are also surprisingly low on San Jose Island, where milk jugs are usually numerous, as a cursory view on any day will show. The numbers decrease in time at some locations, increase at others, but decrease overall when the average of all locations is plotted against year.

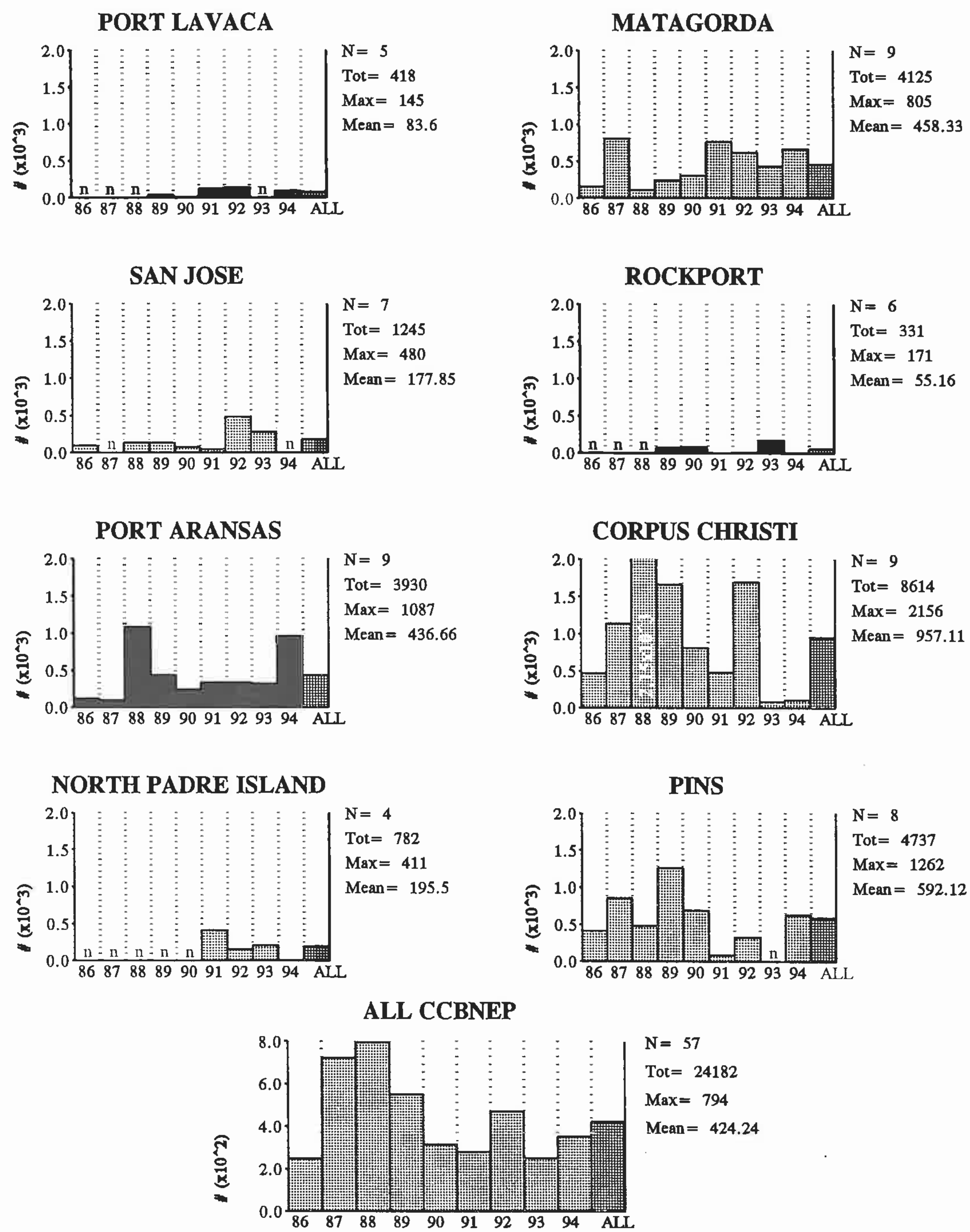


Figure 3a CMC/TGLO data: count by location of PLASTIC MILK JUGS (totals)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean count

At Corpus Christi, counts for several years are very high, while in 1993 and 1994 they are dramatically lower. In Figure 3b, milk jugs at Port Lavaca and Rockport become vanishingly small, while San Jose Island shows a more realistic density. Little trend with time can be discerned. When we plot milk jug totals by year against location (Fig. 4a), the Corpus Christi region dominates, although numbers for 1993 and 1994 are suspiciously low. The emphasis shifts to Matagorda and San Jose Islands when the same data is normalized to number per kilometer (Fig. 4b). A total of 24,182 milk jugs were reported during these years. By comparison, more than 15,507 have been counted on Mustang Island since 1988 during the UTMSI survey, and 4,925 in a year of daily surveys on Padre Island in the PINS survey. While these numbers and others given in this section are by no means directly comparable, they do serve to give an idea of the numerical magnitude of marine debris items and the effort to count them. The CMC effort in our area may be measured in tens of thousands of people working three hours on each of nine single days and covering 100 kilometers, while the other surveys use from one to a handful of people working on hundreds of days covering a few kilometers—perhaps 100,000 man-hours versus two or three thousand man-hours. Hence the difficulty in comparing results from surveys using such disparate methodologies.

Beverage cans are found in abundance on Gulf beaches as well as bay-side and, indeed, along area roadways. Therefore, one might expect the bay sites to have high numbers of these. Figure 5a plots beverage can totals by location as a function of time. The ratio of cans counted at the two bay sites to those counted on Gulf beach sites is higher than is the ratio of milk jugs (Fig. 3a). It is peculiar that the trend is up in Port Aransas and down in Corpus Christi, the two sites being adjacent to each other. 1987 appears to have been a big year but the excess at Corpus in that year biases the mean for all years. Without this, the trend would be positive. However, when the beverage can density is calculated (Fig. 5b), most locations show an increase, the big year of 1987 in Corpus Christi essentially disappears, and the overall trend is up (although now, Matagorda Island biases the overall trend). Looking at the yearly changes in total beverage cans as a function of location (Fig. 6a), sites 5 and 6 (Port Aransas and Corpus Christi) stand out, but normalizing (Fig. 6b) shifts the emphasis to Matagorda. Linear correlation coefficients show little significance. Total beverage cans counted (44,550) compares with 16,799 in the UTMSI count (the PINS study did not count beverage cans).

5-gallon **plastic buckets**, as they are called in the CMC cleanups, are plotted in Figures 7 and 8. The definition of this item is somewhat ambiguous. Similar sized containers which hold "semi-bulk" quantities of oils, paints, chemicals, and occasionally food items, vary from plastic and metal buckets with wire handles and lids (pails) of 3.5-, 5-, and 6-gallon capacities, to molded plastic carboys, usually 5-gallon size, with spouts or screw caps, to variously-shaped foreign chemical containers of 10-, 20-, and 30-liter capacity. Pails from Mexico often are 5-gallon size, but marked in the metric equivalent (17.9 liters). Whether the volunteers count all of these as "buckets" is not known. The PINS study separates the 6- from the 5-gallon containers, while the UTMSI study lumps them all together.

Plotted against year, bucket totals at Port Lavaca, Rockport, and San Jose Island (Fig. 7a) are

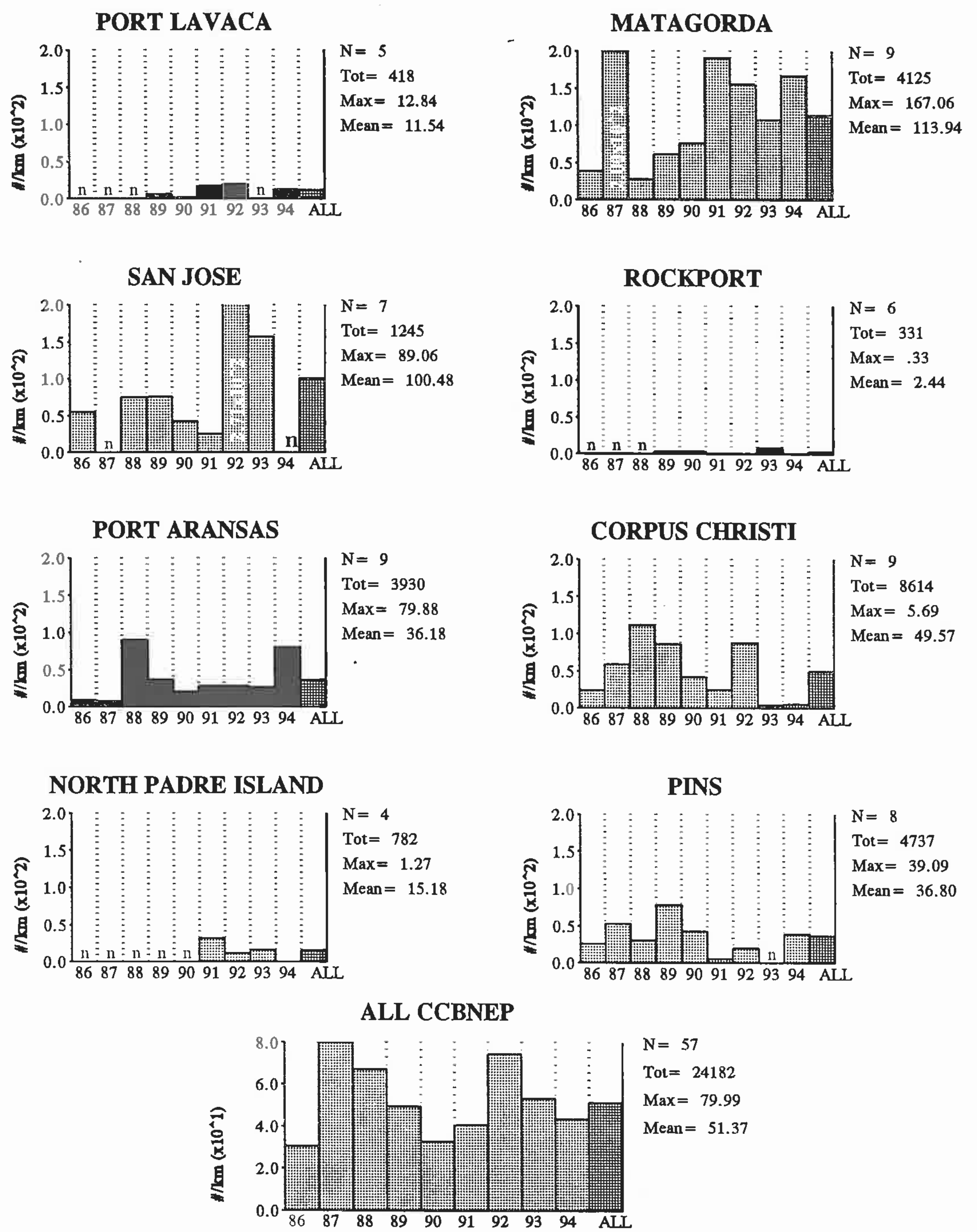


Figure 3b CMC/TGLO data: count by location of PLASTIC MILK JUGS (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

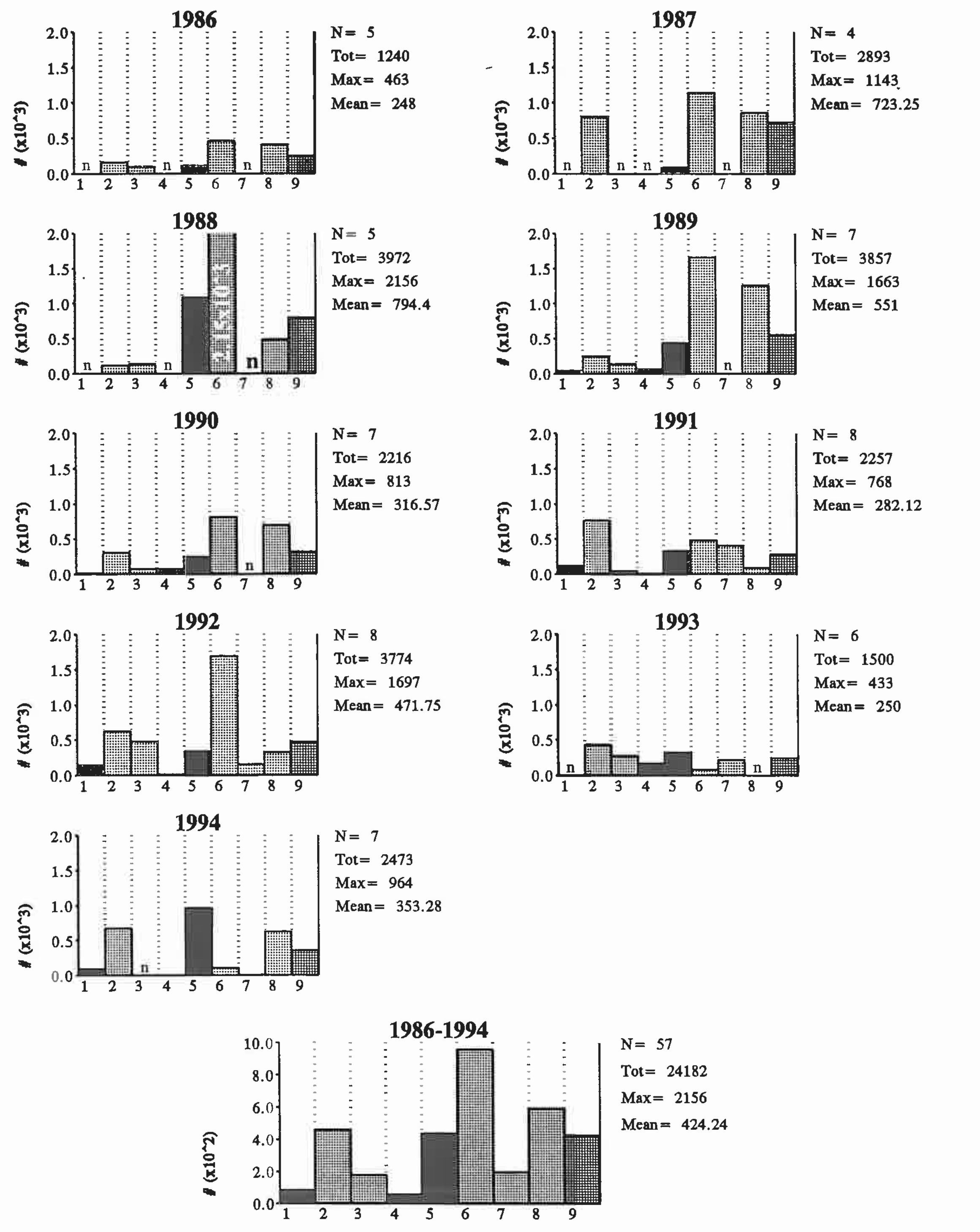


Figure 4a CMC/TGLO data: count by year of PLASTIC MILK JUGS (totals)
Locations are numbered according to key below. An 'n' indicates no data collected
The three sites used for special comparison here are shaded black
1 = PORT LAVACA; 2 = MATAGORDA; 3 = SAN JOSE; 4 = ROCKPORT
5 = PORT ARANSAS; 6 = CORPUS CHRISTI; 7 = NORTH PADRE ISLAND; 8 = PINS; 9 = ALL CCBNEP

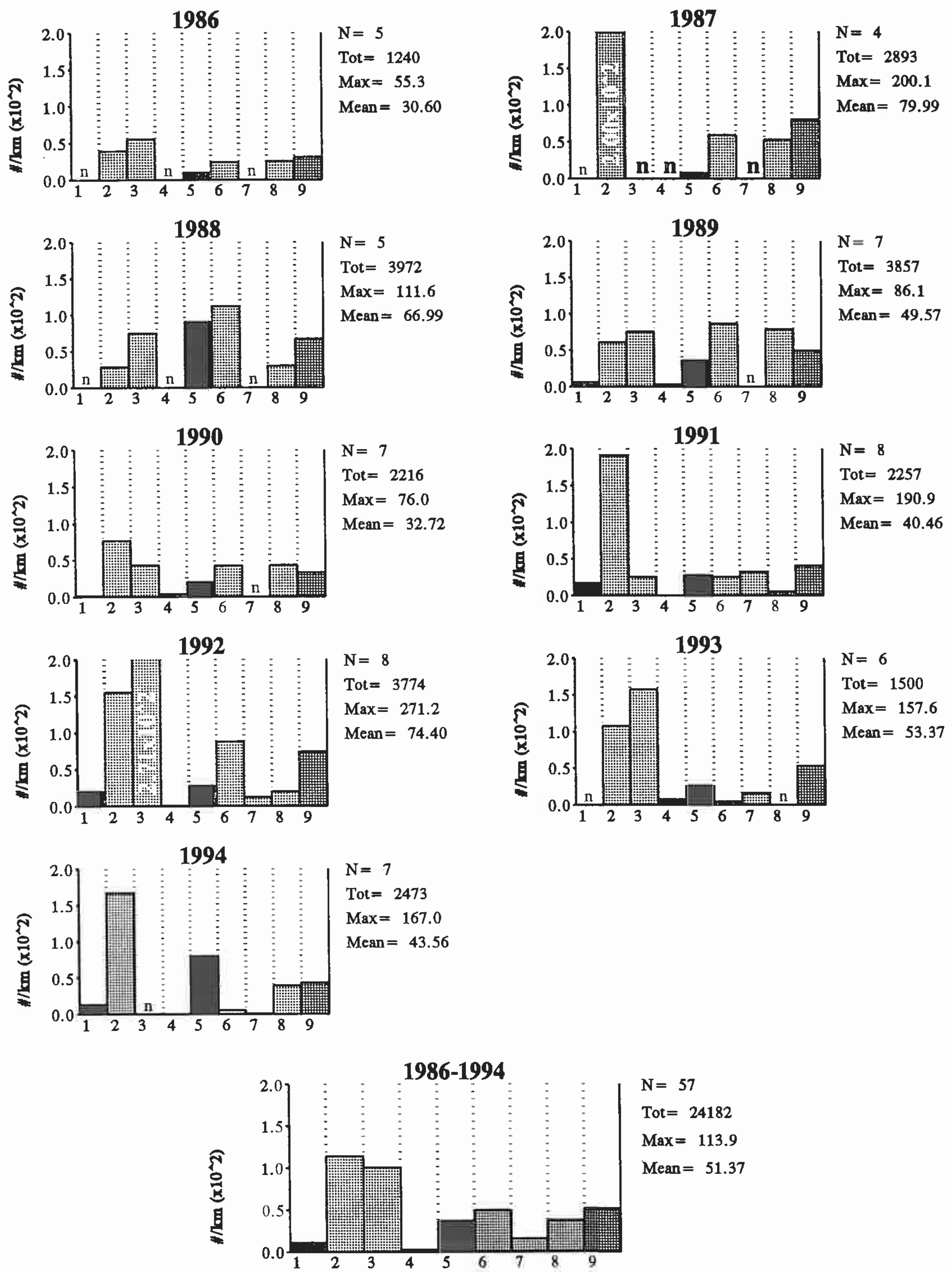


Figure 4b CMC/TGLO data: count by year of PLASTIC MILK JUGS (per kilometer)
Locations are numbered according to key below. An 'n' indicates no data collected
The three sites used for special comparison here are shaded black
1 = PORT LAVACA; 2 = MATAGORDA; 3 = SAN JOSE; 4 = ROCKPORT
5 = PORT ARANSAS; 6 = CORPUS CHRISTI; 7 = NORTH PADRE ISLAND; 8 = PINS; 9 = ALL CCBNEP

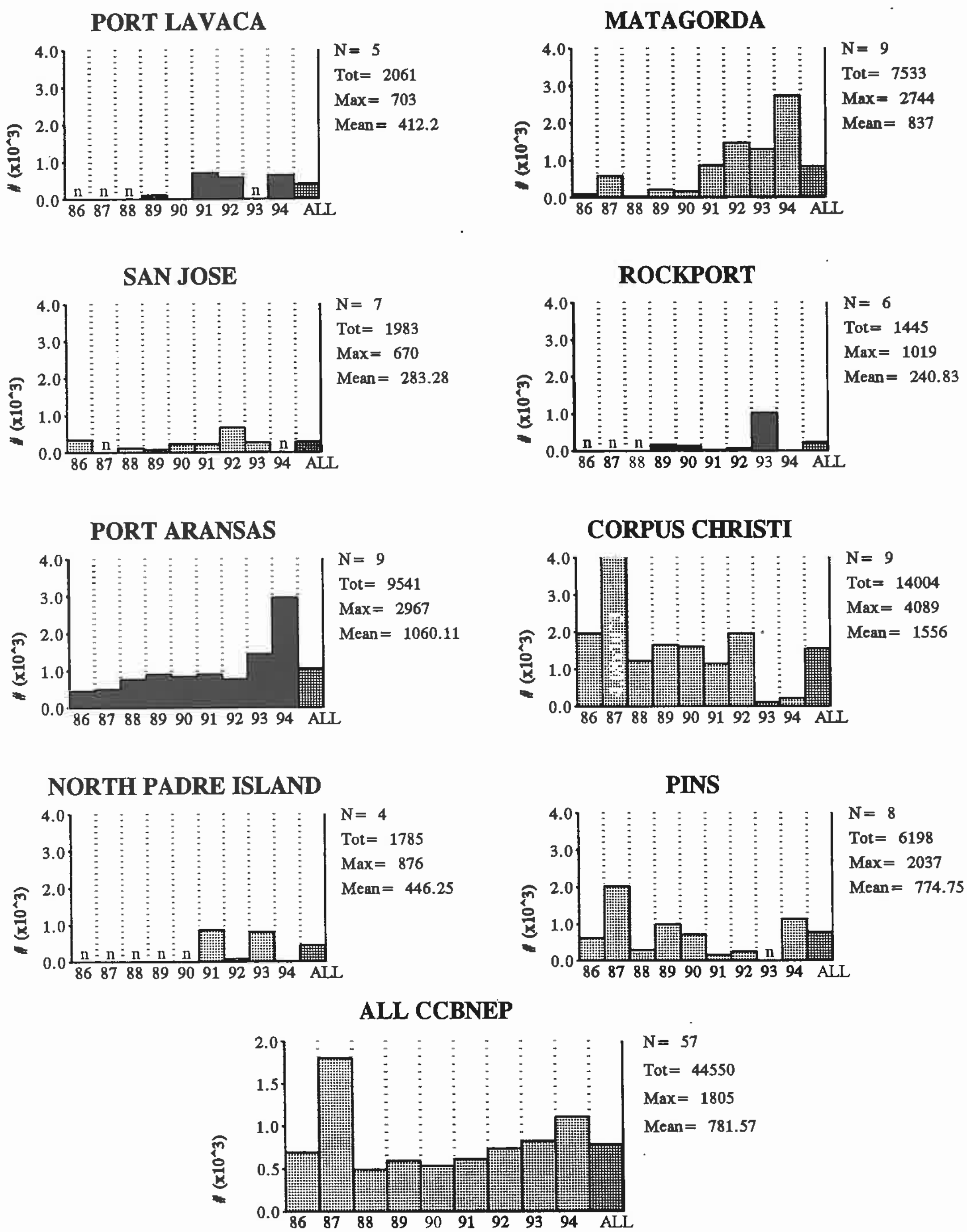


Figure 5a CMC/TGLO data: count by location of METAL BEVERAGE CANS (totals)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean count

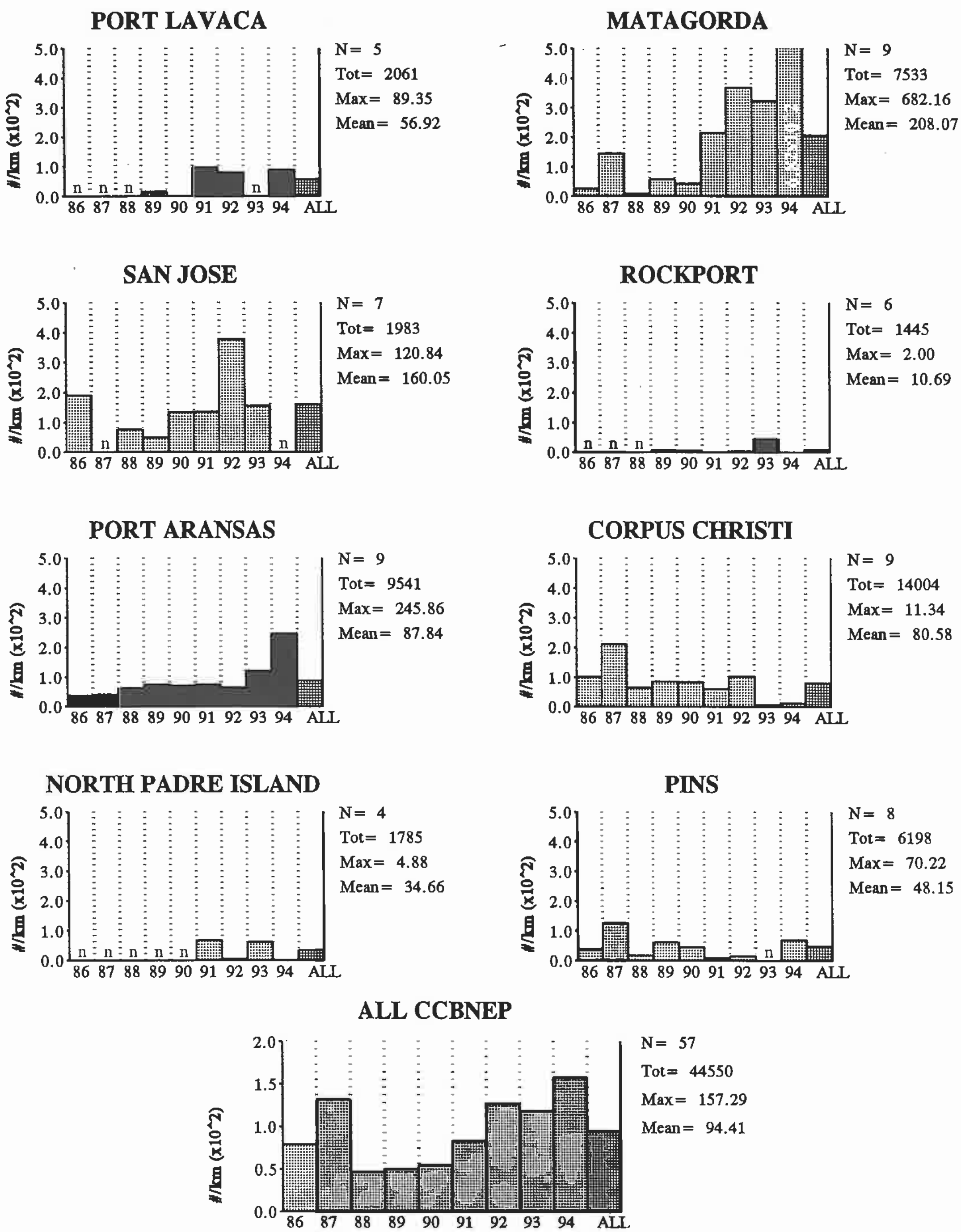


Figure 5b CMC/TGLO data: count by location of METAL BEVERAGE CANS (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups,Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

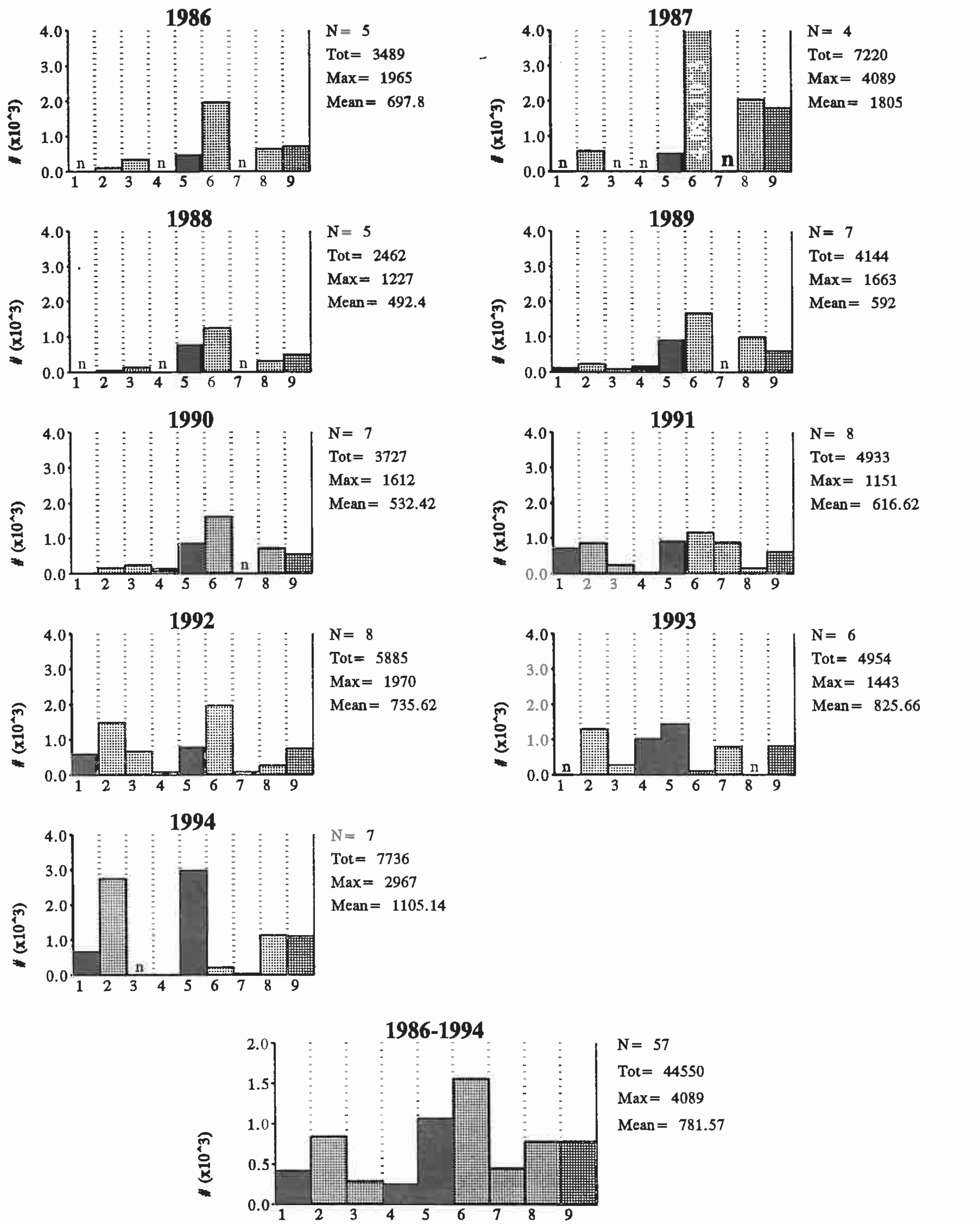


Figure 6a CMC/TGLO data: count by year of METAL BEVERAGE CANS (totals)
Locations are numbered according to key below. An 'n' indicates no data collected
The three sites used for special comparison here are shaded black
1 = PORT LAVACA; 2 = MATAGORDA; 3 = SAN JOSE; 4 = ROCKPORT
5 = PORT ARANSAS; 6 = CORPUS CHRISTI; 7 = NORTH PADRE ISLAND; 8 = PINS; 9 = ALL CCBNEP

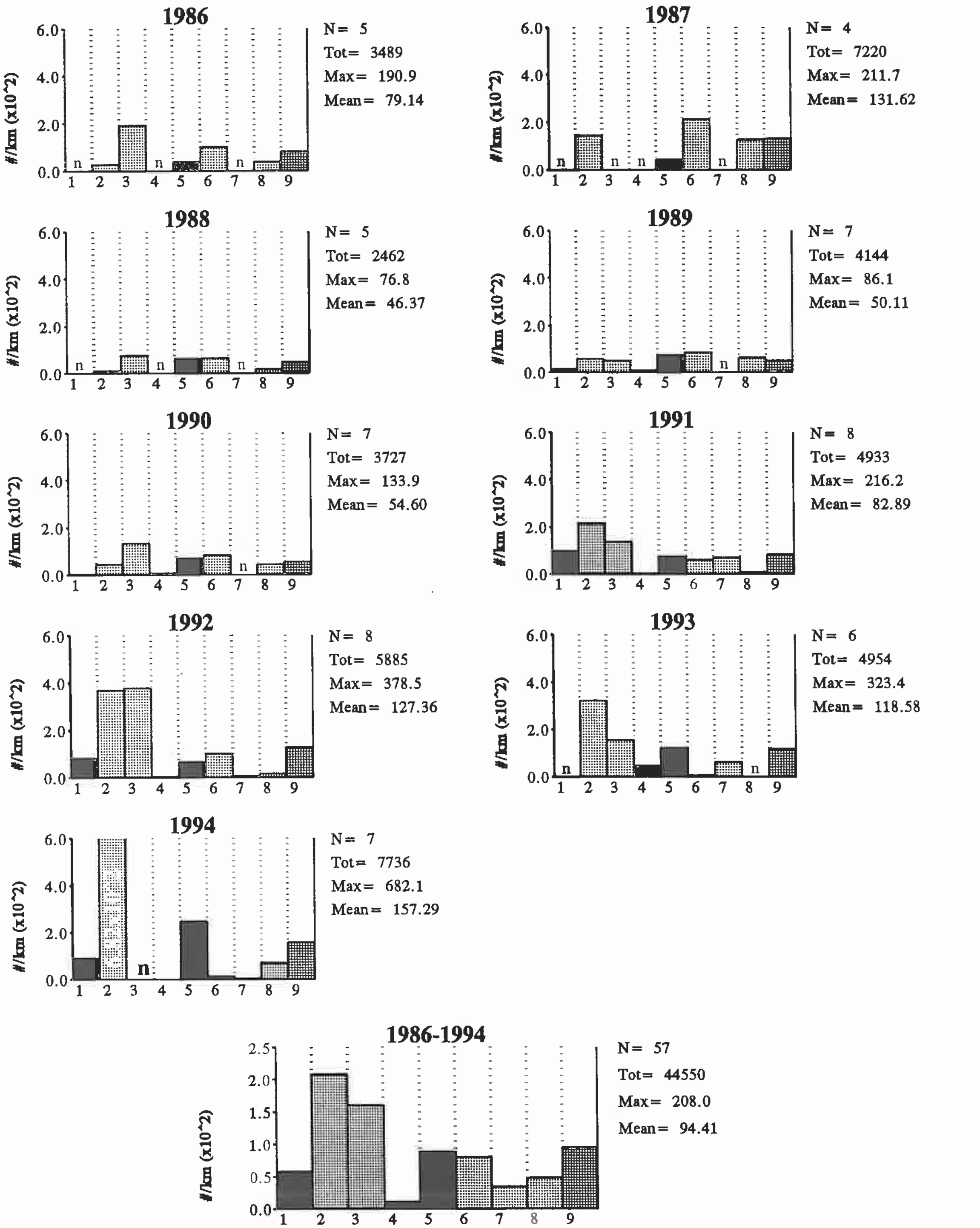


Figure 6b CMC/TGLO data: count by year of METAL BEVERAGE CANS (per kilometer)
Locations are numbered according to key below. An 'n' indicates no data collected
The three sites used for special comparison here are shaded black
1 = PORT LAVACA; 2 = MATAGORDA; 3 = SAN JOSE; 4 = ROCKPORT
5 = PORT ARANSAS; 6 = CORPUS CHRISTI; 7 = NORTH PADRE ISLAND; 8 = PINS; 9 = ALL CCBNEP

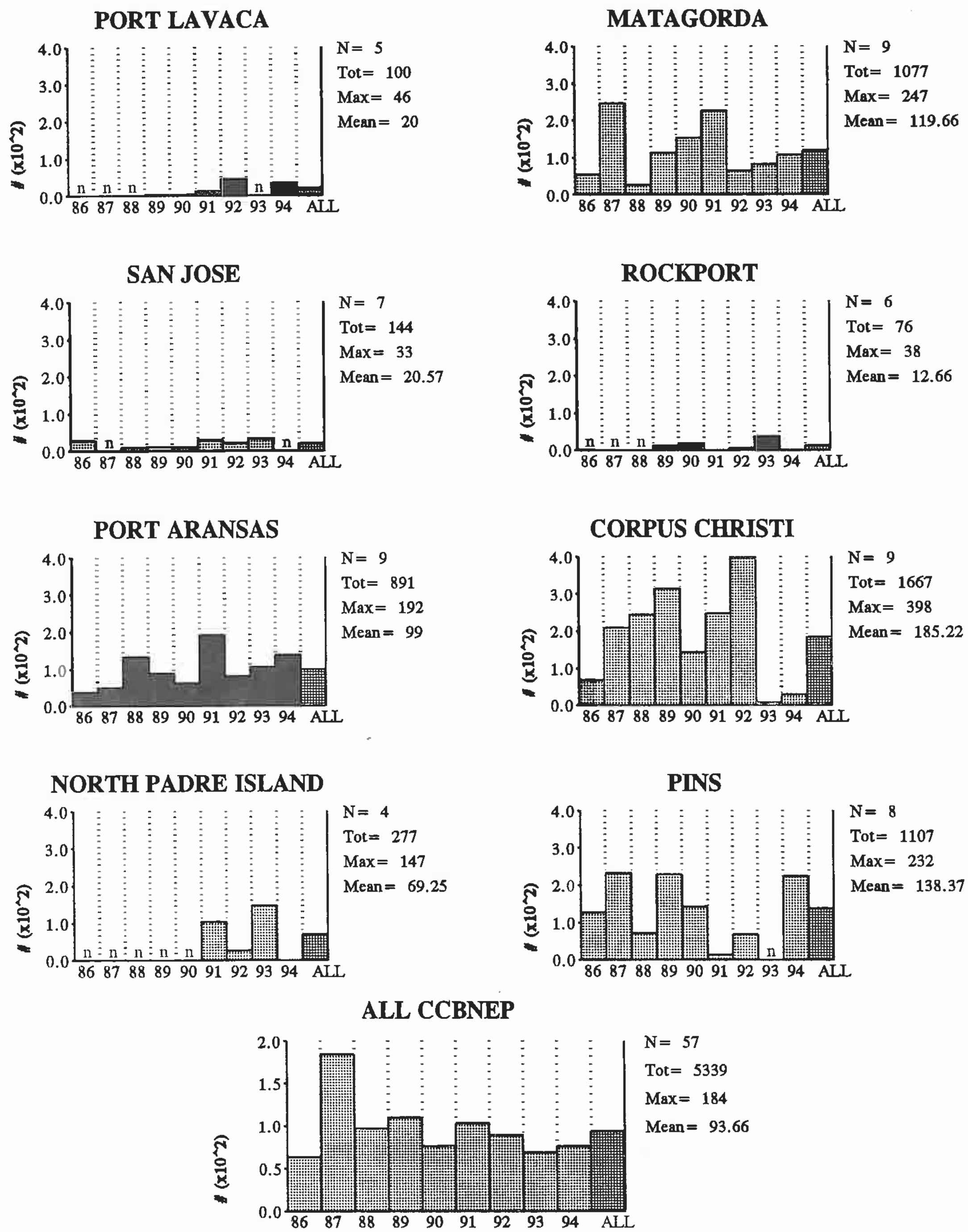


Figure 7a CMC/TGLO data: count by location of PLASTIC BUCKETS (totals)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean count

much lower than those at the other locations. Trends at individual locations vary from positive to neutral to negative, while the overall trend is down from 1986 through 1994. When the density of pails per kilometer is compared (Fig. 7b), Rockport vanishes by comparison with the other locations and Matagorda dominates and biases the overall density. Totals plotted by year (Fig. 8a) would indicate that in most years Port Aransas and Corpus Christi have the highest number of buckets. Again, the emphasis shifts when the density is plotted (Fig. 8b). Matagorda Island had the highest density in seven of the nine years. A total of 5,339 buckets was counted by the CMC volunteers, compared to 2,127 (including carboys) in 8 years of the UTMSI survey., and 409 5-gallon plus seven 6-gallon pails in the PINS one-year survey.

4.2.1.1 Material Proportions In Marine Debris

Of great interest is the proportion of marine debris made up of different materials. We chose to examine plastic (including Styrofoam), glass, rubber, metal, paper, wood, and cloth, and we illustrate the percentages of each to the whole using pie-diagrams for the two bay sites and the Port Aransas Gulf site for each year (Fig. 9). Figure 10 shows the mean for all nine years for all sites in the CCBNEP study area. Although there are many difficulties in comparing counts from CMC/TGLO beach cleanups, there is a consistency in the material percentages reported. It must be remembered that these are counts of items. They indicate nothing about size, bulk, or density of the items. Many plastic items are small (straws, cigarette butts), but most wooden pieces are large and heavy. While plastics dominate the proportion by number in all regions, there are some regional and maybe time-dependent differences. The consistency of the material proportions is, however, evident. Overall material percentages for all regions are ranked in Table 5.

Table 5. Proportions of CCBNEP-area marine debris ranked by material: means of all CMC/TGLO volunteer beach cleanup locations for all years, 1986-1994

MATERIAL	RANK	PERCENT
PLASTIC	1	74.0
METAL	2	9.0
GLASS	3	7.1
PAPER	4	5.1
RUBBER	5	2.2
WOOD	6	2.0
CLOTH	7	0.7

The major difference between the first two (bay) sites is that the percentage of plastic is less (64%) compared to the Gulf site (79%), while the proportion of glass (10%), metal (12%), and paper (9%) is greater on bay shorelines, especially Port Lavaca compared to the Gulf

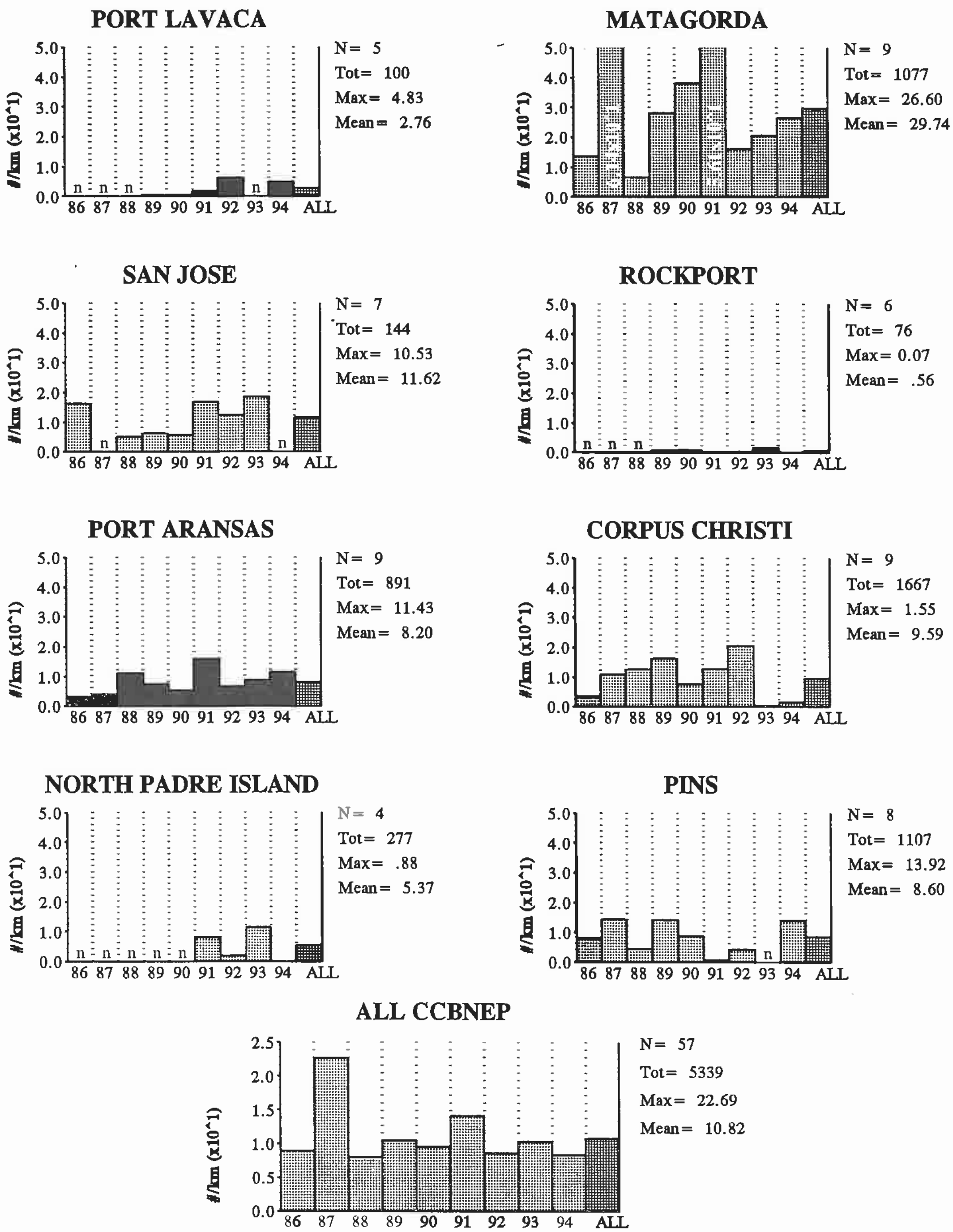


Figure 7b CMC/TGLO data: count by location of PLASTIC BUCKETS (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

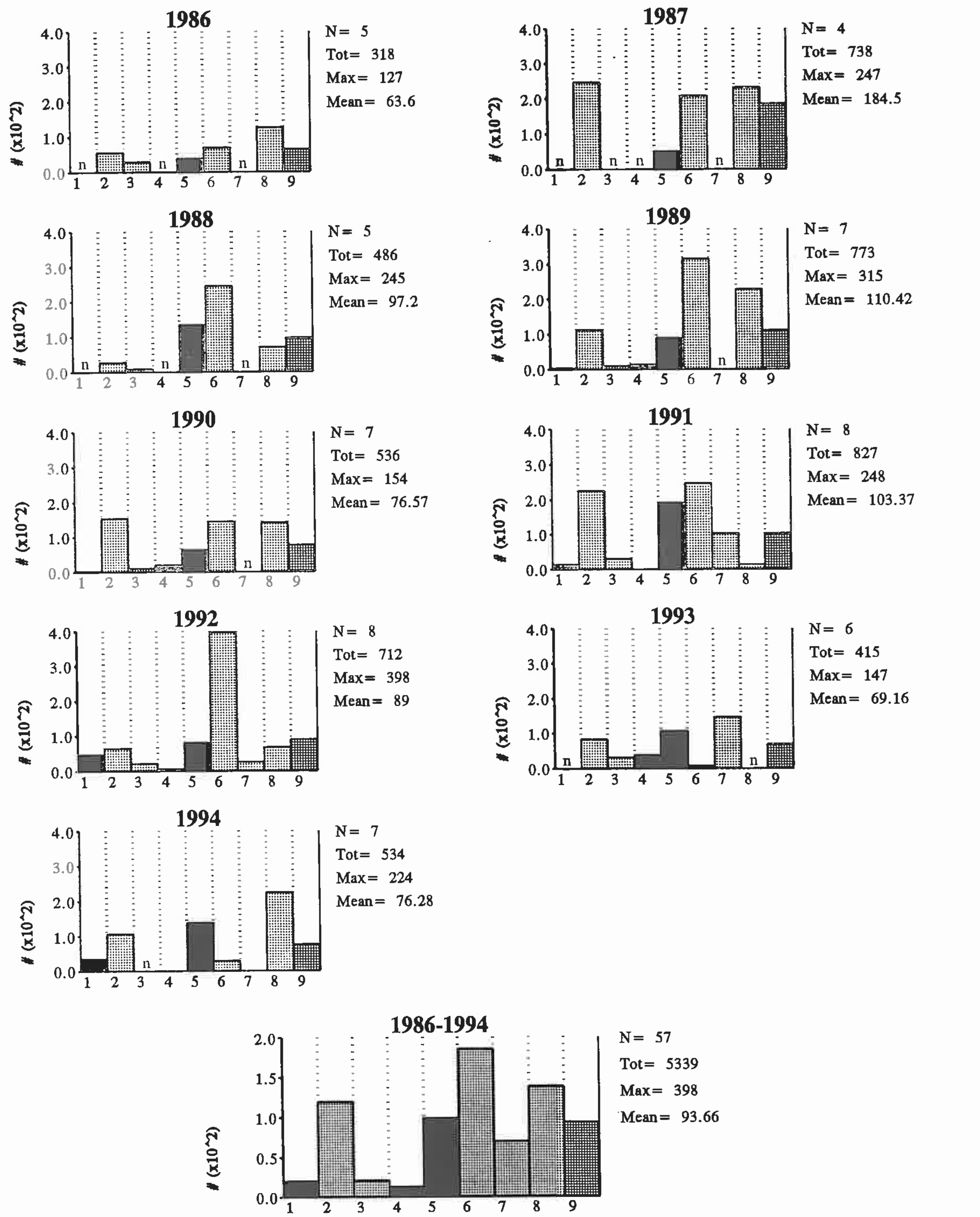


Figure 8a CMC/TGLO data: count by year of PLASTIC BUCKETS (totals)
Locations are numbered according to key below. An 'n' indicates no data collected
The three sites used for special comparison here are shaded black
1 = PORT LAVACA; 2 = MATAGORDA; 3 = SAN JOSE; 4 = ROCKPORT
5 = PORT ARANSAS; 6 = CORPUS CHRISTI; 7 = NORTH PADRE ISLAND; 8 = PINS; 9 = ALL CCBNEP

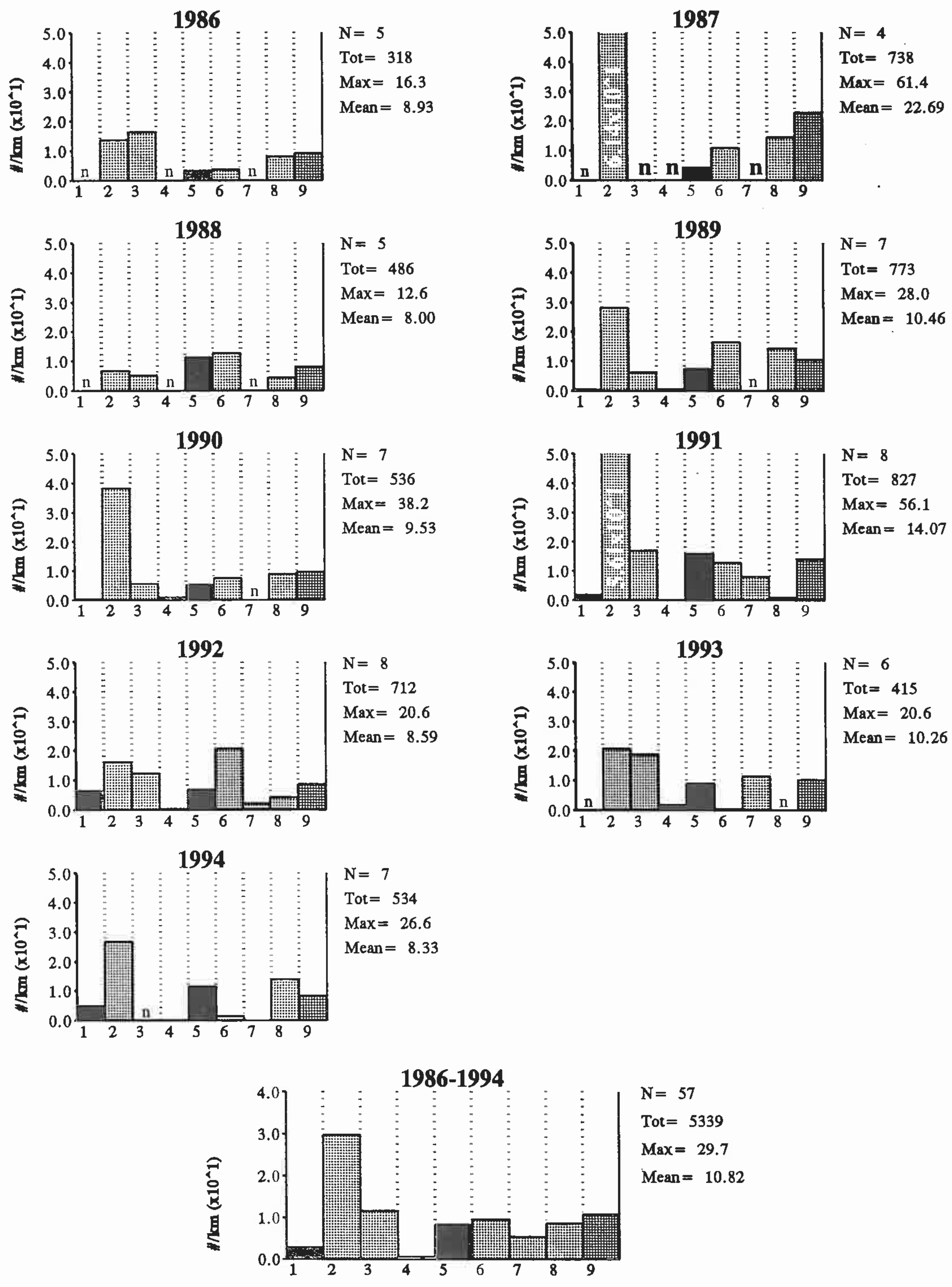
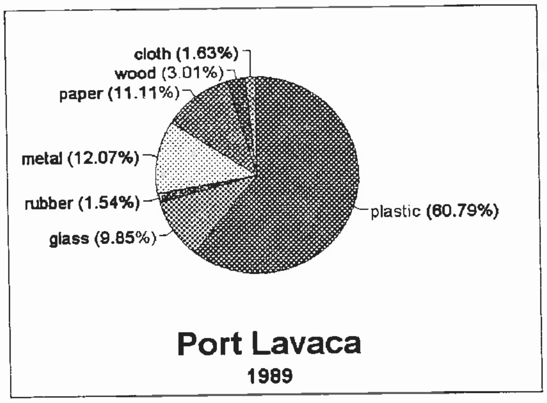
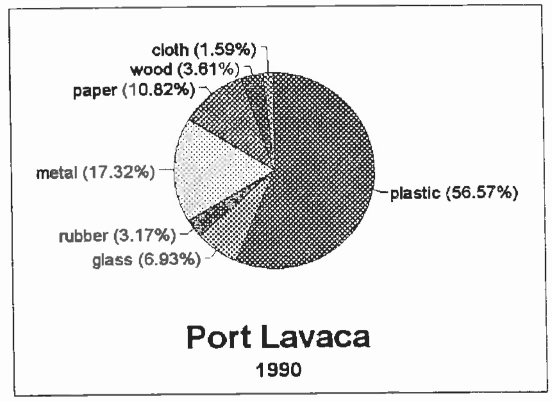
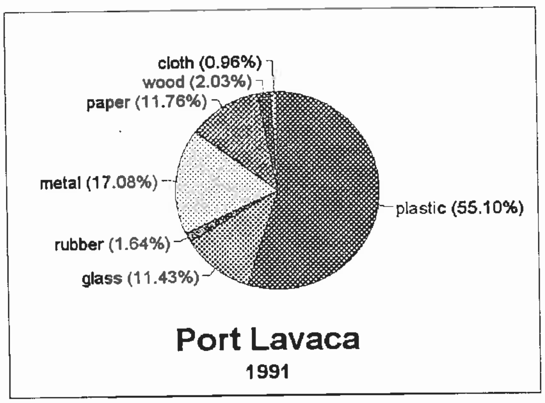
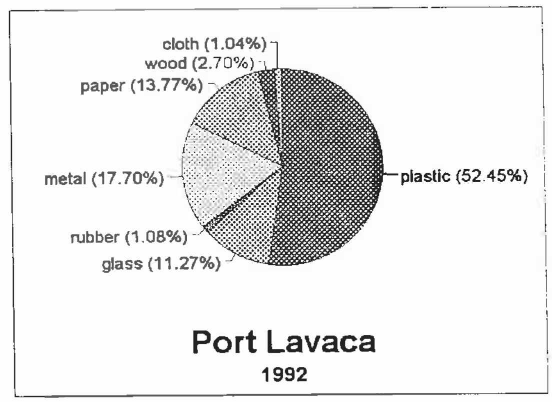


Figure 8b CMC/TGLO data: count by year of PLASTIC BUCKETS (per kilometer)
Locations are numbered according to key below. An 'n' indicates no data collected
The three sites used for special comparison here are shaded black
1 = PORT LAVACA; 2 = MATAGORDA; 3 = SAN JOSE; 4 = ROCKPORT
5 = PORT ARANSAS; 6 = CORPUS CHRISTI; 7 = NORTH PADRE ISLAND; 8 = PINS; 9 = ALL CCBNEP









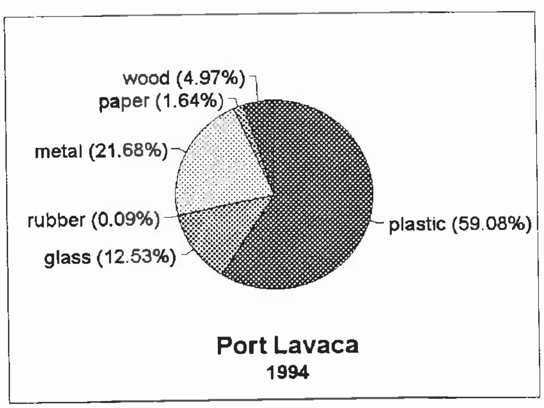
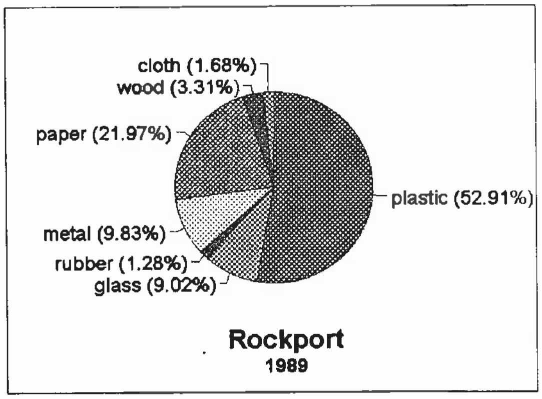
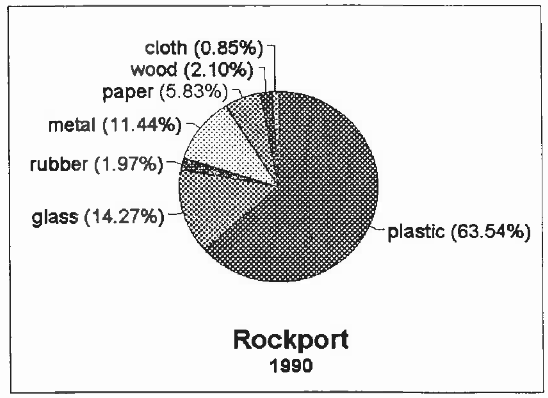
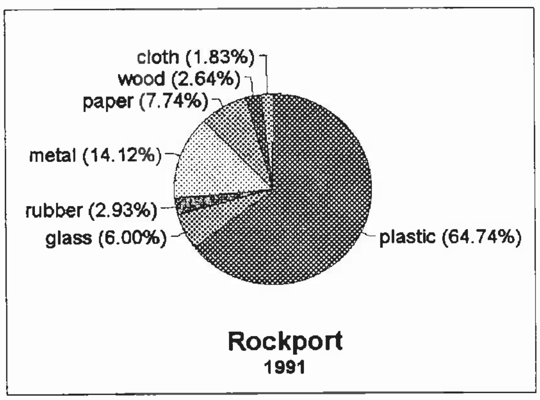
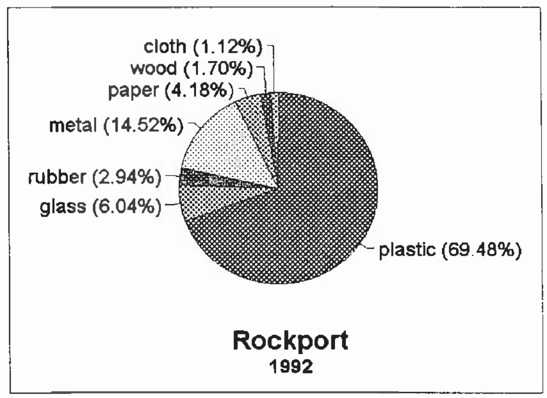


Figure 9a Pie Diagrams showing material composition by percentage of debris at Bay Site, Port Lavaca, 1989-1992 and 1994. Data collected by CMC/TGLO Beach Cleanup Volunteers.









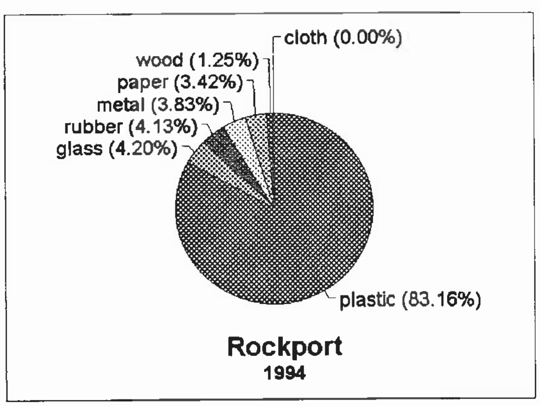


Figure 9b Pie diagrams showing material composition by percentage of debris at Bay Site, Rockport, 1989 - 1992 and 1994. Data collected by CMC/TGLO Beach Cleanup Volunteers.

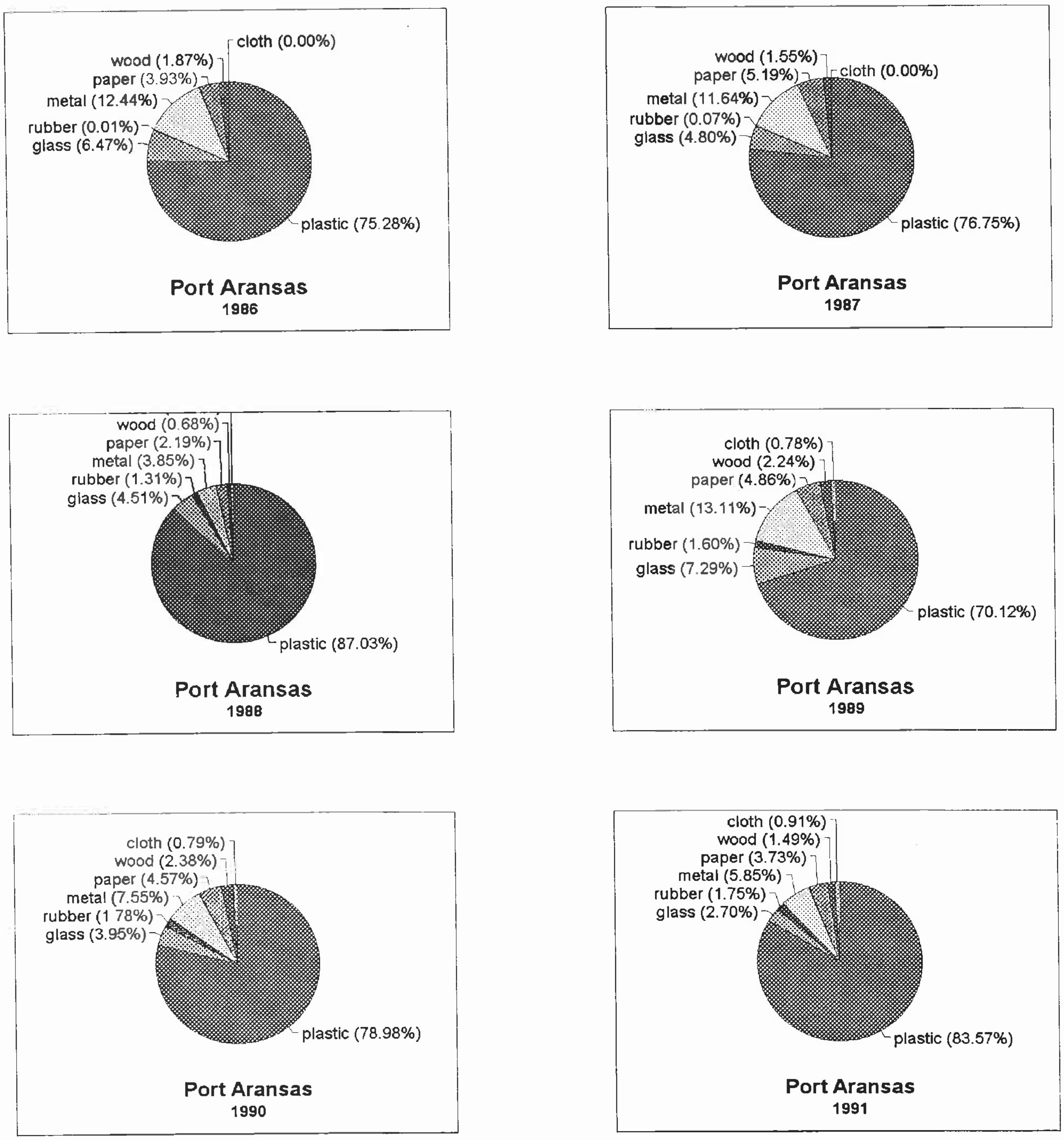
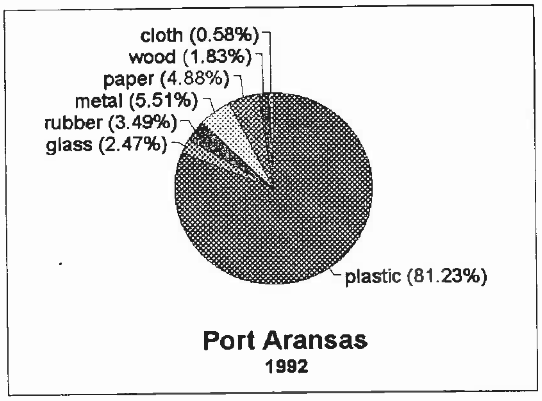
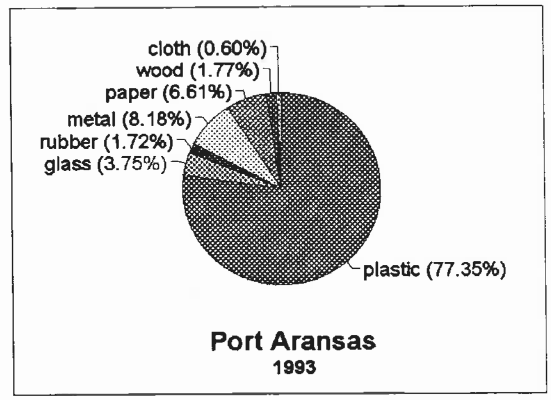


Figure 9c Pie diagrams showing material composition by percentage of debris at Gulf Site, Port Aransas (Mustang Island), 1986 - 1994. Data collected by CMC/TGLO Beach Cleanup Volunteers.





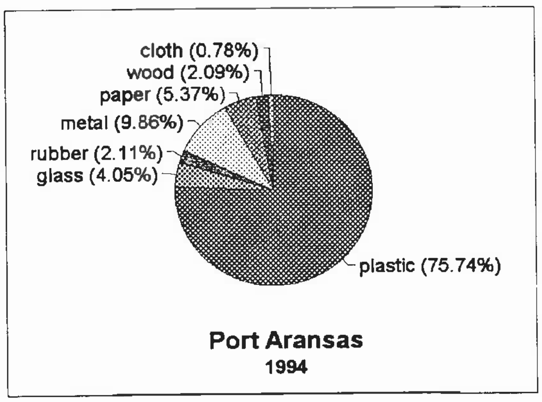


Figure 9c (cont.) Pie diagrams showing material composition by percentage of debris at Gulf Site, Port Aransas (Mustang Island), 1986 - 1994. Data collected by CMC/TGLO Beach Cleanup Volunteers.

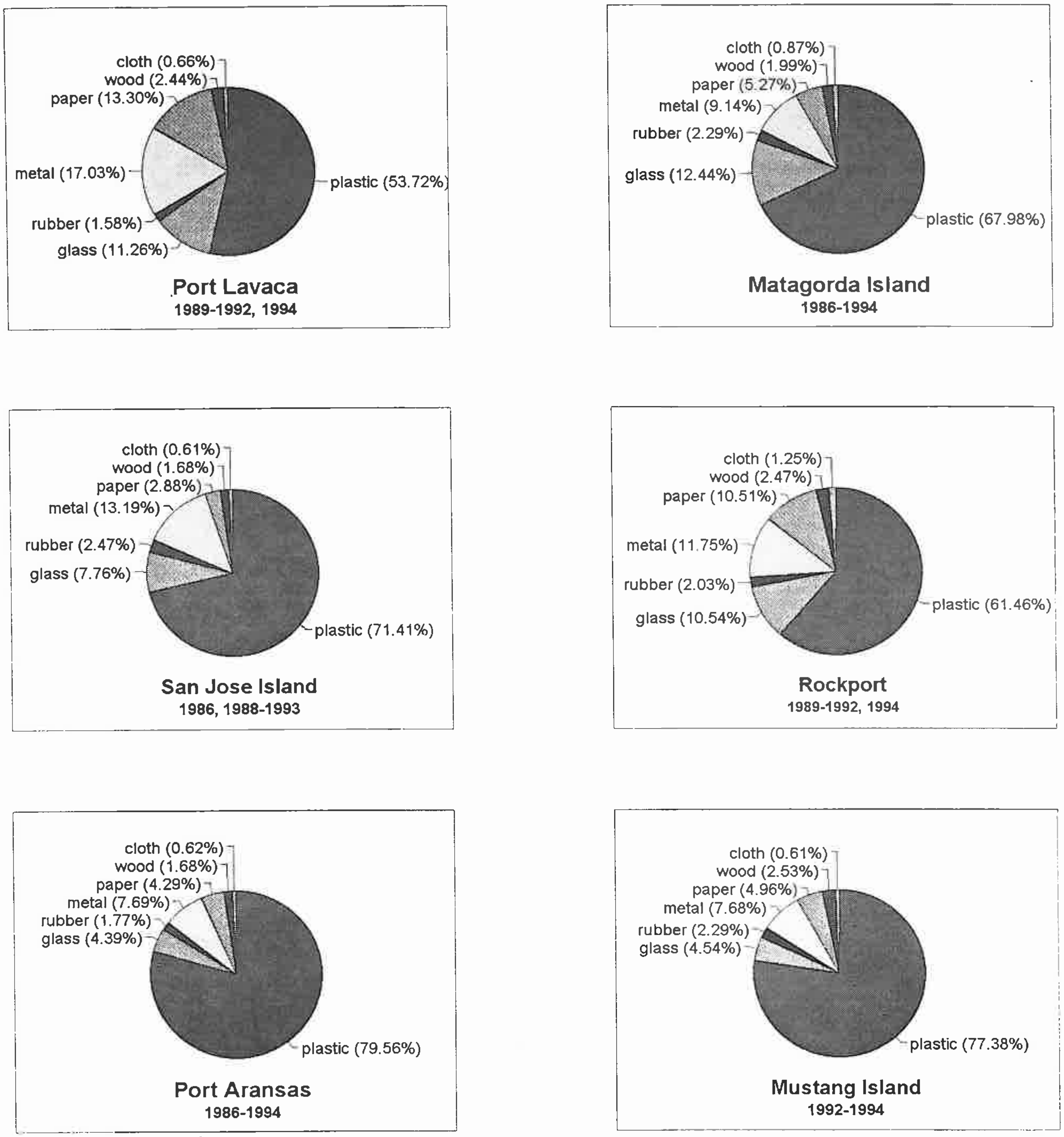
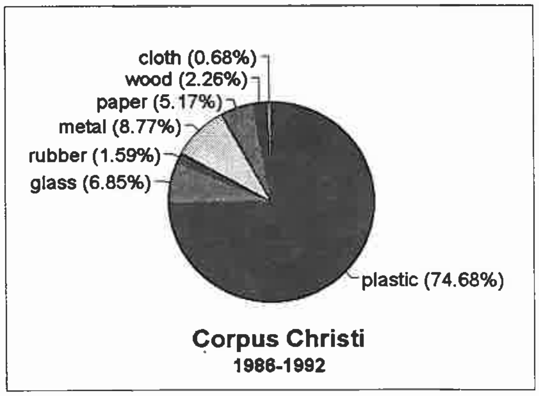
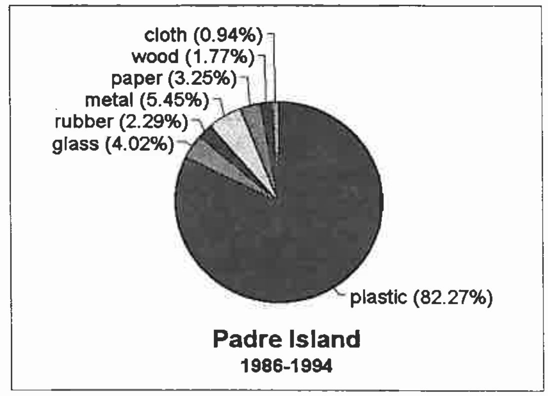


Figure 10 Pie diagrams showing mean material composition by percentage of debris at all sites in the CCBNEP study area. Data collected by CMC/TGLO Beach Cleanup Volunteers.





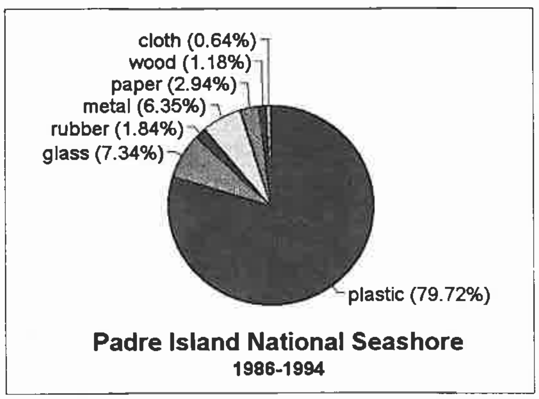


Figure 10 (cont.) Pie diagrams showing mean material composition by percentage of debris at all sites in the CCBNEP study area. Data collected by CMC/TGLO Beach Cleanup Volunteers.

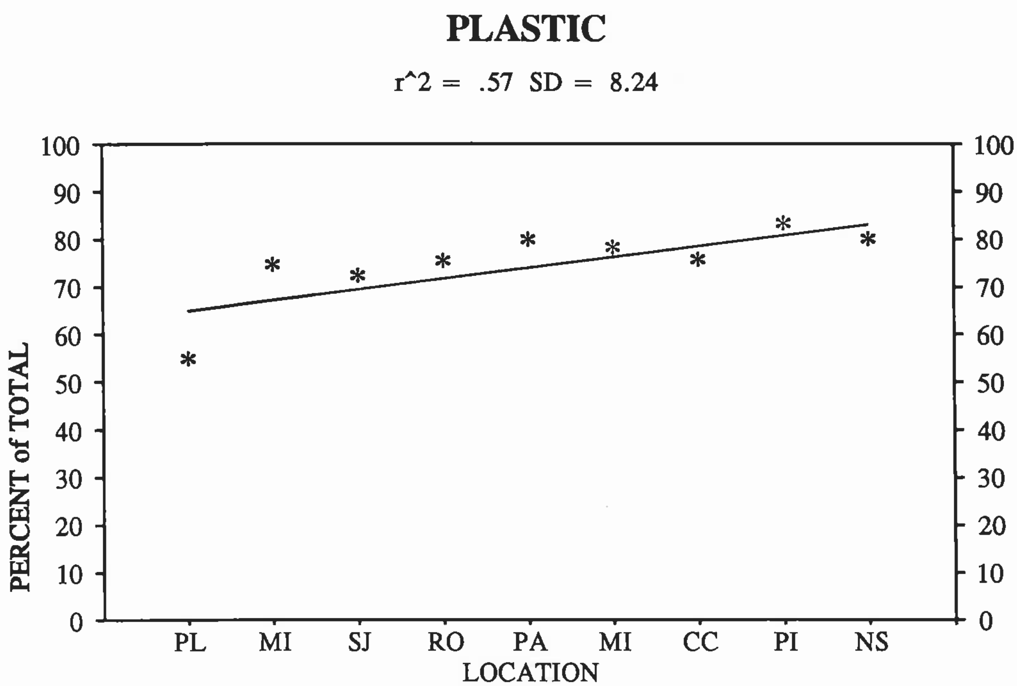
beach (4% glass, 8% metal, and 4% paper). This is due to the greater quantity of packaged food and drink items used in the bay compared to the beach and offshore environs. A statistically valid study of Galveston Bay shorelines in 1992 revealed 59% plastic, 12% glass, 9% metal, and 8% paper (GBNEP, 1993). The percentage of wood varied little around 2% at all the CCBNEP sites, but in Galveston Bay, the percentage was 5%.

As there appeared to be a trend in the proportion of different materials making up the CMC/TGLO debris, we plotted two materials, plastic and metal, as a function of location arranged from north to south in the CCBNEP study area (Fig. 11). There is a linear increase in plastic from north to south, and a linear decrease in metal (mostly beverage cans) in the same direction. There is a moderate correlation coefficient of around 0.5 in these data. Can we see any such trend with time? In Figure 12 we plot the percentage of plastic and metal at Matagorda and at Port Aransas. The lines are flat and there is essentially no trend discernable.

What can we deduce from these results? The consistency of material proportions, both with time and location, lends some statistical validity to the data. The higher proportion of glass and metal in the northern area could be explained by the higher numbers of more domestic than marine debris on the bay sites (beverage cans and glass bottles), and possibly to the prohibition of glass containers on several Gulf beaches, although this ordinance is seldom enforced. The inverse of this in plastic from north-to-south might also be due to the larger numbers of items like milk jugs on Gulf beaches.

Has the material composition of marine debris changed over the nine years of volunteer beach cleaning studied in this report? There have been several basic changes in packaging techniques, the introduction of new products, and the abandonment of old ones during that time. Some examples: the packaging of carbonated soft drinks in large plastic containers with metric volumes (1, 2 and 3 liters), the introduction of the "California Cooler" in glass bottles, the cardboard drink container with plastic coating and removable straw, the lottery ticket, the replacement of the metal pull-away tab on aluminum beverage cans with a tab which remains attached to the can, the introduction of the throw-away Mylar pull-tab which seals soft drink cans, and the disappearance of the magnetic tape write-protect ring as offshore seismic exploration vessels switched from tape to disk. Only a detailed study of individual containers could fully answer this question. However, we looked at the temporal changes in the CMC data by material type to see if any general trends might be detectable.

Figures 13 through 19 shows the trend in plastic, glass, rubber, metal, paper, wood, and cloth for each location plotted against year. These diagrams use numbers of items in each material type per kilometer, not totals. The years 1986 and 1987 are not included because CMC did not standardize its data card until 1988. The disparities in numbers some years is so great that we truncate them in order to show with clarity the years with much lower numbers. Over a million items of **plastic** were counted from 1986 through 1994 (Fig. 13) with a mean density of 1,763 items per km. In Port Lavaca, the mean was 739/km, Rockport 262, and Port



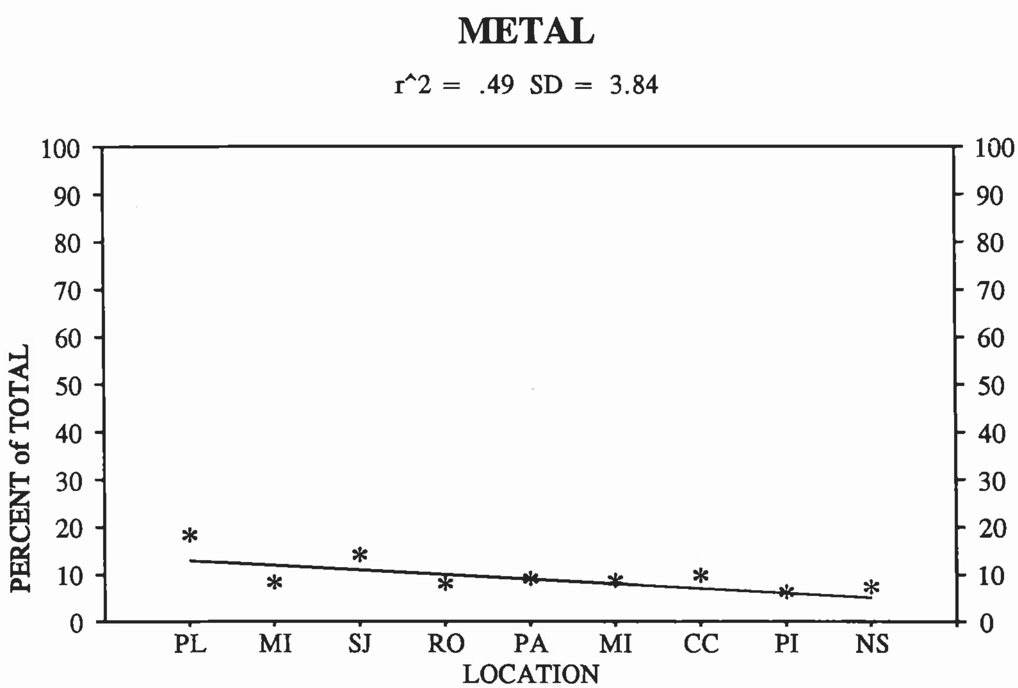
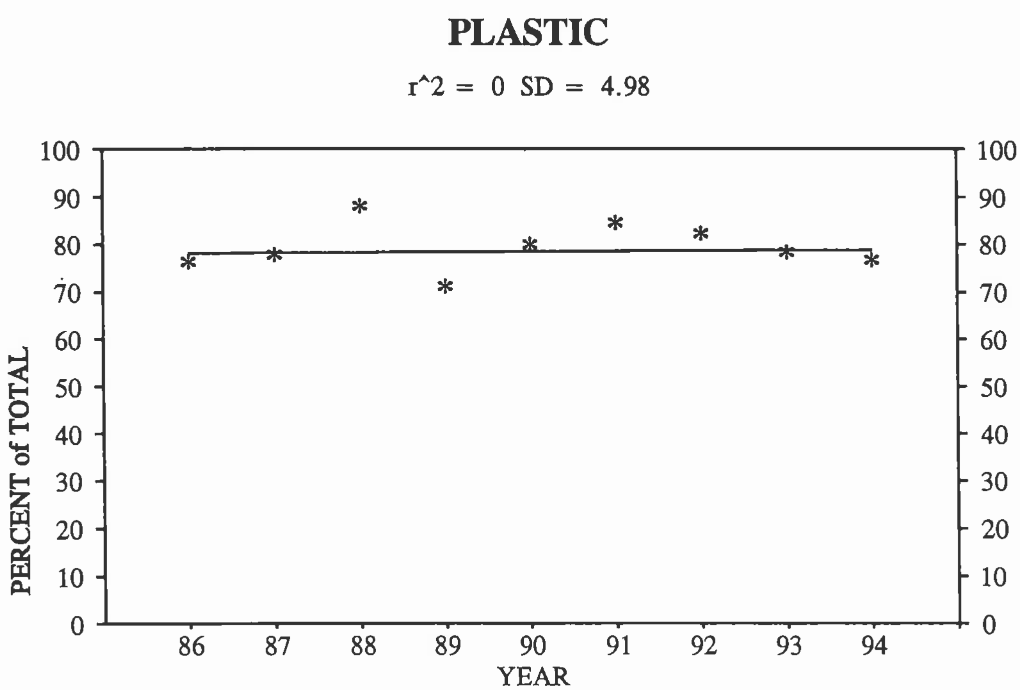


Figure 11 Proportion of PLASTIC and METAL in debris in the CCBNEP area
Data source is the CMC/TGLO beach cleanup counts (% of total material composition)
Location key;
PL-PORT LAVACA. MI-MATAGORDA. SJ-SAN JOSE. RO-ROCKPORT. PA-PORT ARANSAS
MI-MUSTANG I.. CC-CORPUS CHRISTI. PI-NORTH PADRE ISLAND. NS-PINS



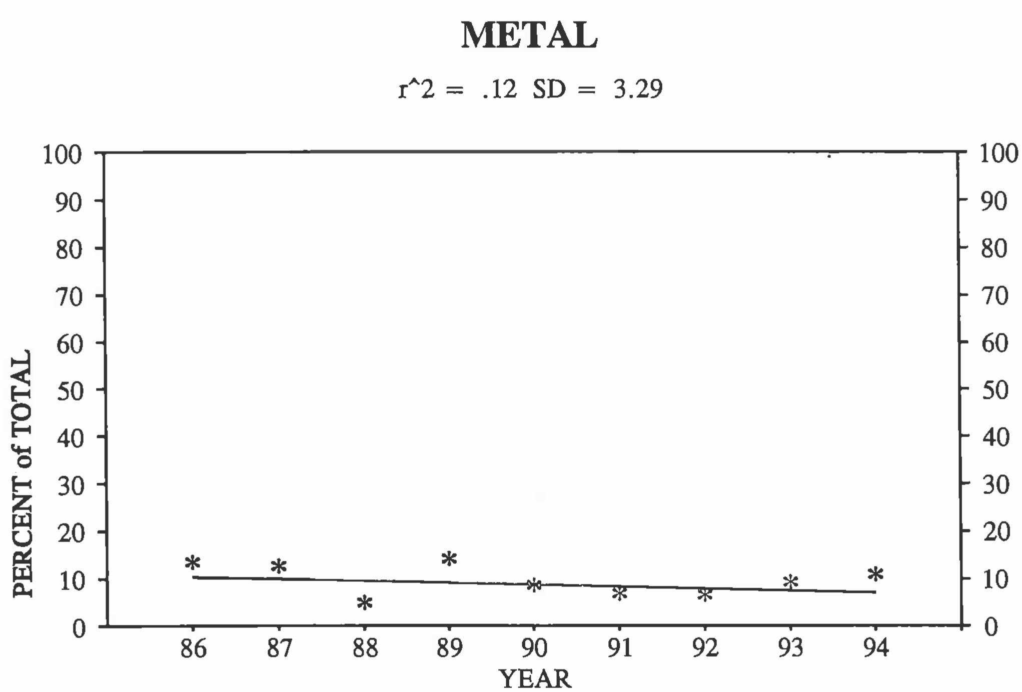
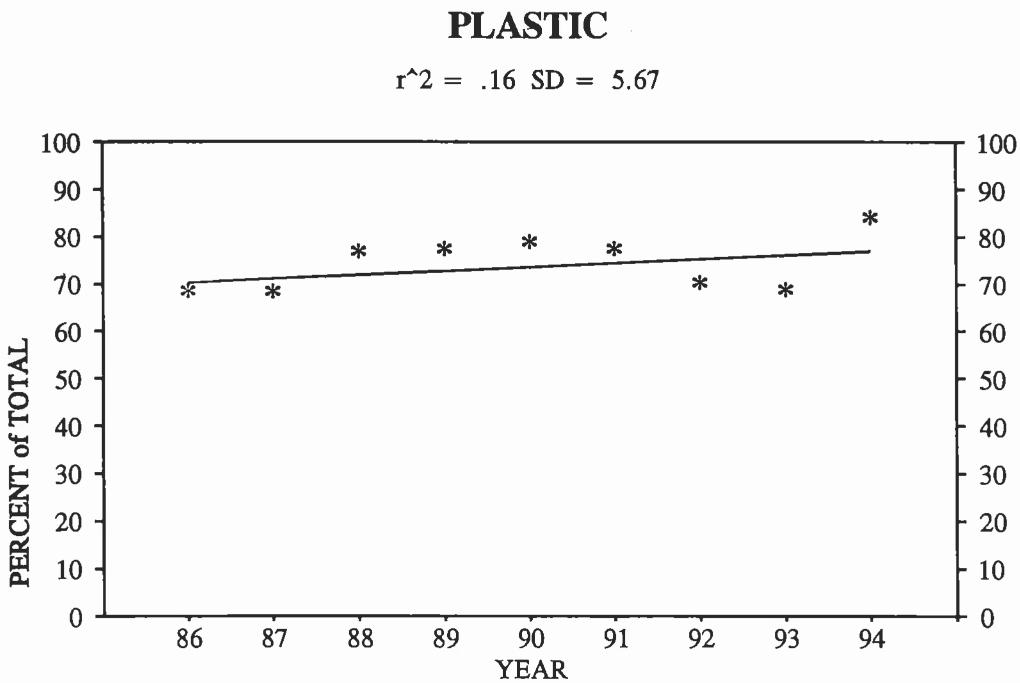


Figure 12a Proportion of PLASTIC and METAL in debris at PORT ARANSAS
Data source is the CMC/TGLO beach cleanup counts (% of total material composition)



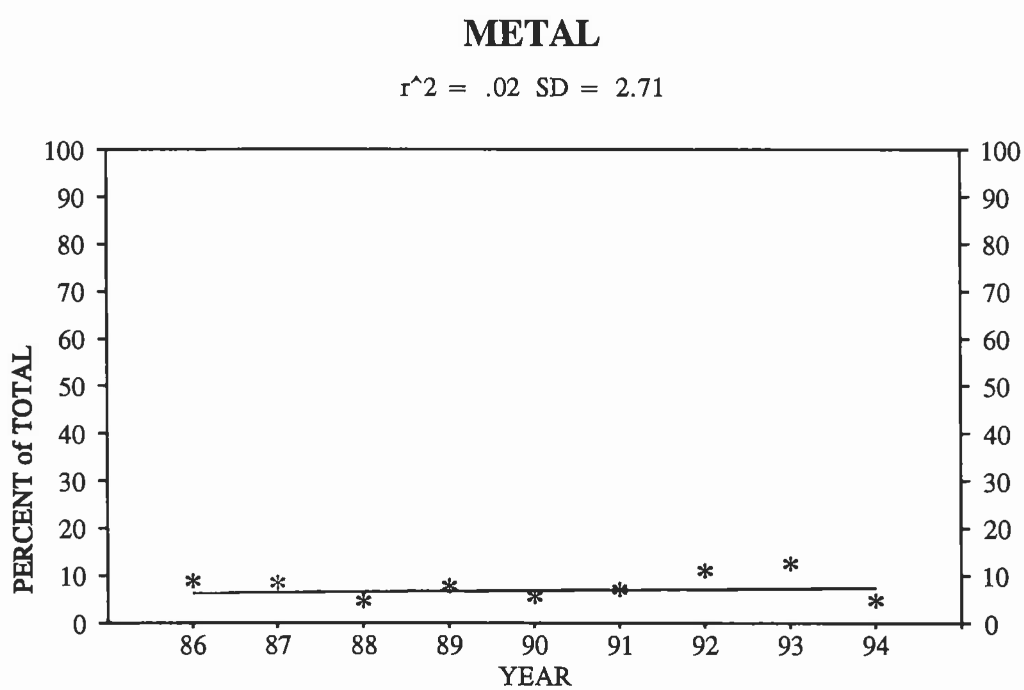


Figure 12b Proportion of PLASTIC and METAL in debris at MATAGORDA
Data source is the CMC/TGLO beach cleanup counts (% of total material composition)

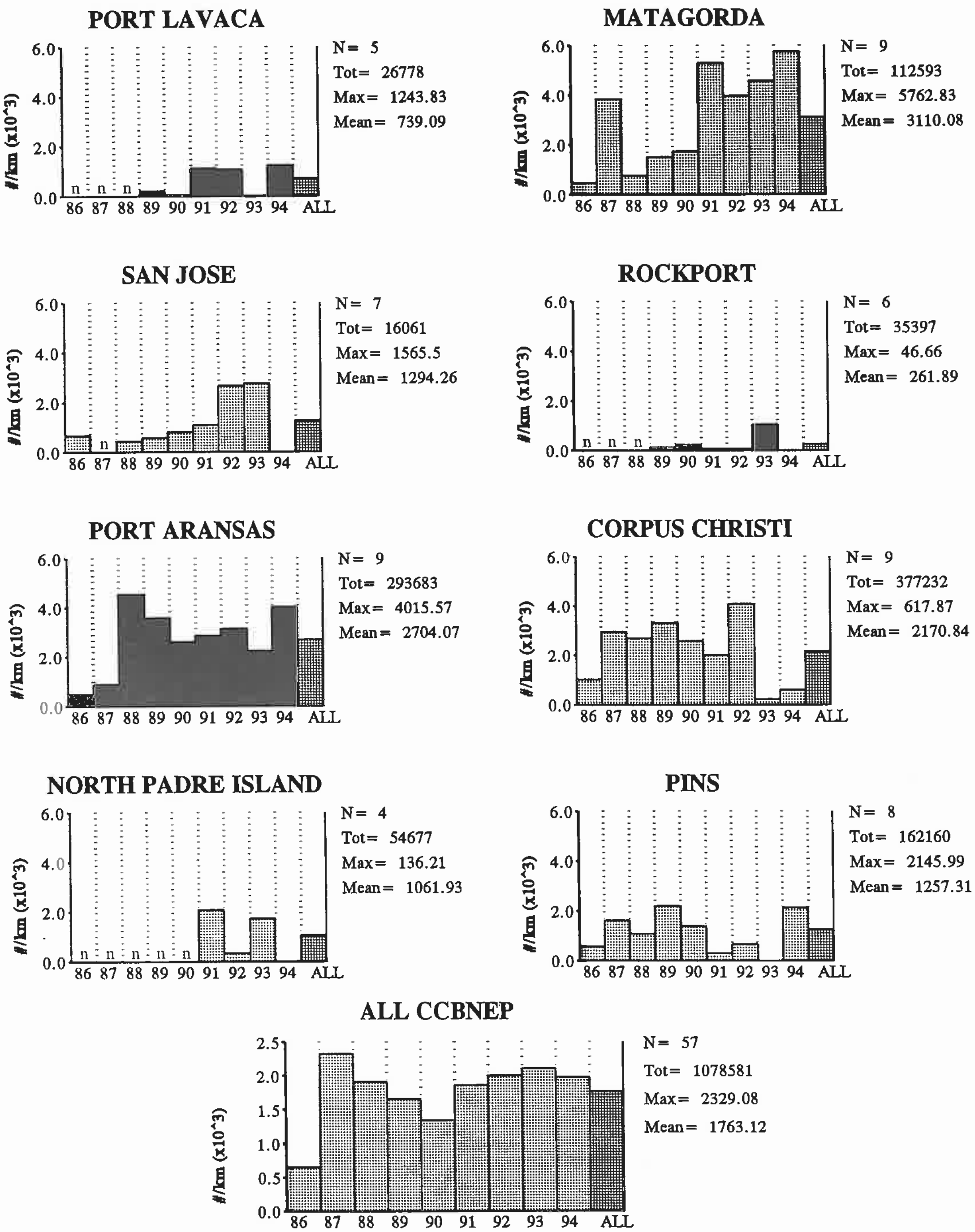


Figure 13 CMC/TGLO data: count by location of PLASTIC (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

Aransas 2,704 (Table 6 lists the density of items on the shorelines of the three sites and the mean for all sites in the CCBNEP area). No overall trend in plastic is obvious, although the Gulf sites, Matagorda and San Jose Islands, show a steady increase with time. **Metal**, consisting mainly of beverage cans (Fig. 14) shows a general increase with time at most sites. Port Lavaca has a much higher density of metal than Rockport and is close to Port Aransas in metal concentrations. All years show an increase in the total density of **rubber** items (Fig. 15). A slight increase with time is seen for **glass** (Fig. 16). Again, Port Lavaca shows a higher, and increasing, density of glass items compared to Rockport. **Paper** (Fig. 17) increases at most locations. Note the high density of paper at Port Lavaca. **Cloth** (Fig. 18) increases overall and at most locations, especially Matagorda, as does **Wood** (Fig. 19). Remote Gulf beaches, like Matagorda are noted for the quantity of driftwood that accumulates on the shore. It is hard to know how to interpret this analysis which shows an increase in most marine debris according to the counts done each September by the CMC volunteers. It is surprising to find these somewhat consistent trends in the data and we discuss the reasons for questioning the CMC data in the following section.

Table 6. Density of items along shoreline (items per kilometer) classified by material type from the CMC/TGLO beach cleanup data cards listed for two bay sites (Port Lavaca and Rockport), one gulf site (Port Aransas), and all cleanup sites in the CCBNEP study area.

LOCATION	Port Lavaca	Rockport	Port Aransas	All CCBNEP
PLASTIC	739.1	261.9	2,704.1	1,763.1
METAL	240.6	34.6	280.1	215.5
RUBBER	34.0	6.7	66.9	52.1
GLASS	170.5	18.3	147.8	176.5
PAPER	159.4	29.7	141.0	109.4
CLOTH	13.9	3.1	22.6	17.6
WOOD	35.1	7.4	61.2	45.4

4.2.1.2 Analysis of Volunteer Beach Cleanup Methods and Data

There are several inherent problems with the volunteer beach cleanups if the data are to be used to evaluate trends. First there is a conflict, although not overt, between the goals of those doing the cleanups and the coastal communities where the cleaning is done. Much publicity is generated by these semi-annual events. Media talk of "tons of trash on area beaches" is not likely to attract tourists, the staple economic base for many of these communities. The result is an effort on the part of municipalities to clean the beaches just before the volunteers arrive. It is what the PI calls "the Jaws syndrome": a denial of a condition which is obvious to almost everyone. Few field guides to local beaches mention this most-prominent beach feature; for example, the otherwise excellent guide to Matagorda Island

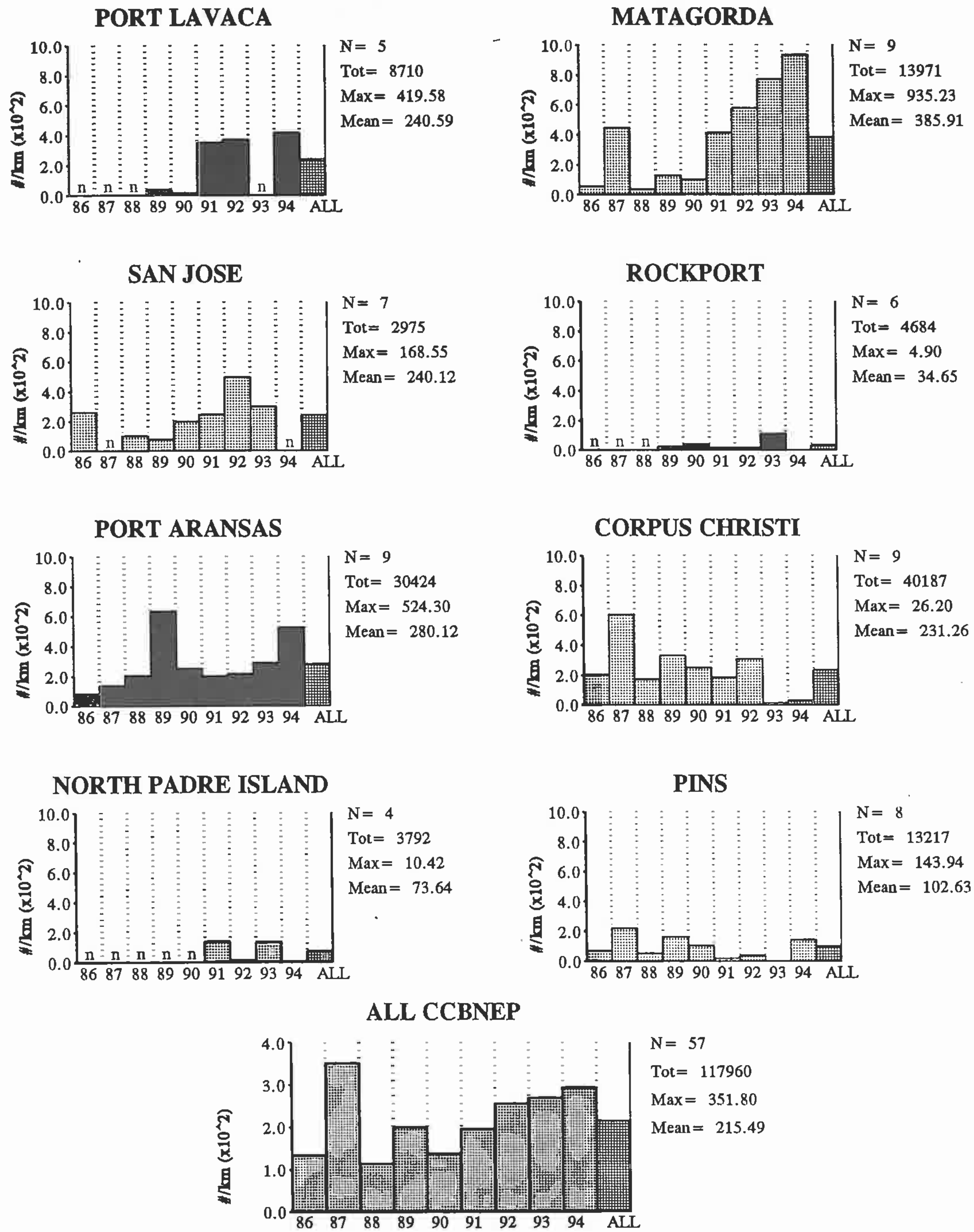


Figure 14 CMC/TGLO data: count by location of METAL (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

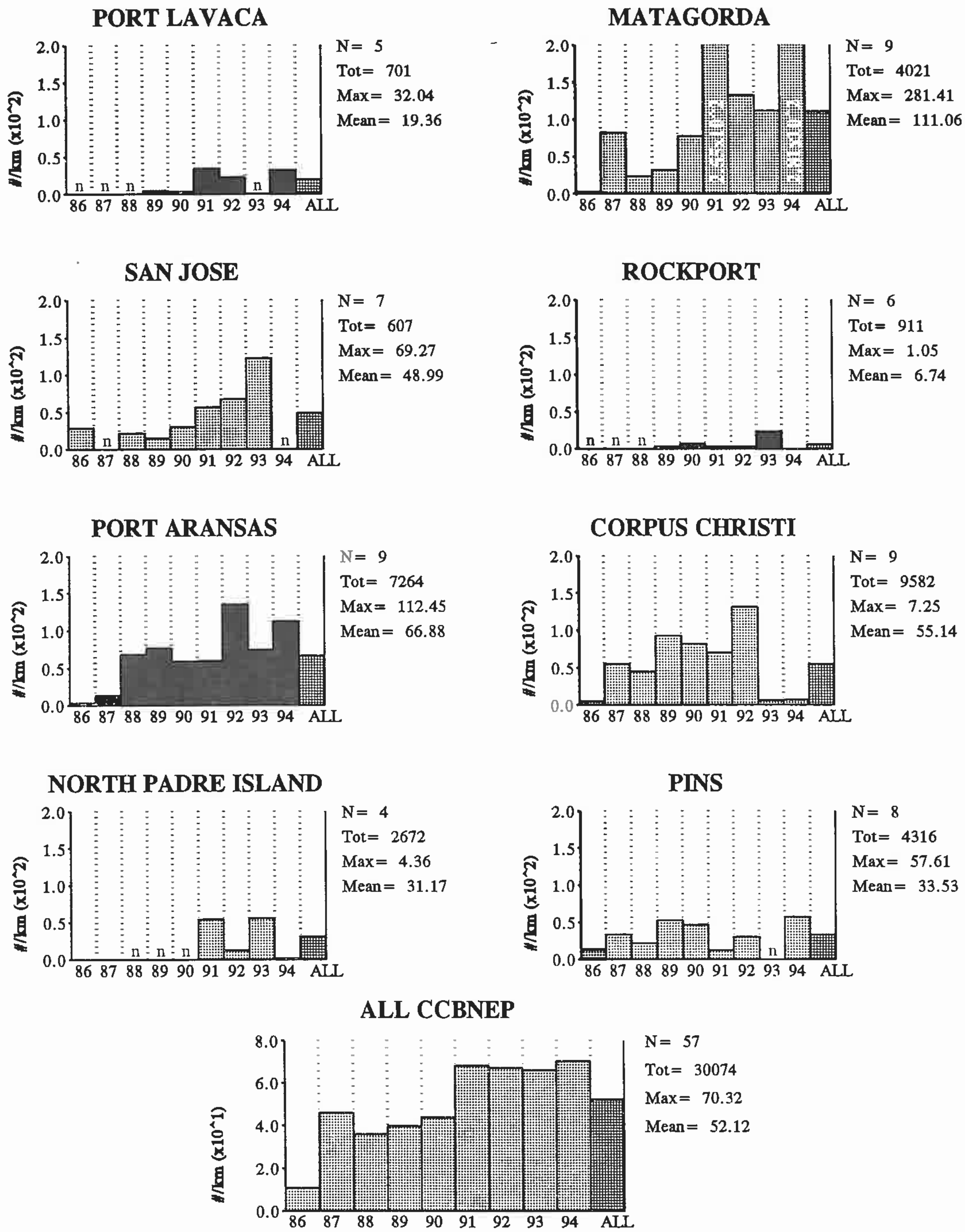


Figure 15 CMC/TGLO data: count by location of RUBBER (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

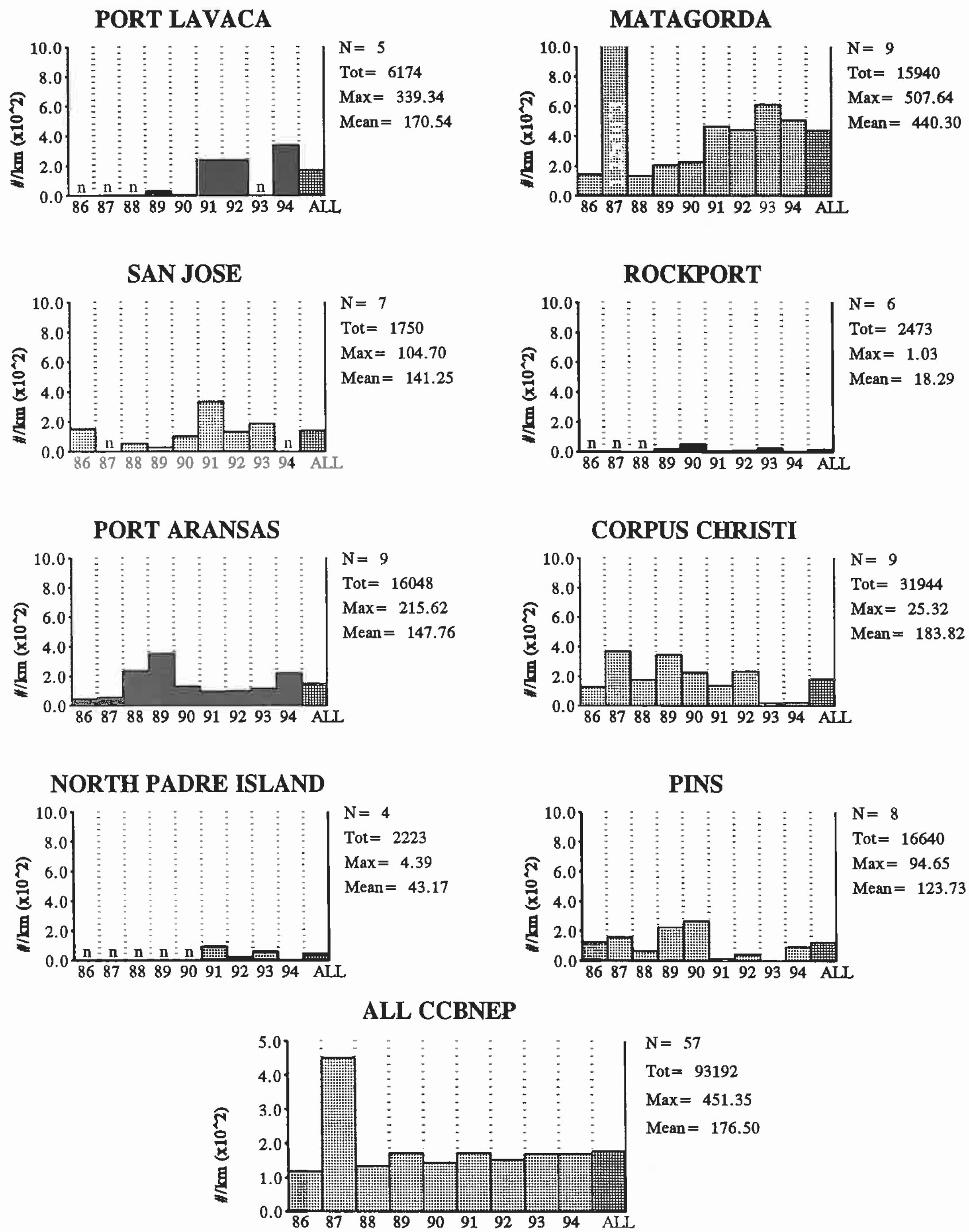


Figure 16 CMC/TGLO data: count by location of GLASS (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

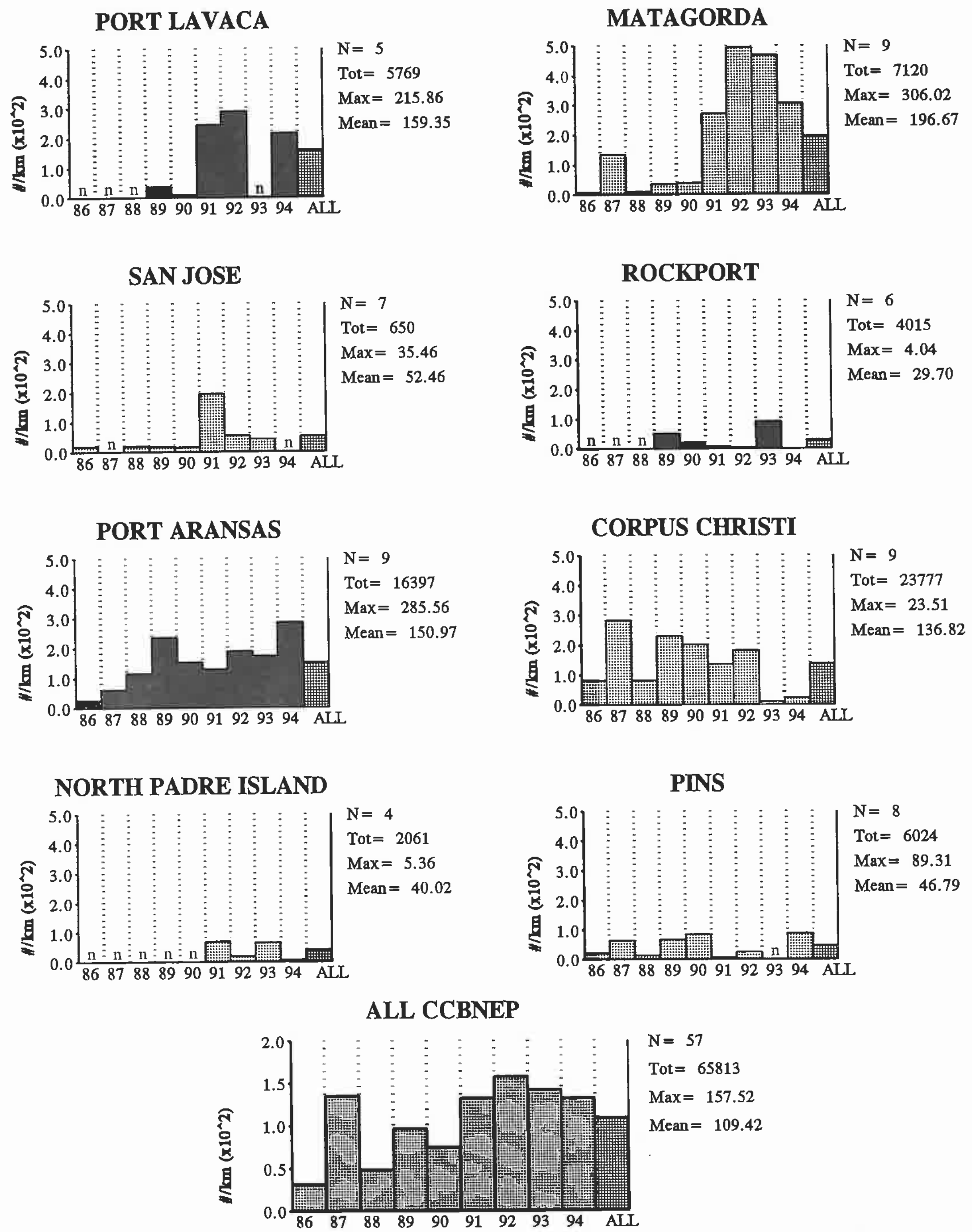


Figure 17 CMC/TGLO data: count by location of PAPER (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

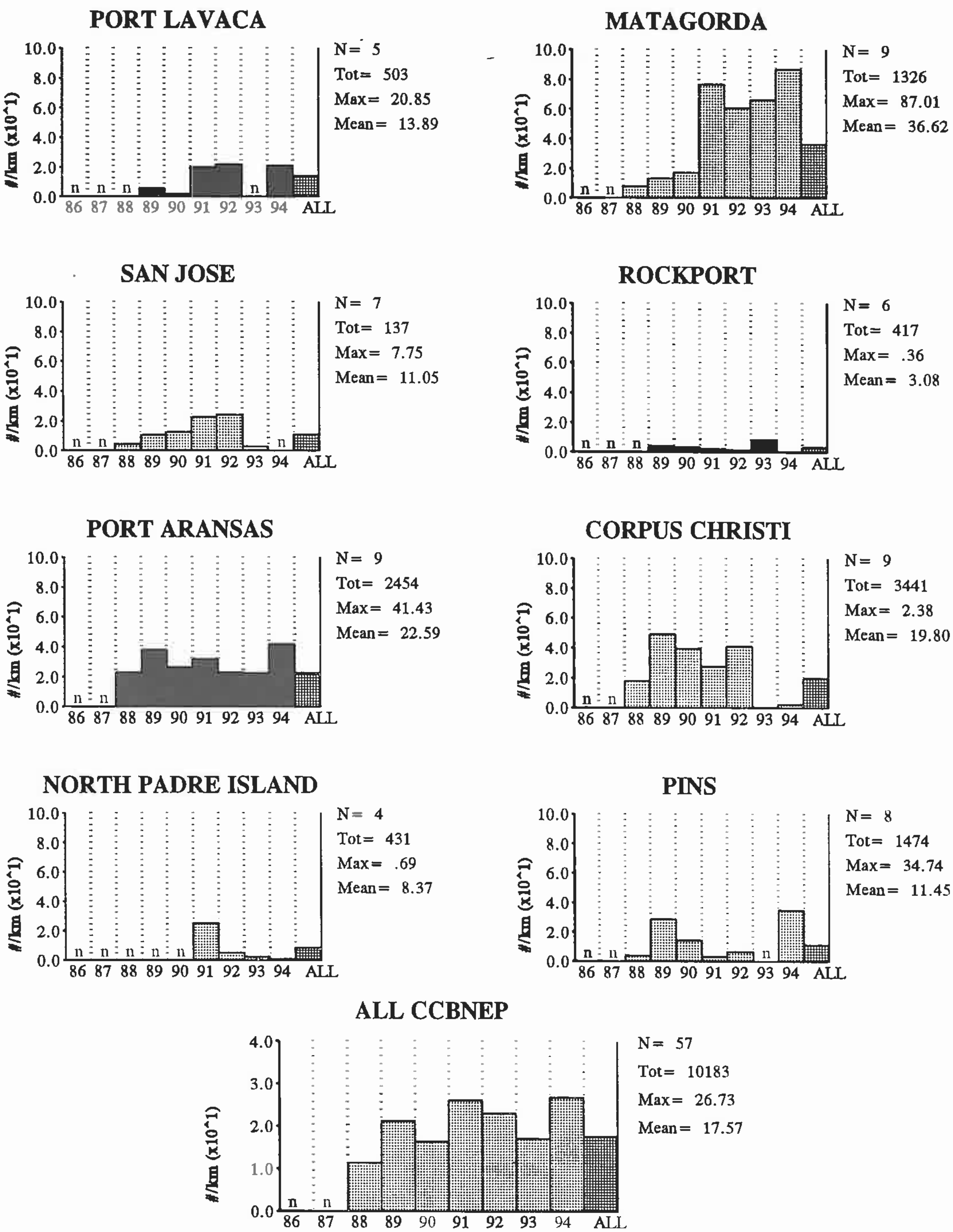


Figure 18 CMC/TGLO data: count by location of CLOTH (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

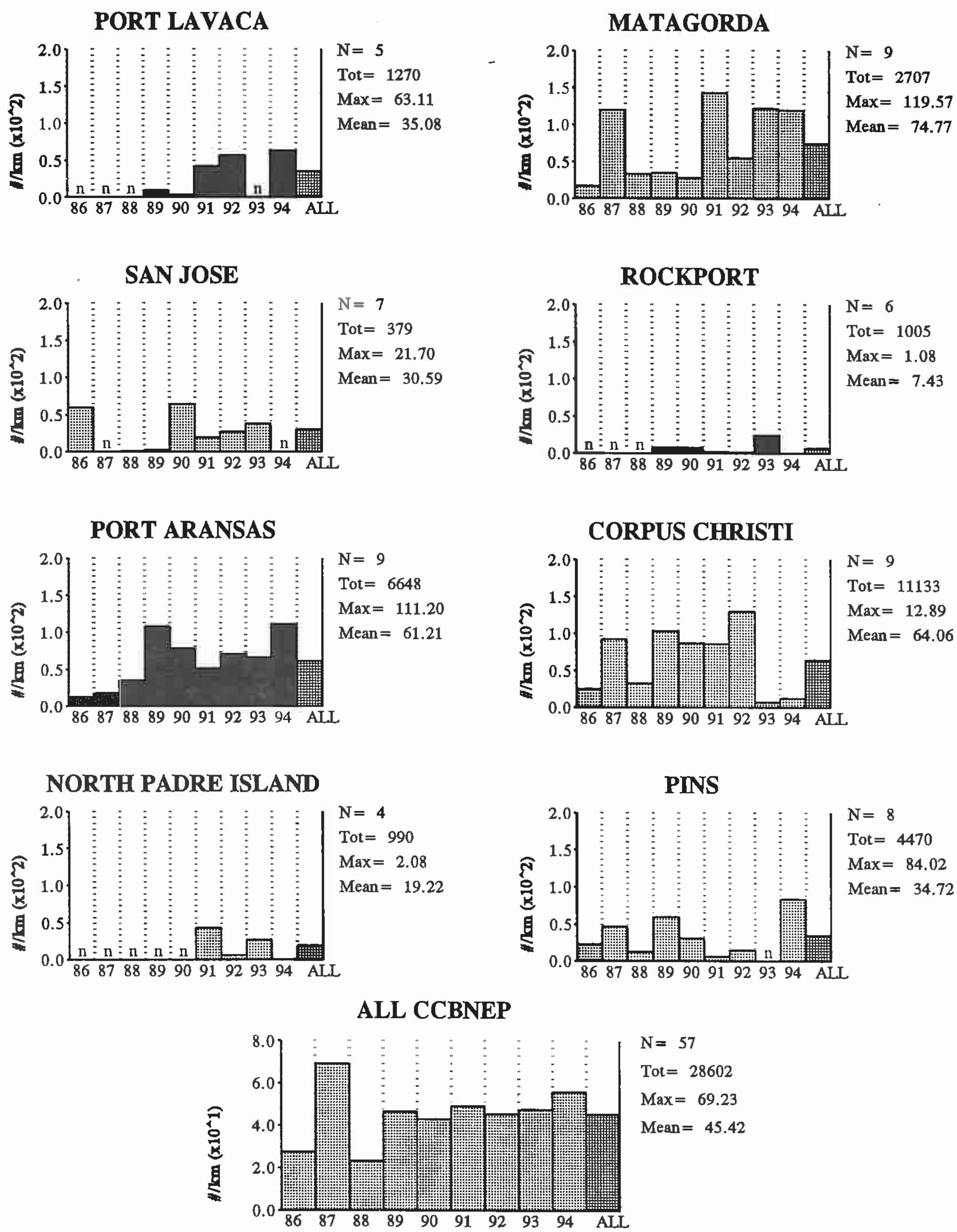


Figure 19 CMC/TGLO data: count by location of WOOD (per kilometer)
Years are numbered along the axes. An 'n' indicates no data collected that year
The three sites used for special comparison here are shaded black
N= Number of Cleanups, Tot= Total # items counted, Max, Mean = Maximum and Mean density/km

(McAllister and McAllister, 1993), although local museums and the Texas State Aquarium feature beach debris in exhibits, and the problem is mentioned at length in the University of Texas Marine Science Institute's brochure "Window on the Sea" (UTMSI, 1987). Methods used by communities to clean the beaches have changed recently in the CCBNEP area. Both the City of Port Aransas and the Nueces County now use grading and raking equipment to scrape the beach clean of both weed and litter. Piles of sand containing this mixture are bulldozed to the coppice dune line. There is less reliance on teams of workers, prisoners, or people doing their community service obligations in hand-picking the garbage and removing it to a landfill away from the beach. All these conditions affect the volunteer cleaners and the information they provide on the data or tally sheets.

Weather conditions also can greatly affect the quantity of debris on a beach. Conditions cannot be predicted prior to the event, which must be planned months in advance. While astronomical tides can be predicted ahead of time, the cleanups must be planned by the calendar rather than the moon and sun. This would be impossible anyway, as the event is nationwide and international in scope. The biggest problems, however, lie in the techniques and lack of controls imposed on the volunteers. What is needed for trend analysis are quantities comparable between locations, seasons and years, and some standardization of units (counts, weights, or volumes per unit length or area of the cleanup site). Are these conditions met in the volunteer cleanups?

We found that records are not readily available on the number of people involved and the length of beach cleaned for each region in each year. This information should be recorded on the standard data cards. To fully analyze the results for the CCBNEP area, the original cards would need to be studied. Are these available? We did not request original data forms from CMC. The job of sorting through these is monumental and CMC has already done this in the compilation of their data supplied to us. The TGLO spring cleanup data forms are only kept for a few months and are then discarded. These data were published for 1986 through 1987 (CEE, 1986; 1988 and CMC, 1989) but not since then have they been analyzed. We have entered these data into spreadsheets and they are included in the data base, but not plotted here due to their paucity. CMC retains the original data cards from the September cleanups. If we were to obtain these thousands of cards, would they contain the necessary data? After interviewing the coordinators of the separate regions, we found that information on numbers of volunteers and distances covered was made available for the past couple of years only, and then only from memory. Could we find out number of items per unit of beach? Could we discover how many people participated and get items per volunteer? We found that the length of beach cleaned changes, the name of the beach changes, some beaches are not cleaned each year and the number of volunteers each year for each beach also varies. The numbers differ in both of those categories year by year. We conclude that the data cannot be compared with any statistical confidence historically or geographically. For example: The nine regions of the CCBNEP area for beach cleanups are, from north to south, Matagorda, Port Lavaca, Rockport, San Jose Island, Port Aransas, Mustang Island, Corpus Christi, Padre Island and PINS. The first three have been fairly consistent (i.e., the regional names have not changed over the years), but as we move south, the regions overlap and actually envelop each other. Port Aransas is located on Mustang Island, Corpus Christi is on Mustang and Padre Islands, and PINS is on Padre Island. Some years, San Jose Island information has been listed separately but the last couple of years (the coordinator is unsure how many) San Jose Island has been included in the Port Aransas region. In some years, San Jose Island has been cleaned by an entirely different group than Port Aransas but when this happened cannot be determined. Port Aransas has also, in some years, included Charlie's Pasture (a section of beach on the backside of Mustang Island facing the Corpus Christi Bay).

Another problem is that the section of Padre Island from the Nueces/Kleberg County line to PINS is sometimes referred to as Corpus Christi and sometimes as Padre Island. The same is true of the section of beach from the Mustang Island State Park to the Nueces/Kleberg County line. In 1994, there was no listing for PINS data; it was called Padre Island. The section of beach on Padre Island from the PINS southern boundary to Mustang Island was simply called Corpus Christi. Much of this is not even in Corpus Christi city limits. So, if a comparison was to be made, Padre Island for 1994 would have to be compared to PINS of 1993, even though there was a Padre Island section for 1993. While the September cleanup data suffers from these discrepancies, we were able to obtain the great majority of the CCBNEP area data from CMC. The GLO, on the other hand, did not have any data from previous years. They only keep their data cards for one year and, apparently, they do not record the totals anywhere. We were given a few press releases that had very basic information for a couple of years. They were able to send us the data cards for 1995. The cards were not complete. Many did not have the tallies totaled or any information about where the trash was collected or how many people were involved. Amos (1993b) examined many of the shortcomings of having volunteers fill out data forms for a San Jose Island cleanup in September 1992. These volunteers were quite experienced, but our examination of the forms from the April 1994 Texas Trashoff revealed numerous deficiencies in their tally sheet entries. This calls into question the information they announce regarding total number of volunteers, areas of beach cleaned and amount of trash collected. We are still trying to obtain the basic numbers from each region for each of the April cleanups, despite the destruction of the original data. The use of counts to evaluate marine debris is open to question: plastic dominates by number, but does it also by volume or weight?

4.2.2 UTMSI Data

The UTMSI data sets are compiled from surveys done exclusively on Mustang and San Jose Island gulf beaches. This section therefore deals with marine debris and not bay debris, but many of the items discussed pertain to both forms of debris.

4.2.2.1 Environmental Measurements and Marine Debris

We present results from environmental measurements made during the UTMSI beach surveys and also at the University of Texas Marine Science Institute's Pier Laboratory facility where weather and sea conditions are monitored continuously. The tides and winds are so important to the fate of debris in the coastal area that it is necessary to review the annual cycle of these parameters, especially as they pertain to the validity of debris surveys already accomplished. Of paramount importance is whether the time and place chosen to survey, and the frequency of the surveys, can generate statistically valid data to indicate trends.

When seaborne debris first washes ashore, it tends to come in pulses, rather than in a steady flow, driven there primarily by the tide. Wind has a considerable direct effect on floating debris. Debris collects at sea in windrows or patches, commonly called "trash-lines" by fishermen. Throughout much of the year, *Sargassum* weed is the dominant flotsam at sea, among which the man-made trash accumulates. Trash lines are also called "weed-lines" by some. These windrows are controlled by the wind blowing over the sea surface and setting up a form of circulation called "Langmuir cells" which causes alternate zones of convergence and divergence, thus concentrating all floating material along convergence lines. Closer to shore, a detritus line is associated with an estuarine front caused by the density difference between bay waters flowing seaward on the ebb-tide and Gulf waters of higher salinity. This can often be seen as a plume extending out into the Gulf from the Aransas Pass. On the flood tide, debris is washed ashore as long-shore currents transport the material north or south from the pass. Natural debris typical of bays and rivers (sea grasses, water hyacinth) is frequently deposited along with the trash on the beach. Figure 20 shows the 1995 predicted astronomical and actual tide for the Aransas Pass tide gage located at the UTMSI pier. Note the long-term fluctuation in sea level (low in January, high in May, low in July, and highest in October, in the predicted tide. Note that this is also seen in the measured tide, but there are far more short-term fluctuations in reality caused by non-astronomical factors. The periodic high tides, lasting a day or two and caused by storms and wind, often bring marine debris which might have been at sea for a long time (months), and which is deposited high on the beach.

After the debris is deposited on the beach, other factors control its distribution, especially wind, but also beach-cleaning activities, trapping by dunes or weed already on the beach, and burial in wet or blown sand. To assess the quantity of marine debris on Mustang Island we had to confine our counts to material observed in the swash zone, i.e., material deposited there since the last high tide. Figures 21 and 22, and several that follow, are box-diagrams illustrating both monthly and yearly trends for each of the parameters measured or counted. All show the entire 18-years of the study along the rows and the months on the columns. Along the top of the diagram, the shaded vertical bars are the yearly averages, while on the left the shaded horizontal bars are the monthly averages. Numbers at the top of the vertical (yearly average) bars give the numerical mean, while italicized numbers at the bottom show the total number of observations done that year and, below that, the number of times the item was seen or the parameter measured. For the horizontal (monthly average) bars, these data appear at the end of the bar. To aid in visually interpreting the results, bars are shaded to show the frequency with which that item or measurement occurred in the period. Darkest shading is 100%. All scales are proportioned to the highest mean value. Within each monthly box the shading height is proportioned to the highest monthly mean which fills the box. Again, numbers are the value of the mean in the units indicated. A thin strip above each box has vertical lines showing the frequency of observation and the interval between observations. The several gaps are when the PI was absent and the survey was not done. Only 11 of the 212 months had no observations. These are indicated by a blank square. If surveys were done but the item not seen, or the parameter not measured, then a "N/S" or "N/M" appears in the square.

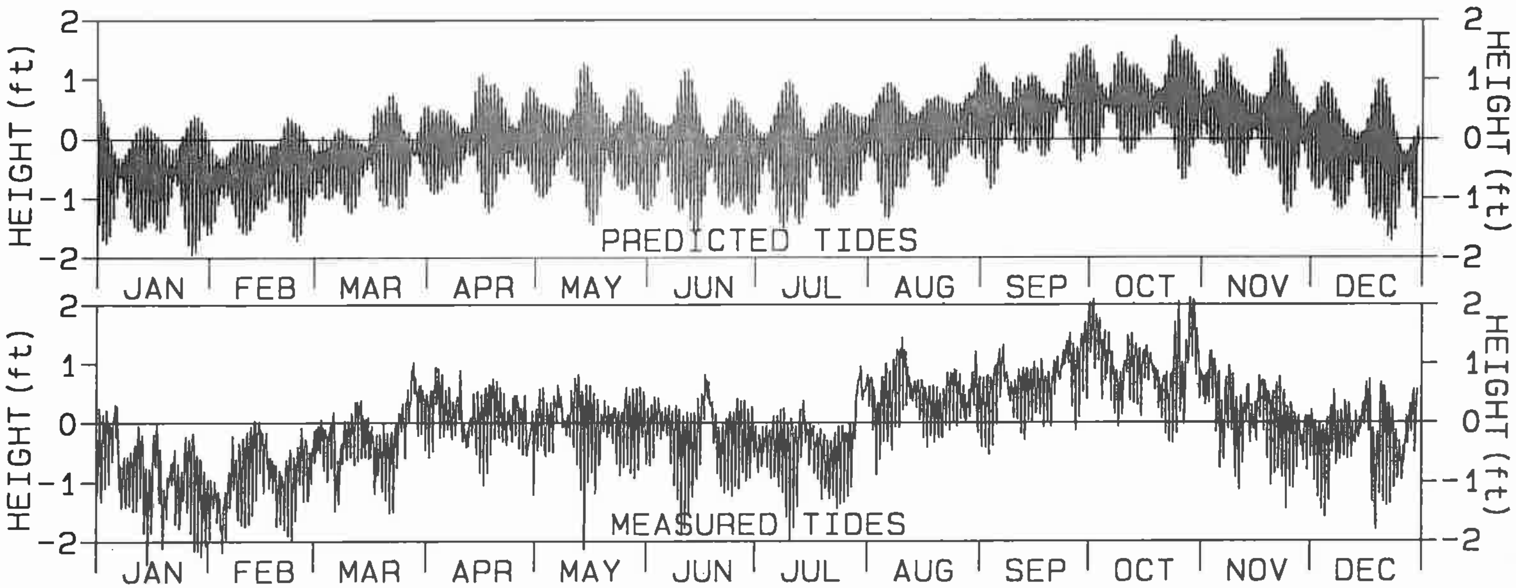


Figure 20 Predicted v/s actual tides at the UTMSI Pier Laboratory (27 50.3'N; 097 03.0'W) for 1995

Figure 21 shows the width of the swash zone where debris was counted. The mean width is 15.6m. There has been a gradual narrowing of this zone, punctuated by two major storm events, hurricanes Allen in 1980, and Gilbert in 1988. In each case, the beach width increased due to re-deposition of sand eroded from the dunes. The beach became less steep, hence the swash zone was wider. The annual cycle is well-illustrated on the left, showing a swash zone wide in winter and narrowing to a minimum in July. This is due to the formation of a summer berm and a steeper foreshore, but is partly due to an artifact of the sampling scheme (see Fig. 23, below). The overall width of the beach (Fig.22) from the dune line to the shoreline at the time of measurement, varies somewhat differently. The mean beach width over 18 years is 42.4m, but the beach is eroding and the dune line advancing so that in 1995 the mean width was 22.7m. The annual beach-width cycle more nearly reflects the tidal cycle with maximum widths (low sea level) in December, January, and February, and again in July and August, and narrowest beaches (high sea level) in May and October.

An interesting peculiarity of beach width versus season is that if surveys are always done at the same time of day, then there are certain stages of the tide which the observer will never witness and others which will always be encountered, depending on the season. This is illustrated in Figure 23, showing the 1996 (predicted) tide for Port Aransas and the height of the tide at 6 am (close to the time that the UTMSI surveys are done), 9 am (start time for volunteer beach cleanups), noon (end time for beach cleanups), and 6 pm. An observer surveying for debris at 0600 hrs will see only low tides in January and February, and high tides in the summer. Volunteer cleanups are traditionally done between 9 am and noon. In September such surveys will generally be done on an outgoing tide, while in April the tide will be coming in. In the UTMSI survey, the PI was well aware of this fact but it was impractical, or impossible at times, to do a daylight survey at the same stage of the tide.

The wind redistributes litter, especially lightweight plastic materials (e.g., empty containers), into the dunes during prevailing southeasterly winds, and back onto the beach during usually stronger northerly winds as cold frontal passages advance through the region. Figure 24 illustrates this with wind roses and stick-vector diagrams for the months of April, July, and September 1995. April has strong southeasterlies, but one or two late fronts can blow through, July is dominated by southeasterlies, and September can be variable with southeast winds and early cold fronts, as well as tropical storms and hurricanes. Also shown in Figure 24 are the wind speed, barometric pressure, air and sea temperature, salinity, and tidal height. Data were collected at the UTMSI Pier Laboratory Facility.

4.2.2.2 Other Factors Affecting Marine Debris Distribution

While the sources of marine debris are manifold, originating anywhere that litter is deposited in the environment by design or accident, debris found on beaches has been concentrated by the forces described above and deposited on the shore in a sporadic fashion. Figure 25 is the result of twelve years of estimates (1,771 separate surveys) of the quantity of *Sargassum* weed on Mustang Island Gulf beach. Seaborne litter is frequently associated with the weed. The peak month for *Sargassum* is May, and Spring is the "weed season". Certain years have seen extraordinary quantities of *Sargassum* come ashore, for example, 1989 and 1993. So much

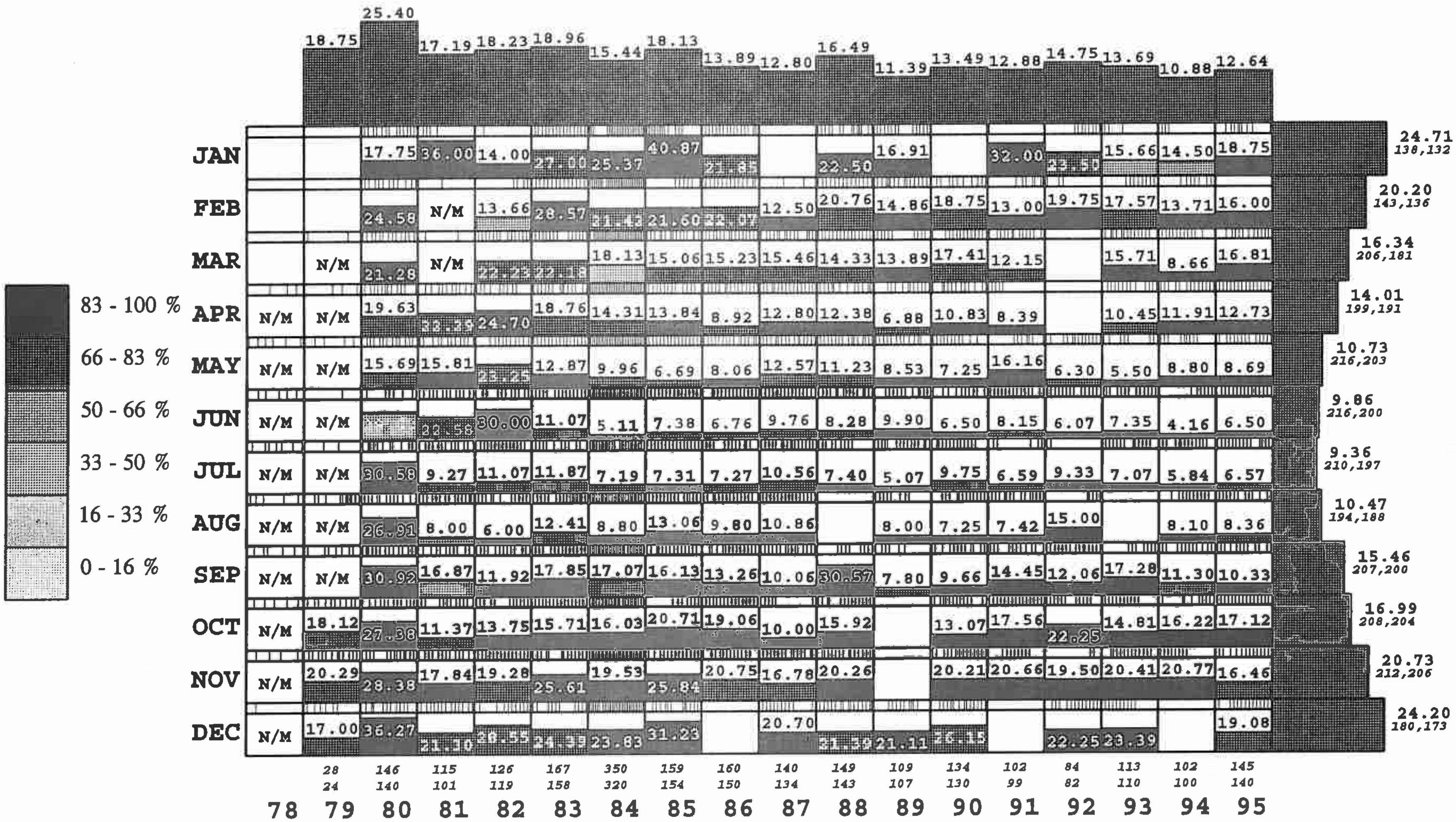


Figure 21 Box diagram of monthly and yearly means for SHORELINE TO HIGH-TIDE LINE. (n =2,536)
MIN = 0; TIMES MEASURED 2,344 (92.4 %); MAX 105 ; AVERAGE 15.35

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

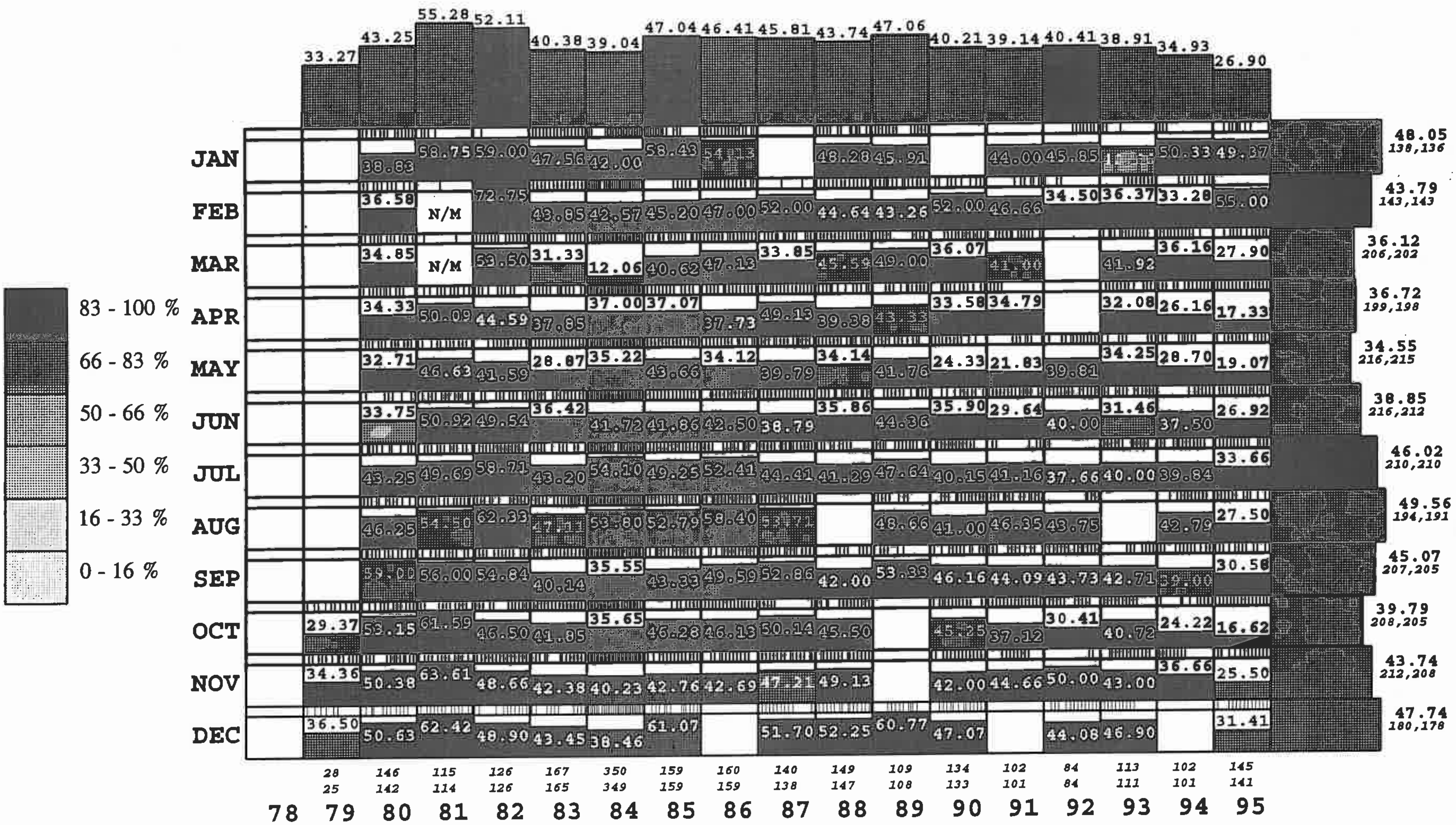


Figure 22 Box diagram of monthly and yearly means for DUNE LINE TO SHORELINE. (n =2,461)
MIN = -27; TIMES MEASURED 2,437 (99 %); MAX 123 ; AVERAGE 41.4

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

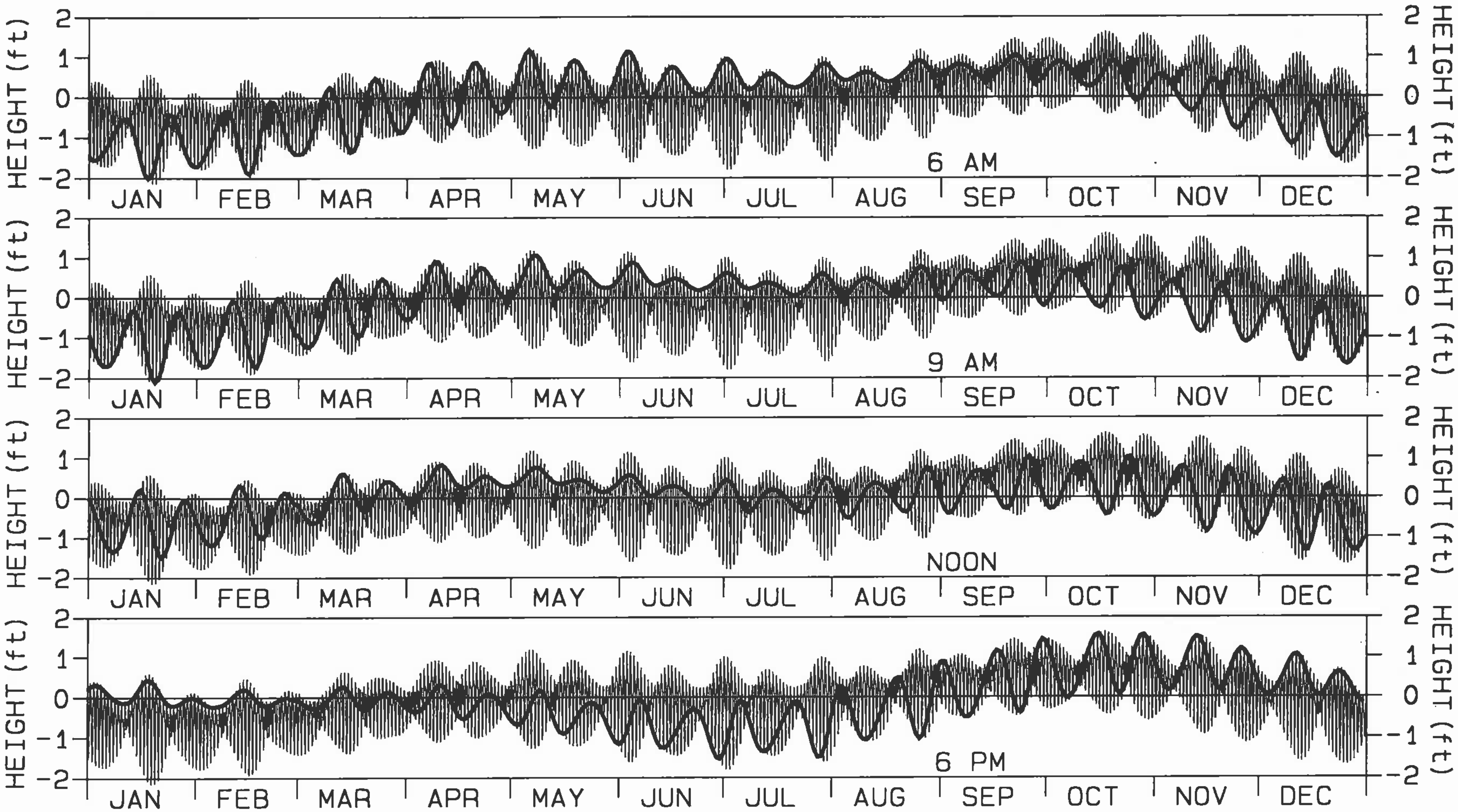
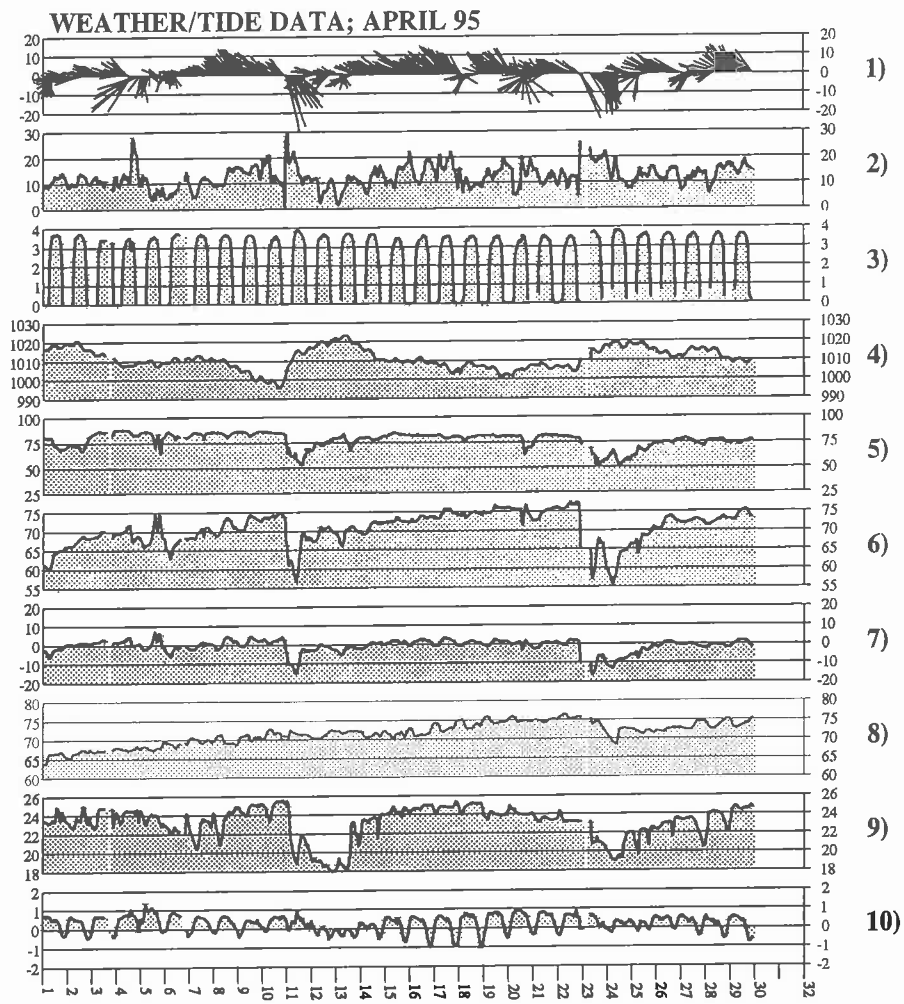


Figure 23 Yearly sea-level at different times of day for the Aransas Pass Ship Channel, Port Aransas, 1996
Heavy curve is the predicted height of tide at the time shown in each panel, superimposed on the curve of the hourly predictions. Zero line is Mean Sea Level. The Volunteer Beach Cleanups are done between the hours of 9 AM and Noon in April and September of each year. The UTMSI surveys are done at local dawn, year-round



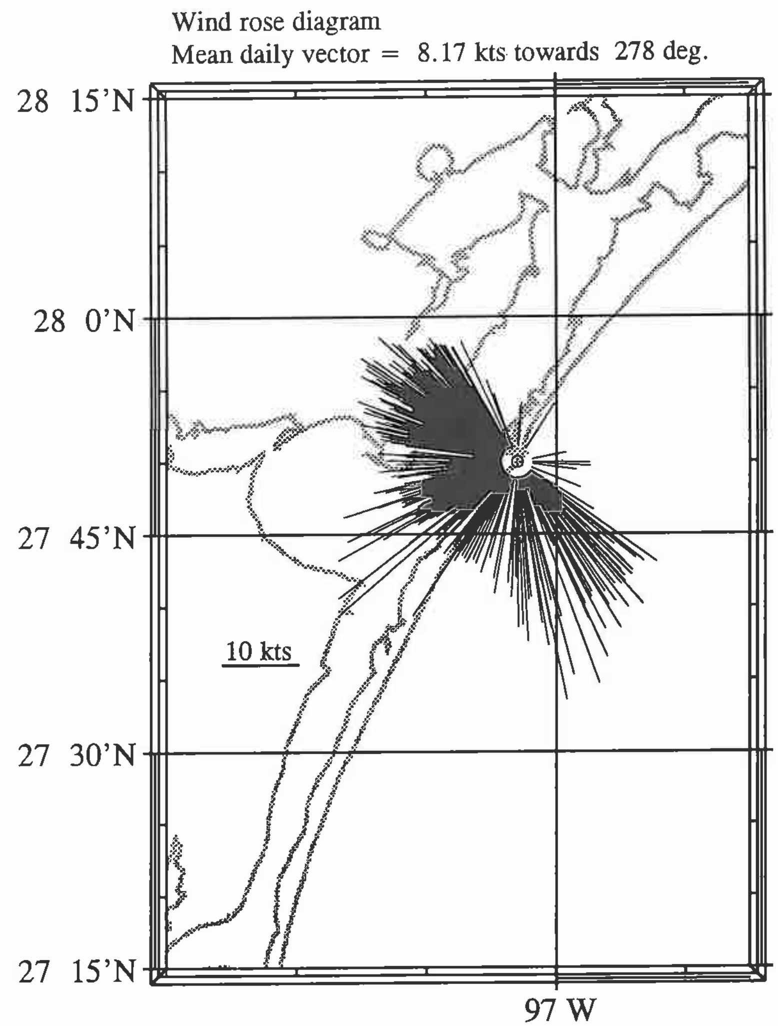
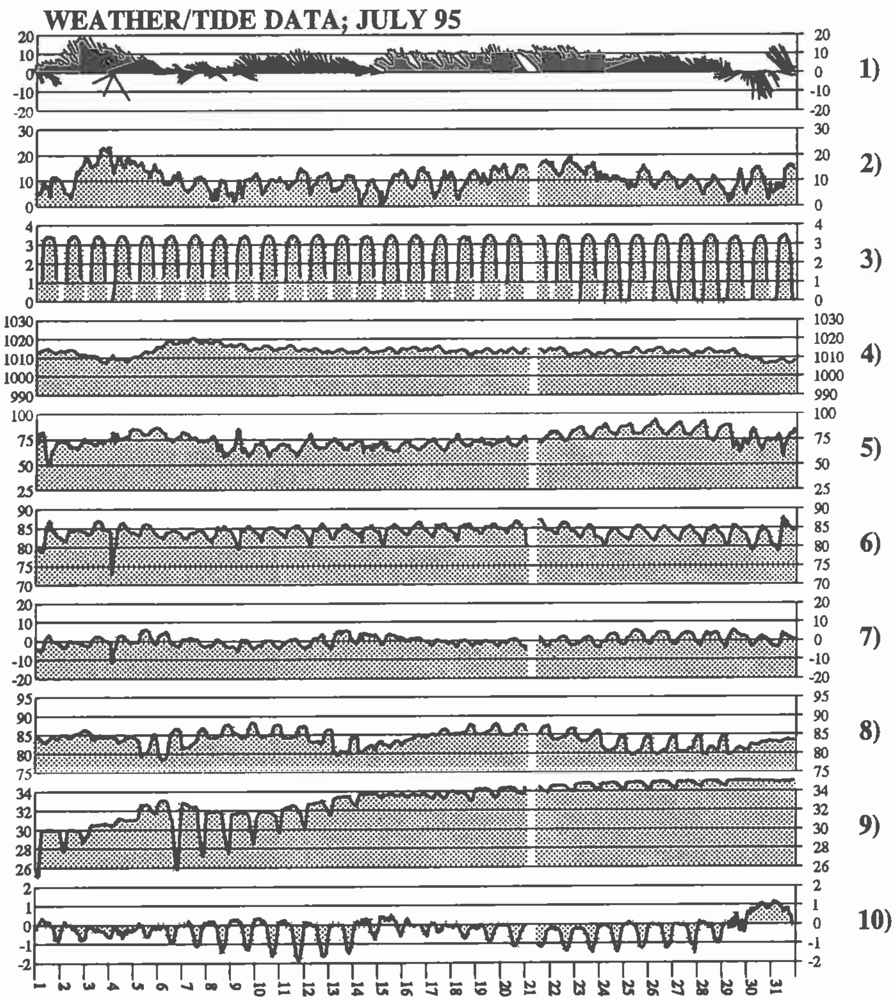


Figure 24a Typical environmental conditions in the CCBNEP study area in APRIL 1995
Panels on left; from top-to-bottom. 1) Wind vector stick diagram (north is up). 2) Wind speed (kt)
3) Solar radiation (sensor voltage); 4) Barometer (mb); 5) Rel. humidity (%); 6) Air temp (F)
7) Air minus Sea temp (F); 8) Sea temp (F); 9) Salinity (psu); 10) Tide height (ft).
Area map with wind rose on right. Scale in kts.



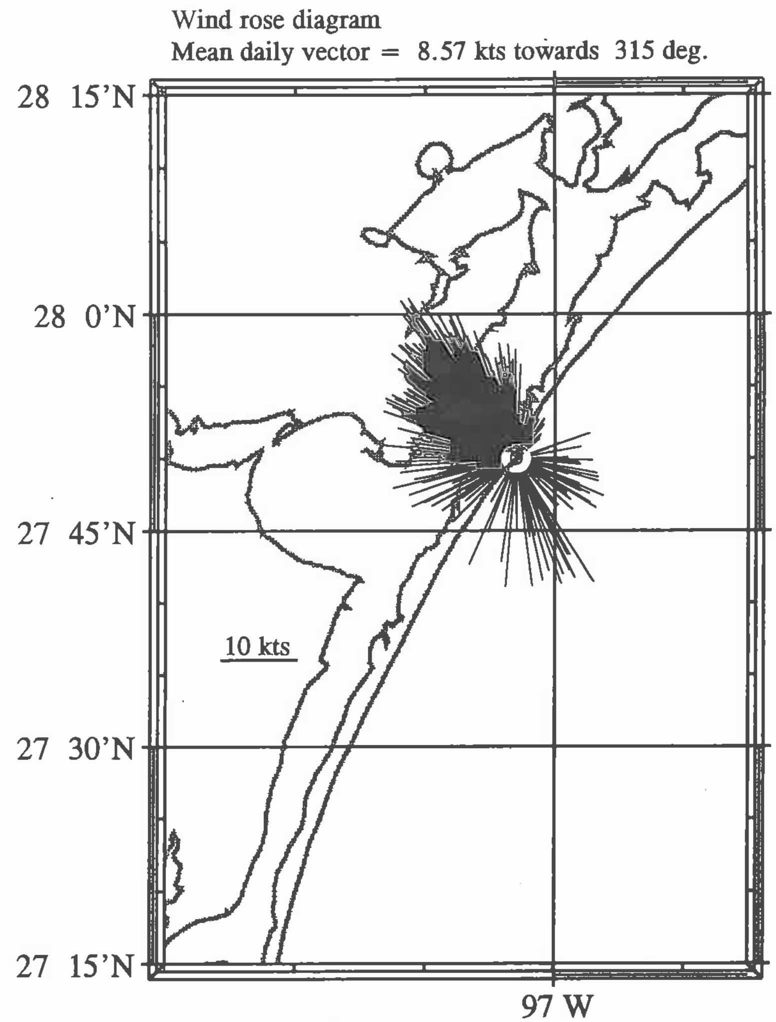


Figure 24b Typical environmental conditions in the CCBNEP study area in JULY 1995
Panels on left; from top-to-bottom. 1) Wind vector stick diagram (north is up). 2) Wind speed (kt)
3) Solar radiation (sensor voltage); 4) Barometer (mb); 5) Rel. humidity (%); 6) Air temp (F)
7) Air minus Sea temp (F); 8) Sea temp (F); 9) Salinity (psu); 10) Tide height (ft).
Area map with wind rose on right. Scale in kts.

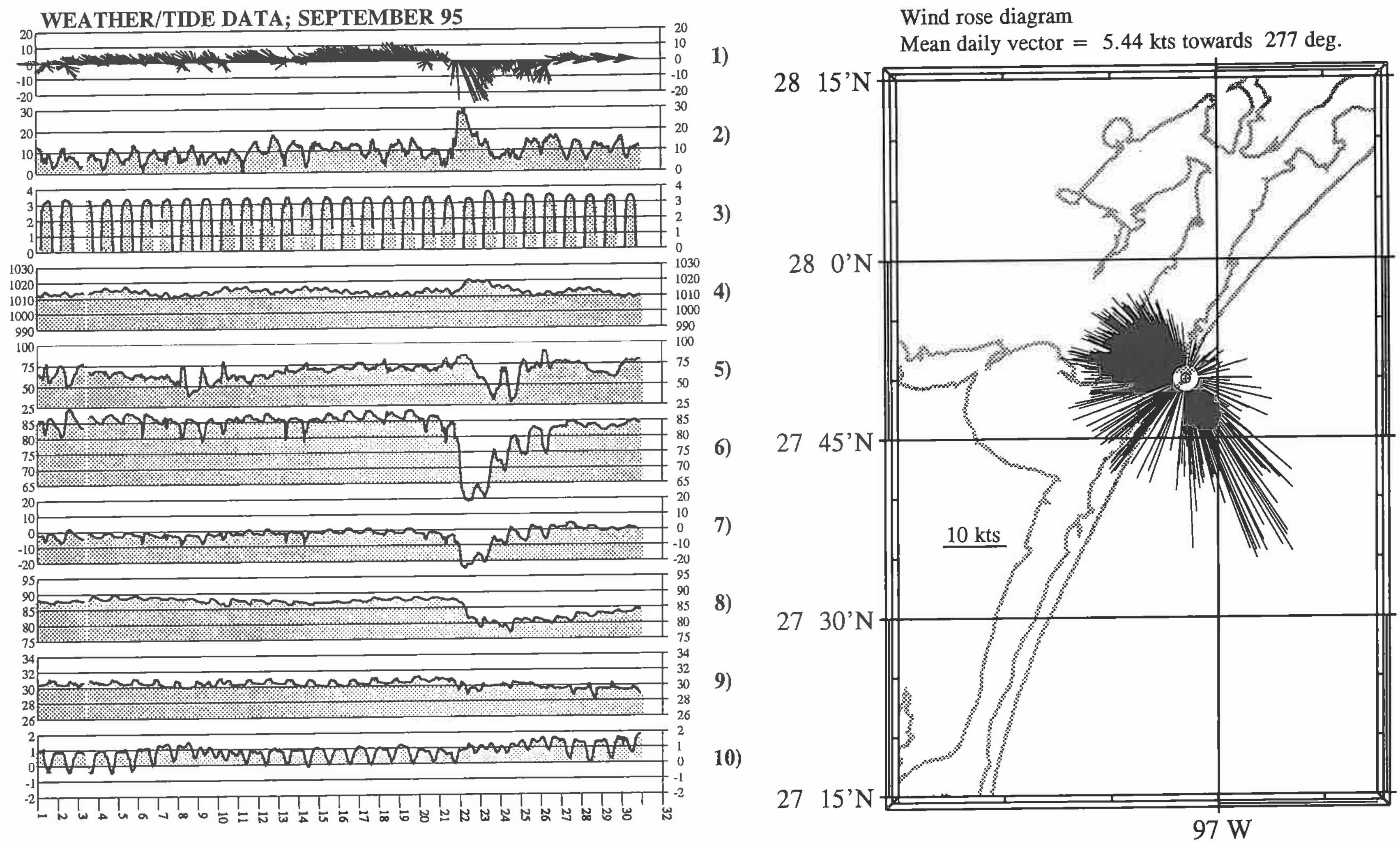


Figure 24c Typical environmental conditions in the CCBNEP study area in SEPTEMBER 1995
Panels on left; from top-to-bottom. 1) Wind vector stick diagram (north is up). 2) Wind speed (kt)
3) Solar radiation (sensor voltage); 4) Barometer (mb); 5) Rel. humidity (%); 6) Air temp (F)
7) Air minus Sea temp (F); 8) Sea temp (F); 9) Salinity (psu); 10) Tide height (ft).
Area map with wind rose on right. Scale in kts.

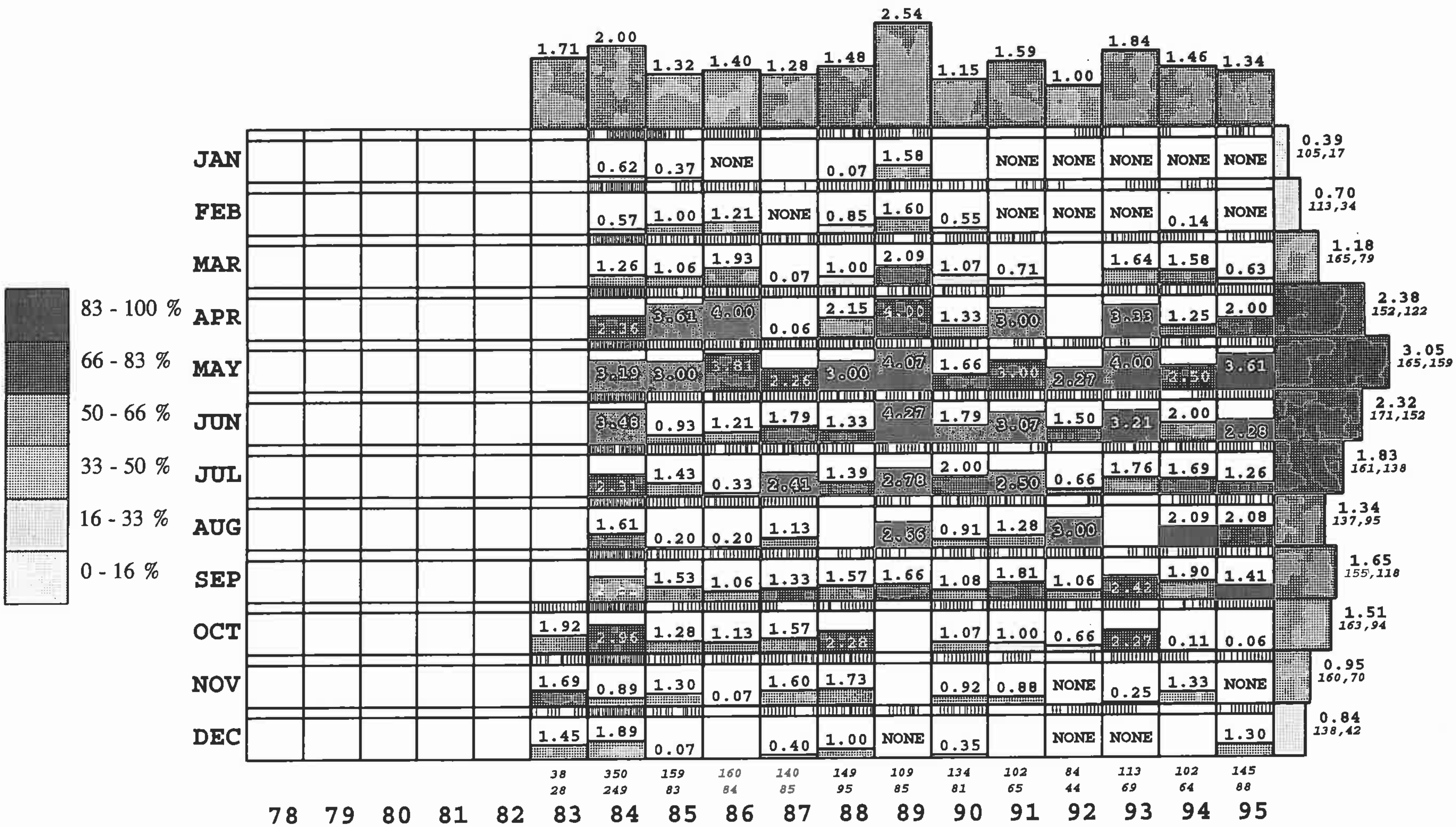


Figure 25 Box diagram of monthly and yearly means for Sargassum WEED. (n =1,916)
TIMES SEEN 1,239 (64.6 %); MAX 5 ; AVERAGE WHEN SEEN 2.5

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

weed piled up on the beach that it made local headlines because of the impact on tourism. Another source of beach debris is not so circuitous: litter left on the beach by beach goers themselves. Events like the annual Spring Break attract tens of thousands of people to South Texas beaches. Littering is "endemic" to these events. In March 1990 the PI observed (video) a beverage-can gleaner collect 900 lbs (25,000 cans) from the Port Aransas area alone. The beach was still littered with uncollected cans. The public usage of area beaches has steadily increased in recent years. Figure 26 illustrates that increase since 1979, showing the density of people per kilometer on a less-used section of Mustang Island beach. Yearly, the number of people on the beach peaks in August, with a secondary peak in March. There is a rapid drop off after October, but the winter beach usage is changing with the increase in "Winter Texans" visiting and staying at the condominiums. These visitors are less-likely to litter the beach than other beachgoers; in fact, they often pick up debris during their walks (a fact, while meritorious, which sometimes compromises the efforts of those trying to count the debris). The diagram is the result of 2,321 survey counts made in the early morning before the peak usage hours: 99,582 people have been counted in 16 years, with a mean density of 3.61/km and a maximum of 54.09/km.

4.2.2.3 The Data

Amos (1993a) chose five items which were easily countable from a moving vehicle and for which a source was known with some confidence. They were gallon **milk jugs** (shrimping), **egg-cartons** (also shrimping), **green** bleach **bottles** from Mexico (possibly also shrimping), **beverage cans** (mostly beach going), and 5- and 55-gallon **chemical pails and drums** (offshore oil industry). Counts were started in 1988 by adding these items to the list of things counted on the ongoing beach survey, done bi-daily since 1978. In 1987 and 1988, a separate survey was begun to quantify the beach litter before the impending MARPOL Annex V agreement was ratified by the U.S. These surveys were done on an eight-day interval so as not to interfere with the regular beach survey. At the end of a year it was decided to continue the counts but only of these five items. The beverage can count did not start until 1989. Figures 27 through 32 box-diagrams show the results.

The peak month for **milk jugs** (Fig. 27) is May. In total, 15,507 were counted giving a mean density over 870 surveys of 1.51/km[1], with a peak of 40.73/km. Milk jugs have declined on the survey beach; they are seen 89.5% of the time. **Egg cartons** (Fig. 28) peak in August with a minimum in June; they, too, have declined over the duration of the survey. Some 5,188 were counted giving mean and maximum densities of 0.50/km and 10.31/km. Egg cartons were found on 65.5% of the surveys. The **green bottles**[2], usually 500- or 750-ml capacity, peak in May and August, and are seldom seen in the winter months (Fig. 29). We

---

[1] Overall density. Densities given on the figures are calculated only when the item was observed.

[2] These are ribbed plastic bottles of commonly used Mexican brands (Clarasol, Cloralex) of domestic bleach.

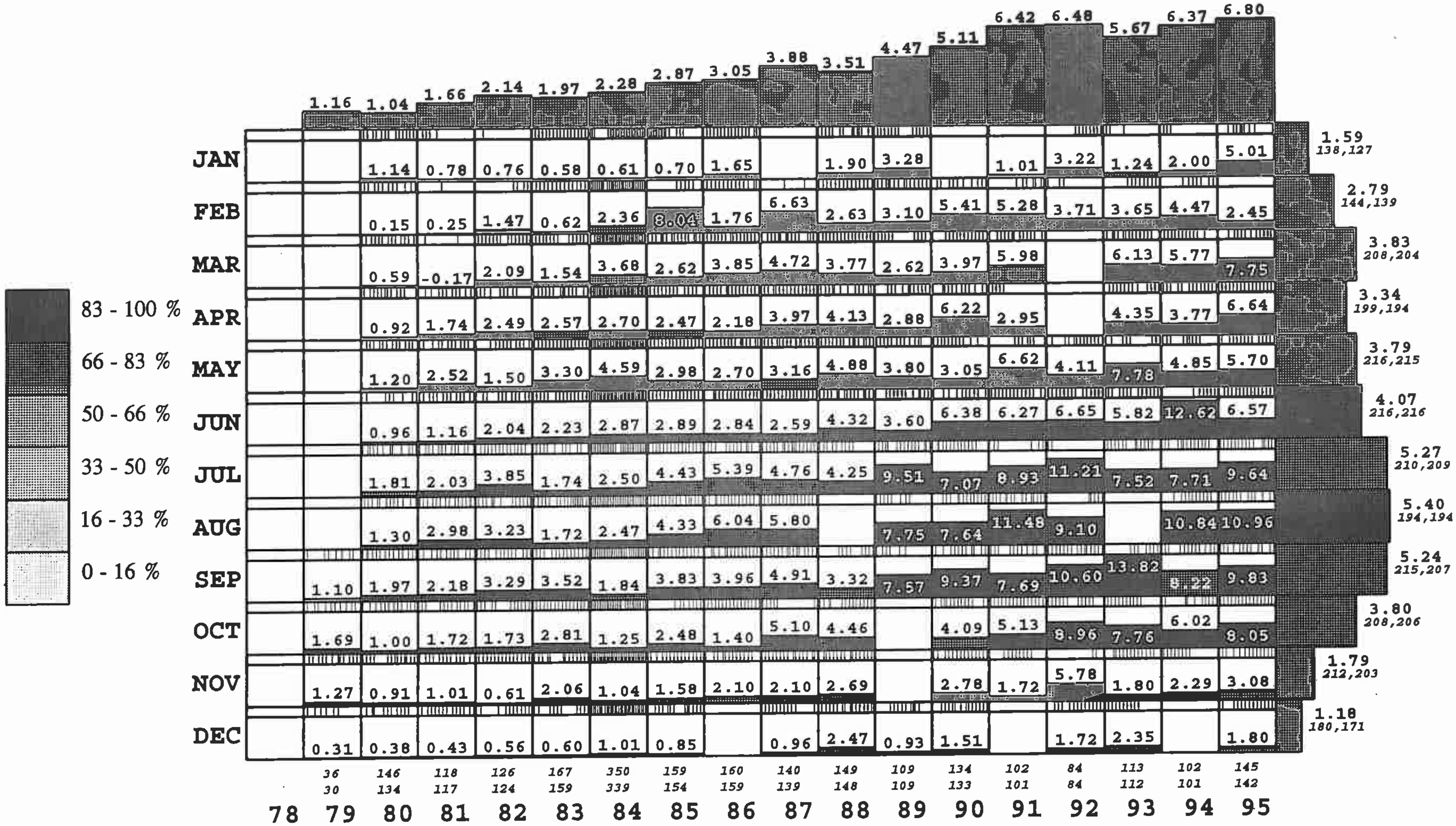


Figure 26 Box diagram of monthly and yearly means for PEOPLE. (n =2,466)
TOTAL = 109,110; TIMES SEEN 2,418 (98 %); MAX 54.09 per/km; AVERAGE WHEN SEEN 3.83 per/km

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

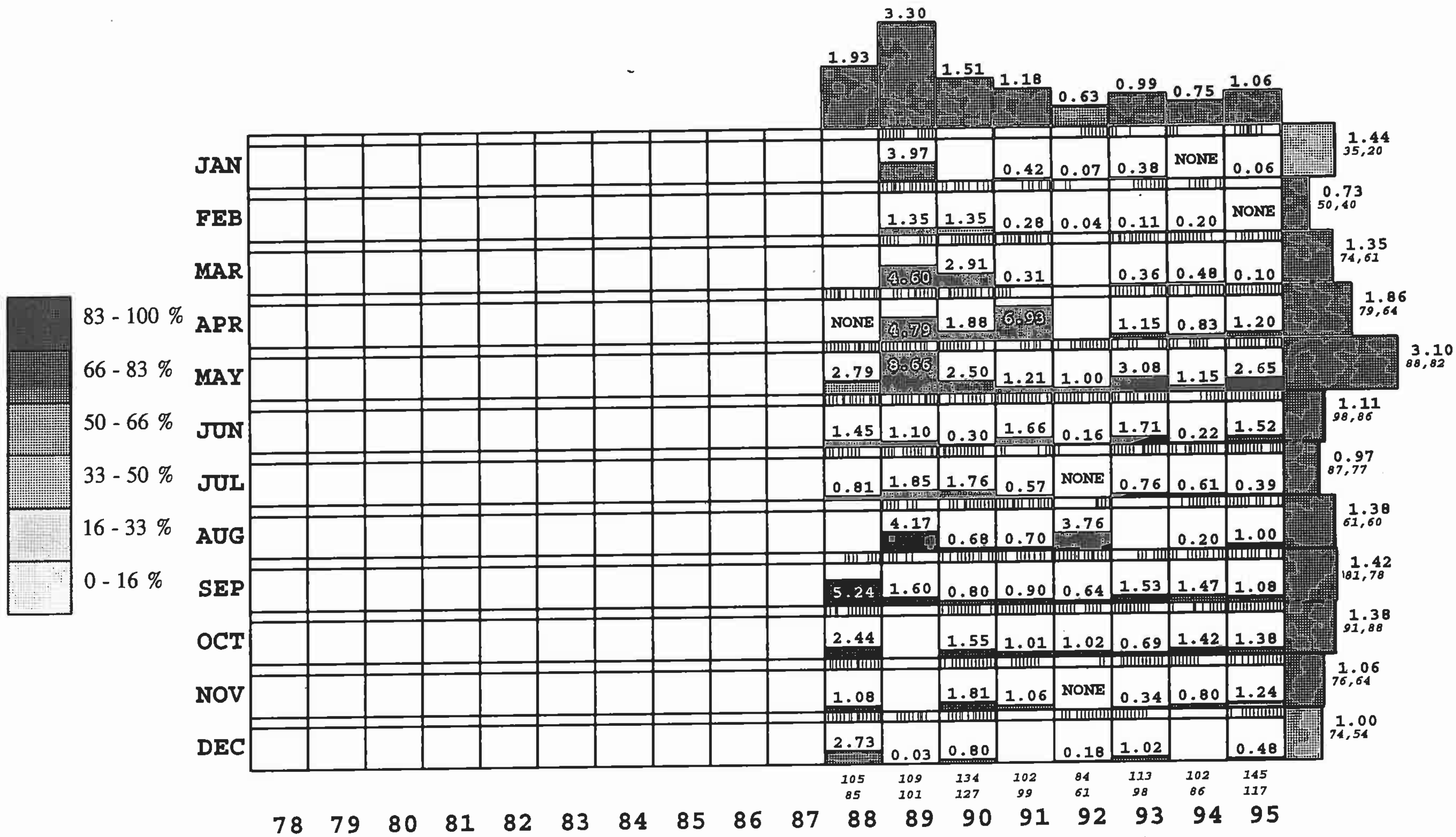


Figure 27 Box diagram of monthly and yearly means for ONE-GALLON MILK JUGS. (n =1,015)
TOTAL = 16,909; TIMES SEEN 910 (89.6 %); MAX 40.73 per/km; AVERAGE WHEN SEEN 1.58 per/km

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

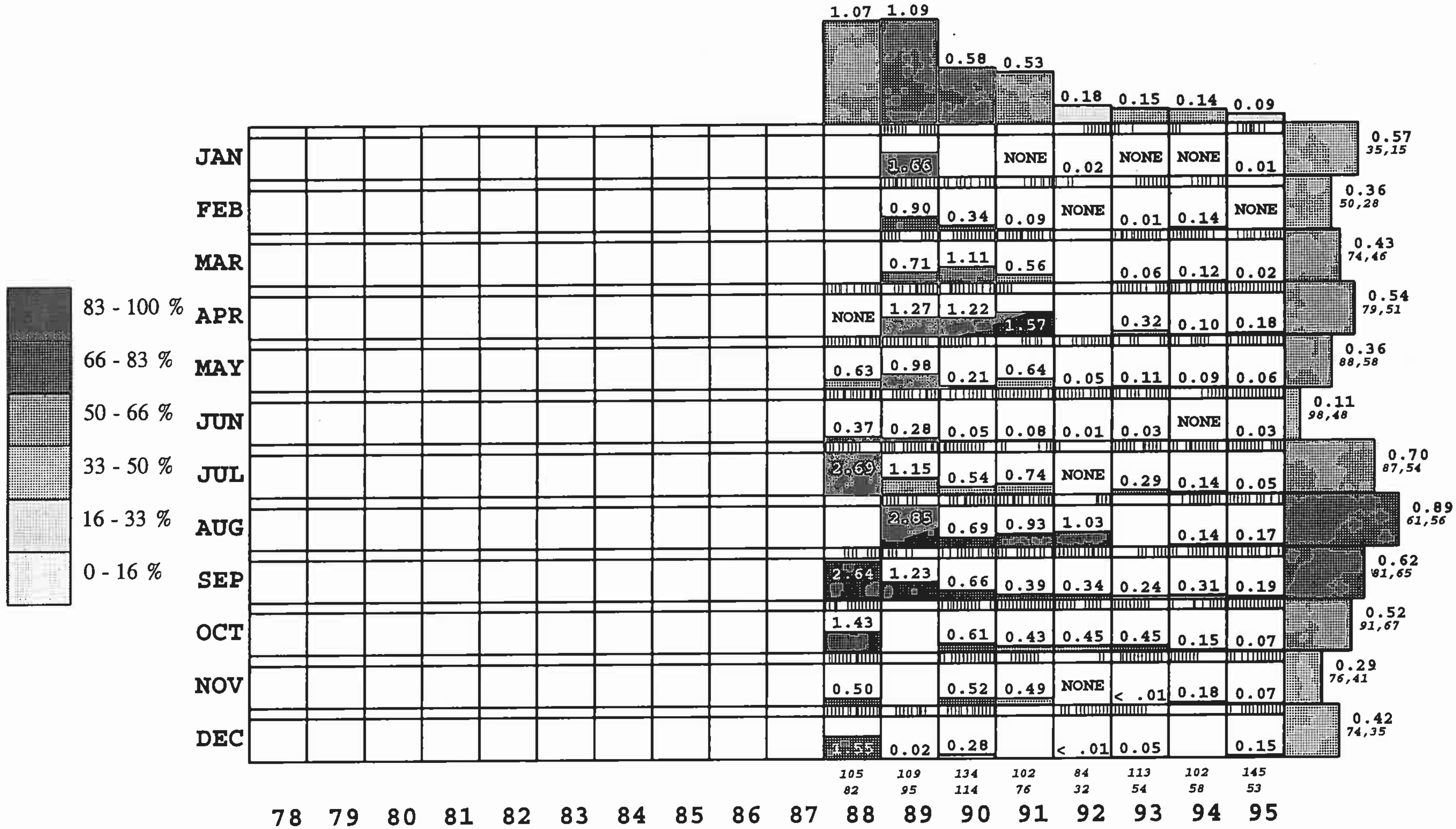


Figure 28 Box diagram of monthly and yearly means for EGG CARTONS. (n =1,015)
TOTAL = 5,358; TIMES SEEN 631 (62.1 %); MAX 10.31 per/km; AVERAGE WHEN SEEN .71 per/km
Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

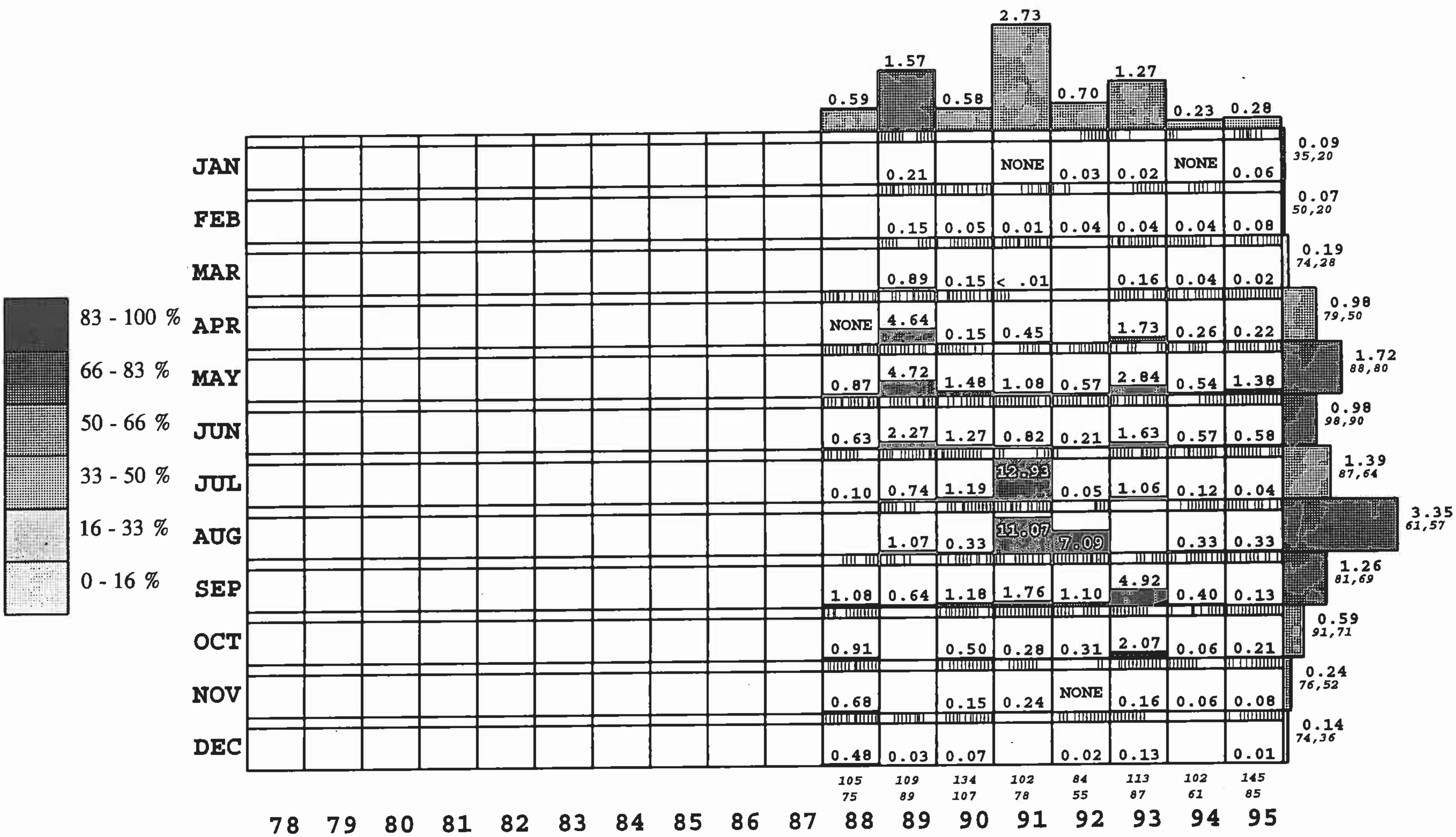


Figure 29 Box diagram of monthly and yearly means for GREEN BOTTLES. (n =1,015)
TOTAL = 11,316; TIMES SEEN 762 (75 %); MAX 53.5 per/km; AVERAGE WHEN SEEN 1.26 per/km

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

speculate that they are transported from the south during the time when longshore currents are northerly. Their source may be the Mexican shrimping fleet. July and August 1990 was a high peak which biases the overall statistic. 10,233 have been counted, the mean and maximum densities were 0.99/km and 53.5/km, and they are found on 74.2% of the surveys. A total of 2,127 **chemical pails and drums**, the great majority being 5-gallon pails, have been counted (Fig. 30). They peak in May and have declined in numbers over the past eight years. These containers often have labels with details of batch numbers, filling date, etc., but never reveal order numbers or other information which might pinpoint their exact source. We record all relevant details for every container found, including the date stamp which indicates when the container was manufactured (see Table 4). Most containers are found on the beach within a year or two of the manufacturing date, and some, within a month or two. A large number of these are sold by distributors in Louisiana and east Texas. In 870 observations, chemical pails and drums average 0.21/km with a maximum density of 7.01/km. **Beverage cans** (Fig. 31) increase to a peak in July, with a secondary peak in March. Although somewhat similar to the yearly distribution of people (Fig. 26), the peak of people is weighted to the fall when beverage cans begin to drop off. There appears to be no trend over the seven years of beverage can counts. A total of 16,799 cans were counted with a peak of 30.25/km and a mean of 2.02/km. Some cans collect in the "gut" offshore between sandbars and are quite old and abraded when washed ashore.

In all, 46,294 of these five items have been counted. A more uneven yearly distribution is seen when the totals are plotted (Fig. 32). The minimum in June may be due to the closure of shrimping during that month. Peak months for garbage are July and August. A January high was due to an unusual winter beaching of *Sargassum* weed in 1989 along with a collection of garbage. Yearly, the trend is not obvious, with peaks in 1989 and 1991. Note that of 296 observations in February, June, July, and August, one or more of the five items was found on every survey (i.e., 100% probability). Overall, the probability is 98.8%. Mean density is 4.49/km and the maximum is 64.57/km. In evaluating all these data, the caveats mentioned in the **Methods** section must be remembered: this is a measure of **standing stock**, as items are not removed after counting yet items are removed by others (beach-cleaning crews) at often irregular intervals. The study beach is definitely a trashy beach. A casual observation confirms this, and the public is well aware of this fact. Yet the density of items overall does not approach the 20-items/km criteria set by the Workshop on Establishing a National Methodology (EPA, 1995) to include any in the list of targeted survey items. We believe this to be a flaw in the proposed methodology (some of these items are on the list anyway). Recent surveys on San Jose Island which, even to the most casual observer, appears to be a garbage dump, have shown peak densities of up to 32/km, but over several surveys, the mean is much less.

Here lies one of the basic problems with assessing the marine debris problem: the variability of the resource. We have been looking at monthly means in the previous several figures. In Figure 33, the two-day mean (surveys are done bi-daily) of four of the five items has been plotted (heavy black line). Vertical bars above and below the line show the maxima and minima for each two-day interval. The numbers of observations are shown in the box below by the length of the vertical lines. Fewer observations have been made in January and

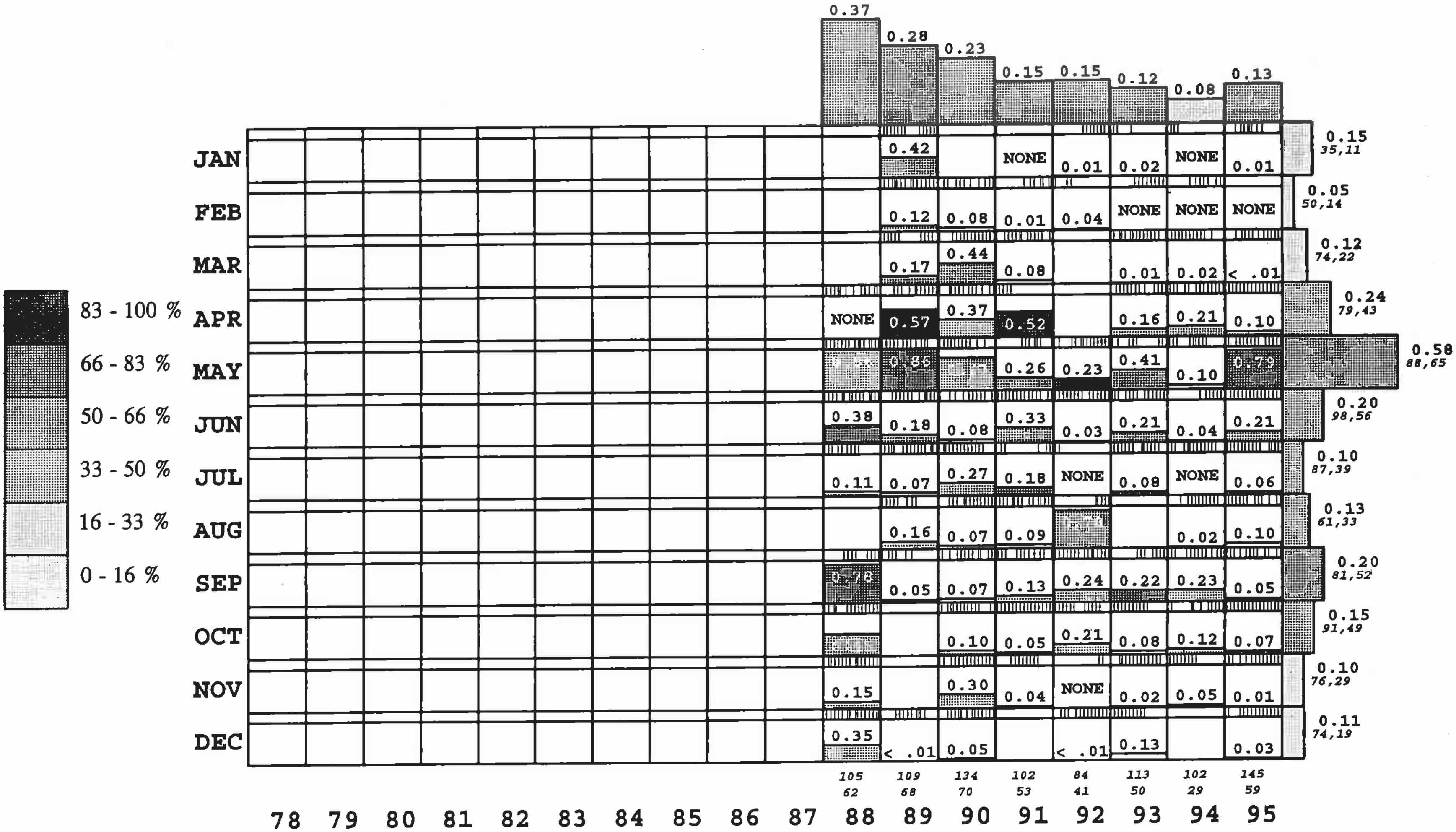


Figure 30 Box diagram of monthly and yearly means for CHEMICAL PAILS & DRUMS. (n =1,015)
TOTAL = 2,325; TIMES SEEN 502 (49.4 %); MAX 7.01 per/km; AVERAGE WHEN SEEN .39 per/km

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

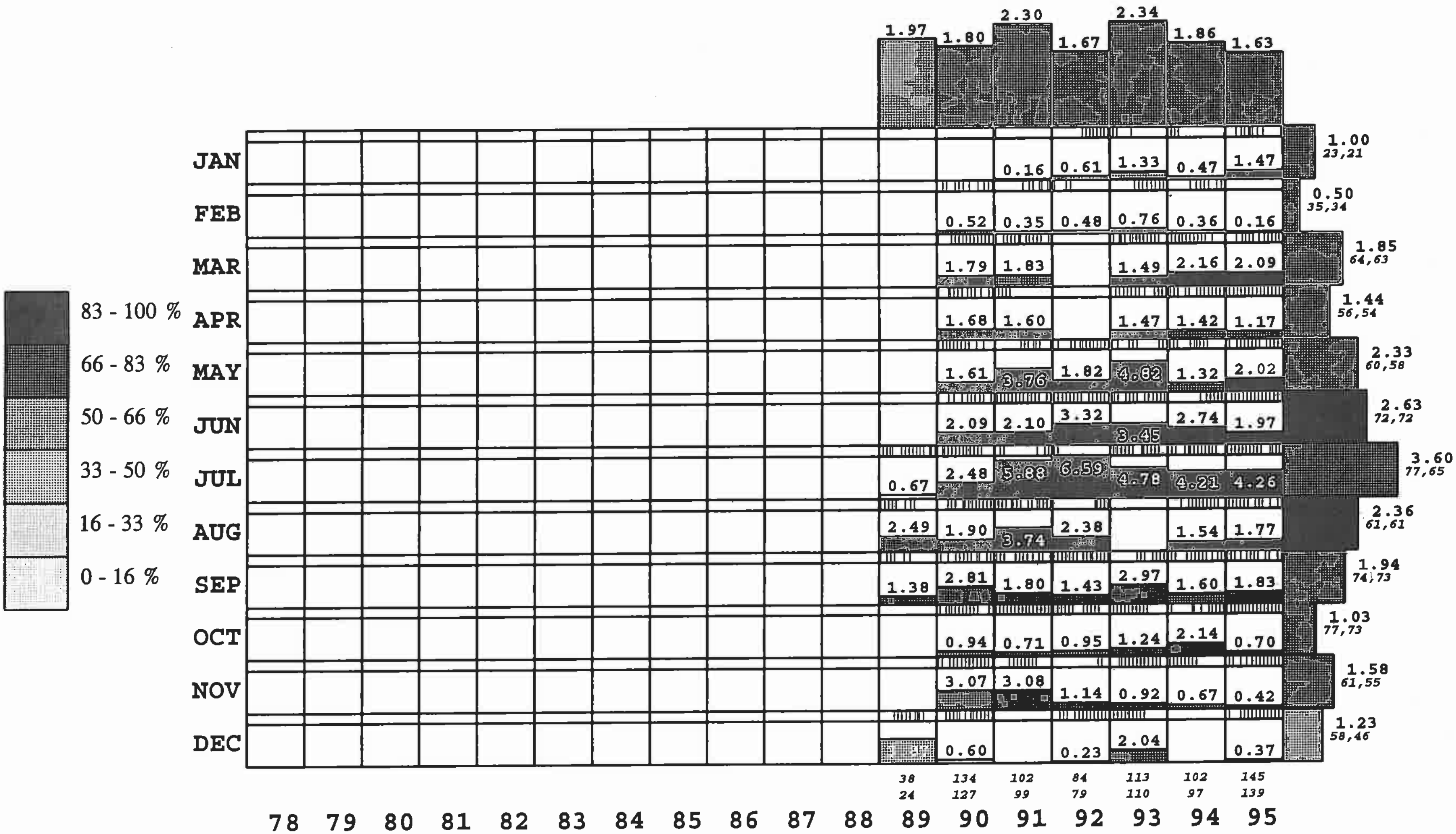


Figure 31 Box diagram of monthly and yearly means for BEVERAGE CANS. (n =848)
TOTAL = 20,577; TIMES SEEN 811 (95.6 %); MAX 77.16 per/km; AVERAGE WHEN SEEN 2.15 per/km

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

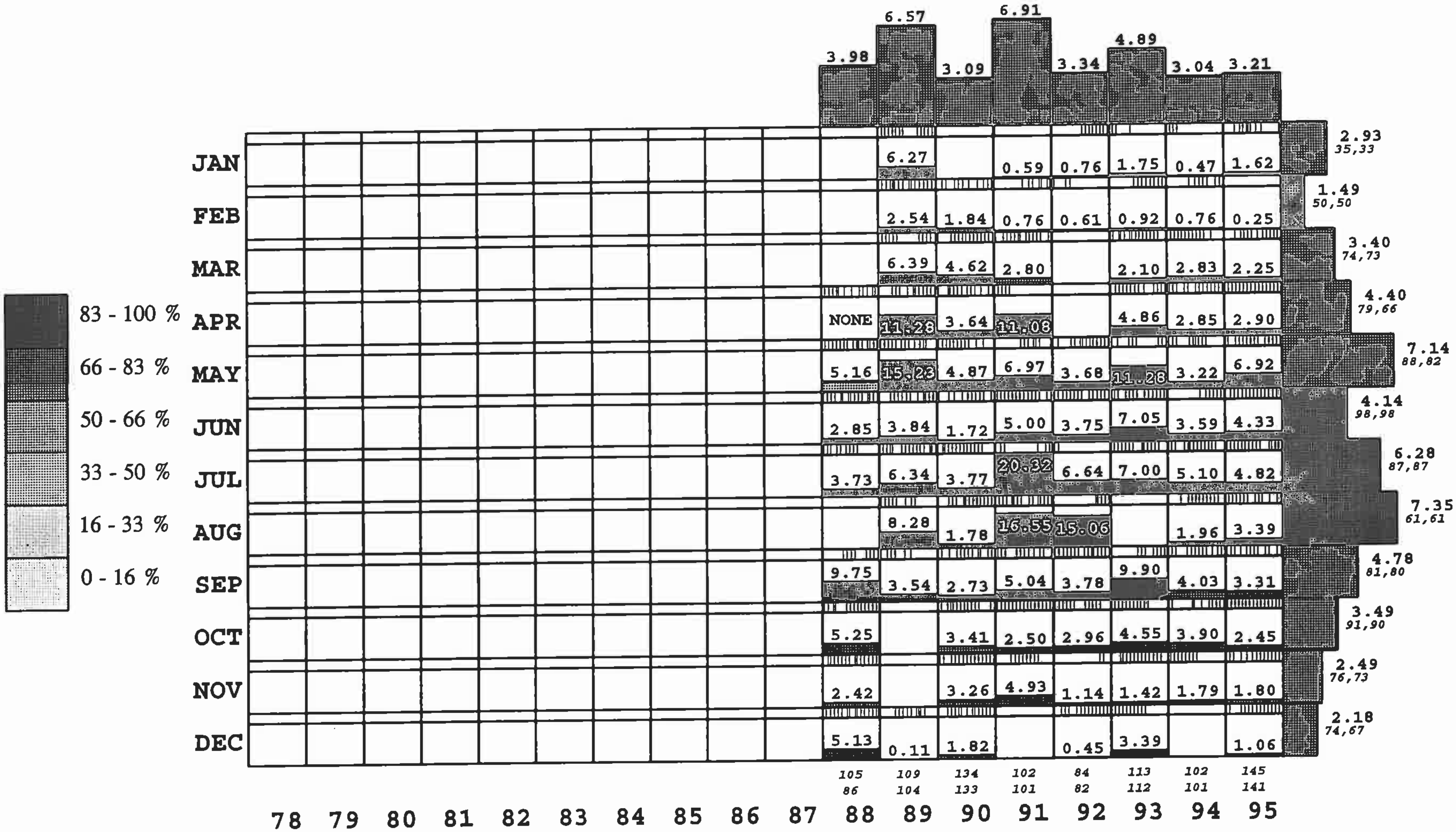


Figure 32 Box diagram of monthly and yearly means for TOTAL # GARBAGE ITEMS. (n =1,015)
TOTAL = 52,920; TIMES SEEN 1,001 (98.6 %); MAX 77.92 per/km; AVERAGE WHEN SEEN 4.48 per/km

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

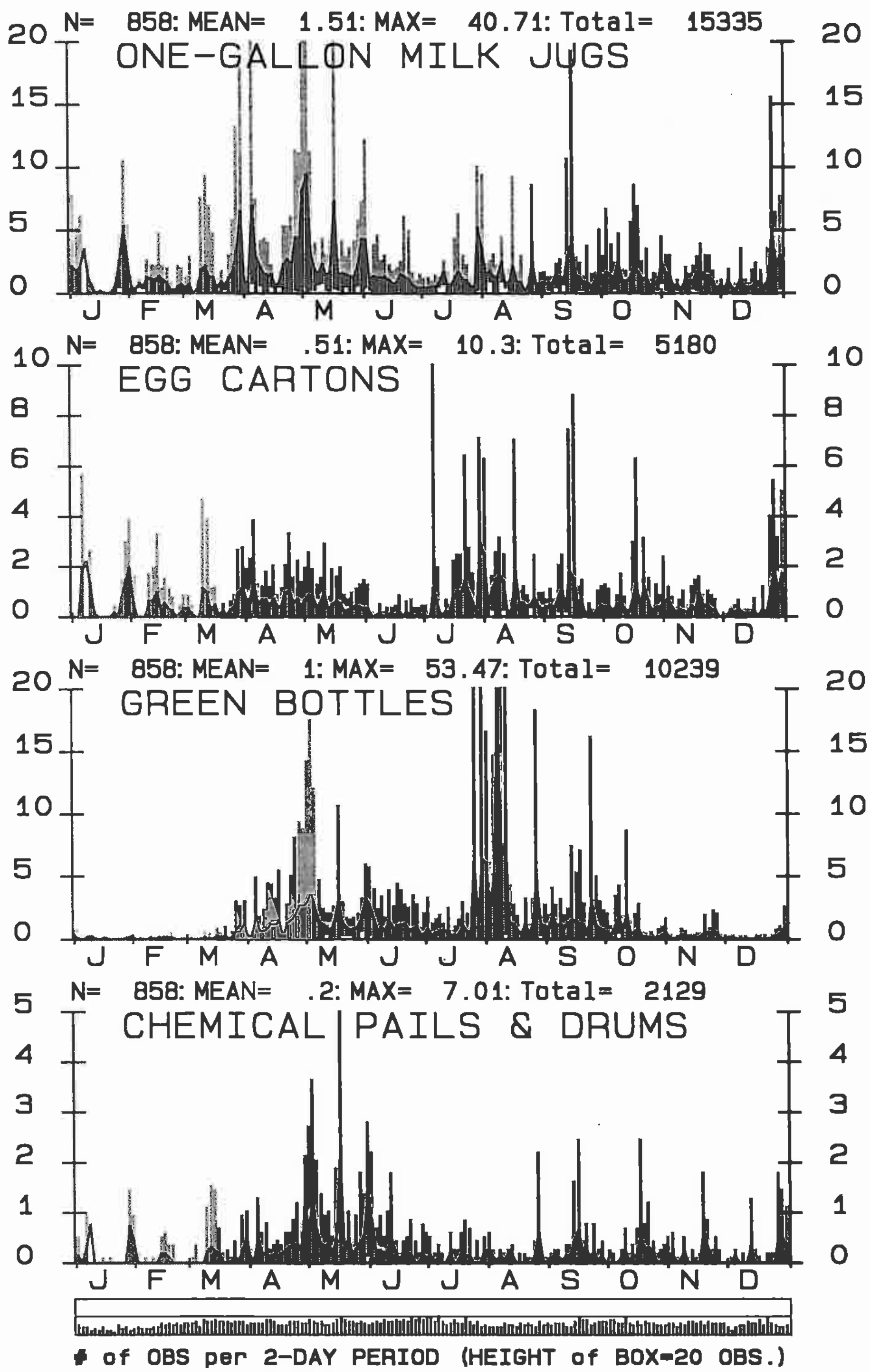


Figure 33. Yearly distribution of targeted items (per/km) averaged bi-daily on Mustang Island gulf beach, 1988-1995. Mean is division between dark & light shading. Short vertical bars = number of obs.

February because of the first author's absences at that time of year. The spikiness of the data is readily apparent from the figure; indeed, to avoid reducing the mean to an unreadably low level on the diagram, some of the spikes have been truncated. Note that the number of surveys, N, in this diagram is 858 rather than 870 for the previous figures, hence the means and extrema are slightly different. Peaks in milk jugs (top panel) are most prominent in the spring, while egg cartons (second from top) peak in late summer. This is mysterious because it is generally assumed that these items come from the galley waste of shrimp boats and long liners. They constitute what the first author calls "the breakfast syndrome." The majority are Texas or Louisiana supermarket brands. Why fishermen would favor eggs in summer is not obvious. Green bottles (third from top) have large peaks in July and August, as well as in the spring. This pattern could be because Mexican shrimpers trawl near the U.S. EEZ (Economic Exclusion Zone) after mid-July to take advantage of the effects that closure has on the shrimp stock. Closure is the legal ban on shrimping for a 45-day period from late May to early July to allow juvenile brown shrimp to complete their migration across the continental shelf [3]. Chemical containers (bottom panel) peak in April and May and show no late summer increase. All these items show a minimum in mid-summer. The consensus is that items identified as originating from the shrimp fleet decrease during closure and increase dramatically when closure ends in July. Casual observation lends credence to this idea, but the counts do not always support the premise. As with most aspects of marine debris, measurement does not often confirm hypothesis. The PINS surveys have been designed specifically to pinpoint offshore sources of debris. This will be discussed in the next results section (**4.2.3 PINS Data**).

To see if a link can be forged between the beachgoer-debris and the usage of the beach, we compare (Fig. 34) the annual distribution of beverage cans with that of visitors to the beach at the time of the surveys. In the top panel, beverage can peaks seemingly follow the popular holidays on the beach: Spring Break, Memorial Day, Fourth of July, and Labor Day. The large peaks in November and December are due to "ancient beer cans" washed ashore during low-tide periods (see above). Interestingly, these same peaks are not so obvious in the people counts. This is probably due to the phase lag between the holiday peak of people and the "day after" when the cans are left but the people have gone.

We now look at the less-rigorous estimates made during the UTMSI surveys to see if the summer lull can be seen over the 12-year span of that effort. Figure 35(a,b) compares four items, using a 0-5 rank-scale established by the first author in an attempt to track when several items of debris, both natural and man-made, are present on the beach. The summer minimum is evident in the yearly means of milk jugs, green bottles, and chemical drums (top 3 panels of Fig. 35a). It is not evident in the beverage can estimates (bottom panel). Most of the summer means are based on at least 15 observations for each interval (see box at bottom of diagram).

---

[3] The authors believe that the preponderance of bleach bottles over any other Mexican domestic garbage is because bleach is used by shrimpers to treat their catch for the condition known as "brown (or black) spot". U.S. shrimpers use sodium metabisulfite for that purpose; 6-gallon containers of that chemical are also found as debris on gulf beaches.

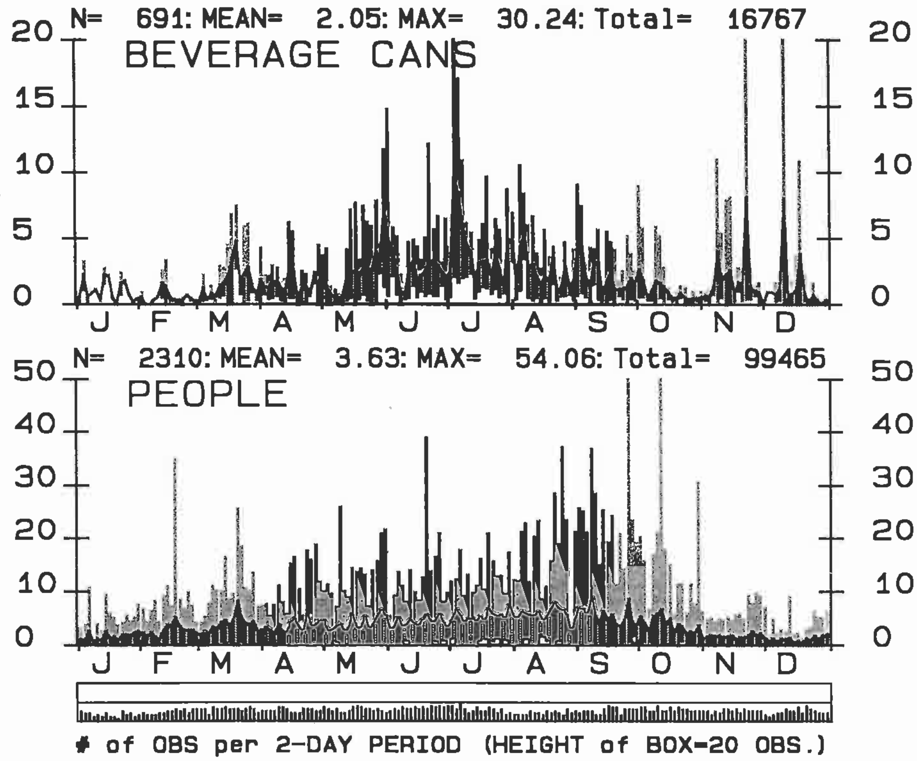


Figure 34. Yearly distribution of targeted items (per/km) averaged bi-daily on Mustang Island gulf beach, 1988-1995. Mean is division between dark & light shading. Short vertical bars = number of obs.

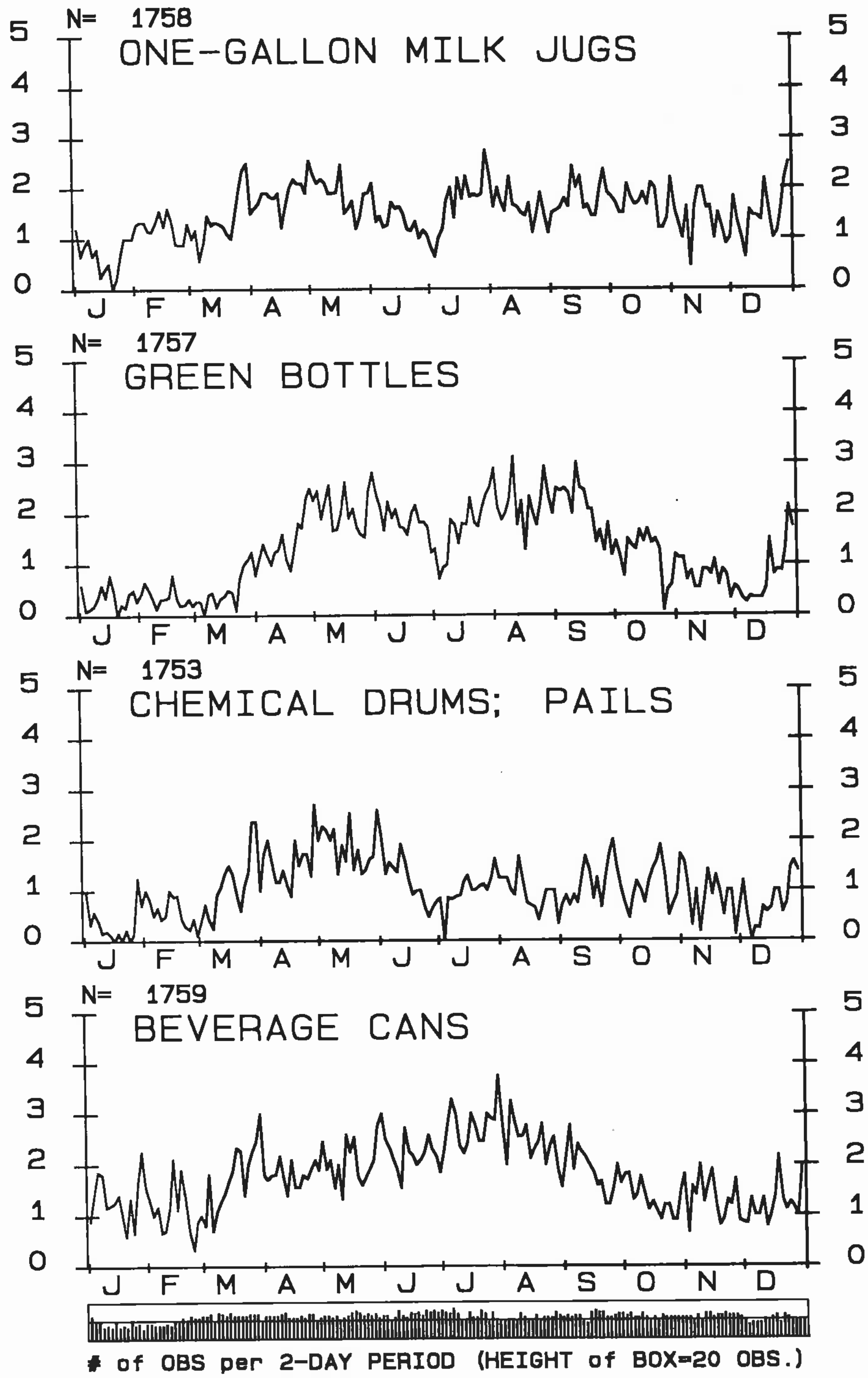


Figure 35a Yearly estimates of four items of debris averaged bi-daily on Mustang Island gulf beach, 1983-1995. Short vertical bars = number of obs.

In Figure 35b, general household garbage and light bulbs both show the summer minimum, *Sargassum* weed does not, but driftwood does have a distinct minimum at the end of June. Driftwood here describes all large woody debris, including lumber, pallets, trees, and dunnage. Much of this material has its origins in man's activities such as the clearing of brush.

4.2.2.4 Trends

What can be derived from these data about trends in these five key items over the past eight years? We performed linear and higher-order regressions on the targeted-item data, but the fit of regression lines with time is generally poor with low correlation coefficients. This is due to the high degree of variance in the raw data. Smoothing by averaging to monthly means improves the results somewhat, but at the request of the reviewers, we have omitted regression lines from our data graphs. In Figures 36 through 41 we show the monthly and yearly means of the four items: milk jugs, egg cartons, green bleach bottles from Mexico, chemical pails, and beverage cans. Each of the diagrams has thirteen bar-graph panels, one for each month and one which shows the yearly means. The X-axis is years from 1988 through 1995, with the mean of **all** years on the right. To aid in comparison, the same vertical scale is used for each month, except for the thirteenth graph labeled "ALL", which is the mean of each year and hence will have overall lower values. Statistical information is shown to the right of each panel. Listed are the **n**umber of observations, the **Tot**als, **Max**ima, and **Mean**s. Values are numbers counted per kilometer over the 11.83-km survey transect (occasional surveys did not go the full distance, but the totals are given for the whole survey distance, hence there may be slight differences between these totals and those shown in previous figures). Where no surveys were made on a particular month, an "n" appears in place of a bar.

We include here a table (Table 7) showing statistics on the five targeted items. The coefficient of variation (CV) is the standard deviation divided by the mean. It is a measure of the variance in any one item and is used by the Marine Debris Monitoring Program (CMC, 1996) in the establishment of methods for a National Monitoring Program. The higher the number, the greater is the variance compared to the mean. A CV of 1.0 shows that the item might vary by up to twice the mean, while 0.1 indicates a small variability in the distribution of the item with time. The CVs are calculated from the entire data set. All items have a high CV, indicating the high degree of departures from the mean, and all have insignificant linear correlation. We include survey start time to illustrate a low CV. There is some variation here as surveys are started at dawn which, of course, changes throughout the year.

The trends in all items except beverage cans shows that less marine debris is present now on Mustang Island gulf beach at the start of the project. As stated previously, the recent data may be biased by irregular, but often intense, beach cleaning and scraping efforts by municipal and county beach management programs. The UTMSI surveys start early in the morning before cleaning starts and when debris deposited overnight is still on the beach. Yet it is undeniable that the cleaning affects surveys which must be regarded as a standing stock evaluation rather than a rigorous trend assessing study. Cleaning efforts vary enormously.

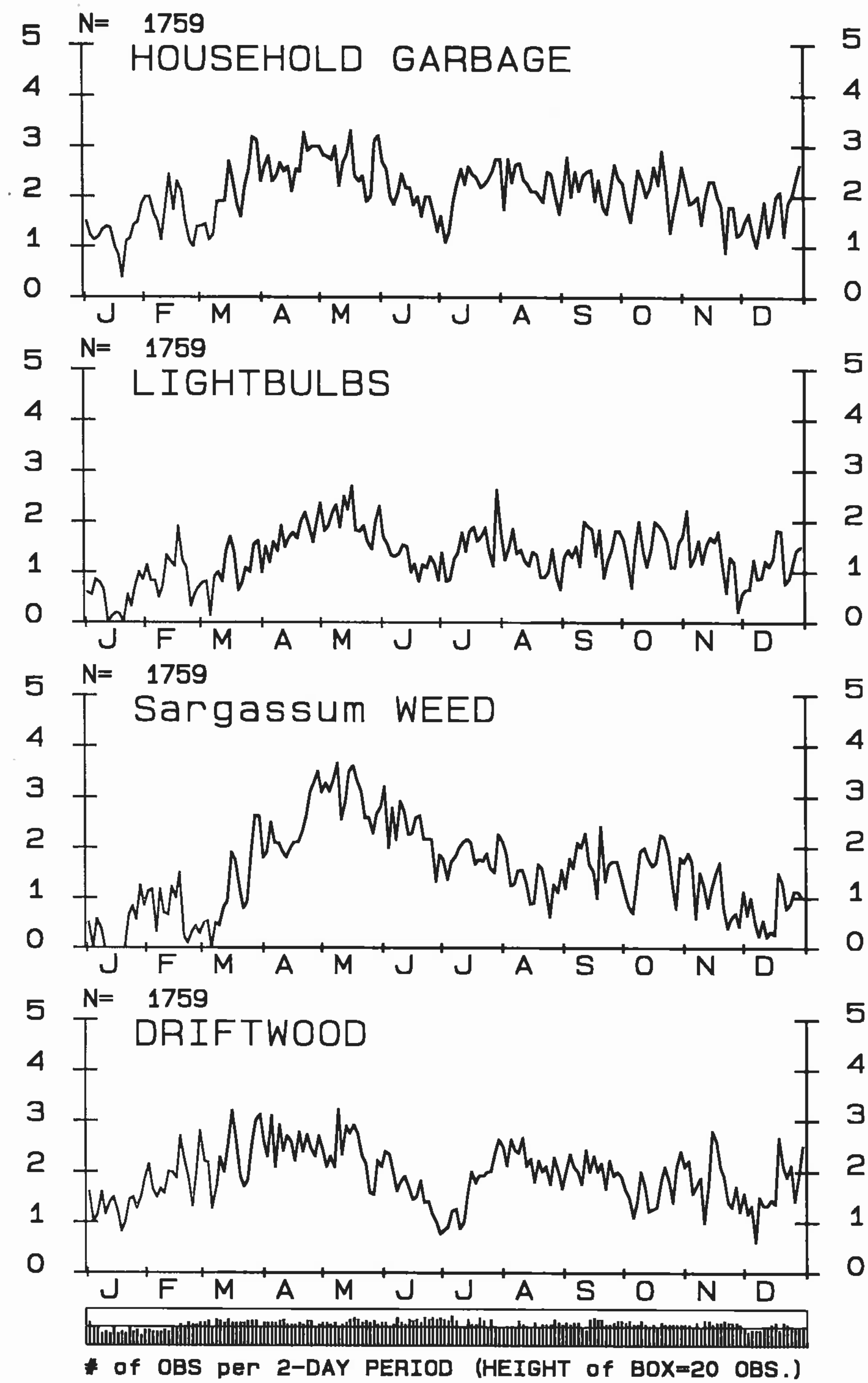


Figure 35b Yearly estimates of four items of debris averaged bi-daily on Mustang Island gulf beach, 1983-1995. Short vertical bars = number of obs.

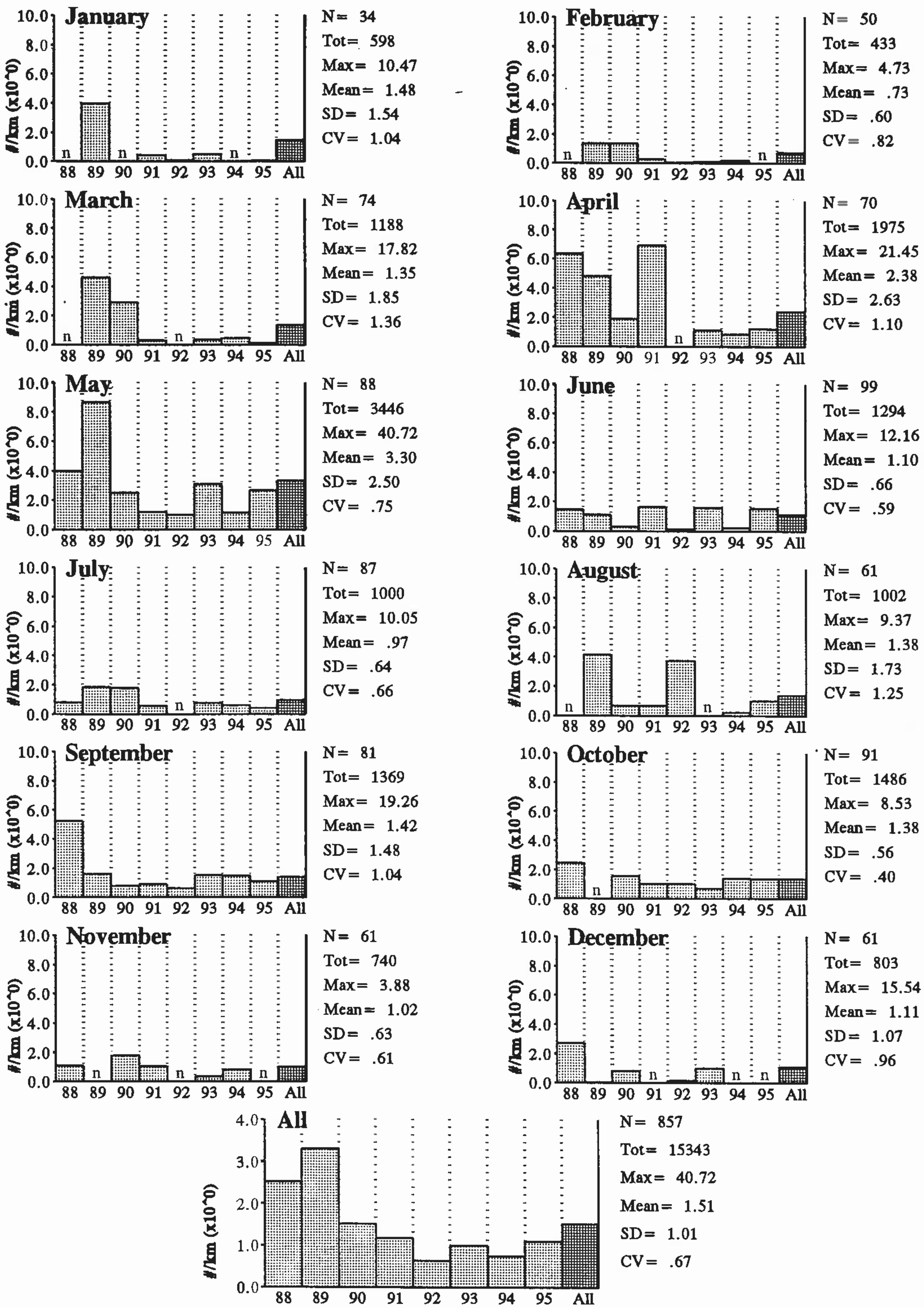


Figure 36 UTMSI Targeted item data; ONE-GALLON MILK JUGS
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max= Maximum (per km) in any one survey
Mean = Overall mean (per km). SD=Standard Deviation. CV = Coefficient of Variance

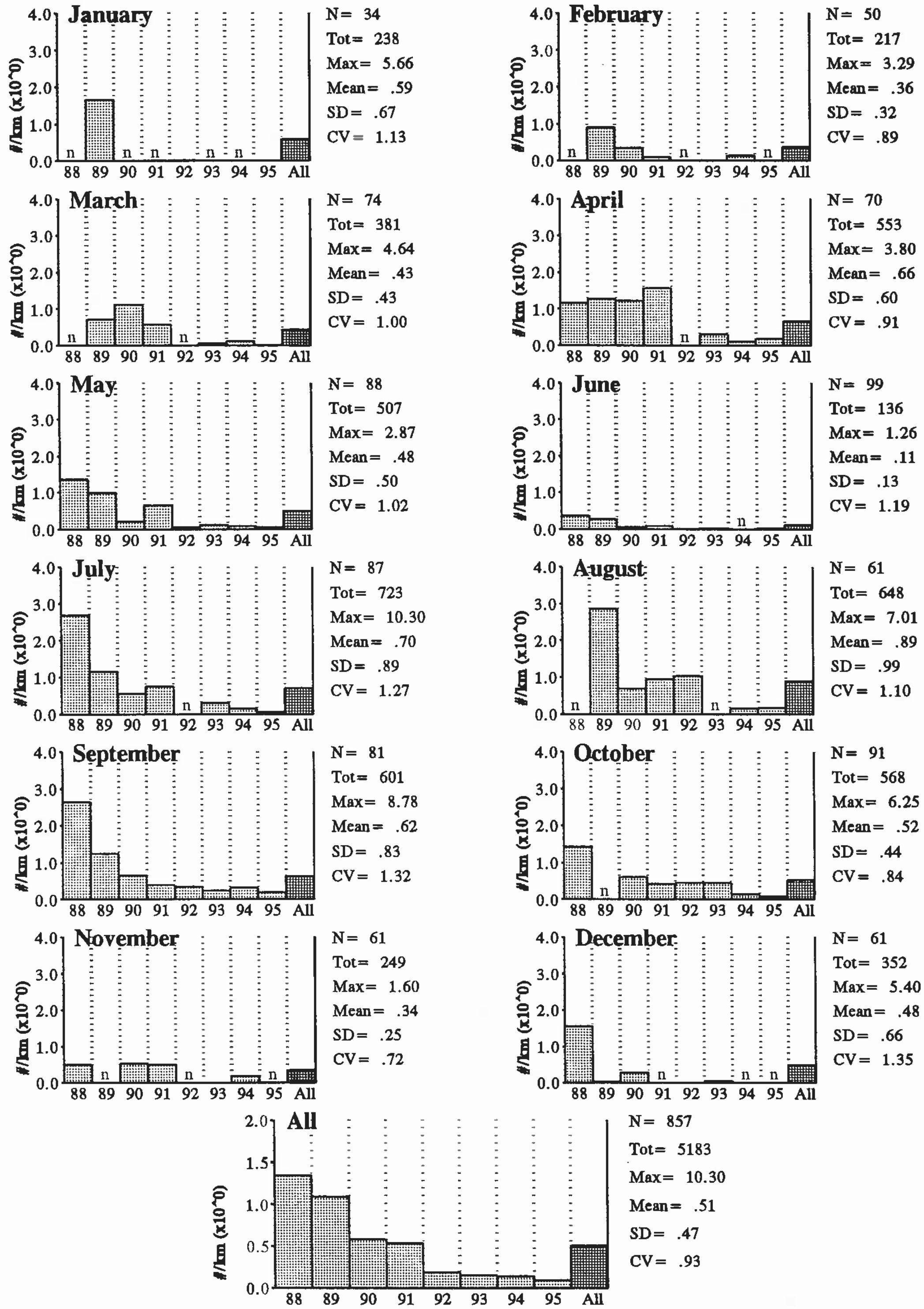


Figure 37 UTMSI targeted item data; EGG CARTONS
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max= Maximum (per km) in any one survey
Mean = Overall mean (per km). SD=Standard Deviation. CV = Coefficient of Variance

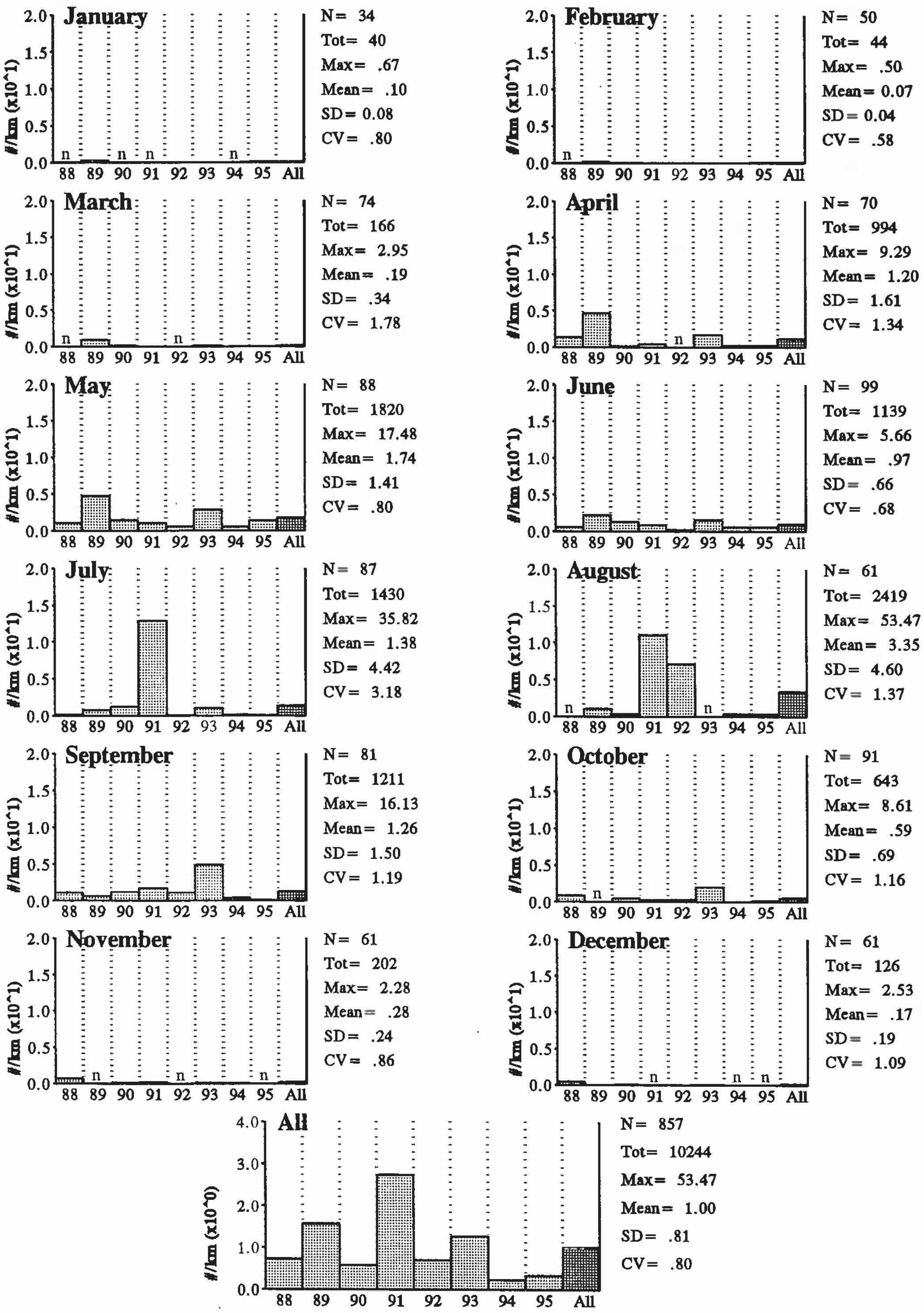


Figure 38 UTMSI targeted item data; GREEN BOTTLES
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max= Maximum (per km) in any one survey
Mean = Overall mean (per km). SD=Standard Deviation. CV = Coefficient of Variance

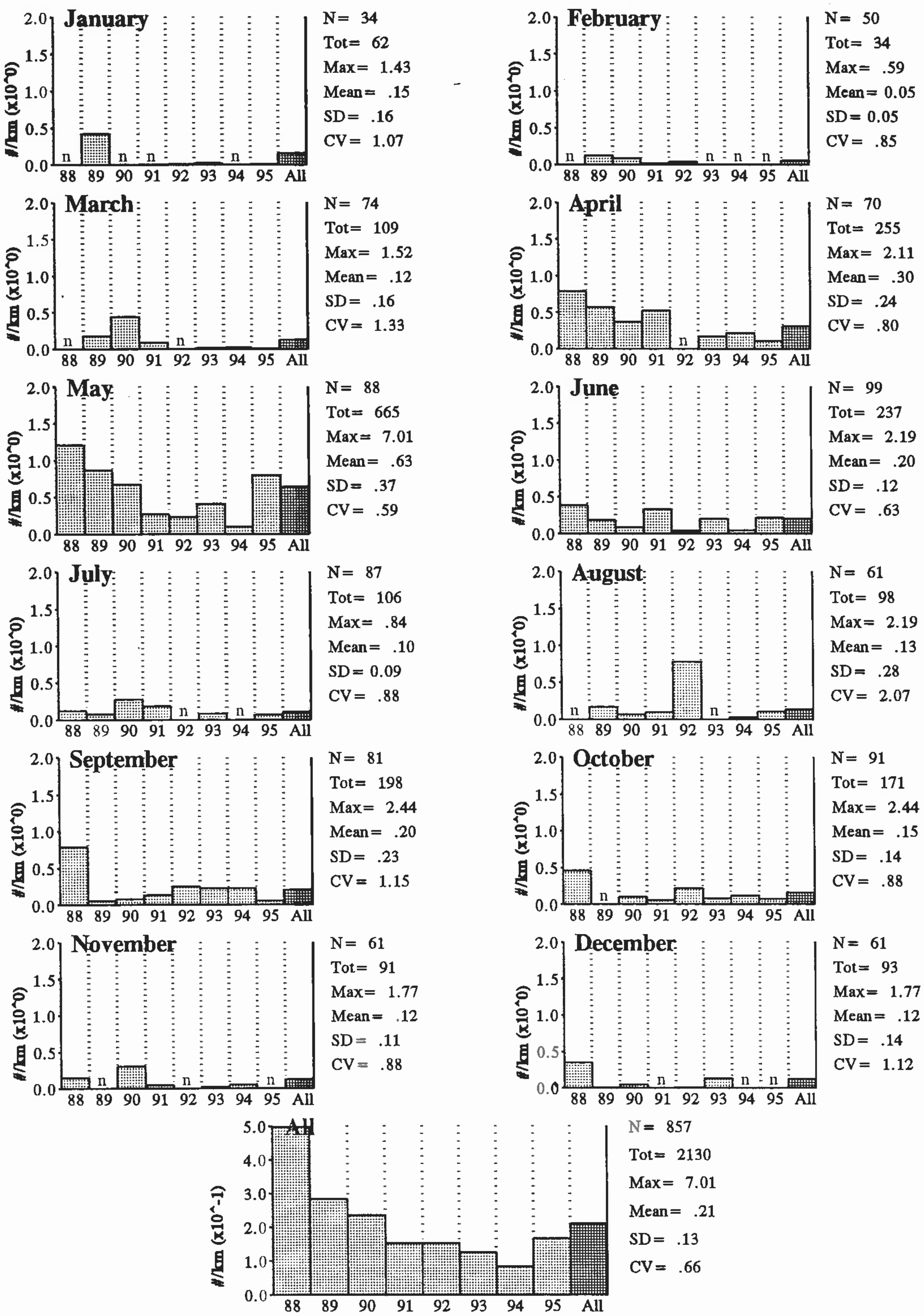


Figure 39 UTMSI Targeted item data; CHEMICAL PAILS & DRUMS
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max= Maximum (per km) in any one survey
Mean = Overall mean (per km). SD=Standard Deviation. CV = Coefficient of Variance

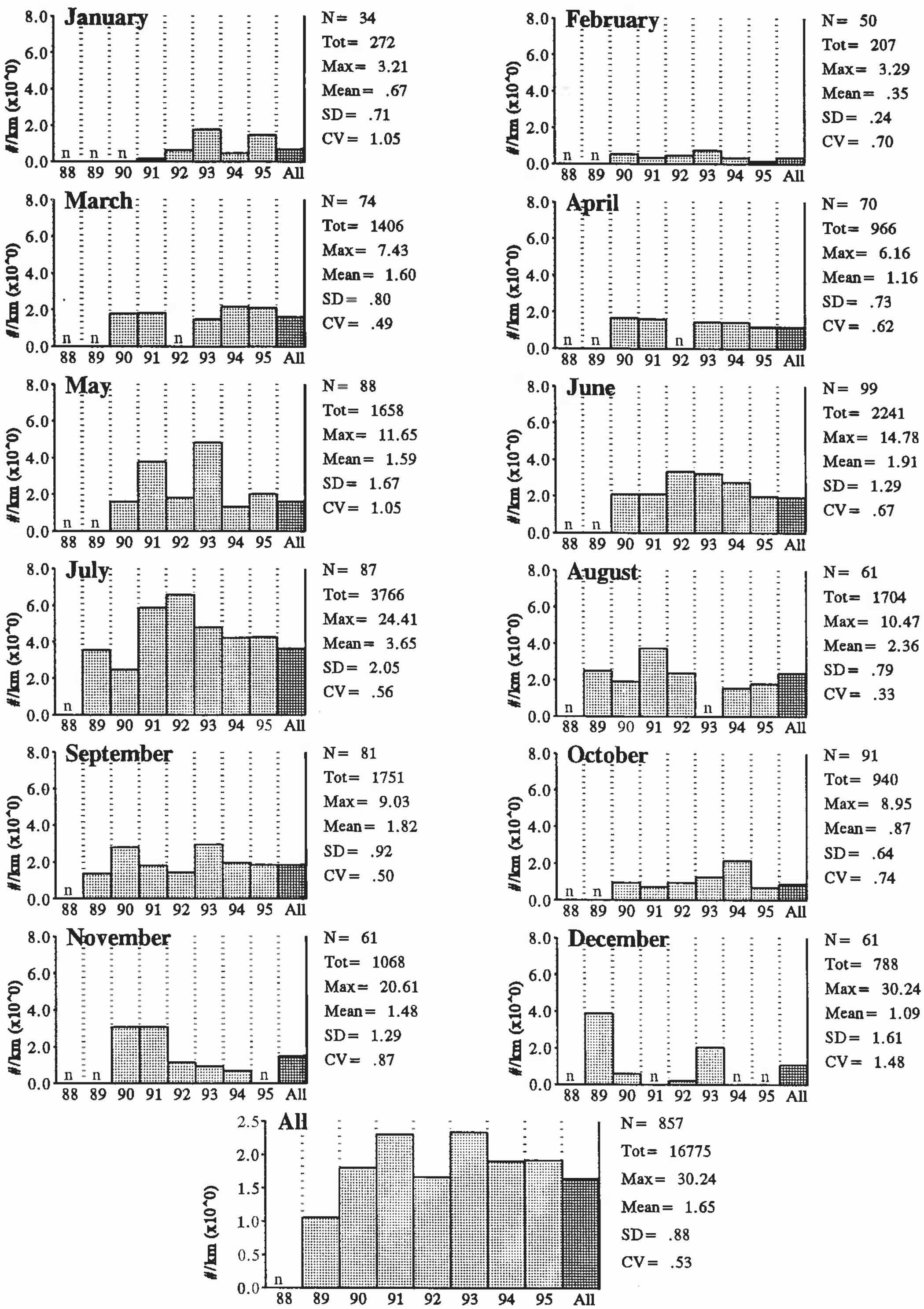


Figure 40 UTMSI Targeted item data; BEVERAGE CANS
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max= Maximum (per km) in any one survey
Mean = Overall mean (per km). SD=Standard Deviation. CV = Coefficient of Variance

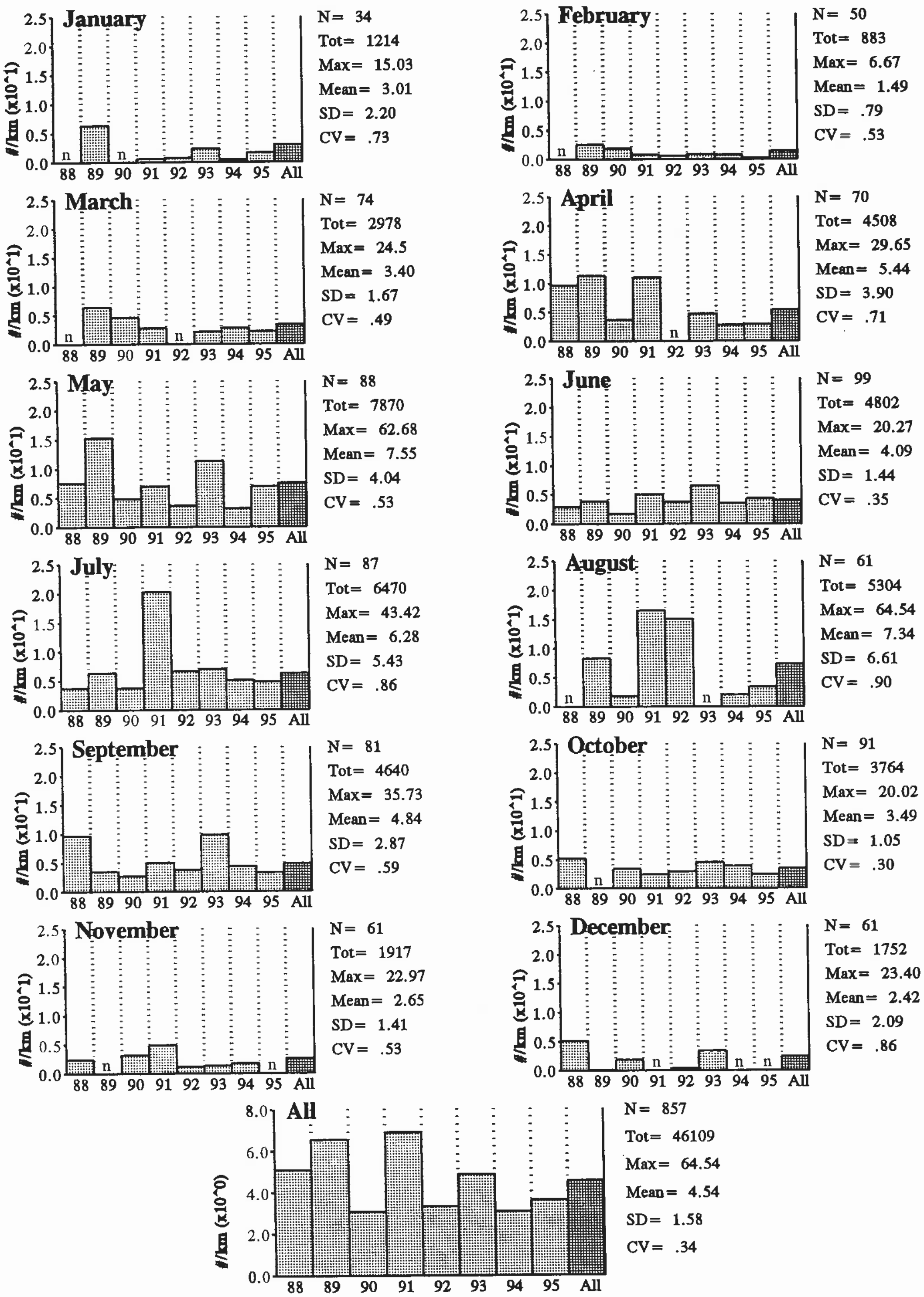


Figure 41 UTMSI Targeted item data; TOTAL # GARBAGE ITEMS
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max= Maximum (per km) in any one survey
Mean = Overall mean (per km). SD=Standard Deviation. CV = Coefficient of Variance

Examples of observed municipal beach-cleaning operations:-

- One man in a pickup truck leaning out of the window as he drives, spearing trash.
- A beach rake scraping the areas in front of the condominiums of weed, debris, and litter.
- A busload of prisoners, up to 20 people, fanned out over the width of the beach walking and picking trash as they go. Sometimes starting at the south end of the survey transect heading north, other times starting half-way at the County line.
- Citizens doing civic duty collecting trash on their morning strolls.
- Days or weeks go by with no cleaning effort.
- The beach is cleaned when there is nothing to clean.

Table 7. Coefficients of variation for the targeted items used in the UTMSI study analysis

ITEM	N	r^2	SD	CV
MILK JUG	857	0.05	3.04	2.01
EGG CARTON	857	0.16	1.01	1.98
GREEN BOTTLE	857	0.01	3.24	3.21
BEVERAGE CAN	690	0.00	2.76	1.34
CHEMICAL PAIL	857	0.04	0.51	2.44
PEOPLE	2309	0.17	4.54	1.25
START TIME	2379	0.02	1.53	0.22

N = Overall number of surveys when the item was counted.
All units are counts per kilometer, except start time which is in hours, and CV which is dimensionless.

Despite these difficulties, we conclude that a diminishing trend is evident for these five items and, indeed, for most items of marine debris on the Gulf side of Mustang Island.

4.2.2.5 Marine Debris and MARPOL

In 1987, we started a survey based upon the regular beach survey, but counting debris items at an interval of eight days. The MARPOL Annex V agreement (NRC, 1995) was due to be ratified and an attempt was made to do a pre-MARPOL baseline study of marine debris on Mustang Island gulf beach. The methods have been described above in the **Methods** section (4.1.2). The surveys were abandoned in 1990, but revived in 1991 and 1992 as a post-MARPOL survey, with financial support from the U.S. Minerals Management Service. Our general conclusions were that marine debris on the gulf beaches had declined, but we could not link that decline with the MARPOL prohibitions on discharging plastic and other garbage at sea (Amos, 1993a). For this present report, we re-examined some of the data (Figs. 42-44). The data were plotted as monthly means for each of the 61 items counted, of which typical items are analyzed here. The form of the diagrams is the same as for Figures 36-41, except that the X-axis is years from 1987 through 1992, but not including 1990. Table 8 lists the CV for all the data points used in the analysis. The CVs in the MARPOL study are somewhat less than those in the ongoing targeted-item study. We included an item of natural debris, driftwood, and the start time for comparison of CV values.

Table 8. Coefficients of variation for selected items in the UTMSI MARPOL study analysis.

ITEM	N	r^2	SD	CV
MILK JUG	174	0.03	4.98	1.76
EGG CARTON	174	0.07	2.84	1.22
GREEN BOTTLE	174	0.00	3.55	1.84
BEVERAGE CAN	174	0.00	4.13	1.02
CHEMICAL PAIL	174	0.03	0.76	1.97
PEOPLE	174	0.08	11.35	1.35
DRIFTWOOD	174	0.00	38.58	2.38
START TIME	174	0.04	1.65	0.19

N = Overall number of surveys when the item was counted. All units are counts per kilometer, except start time which is in hours, and CV which is dimensionless.

Included here are five special study surveys which were not used in the overall statistical analysis in this report. Figures 42 through 44 show the monthly and yearly mean counts of three items (milk jugs, beverage cans, and chemical pails), the same items used in the analysis of the CMC volunteer beach cleaning data (next section). **Milk jugs** (Fig. 42) declined in all months and overall. 1988 and 1989 were big milk jug years. A total of 3,879 jugs were counted[4], giving a mean density of 2.69/km. Milk jugs were found on 90.2% of the surveys. **Beverage cans** (Fig. 43) declined in all months except August and October. CVs were relatively low during the summer months compared to the other items presented here indicating a more steady source. 6,399 cans were counted with a mean density of 4.04/km and a maximum of 34.76/km; they were found 100% of the time. The beverage can is a permanent item of beach litter! The 5-gallon **chemical pail** (Fig. 44) has its source primarily in offshore oil and gas and its service industries. Pails, containing motor oils and some other chemicals, also come from the commercial fishing fleet. In the MARPOL study we also included carboys, but not 55-gallon drums. There has no doubt been a decline in the number of these items washing ashore on Mustang Island. Figure 44 shows a decline in all months

[4] These were the actual number counted. Totals given in the figures are for the full survey distance of 11.83km. For part of 1988 and 1989, we ran the MARPOL study without funding and had to cut down on the time spent on the project, hence the full distance was not always covered. In 1991 and 1992, we resumed the full transect counts. The numbers given in the text are about 77% of those in the diagrams which are for the full survey distance. The density per kilometer is not based on any extrapolation.

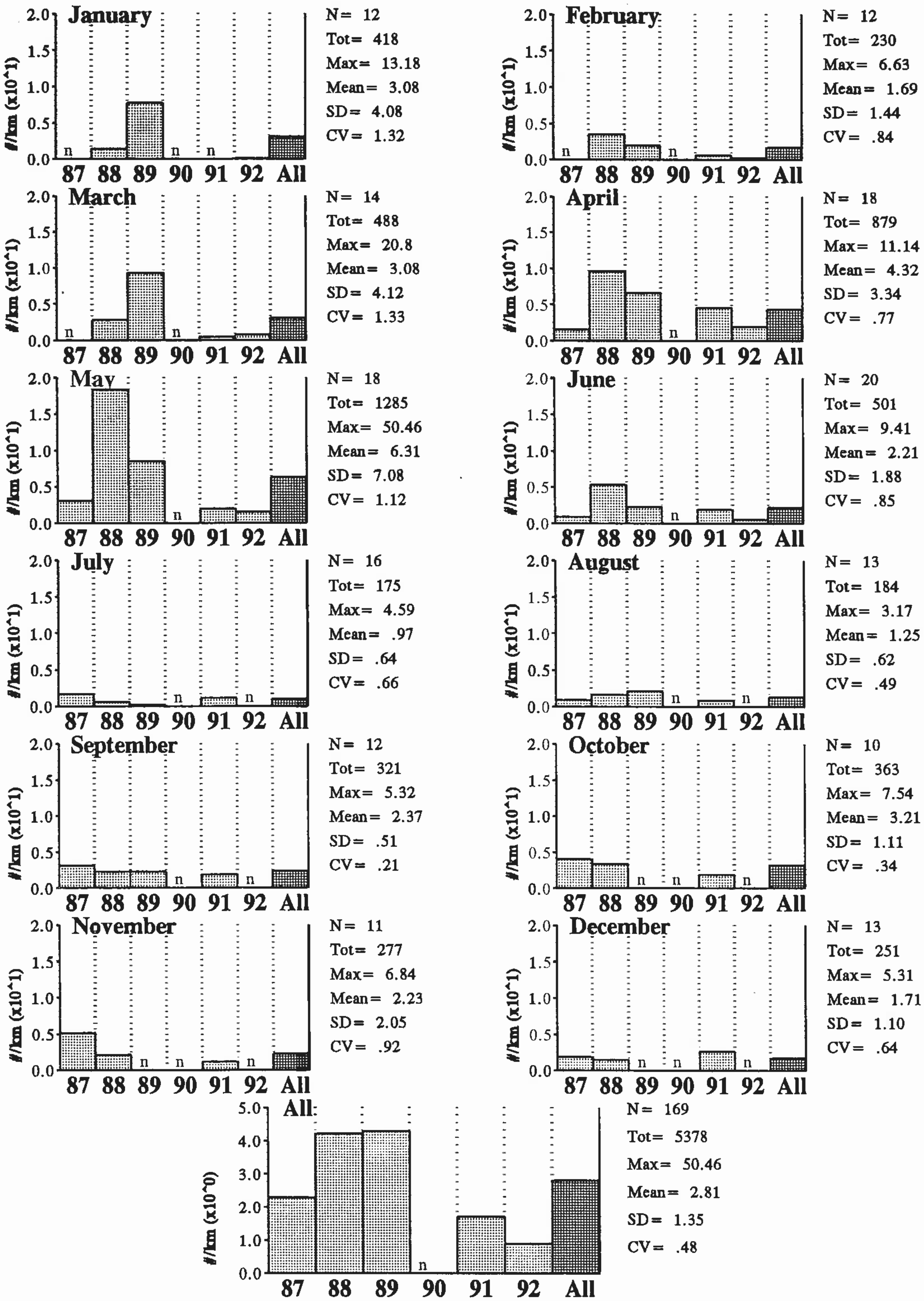


Figure 42 MARPOL Study; Density (#/km) of ONE-GALLON MILK JUGS
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max = Maximum (per km) in any one survey
Mean = Ovearall mean (per/km). SD = Standard Deviation. CV = Coefficient of Variance

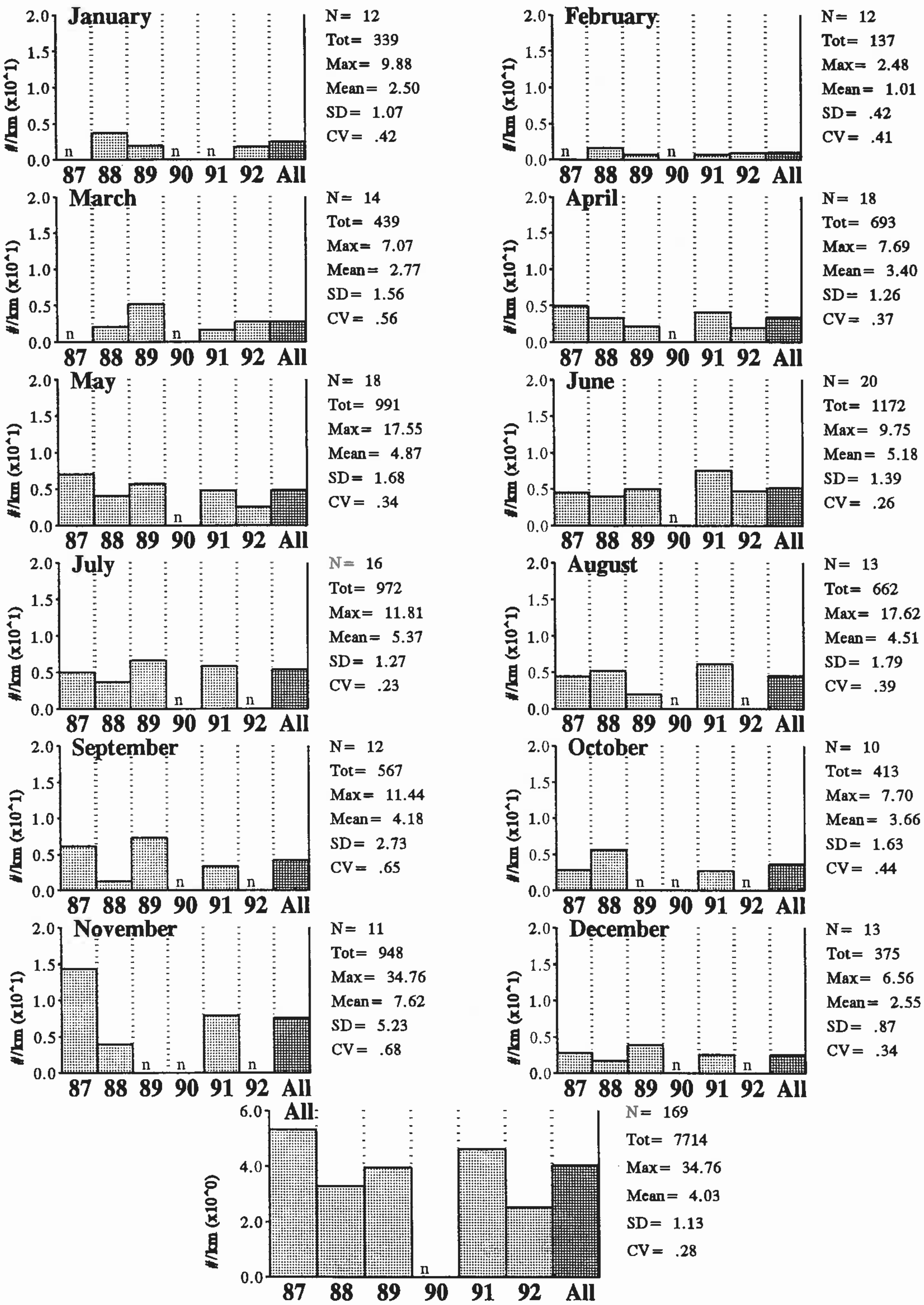


Figure 43 MARPOL Study; Density (#/km) of ALUMINUM BEVERAGE CANS
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max = Maximum (per km) in any one survey
Mean = Ovearall mean (per/km). SD = Standard Deviation. CV = Coefficient of Variance

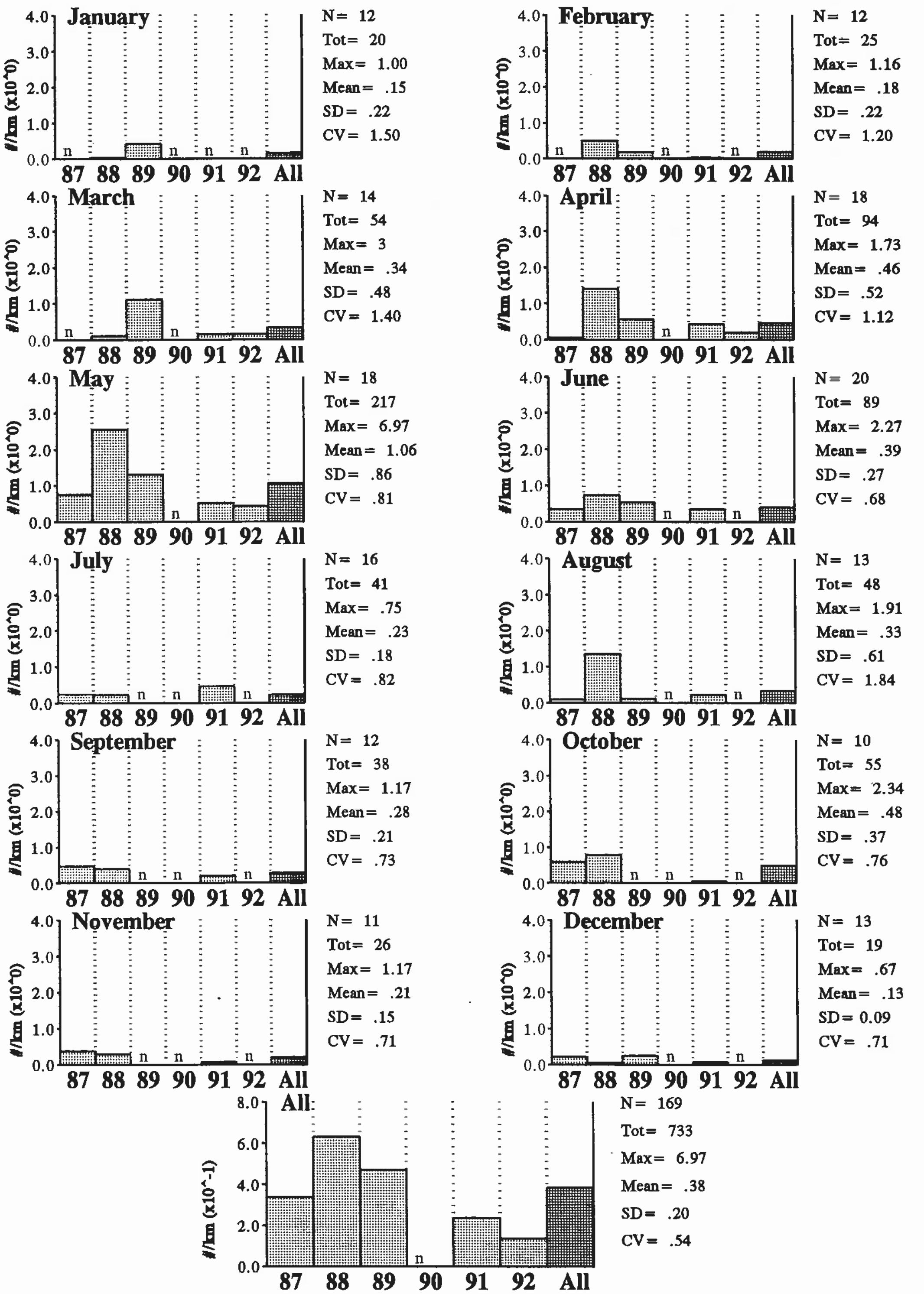


Figure 44 MARPOL Study; Density (#/km) of 5-GAL PLASTIC PAILS
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max = Maximum (per km) in any one survey
Mean = Ovearall mean (per/km). SD = Standard Deviation. CV = Coefficient of Variance

except September. The total counted in the study was 524 with a mean density of 0.38/km and a maximum of 6.93/km. They were found on 60.3% of the surveys.

In Amos (1993a), we discussed the differences between assessing marine debris by weight, volume, and number, but did not break the MARPOL count data into material categories. We will compare this with the CMC volunteer data in the previous section. The items used in each material category are listed in Table 9. Compare with the items used by CMC, Table 3.

Thirty items were totaled to make the **plastic** category (Fig. 45). Some items, such as cigarette lighters, are made of a composition of materials but are included under plastics, following the CMC categories. Gloves (used on shrimp boats) are included in plastics although in the CMC data sheet they are under rubber. It is a moot point whether the material is plastic or rubber. We do not include a rubber category here. Plastics declined in all months except December. The CV numbers are generally high. A total of 231,040 items were actually counted with a mean density of 149.0/km and a maximum of 1180.0/km.

Three items were totaled to make up the **glass** category (glass bottles, light bulbs, and fluorescent tubes). Glass material (Fig. 46) decreased overall and in all months except June and December. Glass containers are prohibited on the study beach, although this law is often ignored. The great majority of the 9,591 glass items were galley waste containers. The mean density was 6.46/km with a maximum of 39.72/km.

Eight items make up the **metal** category (Fig. 47), of which beverage cans make up about 70% of the total. Metal declined in all months except June, July, and December. As with the counts done on beverage cans in the targeted item surveys, CVs are low throughout. There is a steady supply of beer cans to the beach. Actual total counted was 9,591 with a mean density of 5.98/km and a maximum of 34.74/km.

Five **paper** items were totaled (Fig. 48), of which paper cups and miscellaneous paper products dominate. July, August, and September totals increase throughout the study while May totals are level. Paper deceases in all other months and shows a very slight decrease over the six-year study period. A total of 13,087 paper items was counted. The mean density was 8.55/km and the maximum 104.7/km. The variability of paper on the beach is high.

Of the four items of **Wood** totaled (Fig. 49), the driftwood dominates. On occasion, driftwood is the major item of debris on the beach. Its composition, as defined in the MARPOL study, is varied and may include items which have not been dumped at sea but wash down rivers both to the north and to the south of the study area. Often, driftwood becomes waterlogged and accumulates in the troughs (the "gut") between the sandbars offshore from the study beach. It may then be deposited as part of the beach debris when tides are low but the tidal amplitude large, especially in the winter. We counted this material in the study. Driftwood counts diminished with time in all months except February and July. A total of 26,224 pieces of driftwood was counted. The mean density was 14.88/km with a maximum of 353.42/km.

Table 9. Items of debris used in the MARPOL study grouped by material composition. A four-letter code aids in computer processing of the data.

ITEMS MADE of PLASTIC		PLASTIC (cont)	
CODE	**DESCRIPTION**	**CODE**	**DESCRIPTION**
GLOV	GLOVES	LGHT	DISPOSABLE LIGHTERS
SHOE	SHOES		
CRAT	WOODEN CRATES	**ITEMS**	**MADE of GLASS**
TOYS	TOYS	GLAS	GLASS BOTTLES
LIDS	LIDS (PLASTIC)	FLOR	FLUORESCENT TUBES
HAWS	HAWSERS	BULB	LIGHT BULBS
STRP	PLASTIC STRAPPING		
BALO	BALLOONS	**ITEMS**	**MADE of METAL**
HARD	HARD-HATS	FCAN	FOOD CANS
EGGC	EGG CARTONS	OCAN	CANS (NOT BEVERAGE CANS)
STIK	LIGHT STICKS	BEVG	ALUMINUM BEVERAGE CANS
SACK	PRODUCE SACKS	METL	MISCELLANEOUS METAL PIECES
PBAG	PLASTIC BAGS	WIRE	WIRE AND CABLE
DIAP	DIAPERS	TABS	PULL TABS
SPAK	SIX-PACK RINGS	TRAP	CRAB AND OTHER TRAPS
PAIL	5-GAL PLASTIC PAILS	APPL	LARGE APPLIANCES
GBOT	GREEN BOTTLES (MEXICAN)		
MILK	ONE-GALLON MILK JUGS	**ITEMS**	**MADE of PAPER**
FOAM	FOAM (NOT STYROFOAM)	PAPR	PAPER PRODUCTS
STYR	STYROFOAM PIECES	CART	CARDBOARD CARTONS
RING	WRITE-PROTECT RINGS	CUPS	DISPOSABLE DRINK CUPS
PLAS	PLASTIC SHEETING	FIRE	SPENT FIREWORKS
LINE	FISHING LINE	NEWS	NEWSPAPERS; MAGAZINES
BAGS	PAPER BAGS		
NETS	FISHING NETS	**ITEMS**	**MADE of WOOD**
FLOT	FISHING AND SEISMIC FLOATS	BROO	BROOMS; BRUSHES
ROPE	ROPE AND HAWSERS	PALL	WOODEN PALLETS
PMSC	MISCELLANEOUS PLASTIC PCS.	DRFT	DRIFTWOOD
LUBE	TUBES OF GREASE	DUNG	DUNNAGE

Of the five material categories, plastic, metal, and paper were found 100% of the time, wood 99.4%, and glass, 94.4%. It should be pointed out that all items in this study were designated as "macro-trash" (Amos, 1993a), items big enough that they could easily be seen and counted from the slowly-moving survey vehicle. The MARPOL study also included an evaluation of the "micro-trash", small-to-minute items which were collected at three 10-m wide sites on the study beach. The entire swath of beach wrack was collected at these sites, including natural debris. The material was then sorted into 40 different categories and its components weighed. Small plastic pieces were found 100% of the time in 119 surveys, glass 42.2%, metal 47.4%, paper 39.7%, and wood 72.4%. It is instructive to look at the proportion of each material type as a percentage of all marine debris.

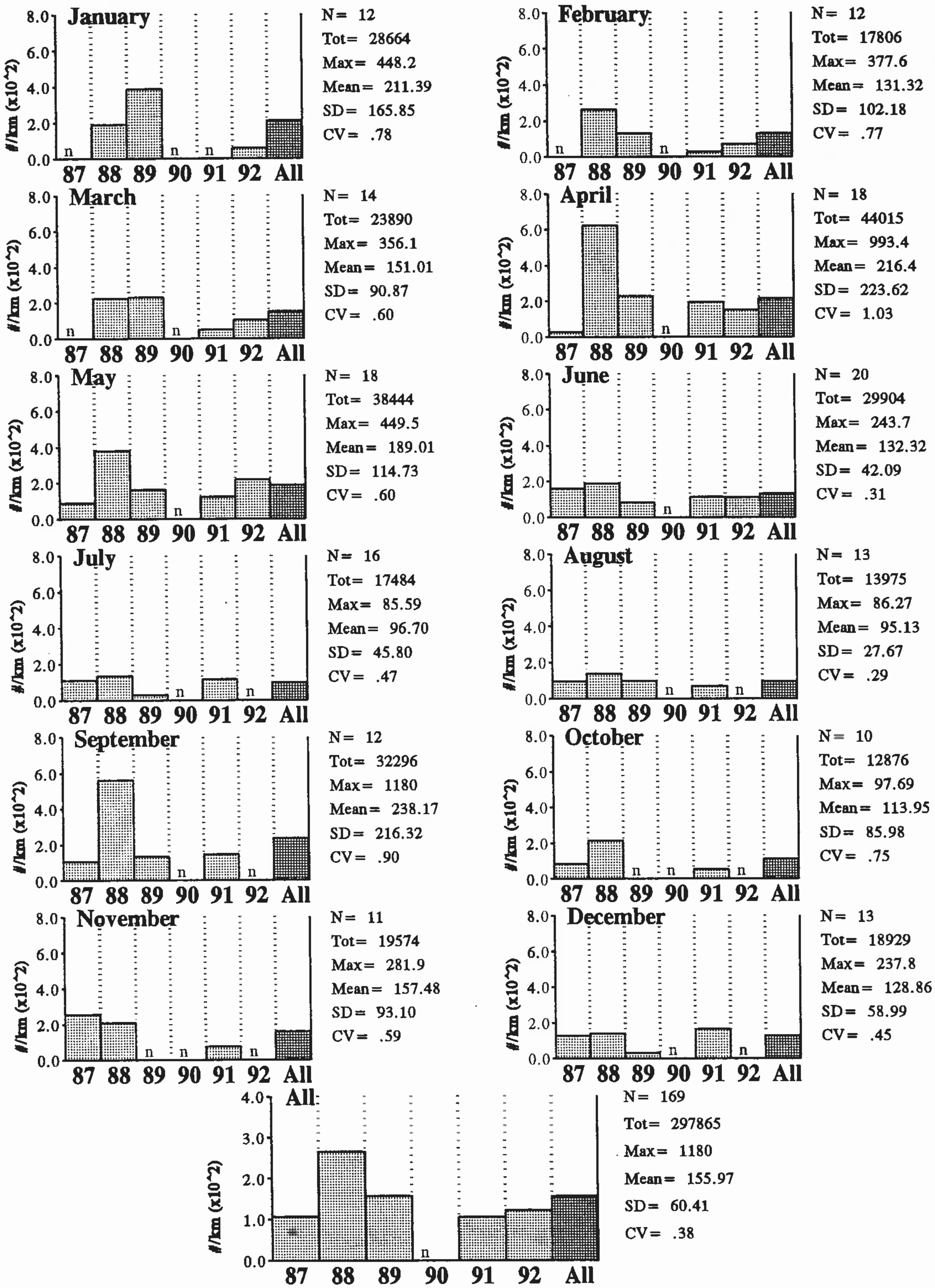


Figure 45 MARPOL Study; Density (#/km) of ALL PLASTIC MATERIAL
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max = Maximum (per km) in any one survey
Mean = Oevarall mean (per/km). SD = Standard Deviation. CV = Coefficient of Variance

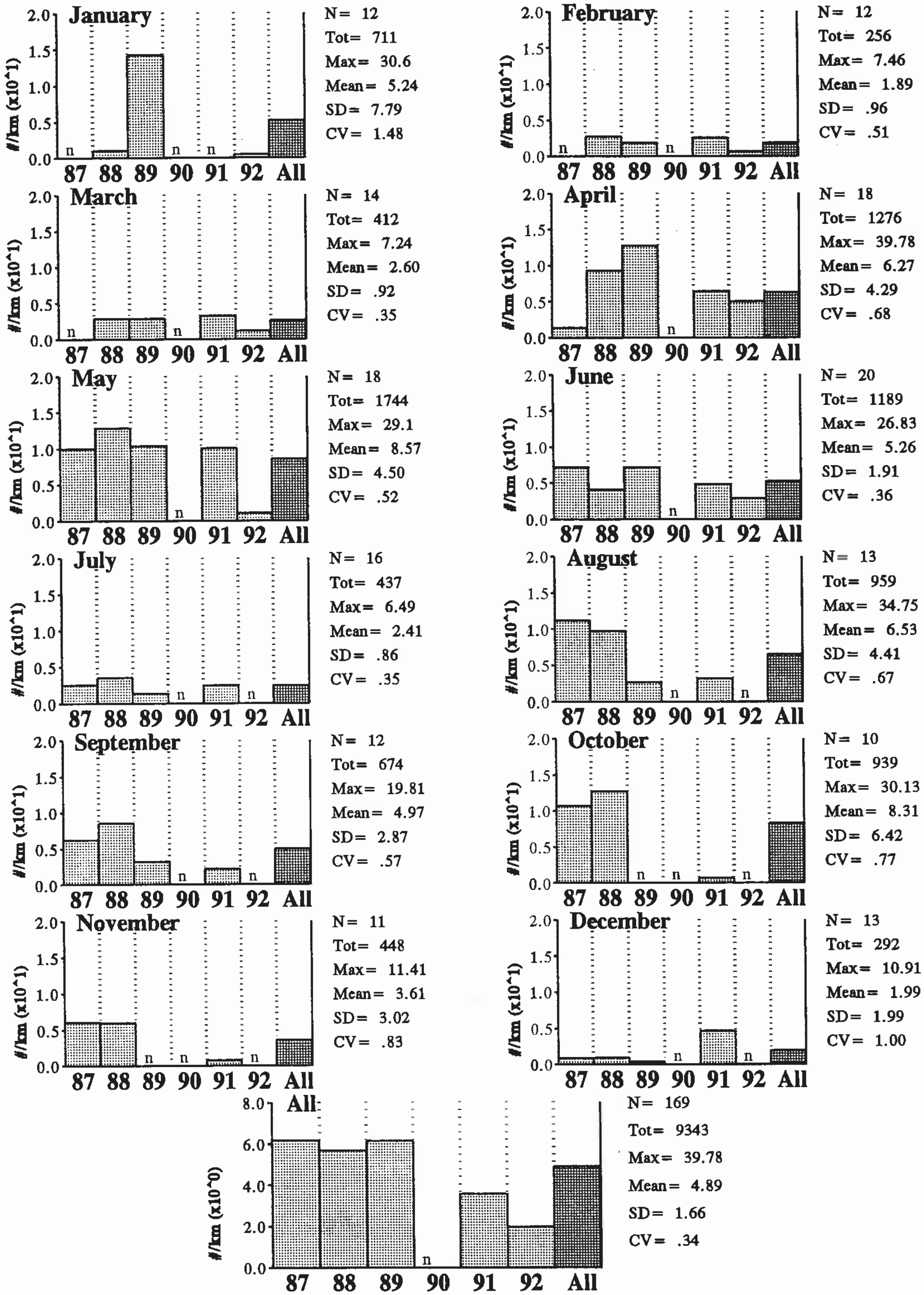


Figure 46 MARPOL Study; Density (#/km) of GLASS BOTTLES
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max = Maximum (per km) in any one survey
Mean = Oeverall mean (per/km). SD = Standard Deviation. CV = Coefficient of Variance

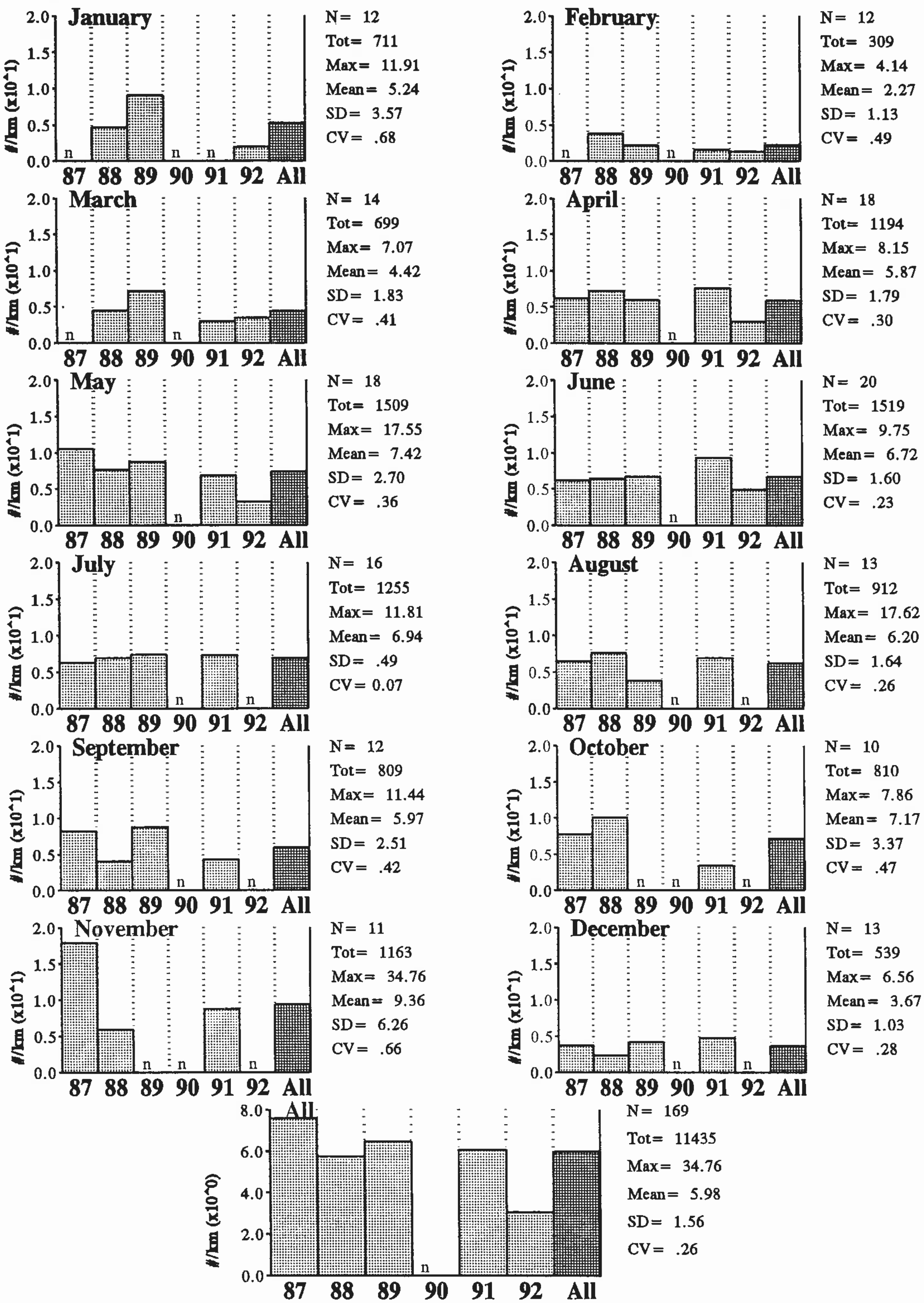


Figure 47 MARPOL Study; Density (#/km) of ALL METAL MATERIAL
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max = Maximum (per km) in any one survey
Mean = Ovearall mean (per/km). SD = Standard Deviation. CV = Coefficient of Variance

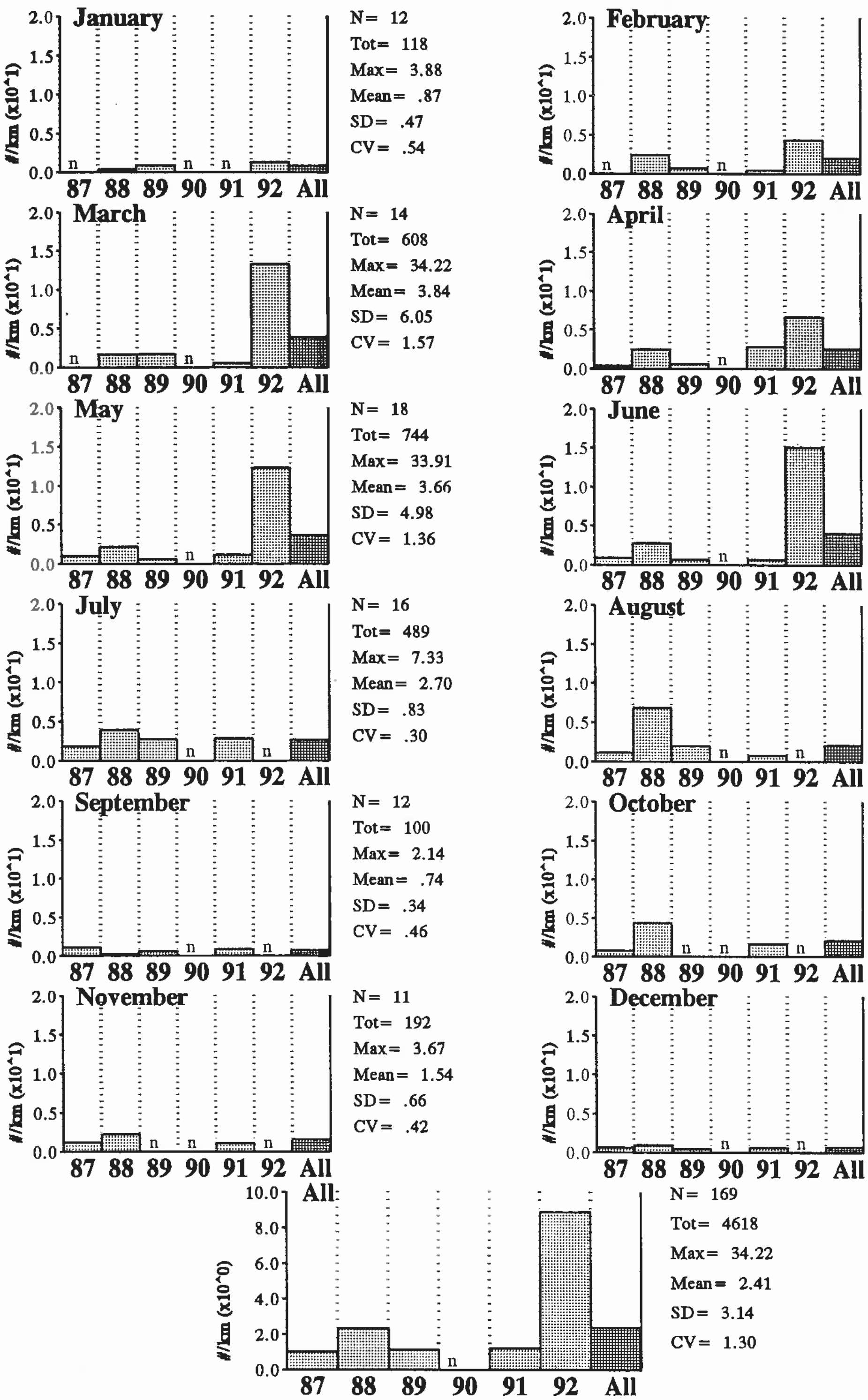


Figure 48 MARPOL Study; Density (#/km) of PAPER PRODUCTS
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max = Maximum (per km) in any one survey
Mean = Overall mean (per/km). SD = Standard Deviation. CV = Coefficient of Variance

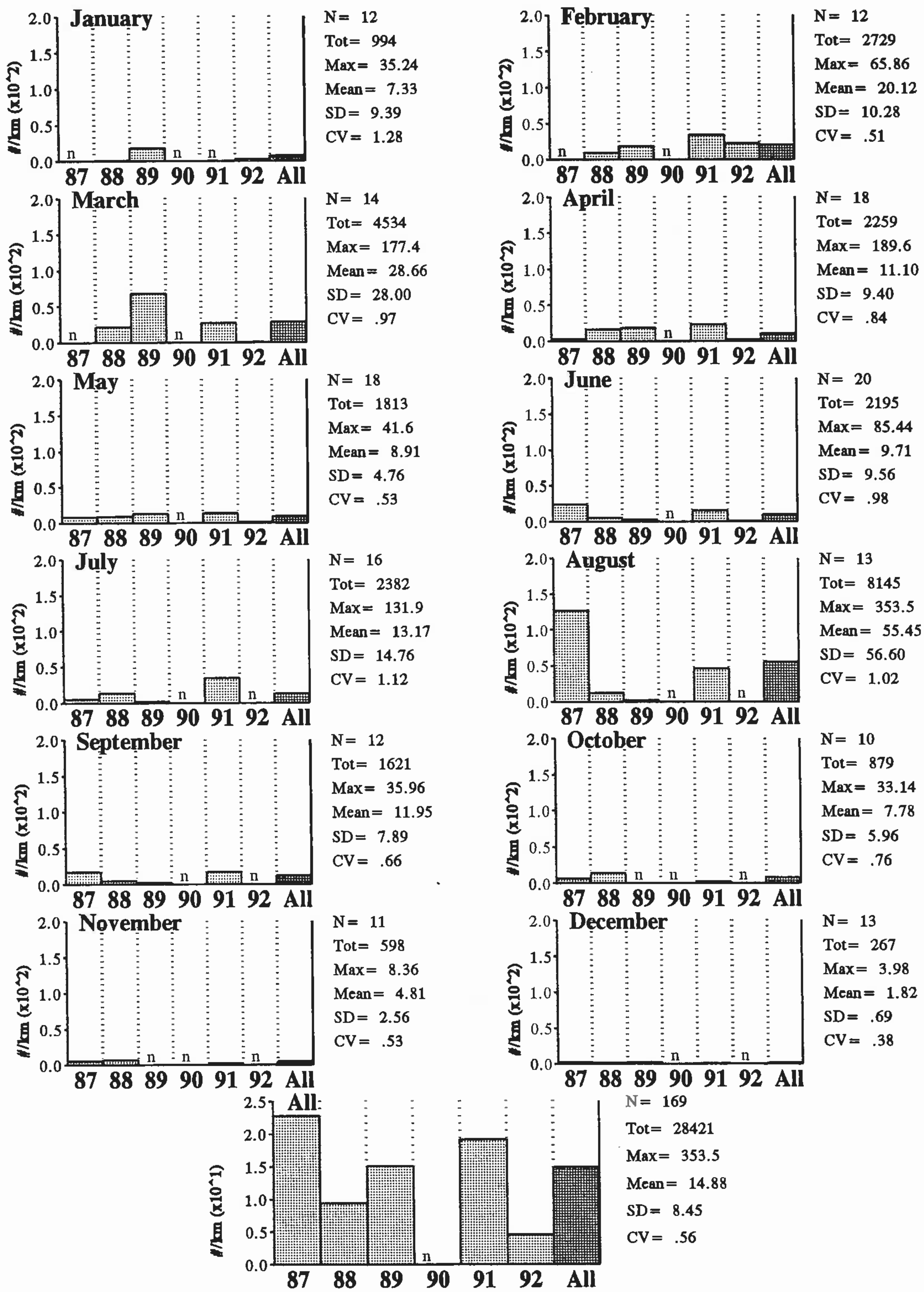


Figure 49 MARPOL Study; Density (#/km) of ALL WOOD MATERIAL
Number of items per km counted along 11.8-km survey beach by month from 1988 through 1995
N = # counts. Tot = Total # counted. Max = Maximum (per km) in any one survey
Mean = Ovearall mean (per/km). SD = Standard Deviation. CV = Coefficient of Variance

Table 10. Marine debris: proportion by of material composition by percentage of total. Column 2 includes counts of wood; columns 3, 4, and 5 are the result of a study of all debris, both natural and man-made.

MATERIAL	MARPOL STUDY (by COUNT)	MARPOL STUDY (by WEIGHT)	INCLUDING WOOD (by WEIGHT)	INCLUDING ALL DEBRIS (by WEIGHT)
PLASTIC	79.7	88.3	11.6	1.9
GLASS	3.3	5.2	0.6	0.1
METAL	3.3	2.6	0.3	<0.1
PAPER	4.5	3.9	0.5	0.1
WOOD	9.1	---	86.8	13.4
ANIMAL	---	---	---	6.1
VEGETABLE	---	---	---	75.5
MINERAL	---	---	---	2.6

In Table 10, the first data column shows the proportion of each material type as a percentage of the whole, including driftwood[5]. The last three columns are the results of the 119 separate surveys done in 1987/1988, and 1991/1992, when 4,075 kg of material were collected, classified, and weighed. The man-made material, mostly fragments, show a similar material make-up by weight to the count proportions. When wood is included, the proportion of man-made debris lessens considerably, and when all marine debris is weighed, diminishes into insignificance (last column).

4.2.2.6 Tarballs

Tar on beaches is one type of marine debris, often thought to be primarily due to spillage during the exploration for, and production and transportation of oil in the Gulf of Mexico. The history of tar deposits on gulf beaches is a long one. The use of tar, by the Karankawa Indians in making utensils, and by shipwrecked European explorers in caulking their vessels, is often quoted anecdotally and in the literature (e.g., Geyer and Giammona, 1980). It is also known that many areas beneath the Gulf of Mexico seep oil into the water naturally. It is beyond doubt that tar deposits in the form known as tarballs are frequently found among the debris on beaches, quite apart from known oil spills and their much-publicized aftermaths.

[5] We also counted some items of natural debris such as the cabbagehead jellyfish, but did no comparison between man-made and natural debris here because the main items of natural debris, *Sargassum* weed, algae, and tar, are not "countable".

One effect of such events is to discourage tourism, and so affect the economy of the Corpus Christi Bay area. Every beach-front condominium and hotel has "tar-cleaning" stations at their entrances so that guests can remove tar from their footwear before entering. Identifying the exact origin of tarballs on the beach is beyond the scope of this report; however, during the 18 years of beach surveys done by the first author, the incidence of tar on Mustang Island gulf beach has been documented both anecdotally, by estimates, and numerically. The biggest tarball-producing event locally, was the IXTOC I well blowout in the Gulf of Campeche, Mexico, which spilled 5,000,000 barrels of oil into the Gulf of Mexico for a period of 294 days from June 1979 until the well was capped in March 1980 (NOAA, 1981). Oil from this spill reached area beaches in August 1990 in massive quantities. A local history of the IXTOC oil at sea and on the beaches is given in Amos (1980). A series of storms in the fall of that year and the cleanup effort which lasted until the end of 1979, removed and redistributed IXTOC I's oil. Extensive tar reefs were deposited underwater just offshore from Mustang and other barrier island beaches. The first author followed the fate of these deposits for several years and documented the effects of tar on local fauna (Amos, 1981; 1983). After IXTOC I oil weathered, tarballs were left on the beach at each successive high tide line, washed back out to sea, and sometimes pushed into the dunes. Tar reefs were eroded by storms and rough surf and deposited in the form of tarballs with shape, color, and morphology characteristic of IXTOC. This happened long after the reefs themselves were buried offshore by sediment. The reefs resisted the energy of the surf zone for a surprisingly long time. Hurricane Allen in August 1980 did not destroy these structures. Allen was the most destructive hurricane to hit the CCBNEP area since Celia in 1970, and no other storm has eroded the beach as much to this day. It exposed marine debris "deposits", including strata of tar in the dunes cut by the storm.

One effect of IXTOC's tarballs was seen in the multitude of birds which feed among the beach wrack. This was especially true of the sandpipers, in particular the second-most abundant bird using the beach, the sanderling (*Calidris alba*). Also affected were piping plover (*Charadrius melodius*), snowy plover (*C. alexandrinus*), black-bellied plover (*Pluvialis squatarola*), and ruddy turnstone (*Arenaria iterpres*). At times, over 90% of some species were oiled (Amos, 1980). While very few of the oiled birds died on area beaches, the number of oiled birds provided an indirect measure of the quantity of tarballs on the beach.

Figure 50 (box diagram) documents the 12,591 oiled birds observed since April 1978. The huge peak in 1979 is due to IXTOC I in August and September of that year. The following spring, and several subsequent springs, saw a resurgence in the number of oiled birds so that the month of May emerges as the peak oiling period for birds on the beach. Notice that there has been a steady decline in oiled bird numbers until now, when it is rare to see any. Since the last substantial oiling event in 1990, only 36 oiled birds have been observed. There have been several tarball events since IXTOC and most have been mirrored by the incidence in shorebird oiling. Can the number of oiled birds be used as an index of tarball concentration on the beach? The first author attempted to document tarballs themselves in 1983. Because tarballs are essentially "uncountable," an estimate was made of the their relative abundance using the 0-5 index used in other estimates reported here. Figure 51 shows how the estimates do indeed reflect the oiled bird numbers, showing the peak in May, and the decline in tarballs

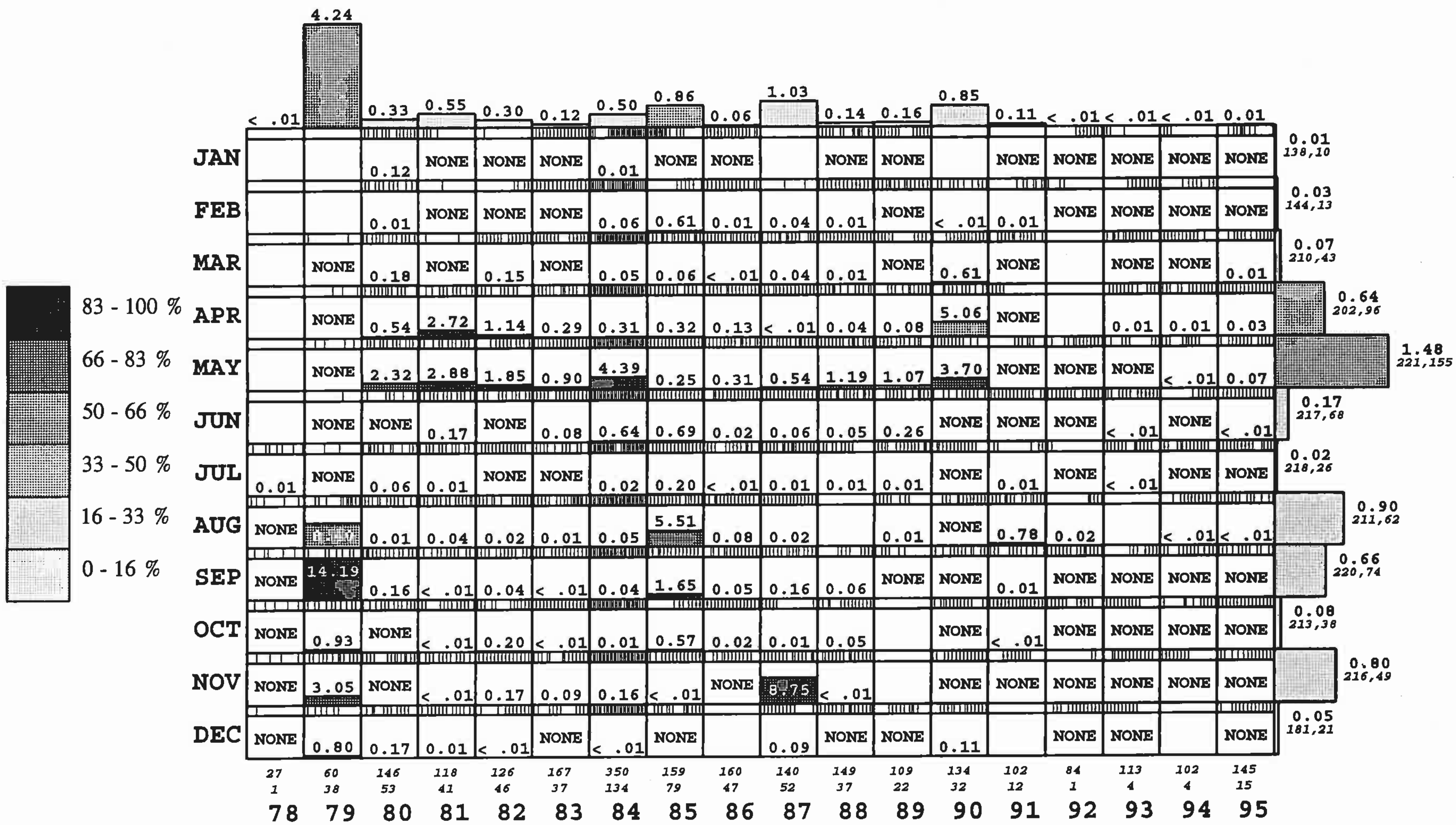


Figure 50 Box diagram of monthly and yearly means for OILED BIRD. (n =2,518)
TOTAL = 12,666; TIMES SEEN 673 (26.7 %); MAX 40.14 per/km; AVERAGE WHEN SEEN 1.59 per/km

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

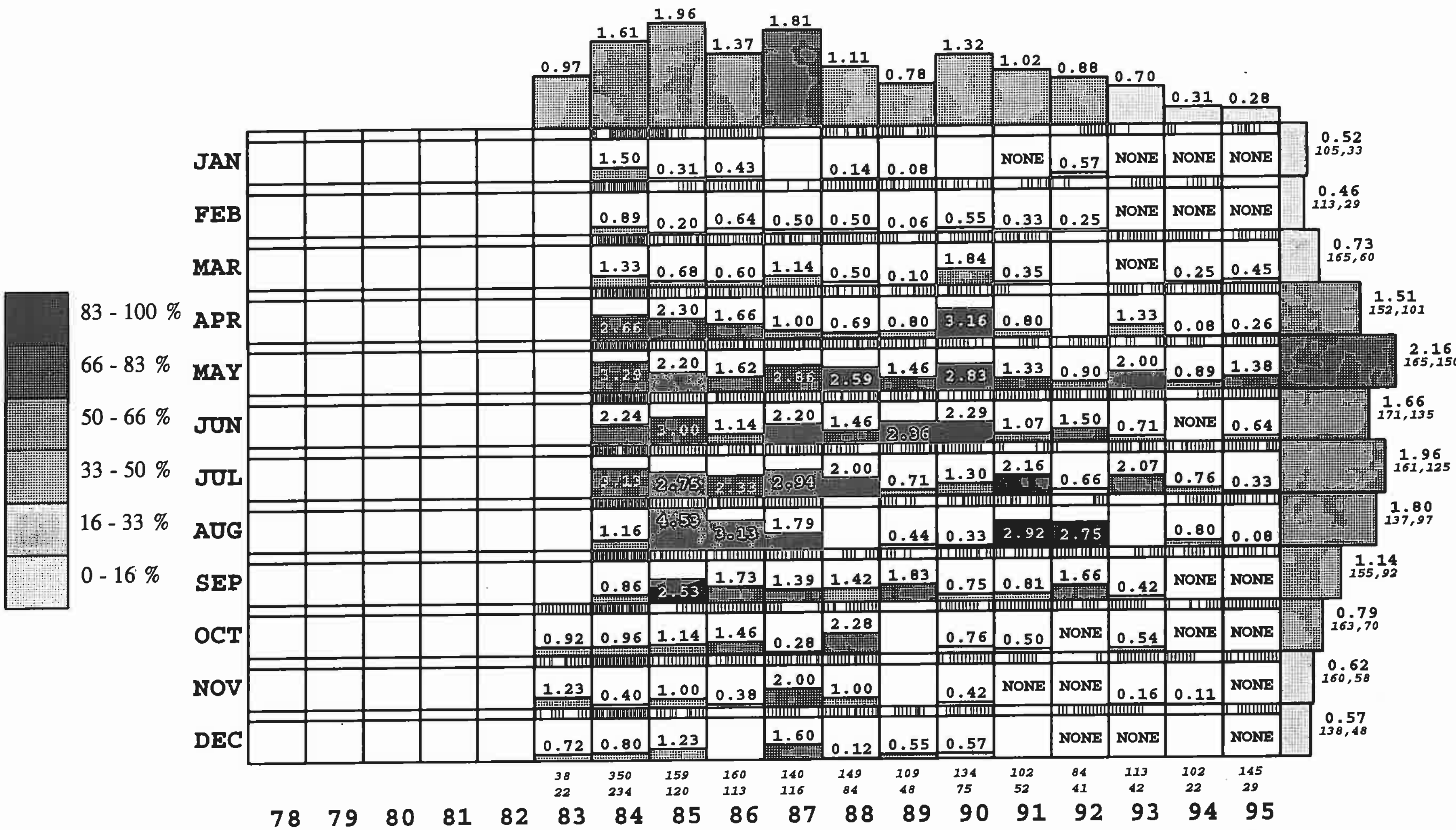


Figure 51 Box diagram of monthly and yearly means for TARBALLS. (n =1,916)
TIMES SEEN 1,076 (56.1 %); MAX 5 ; AVERAGE WHEN SEEN 2.12

Each box is shaded to a height proportional to the maximum monthly number or density (per km) seen in the 18-year study. Numbers in each box are the mean value for that month. NONE = none seen. Blank = no surveys that month. Thin vertical bars show when surveys were done within each month. Histograms along the top axis are mean yearly values, proportioned to the maximum yearly mean. Numbers above bars are mean annual value. Italicized numbers below yearly columns are total # surveys and # surveys when item was seen. Histograms to the right are mean monthly values for the 18-year study period. Numbers to the right of each histogram give the 18-year monthly mean, below which (italicized) are # surveys and # surveys in month when the item was seen. Shading density shows percentage of surveys when item was encountered (key on left).

over the years. The apparent disagreement in midsummer is because shorebirds desert Texas beaches in that period for their northern nesting grounds. Tar, on the other hand, does not.

We conclude from these data that tarballs have diminished considerably on the barrier island beaches, especially since 1990. Not only does the data indicate a dramatic decline, but so does the first author's anecdotal observations, as well as the opinions of many long-time visitors to the beach.

4.2.3 PINS Data

The Padre Island National Seashore (PINS) data on marine debris is an important data set, concentrating on the National Seashore gulf beach and directed towards identifying sources of debris. There are two main data sets: the **quarterly surveys**, which were done in coordination with other coastal National Parks and Seashores from 1989 to 1993 (Cole et al., 1995), and the **daily surveys** which are ongoing (Miller et al., 1995). The daily surveys are undoubtedly the most intensive survey of marine debris ever attempted. We were unable to obtain the raw data from these surveys, hence we have not included any PINS data in this report. We briefly review the daily survey results for 1994/1995, as reported in Miller et al. (1995).

It is important to note that there is disagreement between PINS and the CMC on the validity of the respective methods of surveying for marine debris on beaches, and the first author also questions some of the assumptions in Miller et al. (1995). Unlike the UTMSI methods[6], PINS surveyors remove the items counted following each survey. Also, the PINS survey-beaches are not cleaned of debris by Park workers, and vehicular traffic and camping is prohibited on part of the PINS beach. CMC volunteers also remove items tallied from the beach (one of the primary objectives is a beach cleanup). The proposed National Marine Debris Program will also remove the targeted items. No doubt this is the preferred method for assessing trends, unless the object of the survey is to measure the standing stock of debris.

PINS tallied 40,580 items in 42 different categories. They did not include beverage cans in the surveys. We assume they did 365 daily surveys from March 1994 through February 1995. Based on this, they traveled 5,840 statute miles (9,397 km). The overall density was therefore 4.31 (targeted) items per kilometer. Miller et al. (1995) do not say what percentage of the time any of the items was encountered, but more than half the items counted (24) must have been missed on one occasion or more (i.e., there were less than 365 total of these items). The graphs in the report show several months with no data for some items.

The PINS study makes the statement, by statistical correlations between the shrimping effort and certain items identifiable with that industry, that shrimping is "directly responsible for thirty percent of garbage that washes onto Texas beaches," and that the industry is "suspected of contributing an additional thirty-five percent." While we agree that shrimping is responsible

---

[6] The UTMSI micro-trash study and San Jose Island survey did remove material from the beach.

for perhaps the majority of debris on Texas beaches, this should more properly be stated as being a percentage of the items they targeted, not a percentage of all marine debris.

4.2.4 Bay Debris: Potential Sources

We find that marine debris literature and data in the CCBNEP study area is strongly biased towards gulf, rather than bay shorelines and beaches. To balance this somewhat and to help in our recommendations to the program, we did some research on potential sources of bay debris not based on either existing literature or data. Sources of bay debris may be both point and non-point. We considered such locations as boat ramps, harbors, industrial boat-yards, and marinas to be point sources, while roadways bordering the water and general storm run-off could be considered to be non-point sources. Our contribution was to catalog these places in the CCBNEP study area by geographical position so that they could be easily incorporated into a GIS system. To identify and catalog the source locations, we first collected all the USGS 7.5-minute series quadrangle maps (Fig. 52, Table 11) which are of sufficiently small-scale to depict many of these places.

Table 11. USGS quadrangle maps: latitude and longitude of lower left corner of map

NAME	MAP NUMBER	LATITUDE	LONGITUDE
ST. CHARLES BAY	DMA 6640 III NW	28 07.5	97 00.0
ROCKPORT	DMA 6540 II SE	28 00.0	97 07.5
TAFT	AMS 6539 IV NW	27 52.5	97 30.0
GREGORY	AMS 6539 IV NE	27 52.5	97 22.5
ARANSAS PASS	AMS 6539 I NW	27 52.5	97 15.0
ESTES	DMA 6539 I NE	27 52.5	97 07.5
ALLYNS BIGHT	AMS 6639 IV NW	27 52.5	97 00.0
CORPUS CHRISTI	AMS 6539 IV SW	27 45.0	97 30.0
PORTLAND	AMS 6539 IV SE	27 45.0	97 22.5
PORT INGLESIDE	AMS 6539 I SW	27 45.0	97 15.0
PORT ARANSAS	DMA 6539 I SE	27 45.0	97 07.5
OSO CREEK NW	AMS 6539 III NW	27 37.5	97 30.0
OSO CREEK NE	DMA 6539 III NE	27 37.5	97 22.5
CRANE ISLANDS NW	AMS 6539 II NW	27 37.5	97 15.0
CHAPMAN RANCH	AMS 5639 III SW	27 30.0	97 30.0
PITA ISLAND	DMA 6539 III SE	27 30.0	97 22.5
CRANE ISLANDS SW	AMS 6539 II SW	27 30.0	97 15.0
SOUTH BIRD ISLAND SW	AMS 6538 IV NW	27 22.5	97 30.0
SOUTH BIRD ISLAND	AMS 6538 IV NE	27 22.5	97 22.5
KLEBERG POINT	AMS 6438 I SE	27 15.5	97 37.5
POINT OF ROCKS	AMS 6538 IV SW	27 15.0	97 30.0
SOUTH BIRD ISLAND SE	AMS 6538 IV SE	27 15.0	97 22.5
LA PARRA RANCH NE	DMA 6438 IV NE	27 07.5	97 37.5
YARBOROUGH PASS	AMS 6538 III NW	27 07.5	97 30.5

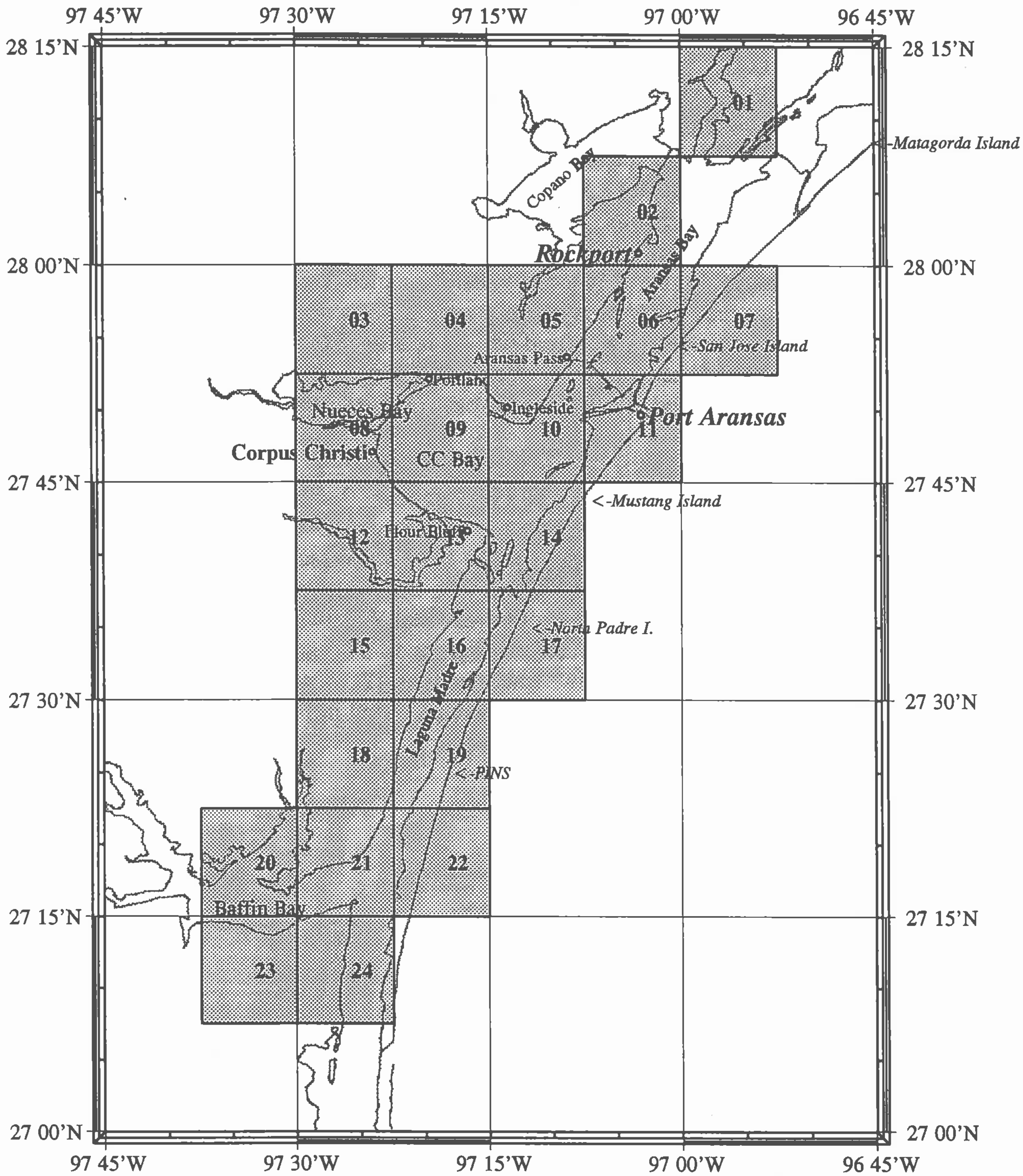


Figure 52 USGS 7.5-minute quadrangle maps covering the CCBNEP Marine/Bay debris study area. See Table 11 for map details.

We also obtained a list of marinas (Hollin, 1995) and public boat ramps from the Texas Parks and Wildlife Department (TPWD, 1995) and started to locate them on the maps. However, we found it unproductive to identify locations from descriptions and initiated a series of field trips to locate ramps and other features using a truck-installed GPS receiver and an interactive computer program developed by the PI to allow continuous recording of positional data and specific notations to be keyed by latitude and longitude. A useful aid was the Texas Road Atlas (Shearer Publishing, 1998). The PI made several trips from Copano to Baffin Bays, following the coastal roads and searching for ramps other than those in the TPWD list and those already known to him. At each ramp, an entry was made in the computer with a ramp, street, R/V park, bait stand, or other identifying name. The program, adapted from one developed for shipboard use, automatically appends the geographical position to the entry and a line is recorded in the computer file. At all other times while the vehicle is "underway", positional data is recorded at one-minute intervals. Comments can be entered at any time and this ability was used to record additional information, such as where highways bordered the water as potential areas of pollution by road litter. Each location was also photographed. The photographs have been digitized and can be incorporated electronically into a GIS system or document. Photos are archived with this report but not reproduced here other than the ramp example in Figure 53.

This method also gave the PI a direct look at these points and an idea of how littered each one was, as well as their location within the estuary. The industrial facilities bordering the CCBNEP waters were often inaccessible from the road due to security requirements (entrance restricted). These were located from the water using a small boat outfitted with a GPS system. The boat was driven along the adjacent Gulf Intracoastal Waterway (GIW), slowing down to identify, locate, and photograph each facility. Figures 54-57 locate the ramps; the identifying numbers on the maps correspond to those listed in Table 12. Industrial sites and Residential complexes along the Gulf Intracoastal Waterway are mapped in Figure 58 and listed in Table 13.

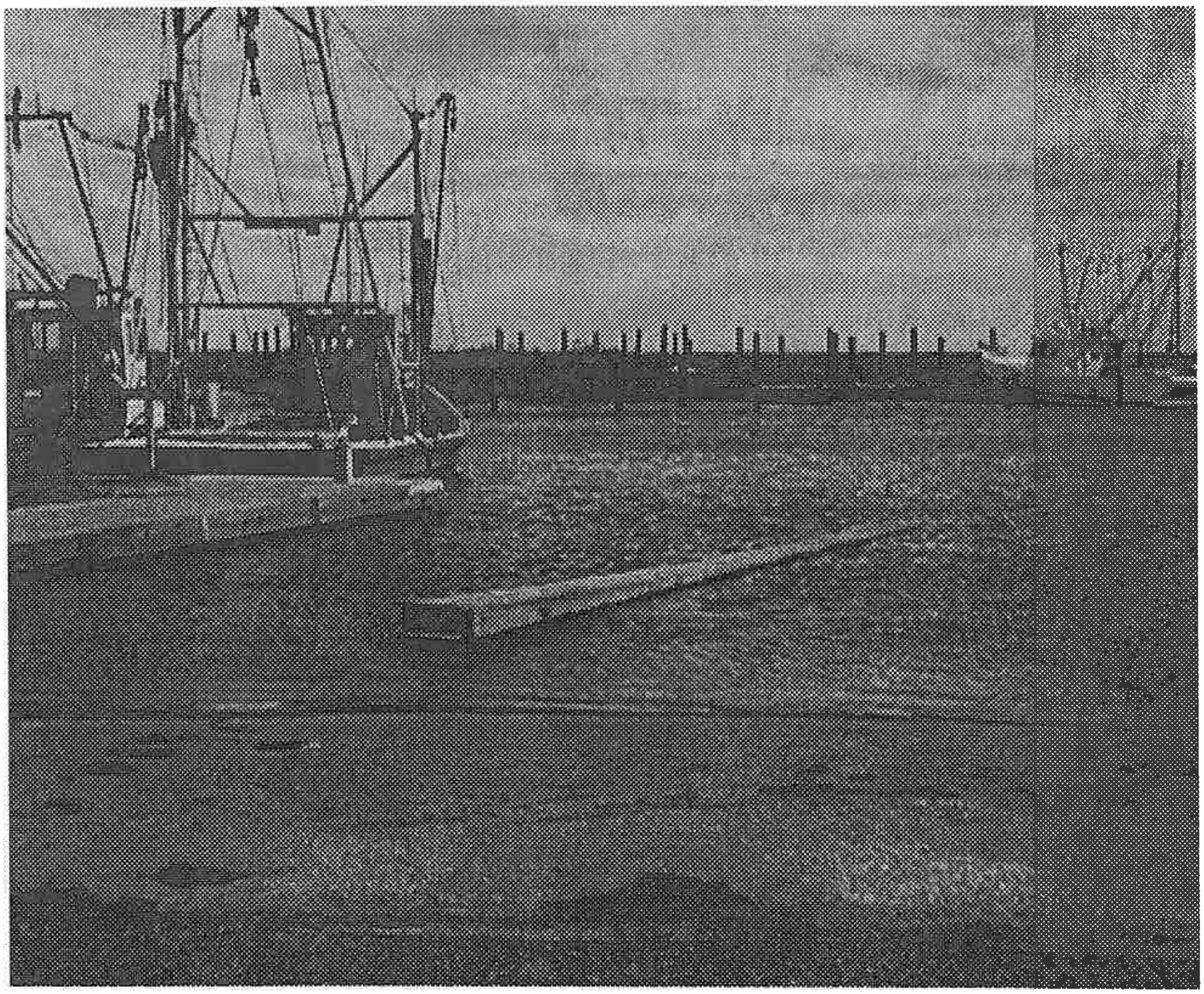


Figure 53   Typical private boat ramp in the CCBNEP study area.

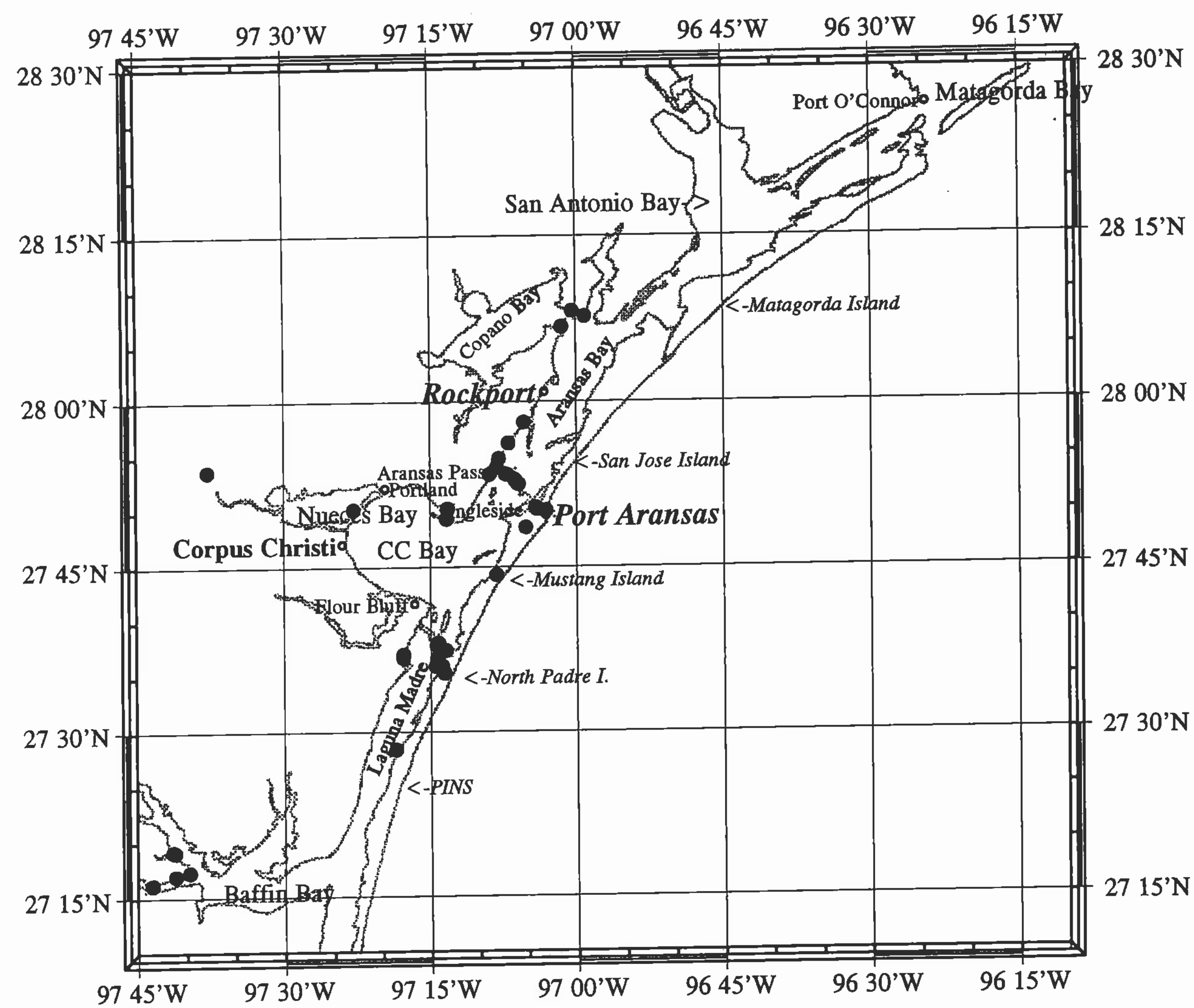


Figure 54 Boat ramp locations in the CCBNEP area. See following maps & Table 12 for identification.
There may be slight misregistration of ramp positions relative to shoreline
Some ramps are connected to the bay system via canals not shown.
Others are on causeway land-fills not appearing on map.

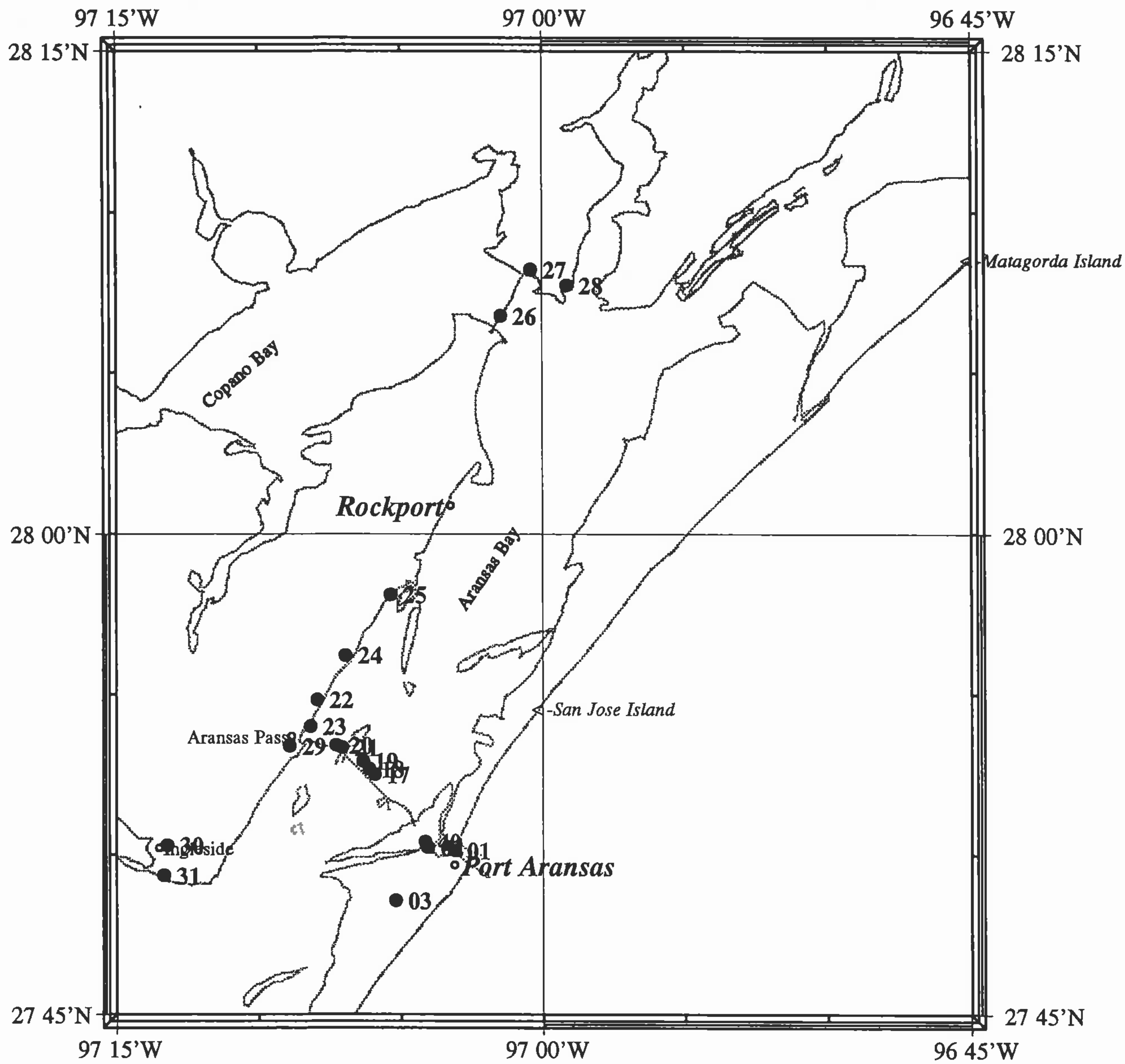


Figure 55 Boat ramps in the Redfish/Aransas/Copano Bays region. See Table 12 for ramp names.
There may be slight misregistration of ramp positions relative to shoreline
Some ramps are connected to the bay system via canals not shown.
Others are on causeway land-fills not appearing on map.

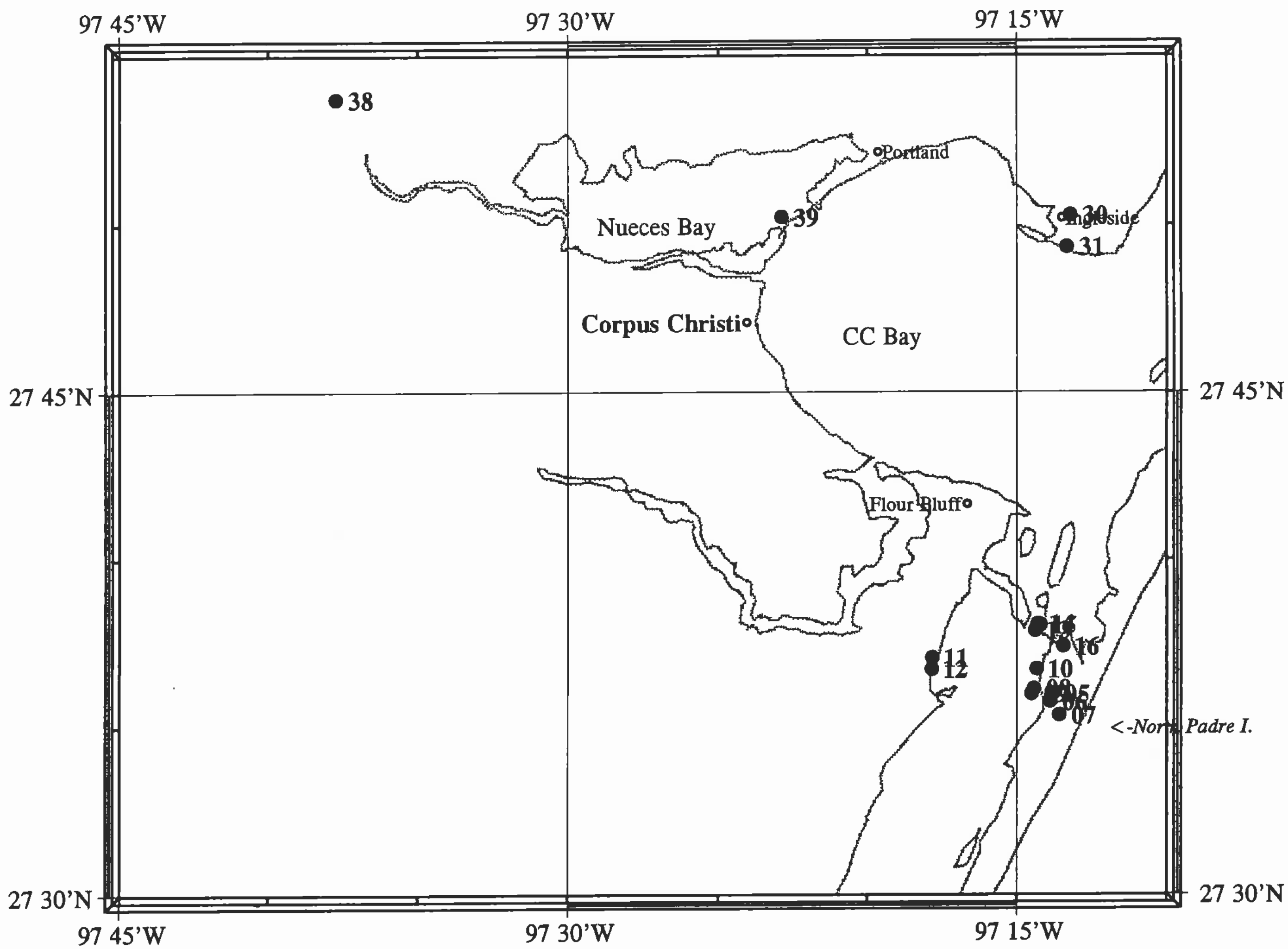


Figure 56 Boat ramps - Corpus Christi Bay/Upper Laguna Madre area. See Table 12 for ramp names.
There may be slight misregistration of ramp positions relative to shoreline
Some ramps are connected to the bay system via canals not shown.
Others are on causeway land-fills not appearing on map.

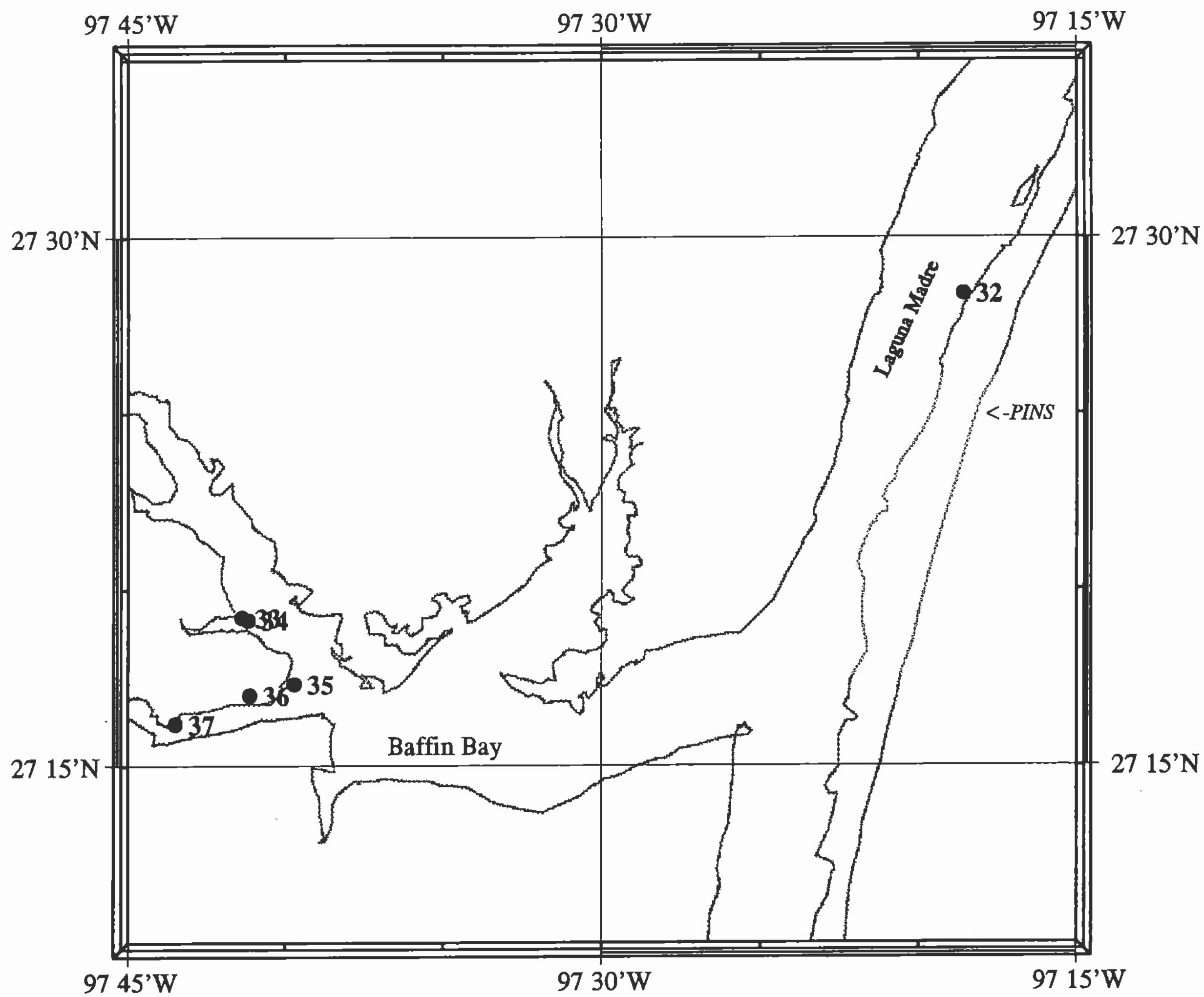


Figure 57 Boat ramps - Baffin Bay. See Table 12 for ramp names
There may be slight misregistration of ramp positions relative to shoreline
Some ramps are connected to the bay system via canals not shown.
Others are on causeway land-fills not appearing on map.

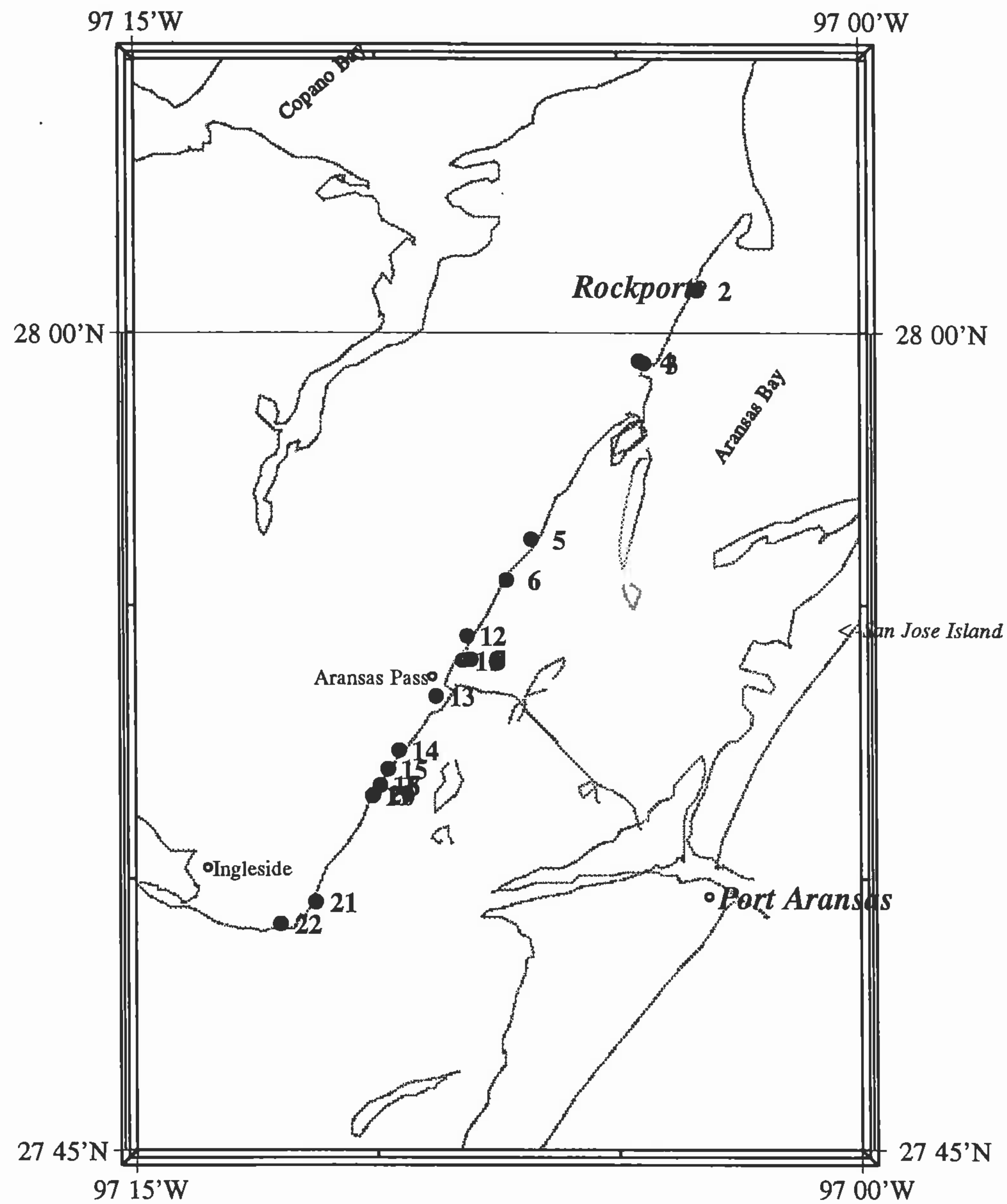


Figure 58 Industrial and Residential sites along the Gulf Intracoastal Waterway. See Table 13 for names.

Table 12. Boat ramp locations for the CCBEP study area. Numbers in the first column are shown in location in Figures 54-58.

#	COUNTY	NAME\LOCATION	PUBLIC\ PRIVATE	LAT (°N)	LON (°W)
01	NUECES	UT BOAT BASIN RAMP, END OF CHANNELVIEW DR., PORT ARANSAS, INTO THE ARANSAS PASS	PUBLIC	27°50.24	97°03.14
02	NUECES	PORT ARANSAS CITY BOAT RAMP, NORTH STREET AND ROAD B, PORT ARANSAS, LEADS INTO ARANSAS PASS	PUBLIC	27°50.34	97°04.07
03	NUECES	ISLAND MOORINGS MARINA, OFF COTTER AVE., PORT ARANSAS, INTO THE CORPUS CHRISTI CHIP CHANNEL	PRIVATE	27°48.55	97°05.20
04	NUECES	WILSON'S CUT RAMP, W. SIDE OF STATE HWY 361, ACROSS FROM SHAMROCK ISLANDS, CORPUS CHRISTI, INTO THE CORPUS CHRISTI BAY	PUBLIC	27°44.22	97°08.20
05	NUECES	GYPSY ROAD RAMP, NORTH PADRE ISLAND, CORPUS CHRISTI, INTO CHANNELS LEADING TO THE LAGUNA MADRE	PRIVATE	27°35.99	97°13.81
06	NUECES	FORTUNA ROAD RAMP, NORTH PADRE ISLAND, CORPUS CHRISTI, INTO CHANNELS LEADING TO THE LAGUNA MADRE	PRIVATE	27°35.76	97°13.89
07	NUECES	ENCANTADA DRIVE RAMP, NORTH PADRE ISLAND, CORPUS CHRISTI, INTO CHANNELS LEADING TO THE LAGUNA MADRE	PRIVATE	27°35.35	97°13.59
08	NUECES	CARAVEL DRIVE RAMP, NORTH PADRE ISLAND, CORPUS CHRISTI, INTO CHANNELS LEADING TO THE LAGUNA MADRE	PRIVATE	27°36.14	97°14.43
09	NUECES	CARTAGENA RAMP, NORTH PADRE ISLAND, CORPUS CHRISTI, INTO CHANNELS LEADING TO THE LAGUNA MADRE	PRIVATE	27°35.99	97°14.51
10	NUECES	COBO DE BARA CIRCLE RAMP, NORTH PADRE ISLAND, CORPUS CHRISTI, INTO THE CHANNELS LEADING TO THE LAGUNA MADRE	PRIVATE	27°36.73	97°14.34
11	NUECES	YORKETOWN AT LAGUNA SHORES RAMP, CORPUS CHRISTI, INTO THE LAGUNA MADRE	PRIVATE	27°37.06	97°17.82
12	NUECES	BOONDOCKS LANDING & BAR RAMP, AT THE END OF LAGUNA SHORES ROAD, CORPUS CHRISTI, INTO THE LAGUNA MADRE	PRIVATE	27°36.72	97°17.84
13	NUECES	MARKER 37 RAMP, S.W. END OF JOHN F. KENNEDY CAUSEWAY, CORPUS CHRISTI, INTO THE LAGUNA MADRE	PUBLIC	27°37.88	97°14.39
14	NUECES	PACKERY CHANNEL RAMP, ALONG SIDE JOHN F. KENNEDY CAUSEWAY, N.E. OF TRESSLES, CORPUS CHRISTI, INTO THE LAGUNA MADRE	PUBLIC	27°38.07	97°14.30
15	NUECES	PACKERY CHANNEL SOUTH RAMP, ALONG SIDE JOHN F. KENNEDY CAUSEWAY, N.E. OF TRESSLES, CORPUS CHRISTI, INTO THE LAGUNA MADRE	PUBLIC	27°63.40	97°14.21
16	NUECES	JACKFISH AVE RAMP, S.W. END OF JOHN F. KENNEDY CAUSEWAY, CORPUS CHRISTI, INTO CHANNELS LEADING TO THE LAGUNA MADRE	PRIVATE	27°37.41	97°13.46
17	NUECES	CRAB MAN MARINA RAMP, ARANSAS PASS CAUSEWAY, INTO REDFISH BAY	PRIVATE	27°52.50	97°05.56
18	NUECES	CAUSEWAY BAIT STAND RAMP, ARANSAS PASS CAUSEWAY, INTO REDFISH BAY	PRIVATE	27°52.68	97°05.76
19	NUECES	REDFISH BAY MARINA RAMP, ARANSAS PASS CAUSEWAY, INTO REDFISH BAY	PRIVATE	27°52.92	97°05.82
20	NUECES	BAIT BUCKET RAMP, ARANSAS PASS CAUSEWAY INTO REDFISH BAY	PRIVATE	27°53.42	97°06.62

#	COUNTY	NAME\LOCATION	PUBLIC\ PRIVATE	LAT (°N)	LON (°W)
21	NUECES	FIN & FEATHER RAMP, ARANSAS PASS CAUSEWAY, INTO REDFISH BAY	PRIVATE	27°53.35	97°06.71
22	NUECES	CONN BROWN HARBOR NORTH RAMP, N.W. END OF ARANSAS PASS CAUSEWAY, INTO REDFISH BAY	PRIVATE	27°54.82	97°07.95
23	NUECES	CONN BROWN HARBOR SOUTH RAMP, N.W. END OF ARANSAS PASS CAUSEWAY, INTO REDFISH BAY	PRIVATE	27°54.00	97°08.19
24	NUECES	LINDSAYS LANDING RAMP, INTO REDFISH BAY	PRIVATE	27°56.22	97°06.95
25	NUECES	MICKEYS/PALM HARBOR RAMP, S.W. END OF ARANSAS PASS CAUSEWAY, INTO REDFISH BAY	PRIVATE	27°58.11	97°05.37
26	ARANSAS	COPANO BAY, S.W. SIDE OF COPANO BAY CAUSEWAY STATE PARK, LIVE OAK PENINSULA	PUBLIC	28°06.76	97°01.47
27	ARANSAS	SEA GUN INN RAMP, N.E. SIDE OF COPANO BAY CAUSEWAY STATE PARK, INTO ARANSAS BAY, LAMAR PENINSULA	PRIVATE	28°07.96	97°04.08
28	ARANSAS	GOOSE ISLAND STATE PARK RAMP, N.E. OF COPANO BAY CAUSEWAY STATE PARK, INTO ARANSAS BAY, S.E. TIP OF LAMAR PENINSULA	PUBLIC	28°07.71	96°59.13
29	SAN PATRICIO	HAMPTON'S LANDING RAMP	PRIVATE	27°53.39	97°08.92
30	SAN PATRICIO	INGLESIDE COVE PARK RAMP, BESIDE FM 1069, INTO CORPUS CHRISTI BAY	PUBLIC	27°50.28	97°13.22
31	SAN PATRICIO	CHANNELVIEW MARINA, INGLESIDE ON THE BAY RAMP, CORPUS CHRISTI BAY	PUBLIC	27°49.34	97°12.92
32	KLEBERG	BIRD ISLAND BASIN	PUBLIC	27°28.41	97°18.60
33	KLEBERG	BEACH RAMP OFF COUNTY ROAD 1144	PUBLIC	27°19.47	97°41.04
34	KLEBERG	CAYO DEL GRULLO RAMP	PRIVATE	27°19.12	97°40.95
35	KLEBERG	KRAATZ BOAT AND BAIT CAMP RAMP	PRIVATE	27°17.31	97°39.72
36	KLEBERG	RIVIERA BEACH DEAD END RAMP	PUBLIC	27°16.99	97°41.14
37	KLEBERG	UNPAVED, SOUTH OF FM 2510, A POTENTIAL RAMP	PUBLIC	27°16.18	97°43.51
38	NUECES	NUECES RIVER	PUBLIC	27°53.72	97°37.74
39	SAN PATRICIO	NUECES BAY, OFF US HIGHWAY 181	PUBLIC	27°50.23	97°22.89
40	NUECES	TURTLE COVE IN ROBERTS POINT PARK ADJACENT TO SH 361 FERRY LANDING IN PORT ARANSAS, IN TO THE CORPUS CHRISTI SHIP CHANNEL	PUBLIC	27°50.40	97°04.17

Table 12 (continued above)

Table 13. Location of some marinas and industrial sites in the CCBNEP study areas.

#	COUNTY	NAME	TYPE	LAT (N)	LON (W)
01	ARANSAS	KEY ALLEGRO	MARINA	27 49.42	97 29.54
02	ARANSAS	ROCKPORT CITY MARINA	MARINA	27 50.31	97 03.12
03	ARANSAS	COVE HARBOR	SHRIMPING AND INDUSTRY	27 59.44	97 04.46
04	NUECES	PALM HARBOR MARINA	MARINA	27 59.49	97 04.56
05	NUECES	LINDSAY'S LANDING/ASHLAND CHEM. CO.	BOAT RAMP AND BARGE FACILITY	27 56.21	97 06.80
06	NUECES	ARANSAS TERMINAL	STORAGE TANKS	27 55.46	97 07.31
07	NUECES	TETRA TECHNOLOGIES	SUPPLY COMPLETION FLUIDS TO RIGS	27 54.00	97 08.05
08	NUECES	COASTLINE RESOURCES	DOCK, SCRAP METAL, TEAR-DOWN	27 54.00	97 08.05
09	NUECES	ARANSAS MARINE WAYS	HAUL-OUT FACILITY	27 54.00	97 08.05
10	NUECES	GULF KING INDUSTRIES	SHRIMPING	27 53.98	97 08.23
11	NUECES	CONN BROWN HARBOR	MARINA AND SHRIMPING	27 53.98	97 08.23
12	NUECES	HARBOR SHRIMP CO.	BOAT RAMP AND PIER	27 54.43	97 08.13
13	NUECES	ARANSAS PASS CITY HARBOR	MARINA AND ENTRANCE TO PELICAN COVE	27 53.33	97 08.78
14	NUECES	REDFISH BAY SHIPYARD	SEVERAL BUSINESSES	27 52.34	97 09.55
15	NUECES	AKER GULF MARINE FABRICATORS	INDUSTRIAL MANUFACTURING	27 51.99	97 09.77
16	NUECES	ALAMO CONCRETE PLANT	CONCRETE PLANT	27 51.70	97 09.93
17	NUECES	PART OF TETRA TECHNOLOGIES	TANKS TO STORE COMPLETION FLUID	27 51.51	97 10.10
18	NUECES	MJP	WAS A SHRIMPER DOCK-HAS SINCE CLOSED	27 51.70	97 09.93
19	NUECES	ENJET REFINING-HESS-NORTH BANK TERMINAL - OCEANEERING-ADVANTAGE RECYCLING-TESORO	SEVERAL BUSINESSES	27 51.52	97 10.08
20	NUECES	NEWPARK ENVIRONMENTAL-GARRET CONSTRUCTION	SEVERAL BUSINESSES	27 51.52	97 10.08
21	NUECES	BAKER MARINE, INC.	RIG MANUFACTURING	27 49.57	97 11.28
22	NUECES	BAKER MARINE CONTINUED	RIG MANUFACTURING	27 49.17	97 12.00

To illustrate the potential sources of bay debris, one of us (KCK) conducted interviews at two locations bordering Corpus Christi Bay, Ingleside-on-the-Bay, and the Corpus Christi Boat Basin and adjacent urban coastline. Here follow her notes, edited for clarity.

4.2.4.1 Ingleside-on-the-Bay

Carol Cervenka: (512-776-7988)
Carol is a member of the CCBNEP Local Government Advisory Committee. Almost every day she walks the beach in Ingleside-on-the-Bay, picking up trash, dead birds and making general observations. The dead birds she takes to Robyn Cobb at U.S. Fish and Wildlife Service. The city of Ingleside-on-the-Bay has 9/10th of a mile of bayfront, 2/10ths of which is the Ingleside Beach Club. The shoreline is not straight, but curves in. The wind usually blows from the direction of the Navy (Naval Station Ingleside), Carol says. Carol has been walking the beach for the past three years, and she says that the amount of trash on the beach has decreased by about 75%, although after weekends, is a bit less. Part of the reason for this, Carol believes, is the tightening of regulations on shrimpers in the marina at Ingleside. She started to notice a change in the amount of trash when the owner of restaurant in the Marina (the "Country Cajun") imposed regulations on the shrimpers. When the ownership changed (restaurant is now "Frenchy's"), even tighter regulations were set, a dumpster was provided, and Carol started seeing drastic improvements in the amount of trash on the beach. She mentioned that she doesn't see and pick up hand brushes (to scrub the deck), lids off bait buckets (used to see more lids than buckets) and other items that usually came from small shrimp boats. Other things no longer found: life vests, bait buckets and large plastic bags. She guessed that aluminum cans have decreased by 30-40%. Discarded items which have decreased in frequency are the large plastic beverage bottles, large wax-paper cups (like the "big gulp"), milk jugs (very few now), and 3-liter cola jugs. The wood and large rope that washes up every now and is [put to good use] by piling it in areas where erosion is becoming a threat. One thing that Carol did say was increasing in number is the glass beer bottles (by about 20-35% from 2 years ago). Three years ago Carol used to almost fill two of the large heavy plastic leaf/garbage bags, and now she will fill a regular kitchen bag about 1/3rd full or 2/3 on a particularly bad day.

I went to visit Carol in Ingleside-on-the-Bay on Tuesday, September 5. This is a small town of about 265 homes and 550 people. It is located on a tiny peninsula off Highway 1069 in the shape of a "sock". The Beach Club beach area that Carol cleans is at the bottom of the sock, with a bulkhead on the western end and Frenchy's restaurant plus a couple of houses on the eastern end. Erosion has been a large problem in this area, in the last few years, taxes have been re-evaluated due to the loss of land. The bay is generally very calm, Carol says, and the erosion is from large ships coming through the area creating waves and washing away the beach. Tires have been placed on the beach to help combat the erosion. On the morning of the fifth when I saw Carol, it was at high tide, and only 4-5 feet of beach was exposed on the eastern portion of the beach. The vegetation is normal for a bay area. First there was the *Spartina* and *Distichlis*, then *Salicornia*, then the Camphor and Sea Ox-eye daisies and then the domestic grasses and sunflowers. There was also a small wall in that area, about 20 feet from the water in the widest area. This wall becomes the bulkhead further down to give an indication of the erosion. At the widest area of beach, it was about 8-10 feet. This was on the inside side of an inward curve of the beach. Carol said that this area didn't catch much debris due to the southeasterly wind. Therefore, the small outcrop before the inward curve got a big chunk of trash. Carol said that by the time she cleaned that area, she had a large garbage bag full of debris. On the morning of our walk, Carol said she had not cleaned the beach in two days. There was one small piece of glass, two or three milk jugs and a few plastic water bottles, a piece of plastic bag that looked as though is had been buried a while, and a few other odds and ends. Not really very much for two days compared to the beaches on the gulf side.

4.2.4.2 Corpus Christi Marina

On 21 September 1995, at 0800, I met with Mark Smith, the Harbor Master, and Rene Garza, an employee, to discuss their efforts to control debris in the marina area. They said that today was unusually light in trash, especially for after a rain, due to the light winds, high tide and still water. Once, after a storm, they filled an eighteen-wheeler [truck] full of bags of trash. Mark and Rene said that they always get fisherman's debris, such as scraps from cleaning fish, old bait, plus the usual cups and plastic. Mark estimated that probably 75 percent of the trash they get is from land sources. After a heavy rain, all of the trash in the gutters and streets of the downtown area flows into storm drains that flow directly into the bay. There are eighteen of these drains along the bayfront down Ocean drive to Oso pier. From these drains come a lot of grass clippings, cups, food wrappers, plastic bits, twelve pack cardboard packaging, six-pack rings, diapers, etc.

Another large source of debris is from people setting down [leaving] cups, cans and other items on the seawall, which are then blown into the bay. Also, festivals and special events create an added problem of trash that blows into the bay, or is washed down drain outfalls. They did mention that Styrofoam cups are a very large problem, do to the lightness of weight, and [the fact that they] will blow directly to the water. Mark and Rene also mentioned that hospital debris is often found. Mark was not sure if the hospital debris came in with the tide, or from the storm drains, or if they were being dumped. On one occasion, his men pulled out over 500 needles from one particular area. They said they pull out [remove] about one [55-gallon] barrel per year, which is a decrease from earlier years, as well as five-gallon buckets from industry off passing ships, but not often. They also pull out tires, and the occasional body from a murder or a jumper from the Harbor Bridge.

One interesting thing was that the sea grass detritus often helps in the trash collection, because the patches of detritus often pick up [entrains] trash along the way, which allows it [the trash] to be picked up rather than the debris sinking to the bottom. Sometimes, a small-scale oil spill occurs when someone empties their bilge, in which case, the Coast Guard and MSO participate to help clean. If the offender is found that person is fined. Winter time is another time of increased garbage. Due to the winds, debris from across the bay will float to the Corpus Christi side, including lumber, oil filters, pieces of cars, deer and hog bodies after hunting season begins. They also mentioned that some old trash is found that was already in the sediment, but for some reason has worked back up and floated to the surface.

4.2.4.3 Corpus Christi Urban Shoreline

We took a drive around Corpus Christi Bay, from Cole Park to the end of land of the Nueces Bay Causeway, stopping at each of the drain outfalls to see what was coming out and to see what kind of debris there was on another side of the bay. At the boat ramp of the L-head, there were food wrappers, particularly chip sacks, bottle caps and beer bottles. As we were going toward Cole Park, Mark pointed out the cans and other items that were in the gutter that will now blow into the bay. We first stopped at the Louisiana Parkway outfall at Cole Beach, south end. This is a very large outfall, collecting water from all over downtown. Beside [next to] the outfall, on land, there were ice bags, monofilament line, lots of drinking straws, cans, condoms, beach toys, and a large amount of tiny pieces of plastic. Mark mentioned that these pieces may be from lawn mowers running over them, then when the plastic is small enough, and air borne, it travels to here. From the outfall in the water came small spots of oil, lots of cans, Styrofoam cups, individual sized chip wrappers. The debris comes out of the drain, catches the current and travels down to a gravely, shell area where it is deposited. Along McGee Beach, there are several small outflow pipes that remain under the water. A tube is stretched from the opening to the end of the swimming area. There I saw prescription bottles, six-pack rings, plastic eating utensils, Styrofoam and plastic cups, and fishing lures.

There are only eighteen trash cans for the entire bayfront area for both sides of shoreline drive. Mark is working now to remedy that. On the north side of the McGee Beach Concession and Fishing Pier, there is a nearby outfall. This is an area of more intense concentration most days due to the jetty that runs from the fishing pier and around the entire marina. The jetty is to protect the marina from hurricanes, but it also creates an area that, when the wind blows, or it rains, it gets filled with trash. The outfalls at the Matador Gazebo and north of the Corpus Christi Marina had some cups and other items, but not as much as the south end. Mark thought this might be due to that area getting more rain than the area we are in now. From this site, we can see Sunfish Island. During the winter, there were reports of about 2 to 3 feet of sea grass mixed with debris. Another large outfall [is located] at the Power Street Fishing Pier at the end of Shoreline [Boulevard], but there was not much debris. From here we went across Harbor Bridge to the Nueces Bay Causeway, on the south side, at the water's edge. There was garbage everywhere; garbage bags left full of trash, many bottles, food wrappers, ice bags, diapers, cardboard, lure packages, monofilament, covering approximately 45 percent of the area. Rene said that during the winter, this area is completely covered with trash. At Corpus Christi beach, near North Beach, there was not much either, just a few bottle tops and cans. What seems to be happening is that the debris from the north side of Corpus Christi Bay is being blown to the South end, thus it does not have as much, and as mentioned earlier, during the winter, the prevailing winds carry debris from across the bay.

Back in the office, Mark is compiling a yearly report of man hours, expenses and approximate amounts of trash that they have been collecting. The average is about 6 hours per month with 2 men at 25$ per hour to tow things out of the water and dipping things out from the boat. For July of 1995, 18 workers, 187 man-hours at 5.50$ per hour cost $1028.50. This cost does not include equipment, or the community service, the McKenzie Annex jail workers (a division of the Corpus Christi Sheriff's Office) and the Sea Scout members that pick up trash for free at least once a week.

Judge Robert Blackmon is the head of the Sea Scouts, a group for teens, 14 to 20, [who] can learn citizenship, character, and sail a boat. Mr. Blackmon is the skipper of the *Sea Explorer I*, also known as the *Calamari*, which is docked at the Corpus Christi Marina. To pay for the slip, the kids meet once a month to clean up the marina equivalent of 25 man hours. The Bay Yacht Club is their sponsor, and usually get 14 to 20 kids each time. They also race the *Calamari* each Wednesday, being the "second fastest boat in their division". He has been doing this for 6 years and doesn't think the amount of trash has increased or decreased. Blackmon's group has found about the same things that Mark and Rene mentioned, although he thought there weren't as many syringes as they [the Marina personnel] thought. The Judge thought they were mostly from drug users because his group always found at least one per trip on the beach in front of the coliseum.

5 DISCUSSION

5.1 Three Surveys

Marine debris data surveys in the CCBNEP study area done by UTMSI, the CMC volunteers, and PINS give diverse results with some areas of agreement and some disparities. Perhaps the key problem in assessing the extent of marine debris in the area, the sources of debris, and especially the historical trends, is the method employed by the surveyors. To summarize the aspects of marine debris which survey designs must address:

- The extreme variability of debris quantities on any beach or shoreline as a function of time.
- The considerable effect which environmental mechanisms such as winds, tides, currents, rainfall, geography, topography, and burial by sediment, have on the fate of debris.
- The multiple sources of many common items concentrated in one location by the environmental forcing.

In assessing the validity of a debris survey, one must take into consideration:

- The choice of survey location, length of the transect, frequency of survey repetitions, and overall duration of the project.
- Whether the location is representative of a mean accumulation of debris so that results might be considered typical of the area as a whole.
- The purpose in doing the survey, e.g., to assess standing stock, accumulation rates, trends, identify sources, promote public awareness, reduce the problem, prosecute the offenders.
- The use of volunteers or experienced surveyors.

We comment on the genesis, methodologies and purpose behind each of the three surveys studied here. Criticism here of any of the efforts at assessing marine debris in the CCBNEP area (including our own) are based on scientific considerations and are not meant to detract from the considerable effort and usefulness of these programs in public outreach and education. Our objective was to answer the question: "Can existing data provide reliable information on (a) current status and (b) historical trends in the incidence of marine/bay debris in the Corpus Christi Bay National Estuary Program (CCBNEP) study area? The answer to the first (a) is a qualified "Yes"; to the second (b), almost certainly, "No".

5.1.1 CMC/TGLO

The Center for Marine Conservation (CMC) and the Texas General Land Office (TGLO) have pioneered the use of volunteers to clean beaches of marine debris and, at the same time, gain some information on the makeup of the debris. The semi-annual national (and international) beach cleanups were started in Texas in 1986. The data collected and tabulated were not designed to give statistically supportable information on quantities and trends in the resource. They support CMC's main purpose which is public education. As such they have been invaluable in drawing world-wide attention to the marine debris problem, helped in reducing the dumping of debris into the sea, promoted laws protecting the oceans and their enforcement, changed industrial packaging techniques, promoted recycling, and shown hundreds of thousands of people of all ages, especially the young, the seriousness of the littering of the coastal environment. Annual publication of the cleanup results and the high level of media exposure given to the cleanups inevitably lend credence to the numbers amassed on data cards filled out by the volunteers. No environmental data is collected. CMC has published several booklets and pamphlets on conducting marine debris surveys for the general public, but quality control is lacking.

5.1.2 UTMSI

The various UTMSI surveys evolved over many years. Initially, only anecdotal records were kept on debris observed on Mustang Island gulf beach while conducting an unfunded survey designed to monitor bird populations and increasing human usage of the beach. Sporadic surveys were made to count some debris items, starting in 1979, but it was not until 1983 that a regular attempt was made to estimate items of debris, both man-made and natural. The idea was to study the seasonal changes in beachings of debris, how long material remained on the beach, and whether any effect on the bird population could be discerned. Counts of debris were started in 1987 along the same stretch of beach, but done at different times than the regular bird surveys. This was in response to the increased national interest in trash on beaches, the impending MARPOL agreement, and the initiation of the CMC surveys, to which the first author contributed ideas on how to monitor debris. Some funding was provided by the Texas A&M Sea Grant Program, especially to study the ingestion of plastic by marine turtles frequently found dead on the beach. Three sites were chosen to collect and analyze debris which could not be assessed from by counting. We attempted to continue the surveys when funding expired, but they became sporadic in 1990. However, we decided to add five items of debris to the continuing bird survey (the targeted item study, which continues to date). With funding from MMS, the MARPOL study was resumed in 1991 until 1992. This included a special container survey on San Jose Island designed to identify the make up and sources of marine debris.

With the exception of the debris collections and the container study, all these surveys assess standing stock of debris on the beach. They have been compromised by changing beach-cleaning practices. Although trends in the standing stock have been deduced from the data sets, the main objection is that debris is not removed during the survey, so recounting is probable, and conclusions on trends in the sources of debris cannot be statistically supported. The UTMSI surveys have extensive supporting data on environmental controlling mechanisms, which has contributed to the understanding of debris pathways. The counts rely on the skill of the observers who have long-standing experience. Built-in systematic errors may be present, but should be constant. Quality control may be lacking in these surveys although occasional efforts have been made. The length and frequency of the surveys (11.83 km and bi-daily; daily in 1984) allow us to observe the extreme variability in debris quantity with time. The duration of the counts (targeted items counted using same method since 1987, estimates since 1983) gives an idea of the long-term trend in standing stock. The studies are not, however, classically designed hypotheses-testing efforts.

5.1.3 PINS

The Padre Island National Seashore has been doing marine debris surveys since 1988. The main purpose is to reduce the quantity of debris on the National Seashore gulf beach. Such debris is a source of numerous complaints by visitors to the park and is a hazard to the well-being and enjoyment of the million or so annual visitors. By identifying sources of debris to this remote beach, much of which is accessible only by four-wheel drive vehicles, PINS hopes to accomplish a reduction in beach trash. They work in conjunction with and have obtained financial support from other federal agencies and from state agencies. Since March 1994 they have settled on a daily survey counting several targeted items along a 16-mile stretch of the beach. PINS methodology for this survey has been determined from experience gained on previous efforts and is done under carefully controlled conditions. The personnel doing the surveys are employees of the Park Service and have had long-term experience in debris monitoring. Quality control is good. They stress the importance of environmental conditions which control the distribution of debris but have not published any such data in their report. The mandate to identify and prosecute violators of MARPOL in various offshore industries may bias the PINS data set, although there is no doubt that the sources of much of the debris on PINS beaches comes from these sources. The PINS surveyors have not done any trend analysis and, in general, are highly critical of other survey methods, in particular the quarterly surveys done at National Seashores, including their own. They do relate seasonal variation to activities by the offshore shrimping and oil industries.

5.2 Comparison of Data from the Three Surveys

To illustrate the differences and similarities between the three surveys, we tabulate the overall densities of four items of marine debris (Table 14) as determined from the data.

Table 14. Comparison of densities of five debris items for the UTMSI, CMC, and PINS surveys: n=number of surveys done in the period shown; d=distance covered. Values in the data columns are number of items per kilometer. Shaded columns indicate surveys which are coincidental in time.

ITEM	UTMSI 94/95 n=101 d=11.83km	UTMSI 88-95 n = 857 d=11.83km	CMC 86-94 n=9 d = 62.21km	PINS 94/95 n= 365 d = 25.74km
MILK JUGS	0.75	1.51	51.37	0.53
EGG CARTONS	0.13	0.51	17.68	0.15
GREEN BOTTLES	0.24	1.01	43.63	0.35
5-GAL PAILS	0.09	0.21	10.82	0.04
BEVERAGE CANS	2.00	2.05	94.41	----

The first two columns show the UTMSI targeted item data densities. On the left are densities calculated from 101 observations made from March 1994 through February 1995 to compare directly with the PINS data. The second column shows densities using all 857 observations since 1988. The second column is densities calculated from the nine CMC September surveys done from 1986 through 1994, and the third column is calculated from the 365 PINS surveys done in 1994/1995. Note the close similarity between UTMSI column 1 and PINS densities and the extreme difference in the CMC densities. Note that over the longer time period, the UTMSI densities are higher by a factor of about two which may indicate the overall reduction in these items in recent years.

The similarity between UTMSI and PINS 1994/95 data belies the contention that it is essential to remove debris from the survey site. If, as PINS contends (Miller correspondence to the CMC National Marine Debris Program), any one day is indicative of only that day's accumulation of debris, one would expect considerable differences in calculated densities. In fact, one could deem it unnecessary to remove the debris counted, as natural forces will remove it and replace it with a new batch the next day. This is, of course, a simplification, and the argument between the efficacy of various methods to assess accumulation rates and trends will continue. Nonetheless, it is satisfying to see that the two most carefully conducted surveys yield similar results. Yet these densities are really quite small (less than one milk jug per kilometer for example) and tends to trivialize the visual impact of what appears to be thousands of debris items littering our beaches at any one time. It is also puzzling in light of the CMC methodology workshop's determination that a debris item cannot be used to statistically evaluate trends unless it is present in densities of 20 or more per kilometer.

What about the disparity in the CMC volunteer data densities which are orders of magnitude larger? It is doubtful that the counts of such items as pails are orders of magnitude in error, although Amos (1993b) did find large errors in counting by volunteers of some easy-to-count items. It is more probable that the thousands of volunteers collect debris which has accumulated over long periods of time, especially at collection points such as jetties, groins, dunes, marinas, boat ramps, etc. Again, this shows that marine debris does accumulate in places and locations where other, more targeted, surveys such as UTMSI's and PINS' do not count. Therefore, in evaluating the validity of any survey, its purpose must be taken into account. The ultimate goal of doing any survey must indirectly be to eliminate marine debris and put the surveyors out of business. Man-made debris should not be part of the marine environment. Surveys designed to measure trends are quite different from those whose purpose is to measure effects on wildlife, social ramifications, public education, or law-enforcement.

Several types of marine and bay debris are of particular concern because of their effect on human, animal, and plant communities. Marine animals have been found entangled in monofilament line, six-pack rings, onion sacks, netting, polypropylene ropes, plastic bags, and plastic fiber strapping bands (Plotkin and Amos, 1993). Small plastic and styrofoam pieces, plastic pellets, plastic bags, "peanut" packing material have been found in the stomachs and guts of marine animals. Large plastic sheeting and large appliances can cover bottom sediments, affecting benthic animals and sea grasses, and chemical containers with contents intact, or residue of contents still inside are hazardous to both people and marine animals. Often these are unlabeled or mislabeled. Medical waste, glass and metal items also present a hazard to beachgoers, while floating items can cause damage to boats and people engaged in watersports. We feel that all items of litter and garbage on shorelines or floating in the waters are aesthetically displeasing and affect the economic well-being and reputation of a community with a substantial tourist industry and one which attracts residents because of the lure of its bays and beaches.

6 RECOMMENDATIONS

It became clear from the outset of this project that the bay shorelines which make up the Corpus Christi Bay National Estuary study area have been essentially ignored by marine debris surveyors. We recommend that the lack of information on bay debris and general lack of statistical control on beach litter surveys be remedied by some properly-designed surveys. The Committee on Marine Debris has recommended that a national methodology for beach surveys be implemented at a number of sites to determine trends in beach debris. Texas has been selected as one of the initial regions. We recommend that CCBNEP pursue this effort and seek a site or sites within the study region for these monthly surveys which will utilize **trained** volunteers.

However, we believe that the present groups of volunteers who come to clean the beach twice every year be better equipped to fill in the data cards with some measure of accuracy. To do this, we recommend that CCBNEP make contact with some of the area captains and, using local experts, do some training with the goal of getting a higher quality control on the data collected. We should encourage the CMC and TGLO to select a bay survey site to add to the list of sites presently cleaned. Some sites are already being cleaned, such as "Charlies Pasture" in Port Aransas. We also urge the TGLO to make better use of the data collected during the "Great Texas Trashoff" cleanups done every April. The data cards should be tallied by experienced people and not discarded as has been the practice in the past. We recommend that a local marine debris workshop be held under the auspices of the CCBNEP so that experts and volunteers alike can discuss the complex aspects of monitoring debris. This would also give a chance for the experts to discuss among themselves the sometimes contentious issues regarding the design and purpose of debris monitoring.

On another level, we note that two sites, on San Jose Island, and the Padre Island National Seashore have been chosen by the CMC National Marine Debris Program as one of their pilot locations, upon which the national methodology will be modeled. The surveyors will be students from a Corpus Christi high school and they will do monthly surveys. We are somewhat concerned about this choice of the San Jose site because the part of the beach where the students will have access accumulates an anomalously high rate of debris due to its proximity of the jetty. We recommend that CCBNEP urge the National Marine Debris Program coordinator to consider doing one or more bay-side survey in addition to the San Jose survey. We also recommend that a close liaison be established between the various local beach-cleanup captains to assure a better quality control over the data collected from the valuable resource of thousands of concerned citizens who spend their time cleaning the beach.

To aid in identifying sources of bay debris in particular, we recommend that a complete inventory of sites of potential input of debris to the bays should be compiled in one place, an effort started here with a review of boat ramps, and some industrial and residential complexes. The list should include sewer and storm-drain outfalls, creeks and streams, waterside parks, and roadways bordering waterways and bays, and should be put in both tabular and GIS formats.

7 REFERENCES

Amos, A.F., M.G. Langseth, Jr. and R.G. Markl 1972. Visible oceanic saline fronts. in *Studies in Physical Oceanography*, Vol 1, A.L. Gordon, Ed., Gordon and Breach, London, 48-62.

Amos, A.F. 1993a. Solid Waste Pollution of Texas Beaches: A Post-MARPOL Annex V Study. OCS Study MMS 93-0013, Vol 1(90pp), Vol. 2(214pp).

Amos, A.F. 1993b. Technical Assistance for the Development of Beach Debris Data Collection. UTMSI Tech. Rept 93-005. 45pp.

Battelle Ocean Sciences. 1992. The Study of Floatable Debris in U.S. Waters (Harbor Studies Program (March 1989 through April 1991). Final Data Report to U.S. Environmental Protection Agency Contract No. 68-c8-0105. Work Assignment 3-31. Feb. 28, 1992. Battelle Ocean Sciences, Duxbury, MA. 239p + appendices.

Beebe, W. 1926. *The Arcturus Adventure*. Puntam, N.Y. 439p.

Bourne, W.R.P., and M.J. Imber. 1982. Plastic pellets collected by a prion on Gough Island, central south Atlantic Ocean. *Mar. Poll. Bull.* 13(1): 20.

Carlson, R. 1962. *Silent Spring*. Houghton, Mifflin Company: Boston, 368pp.

CEE (Center For Environmental Education). 1986. Texas Coastal Cleanup Report—1986. CEE, Gulf Coast States Regional Office, Austin, TX. 52 p.

____. 1988. Texas Coastal Cleanup Report: Marine Debris on the Texas Coast—April 1987, September 1987, April 1988, with summary data from other coastal states, recommendations and updates. CEE, Gulf Coast States Regional Office, Austin, TX. 105p + appendices.

CMC (Center for Marine Conservation). 1989. Cleaning America's Beaches: 1988 National Beach Cleanup Results. CMC, Washington, DC. 179p + appendices.

____. 1990. Cleaning North America's Beaches: 1989 Beach Cleanup Results. Center for Marine Conservation, Washington, DC. 286p + appendices.

____. 1991. Cleaning North America's Beaches: 1990 Beach Cleanup Results. Center for Marine Conservation, Washington, DC. 254p + appendices.

____. 1992. International Coastal Cleanup Results. Center for Marine Conservation, Washington, DC. 442p + appendices.

____. 1993. 1992 National Coastal Cleanup Results. Center for Marine Conservation, Washington, DC. 314p + appendices.

____. 1994. 1993 National Coastal Cleanup Results. Center for Marine Conservation, Washington, DC. 262p + appendices.

____. 1995. 1994 National Coastal Cleanup Results. Center for Marine Conservation, Washington, DC. 312p + appendices.

____. 1996. National Marine Debris Monitoring Program: Final Report. Center for Marine Conservation, Washington, DC. 38p.

Cooke, A.J., and T.R. Dixon. 1977. Discarded containers on a Kent Beach. *Mar. Poll. Bull.* 8(5): 105-108.

Cole, C.A., J.P. Kumer, D.A. Manski, and D.V. Richards, eds. 1990. Annual Report of National Park Marine Debris Monitoring Program: 1989 Marine Debris Survey. Tech. Rept NPS/NRWV/NRTR-90/04.

GBNEP. 1993. Sources and Distribution of Debris in the Galveston Bay Estuary. Report on Galveston Bay National Estuary Program to EPA and Texas Natural Resources Conservation Commission (Project #CE-006550-01, A.M. Morgan and W.Y. Lee, Principal Investigators). Texas Parks and Wildlife Dept. Publ. GBNEP-35, September 1993. 36p.

Geyer, R.A. and C.P. Giammona 1980. Naturally occurring hydrocarbons in the Gulf of Mexico and Caribbean Sea. In: *Marine Environmental Pollution 1. Hydrocarbons*. R.A. Geyer, ed. Elsevier Oceanography Series, 27a. pp 37-105. Elsevier Scientific Publishing Co: Amsterdam.

Goldberg, E.D. 1976. *The Health of the Oceans*. 172 pp. The UNESCO Press: Paris.

Harwood, M. 1976. *The View from Great Gull.* Clarke, Irwin and Co. Limited: Toronto and Vancouver. 139 p.

Hayward, S.J., V. H. Gomez and W. Sterrer. 1981. *Bermuda's Delicate Balance*. Island Press: Hamilton, Bermuda. 402 p.

Heyerdahl, T. 1971. *The Ra Expeditions*. Translated by P. Crampton. Doubleday: Garden City: NY. 341pp.

Hollin, D.H. 1995. *Marinas Along the Texas Gulf Coast. A directory*. Texas A&M University Sea Grant College Program Publication TAMU-SG-81-502. 28p.

Manski, D.A., W.P. Gregg, C.A. Cole and D.V. Richards. 1991. Annual report of National Park Marine Debris Monitoring Program: 1990 Marine Debris Surveys. Tech. Rep. NPS/NRWV/NRTR-91/07.

Matthews, W.H, F.E. Smith and E.D. Goldberg, eds. 1971 *Man's Impact on Terrestrial and Oceanic Ecosystems*. MIT Press: Cambridge, MA. 540p.

Maraniss, L. 1989. All About Beach Cleanups: a helpful guide to planning a beach cleanup. Center for Marine Conservation, Washington, D. C.

McAlister, W.H. and M.K. McAlister. 1993. *Matagorda Island.* University of Texas Press: Austin, Texas. 354 p.

Miller, J.E., S.W. Baker and D.L. Echols. 1995. Marine Debris Point Source Investigation 1994-1995. Padre Island National Seashore. U. S. Dept. Interior, National Park Service. 40p.

MIT. 1970. *Man's Impact on the Global Environment*. 319 pp. MIT Press: Cambridge, MA.

NAS/NAE. 1970. *Wastes Management Concepts for the Coastal Zone*. National Academy of Sciences, National Academy of Engineering, Washington, D.C. 126p.

NOAA. 1981. The IXTOC Oil Spill: The Federal Scientific Response. C.H. Hooper, ed. NOAA Hazardous Materials Response Project, Boulder, CO. 202 p.

Pequegnat, L.H. 1979. Pelagic tar concentrations in the Gulf of Mexico over the South Texas continental shelf. *Contributions in Marine Science* 22: 31-39.

Smith, S.C. 1857. *Chili Con Carne: the Camp & the Field.*

Shearer Publishing. 1988. *The Roads of Texas*, Shearer Publishing, Fredricksberg, Texas. 170pp.

TPWD. 1995. List of Boat Ramps (unpublished list)

UTMSI. 1987. Window on the Sea, The University of Texas, Marine Science Institute, 39p.

APPENDIX A—LITERATURE ON MARINE/BAY DEBRIS

A.1 Articles in Scientific Literature and Reports

A.1.1 Marine/Bay Debris

Aizawa, M. and A. Satou. 1990. Disposition and recycling of plastic products including used nets. *In* Proceedings, Second International Conference on Marine Debris. 2-7 April 1989, Honolulu, Hawaii. R.S. Shomura and M.L. Godfrey, eds. U.S. Department of Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154: 935-943.

Amos, A.F. 1987. Debris and litter on a south Texas Gulf beach: long-term study. Plenary Session, Proceedings, 7th Ann. Gulf of Mexico Inform. Trans. Mtg., USDI/MMS, OCS Rep. MMS87-0058, 15-24.

____. 1988. Forward. *In* Texas Coastal Cleanup Report, CEE, 9-10.

____. 1989. Litter and debris on coastal bend gulf beaches. *Coastal Bend Medicine* 29(3):14-15.

____. 1990. Portrait of a Barrier Island Beach. 1990. *In* Proceedings, Second International Conference on Marine Debris. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154(2): 1197.

____. 1993. Solid waste pollution of Texas beaches: a post-MARPOL Annex V study. OCS Study MMS 93-0013. Vol 1(90p), Vol. 2(214p).

____. 1993. Technical assistance for the development of beach debris data collection. Univ. of Texas Marine Science Institute Tech. Rept. 93-005. 45p.

Amos, A.F. and P.T. Plotkin. 1989. Anthropogenic and natural debris on a South Texas barrier island beach. *In* Proceedings, Second International Conference on Marine Debris. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154(1): 367-368.

Andrady, A.L. 1990. Environmental degradation of plastics under land and marine exposure conditions. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.S. Shomura and M.L. Godfrey, eds. U.S. Dept. Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154: 848-869.

Anonymous. 1982. The number and origin of dead marine seabirds found on Monterey Bay beaches in 1980 and 1981. *Calif. Fish and Game.* Unpublished Report.

Anonymous. 1987. Cleaning up Chesapeake Bay-Cooperating for better management to protect the land and the bay. *Soil and Water Conserv. News.* 8: 4-9.

Austin, H.M., and P.M. Stoop-Glas. 1977. The distribution of polystyrene spheres and nibs in Block Island Sound during 1972-1973. *Chesapeake Sci.* 18: 89-92.

Balazs, G.H. 1985. Impact of ocean debris on marine turtles: entanglement and ingestion. *In* Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November, 1984, Honolulu, HI. R.S. Shomura and M.L. Godfrey, eds. NOAA Tech. Memo. NOAA-TM-NMFS-SWFC-54: 387-429.

Barros, C.A. and N.B. Barros. 1991. The impact of debris on the Florida manatee. *Mar. Poll. Bull.* 22(10): 508-510.

Bean, M.J. 1985. United States and International Authorities Applicable to Entanglement of Marine Mammals and Other Organisms in Lost or Discarded Fishing Gear and Other Debris. Final Report for the Marine Mammal Commission, Contract MM2629994-7. NITS PB85-160471. 65 p. (A04)

Bean, M.J. 1987. Legal strategies for reducing persistent plastics in the marine environment. *Mar. Poll. Bull.* 18 (6b): 357-360.

Boomsma, J.J.I. 1993. Establishing scientific guidelines for the sampling and source identification of beach debris: a pilot survey. Unpublished Thesis, Florida Institute of Technology, Melbourne, Florida.

Bourne, W.R.P., and M.J. Imber. 1982. Plastic pellets collected by a prion on Gough Island, central south Atlantic Ocean. *Mar. Poll. Bull.* 13(1): 20.

Bourne, W.R.P. and G.C. Clark. 1984. The occurrence of birds and garbage at the Humboldt front off Valparaiso, Chile. *Mar. Poll. Bull.* 15(9): 343-334.

Brillinger, D.R. 1994. Trend analysis: time series and point process problems. *Environmetrics* 5: 1-19.

Bruner, R.G. 1990. The plastics industry and marine debris: solutions through education. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.S. Shomura and M.L. Godfrey, eds. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154: 1077-1089.

Burger, J. 1988. Effects of demolition and beach clean-up operations on birds on a coastal mudflat in New Jersey. *Estuar. Coast. Mar. Sci.* 27(1): 95-108.

Burnham, K.P., D.R. Anderson, and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monographs*, No. 72.

Carpenter, E.J. 1976. Plastics, pelagic tar, and other litter. *In* Strategies for Marine Pollution Monitoring, E.D. Goldberg, ed., Wiley: N.Y. p.77-89.

Carpenter, E.J., S.J. Anderson, G.R. Harvey, H.P. Miklas and B.B. Peck. 1972. Polystyrene spherules in coastal waters. *Science* 178(4062): 749-750.

Carr, A. 1987. Impact of nondegradable marine debris on the ecology and survival outlook of sea turtles. *Mar. Poll. Bull.* 18(6B): 352-356.

Carson, R. 1962. *Silent Spring*. Houghton, Mifflin Company: Boston, 368pp.

CEE (Center For Environmental Education). 1986. Plastics in the Ocean: A Special Report. CEE, Gulf Coast States Regional Office, Austin, TX.

____. 1986. Texas Coastal Cleanup Report—1986. CEE, Gulf Coast States Regional Office, Austin, TX. 52 p.

____. 1987. The Gulf of Mexico as a Special Area under MARPOL Annex V: Report Compiling Information in Support of Designation. Draft for consideration by United States Delegation to the International Maritime Organization. Prepared for the Texas General Land Office. 105p + appendices.

____. 1988. Texas Coastal Cleanup Report: Marine Debris on the texas Coast—April 1987, September 1987, April 1988, with summary data from other coastal states, recommendations and updates. CEE, Gulf Coast States Regional Office, Austin, TX. 105p + appendices.

Clarke, R.B. 1986. *Marine Pollution*. Clarendon Press: Oxford. 215p.

CMC (Center for Marine Conservation). 1989. Cleaning America's Beaches: 1988 National Beach Cleanup Results. CMC, Washington, DC. 179p + appendices.

____. 1990. Cleaning North America's Beaches: 1989 Beach Cleanup Results. Center for Marine Conservation, Washington, DC. 286p + appendices.

____. 1991. Cleaning North America's Beaches: 1990 Beach Cleanup Results. Center for Marine Conservation, Washington, DC. 254p + appendices.

____. 1992. Development and Evaluation of Demonstration Programs to Involve Local Groups in the Monitoring and Reporting of Marine Debris. Center for Marine Conservation, Washington, DC.

____. 1992. International Coastal Cleanup Results. Center for Marine Conservation, Washington, DC. 442p + appendices.

____. 1993. 1992 National Coastal Cleanup Results. Center for Marine Conservation, Washington, DC. 314p + appendices.

____. 1993. 1992 International Coastal Cleanup Results. Center for Marine Conservation, Washington, DC. 201p + appendices.

____. 1994. 1993 National Coastal Cleanup Results. Center for Marine Conservation, Washington, DC. 262p + appendices.

____. 1994. Florida Coastal and Inland Shoreline Litter Pilot Survey; Appendix B. The Florida Litter Survey: 1994. Florida Center for Solid and Hazardous Waste Management, Gainesville, FL.

____. 1995. 1994 National Coastal Cleanup Results. Center for Marine Conservation, Washington, DC. 312p + appendices.

Coco, M. 1988. Plastics: concerns about a modern miracle. *EPA Journal*. 14(1): 40-42.

Cole, C.A., J.P. Kumer, D.A. Manski and D.V. Richards, eds. 1990. Annual Report of National Park Marine Debris Monitoring Program: 1989 Marine Debris Survey. Tech. Report NPS/NRWV/NRTR-90/04.

Cole, C.A., W.P. Gregg, D.V. Richards and D.A. Manski. 1992. Annual Report of National Park Marine Debris Monitoring Program: 1991 Marine Debris Surveys with Summary of Data from 1988 to 1991. Tech. Report NPS/NRWV/NRTR-92/10.

Conner, D.K. 1988. The tightening net of marine plastics pollution. *Environ*. 30: 16-17.

Cooke, A.J. and T.R. Dixon. 1977. Discarded containers on a Kent beach. *Mar. Poll. Bull.* 8(5): 105-108.

Culliton, T.J., M.A. Warren, T.R. Goodspeed, D.G. Remer, C.M. Blackwell and J.J. McDonough III. 1990. 50 Years of Population Change Along the Nation's Coasts, 1960-2010. Second Report of a Coastal Trends Series. U.S. Department of Commerce, NOAA-NOS.

Cundell, A.M. 1993. Plastic materials accumulating in Narragansett Bay. *Mar. Poll. Bull.* 4: 187-188.

Day, R.H., D.H.S. Wehle and F.C. Coleman. 1985. Ingestion of plastic pollutants by marine birds. *In* Proceedings, Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984, Honolulu, HI. R.S. Shomura and H.O. Yoshida, eds.), pp. 344-386. U.S. Dept. Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SWFC-**54 ???**

Dixon, T.R. and T.J. Dixon. 1981. Marine litter surveillance. *Mar. Poll. Bull.* 12(4): 289-295.

____. 1983. Marine litter distribution and composition in the North Sea. *Mar. Poll. Bull.* 14(4):145-147.

Dolah, R.F. Van, V.G. Burrell, Jr. and S.B. West. 1980. The distribution of pelagic tars

and plastics in the South Atlantic Bight. *Mar. Poll. Bull.* 11(12): 352-355.
Downing, J.A. and W.L. Downing. 1992. Spatial aggregation, precision and power in surveys of freshwater mussel populations. *Can. J. Fish. Aqu. Sci.* 49: 985-991.
Duedall, I.W. 1990. A brief history of ocean disposal. *Oceanus* 33(2): 29-38.
Ebbesmeyer, C. and W.J. Ingraham, Jr. 1992. Shoe spill in the North Pacific. *Eos* 73(34).
EPA (Environmental Protection Agency). 1989. Designation of the Gulf of Mexico as a Special Area under MARPOL Annex V. Prepared by The Oceanic Society for the 27th Session of the Marine Environment Protection Committee of the International Maritime Organization, 13-17 March, 1989. U.S. EPA, Gulf Initiative Program Office.
____. 1992. Turning the Tide on Trash: A Learning Guide on Marine Debris. U.S. EPA, Office of Water, Washington, DC. EPA842-B-92-003.
____. 1992. Plastic Pellets in the Aquatic Environment: Sources and Recommendations. Final Report. U.S. EPA, Office of Water, Washington, DC. EPA842-B-92-010.
____. 1994. Status of Efforts to Control Aquatic Debris. U.S. EPA, Office of Water, Washington, DC. EPA-842-K-94-002.
Eyraud, J. and J. Canton. 1988. Development of Estimates of Garbage Disposition in the Maritime Sectors. Final Report. Submitted to U.S. Dept. Transportation by Eastern Research Group, Inc.
Faris, J. and K. Hart. 1995. Seas of Debris: A Summary of the Third International Conference on Marine Debris. N.C. Sea Grant College Program. UNC-SC-95-01.
Franeker, J.A. van. 1985. Plastic ingestion by the North Atlantic Fulmar. *Mar. Poll. Bull.* 16(9): 367-368.
Friligos, N. 1981. An index of marine pollution in the Saronikos Gulf. *Mar. Poll. Bull.* 12(3): 96-99.
Fuentes, R.A. 1989. Handling medical waste. *Coastal Bend Medicine* 29(3): 20-22.
Furness, B.L. 1983. Plastic particles in three Procellariiform seabirds, from Benguela Current, South Africa. *Mar. Poll. Bull.* 14(8): 307.
____. 1985. Plastic particle pollution and accumulation by Procellariiform seabirds at Scottish colonies. *Mar. Poll. Bull.* 16(3): 103-105.
Garner, G.C. 1989. Dumping garbage at sea. *Coastal Bend Medicine*. 29(3): 10-11.
Gay, K. 1990. *Water Pollution*. Franklin Watts: New York.
GBNEP. 1993. Sources and Distribution of Debris in the Galveston Bay Estuary. Report on Galveston Bay National Estuary Program to EPA and Texas Natural Resources Conservation Commission (Project #CE-006550-01, A.M. Morgan and W.Y. Lee, Principal Investigators). Texas Parks and Wildlife Dept. Publ. GBNEP-35, September 1993. 36p.
Geyer, R.A., Ed. 1980. *Marine Environmental Pollution: Hydrocarbon*, Volume 1. Elsevier Scientific Publishing Company: New York.
____. 1981. *Marine Environmental Pollution: Dumping and Mining*, Volume 2. Elsevier Scientific Publishing Company: New York.
Gilligan, M.R., R.S. Pitts, J.P. Richardson and T.R. Kozel. 1992. Rates of accumulation of marine debris in Chatham Co., Georgia. *Mar. Poll. Bull.* 24(9): 436-440.
Golik, A. and N. Rosenberg. 1987. Quantitative evaluation of beach tarballs by means of air photographs. *Mar. Poll. Bull.* 18: 289-293.
Goldberg, E. 1976. *The Health of the Oceans*. The UNESCO Press: Paris, France. 172p.

Gramentz, D. 1988. Involvement of loggerhead turtle with plastic, metal and hydrocarbon pollution in the central Mediterranean. *Mar. Poll. Bull.* 19(1): 11-13.

Gregory, M.R. 1978. Virgin plastic granules on southwest Pacific beaches and their possible environmental implications. *New Zeal. J. Mar. Fresh Wat. Res.* 12: 399-414.

____. 1983. Virgin plastic granules on some beaches of eastern Canada and Bermuda. *Mar. Environ. Res.* 10: 73-92.

Harwood, M. 1976. *The View from Great Gull.* Clarke, Irwin and Co. Limited: Toronto and Vancouver. 139 p.

Hayward, S.J., V. H. Gomez and W. Sterrer. 1981. *Bermuda's Delicate Balance.* Island Press: Hamilton, Bermuda. 402 p.

Henderson, J.R. 1984. Encounters of Hawaiian monk seals with fishing gear at Lisianski Island, 1982. *Mar. Fish. Rev.* 46: 59-61.

Heneman, B. 1988. Persistent Marine Debris in the North Sea, Northwest Atlantic Ocean, Wider Caribbean Area, and the West Coast of Baja California. A Report by Center for Environmental Education to U.S. Department of Commerce, MMC-NOPPO-NOAA.

Horsman, P.V. 1982. The amount of garbage pollution from merchant ships. *Mar. Poll. Bull.* 13(5): 167-169.

Interagency Task Force. 1988. Report of the Interagency Task Force on Persistent Marine Debris, NOAA, Washington, DC.

Kartar, S., R.A. Milne and M. Sainsburg. 1973. Polystyrene waste in the Severn Estuary. *Mar. Poll. Bull.* 4: 144.

Kauffman, M. 1992. Launching a Recycling Program at Your Marina. Coastal Resources Center.

Kullenberg, G. 1986. The IOC programme on marine pollution. *Mar. Poll. Bull.* 17: 341-52.

Laist, D.W. 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. *Mar. Poll. Bull.* 18 (6B): 319-326.

Lecke-Mitchell, K.M., and K. Mullin. 1992. Distribution and abundance of large floating plastic in the north-central Gulf of Mexico. *Mar. Poll. Bull.* 24(12): 598-600.

Lettenmaier, D.P. 1978. Design considerations for ambient stream quality monitoring. *Water Res. Bull.* 14: 884-902.

Lindstedt, D.M., and J.C. Holmes. 1989. Debris is Not Cheese: Litter in Coastal Louisiana. *In* Proceedings, Sixth Annual Symposium on Coastal and Ocean Management, pp. 1297-1310.

Lukens, B. 1985. Unpublished Letter to H.P. Sieverding, Regional Supervisor, Leasing and Environment, Minerals Management Service. Letter concerning trash and zonation on Padre Island National Seashore.

Manski, D.A., W.P. Gregg, C.A. Cole and D.V. Richards. 1991. Annual Report of National Park Marine Debris Monitoring Program: 1990 Marine Debris Surveys. Tech. Rep. NPS/NRWV/NRTR-91/07. 40p.

Maraniss, L. 1989. All About Beach Cleanups: A Helpful Guide to Planning a Beach Cleanup. Center for Marine Conservation, Washington, D.C. 39p.

MMC (Marine Mammal Commission). 1995. Entanglement of Marine Life in Marine Debris, Including a Comprehensive List of Species with Entanglement and Ingestion Records, (manuscript) Marine Mammal Commission, Washington, DC.

____. 1990. Impacts of Marine Debris. Annual Report of the Marine Mammal Commission, Calendar Year 1989, A Report to Congress. 31 January. Marine Mammal Commission, Washington, DC. 228p.

____. 1991. Entanglement in Marine Debris. Annual Report of the Marine Mammal Commission, Calender Year 1990. A Report to Congress. 31 January. 270p.

____. 1992. Impacts of Marine Debris. Annual Report to Congress, 1991. Marine Mammal Commission, Washington, DC. 31 January. 227p.

____. 1993. Impacts of Marine Debris. Annual Report to Congress, 1992. Marine Mammal Commission, Washington, DC. 31 January. 226p.

____. 1994. Impacts of Marine Debris. Annual Deport to Congress, 1993. Marine Mammal Commission, Washington, D.C. 31 January. 240p.

Matthews, W.H., F.E. Smith and E.D. Goldberg. 1971. *Man's Impact on Terrestrial and Oceanic Ecosystems*. Massachusetts Institute of Technology Press: Cambridge, Mass. 540p.

Meade, N.F., K.M. Drazek and V.R. Leeworthy. 1990. An Economic Perspective on the Problem of Marine Debris. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.S. Shomura and M. L. Godfrey, eds. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154: 777-791.

Merrell, T.R. 1980. Accumulation of plastic litter on beaches of Amchitlea Island, Alaska. *Mar. Environ. Res.* 3:171-184.

____. 1984. A decade of change in nets and plastic litter from fisheries off Alaska. *Mar. Poll. Bull.* 15(10):378-383.

____. 1985. Fishnets and other plastic litter on Alaska beaches. *In* Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 Nov. 1984, Honolulu, HI. R.S. Shomura and H.O. Yoshida, eds. U.S. Dept. Commerce, NOAA Tech. Memo. NOAA-TTM-NMFS-SWFS-54:160-182.

Miller, J.E., S.W. Baker and D.L. Echols. 1995. Marine Debris Point Source Investigation, 1994-1995, Padre Island National Seashore. U.S. Dept. Interior, National Park Service, Corpus Christi, TX. 40p.

MIT. 1970. *Man's Impact on the Global Environment*. 319 pp. MIT Press: Cambridge, MA.

MMS (Minerals Management Service). 1985. Environmental Impact Statement, Proposed Oil and Gas Lease Sales 104 and 105, Gulf of Mexico OCS Region. OCS EIS, MMS 85-0006. 526 p.

____. 1986. Environmental Impact Statement, Proposed Oil and Gas Lease Sales 110 and 112, Gulf of Mexico OCS Region. OCS EIS, MMS 86-0013. 389p + appendices.

____. 1987. Gulf of Mexico Sales 131, 135, and 137. Central, Western and Eastern Planning Areas. OCS EIS/EA, MMS 90-0042. Volumes I and II.

____. 1988. Gulf of Mexico Sales 118 and 122: Central and Western Planning Areas. OCS EIS/EA, MMS 88-0003.

____. 1989. Gulf of Mexico Sales 123 and 125: Central and Western Planning Areas. OCS EIS/EA, MMS 89-0005.

Morell, J.M. 1992. Marine Debris Pilot Monitoring Project for the Greater Caribbean. UNESCO Contract # SC/FIT/218.112.0.

Morris, R.F. 1980. Floating plastic debris in the Mediterranean. *Mar. Poll. Bull.* 11(5):

125.
____. 1980. Plastic debris in the surface waters of the south Atlantic. *Mar. Poll. Bull.* 11(6): 164-165.
NAS (National Academy of Sciences) and National Academy of Engineering (NAE). 1970. *Wastes Management Concepts for the Coastal Zone*. Printing and Publishing Office, National Academy of Science and National Academy of Engineering, Washington D.C. 126p.
NAS. 1975. Assessing Potential Ocean Pollutants. A Report of the Study Panel to the Ocean Affairs Board Commission on Natural Resources, National Research Council.
NOAA (National Oceanographic and Atmospheric Administration). 1981. The IXTOC Oil Spill: the Federal Scientific Response. NOAA Special Report, U.S. Dept. of Comm. C.H. Hooper, ed., 202p.
NRC (National Research Council). 1990. Annual Report. Marine Board, Commission on Engineering and Technical Systems, National Research Council. National Academy Press: Washington, DC.
____. 1991. Annual Report. Marine Board, Commission on Engineering and Technical Systems, National Research Council. National Academy Press: Washington, DC.
____. 1995. Annual Report. Marine Board, Commission on Engineering and Technical Systems. National Research Council. National Academy Press: Washington, DC.
____. 1995. *Clean Ships, Clean Ports, Clean Oceans: Controlling Garbage and Plastic Wastes at Sea*. National Academy Press: Washington, D.C. 355p.
O'Hara, K.J., S. Iudicello and R. Bierce. 1988. A Citizen's Guide to Plastic in the Ocean: More Than a Litter Problem. Center for Marine Conservation, Washington, DC. 95p. + appendices.
____. 1994. A Citizen's Guide to Plastic in the Ocean: More Than a Litter Problem. Center for Marine conservation, Washington, DC. 128p.
Oostdam, B.L. 1984. Tar pollution of beaches in the Indian Ocean, the south China Sea and the south Pacific Ocean. *Mar. Poll. Bull.* 15 (7): 267-270.
Parker, N.R., S.C. Hunter and R.J. Yang. 1987. Development of Methodology to Reduce the Disposal of Non-degradable Refuse into the Marine Environment. KVB, Inc., Engineering and Research Division, January 1987. 89p.
Pearson, E.A., P.N. Storrs and R.E. Selleck. 1969. Waste Discharges and Loadings, Vol. III, Final Report Series, Comprehensive Investigation of San Fransisco Bay. University of California Sanitary Engineering Research Laboratory Publication.
Philipp, R., K. Pond and G. Rees. 1994. Medical wastes increasing on the coastline. *Br. Med. Jr.* 309: 471.
Plotkin, P.T. and A.F. Amos. 1988. Entanglement in and Ingestion of Marine Debris by Sea Turtles Stranded Along the South Texas Coast. *In* Proceedings of the 8th Annual Workshop on Sea Turtle Conservation and Biology. NOAA Tech. Memo. NMFS-SEFC-214; 79-82.
____. 1989. Effects of Anthropogenic Debris on Sea Turtles. *In* Proceedings, Second International Conference on Marine Debris. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154(1): 736-743.
Podolsky, R.H. 1989. Entrapment of sea-deposited plastic on the shore of the Gulf of Maine island. *Mar. Environ. Res.* 27: 67-72.

Prosser, W. 1993. MARPOL V: Responsibilities for Enforcement and International Aspects. *In* Proceedings of the Gulf of Mexico Symposium, 10-12 December 1992, Tarpon Springs, FL. J.D. Jacobson, ed.

Pruter, A.T. 1987. Sources, quanitities and distribution of persistant plastics in the marine environment. *Mar. Poll. Bull.* 18: 344-349.

Ribic, C.A. and L.J. Bledsoe. 1986. Design of Surveys for Density of Surface Marine Debris in the North Pacific. Northwest Alaska Fish. Cent., NMFS-NOAA, Seattle, WA. NWAFC Processed Rept. 86-12, 69 p.

Ribic, C.A. (Chair). 1990. Report of the Working Group on Methods to Assess the Amount and Types of Marine Debris. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.H. Somura and M.L. Godfrey, eds. U.S. Dept. Commerce, NOAA-TM-NMFS-SWFSC-154: 1201-1206.

____. 1991. Design of Shoreline Surveys for Aquatic Litter Pollution. Environmental Research Laboratory, Corvallis, U.S. Environmental Protection Agency, Corvallis, OR.

____. 1995. Design of a National Monitoring Program for Marine Debris. Progress Report, NBS, Madison, Wisconsin.

Ribic, C.A. and L.J. Bledsoe. 1990. Estimating the Density of Floating Marine Debris: Design Considerations. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.H. Shomura and M.L. Godfrey, eds. U.S. Dept. Commerce, NOAA-TM-NMFS-SWFSC-154: 302-308.

Ribic, C.A., T.R Dixon and I. Vining. 1992. Marine Debris Survey Manual. NOAA Tech. Rep. NMFS 108. U.S. Dept. Commerce.

Ribic, C.A. and S.W. Johnson. 1990. Guidelines for the Design of Beach Debris Surveys. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April, 1989, Honolulu, HI. R.S. Shomura and M.L. Godfrey, eds. U.S. Dept. Commerce, NOAA-TM-NMFS-SWFSC-154: 392-402.

Ross, J.B., R. Parker and M. Strickland. 1991. A survey of shoreline litter in Halifax Harbour 1989. *Mar. Poll. Bull.* 22: 245-248.

Ryan, P.G. 1988. Effects of ingested plastic on seabird and evidence from chickens. *Mar. Poll. Bull.* 19(3): 125-128.

Ryan, P.G., A.D. Connell and B.D. Gardner. 1988. Plastic ingestion and PCB's in seabirds: is there a relationship? *Mar. Poll. Bull.* 19(4): 174-176.

Ryan, P.G. and S. Jackson. 1987. The lifespan of ingested plastic particles in seabirds and their effect on digestive efficiency. *Mar. Poll. Bull.* 18(5): 217-219.

Schuler, J.E. 1993. Report on the Implementation Relating to the Prevention of Pollution by Ships Known as MARPOL Annex V. *In* Proceedings of the Gulf of Mexico Symposium, 10-12 December 1992, Tarpon Springs, FL. J.D. Jacobson, ed.

Schuyler, L.R. 1993. Non-point source program and progress in the Chesapeake Bay. *Agri. Eco. Environ.* 46: 217-222.

Scott, C. 1972. Plastics packaging and coastal pollution. *Intl. J. Environ. Studies* 3: 35-36.

Scott, G. 1975. The growth of plastic packaging litter. *Intl. J. Environ .Studies* 7:131-132.

____. 1990. The philosophy and practice of degradable plastics. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.S. Shomura and M.L. Godfrey, eds. U.S. Dept. Commerce, NOAA-TM-NMFS-SWFSC-154: 392-402.

Shaughnessy, R.D. 1980. Entanglement of Cape fur seals with man-made objects. *Mar. Poll. Bull.* 11(11): 332-336.

____. 1985. Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, HI. U.S. Dept. Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154. 580 p.

____. 1990. Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. Volumes I and II. U.S. Dept. Commerce, NOAA-TM-NMFS-SWFSC-154. 1274 p.

Siung-Chang, A.,and A. Deane. 1984. A survey of beach litter in the NW peninsula of Trinidad, W.I. *Proc. Assoc. Isl. Mar. Lab. Caribb.* 18 (9): 9.

Slater, J. 1991. *Flotsam and Jetsam.* The Department of Parks, Wildlife and Heritage, Tasmania, Australia.

Slip, D.J. and H.R. Burton. 1991. Accumulation of fishing debris, plastic litter and other artifacts, on Heard and Macquarie Islands in the Southern Ocean. *Environ. Conserv.* 18: 249-254.

SPI (The Society of the Plastics Industry). 1994. Plastics and Marine Debris. A Report on the Plastics Industry's Response, 4th Edition.

Study of Critical Environmental Problems (SCEP). 1970. *Man's Impact on the Global Environment.* Massachusetts Institute of Technology Press: Cambridge. 319p.

Takehama, S. 1990. Estimation of Damages to Fishing Vessels Caused by Marine Debris, Based on Insurance Estimates. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.S. Shomura and M. L. Godfrey, eds. U.S. Dept. Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154: 792-809.

Taylor, L. 1979. Degradable Plastics: Solution or Illusion? *Chemtech.* 9: 542-548.

Thorjussen, T. 1993. Responsibilities of the Shipping Industry and How They are Being Addressed. *In* Proceedings, Gulf of Mexico Symposium, 10-12 December 1992, Tarpon Springs, FL. J.D. Jacobson, ed.

Trulli, W.R., H.K. Trulli and D.P. Redford. 1990. Characterization of Marine Debris in Selected Harbors of the United States. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.S. Shomura and M. L. Godfrey, eds. U.S. Dept. Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154: 309-324.

Wade, B.A., B. Morrison and M.A.J. Jones. 1991. A study of beach litter in Jamaica. *Car. J. Sci.* 27 (3-4): 190-197.

Wagner, K.D. 1990. Medical Wastes and the Beach Washups of 1988: Issues and Impacts. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.S. Shomura and M. L. Godfrey, eds. U.S. Dept. Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-154: 811-823.

Walker, W.A. and J.M. Coe. 1990. Survey of Marine Debris Ingestion by Odontocete Cetaceans. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.S. Shomura and M.L. Godfrey, eds. NOAA-TM-NMFS-SWFS-154.

Winston, J.E. 1982. Drift plastic—an expanding niche for a marine invertebrate? *Mar. Poll. Bull.* 13(10): 348-350.

Witzell, W.N. and W.G. Teas. 1994. The Impacts of Anthropogenic Debris on Marine Turtles in the Western North Atlantic Ocean. U.S. Dept. Commerce, NOAA-NMFS-SFSC: 335.

Wood, E.J. and R.E. Johannes, eds. 1975. *Tropical Marine Pollution*. Elsevier Publishing Company: New York.

Ye, S. and A.L. Andrady. 1991. Fouling of floating plastic debris under Biscayne Bay exposure conditions. *Mar. Poll. Bull.* 22(12): 608-613.

Yukinawa, M. and S. Mio. 1990. Preliminary Report on the Distributions of Small-sized Marine Debris in Suruga Bay. *In* Proceedings, Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, HI. R.S. Shomura and M.L. Godfrey, eds. NOAA Tech. Memo. NOAA-TM-NMFS-SWFS-154.

Zonfrillo, B. 1985. Petrels eating contraceptives, polythene and plastic beads. *Brit. Birds*. 78: 351-360.

A.1.2 Tarballs

Amos, A.F. 1980. *Longhorn* Reports: The IXTOC Oil Spill, Part I: Field Observations, Jul-Nov. 1979, The Univ. Texas at Austin, Marine Science Institute, Tech. Rept. 284p, 120 figures, 8 tables, appendix.

____. 1980. The oiling of shorebirds on a south Texas barrier island following the IXTOC oil spill. 98th Stated Annual Mtg., *Amer. Ornithol. Union*, Fort Collins, CO, Aug. 12.

____. 1984. Persistence of IXTOC-I Oil Along the South Texas Coast. Proceedings, 4th Ann. Gulf of Mexico Inform. Trans. Mtg., USDI/MMS, OCS Rep. MMS-0026:206-210.

Amos, A.F., S.C. Rabalais and R.S. Scalan. 1983. Oil-filled *Callianassa* burrows on a Texas barrier island beach. *J. Sed. Petrol.* 53(2): 412-416.

Casey, R., A.F. Amos, J. Anderson, R. Koehler, R. Schwarzer and J. Sloan. 1980. Preliminary report on the microplankton and microbenthos responses to the 1979 Gulf of Mexico oil spills (IXTOC I and *Burmah Agate*) with comments on avenues of oil to the sediments and the fate of oil in the column and on the bottom. (Abst.) *Trans. Gulf Coast Assoc. Geolog. Socs*.30: 273-281.

Carpenter, E.J. 1976. Plastics, pelagic tar, and other litter. *In* Strategies for Marine Pollution Monitoring, E.D. Goldberg, ed., Wiley: N.Y. p.77-89.

Dolah, R.F. Van, V.G. Burrell, Jr. and S.B. West. 1980. The distribution of pelagic tars and plastics in the South Atlantic Bight. *Mar. Poll. Bull.* 11(12): 352-355.

Golik, A. and N. Rosenberg. 1987. Quantitative evaluation of beach tarballs by means of air photographs. *Mar. Poll. Bull.* 18: 289-293.

NOAA (National Oceanographic and Atmospheric Administration). 1981. The IXTOC Oil Spill: the Federal Scientific Response. NOAA Special Report, U.S. Dept. of Comm. C.H. Hooper, ed., 202p.

Oostdam, B.L. 1984. Tar pollution of beaches in the Indian Ocean, the south China Sea and the south Pacific Ocean. *Mar. Poll. Bull.* 15 (7): 267-270.

Pequegnat, L.H. 1979. Pelagic tar concentrations in the Gulf of Mexico over South Texas continental shelf. *Contributions in Marine Science* 22: 31-40.

Rabalais, S.C. and R.W. Flint. 1983. IXTOC-1 effects on intertidal infauna of south Texas beaches. *Contributions in Marine Science* 36:23-25

Scalan, R.S. and J.K. Winters. 1980. Quantitation and Organic Geochemical Characterization of Petroleum-like Materials Found on an Undisturbed Beach of the Padre Island National Seashore. Unpublished Report, Univ. Texas at Austin, Marine Science Institute to U.S. Dept. Interior, National Park Service, Santa Fe, New Mexico.

A.2 Unpublished Reports, Pamphlets, Testimonies, and Talks

Abel, H. 1996 Photometric Index of spatial distribution of litter in Port Aransas, Texas. Keep America Beautiful, Inc. Unpublished Report.

Amos, A.F. 1984. Beach Trash: Report to Texas Coastal and Marine Council Committee Meeting, Univ Texas at Austin, Marine Science Institute, Port Aransas, 20 November 1984.

____. 1985. Testimony before the President's Commission on Americans Outdoors: Litter on Texas Barrier Island Gulf Beaches, Univ. Texas at Austin, Marine Science Institute, 12 December 1985.

____. 1990a. Invited Witness Testimony before the Texas House of Representatives Select Committee on Coastal Preservation, Corpus Christi, Texas, 8 February, 1990.

____. 1990b. Seaborne Litter on a South Texas Beach: Origins, Pathways and Fate. 2nd Congress on Marine Sciences, Havana, Cuba, 16-23 June.

____. 1991a. Informing the public via museums about our fragile Texas beaches. Assoc. of Museums Annual Meeting, Corpus Christi, 12 April 1991.

____. 1991b. Effects of Litter on Marine Animals in Texas Waters. Texas Institute of Oceanography, President's Lecture Series, 28 March 1991.

____. 1992. Fifteen Years in the Life of a Gulf Barrier Island Beach. The Gulf of Mexico Program, Gulf of Mexico Symposium, Tarpon Springs, FL. 10-12 December.

____. 1993a. Natural and Anthropogenic Marine Debris in the Gulf of Mexico. Texas A&M Sea Grant College Program, Natural and Anthropogenic Perturbations in the Gulf of Mexico: Evidence and Consequences. College Station, TX. 2 April 1993.

Amos, A.F. and P.T. Plotkin. 1987. Survey and Findings of Beach Debris on Mustang Island, Texas. 8th Ann. Gulf of Mexico Inform. Trans. Mtg., New Orleans, LA. 1-3 December.

CMC, 1995a. Pamphlet, "Underwater Marine Debris Cleanup."

____. 1995b Pamphlet, "National Marine Debris Monitoring Program."

Echols, D. and J. Miller. 1992. National Park Service Padre Island National Seashore Marine Debris Monitoring Plan — 1991 Annual Report. Unpublished. Padre Island National Seashore, Corpus Christi, TX. 22p.

Gillett, M. Environmental Study Guide: Beach Trash at Padre Island National Seashore. Draft Report. Padre Island National Seashore, Corpus Christi, TX.

Hollin, D. and M. Liffmann. 1991. Use of MARPOL Annex V Reception Facilities and Disposal Systems at Selected Gulf of Mexico Ports, Private Terminals and Recreational Boating Facilities. A Report to the Texas General Land Office, September.

Koss, L. 1994. Navy Solid and Plastics Waste Management Program: Status Briefing to the Marine Board, National Academy of Sciences. Annapolis, MD.

Lindstedt, D. 1991. Marine Debris at Fourchon Beach: a Pilot Project. Final Report to the EPA. Louisiana Geological Survey, Louisiana State University, Baton Rouge, LA.

Lukens, W.M. 1985. Hazardous Waste Problem, Padre Island National Seashore. Unpublished Report. Padre Island National Seashore, Corpus Christi, TX. 12p.
____. Where Does the Beach Litter Come From? Is It Really That Big a Problem? Unpublished Report. Padre Island National Seashore, Corpus Christi, TXs. 5p.
Miller, J.E., D.L. Echols and D. Shaver. 1993. Daily Marine Debris Survey for Padre Island National Seashore. Unpublished Report. Padre Island National Seashore, Corpus Christi, TX. 21p.
Miller, J.E. 1993. Marine Debris Investigation, Padre Island National Seashore. Resource Management Division, Padre Island National Seashore, Corpus Christi, TX.
O'Donnell, J. 1988. Plastics in the Marine Environment: Congress Responds. Environment and Energy Study Conference Special Report. U.S. Congress, Washington DC. 9p.
Reggio, V.C. 1993. MMS and Implementation of MARPOL, Annex V. Presentation to Marine Board Committee on Shipboard Waste, National Academy of Sciences, 16 February 1993.
Shaver, D., B. Coffee-Davidson and D. Bienieck. 1991. Marine Debris Survey Report, Padre Island National Seashore, 1989-1990. Unpublished Report. Padre Island National Seashore, Corpus Christi, TX. 23p.
Society of the Plastics Industry, Inc. 1987. Press release on the plastics industry and marine debris.
Society of the Plastics Industry, Inc. 1988. Press release on SPI's sponsorship of a recycling demonstration and beach clean-up. 21 April 1988.
The Oceanic Society. 1989. Designation of the Gulf of Mexico as a Special Area Under MARPOL Annex V. Draft for submission to The 27th Session of the Marine Environment Protection Committee of the International Maritime Organization. 13-17 March 1989. EPA, Gulf Initiative Office. 45p.
Verbanac, P. Padre Island Tar Sampling Project. Unpublished Report. Padre Island National Seashore, Corpus Christi, TX.

A.3 Newspaper Articles and Popular Press

A.3.1 Beach Cleanups

"Texas' beach trash stirs swell of concern." *Houston Chronicle*. July 13, 1986.
"Beach litter spurs cleanup plan." *Austin American-Statesman*. July 20, 1986.
"Panel say coast littered with plastic." The Houston Post. August 15, 1986.
"Local beach cleanup nets 11 tons of trash." *Harte-Hanks Austin Bureau*. February 17, 1987.
"Fighting back against beach pollution." *The Christian Science Monitor*. September 29, 1988.
"5,000 volunteers stash trash." *Corpus Christi Caller-Times*. April 1, 1990.
"Amazing junk is collected by Adopt-a-beach group." *The Journal of the San Juan Islands*. May 16, 1990.
"89 beach cleanup called small victory in ongoing battle." *Corpus Christi Caller-Times*. May 25, 1990.
"Divers, students deep clean jetty waters." *Corpus Christi Caller-Times*. October 4, 1992.
"Youths carry bulk of beach-cleaning load." *Corpus Christi Caller-Times*. August 15, 1995.

"Try beach cleaning: you might write a book." *Corpus Christi Caller-Times*. September 16, 1995.
"Volunteers hit the beaches for Texas cleanup." *Corpus Christi Caller-Times*. September 17, 1995.
"Ingleside project may serve as model in clean-bays effort." *Corpus Christi Caller-Times*. October 4, 1995.

A.3.2 Beach Litter, General

"Tons of gulf trash foul Texas coast." *Austin American- Statesman*. December 14, 1984.
"Litter on Texas coastal beaches: status report and recomendations." *Texas Coastal and Marine Council*. January 1985.
"Sea litter trashes Texas beaches." *Lone Star Sierran*. February, 1985.
"Texas beaches awash in garbage from Gulf." *The Sunday Express-News*. May 3, 1987.
"Texas' trashy shoreline: Garbage collector of Gulf." *Los Angeles Times*. May 3, 1987.
"Our befouled beaches." *Newsweek*. July 27, 1987.
"What to do with our waste." *Newsweek*. July 27, 1987.
"Trashing the Texas coast: the truth, consequences and proposed solutions." *Texas Fisherman*. September/October 1987.
"Currents carry blame for foul beaches." *Austin American-Statesman*. November 9, 1987.
"Beach trash-hats to lightbulbs." *Austin American-Statesman*. April 22, 1988.
"A shore thing." *Alcalde* 76(5):15-18, May/June 1988
"Gulf beaches need special help." *Corpus Christi Caller-Times*. June 2, 1988.
"Don't go near the water." *Newsweek*. August 1, 1988.
"RONdom throughts (sp.) on [the] Dirty Cleaners." *The Vista*. 1(4): July 1989.
"Plastic: the problem that won't go away." *Texas Parks and Wildlife*. 48(7): 34-41. 1990.
"Seashore attracting attention, garbage." *Corpus Christi Caller-Times*. May 18, 1990.
"Waves of trash hit Texas coast." *Chicago Tribune*. June 17, 1990.
"Environmental trash still cluttered up Earth Day." *Corpus Christi Caller-Times*. June 17, 1990.
"Beach chair 1, Sea turtle 0." *The Beachcomber*. August 2, 1991.
"ALO hosts who's who of clean beaches; embarks upon pilot floatable study." *The Sandpaper*. July 17, 1991.
"Drums wash toxic trouble onto island." *Corpus Christi Caller-Times*. October 7, 1992.
"EPA wonders who trashed island." *Corpus Christi Caller-Times*. July 23, 1994.
"Sea debris: troubling trends." *Corpus Christi Caller-Times*. March 31, 1995.
"Shrimpers trashing the local beaches, study says." *CorpusChristi Caller-Times*. Section B. July 26, 1995.
"State program to educate fishermen about litter." *Corpus Christi-Caller Times*. Sept. 7, 1995.
"For those who think they might as well dump: Beware!" *Corpus Christi Caller-Times*. Sept. 25, 1995.
"Beach trash ranges from the exotic to the erotic." *Corpus Christi Caller-Times*. September 27, 1995.

A.3.3 Pollution Regulation

"Ocean-dumping law to affect port." *Corpus Christi Caller-Times*. February 26, 1989.
"Officials to discuss privatizing beach and rural trash pickup." *Corpus Christi Caller-Times*. June 5, 1990.
"Recycling program begins in Calallen." *Corpus Christi Caller-Times*. June 5, 1990.
"State to assume regulation of hazardous waste." *Corpus Christi Caller-Times*. June 17, 1990.
"Ban on dumping plastics at sea credited for cleaner area beaches." *Corpus Christi Caller-Times*. February 27, 1991.

A.3.4 Beach Misclellaneous

"Don't mess with the Gulf either." *Houston Chronicle*. July 15, 1986.
"Texas beaches littered world's refuse." Austin American-Statesman. August 15, 1986.
"Port A resident chronicles life on the shoreline." *Corpus Christi Caller-Times*. November 13, 1988.
"Sand, surf, science." *Corpus Christi Caller-Times*. December 25, 1988.
Kruse, K. 1989. "On the beach with Tony Amos." *Texas Parks and Wildlife* 47(5): 14-19.
"Ideas shared on coastal management." *Corpus Christi Caller-Times*. March 29, 1990.
"Oceanographer monitors Texas coast for debris." *On Campus, the University of Texas at Austin*. October 7, 1991.
"Trash Man." *Project Earth*. November 5, 1991.

A.3.5 Marine Debris, General

"Trash strangling the Gulf of Mexico." *Sentinel*.
"Net murder at sea." *The New York Times*. February 17, 1986.
"Texas' trashy shoreline: Garbage collector of Gulf." *Los Angeles Times*. May 3, 1987.
"Grim harvest." *This World*. October 9, 1988.
"Marine debris: a matter of national concern." *Sport Fishing Bulletin*, No. 397, August 1988.
"Stinker of a problem piles up at port." *Corpus Christi Caller-Times*. June 22, 1989.
"Oil on troubled waters." *The Beachcomber*. August 2, 1991.
"Study gets down to the nitty-gritty." *Houston Chronicle*. October 13, 1991.
"*Pride*'s at sea with flotsam, trash, junk." *New Bay Times*. 1994.

A.3.6 Medical Waste

"Medical waste includes more than beach litter." *Corpus Christi Caller-Times*. July 10, 1989.
"Medical waste subsiding." *Corpus Christi Caller-Times*. July 27, 1991.
"Medical waste washes up in Padre Island." *Corpus Christi Caller-Times*. July, 25, 1991.

A.3.7 Plastics

"The oceans are choking on plastic debris." *The New York Times*. March 1, 1986.

"Plastics seen major problem on beaches." *The Victoria Advocate*. August 15, 1986.
"Plastic perilous in the sea." *The Houston Post*. April 2, 1988.
Weisskopf, S. 1988. "In the sea, slow death by plastic." *Smithsonian* 18(12):58-67.
"Discarded plastic prime ocean killer." *Corpus Christi Caller-Times*. June 29, 1989.
"The plastics industry and marine debris." Pamphlet by The Society of the Plastics Industry, Washington, DC.
"'Plastic jellyfish". *J. Mar. Educ*. 9(1): 24-25.
"More information about plastic debris." *J. Mar. Educ*. 9(1): 20-23.

A.3.8 MARPOL Articles

"Marine life dependent upon MARPOL compliance." *Corpus Christi Caller-Times*. November 27, 1988.

A.4 Newspaper Articles by A. F. Amos

"Observer" weekly column, *Island News* newspaper, Port Aransas, TX (1984-85).
"Island Observer" weekly column, *South Jetty* newspaper, Port Aransas, TX (1986-present).
These issues had part or all of the column devoted to marine debris or tarballs.

A.4.1 Marine Debris

***Island News* 1984**
02 February
23 February
22 March
31 May
07 June
14 June
21 June
05 July
02 August
30 August
13 September
27 September
11 October
18 October
25 October
15 November
22 November
06 December
13 December
20 December
***Island News* 1985**
03 January
21 March
04 April
06 June
20 June
27 June
01 August
19 September
26 September
***South Jetty* 1986**
10 April
24 April
22 May
12 June
24 July
07 August
20 October
***South Jetty* 1987**
30 April
14 May
28 May
18 June
25 June
09 July

23 July
06 August
12 November
17 December
24 December
31 December
***South Jetty* 1988**
14 January
31 March
14 April
28 April
12 May
02 June
07 July
24 November
29 December
***South Jetty* 1989**
02 February
13 April
04 May
11 May
14 December
***South Jetty* 1990**
22 February
15 March
22 March
12 April
24 May
27 September
15 November
Thanksgiving Issue
27 December
***South Jetty* 1991**
18 April
23 May
03 October
14 November
***South Jetty* 1992**
06 February
01 October
***South Jetty* 1993**
25 March
15 April
22 April
13 May
10 November
***South Jetty* 1994**
21 July
22 September
06 October
***South Jetty* 1995**
02 May
27 July

A.4.2 Tarballs

Island News **1984**
01 March
22 March
10 May
31 May
21 June
28 June
16 August
13 September
18 October
13 December
Island News **1985**
10 January
28 March
27 June
01 August
22 August
05 September
South Jetty **1986**
07 August

South Jetty **1987**
14 May
11 June
23 July
03 September
12 November
South Jetty **1988**
23 June
South Jetty **1990**
15 March
22 March
5 April
12 April
19 April
26 April
3 May
24 May
15 November
South Jetty **1991**
18 March

A.5 Audio Visual Material

Trashed Out Texas Beaches [Videorecording]. Texas A&M Seagrant Program, Atlantic City Toxic, Beaches Closed [Videorecording]. Good Morning America. 8/21/87. 3:14.

Tides of Trash [Videorecording]. Padre Island National Seashore.

Conserving America; The Challenge of the Coast [Videorecording]. KQED, Public Broadcast Company. 10/4/89

What about tomorrow? (Green Version) [Videorecording]. Performed by Bill Oliver & Glen Waldeck. 4:36.

Take Pride Gulf-Wide: An Action Plan For A Clean Gulf of Mexico [Videorecording]. Texas General Land Office. Summer, 1991. 18:04.

Beaches, Bays & Estuaries: A Texas Perspective [Videorecording]. Texas General Land Office. September, 1994. 29:00.

Finding Solutions [Videorecording]. Wilson/Brown for EPA Gulf of Mexico Program.

The Oceans [audio recording]. PBS/National Geographic Society Radio Documentary, October 1995.

Morning Edition [audio recording], October 1995

National Public Radio/National Geographic Society, 1995 [audio recording]. Radio Documentary; The Oceans.

A.6 Newsletters

ALO News - Alliance for a Living Ocean
Summer 1991.

Aqua Notes - Louisiana Sea Grant College Program
Vol. 16 No. 2

Coastal Connection - Center for Marine Conservation
Summer 1995

EDF Letter - Environmental Defense Fund Newsletter
Vol. 20 No. 3
Vol. 21 No. 2
Vol. 22 No. 4
Vol. 23 No. 2, 3
Vol. 24 No. 6
Vol. 25 No. 2, 4

Gulf Line - Gulf of Mexico Program
14 May 1993
04 June 1993
06 August 1993
27 August 1993
09 November 1993
August 1994
September 1994
February 1995
August 1995

Gulf Watch - National Association of Conservation Districts and the Gulf of Mexico Program
Vol. 01 No. 1
Vol. 02 No. 3, 4
Vol. 03 No. 1, 2
Vol. 04 No. 2
Vol. 05 No. 6

Horizons - Texas Nature Conservancy
Vol. 15, No. 2

IOCARIBE News - Intergovermental Oceanographic Commission, UNESCO, Cartegena, Columbia
March 1991
June 1991
August 1991
September 1992
September 1994
May 1995

IMS Newsletter - International Marine Science, UNESCO, Paris, France
No. 59/60
No. 66

Marine Conservation News - Center for Marine conservation
Vol. 03 No. 1, 2, 3, 4
Vol. 04 No. 1, 2
Vol. 05 No. 2, 3, 4
Vol. 06 No. 1, 3
Vol. 07 No. 2,3

Marine Education - Tx A&M Sea Grant College Program
Vol. 08 No. 3

Marine Safety Office Newsletter - U.S. Coastguard
Vol. 13 No. 1, 3

New Waves - Texas Water Resources Institute
Vol. 13 No. 3

Texas Beach Bulletin - Texas Land Commission
Vol. 01 No. 1, 2
Vol. 02 No. 1, 2
Vol. 03 No. 1, 2
Vol. 04 No. 1
Vol. 05 No. 2
Vol. 07 No. 1, 3

Texas Coastal Management Program Newsletter
April 1993
June 1993
July 1993
October 1993
November 993
March/April 1994

Texas Shoreline - Texas A&M Marine Advisory Newsletter, Texas A&M Sea Grant College Program
Vol. 04 No. 2
Vol. 07 No. 2, 4
Vol. 08 No. 2

Texas Watch - Newletter of Volunteer Environmental Monitoring Programs in Texas
Autumn 1993
Summer 1993

WCISW News - International Maritime Organization on the Wider Caribbean Initiative on Ship Generated Waste
October 1994
December 1994
March 1995
June 1995

Marine Plastic Debris Newsletter - Environmental Canada, Ontario
All issues

Marine Debris Worldwide - North Carolina Sea Grant Program
All issues