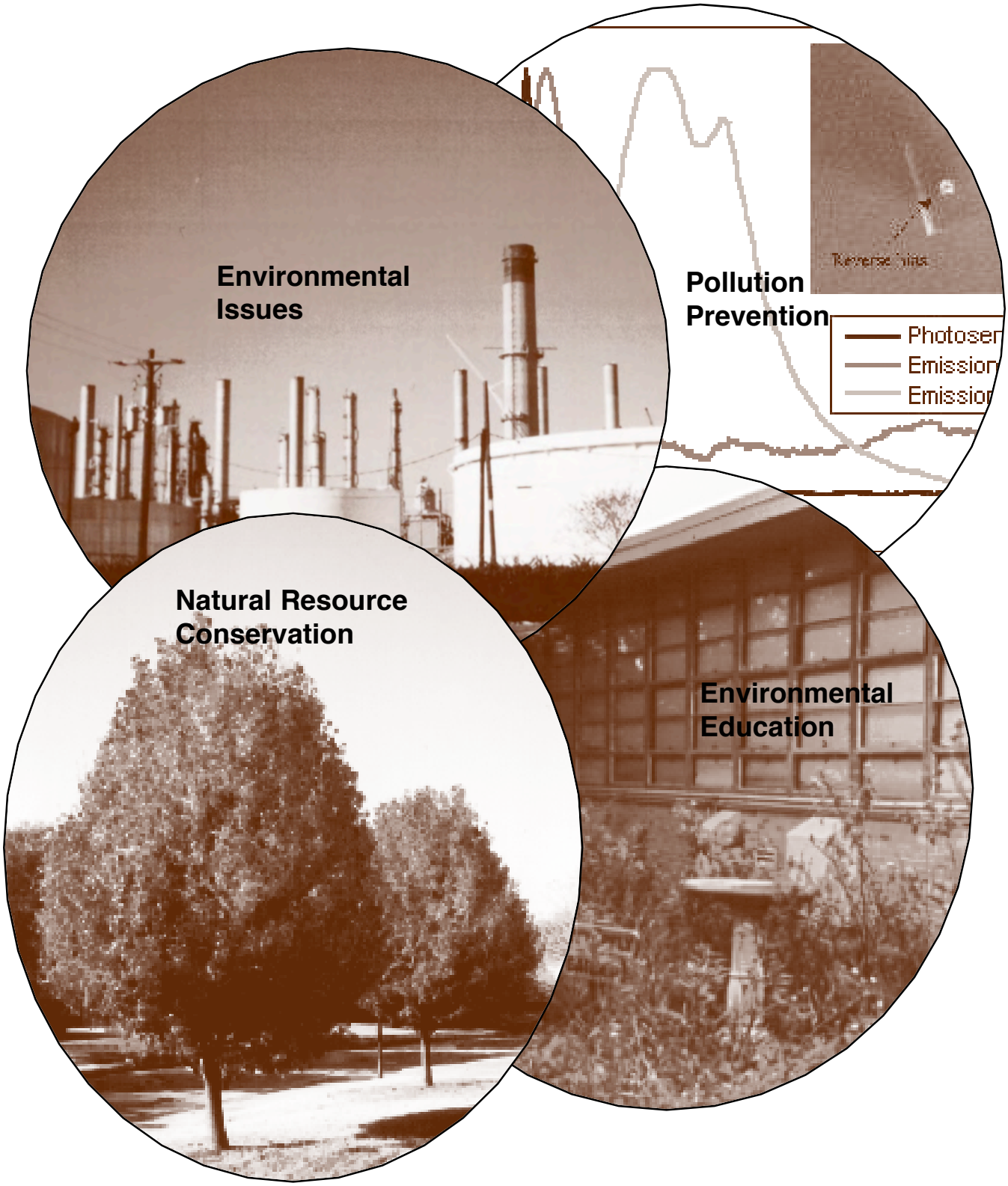
The Environmental Institute of Houston • University of Houston—Clear Lake • University of Houston • Houston, Texas • 1999



The Environmental Institute of Houston
University of Houston—Clear Lake
University of Houston
Houston, Texas

Annual Report • 1999

University of Houston—Clear Lake

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March 2000

The UH Coastal Center

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A path through the Coastal Center.
A sea gull perched at Kemah.

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The Environmental Institute of Houston

The Director's Report

Photo courtesy of Jim Lester

Dr. Jim Lester, Director
The Environmental Institute of Houston

"Think Globally; Act Locally"

This anthem has been common among environmentalists for years, but it does not address a problematic level of environmental planning, regional development. Before acting locally, consideration should be given to environmental, economic and social impacts at larger scales. EIH is prepared to address many regional issues or facilitate their debate before actions occur. Unfortunately, there is often no appropriate decision-making body to receive the information developed.

Problems addressed by EIH and our affiliated researchers are not restricted by local political boundaries and many of them do not have a global context. There are two reports in this volume on the history of the Galveston Bay region, which matches no political boundaries. Also, two of the reports study the issues of ozone formation and air pollution exposure. The ozone problem connects our region to Beaumont, Dallas and perhaps San Antonio, and it certainly calls for regional action. However, outside of regulated industries, ozone has generated little local action. EIH and UH System researchers have little input to the regional implementation plan for compliance with Clean Air standards. This should change if this university is to serve our region well.

Similarly, the controversy surrounding the Port of Houston Authority's Bayport container terminal proposal suggests regional action. It certainly makes sense to have a decision-making body for the development of shipping facilities around Galveston Bay, but there is no regional authority deciding the future of Galveston Bay. Again Houston's universities are providing little information to the debate.

The controversy over the Bayport container terminal encapsulates a full spectrum of environmental issues. The Port Authority proposes an expansion over the next 20 years of container docks and cruise terminals at a location adjacent to residential areas, but already used as a port for petrochemicals. The project promises jobs and economic growth. The project brings concomitant air pollution, water pollution, erosion, traffic congestion, and noise. Local citizens dread the development because of potential impact upon health, safety and quality of life. Labor and some businesses support it because they envision income and jobs. The basic policy question in this conflict is "When does quality of life for a community become more important than increasing income and jobs?" Universities are charged with generation of knowledge for the benefit of society. Surely we should work to inform decision processes such as this one.

The decision process for large public projects should be based on the best information obtainable on the economic, environmental and social impacts of such projects. This is the type of information EIH should strive to provide. The research projects described in this annual report have much to do with technology to identify or mediate problems and little to do with policy changes to prevent problems.

Bayport is a project based on old approaches to transportation and distribution of goods, old technology: diesel trucks and bunker oil burning ships, old problems: erosion, oil spills, air pollution. Where is the better way? Alternatively fueled ships and trucks, smaller ecological footprints for cities, soft engineering for erosion control should be part of the future. Where is the transportation system of the 21st century for the Houston region? The new thoughts, the new solutions, should be coming from universities. Are we doing our best?

In this volume, we present new ideas on modeling air pollution exposure, estimating urban environmental capital, developing new lasers for detecting volatile organics, finding new synthetic pathways for polyolefins, and building new chips for monitoring effluents. These new solutions are joined by studies to obtain better information for regional policy decisions: better statistical analysis of ozone related data, better communication to the public on volatile organic pollutants, more information on the ecological impacts of mercury pollution at the Lavaca Bay superfund site, and increased understanding of the impact of climate change on amphibian development. Given the quantity and quality of expertise represented in this volume, we have much to offer to regional policy debates.

What are the appropriate spatial and temporal boundaries for environmental debate? In the Bayport case, only Harris

Seagulls on the Kemah wharf.

EIH seeks a long-term vision for
- **the greening of the region**
- **restoration of natural resources**

County residents may vote on financing, but Galveston and Chambers County surround the bay and will share the impacts. In the case of air pollution, the problem is concentrated in urban centers of eastern Texas, but a state agency is producing the implementation plan. Universities are accepted change agents at all scales, from community to global. We could take an active role in organizing discussions on the actions and processes that will define our region's future.

EIH researchers have adopted a long-term, regional vision for the green issues around us and are working to support long-term management and restoration of regional natural resources. Also in this volume, are reports on understanding the dynamics of exotic fire ant colonies, finding methods to define the similarities of seagrass populations, determining the recruitment patterns of fish at the Flower Gardens coral reefs, analyzing the threat of exotic shrimp and viruses to native shrimp, and documenting the role of clay in transporting exotic shrimp diseases.

Some EIH projects address fundamental concepts that are broadly relevant to conservation or environmental issues globally. These include the study on quantitative trait loci in house flies, the genetic effects of habitat fragmentation on sparrows, the adaptive radiation process in bacteria, the water budgets of hurricanes, and new inhibitors of ice growth.

Even though we try to keep our focus on local and regional issues, EIH will at times look beyond our metropolitan area. There are certainly no clear boundaries to concerns for pollution prevention, natural resource conservation, environmental policy and environmental education. I have responded to specific requests for help from the Instituto de Estudios Superiores de Taumalipas and the Business Council for Sustainable Development—Gulf of Mexico. Numerous EIH affiliated faculty have international applications of their expertise. In this volume, there is a report by Dr. Fitzgibbon on a project to provide mathematical ecology expertise to a network of international long-term ecological research stations. Our expertise may have been developed locally, but we would be remiss if we did not use it to act globally when needs are presented.

One of the guiding principles of EIH is to cooperate and work with partners whenever appropriate. Two projects highlighted here represent some of our local partnerships from the perspective of environmental education. There is a report on the development of field guides for schools that have committed to outdoor education and the EIH commitment to corporate partnerships for EE is demonstrated in the report on development of a volunteer handbook for EE.

There is one last area of leadership that I would like to find among our EIH projects. Where are the ideas, the ethical and civil values, to counter consumerism? We fund some humanities projects, but I would like to see humanities and social science projects that would illuminate the rewards from changes in regional and global value systems.❖

Developing Human Exposure Estimates for Indoor/Outdoor Air Pollution in Houston

Hanadi S. Rifai, Ph.D., Department of Civil and Environmental Engineering, Loren Hopkins, Ph.D., and Fariba Mehdizadeh, Department of Civil and Environmental Engineering, UH

The Houston area is currently in non-attainment for ozone and there is a possibility that Houston will not be in compliance with the new $PM_{2.5}$ standards. In order to address this problem, the City Council funded a study, conducted by Sonoma Technology Inc. (STI) of Petaluma, California, to assess the health benefits achieved by improving the air quality in the Houston area. In this study STI utilized a human exposure model, REHEX-II, to evaluate exposure to air pollutants. The REHEX-II model exposure analysis is based on time spent in different environments and the concentration to which the individual is exposed in that environment. Different time-activity patterns are applied in the REHEX-II model to incorporate all the possible patterns of human activities during a 24-hour period. There are currently no data on Houston-specific time-activity patterns. STI, in their Houston study, applied the National Human Time Activity pattern Survey (NHAPS) for the southern states as well as the 48-state NHAPS for this study.

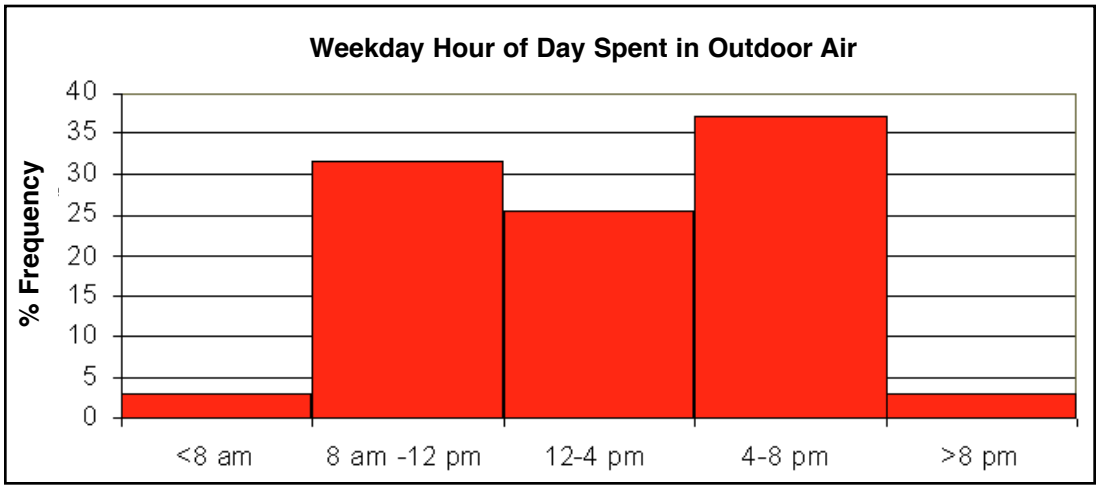


Figure 1. Frequency of exposure for children 0-4 years old throughout the day on weekdays.

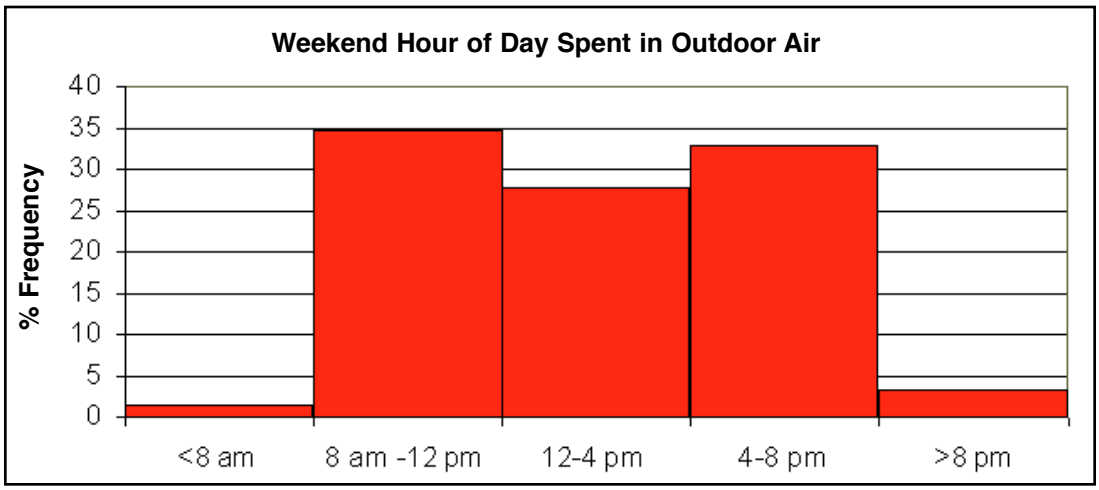


Figure 2. Frequency of exposure for children 0-4 years old throughout the day on weekends.

The purpose of this project was to obtain Houston-specific time-activity data and compare the results to the NHAPS data. Two age groups were chosen for this purpose: children 0-4 years of age, who were divided into those children attending day care and those who do not attend day care (non-day care). The second age group was comprised of college students, who were chosen for comparison purposes. The time-activity profiles and the amount of time spent in different environments were determined by surveying the two groups. Results from surveying a total of 69 college students over 14 days (including weekends and weekdays) indicate that the mean time spent outdoors by this age group is, with 95 percent confidence, between 4.5-5.2 hours per day.

In the category of daycare, a total of 636 children from 18 day cares were surveyed. Data on non-daycare children were collected from 110 children at three public libraries and The Houston Zoo. Data collected from the day cares was focused upon summer and non-summer weekdays. Data collected from the non-day care children covered weekdays and weekends for summer and non-summer months. The data were weighted according to the total number of children 0-4 years of age, in order to obtain one value for the children 0-4 years old for each day paradigm. Data collected for the children 0-4 years indicate that the difference between the Houston-specific mean time spent outdoors for a summer weekend (3.8 hours/day) and the NHAPS mean for a summer weekend (2.28 hours/day), is about 1.5 hours/day. Data on Houston, in specific, show a higher exposure time for this age group.

The REHEX-II code used by STI, obtained from the model developers, enabled

Table 1. The number of hours spent outdoors by children 0-4 years compared to NHAPS data. For example, on a typical weekend day in the summer, NHAPS data indicate a mean time-outdoors of 2.28 hours whereas the Houston-specific database compiled in this study indicates a mean time-outdoors of 3.8 hrs.

	NHAPS	Houston-specific Outdoor Time				
Day Type	mean	95UCL	95LCL	mean	min	max
Summer Weekday	2.42	2.37	2.22	2.29	0.25	15.00
Summer Weekend	2.28	4.20	3.30	3.80	0.50	16.00
Non-Summer Weekday	1.03	2.33	2.21	2.27	0.00	15.00
Non-Summer Weekend	2.28	4.60	2.80	3.50	0.00	15.00

Table 2. The number of people in Houston receiving l-hour ozone exposures above various thresholds for various REHEX-runs. For example, for the exposure concentration range 120-130 ppb, using the NHAPS mean time-outdoors data, 275,342 people are exposed to this concentration level during a year. In contrast, using the data collected in this study for children 0-4 years of age, this exposure frequency increases 8 percent to 296,966 people per year.

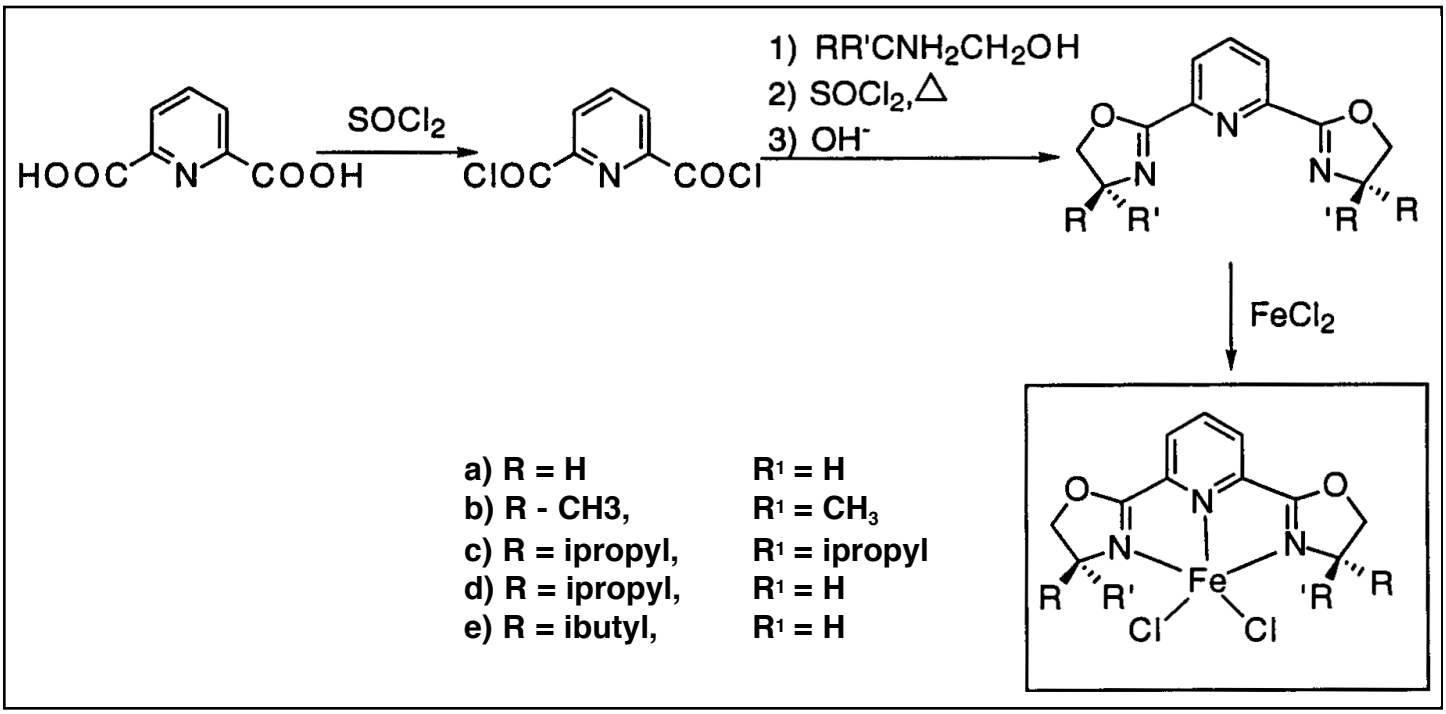
Range	All hours	All hours	NHAPS	Houston-specific Outdoor Time		
(ppb)	outdoor	indoor	mean	95UCL	95LCL	mean
210-220	4004.00	0.00	0.00	0.000	0.00	0.00
200-210	9863.00	0.00	0.00	0.000	0.00	0.0
190-200	26660.00	0.00	0.00	2395.00	2395.00	2395.00
180-190	44485.00	0.00	0.00	9511.00	9511.00	9511.00
170-180	82409.00	0.00	7635.00	27967.00	27967.00	27967.00
160-170	142491.00	0.00	25818.00	53067.00	53067.00	53067.00
150-160	230675.00	178.00	86614.00	105378.00	105378.00	105378.00
140-150	341795.00	1213.00	168270.0	186996.00	186996.00	186996.00
130-140	442599.00	2174.00	229282.00	248446.00	248024.00	248024.00
120-130	442599.00	7407.00	275342.00	296976.00	296966.00	296966.00
110-120	678629.00	18899.00	336269.00	363743.00	363743.00	363743.00
100-110	837979.00	33450.00	447674.00	492331.00	492331.00	492331.00
90-100	933266.00	49506.00	611717.00	672350.00	672350.00	672350.00
80-90	1031322.00	63225.00	852954.00	886000.00	886000.00	886000.0
70-80	1124267.00	84515.00	980370.00	1027435.00	1020759.00	1022565.00
60-70	1275466.00	96908.00	1202495.00	1260938.00	1227298.00	1228933.00
50-60	1299307.00	114792.00	1285665.00	1299307.00	1295440.00	1295508.00
40-50	1301604.00	151398.00	1293514.00	1301604.00	1298058.00	1299583.00
30-40	1301604.00	404370.00	1297150.00	1301604.00	1301604.00	1301604.00
20-30	1301604.00	925434.00	1301604.00	1301604.00	1301604.00	1301604.00
10-20	1301604.00	1301398.00	1301604.00	1301604.00	1301604.00	1301604.00
0-10	1301604.00	1301604.00	1301604.00	1301604.00	1301604.00	1301604.00

researchers to compile and run analyses together with some of the Houston-specific data. The results indicate a potential sensitivity to the Houston-specific data. Higher human exposure was observed in some of the scenarios than was analyzed by STI. For example, the NHAPS model indicates, on the average, 275,342 exposures to one-hour ozone concentrations between 120-130 ppb (which is the NAAQS for ozone), whereas the Houston-specific data model runs indicate 296,966 exposure hours (8 percent higher). Utilizing the Houston-specific data 2,395 person-exposures are observed above 190-200 ppb ozone (dangerous levels), whereas, utilizing the NHAPS data, no exposure above this threshold is observed. Therefore UH researchers can conclude that Houston-specific data influence the exposure results of the REHEX-II model.

Figures 1 and 2 depict the hours of the day children aged 0-4 years old that are not in a day care spend in an outdoor environment during the week and on the weekend. For example, 37 percent of the exposure in this age group during the week occurs in the late afternoon hours between 4-8pm. On the weekend the frequency of being outdoors at this time is reduced to about 33 percent, whereas a maximum frequency is observed between 8am-12pm.❖

Development of Environmentally Benign Routes to the Synthesis of Polyolefins

T. Randall Lee, Ph.D., Kayo U. Vizzini, and June-Ho Jung, Department of Chemistry, UH



Scheme 1. Synthesis of New *Fe*-based Catalyst Precursors.

ZIEGLER-NATTA POLYMERIZATION IS an economically viable synthetic method used for the preparation of technologically important polyolefins applied to durable materials, fibers, and films.[1,2] Current Ziegler-Natta polymerization techniques based on early transition metals such as *Ti*, *Zr*, and *Hf*, however, can produce only non-functionalized polyolefins. The direct synthesis of functionalized polyolefins is important for the environment because the obtained polymers permit facile degradation and thereby reduce environmental pollution.

At present, the introduction of functional groups into polyolefins requires additional reaction steps involving high pressure/temperature radical reactions. The development of new Ziegler-Natta catalysts that permit the synthesis of functional polyolefins in one reaction step will not only reduce manufacturing costs but also reduce the use of environmentally hazardous chemicals utilized in the manufacturing process. In addition, catalysts active in the polymerization of polar functional monomers will likely tolerate aqueous solutions. Water-based synthetic methods are more environmentally friendly than conventional hydrocarbon-based technologies because hydrocarbons, which are derived from oil, can pollute the air and ground.

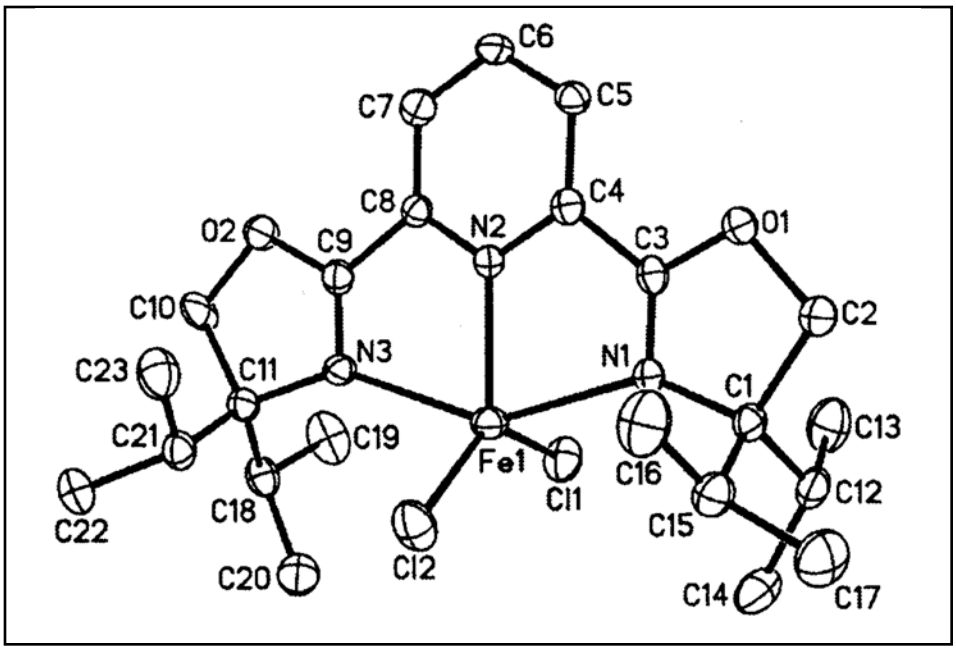


Figure 1. Single crystal x-ray structure of the *Fe* catalyst precursor 2,6-bis-(4,4-diisopropyloxazolin-2-yl)pyridine $FeCl_2$.

Few examples of Ziegler-Natta catalysts can be found that can polymerize functional olefins,[3] or polymerize olefins in aqueous solution.[4] In the past year, we have examined the development of cata-

lysts based on VIII metals such as ruthenium because of recent reports that certain *Ru* complexes are capable of ring opening metathesis polymerization of polar functional monomers in aqueous environments.[5-7] Our studies have found, however, that readily available *Ru* complexes appear to be inactive in Ziegler-Natta polymerization.[8-9] More recently, we have been targeting *Fe*-based complexes as catalysts because the activity of catalysts is generally greater in first-row metals, and there have been recent successful reports of ethylene polymerization by iron complexes.[10-11] In our studies, we have synthesized a new family of iron-based catalyst precursors having bis(oxazalinyl)pyridine as the primary ligand (see Scheme 1).[12] These high-spin complexes are stable in air. The x-ray structure of 2,6-bis-(4,4-diisopropyloxazolin-2-yl)pyridine $FeCl_2$ possesses distorted trigonal pyramidal geometry, as shown in Fig. 1.

The catalyst precursor was activated by exposure to methylaluminoxane (*MAO*). This agent alkylates and abstracts one of the methyl groups, leaving a coordinatively unsaturated metal center for coordination of the olefin. The activated catalysts produced trace amounts of polymers under selected experimental conditions. The low activity of polymerization may be due to the lack of the steric bulkiness on the ligand, which might increase the rate of terminating reactions.

We are currently synthesizing new bis(oxazalinyl)pyridine ligands with increased steric bulkiness. Once we have synthesized *Fe* complexes having these new ligands, we will examine the polymerization of ethylene as well as the polymerization of functional olefins.❖

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Development of Mid-Infrared Semiconductor Lasers Suitable for a Portable Methane LIDAR Detector

Han Q. Le, Ph.D., and S. S. Steven Pei, Ph.D., Department of Electrical and Computer Engineering and the Space Vacuum Epitaxy Center

DETECTION AND REDUCTION OF natural gas and other combustible hydrocarbon leakage into the atmosphere are environmental requirements enacted by the Clean Air Act. The issues also provide a significant safety and legal liability issue for companies involved in oil/gas exploration, refinery, distribution, and utilities.

There is a need for portable line-of-sight sensors, and University of Houston researchers aim to develop such a sensor using DIAL (differential absorption lidar) architecture with mid-infrared semiconductor lasers. This system should enable the gas industry to meet safety and environmental protection regulations. The system will include three principal components: a laser transmitter, a receiver, and electronics. For the transmitter, the wavelength requirement is 3.313 μm, and the power requirement is ~ 20 mW average.

In the past 8 months, UH investigators focused on developing the transmitter. A package design has been completed and optics have been acquired. Mid-IR lasers have been developed with power exceeding 20 mW average at 3.7-3.85 μm. The laser design and optimization will be fine-tuned to obtain 3.3 μm.

Based on extrapolated results, lasers with power > 100 mW average can be achieved. The subsequent work will be to integrate the 3.3 μm laser into the transmitter package. Subsequent studies will provide a comprehensive system evaluation of the sensor.❖

Environmentally Benign Inhibitors of Ice Growth and Ice Nucleation

Anthony D. J. Haymet, Ph.D.,
Department of Chemistry, UH

NUCLEATION AND THE GROWTH OF ICE (and related compounds) cause problems in a wide range of industrial and biological applications, including:

- shelf life of frozen foods,
- storage of blood platelets,
- tumor cell destruction via cryosurgery,
- icing of airplane wings,
- ice formation in (non-preheated) fuel for military jet engines,
- crystal ice formation during transport and storage of frozen foods (e.g. low-fat ice-cream)
- ice growth (and consequent cell rupture) in organs for human transplant
- inability to freeze and store horse sperm (in contrast to other mammals), and
- clathrate hydrate formation (and consequent line blockage) in natural gas pipelines.

The objectives of this research are to study experimentally the inhibition of ice growth and ice nucleation, in order to understand how the inhibition effect works at the molecular level. The second, and longer term stage of the research, is to take this knowledge and use it for the design of inexpensive, safe alternatives to traditional ice growth inhibitors. Support from industry and government will be sought for this second stage. There is a possibility of obtaining a patent for designed ice growth inhibitors in collaboration with the food technology industry, especially ice cream manufacturers.

Many if not most classical inhibitors of ice formation and ice growth, such as ethylene glycol for auto radiators and airplane wings, and methanol in hydrate prevention have high BOD (Biological Oxygen Demand) or other adverse biological consequences; hence both are (1) unsuited for biological applications such as cell preservation, and (2) increasingly unpopular and expensive in industrial applications.

A NIKON trinocular dissecting microscope with video camera capability has been ordered, installed, and tested. This microscope images and records the results of UH ice growth inhibition experiments.

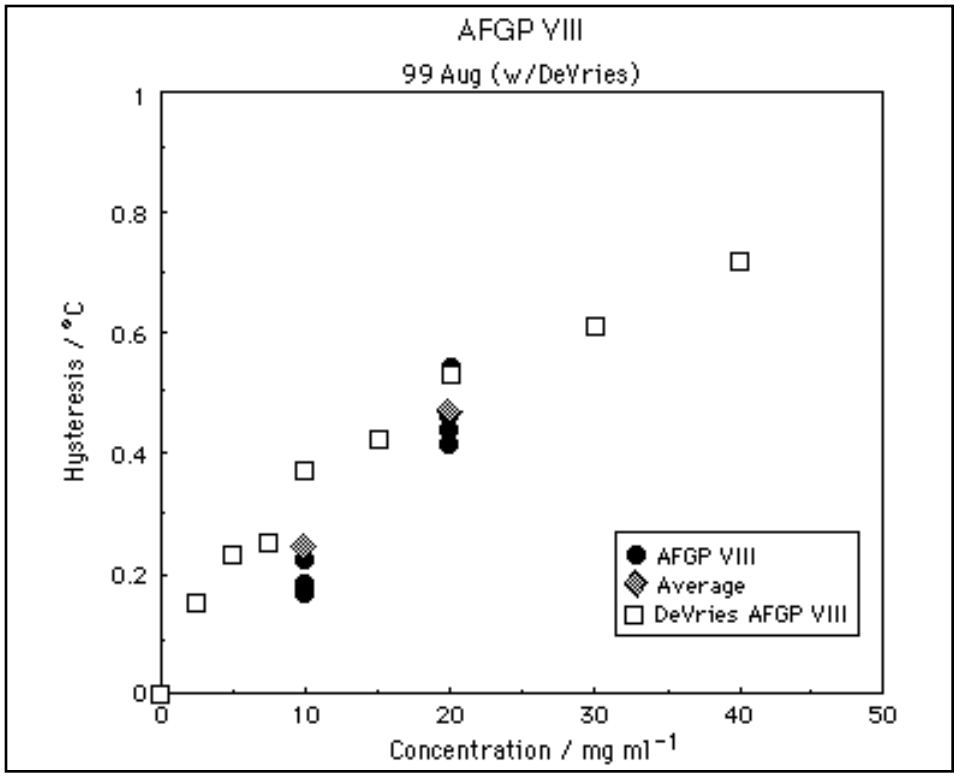

Figure 1. Thermal hysteresis data for antifreeze glycopeptide VIII, compared with literature data.

At the beginning of the summer semester 1999, two graduate students were recruited to the group, adding significantly to the undergraduates already engaged in setting up experiments.

The new experimental apparatus has been shown to duplicate literature data within statistical uncertainty (Fig. 1). These data show the concentration dependence of kinetic ice growth inhibition by dilute solutions of glycoprotein. The apparatus is shown in Fig. 2.

In the next six months, UH investigators will collect data on new insect antifreeze compounds, mutant fish antifreeze proteins, and inorganic analogues.❖

Figure 2. Clifton Nanoliter Osmometer and trinocular microscope.

High Performance Integrated Solar-Blind Optoelectronic Chemical Sensor Based on Gallium Nitride

Wanda Zagozdzon-Wosik, Ph.D., Department of Electrical and Computer Engineering, Abdelhak Bensaoula, Ph.D., Department of Physics and SVEC; and David Starikov, Ph.D., SVEC, UH

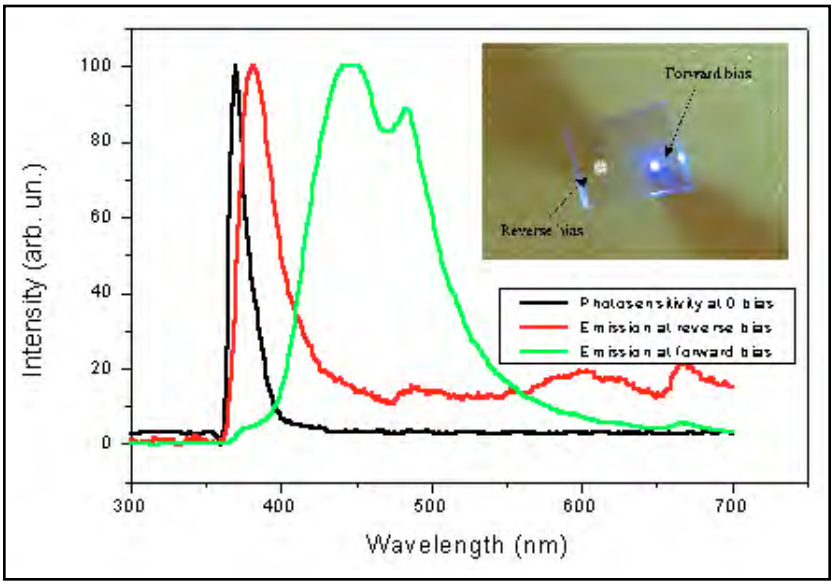

Figure 1. Spectral characteristics of the optoelectronic Schottky barrier diode structures based on *p-GaN*.

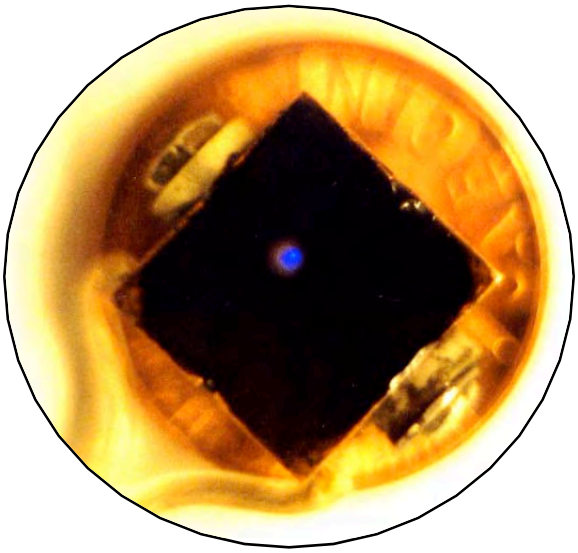

Figure 2. Photograph of a packaged LED based on *p-GaN* Schottky barrier placed on a one cent coin.

RESEARCHERS AT THE UNIVERSITY OF Houston sought to develop, fabricate, and evaluate nitride-based solar-blind solid-state integrated chemical sensor structures for chemical reagent identification and concentration measurements. The first task led to optimized epitaxial growth of GaN layers on sapphire. Since fabricated Schottky barrier diode structures exhibited better performance on *p*-type, than on *n*-type *GaN* layers, closer attention was paid to the growth of *Mg*-doped *GaN*. Hall effect measurements performed on these layers indicated *p*-type doping concentrations up to 7 x10^{17} cm^{-3} and a carrier mobility of 1.2 cm^2/V-sec.

A second task resulted in the fabrication and characterization of *GaN*-based optoelectronic Schottky barrier diode structures. The photosensitivity of these structures was in the near-UV range of 365-400 nm. A UV/blue optical emission with a maximum peak at 450 nm was observed at forward bias, and a broad band emission ranging from near UV to near IR with a maximum peak at 382 nm was observed at reverse bias (Fig. 1). The total Lambertian UV power measured from a packaged (Fig. 2) Light Emitting Diode (LED) in the spectral range 200-300 nm from a forward biased 0.5 mm diameter contact was 0.46 mW. Both the optical emission and the photosensitivity spectra indicated a limit in the near-UV at the wavelength of 365 nm corresponding to the band gap energy of *GaN* (~3.4 eV). This is a result of the optical emission absorption by the *GaN* base material.

To avoid such absorption and extend the spectral characteristics of our structures further into the UV part of the spectrum, we have developed a process for deposition of electrically conductive UV transparent electrodes based on fluorine-doped semiconductor tin oxide (SnO_2) layers. Such layers deposited on sapphire demonstrated up to 80 percent of the optical transmittance in the UV range from visible down to 260 nm. UV photosensitive Schottky barrier structures fabricated using SnO_2 electrodes indicated dark currents in the order of ~ 1 pA and a radiant sensitivity around ~0.01 A/W in the spectral range from at least 250 nm to 475 nm (Fig. 3).

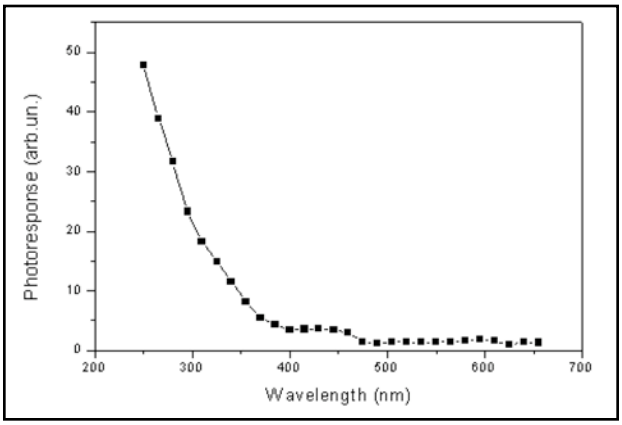

Figure 3. Spectral sensitivity of *p-GaN*-based photosensitive structure with electrically conductive UV-transparent SnO_2 electrodes.

Results described above indicate that both light emitting and photosensitive Schottky barrier UV structures based on *p-GaN* can be fabricated on the same substrate in a single technological process.

The next effort in the development of the advanced optoelectronic sensors will be directed towards the improvement of the processing in order to integrate the sensor components onto a single substrate and to develop appropriate optical wave guides.❖

Modeling of Ground-Level Ozone Using Meteorological and Volatile Organic Compound (VOC) Measurements

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THIS STUDY IS DESIGNED TO SERVE both a research need in the area of toxic air pollution and a program development need in the areas of environmental science and statistics. The results will help assess the need for the development of a course in the area of environmental statistics and develop statistical techniques suitable for analysis of environmental data. It is hoped that students of both statistics and environmental science will benefit from this proposed course that would include topics from both fields.

A preliminary trend analysis has been made of volatile organic compound (VOC) measurements obtained from the Texas Natural Resources Conservation Commission (TNRCC) from air monitoring sites in the Houston-Galveston area during the years from 1992-1997. The ground level ozone at two of these sites (Clinton and Clute) is modeled as a function of meteorological and VOC measurements using a more comprehensive VOC data set obtained recently for the period from 1994-1996. Statistical modeling techniques are used to determine the most significant variables in predicting the ground level ozone. The following meteorological measurements make a significant contribution to the ground level ozone: maximum daily temperature (on current and previous day), wind speed (on previous day), and the wind direction. Certain VOC variables are seen to contribute significantly to the ground level ozone. But specific VOC variables contributing to ground level ozone are shown to depend on the location of the air monitoring station.

TNRCC Data Analyses

An initial set of VOC measurements obtained from the TNRCC for the 11 air monitoring sites in the Houston-Galveston corridor during 1992-1997, was analyzed for time trends and to identify factors causing significant variability in VOC measurements. Table 1 lists those VOC variables for which data were available at least during the 1994-1996 time period. It identifies the factors found to be significant in the trend analysis and shows whether there was an increasing or decreasing trend in VOC measurements.

Table 1. Volatile organic compound (VOC) trend analysis results.

VOC Name	Significant Factors	Comparison		Time Trend
		High	Low	
Benzene	Site, Year, Mnth	Haden		
Bromone				
But-1-3	Site, Year, Mnth			
But-1-2-D				
ChloroB	Site, Year, Mnth	Haden		
ChloroF	Site, Year, Mnth, Day	Haden		High in 1993
C-Trich	Day			
Ethylbenzene	Site, Year, Mnth, Day	Chview		Decreasing
Methyl	Site, Year	Clute		Increasing
o-Xylene	Site, Year, Mnth, Day	Clinton, Haden		Decreasing
Tetrach	Site, Year, Mnth, Day	TexCty	Galveston	Decreasing
Toluene	Site, Year, Mnth, Day	Haden, Clinton	Galveston	Decreasing
Trich_B	Site, Year, Mnth, Day	Haden		
Vinyl Chloride	Year			
Carbon	Site, Mnth			
1,2-Dichloroeth	Site, Year, Mnth, Day	Haden		Decreasing
1,1,1-Tricholoroeth	Site, Year, Mnth	Clinton, Chview		
2-Chloropentane	Site, Year, Mnth, Day			High in 1993, 1995
p-Xylene	Site, Year, Mnth, Day	Haden, Clinton	Galveston	Decreasing
Styrene	Site, Year, Mnth, Day	Haden		Decreasing
n-Nonane	Site, Year, Mnth			Increasing
n-Octane	Site, Year, Mnth, Day	Haden, Clinton		High in 1994
n-Pentane	Site, Mnth, Day	Haden, TexCty, Clinton		
n-Propylbenzene	Site, Year, Mnth, Day	Clinton		Decreasing
n-Undecane	Year, Mnth, Day			
1-Pentene	Site, Mnth, Day	Clinton, TexCty, Haden, OldGalv		
1,2,4-TriMethBen	Site, Year, Mnth, Day	Clinton, Haden	Galveston	Decreasing
1,3,5-TriMethBen	Site, Year, Mnth, Day	Clinton, Haden		Decreasing
2,3,4-TriMethBen	Site, Year, Mnth, Day	Clinton, Clute		High in 1994
t-2-Butene	Site, Year, Mnth	OldGalv, TexCty		High in 1994
t-2-Hexene	Site, Year, Mnth, Day	Clinton, TexCty, Haden		
t-2-Pentene	Site, Day	Clinton		

The site and the time factors of day, month, and year are found to be significant for all but a few VOC variables. The time trend is not uniform across different VOCs; however, more often there is a decreasing trend over the years considered in the study. Table 1 also provides for each VOC variable the sites that had relatively high or low measurements.

The statistical modeling of ground level ozone was accomplished using TNRCC air quality data from two air monitoring sites, one site in Clute, Texas, and the other one is on Clinton Drive in Houston, Texas. These two sites were utilized because they had the most comprehensive set of VOC measurements available, along with ozone and meteorological data for every sixth day from 1994 to 1996. These two sites are separated by more than 50 miles and are very different. The Clinton Drive site is near the Houston Ship Channel and was previously identified (Table 1) by Chhikara and Spears (1998) as one of the sites in the Houston area with higher than average VOC levels. The Clute site is in a more rural setting in Brazoria County, but there are some large chemical plants nearby. The difference in the ozone levels and other variable measurements between these two sites allows for the investigation of location or site effects on the ground level ozone pattern.

The ground level ozone measurement modeled in this study was the maximum daily 1-hour average ozone level (oz1hrpk). Prior to 1997, the EPA standards for ozone were based on the 1-hour average ozone; they now are based on the 8-hour average ozone level. The maximum daily 1-hour average is plotted across time in Fig. 1 for both sites, along with a local mean estimate (loses) of the oz1hrpk on a given day and 95 percent confidence intervals for the mean oz1hrpk on such days. It can be seen in Fig. 1 that the worst days in terms of ozone concentrations occur during the summer months. However, there is high level of variability in ground level ozone from day to day. We attempt to account for some of this variability by including meteorological and VOC variables in the model.

The meteorological variables in the TNRCC data included the maximum and average daily temperature, wind speed, and wind direction. We also considered measurements from the previous day for each of these variables. More than 60 VOC variables were available in the TNRCC data for these two sites (Clinton Drive and Clute) analyzed in the present study.

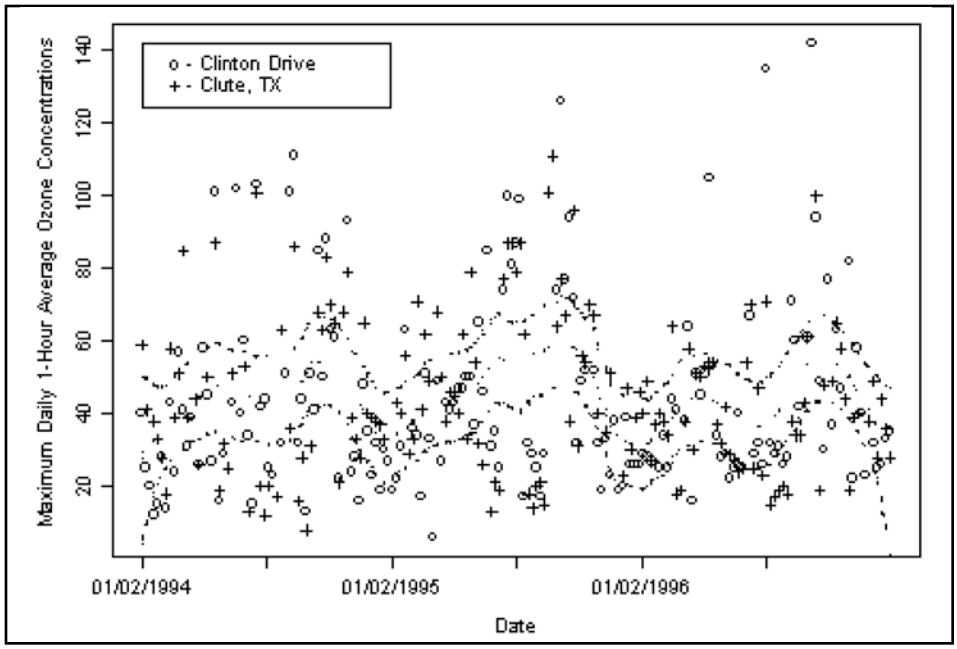

Figure 1. **Worst days in ozone concentrations occur during the summer.**

Table 2. Parameter estimates and *p*-values for TempMax, TempLag1, WindDirX, and WindDirY.

Variable	DF	Parameter Estimate	Standard Error	Student's *t*	*P*-value
Intercept	1	-25.68505	8.08764	-3.18	0.0016
TempMax	1	1.91850	0.20723	9.26	<.0001
TempLag1	1	-1.08282	0.18327	-5.91	<.0001
WindDirX	1	0.91797	0.37319	2.46	0.0144
WinddirY	1	2.94450	0.26516	11.10	<.0001

Since this fitted model accounts for only 33% of the variability in the ground level ozone variability, the VOC measurements are utilized to account for further variability in the ground level ozone.

Table 3. Model parameter estimates and corresponding *p*-values.

Variable	DF	Parameter Estimate	Standard Error	Student's *t*	*P*-value
Intercept	1	-5.75125	10.34666	-0.56	0.5789
TempMax	1	1.57002	0.2388	6.57	<.0001
TempLag1	1	-0.99165	0.19404	-5.11	<.0001
WindSpd1	1	-1.45002	0.49253	-2.94	0.0036
WindDirY	1	2.23903	0.28832	7.77	<.0001
Site	1	14.21M	3.52248	4.04	<.0001
Chloroform	1	72.13101	26.14780	2.76	0.0063
1,2,DiBrEth	1	-106.40459	43.17066	-2.46	0.0145
Benzene	1	2.83479	1.56783	1.81	0.0720
Isoprene	1	11.60069	4.28646	2.71	0.0074
1-Butene	1	-4.10920	1.70042	-2.42	0.0165
n-Undecane	1	26.59428	10.11983	2.63	0.0092

Modeling Ground-Level Ozone

Use of Meteorological Variables Only

It has been shown by Gao *et al*. (1996) that meteorological variables have a significant effect on ground level ozone mea-

surements. Their study pertains to the modeling of ozone concentration using data from an ozone-monitoring network of 45 stations in the Chicago area. A similar approach to modeling the ground level ozone has been considered using the TNRCC data. A general linear regression model was utilized and variable selection techniques were used to determine those variables that contributed significantly to the ozone prediction model. The variables of statistical significance in the fitted model are **TempMax** (maximum daily temperature), **TempLag1** (maximum temperature previous day), **WindDirX** (average daily wind resultant in the east/west direction), and **WindDirY** (average daily wind resultant in the north/south direction). The *R*-square value corresponding to the fitted model was 0.33, which indicated that 33 percent of the variability in ground level ozone is explained by these variables. Parameter estimates and *p*-values for these variables are given in Table 2.

Use of Both Meteorological and VOC Variables

It is scientifically well established that VOCs contribute to the ground level ozone, though no quantitative analyses have been made to evaluate the significance of their contribution. The model in part (a) was extended to include the VOC measurements to enhance the prediction of ground level ozone. Again, variable selection techniques were used to determine the meteorological and VOC variables that contributed significantly to the ozone prediction model. The variables found to be significant were TempMax, TempLag1, WindDirY, 1-Butene, Isoprene, n-Undecane and Chloroform. The *R*-square value corresponding to the extended fitted model was 0.38. It however shows only a slight improvement in accounting for the ground level ozone variability; 38 percent as compared to 33 percent for the model fitted in part (a).

Further analysis of the more comprehensive VOC data showed that the location of the air-monitoring site was a significant factor. If the site location is taken into account in the development of the ozone prediction model, an additional set of variables becomes a significant contributor to the model. The resulting model has an *R*-square value of 0.49. The additional variables included in this model were WindSpd1 (average daily wind speed on previous day), 1,2-dibromoethane, and benzene. The model parameter estimates and corresponding *p*-values are given in Table 3.

Table 4. Fitted model for the Clinton Drive site.

Variable	DF	Parameter Estimate	Standard Error	Student's *t*	*P*-value
Intercept	1	-32.13331	14.42279	-2.23	0.0281
TempMax	1	1.75155	0.33634	5.21	<.0001
TempLag1	1	-1.00518	0.26847	-3.74	0.0003
WindDirY	1	2.84471	0.68208	4.17	<.0001
1,3-Butadiene	1	-2.90898	1.34985	-2.16	0.033
1,2-Dicheth	1	273.86267	79.02656	3.47	0.0008
VinylChlor	1	157.33759	34.80261	4.52	<.0001
n-Octane	1	-30.78839	14.68519	-2.10	0.0385
n-Decane	1	28.92812	14.33302	2.02	0.0462
Isoprene	1	9.45304	5.16501	1.83	0.0702
2,2-DiMethBut	1	27.78150	13.86072	2.00	0.0477
2,3,4-TrMethP	1	35.07609	13.72929	2.55	0.0121

Table 5. Fitted model for the Clute site.

Variable	DF	Parameter Estimate	Standard Error	Student's *t*	*P*-value
Intercept	1	5.23623	10.53310	0.50	0.6200
TempMax	1	1.37197	0.27741	4.95	<.0001
TempLag1	1	-1.01593	0.22791	-4.46	<.0001
WindDirY	1	1.53938	0.30385	5.07	<.0001
VinylChlor	1	-8.47706	2.52387	-3.36	0.0011
p-Xylenes	1	45.23559	8.15413	5.55	<.0001
Isopentane	1	5.07410	1.65177	3.07	0.0026
2-Meth-2-But	1	-133.26007	22.63783	-5.89	<.0001

Site Specific Analysis

Note that the location of the air-monitoring sites is a significant factor in the best fitted model discussed in the previous section. Thus, a single model utilized for fitting data from both sites may not be an optimum strategy. A better modeling strategy would be to allow a site-specific model to be developed. In the development of separate models for two sites, the variables that contributed significantly to each model were selected from the complete set of meteorological and VOC variables. TempMax, TempLag1, and WindDirY are significant parameters in both meteorological circumstances.

For the Clinton Drive site, the fitted model was based on 112 observations, and the *R*-Square was 0.59. The parameter estimates and corresponding *p*-values for the fitted model showed eight VOCs that contribute significantly to the regression. (See Table 4.)

This fitted model has more VOC variables included than the best fitted model obtained for the two sites combined. For the Clute site, the fitted model resulting from the fit of 125 observations has an *R*-square of 0.53. The parameter estimates and corresponding *p*-values for the fitted model showed four VOCs (see Table 5).

This fitted model has fewer number of VOC variables than the best fitted model obtained in the previous section for the two sites together. Moreover, the set of VOC variables in the Clute site model is completely different than the set of VOC variables in the two-site model, and Vinyl Chlorine is the only common VOC variable in the two separately fitted models for the Clinton Drive and Clute sites.

Conclusion

The meteorological variables that contribute significantly to ground level ozone are consistent across the different fitted models, except for the inclusion of WindSpd1 in the model for both sites combined. The VOC variables making a significant contribution to the ground level ozone are not consistent across the fitted models. It is shown that the site location is

a significant factor influencing the ground level ozone. Although a single ozone prediction model has been developed for the two sites combined, site-specific prediction models, as shown, may be preferable because they account for a higher amount of the variability in ground level ozone.❖

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NATURAL RESOURCES CONSERVATION

Assessing the Impact of Chemical and Biological Pollutants on Shrimp

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THE SHRIMP POPULATION OF U.S. coastal waters supports our most valuable fishery. Trawling is the primary capture method of the industry. Along the Gulf Coast, trawling is intensive in many areas and, not only disturbs bottom sediments and fauna, but also captures species not targeted by the fishers. Some bycatch consists of species targeted for protection, e.g. Kemp's Ridley sea turtle and red snapper.

The U.S. consumes several billion dollars more in shrimp annually than the fishery can supply. High demand for shrimp has supported the growth of shrimp aquaculture. Shrimp farms in Texas are distributed from Matagorda Bay to the Lower Laguna Madre. Coastal shrimp farms have received considerable negative attention from environmental organizations because they have potentially large impacts. Effluents discharged from ponds are high in nutrients and can damage receiving waters. All of the U.S. farms grow a non-native shrimp species from the Eastern Pacific. There is concern that escapees may become established and compete with native shrimp. Also, the exotic shrimp sometimes suffer epidemics of diseases not known to occur in native shrimp. These exotic pathogens constitute a type of biological pollution of great concern to resource managers and fishers.

Agencies regulate the shrimp fishery in several ways to protect the shrimp population and bycatch species from over exploitation. Recently shrimp farms came under regulation for the quality of their effluent. Procedures exist to prevent discharge of water from ponds with epidemics, but it is impossible to judge their efficacy. Too little is known about the epidemiology of shrimp diseases. Also, shrimp pathogens enter Texas in dead shrimp sold for human consumption. Virus infected shrimp from Latin America and Asia can be purchased in any neighbor-

hood grocery store. The frequency with which these shrimp are introduced into coastal waters as fish bait is unknown.

Tools are needed to assess the potential impact of biological pollutants on U.S. coastal shrimp populations. One objective of this research is to develop an assay of the virulence of shrimp pathogens. Another is to develop an understanding of the environmental and genetic effects on the likelihood of mortality from an exotic viral infection. There are several difficulties that a standard assay must overcome. There are no shrimp cell lines for culturing viruses. The shrimp viruses of immediate concern seem to lose virulence as soon as they are removed from tissue. Virulence declines strongly with age of homogenate and number of times frozen. The shrimp on which the pathogens are tested are not genetically consistent and are not reared in a controlled environment.

The assay is designed to include a measurement of LC50 for a standard toxicant, potassium dichromate, and a standard preparation of homogenate from shrimp dying of the viral infection. This standard toxicant test was intended as a reference for the condition of the postlarvae. It was thought that weak animals would succumb at lower concentrations of both toxicant and virus.

The laboratory at UH—Clear Lake received shipments of *Penaeus vannamei* postlarvae (PL) from four sources: Florida, Texas, Hawaii, and Venezuela. Shrimp are held and fed in large aquaria at the test salinity for an acclimation period of 3 to 5 days prior to testing. Tests were conducted on PL's between 11 and 23 days post metamorphosis. For the acute toxicity test, five shrimp are stocked in a one-liter beaker with 500 ml of seawater plus the appropriate dilution of the toxicant, potassium dichromate. Six toxicant concentrations are tested plus a zero control with four beakers (20 PLs) at each concentration. Mortality is recorded after 24 hours. There is no feeding or aeration. Temperature is 28ºC. Salinity is usually 18 ppt, but, in some tests, salinity is a variable.

The higher the LC50 value (Table 1), the more resistant the shrimp were to the toxicant. The results of our tests show that the postlarvae provided by three suppliers were similar in their response, but the two shipments obtained from Venezuela appear to be more sensitive to the chemical. Some shipments were tested twice to assess the effect of age on LC50. Resistance to the standard toxicant increases with age from PL11 to PL23.

Table 1. Probit analysis results of 24 hour toxicity tests of potassium dichromate on 16 to 20 day postlarvae of *Penaeus vannamei.* The lethal concentrations for 50 percent mortality are estimated in parts per million.

Source	N LC50 (ppm)	Mean (ppm)	Std. Dev. LC50 (ppm)	Minimum LC50 (ppm)	Maximum
Florida	20	84.7	36.8	17.3	164.4
Hawaii	3	84.2	96.3	20.6	195.0
Texas	7	97.8	28.4	50.6	129.5
Venezuela	2	58.4	15.9	47.1	69.6

Table 2. Results of probit analysis of mortality from potassium dichromate at different salinities.

Test	Source	PL Age (days)	Salinity (ppt)	LC50 (ppm)
KCRO 25	Florida	17/18	2	No survival with toxicant
			18	100.9 ppm
			36	17.3 ppm
KCRO 32	Florida	16/17	2	No survival @ >40 ppm
			18	98.4 ppm
			36	36.7 ppm
KCRO 50	Texas	18/19	2	No survival with toxicant
			10	34.0 ppm
			18	85.6 ppm

The toxicity of potassium dichromate is greater if the PL's are held at high (36 ppt) or low (2 ppt) salinities. Salinity stress seems to lower the resistance of the shrimp to the toxicant. This effect was present despite acclimation of three or more days at the test salinity.

Table 2. A sharp change in salinity at the onset of the test increases the LC50. Moving the PLs from 28 ppt to 18 ppt or from 35 ppt to 10 ppt led to increased resistance to the toxicant. We believe this results from an osmoregulation response which inhibits exchange with the environment.

When the same groups of larvae were exposed to concentrations of Taura Syndrome virus in challenge tests, there was no correlation between the LC50 of TSV and of potassium dichromate. Future studies will concentrate on controlled challenges to viral infections under different environmental conditions.❖

Developing High-Resolution Markers for Metapopulation and Quantitative Trait Locus (QTL) Experiments

Lisa M. Meffert, Ph.D., and Dan E. Wells, Ph.D., Department of Biology and Biochemistry

MOLECULAR ASSAYS OF GENETIC variation have opened new avenues for research in conservation biology and animal behavior, but historically they have not been fully exploited on the housefly experimental model. Prior conservation biology experiments have revealed new complexities of the genetics of inbreeding, calling for a comprehensive examination of how immigration can prevent extinctions. For such an approach, allelic diversity assays are critical for measuring levels of inbreeding and immigration.

In a separate line of research, experiments on housefly mating behavior have uncovered unique potential to examine the genetics of mate choice. In particular, the system is ripe for quantitative trait locus (QTL) approaches to locate genes that influence female preferences and male mating success. Examining these bodies of theory required the development of high resolution molecular assays, in research sponsored by the National Science Foundation.

Progress of Investigation

Allozyme assays were remarkably successful. Six loci were found to be highly polymorphic, with levels even higher than the average reported for microsatellite loci in *Drosophila melanogaster* (Table 1).[1] Through the course of the year, over 6,000 assays were performed on nearly 1,500 individuals. Preliminary analyses[2] have revealed highly significant differences among populations from three separate experiments (Table 2). Preliminary analyses also suggest that phosphoglucomutase (PGM), or loci linked to PGM, may affect mate preferences. For the microsatellite assays, a genomic library was created and screened using two different simple repeat sequences. Several thousand genomic clones with these repeats were identified. Of these, several have been sequenced, and the tests for polymorphisms are underway.

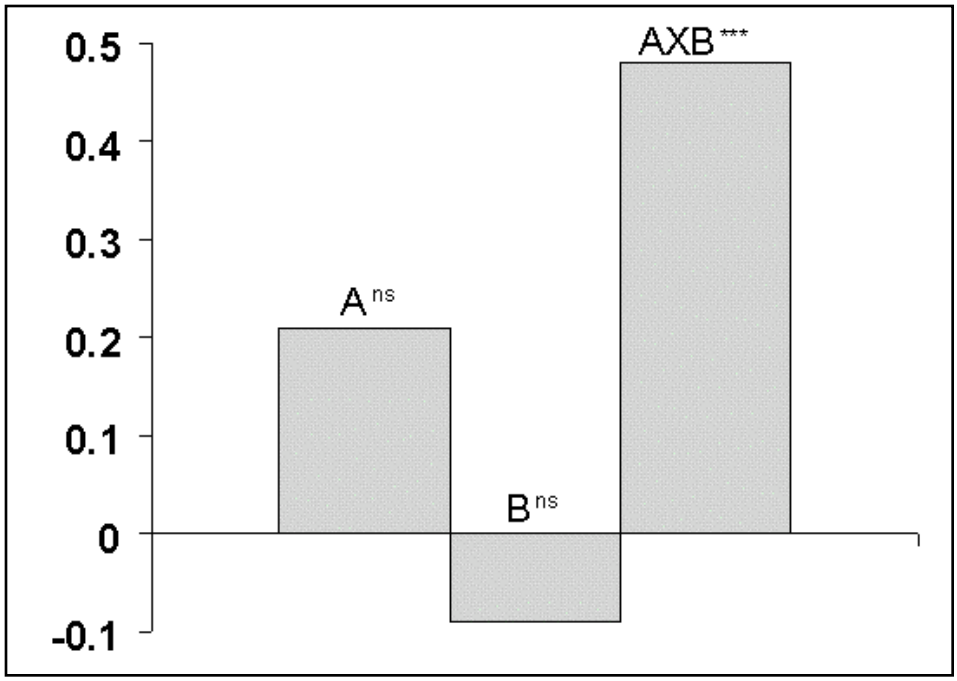


Figure 1. Heritability of mating propensity. "A" and "B" identify populations with inbreeding depression. "AXB" was produced by crossing "A" with "B." Significance values are given for the deviation from zero. The crossed population alone had significant heritability for mating propensity.

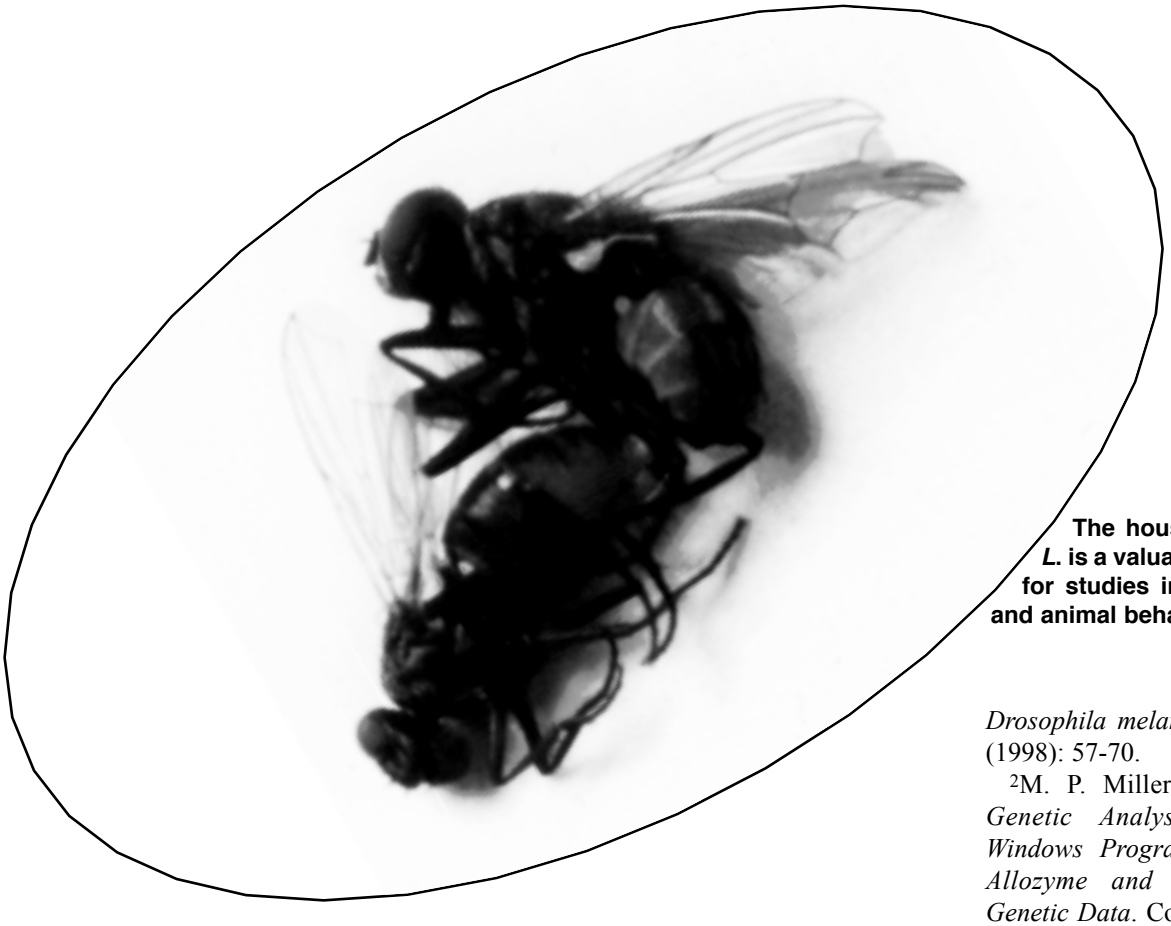
Table 1. Number of alleles found at allozyme loci in *Musca domestica*. The mean allelic diversity is slightly higher than that reported for 115 microsatellite loci in *Drosophila melanogaster* [MEAN (SD) = 5.68 (3.71)[1]].

Enzyme	Abbreviation	#Alleles
Hexokinase	HK	5
Hydroxy acid dehydrogenase	HAD	6
Mannose phosphate isomerase	MPI	7
Phosphoglucodehydrogenase	PGD	5
Phosphoglucomutase	PGM	8
Trehalase	TRE	4
MEAN (SD)		5.83 (1.47)

To further demonstrate the feasibility of metapopulation manipulations, a pilot experiment examined how immigration between inbred populations increases genetic variation. Subsamples of two populations with inbreeding depression were crossed (i.e., allowed to interbreed *ad lib*), followed by assays of the heritability of mating propensity (the proportion of virgin females mating within 30 minutes). As predicted, immigration dramatically increased genetic variation (Fig. 1).

Additionally, the prior EIH project on captive breeding strategies[3] was expanded to testing populations for evolutionary flexibility. Some populations evolved higher fitness by which the evolutionary response was significantly more dramatic in the stressful environment. Preliminary analyses suggest that average heterozygosity is uncorrelated to fitness or adaptability, despite significant differences among populations (Table 2).

Projects have led to publication. Meffert *et al.*[4] showed how convergent evolution of founder-flush populations causes dissolution of incipient speciation. Meffert summarized evidence of increased genetic variation in founder-flush populations as it



The housefly *Musca domestica L.* is a valuable experimental model for studies in conservation biology and animal behavior.
(Photo courtesy of Joe Liggio)

Table 2. Exact tests for population differentiation,[4,7] based upon allozyme loci (see Table 1 for abbreviations). In each experiment, the differences among populations are highly significant.

Experimental populations	Enzymes in analysis	df	χ^2	p
Experiment 1: Divergent courtship repertories	HAD, HK, MPI, PGM	6	59.42	0.0000
Experiment 2: Extinction trajectories	HAD, HK, MPI	6	36.72	0.0000
Experiment 3: Captive breeding strategies	HAD, HK, MPI	6	59.42	0.0000

relates to conservation biology.[5] Meffert detailed how the nonadditive genetic effects of dominance and epistasis can contribute to increased genetic variation in founder-flush populations.[6]

These molecular data have added a new dimension to a suite of conservation biology and animal behavior experiments, and the research will find publication. The EIH data will also provide compelling preliminary evidence of the feasibility of future projects that will seek funding from government agencies such as the National Science Foundation and others. In particular, funding will be sought for (1) a comprehensive conservation biology project on metapopulation dynamics and (2) a QTL investigation of the evolutionary dynamics of female preferences and male mating success.❖

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An Evaluation of the Ecotoxicology of Mercury in Lavaca Bay, Texas—A Continuation Study

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Lavaca Bay, in the Matagorda Bay system, was contaminated with mercury *(Hg)* from aluminum refining and chlor-alkali production during the late 1960s. Since 1988, a large portion of the bay has been closed to recreational and commercial shellfish and finfish harvesting because of elevated levels of *Hg* in the tissues of a number of species collected from the area.

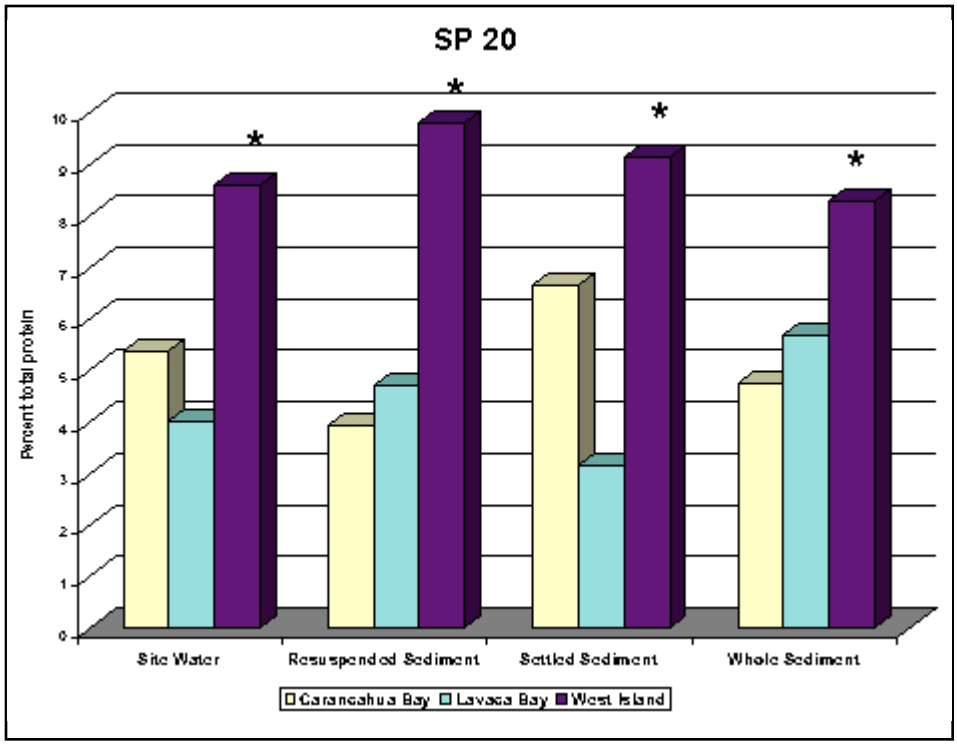
Recently, Lavaca Bay was designated as an EPA Superfund site on the basis of high *Hg* concentrations in its sediments. A number of studies have been conducted to determine the ecological and potential human health impacts of this contamination. Research reported here focused on stress protein induction as a biomarker of *Hg* exposure and adaptation in organisms inhabiting Lavaca Bay.

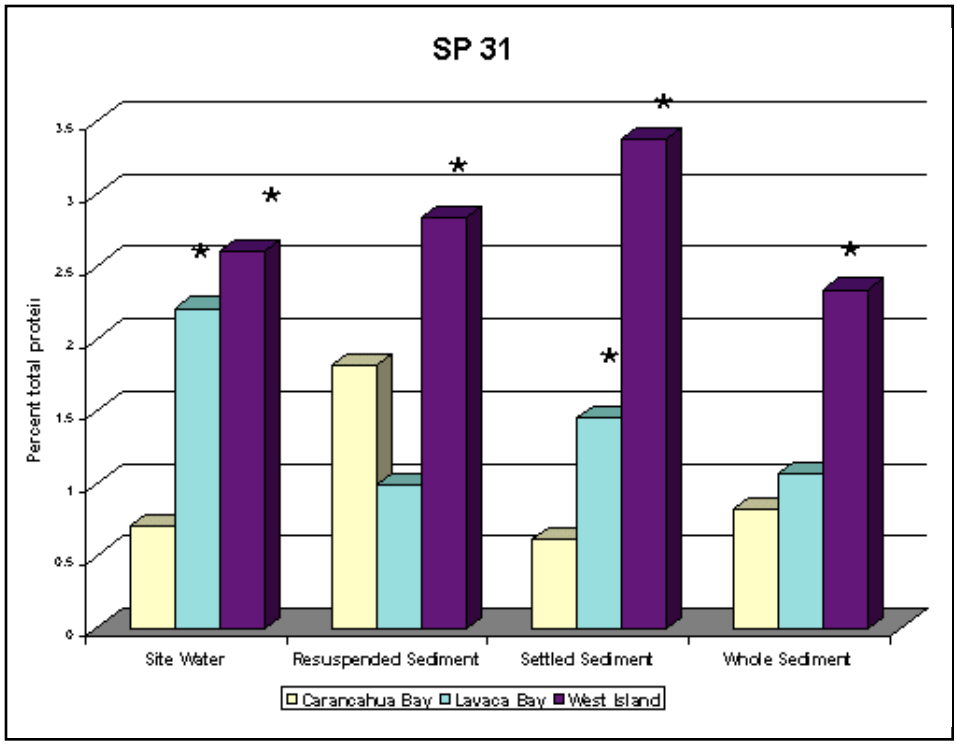
Stress proteins can be induced under conditions such as thermal, heavy metal, and anoxic stresses, and operate in protective and repair roles to maintain cell integrity and function. We have identified several stress proteins that are induced in grass shrimp (*Palaemonetes pugio*) exposed to environmental concentrations of heavy metals. Because grass shrimp are an important link in estuarine sediment-associated food webs and are present in large numbers in Lavaca Bay, their ability to adapt to and bioaccumulate *Hg* is of special interest. Stress protein induction may be one of the mechanisms involved.

Three experiments are being conducted in this project. In the first experiment, samples of sediment and overlying water were collected from two sites in Lavaca Bay located within the *Hg*-contaminated area (West Island and Lavaca Bay) and from a reference site in Carancahua Bay located well outside and to the east of the *Hg*-contamination zone. Sediments from all sites were partitioned into three phases: resuspended, settled resuspended and sieved whole sediment.

Grass shrimp collected from a *Hg*-free site in Galveston Bay were exposed to test and reference water and sediment,[1,2] then were analyzed for stress protein induction using polyacrylamide gel electrophoresis

Table 1. Stress protein levels (*μ*g/g total protein, expressed as percent total protein) in grass shrimp (*Palaemonetes pugio*) exposed to *Hg*-contaminated sediments from Lavaca Bay, Texas. Significant increases in stress proteins ($p<0.05$), compared to Carancahua Bay reference, are indicated by an asterisk.



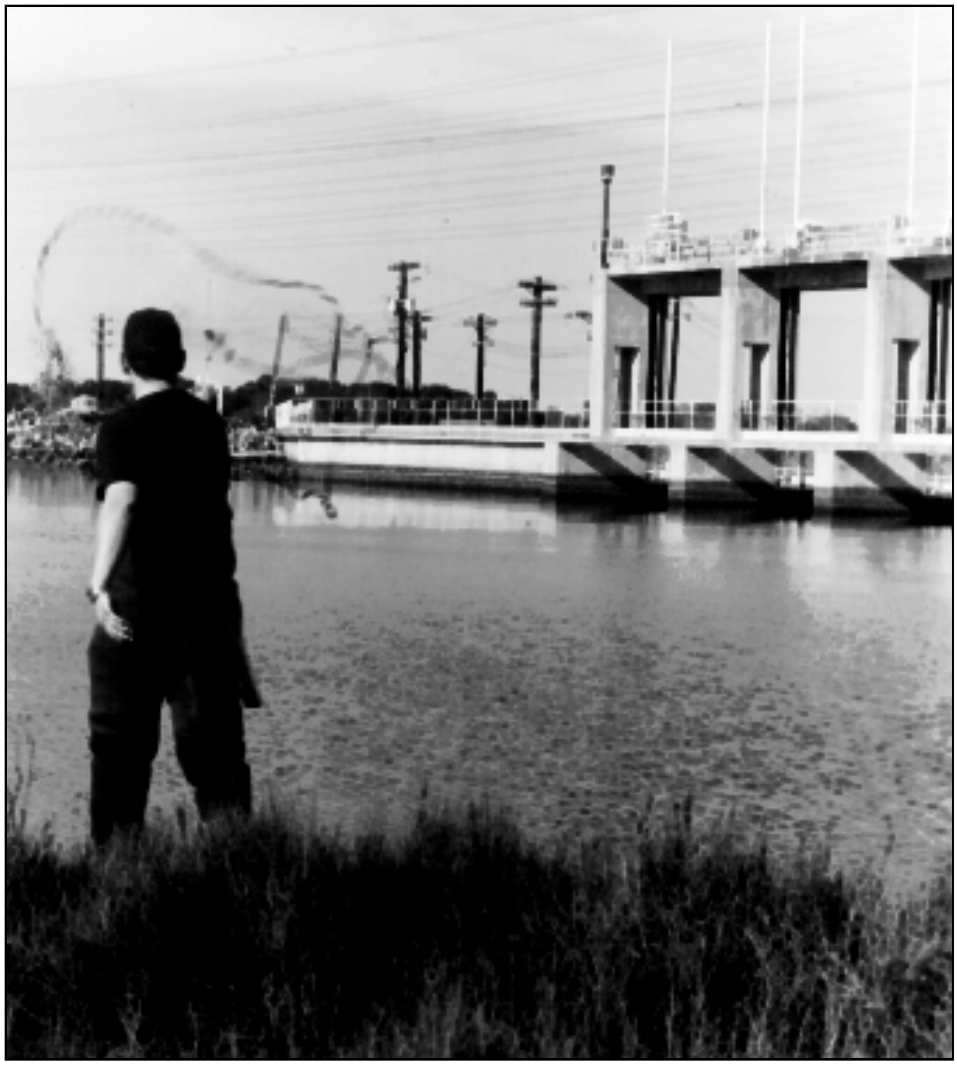


and scanning densitometry. The results showed that grass shrimp accumulate significant amounts of a 20-kD and 31-kD protein when exposed to sediment and water containing environmentally high levels of *Hg*, independent of sediment phase (Table 1). Studies are continuing to determine if these proteins (1) confer *Hg* tolerance or (2) provide a selective advantage to grass shrimp inhabiting contaminated areas.

The second experiment involved the comparison of stress protein induction in Galveston Bay grass shrimp exposed *in situ* for 7 days at the three study sites in Lavaca and Carancahua Bays with ambient stress protein levels of grass shrimp collected from each site. The cage experiments and collection of shrimp from the site populations have been completed. Stress protein analyses are currently in progress.

Shrimp had significant amounts of a 20-kD and 31-kD protein when exposed to *Hg*

In the third experiment, *Hg* concentrations will be determined in the sediment and water samples, bioassay test and control shrimp, cage-exposed and locally collected grass shrimp described above. This information will enable an evaluation of the role stress proteins may play in *Hg*-bioaccumulation.❖



At the floodgates at Kemah, a fisherman tosses a net for the collection of bait.

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Genetic Constraints on Adaptive Radiation

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The process of adaptive radiation is thought to have played a pivotal role in the evolution of life. Numerous studies have examined the importance of adaptive radiation and have attempted to determine the factors that result in explosive and novel ecological diversification.

Empirical studies performed can be grouped into three categories, each with strengths and weaknesses.

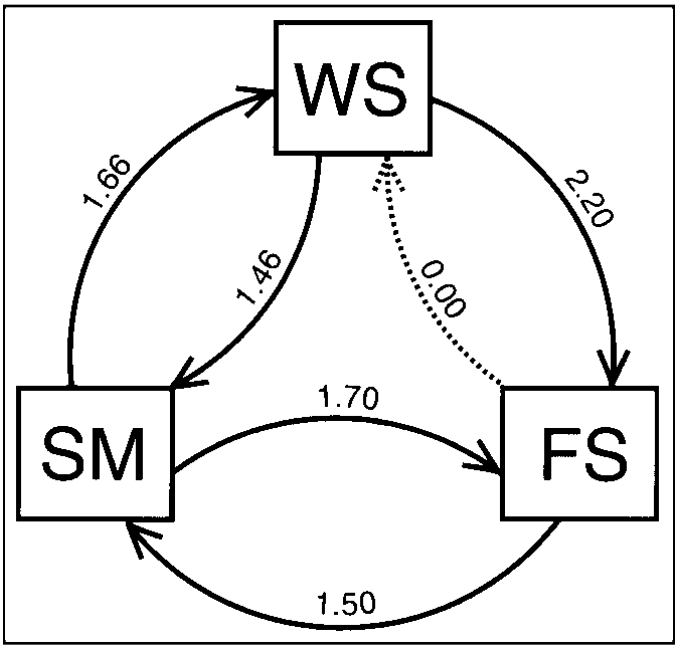
(1) Macroecological studies rely on statistical analysis of broadly-based, generally observational, data, and can yield surprisingly general conclusions. However, a weakness of this approach is that causality is determined by correlation, leaving the results open for alternative conclusions.

(2) In contrast, long-term ecological studies are often experimental in nature, with explicit efforts to directly determine cause and effect. These studies can be particularly useful in elucidating ecological relationships, but are generally laborious and can explore evolutionary change only over relatively few generations.

(3) Studies examining genotype-by-environment interactions by local transplantation or translocation are noteworthy in that they indicate the potential for environmental change to affect species. Although such studies have often detected environmental effects, the context is essentially static and evolvability is difficult, if not impossible, to address experimentally.

Recently, Rainey and Travisano[1] have demonstrated rapid evolution of niche-specialists with bacteria in a heterogeneous environment. This work was performed with the gram negative saprophyte *Pseudomonas fluorescens* which, when propagated in a simple heterogeneous environment (25 ml glass vial containing 6 ml broth medium), undergoes explosive morphological diversification. A striking feature of the evolved morphs is their niche specificity; the ancestral SM morphs (smooth morphology on agar plates) colonize the broth phase, the evolved WS morphs (wrinkly morphology on agar plates) colonize the air-broth interface, and the evolved FS morphs (fuzzy morphology on agar plates) colonize the vial bottom. The serendipitous correspondence between colony morphology and niche preference permits real-time ecological and evolutionary dynamics to be determined by scoring changes in the frequency of colony phenotype.

The objective of proposed research at the University of Houston was the determination of those genetic constraints that affect the potential for diversification. This task required the examination of the potential for thirteen different bacterial species to undergo diversification.



Competitive relationships among niche-adapted classes. Arrows point from the initially rare (invading morph) to the common (invaded) morph for each of the competitions. Values above each curve are the median fitnesses. Fitness measures were determined over seven days by the ratio of Malthusian parameters of the initially rare genotype to the common genotype, so that a fitness of 1.000 indicates genotypes of equal competitive ability. In five out of six cases, the rare morph successfully invaded the common morph, whereas in one case (FS invading WS), the rare genotype was selected against. All interactions are statistically significant (P<00.01) by two-tailed tests. (Diagram in "Letters to Nature," *Nature* 392, 2 July 1998, p. 71).

Results

The thirteen new bacterial species included twelve species closely related to *Pseudomonas fluorescens* SBW25, as based upon a 16S *r*RNA consensus tree. The thirteenth species was *Escherichia coli*, a species much more distantly related to SBW25. All species underwent morphological diversification, but each species did not generate the same level of diversity. *Escherichia coli*, the most divergent genotype, adaptively radiated into both WS and FS morphotypes. In contrast, of the twelve new closely related pseudomonads, all twelve generated SM and WS morphs, but only one species evolved FS morphs. This difference in diversification was unlikely due to large pre-existing genetic differences of the ancestral genotype, given the potential for *Escherichia coli* to fully diversify. Rather, it is more likely that ecological interactions among niche-specialists constrain diversity, and the ecological interactions depend upon minor genetic differences. These results suggest that adaptability may be constrained more severely by recent differences in adaptation than by long-standing phylogenetic relationships.❖

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Genetic Diversity of *Ruppia maritima* and *Halodule wrightii*

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WETLANDS HAVE LONG BEEN considered economically depauperate habitats. Consequently, many wetland areas have been filled for residential development. This renewal included coastal areas where seagrasses were dominant. Seagrasses are vital to southeast Texas shorelines since they anchor sediment that would otherwise increase turbidity and reduce photosynthesis.[1] In addition, seagrasses in the Galveston Bay system provide a nursery habitat for 28 percent of commercial fish species and 30 percent of blue crab and shrimp populations.[2]

The effects of Hurricane Carla and increased dredging and development along coastal waters have decimated 90 percent of seagrass beds in the Galveston Bay system since 1956.[2] U. S. Fish and Wildlife Service has had little success in transplanting the seagrass *R. maritima* in the Galveston Bay area,[3] although this difficulty may be attributed to the selection of sites with high turbidity.

The long-range goal of U. S. Fish and Wildlife is for *Ruppia maritima* to stabilize sediment to create conditions favorable for transplanting of another seagrass, *Halodule wrightii*. *H. wrightii* is now found only in Christmas Bay and part of West Bay. Healthy transplanted populations of *H. wrightii* will hopefully increase genetic diversity, thus restoring evolutionary potential and eventually increasing *H. wrightii's* domain.[4,5] Successful seagrass transplanting is more likely to occur if donor plants are genetically similar to plants at the recipient site.[6] If genetic similarity cannot be determined, using transplants from multiclonal populations may enhance the probability of long-term success in a disturbed seagrass bed.[7]

Previously Amplified Fragment Length Polymorphisms (AFLPs) were used to determine genetic diversity and clonal structure of seagrass populations. This method required "clean" genomic DNA for complete digestion by restriction enzymes. Only partial digestion was possible with *R. maritima* and *H. wrightii* from Galveston Bay. Random Amplified Polymorphic DNA (RAPD) does not require the DNA to be as "clean" for the procedure to yield data on genetic diversity and clonal structure within a population. An endless array of primers may make it possible to identify loci specific to a population. This benefit would then allow the researcher to determine which donor site is most genetically similar to the recipient site. Initial data indicate that there is some genetic diversity within one of the donor sites (see Fig. 1). This would be the first time genetic information from the donor site was used to predict restoration potential in Galveston Bay.❖

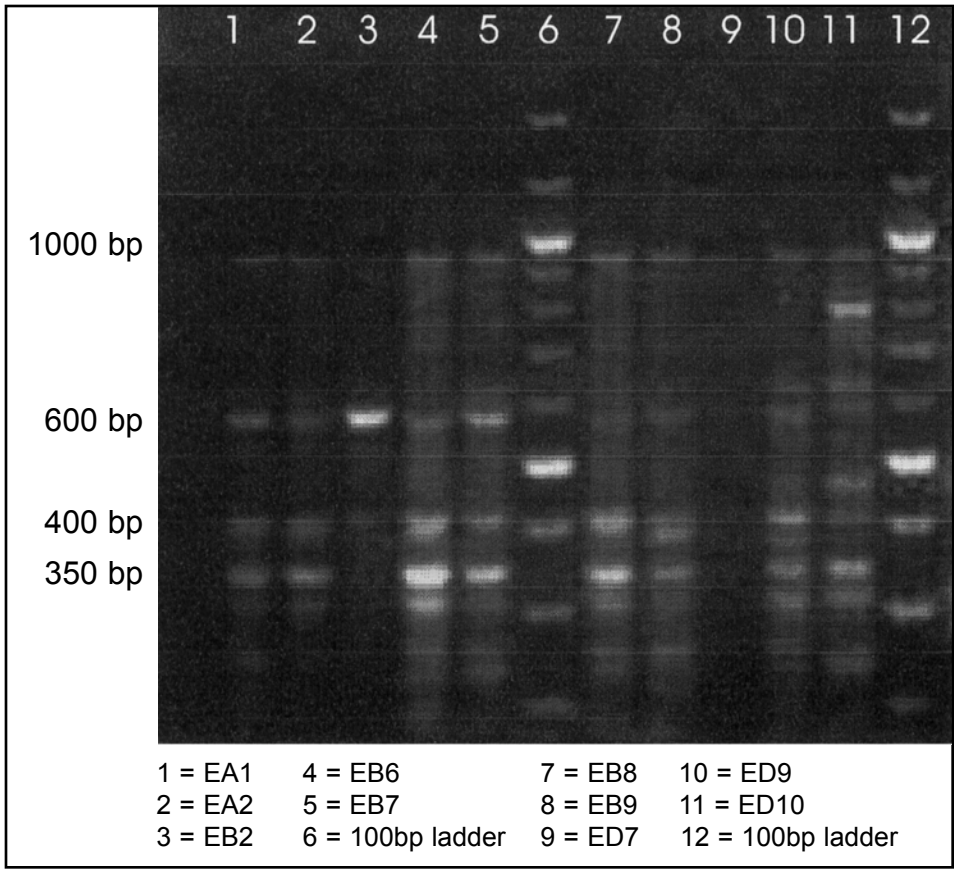

Figure 1. *Ruppia maritima* individuals' RAPD banding patterns.

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The Influence of Colloids and Cations on Infectivity Levels of Taura Syndrome Virus

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TEXAS HAS NINE COASTAL SHRIMP farms that are the subject of continuing environmental controversy. These facilities have been criticized for high turbidity and BOD in the effluent and for release of exotic shrimp and possibly exotic shrimp diseases.

TPDES permitting has begun to address the issue of discharge quality. The farms are still culturing the Pacific white shrimp because there are no sources for seedstock of native shrimp and their culture systems were based on the exotic animal. The farms have been hit by viral epidemics caused by Taura Syndrome virus several times in the last five years.

There is great concern in the shrimping community that disease epidemics will spread from shrimp farms to the wild stock and decimate the fishing industry. There is no evidence to date that epidemics can occur in the wild, but the wild shrimp stock may have been exposed to and infected by shrimp viruses associated with aquacultured stocks.

The epidemiology of shrimp farm epidemics is poorly documented and understood. Pathogenic viruses may be transferred into ponds in water, in plankton, in flying insects, in bird feces or on humans. One major questions after an epidemic is does the active virus survive outside shrimp and if so can the pond and/or water be treated to remove or inactivate the pathogen.

Clay particles have been shown to play a role in transport and infectivity of polio virus. Shrimp ponds are clay lined. Clays are ubiquitous in Texas coastal environment and constitute major components of the sediment in most bays where shrimp farms are located. The type of clay found on our coast has a high cation exchange capacity, which influences the ability to bind virus particles.

If shrimp viruses adhere to clay particles, it may prevent infection and provide protection for shrimp. Although viruses may be inactivated and stabilized by adhering to clay, they can be activated when released from their association with the clay particle. Also, when adhering to clay particles, a virus can be insensitive to various sterilizing agents known to kill free viruses.

We have studied the inactivation or adhesion to clay particle of virus by using a bioindicator system consisting of Pacific white shrimp postlarvae and Taura Syndrome virus, a pathogen responsible for major epidemics from Ecuador to Texas.

Methodology

Young shrimp that are sensitive to the Taura Syndrome virus (TSV) are exposed to homogenates containing viral particles in different concentrations. The exposures occur with and without clay particles in the water. Virus particles were delivered in homogenates obtained from tissue of infected shrimp provided by the Gulf Marine Research Lab in Mississippi. Tissue is homogenized, filtered and centrifuged at speeds that will pellet cells, bacteria and large membrane fractions. Three different clay minerals were obtained from the Clay Mineral Society.

Three series of experiments were conducted.

1. Testing the effect of clay minerals with different cation exchange capacity on lethality of TSV.

The virulence of the TSV homogenate in Experiment 1 is apparently quite low and the presence of clays appears to have no or slightly negative effect. In the second experiment, the viral challenge is more lethal and all of the clay minerals appear to increase survival. Differences in survival among clay minerals and controls are not significant. The TSV treatment in experiment 2 was not replicated because shrimp were in short supply. Montmorillonite was selected for further studies because it is typical of Texas coastal clays.

2. Testing the effect of clay at one concentration on the lethality of TSV at different concentrations. The shrimp were exposed to five concentrations of TSV (expressed as weight of infected tissue homogenized per l of homogenate). All challenge aquaria receive 80 ml of homogenate. Those that receive less than 800 mg/L of TSV tissue receive proportional amounts of homogenate from tissue of uninfected

Table 1. Proportion of shrimp postlarvae surviving after 5 days of exposure to treatments containing TSV virus with and without three types of clay at 1 mg/ml.

Treatment	Expt. 1	Expt. 2
Control	0.99	0.96
Virus Only	0.73	0.36
Virus + *Na* Montmorillonite	0.55	0.61
Virus + Clinoptillolite	0.69	0.59
Virus + Kaolinite	0.49	0.65

Table 2. Survival of shrimp postlarvae after five days following exposure to TSV virus at four different concentrations. Three sets of postlarvae received different additives to the exposure environment: none, 100 mg/l of graphite and 60 ppb of clay (*Na* Montmorillonite).

Treatment	No additive	Graphite	Clay
Control	1.00	1.00	0.96
Virus @ 50 mg/l	0.72	0.96	0.96
Virus @ 100 mg/l	0.52	0.64	0.64
Virus @ 400 mg/l	0.28	0.24	0.80
Virus @ 800 mg/l	0.16	0.04	0

Table 3. Survival of shrimp postlarvae after five days of exposure to different treatments involving changing concentration of clay (Na Montmorillonite). Low clay concentration is 1 mg/ml, medium is 4 mg/ml; high is 8 mg/ml.

Treatment	Expt. 1	Expt. 2
Control	0.92	0.91
High Clay Only	0.96	0.96
Virus + Low Clay	0.74	0.69
Virus + Medium Clay	0.80	0.77
Virus + High Clay	0.64	0.90
Virus Only	0.59	0.76

native shrimp. This is to equalize the amount of shrimp biochemicals added to each challenge aquarium.

Obviously the concentration of virus particles has an effect on the survival of shrimp after challenge. It does not appear that 4 mg/ml clay provides any protection from viral infection at the highest viral concentration. At intermediate concentrations of virus, the clay and even the graphite appear to improve survival. We know of no reason for graphite to protect from a viral disease.

3. Testing the effect of clay concentration on the lethality of TSV.

Again the virulence of the TSV homogenate is low and survivals after challenge are higher than appropriate for comparison to prophylactic treatments. All clay treatments are higher than the TSV only treatment in experiment 1. Only the high clay treatment is substantially higher than the virus only treatment in experiment 2. A t-test comparing survival of the TSV only treatment to TSV + high clay in experiment 2 is not significant at the usual level of significance ($p = 0.06$).

Conclusion

The interaction of Taura Syndrome virus and clay minerals is weak and only partially interferes with the process of infection. These experiments suggest that treatment of virus-containing water with colloidal clay would provide very limited benefit to shrimp at high densities.

It is possible that adherence of viral particles to clay particles resulted in the survival increases seen in some treatments with clays. Whether these viruses are protected from antiviral agents by this association remains to be tested.❖

Long-Term Research in Mathematical Modeling in Ecology

William E. Fitzgibbon, Ph.D., Department of Mathematics, UH, and Marek Kimmel, Ph.D., Rice University, Department of Statistics

In his monograph on mathematical ecology, A. Okubo points out that mathematical investigation of the interrelations between the distributions and the quantity of organisms and their environment is a relatively new subject having its roots in the first half of this century.[1]

Recently we witnessed an increase in this modeling activity. The increase has been fueled by the development of modern computational machinery and by breakthroughs in the formulation of efficient, robust, adaptive, and accurate computational algorithms no less than advances in our fundamental understanding of the dynamics of complex nonlinear systems.[2]

Mathematical models can be applied in different ways. They may be descriptive, explanatory and predictive. Following L. Gross, we provide definitions and examples.[3] Although descriptive models synthesize available data, they make no attempt to explain underlying processes or mechanism. Here a regression fit to data is a good example.

Explanatory models offer hypotheses about the fundamental process under study and derive logical consequences from these hypotheses. An example is provided by the use of random walk models to describe the dispersal of a population. Predictive models anticipate the potential response of selected components of complex systems to variations in various features of the system. An example is provided by the prediction of the potential impact on fish populations in a lake caused by a rise in temperature produced by locating a power plant on the lake.

Predictive models anticipate the potential impact on fish populations in a lake caused by a rise in temperature produced by locating a power plant on the lake.

The majority of ecological models are concerned only with temporal variations and do not account for spatial variations or heterogeneity.[4] Spatial or geographic factors clearly play a practical as well as a theoretical role in ecological considerations.[5,6] For example, one might want to know if a predator can maintain a prey at low densities.[7] Answers based on observations made in cages or small quadrants could be radically different from those obtained when the organisms are allowed to range freely over large areas of varied terrain. Indeed, differences in locale can greatly effect the nature of the predation.

One other aspect important for understanding of ecosystems under environmental stress is the heterogeneity of the population inhabiting the ecosystem. Both animal and plant populations are composed of individuals of different sizes and "social ranks," who compete for environmental resources. Therefore, ecosystems cannot be considered as inhabited by collections of identical independent molecules.

Both discrete and continuous models may be used to describe spatially distributed systems. However, it is often desirable to use discretizations of continuous systems that are derived as approximations of discrete systems. Typically, continuous models are expressed as systems of partial differential equations or integral equations. These distributed parameter systems are typically nonlinear and can be quite large and complex and tractable only by numerical methods.

One of the important elements of modern ecological research is the ability to work with data referenced by spatial or

Can a predator follow a prey at low densities? Answers based on observations of small habitats could be radically different from those obtained when organisms are allowed to range freely over varied terrain.

geographic coordinates. Geographic Information Systems (GIS), a leading system developed for this purpose is both a database system with specific capabilities for spatially-referenced data and a set of operations for working analysis of the data. An example of a successful long-term application of GIS to monitor response of an ecosystem to environmental pollution is the work of ecologists from the Institute of Environmental Biology of the Jagiellonean University in Krakow, Poland.[8] The Niepolomice National Forest is an ancient growth, a forest complex close to the large urban and industrial area of Krakow. It includes a variety of soil and vegetation types; the area is characterized by a relatively high diversity of plant and animal species, including big game. Part of the area is well preserved in its natural state, part has been exploited commercially. Data have been carefully collected since WWII.

In the 1950s the forest began to suffer severely the impact of industrial pollution. Under Communist rule (pre-1989), the forest was exposed to high levels of toxic air dust from nearby metal works. About the year 1990, the pollution dramatically decreased as a result of the collapse of state-sponsored heavy industry in Poland. From about 1996, forest areas gradually started to increase, as the industry recovered. The application of GIS technology tracks the complex changes in air and water quality in this ecosystem and the resulting changes in the ecosystem.

There is great interest at the National Science Foundation in developing ILTER (International Long Term Ecological Research) sites in Poland and in Central Eastern Europe. The Niepolomice National Forest is an excellent example of such a site.

In the United States, the LTER Project (Long Term Ecological Research), established by the National Science Foundation to conduct research on long-term ecological phenomena in the United States, consists of a network of 18 sites within the US representing a broad array of ecosystems and research emphases. The sites function as "research platforms" that lead to explorations of larger areas or regions, provide the scientific basis for management and policy issues, and foster broadly based interdisciplinary work on the dynamics of environmental fluctuations and evolution.

The U.S. endeavor is part of a larger international effort identified as the International Long Term Ecological Research Program (ILTER). The ILTER concept,[9] is predicated on the idea of collaborative research efforts and developing linkages with other long-term research programs, site networks, and science and technology centers. This communication and data sharing distributed among the ILTER sites and between the ILTER program and other scientific communities is facilitated by electronic networking and data management involving on-line Internet accessible databases and bulletin boards. Mathematical modeling and computational simulation are closely allied with modern electronic and data management. The implementation and utilization of mathematical models plays an important role in the ILTER effort.

Currently, several sites in Poland are being evaluated as potential ILTER sites. Many of these are monitored by either the International Centre of Ecology of the Polish Academy of Sciences (ICEPAS) or the Institute of Ecology of the Polish Academy of Sciences (IEPAS). The Polish scientists have done a superb job of documentation and data acquisition. However, it appears that their effort is classical and, as is typical of much European ecology, not supported by ecosystem modeling methodology or modern information technology. Much of their data is manually catalogued, filed, and displayed. They do not make standard use of GIS, nor do they make extensive use of state of the art database and visualization technology. If they are to meet ILTER standards, they must increase their utilization of modern data management and modeling methodology as well as computational and communication technology.

During the course of the academic year, several researchers visited Houston to collaborate with the authors on research pertaining to the mathematical modeling, analysis, and simulation of the long-term behavior of spatially heterogeneous ecological processes. Visits of the longest duration were paid by Prof. Michel Langalis of the University of Bordeaux. William Fitzgibbon and Prof. J. Morgan of Texas A&M University, in collaboration with Langalis, submitted a proposal ($20,000) to the National Science program under the auspices of the International NSF/CNRS program.

In France, a proposal at the same level

The Ecological Research Project conducts research in 18 states, representing a broad array of ecosystems designed to explore policy issues and interdisciplinary work on the dynamics of environmental fluctuations and evolution.

has been submitted to the CNRS (the French equivalent of the NSF). Prof. Michel Langalis will return to Houston for a visit this Fall to pursue this project.

In March, 1999, the authors traveled to Albuquerque, New Mexico to meet with Dr. James Gosz of the University of New Mexico (head of the NSF LTER Program) and Dr. John Vande Castle. Their purpose was to discuss future ILTER projects. As an outcome of the discussion, the authors plan to organize a series of events in Poland which will focus upon the application of modern mathematical modeling methodology and modern information technology. The first will be a workshop that compares data obtained from the NASA LANDSAT Project with field data from selected Polish ecological sites.❖

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Molecular Tools for Identifying Microgeographic Genetic Patterns in Avian Systems

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Habitat loss and fragmentation are widely recognized as the major causes of loss of biodiversity. Proactive investigations which assay the effects of these ongoing processes and provide information useful in designing management programs that minimize deterioration of habitat quality are essential.

Saltmarsh habitat along the Texas Gulf coast has historically been and continues to be particularly vulnerable to practices that result in eradication or degradation. Agricultural, industrial, recreational, and commercial development have eliminated or seriously encroached upon essentially all saltmarsh habitat occurring within Texas's borders. Though the contributions of high quality estuarine wetlands to commercial fisheries, pollution control, and maintenance of biodiversity have been firmly established in the scientific community, public attention has not been successfully mustered to an extent that ensures that continuing measures will be employed to constrain these processes. We believe that in order to recruit requisite public support for the maintenance of habitat quality, it is necessary to provide evidence that demonstrates the consequences of development on saltmarsh biota and, hopefully, encourages an appreciation for the obscure, but highly unique biological dynamics of this habitat.

The Seaside Sparrow is a resident saltmarsh exclusive species that serves as an indicator of habitat quality by measures of abundance and genetic variation. We are involved in directly assaying *inter* and *intra* population genetic variation in order to identify population structure. Our genetic assays permit inferences about (1) the genetic population sizes and (2) degree of gene flow between isolated populations of Seaside Sparrows occurring from the Sabine River to the southernmost extent of its range (Nueces Bay). We are attempting to quantify the degree to which these populations are genetically isolated to determine whether metapopulation models are applicable to management plans for this system.

Nondestructive sampling methods are employed (l00 ul whole blood from the jugular of mistnetted adults), and we now have complete samples (17-23 individuals) from seven sites and three partial samples. Though rigorous censusing procedures have not been employed, it appears that population densities of southern populations are lower. Though we are not prepared to explain this phenomenon at this time, we feel it is cause for concern.

We have screened 17 sets of primers developed in the microsatellite genomic libraries of several passerine species. We have identified eight loci with an appropriate range of polymorphism to uncover present and recent historical genetic migration patterns; and we have scored four of these loci and established variation in frequency distribution for most alleles.

Though it has been our primary goal to obtain qualitative genetic data that will provide us with the means for identifying rates of migration, effective population size, and degree of isolation, we have additionally, recorded morphometric data which can subsequently be analyzed in quantitative genetic analysis, banded the sampled individuals with aluminum tags, and reported our activity to the Bird Banding Laboratory in Laurel, Maryland. These observations have been communicated to personnel of the Texas Parks and Wildlife and U. S. Fish and Wildlife agencies.

We have successfully demonstrated that nondestructive sampling can be employed in conducting fairly large-scale population studies where a large number of individuals need to be sampled. Our methods could be applied to vulnerable populations with minimal risk.

We have also shown that the use of microsatellite primers developed for one species of passerine can be utilized in genetic population studies of related species that diverge at the Family level. Hopefully, findings will encourage personnel in other laboratories to proceed with research that they might have other wise dismissed because of concerns of endangerment or financial cost.❖

Population Age Structure in a Common Species of Damselfish on an Isolated Western Atlantic Reef (Flower Gardens, Texas) and the Florida Keys Patch Reef

Gerard Wellington, Ph.D., and Chris Caldow, Department of Biology, UH

INFORMATION ON POPULATION AGE structure of a reef fish will provide useful data for the management of marine reserves. Age structure analysis can reveal annual variation in recruitment of fish to a reef, as well as differences in growth rates, life expectancies, and other life history traits.[1] By combining information on recruitment with life history data, we hoped to gain insight into the sensitivity of these populations to human perturbation.

For the purpose of our investigation, we chose to examine the otoliths in a species of damselfish common throughout the Caribbean Sea and the Gulf of Mexico, *Stegastes planifrons* (Threespot Damselfish). Our collections were taken from the Flower Garden Banks National Marine Sanctuary in Texas and the Florida Keys National Marine Sanctuary. We obtained information on age structure from the otoliths or ear bones of the fish. As reef fish grow, alternating bands of translucent and opaque materials, corresponding to periods of fast and slow growth respectively, are deposited on the otolith.[2] In addition to distinct daily bands that are deposited in larvae and newly-settled young, bands are formed at yearly intervals in many adult fishes.[3]

Our initial research revealed that annual ring clarity differed along a latitudinal/temperature gradient and between species. This observation is concordant with Fowler[2] who found that two of three damselfish species examined had readable annual rings; one of those species had rings that were readable at only one location. These results enabled us to postulate that both environmental as well as genetic factors play a role in otolith ring deposition. We were also able to demonstrate that *S. planifrons* collected from the Flower Garden Banks show an exponential decline in growth rate and abundance with age. Their populations are composed mainly of fish 1+ and 2+ years old, which, by age 3, will have achieved near maximum growth. Analysis of our data also revealed periodic years of low recruitment or high juvenile mortality (Fig. la,b).

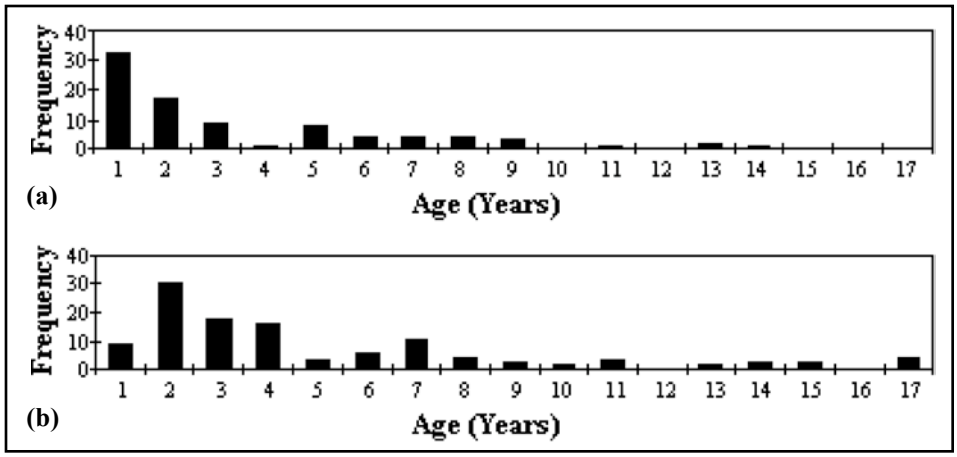

Figure 1(a). Age frequency distribution of Threespot Damselfish collected from the Flower Garden Banks in 1998 (n = 90), (b) Age frequency distribution of Threespot Damselfish collected from the Flower Garden Banks in 1999 (n = 106).

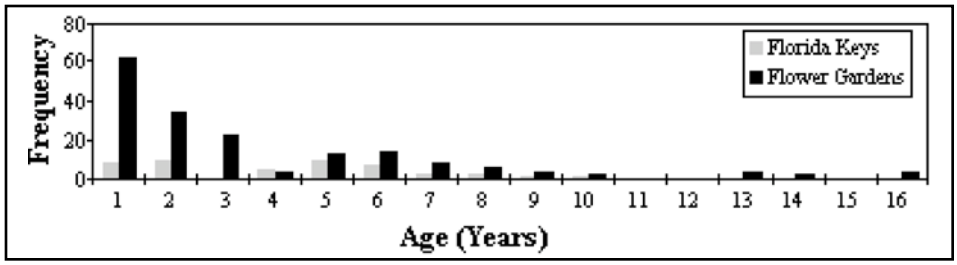

Figure 2. Age frequency distribution of Threespot Damselfish collected from the Florida Keys (n = 16) and the Flower Garden Banks in 1999 (n = 196).

With our most recent data, we are able to make some initial comparisons between the Flower Garden Banks and the Florida Keys. *S. planifrons* collected from the Florida Keys tend to grow at a slower rate than those collected from the Flower Garden Banks. This information suggests either higher productivity in the Flower Garden Banks or decreased competition. Life span also is decreased in damselfish from the Florida Keys (Fig. 2). As with our Flower Garden Banks data, we notice the absence of fish in certain age groups (1+ and 4+). A glance at our collections from the Flower Gardens in 1998 and in 1999 allows us to follow highs in recruitment seen in age class 1+ in 1998 and 2+ in 1999, as well as lows such as 4+ in 1998, which becomes 5+ in 1999 (Fig. 1a,b).

Knowledge of variation in recruitment is important in developing effective management policies since exploitation of stocks with high variability in recruitment can jeopardize the stability of those stocks and others dependent on them. Data collected on life history characteristics as a whole can be used to make predictions about the stability, production and turnover rate of these marine populations.[1] This information is also essential for enacting appropriate management policy.

This research was conducted under National Marine Sanctuary permit number FGBNMS-06-98 and FGBNMS-08-99 and Florida DEP permit number 98S-164A.❖

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The Population Demography of the Polygyne Form of the Red, Imported Fire Ant, *Solenopsia invicta*

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RESEARCHERS SEEK TO UNDERSTAND the spatial dynamics of the polygyne fire ant *Solenopsia invicta*. To find effective methods for controlling fire ants, basic features of their population biology must be understood to measure their endurance and durability. Spatial questions about fire ant populations, which this study emphasizes, ask how nests are located in space, the density of and relationships among these nests, how long nests survive, and how often they move from one location to another.

This project, begun in February 1999, comprises a number of components identified in the following summary.

The first priority of the investigative team was to develop a detailed map of nest locations to gather background data and provide for future projects. We selected a field site in the center of a prairie at the Houston Coastal Center. In an area 30 x 45 meters, we searched for all ant nests in all size classes and have regularly checked for new nests, noting a decline of activity in nests previously occupied. In this circumscribed plot, we have developed a detailed record of time series data for the activity of nests. Figure 1 shows a map of this plot, indicating active nests during May 1999.

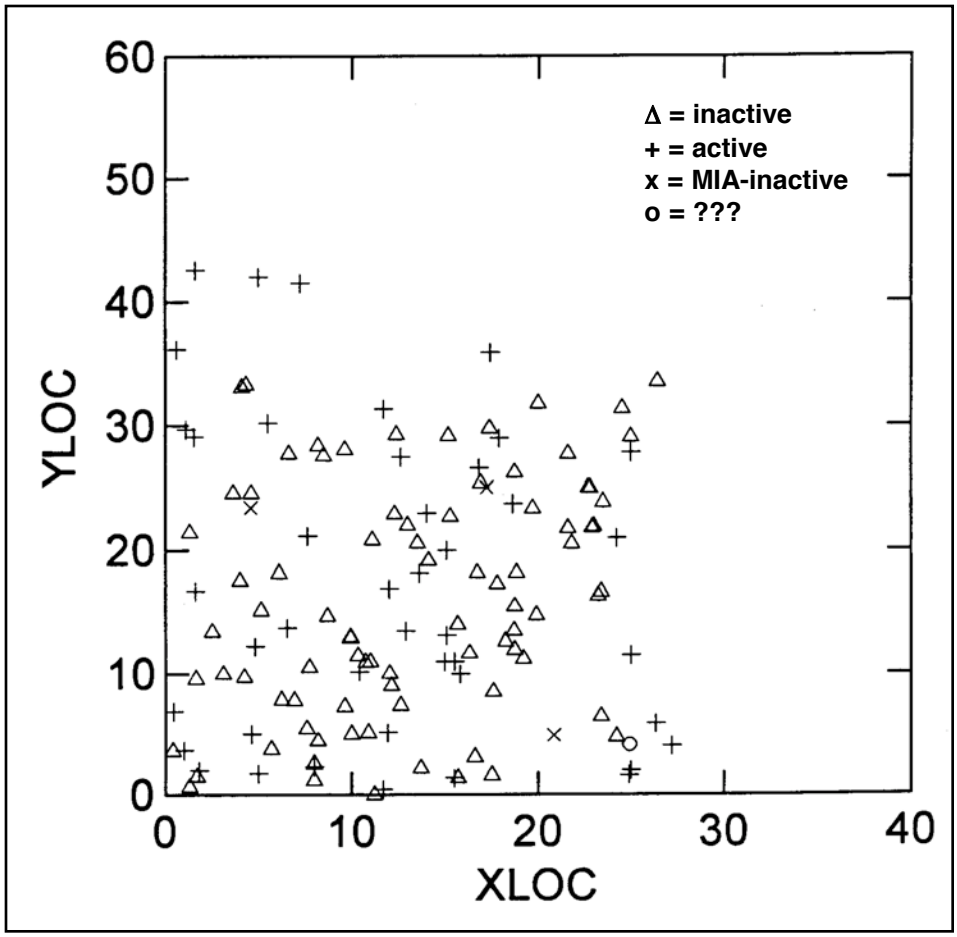

Figure 1. Map of the field site indicating active nests during May 1999.

The development of this plot, including mapping of the site and exhaustive searching, occupied five months of the project. As the uneven distribution of nests became known, it became apparent that an extension of the study into adjacent new plots would help determine the scale of variation. So far, it is clear that the highly dense nests are not evenly distributed. Nest locations may well be affected by small scale topographic areas where the ground remains flooded, as well as vegetational differences tied to the topography.

As spring progressed into summer, activity in these nests dropped significantly. Less than two percent of all the nests first located in the plot have remained active since the study started.

The frequency of nests which remained active was similar in another prairie site at the Houston Coastal Center, in which roughly two percent of 40 active nests marked in February remained active in July. Ants inhabited many temporary nests, which were active for less than two months. Into the summer, fewer nests are active. The emergence of new nests has greatly slowed during the summer.

We have observed very little movement among nests, despite investing many hours in the observation. It is most likely that ants move underground to create new nests. Although ants were seen to be travelling under a thin cover of soil in a few locations, no new nests have resulted from their activity. During the few instances in which we observed ants carrying brood in the open, appearing as if a nest was moving—the ants disappeared underground into discernible locations, but without evidence of the formation of new nests. Tracking the location and activity of nests led to new questions about the relationships of neighboring nests.❖

Defining and Measuring Environmental Capital in Urban Environments

Theodore G. Cleveland, Ph.D., and Jeffrey L. Davis, Department of Civil and Environmental Engineering, UH

DYNAMICS OF AN URBAN ECOSYSTEM are controlled by interactions of the natural, constructed, and social environment that help determine the overall vitality of an urban area. These interactions are poorly understood and improved understanding might allow for prediction of the effect of civic investments on the vitality of an urban area.

While traditional measurements at measuring environmental quality are aimed at regulatory compliance, little is available in the environmental engineering literature that addresses the broader issue of what constitutes a high-quality urban environment. This project addressed this issue with the following objectives:

(1) Generate a literature review on quantification of environmental quality in an urban area from both an engineering and ecological perspective.

(2) Build and deploy an Internet based "environmental quality" game whose player responses can be analyzed to determine variable that are perceived to be important.

(3) Produce sufficient background information to prepare a proposal to the National Science Foundation Urban Research Initiative and would involve a team of researchers, provisionally from political science, economics, ecology, and engineering.

Figure 1 is a diagram of a conceptual model of community vitality. This model uses a concept of three reservoirs of capital resources shown on the perimeter of the circle: social, physical, and the environmental. These three reservoirs of capital have a direct effect on the overall vitality of the community shown in the center, as well as an effect on the other two capital reservoirs. The effect of physical capital and social capital are documented in the literature. The effect of environmental capital is unmeasured (except in extremes; e.g., un-breathable air), and its effect on the social and physical reservoirs is unmeasured.

"Social capital" is defined as a reservoir of mutual trust, civic involvement, and reciprocity that encourages individuals to sacrifice their own short-term interests in the service of some common good. Voter participation rates, community organizations, and political representation are tools employed to measure the amount of social capital available in a community.

"Physical capital" is the entire physical infrastructure as well as the land in an urban region. The infrastructure includes both the public infrastructure and private infrastructure. Measurements of physical capital are public and private capital expenditures, service revenues from mass transit, utility services, telephone service, etc, and inventory of amenities such as parks and cemeteries.

"Environmental capital" is not well defined, and its definition is one on-going objective of this research. Two definitions emerged from the literature searched to date. One definition includes all factors that affect the health of citizens. This definition leads to a large overlap with physical capital. Items such as the number of hospital beds in a community have a major affect on the health of citizens but are also included as physical capital.

A second definition of environmental capital includes only the non-constructed factors such as climate (temperature and humidity), water availability, and geology. This definition means that environmental capital has a bounding effect on the vitality of a community. The bounding effect is clear in a case of an area with physical and social investments outside of the local environmental reservoir. An example of a physical investment in environmental capital that increases the vitality of a community is the capital expenditure in the construction of the California aqueduct designed to increase the water supply flowing to Southern California.

The second and on-going objective of this project is to determine if environmental capital can be measured. As a first approximation, a game is under development where players are presented with a series of images and asked to select preferred "environments" based on a computer selected character. Software development and design of this game has been problematic, particularly the setting of "cookies" to innocuously record user response.❖

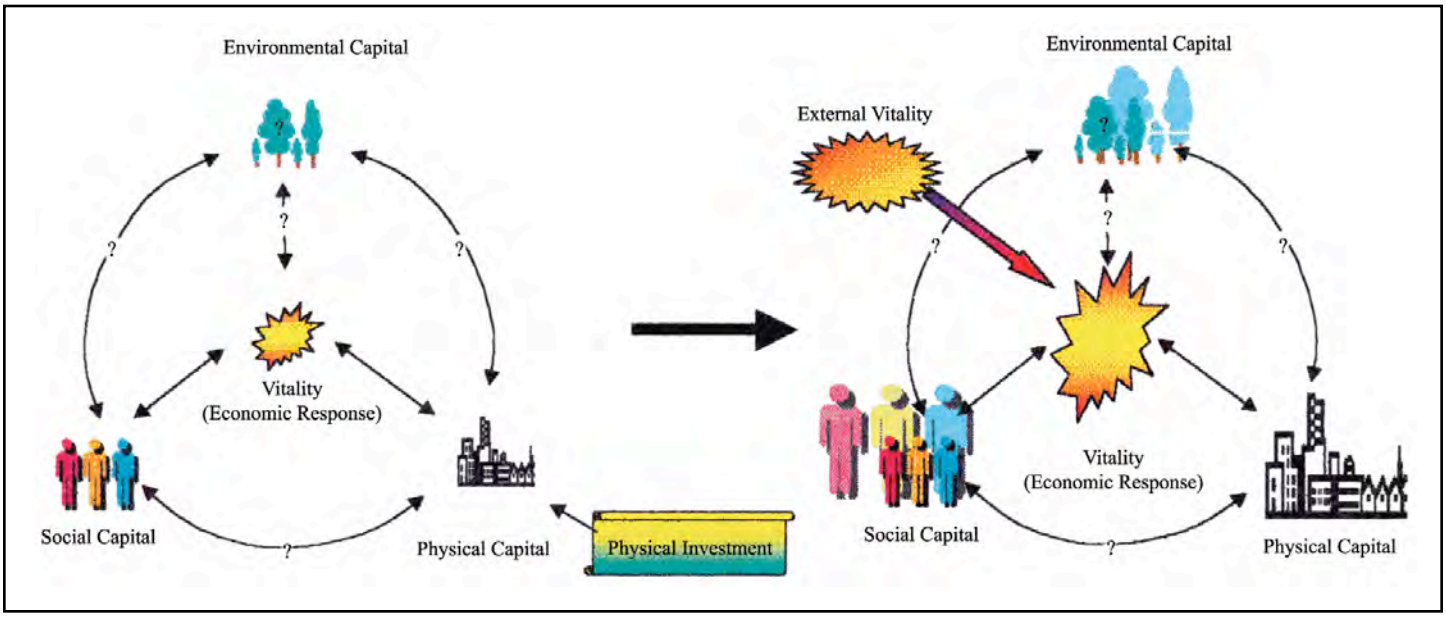

Figure 1. Conceptual Model of Community Vitality

***Current Theory*: Where sufficient social and environmental capital exists, an investment in physical capital will stimulate vitality.**

***Research Questions*: (1) Do physical investments stimulate social capital?**

(2) How is environmental capital measured?

(3) What, if any, generic physical investments work best?

(4) What are the threshold values of social, physical, and environmental capital?

(5) Can one predict the interactions?

(6) What is the threshold vitality that attracts further vitality (economic gravitation)?

Acknowledgements

Many of the bibliographical references and initial concepts were obtained from numerous discussions with Dr. Greg Weiher in the Department of Social Science at the University of Houston.

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An Environmental History of Galveston Bay: Flood Control

Martin Melosi, Ph.D., and Victoria Garcia, Department of History, UH

Floodgates at Kemah

As a first step toward an eventual environmental history of Galveston Bay, we developed a comprehensive bibliography and source guide in 1998. The guide includes 81 pages of archival listings for a variety of depositories holding collections relevant to Galveston Bay. It also includes a selected bibliography of hundreds of sources. Given the wide variety of research materials on many facets of the history of Galveston Bay, we began the process of producing publishable articles based on that material. The publication of key research will ultimately lead to a comprehensive environmental history of Galveston Bay.

This research should (1) help to demonstrate the historical significance of the bay with respect to Texas coastal communities, (2) identify policy issues of contemporary significance, and (3) provide a database comparing the Galveston Bay with other regions of the nation and similar sites in the world.

The environmental history of Galveston Bay comprises the ecological evolution of the complex in its relationship with a variety of human activities that occur along its shores and in its waters. Bits and pieces of that history are known, but a comprehensive understanding of the environmental, social, political, and economic history of Galveston Bay has yet to be written. The significance of the Galveston Bay Complex is broad. It nurtures a vast array of aquatic life, defines many coastal communities, provides a major means of transportation and trade, proves itself a source of economic opportunity, and, antithetically, the Bay has become a sink for all manner of wastes.

The relationship between Galveston Bay and its many coastal communities is symbiotic. The culture of those communities has depended for decades upon the exploitation of the bay. Historically, the bay has seen competing interests vie for dominance–from fishermen to oilmen, from shipping lines to beach-goers.

The research on flood control focuses on the priorities of different structures of government, and how the interaction between separate agencies may have affected flooding issues. It begins with an assessment of the Texas constitution and the responsibilities of several state institutions, and then proceeds to discuss the role of the federal government.

Washington was slow to take an active role in mitigating flood control. Only during the New Deal did flood control become part of a national program of relief. On the state and local levels, flood control districts became central agencies essential for the study of local conditions, as was the Galveston District of the U.S. Army Corps of Engineers. Between 1936 and 1941, flood-control studies of sixteen river systems were conducted by the Galveston District office of the Corps.

Next came the transformation of urban space in the Gulf Coast area after 1945. Of particular importance to the development of the Gulf Coast were issues of economic growth and national security, with particular attention paid to the strategic importance of the Port of Houston.

Federal attention to floodplain development awaited the 1960s and 1970s, with the passage of the National Flood Insurance Act (1968), the Disaster Relief Act (1970), the Flood Disaster Protection Act (1973), and the Disaster Relief Act (1974). These actions were linked to the rising inventories of houses inundated and damaged by floodwaters and greater sensitivity to an array of water pollution issues.

The Garcia report concludes with a thorough discussion of the recent Galveston Bay Plan. Drafted by a partnership of state and federal agencies, local governments, and concerned citizen groups, 82 management initiatives were established to address 17 specific problems. A potentially powerful tool, the plan will challenge property rights and certainly increase suspicion of government action. Most significantly, it will act as a first step toward the resolution of a crucial regional problem.❖

Influence of Global Climate Changes in the Early Development of the Rio Grande Chirping Frog, *Syrrhophus cystignathoides campi*, a Direct Developing Frog

Dan Wells, Ph.D., and Ying Tan, Department of Biology and Biochemistry, UH

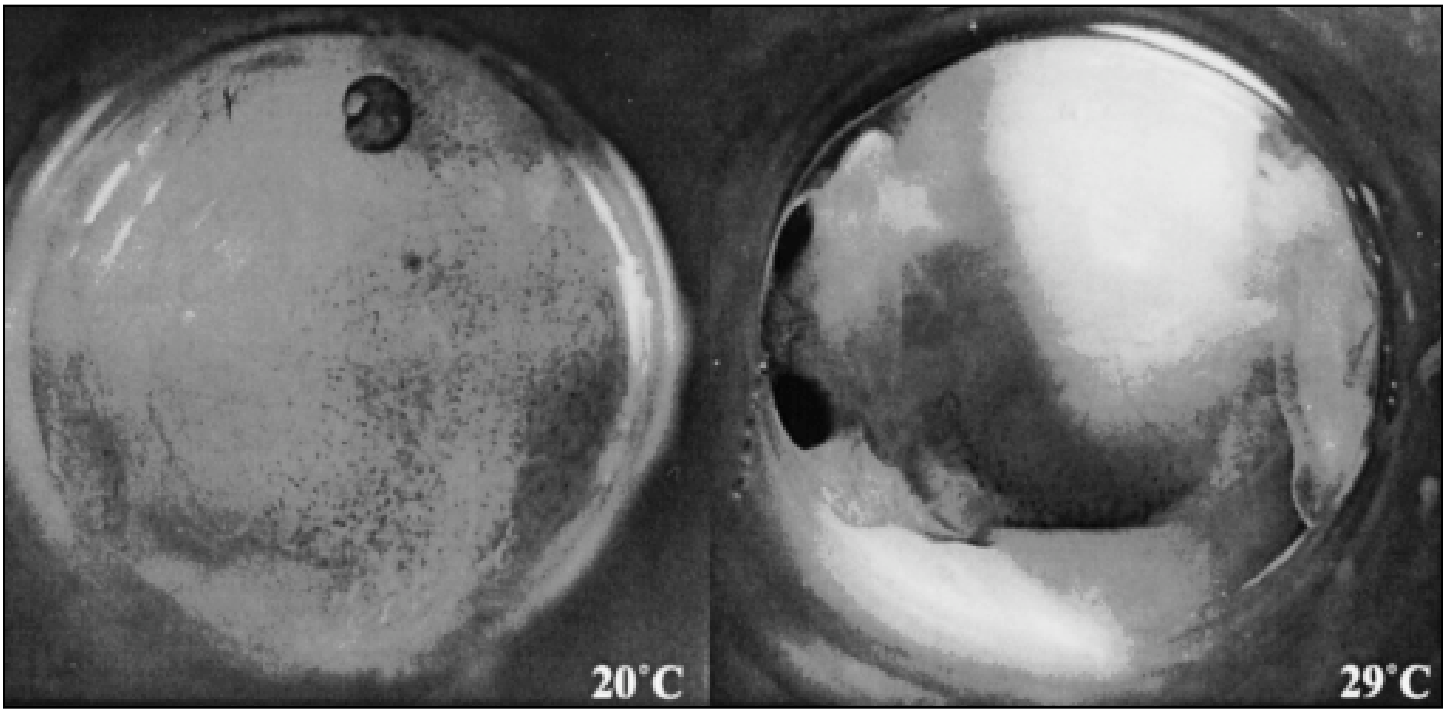

Figure 1. Embryos 7 days into the experiment. Notice the difference in development between the two temperature treatments. The 20°C embryo is at stage VIII: the disc is starting to cover the yolk, melanophores are developing, the pupils are clear, and digits are barely forming. The 29°C embryo is at stage XIII: the disc covers about three-fourths of the yolk, the pigmentation has increased, the pupils are dark, and the digits are clearly visible although not fully developed.

Worldwide amphibian population declines have been observed in the past few decades, with some species becoming extinct while others remain unaffected.[1,2] A National Science Foundation workshop in May 1998 concluded that these population decreases are indicative of a widespread deterioration in environmental quality and attributed to different factors.[3] While several of these declines have been attributed to local factors such as natural epidemics or human disturbances, many of them have occurred in protected, undisturbed habitats.[1,4-7]

Thus, global factors such as increased UV radiation resulting from a thinning of the ozone layer, acid precipitation, and climatic change have also been implicated in these declines. Global factors are usually translated into changes in the regional environment and may act singly or synergistically with other local factors.[2,8,9] Sublethal environmental changes may affect the tadpoles' immune system,[4] cause developmental abnormalities, and retard growth and metamorphosis.[10,11] Temperature affects developmental rate in most organisms.

Amphibians, being poikilothermic, are particularly sensitive to ambient temperature. Global warming resulting in increased temperature and length of dry season will affect embryonic development. Increasing the length of the dry season might result in a shorter breeding season closer to winter (rainfall is one of the cues for reproduction). If this is the case, cooler temperatures would slow development so much that individuals might not have enough time to prepare for hibernation. Embryos might be able to adapt by undergoing hibernation in the egg.

The Rio Grande chirping frog, *Syrrhophus cystignathoides campi*, is native to Mexico and South Texas. This frog belongs to the family *Leptodactylidae* and is, as many members of this family are, a direct developer. It spends its entire life in a terrestrial habitat with the embryo developing inside an egg deposited on loose, humid soil and hatching as a small froglet.

The objective of this study was to evaluate the effect of temperature changes on the early development of *Syrrhophus cystignathoides campi*. In order to investigate the effect of global warming (resulting in a lengthening of the dry season) on the embryonic development of *S. cystignathoides campi*, eggs devoid of their jelly coat were placed on individual 35mm petri dishes in Ringer's solution and reared at two different temperatures: 20°C and 29°C. These embryos were observed and measured daily under a dissecting scope.

Reduced temperatures slow down development significantly (Fig. 1,2). An unexpected result was that the embryos raised at 20°C never hatched (Fig. 2b). Once they reached the final stage of development (Stage XV after Townsend and Steward),[12] they seem to reach a point of homeostasis. Their metabolic rate slowed

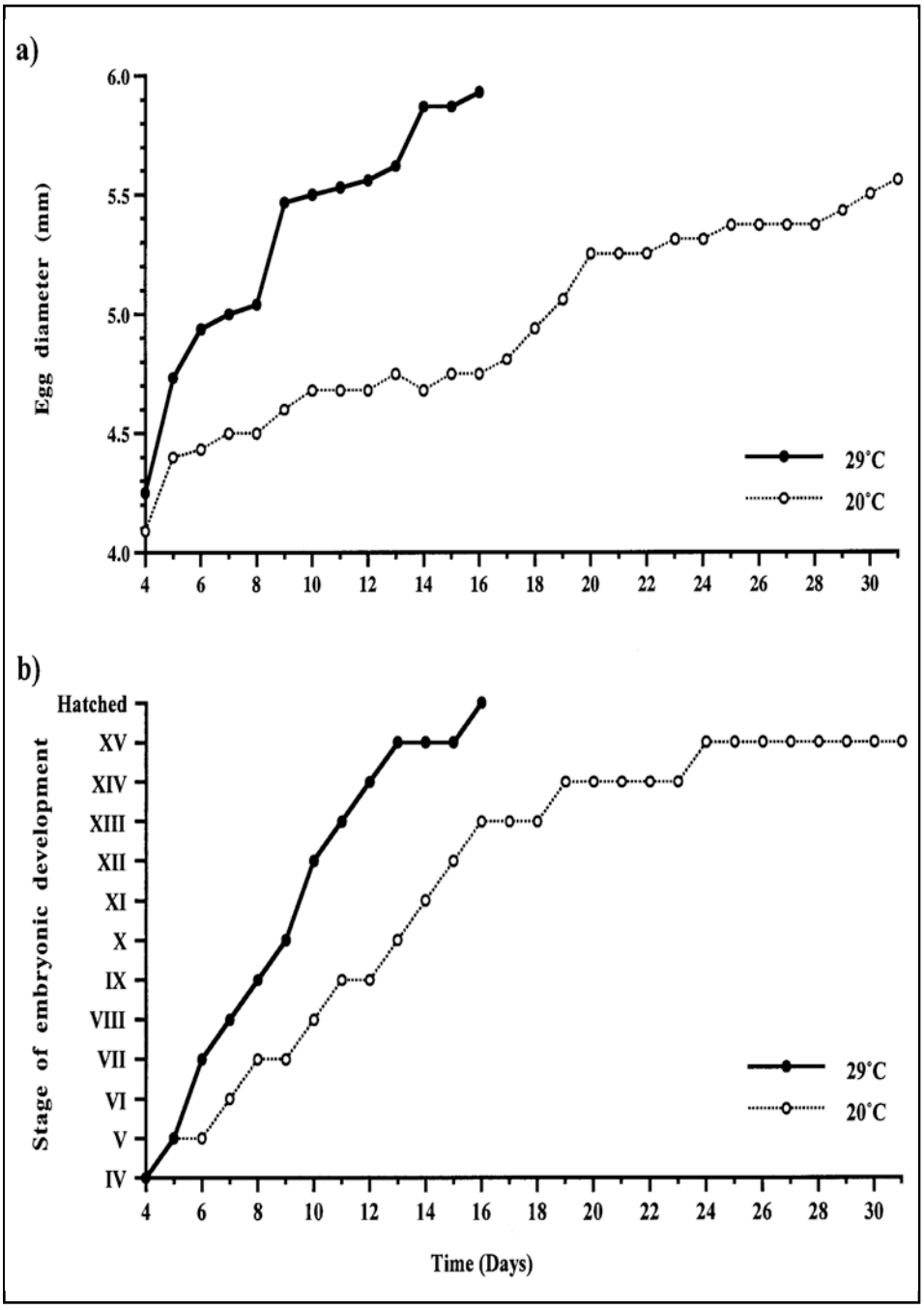

Figure 2. Changes in egg diameter and the developmental stage with time in embryos reared at two different temperatures. The 20°C embryos showed a significant developmental delay when compared to the 29°C embryos.

down to the point that the heart beat was barely noticeable. After nine days of homeostasis, we dissected the embryos to look at their developmental stage. The embryos were not dead; their hearts started beating as they warmed up to room temperature. We plan to repeat this experiment to see how long the embryos will remain viable under these conditions. The question is whether these embryos are slowly dying or whether they reveal an adaptation that enables them to survive longer dry seasons and lower temperatures?❖

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The Social and Natural History of Galveston Bay

Pris Weeks, Ph.D., Research Associate, and Alecya Gallaway, Environmental Historian, EIH, UHCL

The landscape of Galveston Bay has been altered by centuries of human use. The combination of archival research with oral history helps describe the landscape that settlers first encountered, enables us to chronicle human induced changes to the area, and affords the basis for discussion of the importance of the the bay in the development of the social groups living on its shores. UH researchers approached these issues by focusing on the natural resources of the bay. This information will be used to produce a booklet on the social and natural history of Galveston Bay and its littoral zones to be used by educators, agency personnel, researchers, and the public. The booklet will be organized by resources (shell, fish, grazing lands, etc.). Each section will use a particular resource as a point of departure to describe the history of humans' relationship with the bay and the anthropogenic changes that followed.

The waterway itself served an important economic function. The privateer Jean Lafitte came to Galveston Bay around 1817 and used it as a port of entry by which to smuggle goods into the U.S. He subsequently moved onto Galveston Island where he built a town for his men and their families. It grew quickly; and soon entrepreneurs settled around the shores of the bay to supply Lafitte's camp with food, fuel, and building materials.

Although wildlife was a necessary food source for the early settlers, the animals damaged crops and livestock. Hence, the wolf population and other wildlife was endangered or eliminated. Conversely, some introduced species were favored by settlers.

Ironically, cattle was the first major resource to bring settlers to Galveston Bay. Tall grass coastal prairies were important to the production of cattle during the early days of open range. However, when the wild cattle were gathered in large groups and fenced into pastures, their voracious appetites depleted the native grasses. Restoration involved the cultivation of prairies utilizing introduced species of grass. Today a concentrated effort is in effect to preserve some of our native grasses.

The riparian corridors that follow the rivers, bayous, and creeks across the coastal prairies were a major source of building materials for early Texas, and wood was one of the first major exports from Galveston Bay. Today, only a fraction of these corridors survive; few stands of old growth trees are left. Park lands preserved from early land holdings and the trees planted around early homesteads by the settlers across the prairies are where the oldest and largest trees can be found today.

Galveston Bay was a shallow body of water divided in half by a shell bar, and the inlets were shoaled with sand bars that caused numerous ship wrecks and the loss of passengers at sea.

These problems in shipping were resolved by the construction of deep water ports and the removal of the shell bar. Deep channels now criss-cross the bay floor, and jetties have been built to stop the shoaling of the major inlet.

By the beginning of the 1900s, 300-ft deep wells were dug to tap artesian water supplies. Their pipes poured a steady flow of water across the prairies where it eventually flowed into Galveston Bay. Later, industry also used the water from this depth. Next, technology allowed wells at much deeper levels. The removal of ground water was a major factor in the subsidence of Galveston Bay today.

Fish was the first seafood industry; oysters were also harvested during the early settlement days. Shrimp became a major industry during the early 1900s. Oyster shell was used as gravel for the railroads and roads, in the production of cement, and as the raw material source for the first major chemical industries along the Texas coast. Today the shell of Galveston Bay that took thousands of years to accumulate has been mined so heavily that even shell as a substrate for the oyster spat is at a premium.

Galveston Bay was the site of great oil and gas discoveries in the early 1900s and soon became home to many refining companies. Today the production, refinement, and shipping of oil, gas, and their diverse by-products is a major resource for Houston, Bayport, and Texas City. Refining is one of the most important reasons for growth of the Houston area.❖

San Leon Fig Farm, 1923

(Photos provided from historical archives by Alecya Gallaway)

Goose Creek Oil Field, 1912

Winds, Water Budgets, and Stable Isotopes in Tropical Cyclones Using TRMM & QUICKSAT

James R. Lawrence, Ph.D., Department of Geosciences, UH

THE DISCOVERY OF LOW OXYGEN AND hydrogen isotope ratios in rains and vapors from tropical cyclones heralded the arrival of a new tool for understanding the water budgets of storms in the lower latitudes. Low isotope ratios in tropical cyclones were attributed to the high precipitation efficiency and the recycling of water within the storms.[1] The measurement of low isotope ratios of water vapors far from the centers of tropical cyclones indicated the presence of extensive low level outflow regions.[2,3]

Isotopic analyses of rain collected during flights into Hurricane Olivia in 1994, a category 4 storm, showed a change in the water budget of the storm as it peaked out.[4] On the first day, prepeak intensity, a greater fraction of water vapor was being derived from lower relative humidity regions outside the storm whereas on the second day, postpeak intensity, a greater fraction of water was being recycled within the storm at higher relative humidities due to evaporation and exchange.

The discovery in July of 1998 in Puerto Escondido, Mexico of low isotope ratios in water vapors for periods of a few to several days during mesoscale convective activity off the Mexican coast indicates widespread evaporation of rain into downdraft regions (Fig. 1). This mesoscale convective activity was associated with the birth of three hurricanes off the Mexican coast. Low isotope ratios were present in air having high mixing ratios typical of water vapor in the tropics over a warm ocean yet the water vapor was clearly not derived from the sea surface.

These discoveries stimulated the incorporation of a water vapor and rainfall collection effort into the TRMM KWAJEX project in the vicinity of Kwajalein Island in the western Pacific Ocean over the time period July 28 to September 15, 1999. A water vapor collection system using a cryocooling bath and a rain collector were set up on the NOM R H Brown Research Vessel in late July. Routine sampling every eight hours is planned with additional special sampling of convective storm features being undertaken, as suggested by ship-based radar.❖

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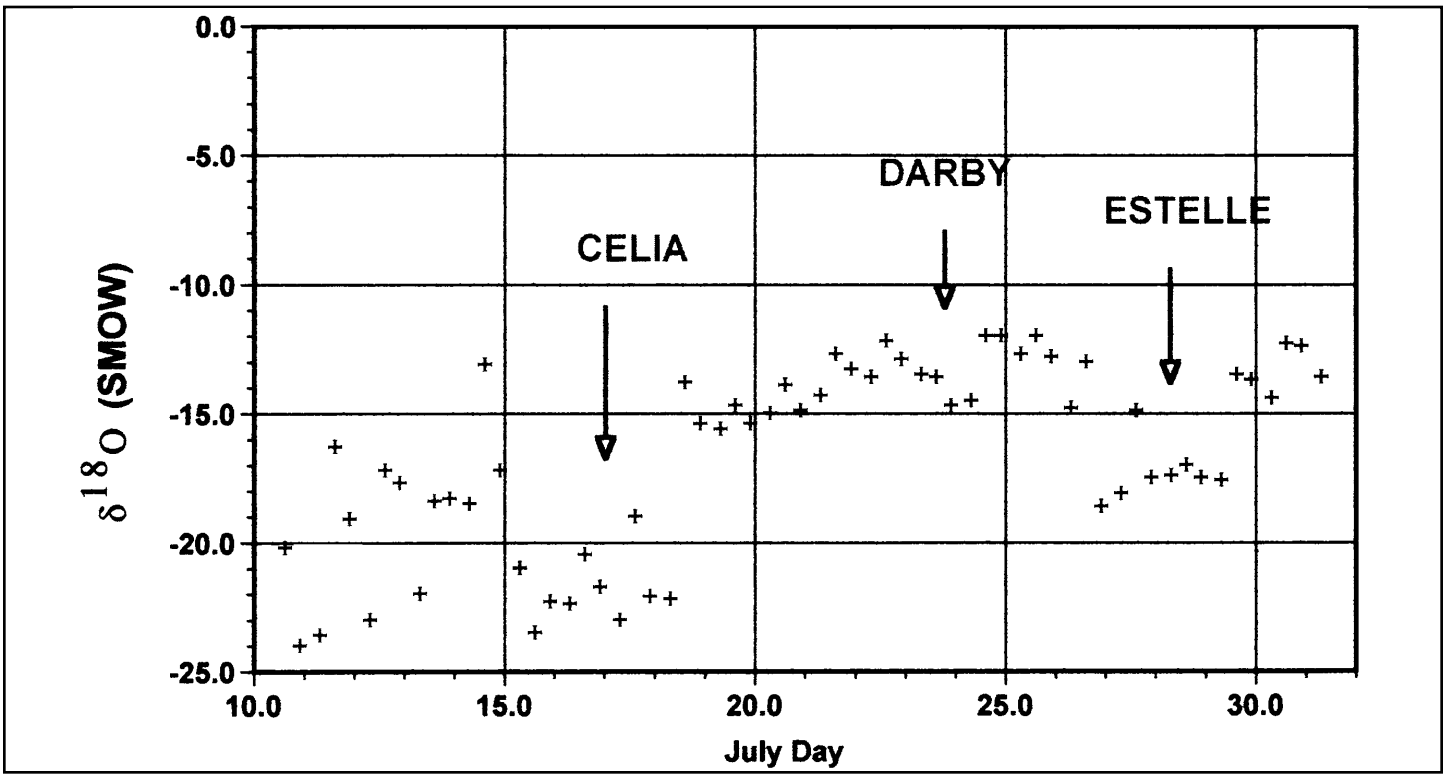
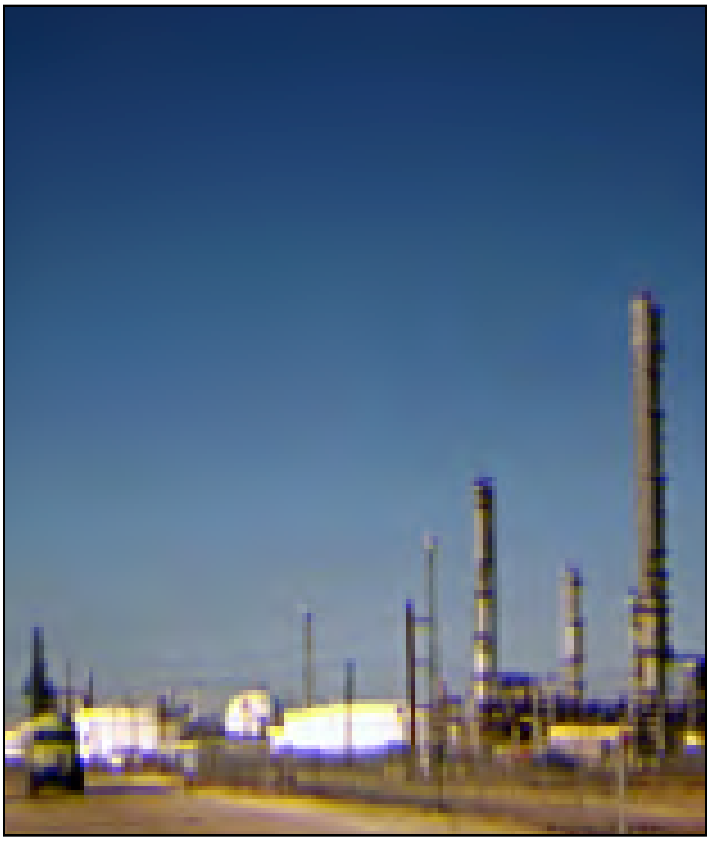


Figure 1. The oxygen isotopic composition of water vapors from Puerto Escondido, Mexico, plotted as a function of time during July 1998.



Petrochemical plants are part of the Harris County environment.

Making a Difference through Environmental Education

Brenda Weiser, Environmental Education Program Manager, EIH, UHCL

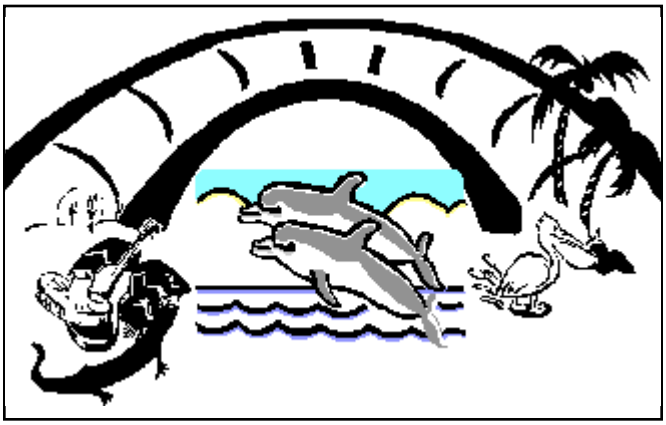
The Environmental Education Program Manager, Brenda Weiser, joined the staff at the Environmental Institute of Houston in 1999. She currently teaches elementary and secondary science methods courses through the UHCL School of Education at the University of Houston-Clear Lake.

One of the primary focuses of the Environmental Institute of Houston is outreach to the community and local educators. The environmental education program of EIH assists in achieving this goal through teacher training workshops that provide guidance to local community groups and corporate volunteers. This past year, EIH conducted nine teacher training workshops reaching over 450 educators. These workshops included training teachers in Project Learning Tree, Project WILD (Wildlife in Learning Design), and habitat development. Teachers were also presented information on environmental education, WET in the City (Water Education for Teachers), and techniques for building environmental education partnerships. WET in the City focuses on familiarizing teachers with the chemical and physical properties of water, quality issues, and the availability of water in runoffs, reservoirs, and aquifers. WET in the City also teaches about aquatic wildlife, ecosystems, and management strategies.

Nine presentations or special training events were delivered to community groups and corporate volunteers, reaching over 200 individuals. Through representation at various local, regional, state, and national meetings, EIH participated in five meetings and reached over 125 leaders in environmental education. Thus, EIH is a leader within the community.

In addition to outreach efforts, EIH strives for leadership and innovation in the field of environmental education. EIH assumed a leadership role at the national and international level in the field of environmental education when the Environmental Education Program Manager volunteered to chair the 2000 Annual Conference of the North American Association for Environmental Educator (NAAEE). The conference is slated for October 17 through 21, 2000, and is being scheduled at South Padre Island, Texas.

The Environmental Education Program Manager is working closely with the NAAEE Board of Directors and staff in conference scheduling and logistics. The Conference Chair is involved in the selection of keynote speakers, chairs for conference committees, and the overall planning and coordination of the conference. EIH developed the logo being used for the conference and the Call for Presentations.



NAAEE conference logo

Staff also continues to provide additional support to the conference through the development of the Registration Packet and will assist during the conference with registration. In return, EIH will be listed as a partner in the conference and will be identified on promotional materials.

The EIH Environmental Education Program Manager is a steering committee member for the Texas Envirothon and Texas Project Learning Tree programs and serves on the advisory council for the Bayou Preservation Association.

EIH is also active in the planning and execution of several local events such as Trash Bash, Marsh Bash, and Bay Day. EIH provides volunteers for these special events.❖

Surveying Schoolyard Ecosystems: Validating Instruction through Science Support Systems

Cameron White, Ph.D., and Carole Basile, Ph.D., Department of Curriculum and Instruction, UH

EARLY CHILDHOOD TEACHERS IN THE Pasadena School District participated in an Eisenhower Project entitled "Change in an Urban Environment." One of the major goals of the project was to strengthen the teachers' knowledge of content. The summer institute focused on environmental biology concepts and the natural history of southeast Texas.

Concepts were developed through three types of activities: (1) field work, (2) observation, and (3) problem solving and interpretation. Teachers were given opportunities to enhance their observational techniques by using lenses, binoculars, microscopes, field guides, and other materials necessary for investigation, for interpreting observations in a scientific framework, and for explaining and writing accurate descriptions of the phenomena they observed.

Project participants were able to identify and describe the change processes of the weather, ecology, geology, and the behavior of animal behavior experienced as it related to young children and their immediate community (i.e. schoolyard, neighborhood).

Throughout the academic year, teachers used this experience to integrate meaningful and accurate environmental education into their instruction. Much of this transfer of information took place in their own schoolyard environment. They expect the opportunity to continue their study about natural history, especially in their own schoolyards, in order to provide their students with useful information about the current ecosystem.

Fourteen teachers participated in the program, representing 10 elementary schools. These teachers who taught curricula ranging from pre-kindergarten students to second-grade, found themselves in the classroom with students from a variety of ethnic and socio-economic communities.

Objectives

The focus of the project had three principal aims: (1) to strengthen the science knowledge and skills of teachers; (2) to increase the integrity of the science content taught to elementary school students; and, (3) to utilize the resources and spatiality of the schoolyard in the development of integrative programs that expose students to environmental issues.

This program had three objectives:

- providing information about schoolyard ecosystems by developing "checklists" of ecosystem components (animals and plants), including brief descriptions of each species.
- providing support to teachers through experts in the field of biology through the use of technology (*e.g.* listservers).
- presenting the findings to interested teachers in each of the ten schools involved in the project.

Project Plan

Two undergraduate environmental science students surveyed plants and insects in the schoolyard. They also reviewed a local list of birds most common to the schoolyards. The checklist included any mammals, reptiles, or amphibians that might have been found in the community.

Pearl Hall Elementary School Habitat

Findings

Teacher projects are available through EIH's website as an extension of the school habitat link (www.eih.uh.edu/ecoscpaes/). Investigators shared their findings with the original teacher participants and their school community. Teachers now have a practical reference guide to assist them in their study of schoolyard ecosystems. More importantly, administrators, parents, and other teachers can recognize the diversity of wildlife on schoolyard properties.❖

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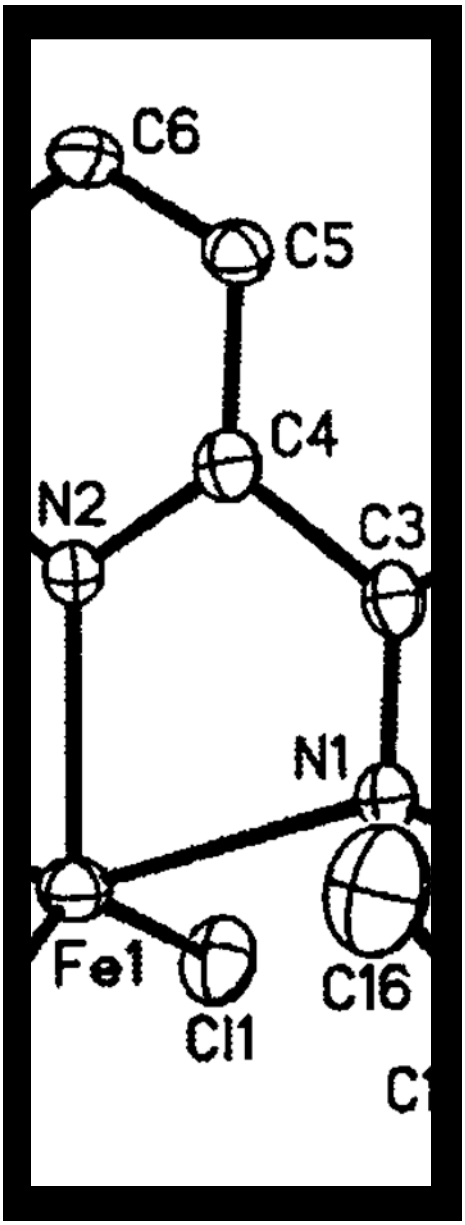

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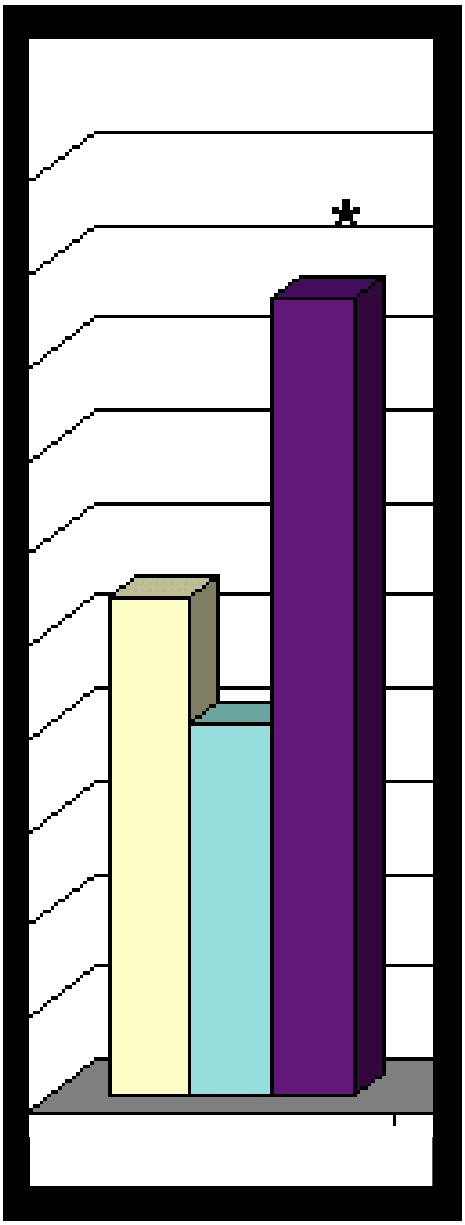

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Dan Wells

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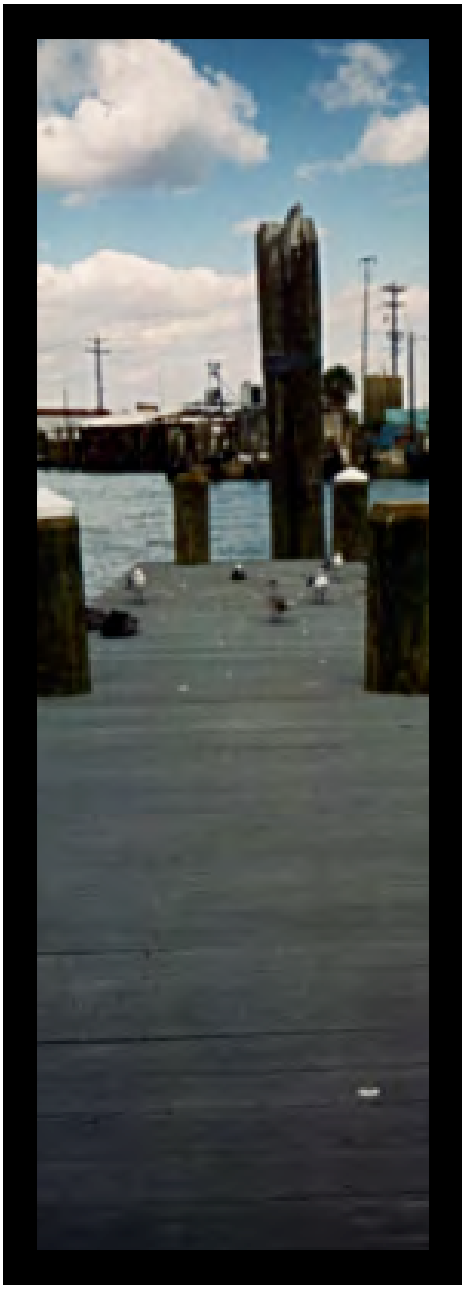
Dai, C. and D. Wells "Isolation and Characterization of sVgl Transcript in the Oocyte and Early Embryo of *Syrrhophus cystignathoides campi*, a Direct Developing Frog," Southwest Regional Developmental Biology Meeting, Austin, TX, March 1999.

Grants



Carole Basile

"Change in the Urban Environment." Eisenhower Professional Development Grant. Co-PI: C. White with approximately 12 Pre-K-3 teachers in Pasadena ISD. The focus of the grant is environmental biology and environmental education for young children. 1998-1999, $85,000/year.

"Environmental Literacy for Teachers of Young Children." Eisenhower Professional Development Grant. Co-PI: C. White with approximately 20 Pre-K-3 teachers in Pasadena ISD, Clear Creek ISD, and Galena Park ISD. The focus of the grant is environmental biology and environmental education for young children. 1999-2000, $85,000/year.

Abdelhak Bensaoula

"Compact III-V Nitrides-Based Integrated Multifunctional Optoelectronic Sensors for Contaminant Characterization in Enclosed Space Environments." Co-PIs: D. Starikov and I. Berishev. Texas Space Grant Consortium, 2000-2001, $50,000.

"Integrated Multifunctional Fluorescence Sensors for Real Time Environmental Effluents & Water Analysis." Principal Investigator: D. Starikov. Advance Texas Technology Program, 2000-2002, $269,682.

"Miniature Optical Sensor for Detection of Water and Air Contamination." Institute for Space Systems Operations Aerospace Post-Doctoral Fellowship Award, 2000-2002, $20,000/year.

"Miniature Optical Sensor for Water Contamination Monitoring." Co-PIs: I. Berishev and D. Starikov. NASA-NRA-99-HEDS, 2000-2002, $553,907. (*Pending*.)

Raj S. Chhikara

"Investigation of Agricultural Surveys Estimators in Terms of List Coverage." US Department of Agriculture, 1998-1999, $25,000.

"The log F: A Distribution for All Seasons." Principal Investigator: F. M. Spears. Univ. of Texas MD Anderson Cancer Center, 1998, $8096.

"Statistical Process Control of Shuttle Maintenance Operations." Institute for Space Systems Operations, 1998, $32,685.

"Unconditional Exact Tests of Binomial Proportions." Principal Investigator: F. M. Spears. Univ. of Texas MD Anderson Cancer Center, 1999, $8855.

Theodore G. Cleveland

"Coanda-Effect Jet Pump for Abrasive Slurry Transport." Texas Higher Education Coordinating Board, Advanced Research Program, 2000-2002, $56,000. (*Not funded*.)

"Electronic Field Notes for Communicating Water Quality Data." Sub-contract to Houston Department of Health and Human Services for pilot project supported by U.S. EPA Environmental Monitoring for Public Access and Community Tracking (EMPACT) grant, 1999-2000, $25,000. (*Contract documents in preparation*.)

"Internet and Component-Based Modeling System for Lake Water Quality and Fish Habitat Projections." Co-PIs: X. Fang, W-R. Zhang, and A. W. Groeger. Texas Higher Education Coordinating Board, Advanced Technology Program; Consortium Proposal with Lamar and Southwest Texas State Univ., 2000-2001, $54,000.

"Investigation of Intervention Strategies to Improve Water Quality on Country Club Bayou." Montgomery Watson Americas, Inc., 1998-1999, $56,000.

"Testate Amoeboae as Natural De-Watering Aids." Co-PI: D. J. Roberts. National Science Foundation, 2000-2003, $440,000. (*Not funded*.)

James R. Lawrence

"Evaluation of Evaporation Processes in Convective Storms Using Stable Isotope Measurements." Co-PI: M. I. Biggerstaff. Texas Advanced Research Program, Texas Higher Education Coordinating Board, $138,700. (*Pending*.)

"Winds, Water Budgets, and Stable Isotopes in Tropical Cyclones using TRMM and QUICK SCAT." NASA, 1998-2001, $153,620.

Han Q. Le

"Portable Gas Leak Sensor." Texas HECB ATP, 1999-2001, $257,800.

Lisa M. Meffert

"Partitioning the Effects of Immigration and Selection in Finite Populations." (*In review*.)

Martin V. Melosi

"Federal Dam Development in the United States." National Parks Service, Corps of Engineers, and Bureau of Reclamation, on-going, $221,000; Energy Laboratory, Aug. 1999, $5,509.

Hanadi Rifai

"Continuous On-Line Non-Point Source Monitoring Network." Galveston Bay Estuary Program, 1999-2000, $126,783. (*Pending.*)

"Developing a Guidance Manual for Modeling Natural Attenuation at Field Sites." Air Force Center for Environmental Excellence, 1999-2000, $74,000. (*Pending.*)

"Developing an Integrated Methodology for Designing Long Term Monitoring Plans (LTMPs)." Air Force Center for Environmental Excellence, 1998-2000. $75,000.

"A Galveston Bay Barometer for Communicating the State of the Bay." Galveston Bay Estuary Program, 1990-2000, $70,614. (*Pending.*)

"Integration of Artificial Neural Networks and GIS for Environmental Forecasting." Texas Higher Education Coordinating Board, 2000-2001, $130,000. (*Pending.*)

"Integration of Artificial Neural Networks and GIS for Spatial and Temporal Forecasting of Natural Hazards." National Science Foundation, 2000-2004, $200,000 (*Pending.*)

"Internet Tool for Conceptual Optimization of Groundwater Pump-and-Treat Systems." Air Force Center for Environmental Excellence, 1999-2000, $78,639. (*Not funded*.)

"Models, Stakeholder Values, and Education: Integrated TMDL Development for Armand Bayou." Environmental Protection Agency, 1999-2002, $899,976. (*Pending.*)

"Multi-Purpose Water Management Technology for the Texas-Mexico Border." Texas Higher Education Coordinating Board, 2000-2001, $600,000. (*Pending.*)

"Transport, Fate, and Risk Implications of Environmentally Acceptable Endpoint Decisions." Co-PI: W. R. Rixey. Gulf Coast Hazardous Substance Research Center, Sept. 1999-Aug. 2002, $156,825.

"Wet in the City: Galveston Bay Connections." Galveston Bay Estuary Program, 1999-2000, $98,318. (*Pending.*)

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Photography by Irving N. Rothman

BACK COVER—Shrimp boat sailing from the wharfs of Kemah into Galveston Bay. The worry is that viruses found in shrimp farm effluent may infect wild shrimp stocks. (See page 12.)

Reviewed: 7/27/2021