

COMPLETED STUDIES OF
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LUMINANT ENVIRONMENTAL RESEARCH PROGRAM

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The original Environmental Research Steering Committee (Advisory Board) involved five members from various universities, and four remain on the Committee today either in an active or emeritus role. The number of Professors on the Committee (active and emeritus) has been expanded to fifteen over the years in order to address new environmental issues. Over the past thirty-eight years, the Committee has designated over \$4.7 million to fund over 124 graduate students in research - unguided by the Company - on the environmental effects of surface mining, power generation and electric transmission lines. The results of the work have been utilized by the Company, the regulatory agencies, and other industries in protection of the environment in the development/utilization of energy resources.

A significant benefit of the process is the worldwide placement of the graduates in key positions - federal/state regulatory agencies, the academic world, industry - wherein they can continue application of the knowledge and training achieved through this program.

NOTE

This book contains only the abstracts of the completed studies. For the entire thesis or dissertation, the reader should contact the researcher's university. Most of the studies have resulted in additional papers or publications which are not listed. These can be obtained by contacting the university or the researcher. Information on the program itself may be obtained from Environmental Services Department, Luminant, Lincoln Plaza, 500 North Akard Street, Dallas, Texas, 75201 or by e-mail: sid.stroud@luminant.com.

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A SOIL ANALYSIS OF THE STRIP MINE SPOIL BANK AT FAIRFIELD, TEXAS

Author: Patrick Nicholas Angel

As an initial step in understanding the spoil material, the chemical and physical properties of areas disturbed by the strip mining of lignite near Fairfield, Texas were determined. The exchangeable cations, available phosphorus, Kjeldahl nitrogen, reaction, texture and moisture content were determined for both the strip mined area and adjacent undisturbed soil. All of the essential plant nutrients were found to be present in adequate concentrations on the spoil bank, but on the agriculturally depleted undisturbed soil, deficiencies of phosphorus and calcium were observed. Reaction, texture, and moisture content of the spoil bank were found to be suitable for plant growth. Compared to the adjacent undisturbed land, the spoil bank has a higher productivity potential and is highly suitable for revegetation in all respects.

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THE EFFECT OF MINE SPOIL RECLAMATION ON SPECIES COMPOSITION AND ABUNDANCE OF ANTS

Author: Carl David Anthony

The effect of strip mine reclamation on ant community structure was investigated. Six study areas, each with different reclamation histories, were sampled to test for effects of age since reclamation, reclamation method, and land use after reclamation. The six areas consisted of an unmined control area; an area reclaimed in 1987; an area reclaimed in 1983; and two areas reclaimed in 1978, one of which had been grazed by cattle since 1985. An additional area, reclaimed in 1981 with mixed grass species (side oats grama and alamo switch grass), was examined to test for the effects of an alternate reclamation method.

The red imported fire ant, Solenopsis invicta, was present on all study areas. Statistical analysis indicated significant effects of month and study area on fire ant abundances. Diversity index values suggest that colonization is open to several ant species early in the reclamation process, but the presence of the red imported fire ant, Solenopsis invicta, confounds ant community recovery. Grazing by cattle and reclamation with mixed grasses appear to accelerate infestation by Solenopsis invicta.

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SOIL FACTORS INFLUENCING ROW CROP PRODUCTION AND PHOSPHATE ABSORPTION ON LEVELED LIGNITE MINE SPOIL BANKS

Author: Paul Ernest Askenasy

A three-year field plot study was conducted to determine the feasibility of raising corn ('Texas 28A'), sorghum ('Top Hand'), and two cultivars of soybean ('Hill' and 'Lee') on leveled mine spoil banks. The location of this field study was near the Big Brown Steam Electric Station near Fairfield, Texas. This is a lignite surface mine and power generation operation. Treatments included nine different phosphorus-nitrogen fertilizer combinations per crop per year. The pH and base status of the spoil in the crop area were monitored throughout the course of this study.

Laboratory experiments were conducted to determine the adsorption characteristics of sodium salts of ortho-, pyro-, and tripolyphosphate by two surface spoil samples and an unmined surface soil sample.

A marked response by the crops to both N and P additions was found in 1974. In 1975 and 1976, only N additions yielded significant increases in both grain and total dry matter yields.

An inspection of soil pH values from 1974 to 1976 revealed a marked drop in pH from 1974 (pH = 6.6 \pm 0.3) to 1975 (pH = 5.3 \pm 0.2) with a subsequent stabilization of these values through 1976 (pH = 5.2 \pm 0.3). The lack of response of the crops to fertilizer P additions was attributed to the dissolution of native P compounds present in the spoils. This dissolution was caused by the increased acidity resulting from the oxidation of pyrite (FeS₂) present in the spoils. Enough P for plant growth was released from this acidulation that no significant response to fertilizer P additions was observed in 1975 and 1976. As this acidity is further increased due to the oxidation of organic sulfide linkages present in lignite particles and the removal of bases, the soluble P becomes increasingly controlled by Al and Fe phosphorus compounds. This is beneficial since more P is released to the soil solution from Al and Fe phosphates than from hydroxyapatite or octacalcium phosphate. The stabilization of the pH values was attributed to the disappearance from the top 20 cm of spoil material of readily oxidizable, acid producing pyrite.

Reaction of NaH₂PO₄ with two spoil samples and a surface soil sample revealed two energy adsorption stages. Only one energy adsorption stage was found from the reaction of Na₄P₂O₇ and Na₅P₃O₁₀ with the surface samples. Adsorption energy sequences varied from one soil to another and with one phosphate species to another. More P was adsorbed as pyrophosphate than as tripolyphosphate. The least amount of P adsorbed came from the reaction of NaH₂PO₄ with the surface samples. Enthalpies of adsorption were found to decrease with increasing surface coverage

by the phosphate species. High initial soluble Ca levels were found in the spoils. It was predicted that soluble phosphate anions would precipitate as Ca salts.

It was concluded that all four row crops tested would grow successfully on leveled mine spoils if proper fertilization and cultural practices were provided. Sorghum, because of its drought tolerance characteristics, was found to be the most promising crop of those tested. Enough native P was made available to plants (caused by pyrite oxidation) that no fertilizer P was needed for plant growth after 1974. This situation is expected to reverse itself as the available native P pool becomes depleted.

LAND CAPABILITY CLASSIFICATION OF MINESOILS IN EAST TEXAS

Author: Amy Kristen Barth

Surface mining regulations require successful reclamation of areas disturbed by mining processes to a condition comparable to or better than the pre-mine soil. The regulations also require a plan for reclamation in which proposed uses must be set for the post-mine land. A land capability classification specific to minesoils will facilitate the design of appropriate land uses or alternative uses or alternative uses for reclaimed mine areas based on observed limitations. The proposed system is similar to the Land Capability Classification System (LCCS) used by the United States Department of Agriculture (USDA), National Resources Conservation Service (NRCS). Soil chemical and physical characteristics were measured to determine what limitations occur in minesoils; measurements included soil pH, potential acidity, exchangeable acidity, acid-base account, particle size distribution, available nutrients (N, P, K), amounts of basic cations, electrical conductivity, cation exchange capacity, permeability, cone index, moisture content, and available water-holding capacity. Comparisons were made between pre-mine soils and minesoils from the dragline and cross-pit spreader methods of overburden removal.

Segments of the study site from the dragline minesoil were limited by slope, texture extremes, low pH, and salinity. Based on averages across the entire study site, the capability class of the dragline soil is IIIe. Segments of the study site from the cross-pit spreader minesoil were limited by slope. Based on averages across the entire study site, the capability class of the cross-pit spreader soil is IIe.

The land capability classes were improved in most cases compared to pre-mine soils due to less extreme slopes and decreased root-zone limitations by means of improved permeability, effective depth of rooting, and available water capacity. The problems presented by some areas of the minesoil (low pH, salinity, texture extremes) can be managed by future land owners if they are aware of the severity and scope of the problem in association with their intended land use.

Application of the LCCS can be useful to predict suitable land uses for minesoils. Allowances for variability of the soils and potential yield should be considered as part of the criteria for classification. Choosing an appropriate scale for classification is equally important, depending on the intended land use.

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THE IMPACTS OF MINING ON THE HABITAT ECOLOGY OF RACCOONS IN EAST-CENTRAL TEXAS

Author: Michele Beucler

Habitat alterations associated with strip-mining and reclamation may reduce the suitability of an area for wildlife by redistributing requirements for survival and reproduction. I evaluated several predictions regarding the impacts of habitat alterations on wildlife by comparing patterns of landscape use and behavior of raccoons (*procyon lotor*) in unmined and reclaimed habitats on the Big Brown Mine in Freestone County, Texas. I hypothesized that changes in vegetation composition and structure and the spatial distribution of habitat types would influence diel activity and movements, habitat use, resting site use, home range size, and ultimately, the demography of raccoons. I captured and radio-collared 12 and 4 adult raccoons in unmined and reclaimed areas, respectively, and observed patterns of habitat use, and annual and seasonal home range sizes. During each season, I monitored continuous 24-hour activity and movement patterns of 4 radio-collared raccoons in unmined and reclaimed areas. I relocated inactive radio-collared raccoons to evaluate resting site use in unmined and reclaimed areas. Estimates of population demographics were based on live-trapped raccoons. Raccoons inhabiting reclaimed areas had larger annual home ranges and their movement patterns within and across the reclaimed landscape suggested those areas offered less abundant and/or more isolate resources for raccoons. Raccoons in unmined habitats used trees more often as resting sites than did raccoons in reclaimed areas; brushpiles were used more often than trees by raccoons in reclaimed areas. Improved pasture was the most abundant habitat type in reclaimed areas and was underutilized by raccoons. Analyses of trapping success and population sex-age structure suggest that reclaimed areas may be incapable of supporting population densities found in unmined habitats. Collectively, these findings support the conclusion that reclaimed habitats may not be mitigating the loss of unmined woodlands. Although it **was** not possible to test the validity of all aspects of the conceptual model, results from this study provided support for the processes it identified and its predictions regarding the potential impacts of strip-mining on raccoons. Based on these results, I discussed 5 recommendations to improve reclamation efforts.

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ON THE RATES OF ORGANIC WEIGHT LOSS, ORGANIC CONTENT, AND CARBON TO NITROGEN RATIO IN THE DECOMPOSITION OF THE LEAVES OF SIX MACROPHYTE SPECIES IN A LAKE RECEIVING A THERMAL EFFLUENT

Author: David Ray Bible

The effects of a thermal effluent from the Big Brown Steam Electric Station, located on Fairfield Lake, North Central Texas, on the rates of decomposition, organic content, and the changes in the carbon to nitrogen (C:N) ratios of the decomposing leaves of the aquatic macrophytes, Potamogeton nodosus, Nymphaea odorata, Sagittaria platyphylla, Typha latifolia, Scirpus californicus, and the oak, Quercus stellata were studied using the litter bag method. Decomposition was studied at two sites, one in an area affected by thermal effluents and one unaffected by thermal effluents, over summer and winter sampling periods extending from June, 1980 to October, 1980, and January, 1981 to August, 1981. This allowed the study of the decomposition of the leaves of these six plant species in four different thermal regimes.

The decomposition rates of the leaves of these six plant species generally increased as temperature increased from 13°C to 36°C. There were no significant differences found among the decomposition rates of the six plant species tested in the two intermediate thermal regimes (mean temperature range = 27.3°C-33.6°C). Such data indicates that the optimal thermal conditions for decomposition in Fairfield Lake may lie between 27.3°C and 33.6°C. In contrast, the decomposition rates of all six plant species studied appeared to be inhibited during the summer at the thermally influenced site (mean temperature = 39.3°C, range = 30°C-42°C). Associated with the inhibition of decomposition was the presence of a blue-green algal bloom and an absence of detritivorous animals.

The initial C:N ratios of the leaves of these six plant species ranged from 16.7:1 to 112.71:1. C:N ratio declined with decomposition, the final C:N ratios of the decomposed leaves generally ranging from 4.5:1 to 16:1. The observed decline in the C:N ratios of decomposing leaves to below 17:1 is related to the development of microbial communities. This decline in C:N ratio increases their nutritional value to second trophic level detritivores as most animals have been shown to require a diet with a minimal protein content of 16.5% by dry weight which corresponds to a C:N ratio of 17:1 or below.

There was apparently little influence of the initial C:N ratios of the leaves of the six plants studied on the rate at which C:N ratio declined nor was there an apparent influence of the initial C:N ratio values on the final C:N ratio attained during the decomposition of the leaves of the six plant species used in this study. In addition, between 13°C and 36°C, there were no significant inter- or intraspecific differences in the rate at which the C:N ratios of the decomposing leaves of all

six plant species declined, indicating that there was apparently little influence of temperature on the rate of C:N ratio decline or the ultimate C:N ratio achieved. These data suggest that the physical structure of decomposing plant material may be more important to developing microbial communities than its initial nutritional quality and that detrital microbial communities may consist of different temperature-adapted species under different thermal regimes.

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ZOOPLANKTON DENSITIES AND DISPERSION IN A SHALLOW RESERVOIR RECEIVING HEATED EFFLUENT

Author: Jerry Lane Bird

Lake Fairfield, Freestone County, Texas is a 953 hectare cooling reservoir for the Big Brown Steam Electric plant. The zooplankton community was sampled monthly from August 1974 to August 1975 and oxygen and temperature values were recorded.

A total of 56 species were identified over the collection period. Mesocyclops edax was the most abundant crustacean and Brachionus caudatus the most abundant rotifer. Analysis of variance was used to detect significant differences in species diversity and evenness, seasonal abundance, abundance between stations, depth distribution of the dominant species at each station and migration tendencies.

There were no differences between the diversity, and evenness among stations receiving the thermal effluent and those unaffected by the thermal plume. However, the heated effluent does appear to affect changes in abundance between stations by possible recruitment of animals or increased food resources. Migration tendencies appear to be strongest in the stations receiving heated effluent. These tendencies are suggested to be the result of feeding in the surface layers followed by retreating to the cooler layers.

Depth distributions are also effected by the thermal plume with the bulk of a species population concentrated on one side or the other of the interface between the heated effluent and the cooler non-effluent waters. These tendencies weaken as the integrity of the plume becomes diffuse.

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THE POTENTIAL FOR CARBON SEQUESTRATION IN SOILS ON LIGNITE COAL MINELANDS IN EAST TEXAS

Author: Cynthia A. Blake

Global warming is becoming an ever-important topic in the world today. In 1998, it was estimated that 40.5% of U.S. anthropogenic CO₂ emissions was attributed to the combustion of fossil fuels during the generation of electricity (U.S. Department of Energy 2000a). In an attempt to mitigate emissions, electric utility companies have become interested in the potential of forests to sequester large amounts of carbon in their above- and below-ground biomass as well as in the soils. It has been estimated that if the world's deforested lands were reforested and properly managed, they could have the potential to sequester five billion megagrams of carbon per year (Kimmins 1997b). To effectively manage forests to store carbon, it is important to study the role forest soils play in the carbon sequestration process. These soils have the potential to store up to 59% of the total carbon pool within a forest ecosystem (Birdsey 1992). This study examined the biological potential of storing carbon in the soils and the economic potential of storing carbon in the soils and trees grown on reclaimed lignite coal minelands in East Texas. Results show that up to stand age 16, these mine soils may be a net source of CO₂ rather than a net sink because lignite carbon, which is subject to microbial decomposition, exceeds modern organic carbon in the soil up to this point.

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PHOTOSYNTHETIC EFFICIENCY OF PHYTOPLANKTON POPULATIONS IN A RESERVOIR RECEIVING THERMAL EFFLUENTS

Author: Gerald Franklin Bowling, III

From October 1978 to October 1979 measurements of primary productivity, incident PAR, temperature, chemical, optical and phytoplankton community characteristics were made monthly to assess the impact of the thermal effluent on phytoplankton photosynthetic efficiency (PE). PE was defined as percentage ratio of rates of calories of PAR received. Results showed Fairfield Reservoir as eutrophic and phytoplankton to be productive and well adapted to the selective forces of entrainment. The impact of increased temperature associated with the thermal effluent varied from stimulation of PE and integral primary productivity during fall months to inhibition during summer. Summer was considered critical for the survival of the phytoplankton community due to thermal, nutrient and light related factors. PE and integral primary productivity declined when summer water temperatures exceeded 32^o. Mean PE for the study was 0.7% and mean integral primary productivity was 125 mgC m⁻² hr⁻¹. Green algae dominated or co-dominated the phytoplankton community most of the year. Blue-green algae dominated or co-dominated during spring and summer months.

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THE EFFECT OF STRIP MINING AND RECLAMATION ON HERPETOFAUNAL COMMUNITIES

Author: Patrick Joseph Bradley

Four habitats (reclaimed field, reclaimed forest, unmined field, and unmined forest) were sampled for amphibians and reptiles to determine the effects of strip mining and reclamation on herpetofaunal communities. Reclamation ponds were also sampled to determine the extent to which they are utilized by turtles.

The unmined and reclaimed areas were very different in relation to their herpetofauna. The unmined area had greater diversities and population densities. Aquatic and semi-aquatic species were the dominant species in the reclaimed areas. The majority of the total species sampled in the reclamation were aquatic or semi-aquatic, and this may be due to the high moisture holding capacity of the soil and large number of reclamation ponds. The reclamation ponds are a key component of the reclamation process. The ponds collect sediment and allow invasion by turtles and amphibians which make up the majority of the herpetofaunal community in the reclaimed area.

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**ORGANIC CARBON ALLOCATION IN THE FRESHWATER
PULMONATE, *PHYSELLA VIRGATA*, IN RESPONSE TO
SEASONAL AND ARTIFICIALLY ELEVATED TEMPERATURES**

Author: David Keith Britton

Organic carbon allocation pathways were estimated under seasonal and artificially elevated ambient temperatures for a common freshwater, pulmonate snail species, *Physella virgata*. Allocation to respiration increased with temperature in all cases. Generally, over the natural temperature range (15-35EC), *P. virgata* allocated the greatest proportion of assimilated organic carbon to reproduction while assimilation efficiencies remained relatively constant at 25-35%. Snails in a heated discharge allocated less organic carbon to growth and reproduction as ambient temperatures surpassed 35EC. These snails increased consumption approximately twice the average level for those held away from the discharge (ca. 4500 versus 2500 Φ g C \cong wk⁻¹) and their assimilation efficiencies fell below 10% as temperatures approached 40EC. This study revealed that ambient temperature greatly impacted organic carbon allocation in a common ectothermic animal, with temperature a few degrees above the natural maximum drastically altering organic carbon allocation.

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THE NATURE OF THERMAL TOLERANCE IN THE WESTERN MOSQUITOFISH, *GAMBUSIA AFFINIS*, EXPOSED TO HEATED EFFLUENTS

Author: David Keith Britton

Gambusia affinis (Baird and Girard), the Western Mosquito fish, a live-bearing species native to the southern United States, is one of the most widespread, introduced species in the world and has a wide thermal tolerance range, surviving 8 °C to 40 °C. High heat tolerance allows this species to inhabit thermal effluents of power stations where temperatures approach and often exceed its upper thermal limit. Thus, artificially induced natural selection may act on these populations, allowing only thermally tolerant individuals to survive during summer months. Potential influences on thermal tolerance in *G. affinis* are examined here, including thermal history, dispersal, and the possibility of natural selection on a population of mosquitofish inhabiting the thermal effluent of a power station in Texas. Natural selection is a syllogism with three main components necessary and sufficient for operation: variation among individuals in some phenotypic trait, heritability of that trait, and fitness differences associated with the trait. Thermal tolerance estimates for heated-effluent mosquitofish were 0.6-1.0 °C higher than the main-reservoir population after both were acclimated to constant temperature. Second-generation offspring retained ancestral thermal tolerance levels and heritability was estimated to be 69.7% by regression of mid-parent with mean offspring thermal tolerance. Fitness differences were suggested by measuring mortality over time while holding thermally sensitive and thermally tolerant mosquitofish in enclosures within the heated effluent during mid-summer. Although reproduction was also monitored, no reproduction occurred. Yet, approximately half of the heated-effluent mosquitofish survived when all main-reservoir mosquitofish perished. Evidence was provided that mosquitofish avoid midsummer temperatures by dispersing into cooler waters within stands of emergent vegetation along the margins of the heated effluent rather than downstream toward the main reservoir. Additionally, thermal history, within the lifetimes of individuals, was found to influence adult thermal tolerance. Exposure temperature change during development was associated with a corresponding change in adult thermal tolerance: mosquitofish exposed to

increasing temperatures during development tended to have higher thermal tolerance, while those exposed to decreasing temperatures had lower thermal tolerance. Thus, although environmental factors influence thermal tolerance, all three components required of natural selection were present in this population, strongly suggesting local adaptation of a thermally tolerant race.

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USE OF LIGNITE FLY ASH AS A SOIL AMENDMENT

Author: Thomas Victor Brown

One-year-old loblolly pine (*Pinus taeda* L.) seedlings were grown in a greenhouse in potted mixtures of two Texas lignite fly ashes and a Troup sand, Sacul sandy loam, and a sandy clay loam strip-mine spoil. Mixtures contained 0, 25, 50, 75 and 100 percent fly ash. After six months, soil:fly ash mixtures were analyzed for N, P, Ca, Mg, K, Na, Mn, Zn, pH, cation-exchange capacity, percent base saturation, and texture. Needle and root tissue analyses were performed on both live and dead seedlings.

Survival and height growth were both adversely affected by fly ash amendments. Nearly all seedlings grown in fly ash amended soils were exhibiting needle die-back at the end of the six-month growing period.

Soil analyses revealed the effects of fly ash amendments to include: 1) elevated pH, 2) excessive free salts, particularly calcium, and extremely high levels of percent base saturation, 3) reduced cation-exchange capacity, 4) reduction of available phosphorus to extremely low levels. Conditions such as these were not conducive to the survival or growth of loblolly pine.

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COLD TOLERANCE AND THERMAL ACCLIMATION OF JUVENILE BLUE TILAPIA, *Tilapia aurea*

Author: Rita Marie Bruckler

Cold resistance of blue tilapia (*Tilapia aurea*) was measured as the first step in development of a simulation model to predict acclimation state and mortality of tilapia exposed to varying low temperature. The model is based on F.E.J. Fry's "lethal dose" concept: Total lethal dose is the sum of accumulated incremental doses defined by the ratio \hat{t} and t_r are, respectively, exposure time and expected resistance time at a given lethal temperature. Fifty percent mortality is predicted if and when total dose equals one.

Cold-resistance times were determined for tilapia acclimated to 16, 20, or 24°C and exposed to lethally low temperature ranging from 6 to 12°C. The data then were used to parameterize a linear regression equation describing resistance time as a function of ambient and acclimation temperatures.

In the next stage of the study, acclimation rate was determined for blue tilapia transferred between 16°C and 24°C and between 24°C and 32°C. Resistance time at criterion temperatures of 6°C and 10°C was used to measure the progress of acclimation. These data were incorporated in a predictive equation for acclimation temperature. Resistance time was calculated from the regression equation and was used to predict accumulation lethal dose. The model gave accurate predictions for step-changes in temperature below the LILT (lower incipient lethal temperature) and reasonable prediction when cooling started above LILT. However, the model consistently underestimated resistance time when temperature fluctuated above and below LILT. The addition of a component to allow recovery from cold damage could improve model predictions. At this time, no data exist on which to base such a component.

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**EARLY SURVIVAL AND TOTAL HEIGHT, AND FOLIAR
ANALYSES OF ELEVEN TREE SPECIES GROWN ON
STRIP-MINE SPOILS IN FREESTONE COUNTY, TEXAS**

Author: Hoy Lee Bryson, Jr.

First-season survival and total height growth were recorded for eleven tree species planted on strip-mine spoil and undisturbed soil in Freestone County, Texas. These species were also grown in potted sub-soil in a greenhouse. Foliage samples from all trees were analyzed for concentrations of N, P, K, Mg, Ca, and Na.

Survival and total height growth results indicated the spoils were as acceptable for the establishment of forest tree species as the undisturbed soil. Influencing factors included: 1) precipitation, 2) planting stock condition, 3) exposure, 4) ground cover, 5) compaction from grading, and 6) spoil texture and pH.

Foliar analyses indicated that the spoil and adjacent soil varied little in nutrient concentrations, except for a much lower N-content in the spoil. The exchangeable cations were in adequate supply. Concentrations of available P were low. The spoil fertility reflected sub-soil nutrient concentrations.

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**PISOLITHUS TINCTORIUS MYCOBIONT INOCULATIONS AS
A FACTOR IN PERFORMANCE OF CONTAINERIZED AND
BARE-ROOT SHORTLEAF PINE SEEDLINGS ON
LIGNITE MINESOILS IN PANOLA COUNTY, TEXAS**

Author: Hoy Lee Bryson, Jr.

The effects of artificial soil infestation with basidiospores and vegetative mycelia of the fungal symbiont Pisolithus tinctorius on ectomycorrhizae development of shortleaf pine (Pinus echinata) seedlings grown in styroblock containers were tested in the greenhouse. These preliminary tests showed that both spores and mycelia will produce satisfactory ectomycorrhizae development. Various methods of inoculation had little effect on growth and development of containerized seedlings or on the accumulation of N, P, K, Ca, Mg, Na, Mn, Zn, or Cu in foliage and lateral roots. The styroblock containerization system used in conjunction with sandy loam soil/vermiculite (2:1 v/v) potting-mix produced excellent quality shortleaf pine seedlings with strong primary and secondary lateral root development.

Ultrastructural examination of inoculated roots revealed that a Basidiomycete and another fungus were mycotrophic, full Hartig-net and mantle development were common, and apparent host and mycobiont physiological activity was positively influenced by intimate symbiotic relationship. Evolution of mycorrhizae progressed from an obvious infection process at the host epidermis and outer cortical cells to a balanced symbiosis in the Hartig-net region of the deep cortex.

The inoculated containerized shortleaf pine seedlings with their far better initial ectomycorrhizae development survived significantly better than 1-0 bare-root nursery-grown seedlings following the first growing season after outplanting on minesoils at the Martin Lake lignite stripmine in Panola County, Texas. Inoculation treatments of bare-root seedlings with P. tinctorius basidiospores and vegetative mycelia at time of planting had no significant effect on survival or growth. After the first growing season, foliar concentrations of N, P, K, Ca, Mg, Na, Mn, Zn, and Cu were little affected by inoculation treatments.

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TEMPORAL AND SPATIAL SULFATE VARIABILITY IN GROUNDWATER AT A LIGNITE MINE, NORTHEAST TEXAS

Author: Margaret Frances Cagle

Sulfate (SO_4) concentrations in the groundwater at the Luminant Monticello lignite mine, northeast Texas, vary with both time and space. SO_4 is monitored closely because it is a product of chemical reactions that can lead to acid mine drainage. Although acid mine drainage is not a problem at Monticello, SO_4 concentrations in some areas are high and correspond to high total dissolved solids (TDS), low pH groundwater. At Monticello, chloride, total dissolved iron, and total dissolved manganese concentrations also are variable. To examine this variability, 46 monitoring wells are divided into those: 1) screened in rock underneath the lignite seam (underburden); 2) screened in the rock over the lignite seam (overburden); and 3) screened in the reclaimed spoil. There is a wide range of SO_4 concentration across the mine with statistically significant differences between the SO_4 distributions for each well category. Three hypotheses may explain the spatial SO_4 variability: (1) The heterogeneity of the mined material (2) Flushing of SO_4 from the reclaimed section into the overburden (3) Exposing iron sulfides to oxidizing conditions when the water table is dropped by mine dewatering operations. Possible sources of SO_4 include the oxidation of pyrite and/or the dissolution of gypsum.

Temporal SO_4 variability is evident in the SO_4 time series for each well. In the underburden, SO_4 seems to be approaching a steady state; however, some wells in the unmined overburden and reclaimed area have SO_4 trends that are increasing or are highly variable with time. Water table fluctuations or flushing caused by seasonal meteorological changes may control these trends.

Correlation analyses show that for most underburden, overburden, and reclaim wells, SO_4 does not correlate with pH, indicating that acidity does not accompany the incorporation of SO_4 and that SO_4 may be advected from another part of the mine. Analysis of water level and SO_4 time series, as well as Cl⁻ and SO_4 time series, show that advection from reclaimed areas cannot account for every high SO_4 value or increasing SO_4 concentration in the overburden and reclaim. Groundwater in most overburden and reclaimed areas are at equilibrium with gypsum, indicating gypsum precipitation if SO_4 is flushed into the area and gypsum dissolution if SO_4 is flushed out.

Time series analyses shows some of the wells with increasing SO_4^{2-} concentration to be approaching equilibrium. Also, most SO_4^{2-} time series have a seasonal component. Flushing from the reclaimed areas is considered to be the dominant process controlling SO_4^{2-} variability in the overburden. A combination of flushing and aqueous geochemical processes related to heterogeneity controls the SO_4^{2-} concentration in the reclaimed land.

AVIAN POPULATION DENSITIES AND SPECIES DIVERSITY ON RECLAIMED STRIP-MINED LAND IN EAST-CENTRAL TEXAS

Author: Peter Christopher Cattle

The objective of this study was to determine the effects of coal strip-mining and subsequent reclamation on population densities and species diversity of a native avian community in the east-central Texas post oak savannah region. I marked three transects in May-June 1976 and measured vegetational parameters (percent canopy cover, percent litter cover, average canopy height, average maximum canopy height and species composition) in June 1977, using a 20 x 50 cm quadrant and canopy-coverage methodology. One transect sampled three successive years (1974-1976) of reclaimed land, with one third of the transect sampling each year; a second transect sampled newly reclaimed land. Both reclaimed areas were essentially monospecific grasslands with low to moderate forb invasion. An unmined control site represented improved pasture/post oak savannah typical of the area. Aerial photographs were used to determine arboreal canopy cover. The control site showed considerably greater vegetation diversity than the reclaimed sites.

A modification of a strip transect method was used to census avian communities, and two indices (h' and S) were employed to chronicle changes in avian community diversity. Results of univariate and multivariate analysis of variance and pair-wise contrasting procedures indicated that 22 of the 42 species considered were adversely affected by mining and reclamation. This was generally attributable to the loss of foraging, nesting and observation substrates from reclaimed areas. Fourteen species, generally grassland types adapted to a vegetationally two-dimensional habitat, were favorably affected. Six species showed no ill or favorable effects attributable to mining and reclamation. Mining and reclamation adversely affected 12 avian associations by destroying necessary foraging and/or nesting habitat. Four associations were favorably affected through addition of foraging and/or nesting habitat. Two associations showed both favorable and adverse effects.

The highest and lowest total densities were always associated with reclaimed areas. Portions of reclaim often appeared barren of birds while other portions supported large numbers. Species richness was generally low on reclaimed sites, with a few select species contributing large densities. The control showed densities mid-way between the reclaim extremes. Permanent resident species remained on the control tract throughout the year; on reclaimed sites, they appeared to emigrate during the winter. The control area also showed the highest number of species considered and, generally, the greatest species richness.

I concluded that mining and reclamation procedures considerably altered the native avian community and that the overall effects were harmful to a majority of species and group associations.

GEOCHEMICAL STUDY OF URANIUM AND VANADIUM IN CORES OF LIGNITE SEAMS AT BIG BROWN, FAIRFIELD, TEXAS

Author: Thomas Girard Chasteen

Purpose of the study: The purposes of the study are three fold: 1) to delineate the concentration of uranium and vanadium in three continuous cores from Big Brown Mine Site, Fairfield, Texas, 2) to make an effort to characterize the distribution of uranium and vanadium in the cores studied, and 3) to estimate the amount of radon-222 contained in lignite seams found in these cores, an estimate based upon uranium-238 content of ten samples.

Procedure: Vanadium was quantitatively determined by atomic absorption using the standard addition method. Uranium was analyzed by delayed neutron activation analysis at Texas A & M University Nuclear Science Center. The distribution ratios (Rd) were determined for uranium in the lignite samples.

Findings: In the vertical cross sections of the cores analyzed, the uranium concentrations ranged from 0 to 16.75 ppm with an arithmetic mean of 5.82 ± 2.98 ppm. The vanadium concentrations ranged from 11.57 to 176.31 ppm with an arithmetic mean of 67.32 ± 50.75 ppm. Significant correlations were found for all non-lignite and non-lignite associated samples for uranium and pyritic sulfur and for vanadium and pyrite sulfur. Also, a correlation between uranium and vanadium was found for these samples. It was observed that uranium, vanadium, selenium, copper, and cadmium exhibit relative concentration enrichment at the soil-lignite interfaces. The distribution ratios for the lignite samples were high, ranging from 6 to 22 indicating a strong affinity of the lignite for uranium under the conditions studied.

Conclusions: The maximum possible release of naturally occurring radon-222 associated with the parent, uranium-238, from the Big Brown Steam Generating plant, Fairfield, Texas, was estimated to be about 24 curies for 1984.

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**THE UTILIZATION OF DEEP CAGES AS A MEANS
OF REDUCING THE INCIDENCE OF GAS BUBBLE DISEASE
IN CHANNEL CATFISH CULTURED IN THERMAL EFFLUENT**

Author: Guy Stevens Chilton

Fingerling channel catfish (*Ictalurus punctatus*) were cultured in floating cages of three depths--0.61 m, 1.83 m, and 3.66 m - suspended in the intake and discharge canals of a steam electric generating station to determine if cage depth could be used as a means of reducing the incidence of gas bubble disease. Survival, growth, and food conversion were compared among the three depths of cage. Fish depth distributions were monitored in the 1.83 m and 3.66 m cages with SONAR on a daily basis, on a diel basis on four occasions, and through sunset and sunrise on four occasions. Mathematical models were constructed to describe correlations between fish depth distribution and hydrological and meteorological factors.

On a daily basis, fish depth was negatively correlated to gas saturation; this may have been the result of increased buoyancy due to gas bladder overinflation. On a diel basis, fish depth cycled with respect to time; fish were deeper in the cages during the day than at night, with the depth change occurring most rapidly at twilight. Depth distribution was probably governed by a behavior pattern triggered by light intensity or changing light intensity.

Survival was poorest in cages in the discharge canal, due to bacterial infections which most likely resulted from chronic exposure to gas supersaturation. Fish in the 3.66 m cages had the poorest survival in either location. Growth rates of fish did not differ among cage depths in the intake canal; the best growth was exhibited by fish in the 1.83 m cages in the discharge canal. Food conversion efficiencies were greatest for fish in the 1.83 m cages in the intake canal; in the discharge canal, the fish in the 0.61 m and 1.83 m cages had significantly better food conversion efficiencies than those in the 3.66 m cages.

Deep floating cages did not provide an adequate means for reducing the incidence of gas bubble disease, since the fish tended to remain in the gas-supersaturated waters due to their response and behavior patterns.

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DISSOLVED GAS SUPERSATURATION ASSOCIATED WITH THE THERMAL EFFLUENT OF AN ELECTRIC GENERATING STATION AND SOME EFFECTS ON FISHES

Author: Alexander Frank Ciesluk, Jr.

Levels of dissolved gases monitored at several locations in the intake and discharge water of the Big Brown Steam Electric Station, Fairfield, Texas, indicated that gas saturation levels in the cooling water of the generating station increased following condenser cooling and were greater than 100%. Percent saturations of total dissolved gas were determined with a Weiss Gas Saturometer and ranged from 100.5 to 115.0% in the discharge water. Saturation levels were directly related to the power plant T and the gas content of the intake water. Percent saturations of dissolved nitrogen gas, calculated from total gas measurements, remained near 100% in the surface intake water and varied little during 24 hour periods. Oxygen saturations in the intake water fluctuated seasonally and during 24 hour periods. Nitrogen had a greater influence than oxygen on total gas levels, but extreme fluctuations in oxygen levels produced noticeable variations in total gas levels. Gas saturations decreased with the distance the effluent had traveled.

Some golden shiners (Notemigonus crysoleucas), longear sunfish (Lepomis megalotis), and channel catfish (Ictalurus punctatus), held in cages, exhibited external symptoms of gas-bubble disease after exposure to the gas-supersaturated effluent water. Channel catfish and longear sunfish were more susceptible to gas supersaturation than bluegill sunfish (Lepomis macrochirus). Incidence of the disease was related to the degree of gas supersaturation and the length of exposure time.

Tolerance of red shiners (Notropis lutrensis), bluegill sunfish, and largemouth bass (Micropterus salmoides) to gas supersaturation was studied in the laboratory. Bluegills and largemouth bass had similar tolerances at all levels tested and tolerated gas saturations as high as 117-118% for 72 hours. Red shiners were more susceptible to gas supersaturation than bluegills or bass.

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**ECOLOGICAL AND PHYSIOLOGICAL CONSIDERATIONS
OF DEPOSIT-FEEDING IN A FRESHWATER BIVALVE,
CORBICULA FLUMINEA**

Author: John David Cleland

A three pronged approach was used during the summer and fall of 1986 to study the physiological ecology of the introduced Asian bivalve, Corbicula fluminea, especially with respect to deposit-feeding and its relationship to downstream transport. Studies were conducted using caged clams which were maintained in Fairfield Lake during the summer of 1986, using clams starved in freshwater aquaria over that same time period, and using clams in an artificial laboratory stream during the fall of 1986.

Specimens used in the caged clam and starvation experiments were collected from a population in the Clear Fork of the Trinity River during May of 1986. All specimens collected were of the light morphotype and a subsample of approximately one thousand animals was collected. Oxygen consumption and ammonia excretion rates were determined for a subsample prior to their use in the two experiments.

Clams used in the field study were individually numbered and their shell lengths (SL) measured before being placed into cages. Their SL was remeasured every two weeks over a 159 day period and the oxygen consumption and ammonia production rates determined for a subsample approximately every three weeks. During the field study, the clams maintained an average shell growth rate of approximately 0.025 mm/day. The O:N ratio was also assessed to determine the nutritional condition of the clams during the study period. The O:N ratio fell below 100:1 during most of the 159 day study period.

Oxygen uptake rates and ammonia excretion rates were periodically determined for a subsample of a second group of clams from the original collection which was subjected to prolonged starvation in the laboratory during the course of the field study. The O:N ratios were consistently above 100:1 throughout the study. Since low O:N ratios may be an indicator of starvation in some bivalve species, these anomalously high O:N ratios in starving clams may indicate that this species converts ammonia into some less toxic form of nitrogenous waste product. Starved clams also displayed a steady increase in weight specific oxygen consumption rate as tissue mass decreased during the study, suggesting that the amount of stored nutrients in cells may seriously affect estimations of weight specific oxygen consumption rates in invertebrate species due to natural variations in the proportion of non-respiratory biomass.

A sample of C. fluminea were subjected to a range of current speeds in an artificial laboratory stream to determine what water flow rates would induce downstream transport. Downstream transport was directly related to shell length with the smallest sized clams being transported at the lowest current speeds.

**THE EVOLUTIONARY ADAPTATION OF THE MOSQUITOFISH,
GAMBUSIA AFFINIS TO HEATED EFFLUENT WATERS
OF STEAM ELECTRIC GENERATING STATIONS**

Author: Stewart Michael Dean

The purpose of this study was to document the adaptation of *Gambusia affinis* to the perturbed environment of heated power plant effluents. Also, the dynamic nature of this adaptation to increased thermal regimes was investigated. Electrophoresis and thermal tolerance methods were used in the study. Three steam electric station cooling lakes were studied, Lake Fairfield, Lake Alcoa and Lake Colorado City.

Electrophoretic differences in gene frequency were found at phosphoglucose isomerase (PGI-2) and phosphoglucomutase (PGM-3). Subpopulation frequencies at PGM-3 appeared random at both Lake Fairfield and Lake Alcoa. Subpopulation frequencies at PGI-2 were nonrandom with heated populations having consistently higher frequencies of PGI-2^b than nonheated populations. Linear regression analyses showed PGI-2^b allele frequency and water temperature to be positively correlated at both Lake Fairfield and Lake Alcoa. Linear regression analyses showed PGM-3^b allele to be slightly negatively correlated with water temperature in both lakes. Seasonal variation in the PGI-2^b frequency was found at both lakes in peak summer temperatures while lowest PGI-2^b frequencies were seen in the coldest temperatures of winter. These results were consistent in both lakes and all sites. Clinal variation was, also, evidenced at the PGI-2 locus. The cline in gene frequency paralleled the cline in water temperature very closely. This was seen in both Lake Fairfield and Lake Alcoa. Although gene frequencies changed throughout the year the clinal nature of the variation seen was always consistent. Lake Alcoa has higher gene frequencies for PGI-2^b than Lake Fairfield possibly due to the fact that it has received heated effluent for twice as long. Heat denaturation electrophoresis results were consistent with other data but inconclusive independently.

Critical thermal maxima (CTM) data revealed higher CTM's for populations inhabiting heated effluents in both lakes. This was seen in both populational means and modal differences. Differences were slightly significant at Lake Fairfield while being significant at Lake Alcoa.

Sexual differences in CTM were seen in addition to acclimation temperature differences. Absolute lethal data show similar results as the critical thermal maxima with Lake Alcoa having significant differences between heated and nonheated populations. Absolute lethal techniques were shown to be accurate measures of upper thermal tolerance since higher acclimation temperature had no effect on absolute lethal values. Genotype and critical thermal maxima were

determined for a sample of mosquitofish. No significant correlation between either locus (PGI-2 or PGM-3) and critical thermal maxima existed.

These results document the adaptation of *G. affinis* populations to heated effluents 6-8°C above ambient. Adaptation is at least at two levels, single gene frequency changes and overall thermal tolerance. This adaptation is due to the selective force of the temperature regime. As the temperature regime in a habitat fluctuates so does the structure of the genetic pool of that habitat fluctuate.

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FEEDING ECOLOGY OF NONBREEDING DUCKS ON STRIP-MINE POND SEDIMENT PONDS IN EAST-CENTRAL TEXAS

Author: Deidre Marie DeRoia

Food habits, characteristics of foraging habitats, and diurnal time-activity budgets were compared among 4 species of nonbreeding ducks using sediment ponds on the Big Brown mine in east-central Texas. Blue-winged teal (*Anas discors*), gadwalls (*A. strepera*), American wigeon (*A. americana*), and ring-necked ducks (*Aythya collaris*) were studied during fall, winter, and early spring, 1989-1992. Ducks were sampled opportunistically from a subset of the total sediment ponds on the mine.

Examination of esophageal contents indicated that vegetation volume was greatest in gadwall and American wigeon diets. Blue-winged teal and ring-necked ducks consumed greater volumes of invertebrates than did gadwalls and American wigeon. All species consumed similar volumes of seeds and grit.

All species foraged in areas with similar amounts of submergent vegetation; gadwalls and blue-winged teal were found in the shallowest areas ($x = 48.7$ cm and 52.7 cm, respectively) where emergent cover was greatest. Ring-necked ducks fed in the deepest areas ($x = 90.9$ cm) with the greatest percent open water. American wigeon foraged at intermediate depths ($x = 64.3$ cm), in areas with moderate vegetative cover. Invertebrate abundance, density, and biomass were greatest at gadwall and blue-winged teal feeding sites and lowest where ring-necked ducks fed.

Focal-animal behavior samples indicate that gadwalls and American wigeon spent more time in diurnal feeding than did ring-necked ducks. Gadwalls spent more time tipping up than did American wigeon; ring-necked ducks fed almost exclusively by diving. All species allocated similar amounts of time to other behavior.

Overlap indices calculated for diets and foraging habitat characteristics were used in an attempt to measure potential competition. Diet overlap and habitat overlap were higher among dabbling species than between dabblers and ring-necked ducks. However, abundance of potential duck foods and differences in feeding behavior could mediate potential competition. Waterfowl sampled on sediment ponds on the Big Brown mine seem to respond to habitat characteristics such that several species may use similar resources; however, results of this study do not provide conclusive evidence that competition for food and habitat affects the structure of the nonbreeding duck community.

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NESTING ECOLOGY OF DICKCISSELS ON RECLAIMED SURFACE-MINED LANDS IN FREESTONE COUNTY, TEXAS

Author: Thomas Pingul Dixon

Surface mining and subsequent reclamation often results in the establishment of large areas of grassland that can benefit wildlife. Grasslands have declined substantially over the last 150 years, resulting in declines of many grassland birds. The dickcissel (*Spiza americana*), a neotropical migrant, is one such bird whose numbers have declined in the last 30 years due to habitat loss, increased nest predation and parasitism, and over harvest (lethally controlled as an agricultural pest on its wintering range in Central and South America). Reclaimed surface-mined lands have been documented to provide important breeding habitat for dickcissels in the United States, emphasizing the importance of reclamation efforts. Objectives were to understand specific aspects of dickcissel nesting ecology (i.e., nest-site selection, nest success, and nest parasitism, and identification of nest predators) on 2 spatial scales on TXU Energy's Big Brown Mine, near Fairfield, Texas, and to subsequently provide TXU Energy with recommendations to improve reclaimed areas as breeding habitat for dickcissels. I examined the influence of nest-site vegetation characteristics and the effects of field-level spatial factors on dickcissel nesting ecology on 2 sites reclaimed as wildlife habitat. Additionally, I developed a novel technique to identify predators at active nests during the 2003 field season. During 2002-2003, 119 nests were monitored. On smaller spatial scales, dickcissels were likely to select nest-sites with low vegetation, high densities of bunchgrasses and tall forbs, and areas with higher clover content. Probability of nest success increased with nest heights and vegetation heights above the nest, characteristics associated with woody nesting substrates. Woody nesting substrates were selected and bunchgrasses were avoided. Oak (*Quercus* spp.) samplings remained an important nesting substrate throughout the breeding season. On a larger scale, nest-site selection was likely to occur farther from wooded riparian areas and closer to recently-reclaimed areas. Nest parasitism was likely to occur near roads and wooded riparian areas. Results suggest reclaimed areas could be improved by planting

more bunchgrasses, tall forbs (e.g., curly-cup gumweed [*Grindelia squarrosa*] and sunflower [*Helianthus* spp.]), clover (*Trifolium* spp.), and oaks (a preferred nesting substrate associated with higher survival rates). Large-scale analysis suggests that larger tracts of wildlife areas should be created with wooded riparian areas comprising a minimal portion of a field=s edge.

PYRITE OXIDATION IN A MINESPOIL ENVIRONMENT: A LYSIMETER STUDY

Author: James Joseph Doolittle

Pyrite (FeS_2) oxidation in a minespoil environment was investigated. Two anoxic Texas lignite overburdens with different amounts of pyrite (Martin Lake 0.8% and Sandow 0.1%) were packed into 0.7m^3 lysimeters with three replications. The lysimeters were leached monthly with 63.5 mm of deionized rainwater for a total period of twelve months. Leachate was collected and analyzed for pH, soluble cations (Ca^{+2} , Mg^{+2} , Na^+ , K^+) and sulfate. Core samples were taken at three month intervals during the leaching period. The cores were sectioned into depth increments and analyzed for pH, extractable cations and sulfate.

Acid-base accounting revealed an excess of acid neutralizing potential in both materials. After twelve months of leaching, leachates from both materials were above a pH of 6.5. The Martin Lake material decreased from an initial pH of 8.3 to 6.5. The Sandow material decreased from an initial pH of 8.2 to 7.5. Potential acidity determinations indicate that 50% of the initial pyrite has oxidized from both materials. Therefore, the pyrite oxidized at an average rate of $11.1 \text{ mg Kg}^{-1} \text{ day}^{-1}$ in the Martin Lake overburden material and $1.6 \text{ mg Kg}^{-1} \text{ day}^{-1}$ in the Sandow overburden material during the 12 month study. The release of acidity through pyrite oxidation was sufficiently slow for the inherent neutralizing materials to consume the acidity as it was generated and maintain a moderate pH. The slow oxidation rate is attributed to low surface area pyrite particles of massive morphology. Silicate coatings on the surfaces of pyrite particles were observed by scanning electron microscopy and confirmed by energy dispersive x-ray analysis (EDAX). The major acid neutralizing constituent was indigenous dolomite. This was substantiated by chemical analyses, a steady efflux of Ca and Mg in the leachates, and a significant increase in extractable Ca and Mg with time in the spoil materials.

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THE KINETICS OF IRON SULFIDE OXIDATION IN LIGNITE OVERBURDEN AS INFLUENCED BY CALCIUM CARBONATE

Author: James Joseph Doolittle

Surface mine reclamation in Texas, is often hindered by the formation of acid minesoil. The acidity is a product of FeS₂ oxidation. Mixed overburden topsoil substitutes containing FeS₂, are often limed to prevent acid minesoil formation.

The main objective of this study was to measure the effects of liming rates on the kinetics of FeS₂ oxidation in overburden. To accomplish this objective, two overburden materials with different FeS₂ content (1.9 and 4.1%) and low acid neutralization potential were limed with CaCO₃. Lime rates of 0, 25, 50, 75, 100 and 125% were based on the amount of CaCO₃ needed to provide an acid/base account (A/B_a) of zero (A/B_a = acid neutralization potential - Potential acidity - exchangeable acidity). The limed overburdens were inoculated with *Thiobacillus ferrooxidans* and leached weekly with deionized water for 53 weeks.

Iron sulfide oxidation followed two different rate laws depending on the pH of the system. The oxidation followed zero-order kinetics with respect to FeS₂ concentration at pH values above 4 and first-order kinetics below 4. The rate of oxidation was also found to differ with FeS₂ source. The zero-order oxidation rate ranged from 0.01 to 0.46 $\Phi\text{mol g}^{-1} \text{d}^{-1}$ in overburden 2 and from 0.01 to 0.22 $\Phi\text{mol g}^{-1} \text{d}^{-1}$ in overburden 4. Oxidation following the first-order rate law had a first-order rate constant of 0.03 d⁻¹ in overburden 2 and 0.01 d⁻¹ in overburden 4. The calculated half-life is 23 and 69 d, respectively. Additions of CaCO₃ affected FeS₂ oxidation by controlling the pH of the system. The higher the pH the slower the oxidation. Liming to 25% of the A/B_a deficit maintained the pH above 4 for approximately 100 d in overburden 4. At that time, oxidation changed from zero- to first-order. The addition of lime did not affect the subsequent half-life of FeS₂ after the pH decreased below 4.

Liming to greater than 50% A/B_a deficit did not significantly affect the zero-order oxidation rate. The dissolution of the applied CaCO₃ was found to be faster than the release of potential acidity. It is projected that the lime would dissolve out of the system before all the FeS₂ would oxidize leaving the potential for acid minesoil formation.

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HYDROGEOCHEMISTRY OF THE UNSATURATED ZONE AT BIG BROWN LIGNITE MINE, EAST TEXAS

Author: Alan Robert Dutton

The amount of ground-water recharge and movement of dissolved ions through the unsaturated zone is negligible in unmined interdistributary-mud facies in the Calvert Bluff Formation (Wilcox Group, Eocene). Strip-mining of lignite in the unsaturated outcrop of the Calvert Bluff at Big Brown Mine, Freestone County, Texas will not degrade ground-water quality in the Wilcox-Carrizo Aquifer. Overburden at Big Brown Mine primarily consists of claystone and mudstone. A thick aquitard separates most of reclaimed facies from the subjacent aquifer. Water in the Wilcox-Carrizo Aquifer moves only a short distance past Big Brown Mine before being discharged into the Trinity River Valley.

The amount of recharge to unmined distributary-sand facies and to reclaimed mud facies is at least 10 times the recharge to unmined mud facies, based on estimates of the water budget for the period from mid-1979 to mid-1981. Water content of reclaimed mud facies is not different from water content of unmined facies. The brecciated deposits of reclaimed mud are still rewetting 4 to 7 years after reclamation, and a saturated zone eventually will form in reclaimed facies.

Ca, Na, Mg, C1-type water with a concentration of dissolved solids of as much as 8,000 parts per million in an interdistributary-mud facies is interpreted as old marine water that has been changed in composition by dilution with rain water and by ion exchange. Water chemistry changes through a 6-m section of the unsaturated zone from a Ca, Na, HCO₃-type to a Na, HCO₃-type in unmined distributary-sand facies and from a Ca, Mg, SO₄C1-type to a Ca, Na, Mg, HCO₃, C1-type in reclaimed-mud facies. Argillation of feldspar, evapotranspiration, and movement of brackish water from unmined mud facies account for changes in water chemistry in distributary-sand facies. In reclaimed-mud facies, the chemical changes are due to dilution of formation water by rain water, ion exchange, solution of calcite, and oxidation of pyrite. Total dissolved solids (t.d.s.) in reclaimed mud facies is less than t.d.s. in unmined mud facies because of the increased rate of flushing in the reclaimed deposits.

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AVIAN ASSOCIATIONS WITH HYDRILLA ON LAKE FAIRFIELD, TEXAS

Author: Daniel Esler

The relationship between birds and the exotic submergent plant hydrilla (*Hydrilla verticillata*) was studied throughout 1986 and 1987 on Lake Fairfield during the initial stages of hydrilla invasion.

Hydrilla was the only major habitat to exhibit significant ($p < 0.05$) increases in coverage from 1986 to 1987. The maximum coverage of hydrilla during this study occurred in fall 1987 and was 5.1%.

Birds of several guilds selected hydrilla as a foraging habitat. Herbivorous, swimming birds, such as American coots (*Fulica americana*), American wigeon (*Anas americana*), gadwalls (*Anas strepera*), canvasbacks (*Aythya valisineria*), and ring-necked ducks (*Aythya collaris*), selected hydrilla over all other habitats. Northern shovelers (*Anas clypeata*), which utilize a high percentage of invertebrates, also selected hydrilla. Piscivorous, swimming birds, including pied-billed grebes (*Podilymbus podiceps*), American white pelicans (*Pelecanus erythrorhynchos*), and cormorants (*Phalacrocorax* spp.), showed a close association with hydrilla.

Changes in bird community structure were associated with the significant increase of hydrilla from 1986 to 1987. Species richness increased significantly ($p < 0.05$) in winter and fall from 1986 to 1987 and total number of individuals was significantly ($p < 0.05$) higher for fall 1987. Taxa exhibiting increased numbers included American coots, pied-billed grebes, and several waterfowl species.

Bird counts and vegetation sampling in 26 plots indicated a significant ($p < 0.05$) positive correlation between hydrilla coverage and bird use of plots.

Four experimental plots created by removing hydrilla were paired with plots with abundant hydrilla. Bird use was significantly ($p < 0.05$) greater in hydrilla plots in fall and winter.

An assessment of the extent of coot herbivory on hydrilla was conducted using exclosures and corresponding open frames. Depth of hydrilla was greater, and biomass lower, in open frames than in exclosures.

Hydrilla increased vegetative diversity and provided foraging habitat for several bird guilds. No detrimental effects of hydrilla on birds was observed. Hydrilla's primary influence was in winter and fall, seasons showing the greatest numbers of migrating and wintering birds.

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HYDROGEOLOGIC ASPECTS OF LIGNITE STRIP MINES NEAR FAIRFIELD, TEXAS

Author: Lawrence Nelson French

The Big Brown lignite strip mines, northeast of Fairfield, Texas, are operated by Texas Utilities Generating Company (TUGCO). The lignite is mined from the lower Calvert Bluff Formation (Eocene), a 300-meter thick sequence of interbedded sand and shale with lignite. Discontinuous sand units in the Calvert Bluff Formation yield ground water suitable for domestic and agricultural purposes.

Strip mining produces a sandy clay-loam spoil. Two field tests yielded hydraulic conductivities of 10^{-4} cm/sec at the "A" area test site and 2.6×10^{-3} cm/sec at the "B" area test site. The older spoil of the "A" area may be less permeable owing to post-reclamation compaction. The hydraulic conductivity of the compacted spoil is approximately equal to the hydraulic conductivity of undisturbed minor silty sand units in the Calvert Bluff Formation.

The rate of leachate generation is controlled mostly by the rate of infiltration of surface water. The calculated water budget shows that 13 cm of water, about 13% of the average annual precipitation, will percolate into the spoil. This equals an infiltration of about 1.7×10^7 liters of surface water per day over the area of the mines. Flow of ground water into the mines will be most significant where mining of the "C" area intersects a major sand unit of the Calvert Bluff Formation. Eventually about 2.3×10^4 liters per day of ground water will flow from this major sand unit into the adjacent "C" area.

No acid-mine drainage has been found at the Big Brown mines. The pH of mine waters range from 5.1 to 7.3. The lowest pH values measured were in water emerging from a spring in the spoil near the west boundary of the "B" area. Most of the acidity has been neutralized by calcium carbonate in the spoil. Oxidation of pyrite has created large concentrations of sulfate in the unsaturated and saturated zones of the spoil. Concentrations of sulfate may be further influenced by precipitation and dissolution of gypsum, leaching of soil-sulfate compounds, and sorption by the soil. Most of the ground water is oversaturated with respect to gypsum. Large concentrations of dissolved solids and hardness occur in all waters, and concentrations of ferrous iron as large as 25.0 mg/l may occur in water of the saturated zone.

As a saturated zone develops in the spoil, leachate will move into adjacent, unmined, sand units in the Calvert Bluff Formation. Ground water in the confined Simsboro Sand aquifer in Freestone County moves downdip to the east and a small amount moves upward to the surface

through confining shale units. Hydraulic communication may exist between the major sand units of the Calvert Bluff Formation and Simsboro Sand aquifer. The "C" area intersects a major sand unit of the Calvert Bluff Formation; mining will partially dewater the sand unit and will cause ground water to flow through the spoil. This will prevent drainage of the mine effluent into the Simsboro Sand aquifer.

RECOLONIZATION OF SURFACE-MINED LANDS BY POCKET GOPHERS (*GEOMYS BREVICEPS*) IN EAST TEXAS POST OAK SAVANNAH

Author: Paula B. Gutierrez

Surface mining involves the use of heavy equipment that would theoretically create underground vibrations sensed by pocket gophers. To determine if vibrations cause pocket gopher movement away from areas being mined, gopher movements were monitored in a hay field adjacent to an active mine pit on Big Brown Mine in Freestone County, Texas. Gophers were live-trapped in summer 2000 prior to mining activity, injected subcutaneously with a passive integrated transponder (PIT) tag, and released. Coordinates of each capture location were recorded. After mining began and spoil piles were established adjacent to the field, re-trapping was conducted. Upon capture each pocket gopher was scanned for a PIT tag and newly caught animals were tagged. Location coordinates were recorded to determine movement between capture sites. Of the 58 gophers captured and tagged, 9 individuals were recaptured. Pocket gophers did not appear to move away from mining activity, so they might have been adversely affected. However, the number of individuals in the population remained constant during the study, indicating there was no population effect. During January and February 2001, all remaining non-mined and reclaimed lands within the mine were surveyed for pocket gopher activity (mounds). Activity was found on non-mined land adjacent to reclaimed land but no activity was found on reclaimed land. Pocket gopher populations did not reestablish on reclaimed lands because of the removal of sandy soils and subsequent replacement with hard, loamy soils. If pocket gophers are desired on reclaimed lands, then it would be important to retain areas of topsoil containing at least 80% sand.

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SMALL MAMMAL POPULATIONS ON RECLAIMED STRIP-MINED AREAS IN FREESTONE COUNTY, TEXAS

Author: Deborah Anne Gust

The Composition and structure of small mammal communities was examined at four areas on and around a strip-mine in Freestone County, Texas. Monthly live-trapping over a one year period was conducted on three reclaimed and one control area. Seven species (Reithrodontomys fulvescens, R. humulis, R. montanus, Peromyscus maniculatus, Baiomys taylori, Sigmodon hispidus and Mus musculus) were caught. Peromyscus maniculatus was the earliest invader on the recently reclaimed area when vegetative cover was sparse, but as vegetative cover became more abundant Sigmodon hispidus emerged as the dominant species. S. hispidus was the only small mammal present on the reclaimed area utilized for seasonal grazing. Species diversity was highest at the control area. Mean total small mammal biomass was greatest at the recently reclaimed area. The recently reclaimed and the seasonally grazed pasture areas were the most alike in terms of species similarity. Vegetative cover, method of reclamation, and the subsequent use of the reclaimed lands seem to influence the structure and composition of small mammal communities.

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**FISH POPULATIONS OF FAIRFIELD RESERVOIR, TEXAS
TEN YEARS AFTER IMPOUNDMENT AND THE EFFECTS
OF THE INTRODUCTION OF TILAPIA AUREA**

Author: James Gregory Hanifen

Gillnet, seine, and trawl samples were taken monthly, June, 1979 through June, 1980, to determine species composition, relative abundance, and distribution of fish species within Fairfield Reservoir near Fairfield, Freestone County, Texas. The effects of the introduction of Tilapia aurea on native fishes was investigated using these data. Hydrological parameters were measured concurrently with catch data. Twenty-nine species and two hybrid fishes were collected. Gillnet sampling resulted in the capture of 23 species of which seven comprised 90 percent of total catch. The seven were: Tilapia aurea, Lepomis macrochirus, Morone chrysops x M. saxatilis, Ictalurus punctatus, Dorosoma cepedianum, Micropterus salmoides and Cyprinus carpio. Seine catches were comprised of 12 species of which Menidia beryllina, Dorosoma petenense, and T. aurea constituted 95 percent of catch. Seven species were taken in trawls with D. petenense comprising 98 percent of catch. Mean catch-per-unit-effort of game fish species has increased since impoundment. The decline in the ratio of game:non-game species was due to the expansion of T. aurea in the lake. Native species likely to be affected by continued increase of tilapia include D. cepedianum, Cyprinus carpio, Notropis lutrensis, Pimephales vigilax, Carpionodes carpio, Lepomis species, M. salmoides, and Pomoxis species. Abundant predators, especially Morone hybrids, may also have contributed to population changes already observed in these species. Predation by Monroe hybrids may account for the large size attained by T. aurea in Fairfield Lake. The feasibility of a commercial harvest of T. aurea should be considered.

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EVALUATION OF THE RHIZOBIUM-SUBTERRANEAN CLOVER SYMBIOSIS AND ECOLOGY OF RHIZOBIUM IN LIGNITE MINE SPOIL

Author: Pamela Ann Harris

Lignite mine spoils in Texas are commonly revegetated with coastal bermudagrass (Cynodon dactylon L.). Clovers have been utilized in reclamation programs, but information regarding their establishment and persistence in mine spoil is limited. Field, greenhouse, and laboratory studies were conducted to investigate the Rhizobium-subterranean clover (Trifolium subterraneum L.; subclover) symbiosis in mine spoil.

Subclover was broadcast seeded into a six-month-old bermuda-grass sod. Plots were fertilized with 336 kg ha⁻¹ of 17-17-17 or 0-17-17 or left unfertilized at the onset of each clover season. All plots were fertilized with 336 kg ha⁻¹ of 17-17-17 at the beginning of each grass season.

Although low numbers (0 to 10² g⁻¹) of native rhizobia were present in field plots, inoculation with a commercial, multi-strain inoculant increased biomass production (100%) and total N and P yields of subclover in the early portion of the first season. Yields from inoculated and uninoculated plots were generally comparable later in the first season and in the second year. Subclover production in the field was increased by P-K fertilization, whereas addition of N with P and K did not affect production. In pot studies, clover production was increased by P rates of 40 to 80 mg kg⁻¹.

The presence of subclover prior to bermudagrass increased grass production (50%) and total N and P yields later in the first year and in the second season. Concentrations of N and P in the grass were increased when subclover was an antecedent crop. Fertilization of clover with N and P increased grass yields (25 to 50%), indicating that levels of both nutrients in spoil were insufficient for grass production.

Introduced and native rhizobia maintained sufficient levels (10³ to 10⁴ g⁻¹) to nodulate emerging clover in subsequent years. The percentages of total numbers of effective rhizobia were lowest when subclover was absent, and percentages increased when subclover was introduced at a site.

Survival of individual strains of Rhizobium was evaluated using the enzyme-linked immunosorbent assay (ELISA). After two years, strains 162x97 (subclover inoculant) and 162K10 (crimson clover inoculant) codominated in the spoil. The relative abundances of these strains were generally similar to those observed on the older, reclaimed sites planted with inoculated subclover in 1981.

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ECOLOGICAL ASSESSMENT OF NINE CREATED WETLANDS AT THE BIG BROWN MINE, FAIRFIELD, TEXAS, USA

Author: Tyson Michael Hart

Over the past 200 years, an estimated 53% of the original wetlands in the conterminous United States have been lost mainly as a result of human activities such as urban development and conversion to agriculture. Mining entities, including large utility corporations such as TXU, are legally required to mitigate land back to its natural state, including wetlands. TXU is required to reclaim its destroyed freshwater wetlands back into their natural state. The scope of my research focused on two fundamental components of the wetland ecosystems at the Big Brown Mine, Fairfield, TX, USA - the abiotic (soils and hydrology) and biotic (vegetation and benthic invertebrates). Specifically, my objectives were to 1) evaluate the surface water and soil characteristics in mine wetlands at Big Brown Mine over a period of 1 year, and 2) relate patterns in surface water and soil conditions within wetlands to hydroperiod, across all wetlands to season, and between different age groups of wetlands to time since creation (i.e., age). Using the results of these analyses, I wanted to determine a metric that best reflected the Amaturity® of these reclaimed wetlands.

Trends in soil data showed clear increases in total carbon (C) and nitrogen (N) as the wetlands developed. Soil redox behaved similarly to soil nutrients, in that as wetlands developed the soil redox potential decreased. With increased inundation periods, soil redox also decreased. Hydrologic results were linked mainly to atmospheric conditions and seasonal variability, rather than wetland maturity. Vegetation provided the greatest insight into wetland development. As wetlands developed, a higher diversity of obligate wetland plants and increased plant biomass resulted. A quick survey of vegetation development in and around the wetland could lead to the determination of the wetland's developmental status. Benthic invertebrates thrived in wetlands where the soil, hydrology, and vegetation were indicative of healthy, mature wetlands. The invertebrates data helped solidify the developmental progress of each wetland.

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GEOSTATISTICAL ANALYSIS OF THE SPATIAL VARIABILITY OF LEVELED LIGNITE MINE SPOIL IN EAST TEXAS

Author: Hilda Helen Hatzell

An understanding of the spatial variability of mine spoil is needed to improve sampling techniques. Core samples were taken at two sites at intervals of 3.05 m along four intersecting transects located at 0, 45, 90, and 135 degrees relative to the mine pit length. The spatial distribution of pH, lignite, carbonates, NaHCO_3 -extractable P, DTPA-extractable Zn, and Zn concentration in millet (*Pennisetum americanum* (L.) Leeke) were evaluated with directional variograms. The ranges for pH of 15-90 cm samples were 22.0, 20.7, 12.2, and 30.5 m for the 0, 45, 90, and 135 degree directions at one site and <3.0, 19.8, 13.7, and 15.2 m for the same directions at the second site. Ranges were less than a single pit width. Larger ranges at the first site were related to larger spoil piles associated with thicker overburden. The elongation in the 45 and 135 degree directions corresponded to the shape and orientation of the traces of the spoil piles at the leveled surface. Cycling in the variograms reflected the location of the former mine pits. Directional variograms for extractable Zn exhibited elongation of ranges and cycling similar to the variograms for pH. The levels of pH and Zn were inferred to occur throughout the undisturbed overburden in varying amounts. Redistribution during the spoiling process created a spatial pattern related to the accretion of the spoil piles. Lignite, carbonates, and extractable P were not spatially distributed at the surface of the leveled spoil. Lignite and carbonates were inferred to be localized within the overburden in insufficient amounts to be redistributed in a spatial pattern. Directional variograms for Zn concentration in millet reflected the spatial structure found in extractable Zn. The ratio of the ranges in the 0:45:90:135 degree directions was 1.2:1.0:1.1:2.0 for Zn concentration and 1.4:1.0:1.2:2.0 for extractable Zn. This spatial interaction between Zn concentration and extractable Zn was verified with cross-variograms. Parameters that exhibit spatial dependence are not distributed independently at the spoil surface. Sampling schemes should consider both the periodicity associated with the pit locations and the spatial structure related to the configuration of the spoil piles.

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HYDRAULIC PROPERTIES OF THE SATURATED ZONE OF A RECLAIMED LIGNITE SURFACE MINE, EAST TEXAS

Author: Charles Dale Hewitt

Near-surface lignite resources in the Calvert Bluff Formation of the Wilcox Group often underlie shallow aquifers. Surface mining methods require that these shallow aquifers be dewatered prior to mining. During mining, overburden sands and muds are mixed randomly. The resulting material, or spoil, can be considered homogeneous and isotropic on a field scale but strongly heterogeneous on the scale of a few meters. Resaturation of the spoil can lead to the development of a shallow water table aquifer.

Two study areas at the Big Brown Mine in Freestone County, Texas, were found to have developed saturated zones ranging from 3 to 16 m in thickness for 4 and 9-year old spoil respectively. The thickness of the saturated zone in the 9-year-old spoil did not vary over the duration of this study which suggest that the water table may be at an equilibrium position. Multiple screened intervals in monitoring wells installed in the 9-year-old spoil permitted the detection of a downward vertical component of groundwater flow. The spoil, therefore, is acting as a recharge zone for the underlying unmined strata. Hydraulic conductivities measured in the saturated zone of the spoil ranged from 2.75×10^{-4} to 4.41×10^{-4} cm/s which are similar to those of unmined silty sand aquifers.

Resistivity surveys conducted in the both the 4 and 9-year-old study areas were unsuccessful in delineating the water table. They did, however, provide a qualitative assessment of the overall degree of resaturation of the areas. The 4-year-old site displayed generally higher resistivities and contained a poorly developed zone of low resistivity (high moisture content). The 9-year-old spoil contained a thick, laterally extensive low resistivity zone corresponding to its more extensive and uniform degree of saturation.

Recharge to the spoil from the percolation of precipitation does not alone account for the rapid development of saturated zones in the study areas. Reconstruction of pre-mining topography and, therefore, pre-mining groundwater flow directions and gradients, may induce water to flow through the spoil to regional discharge areas such as the Trinity River. This lateral inflow may account for the rapid resaturation of spoil.

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REDEVELOPMENT OF THE GROUNDWATER SYSTEM AT A RECLAIMED LIGNITE SURFACE MINE, EAST TEXAS

Author: Frederick J. Holzmer

Strip mining for near-surface lignite disrupts the hydrogeologic system, resulting in localized dewatering of aquifers wherever the water table intersects a recoverable lignite seam. In addition, mining of the overburden exposes reducing zone sediments to oxidizing conditions, leading to a rapid change in groundwater chemistry upon resaturation. This study examined rates and sources of recharge, flow dynamics, and groundwater chemistry processes in the saturated zone of a reclaimed lignite mine in East Texas.

Lignite deposits at Big Brown Mine, located in the outcrop of the Calvert Bluff Formation, are interlayered within silty-sand and mud deposits. The reclaimed spoil has experienced a highly variable rate of resaturation. Water table increases during 1990-1991 ranged from 2 to 10 ft/yr. The higher rate of resaturation is attributed to fracture-enhanced recharge through clay-rich spoil during a period of unusually high rainfall. Fractures exist in the unmined clay facies and are further developed by mining processes. Groundwater flow modeling of a developing recharge mound indicates that permeability decreases with depth in reclaimed spoil. Hydraulic conductivity ranges from 10^{-3} to 10^{-5} cm/sec. Specific yield is generally low in the spoil aquifer, estimated at 4 to 6%, which results in relatively large water level increases per unit input of recharge.

Postmine groundwater chemistry exhibits a significant increase in dissolved solids, from permine concentrations of 100 to 1,700 mg/l, to postmine concentrations of 1,200 to 4,000 mg/l. Postmine water chemistry processes are dominated by pyrite oxidation, with a resultant increase in SO_4 concentrations. Postmine pH ranges from 4.6 to 6.4 and is greater than 6 in most areas of the reclaimed mine.

Redox reactions are occurring in the spoil aquifer, beginning with oxidation of organic carbon in the oxygenated recharge zones. Dissolved oxygen values range from 0 to 1.5 mg/l. Spoil groundwaters were analyzed for the following redox pairs: NO_3/NO_2 , NO_3/NH_3 , $\text{Fe}^{3+}/\text{Fe}^{2+}$, and $\text{SO}_4/\text{H}_2\text{S}$. Based on the $\text{SO}_4/\text{H}_2\text{S}$ redox pair, the pE of spoil groundwater ranges from 0 to -2.5. As sulfate reduction continues, SO_4 concentrations decrease and HCO_3 concentrations increase. Where pE is lowest, the groundwater is at equilibrium with respect to calcite, siderite and iron sulfide. The precipitation of minerals in areas of active sulfate reduction provides a mechanism for reducing the concentrations of dissolved solids and may be important process affecting the long-term evolution of postmine groundwater.

The spoil aquifer comprises a local flow system that discharges slowly to area creeks and to the nearby Trinity River Valley. Groundwater discharge will be diluted in the streams by surface runoff in this humid subtropical climate, except during times of drought.

CHEMICAL AND PHYSICAL PROPERTIES OF LIGNITE SPOIL MATERIAL AND THEIR INFLUENCE UPON SUCCESSFUL RECLAMATION

Author: Frank Michael Hons

A three year forage crop study was initiated in 1975 at the Big Brown mine in Freestone County, Texas, to determine the yield and reclamation potentials of various grasses and legumes on a lignite mined soil. Grasses used in the study included NK-37 bermudagrass, Coastal bermudagrass, Kleingrass, bahiagrass, and Callie Giant bermudagrass. Legumes utilized included Yuchi arrowleaf clover, Crimson clover, and alfalfa. Kleingrass, Coastal bermudagrass, and Yuchi arrowleaf clover proved to be the most productive species of the forages tested.

Statistical analyses demonstrated that nitrogen was the most limiting fertilizer nutrient necessary for the production of grasses on the mined soil. Phosphorus was shown to be the most important fertilizer nutrient which must be added for adequate legume production.

Nitrate-N was more effective in increasing Kleingrass production than was $\text{NH}_4\text{-N}$ because of surface application of the nitrogen fertilizers, extremely low nitrification potentials in the mined soils, droughty soil surface conditions during summer months, and the low surface rooting density of Kleingrass. This result was also observed for Coastal bermudagrass when the nitrogen fertilization rate was less than 112 kg/ha/yr.

Ammonium fixation capacities as high as 7.8 meq $\text{NH}_4\text{-N}/100\text{g}$ soil were obtained with mined soil samples in the laboratory. Residual lignite in the soil was responsible for fixing a large portion of this $\text{NH}_4\text{-N}$. Decreased nitrogen availability because of NH_4 fixation should not be a problem on a field basis, however, as demonstrated by recoveries of applied NH_4 fertilizers.

Soil reaction apparently declined rapidly after mining until the readily oxidizable pyrite was consumed. Soil pH values then stabilized and did not change significantly during the three year period of study. The final mean pH of the study area was approximately 4.4.

Soil oxygen concentrations in the mined soils were correlated with soil moisture by volume and depth in linear regression models. Depth better explained the soil oxygen concentrations in wet portions of the year than did soil moisture. Soil moisture, however, explained as much or more of the soil oxygen concentration in drier portions of the year.

*Doctoral Dissertation
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NEST PREDATION, PREDATOR ABUNDANCE, AND AVIAN DIVERSITY IN TRANSMISSION LINE CORRIDORS AND ADJACENT HABITATS IN EAST CENTRAL TEXAS

Author: Tani Ann Hubbard

Transmission line corridors and other types of rights-of-way (ROW) are narrower and more continuous than other types of disturbances and, therefore, result in a proportionately higher amount of edge in the vegetation types they bisect. These ROW corridors may have differential effects on wildlife communities in adjacent vegetation types in a heterogeneous landscape. I evaluated the effects of ROW corridors on avian and nest predator communities in forests and pastures in east central Texas in 1998 and 1999. I measured nest-predation rates, avian richness and abundance, and predator abundance in ROW corridors and in edges and interiors of adjacent forests and pastures. Forest blocks had higher ($P < 0.05$) bird richness and abundance than ROW corridors and pastures. Bird richness and abundance increased ($P < 0.05$) in forests with increasing distance from the forest/corridor edge. Nest-predation rates were higher ($P < 0.05$) on forest sites than on pasture sites and did not differ ($P > 0.05$) between edge and interior. Mammal predator abundance was higher ($P < 0.05$) in adjacent sites than in ROW corridors in 1998 and was higher ($P < 0.05$) in forest than in pasture in all but one trial. Predators may not use ROW corridors as travel lanes through all vegetation types. These corridors may act as filters of activity for birds, evidenced by the decreased activity near corridors and increased activity in forest interiors, which may effectively decrease available habitat for birds. Edge effects may extend to the interiors of forests due to patch size and the level of disturbance in the larger landscape. Small forest patches in this agricultural landscape may serve as an ecological trap for birds due to predator saturation. Consolidation of ROW corridors and planning for ROW construction along the peripheries of existing vegetation types may be less deleterious to wildlife communities.

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MOURNING DOVE DIFFERENTIAL USE OF RECLAIMED SURFACE-MINED LANDS IN EAST-CENTRAL TEXAS

Author: James Eric Huff

The mourning dove (*Zeniada macroura*) is the most abundant and widespread North American game bird despite the fact that declines have been observed throughout much of the United States. The U.S. Fish and Wildlife Service's Central Management Unit has experienced a significant decline in the number of mourning doves heard during the Mourning Dove Call Count for the past 10- and 34-year periods. Land-use changes and loss of mourning dove habitat is often cited as reasons for these declines. Fourteen transects in different aged reclaimed surface-mined lands and in different land-use types were monitored during morning and evening hours monthly for 1 year to examine differential use by mourning doves. Mourning dove densities were determined for transects representing different aged reclaimed lands and land uses. Vegetation measurements including obstruction of vision, plant height, percent bare ground, and percent canopy cover of dominant grass, forb, and woody species were taken at systematically selected points along the transects in summer, fall, and spring. A Pearson's product-moment correlation and regression analysis was used to examine relationships between dove densities and vegetation measurements. Significant differences ($P < 0.05$) were found in dove densities among different aged reclaimed lands in summer, fall, and spring. Younger age classes (lands reclaimed 0-5 or 6-10 years prior to initiation of this study) and 1 of 2 controls had higher dove densities than other transects. Percent bare ground explained differences in dove densities. Plant height and obstruction of vision were negatively correlated with dove densities during spring months. Significant differences were seen in dove densities on different reclamation types. Newly reclaimed land and areas of native pasture had higher dove densities than other reclamation or vegetation types. Structural measurements explained at least part of the variation in dove densities between different reclamation types.

*Masters Thesis
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**COMPETITIVE INTERACTIONS BETWEEN THE EXOTIC BLUE
TILAPIA, SAROTHERODON AUREUS, AND LARGEMOUTH BASS, MICROPTERUS
SALMOIDES, IN A HEATED RESERVOIR**

Author: Daniele Fausto Ippolito

The purpose of this study was to assess the impact of the exotic blue tilapia (Sarotherodon aureus) on a population of largemouth bass (Micropterus salmoides) in a heated reservoir (Lake Fairfield in Freestone County, Texas).

The study was conducted from January 1983 to November 1984. An analysis of the relative abundances of the two species revealed that both adult and young-of-the-year tilapia were significantly most abundant in the cove adjacent to the mouth of the heated effluent. No clear correlation between catch-per-unit-effort (CPUE) and water temperature was found, however.

There were no significant differences in CPUE for adult bass at the various sampling stations. Bass reproduction, however, appeared to be significantly most successful in the cove that displayed the most extensive amount of inundated brush on its shores. Inundated vegetation may have provided protective cover for bass fry at a time when they would have otherwise been vulnerable to predation.

A winterkill in December 1983-January 1984 significantly depressed the tilapia population, but it had no impact on the bass population.

High tilapia concentrations have been reported in the literature to inhibit bass spawning. This appeared to be the case in Fairfield Reservoir. In April 1983, high gonosomatic indices (GSI's) were found in sexually mature female bass collected in the cove where bass reproduction appeared to be least successful and mature tilapia were most abundant (the cove at the mouth of the heated effluent). High GSI's in the absence of corresponding reproduction indicate failure of bass to spawn, presumably due to high densities of tilapia.

Bass GSI's dropped significantly from April 1983 to April-May 1984. This drop corresponded to a drop in the tilapia population due to the above-mentioned winterkill. Bass reproduction appeared to be significantly more successful in 1984 than it had been in 1983, presumably due to the release of spawning inhibition by tilapia.

Bass and tilapia in the 0-60 mm SL range appeared to compete for food. This competition probably contributed to low bass recruitment in 1984 (young tilapia were most abundant in 1984).

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CHEMOAUTOTROPHIC METABOLISM AND ACID PRODUCTION IN RECLAIMED SOIL FROM A LIGNITE SURFACE MINE

Author: James Arthur Jackson

Purpose of the Study: This investigation was undertaken to clarify and substantiate the involvement of chemoautotrophic bacteria in acid production in reclaimed soil from a lignite surface mine.

Procedure: The activity of chemoautotrophic bacteria was indexed using a modification of an isotopic technique reported by Belly and Brock (1973). Numbers of chemoautotrophic bacteria, heterotrophic bacteria, and fungi were determined using the Most-Probable-Number Technique. Soil moisture and soil pH were determined using the methods described by Allison et al. (1965). Statistical analysis of the data collected was performed according to the methods outlined by Zar (1974).

Findings: A significant negative correlation was determined for soil pH and the index of chemoautotrophic activity. A significant positive correlation was demonstrated between numbers of chemoautotrophic bacteria and the chemoautotrophic index. A model was constructed from the experimental parameters studied accounting for 67.7% of the variance in soil pH. The populations of the two types of chemoautotrophic bacteria studied, iron-and sulfur-oxidizing bacteria, demonstrated a good correlation with the chemoautotrophic index.

Conclusions: Results of the study suggested an intimate involvement between chemoautotrophic bacteria and decreased pH in reclaimed soil. Of the two types of chemoautotrophs, iron-oxidizing bacteria contribute more significantly to decreased soil pH.

*Masters Thesis
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**PROPERTIES OF AND FACTORS INFLUENCING INFILTRATION
RATES A RECLAIMED LIGNITE MINE,
FREESTONE COUNTY, TEXAS**

Author: Karen E. Jarocki

Over the last 30 years, lignite has become an important energy resource for the State of Texas. Production of lignite involves strip mining large areas of land in the Texas Gulf Coast region. Lignite at the Big Brown Mine, Freestone County, Texas, is produced from fluvial-deltaic sediments of the Calvert Bluff Formation of the Paleocene-Eocene Wilcox Group. Mining processes mix overburden material resulting in a spoil that is more homogeneous than the original unmined material over the area of the mine. The effects of mining on the environment are wide and varied, but mining is especially disruptive to the groundwater system. Groundwater recovery begins immediately after the spoil is placed, but occurs at highly variable rates. Hydrogeologic properties change rapidly in the first few years after the mining and much of the groundwater recovery is dependent on the infiltration capacity of the spoil material. Resaturation of shallow spoil aquifers at the Big Brown Mine occurs at rates ranging from 0.6 to 3.0 m/yr (2-10 ft/yr). Recharge to the groundwater system is principally from direct infiltration of precipitation with variable resaturation rates attributed to variations in infiltration.

For this study, four sites at the Big Brown mine were chosen for characterization. Three sites, designated fields C-13, C-24 and C-32, are located in reclaimed areas of the mine and range in age from 9 to 14 years old, while the fourth site is located in an unmined area (UM) between the two active mining pits. Infiltration rates were quantified using a drip infiltrometer to simulate rainfall. Results show that mining and reclamation processes can reduce infiltration rates by as much as 53 percent from the unmined values. Unmined areas show infiltration rates ranging from 12 to 30 cm/hr (4.7-11.8 in/hr) with a mean value of 20 cm/hr (7.9 in/hr). Mined areas show infiltration rates ranging from 3 to 33 cm/hr (1.2-8.7 in/hr) with a mean value of 9 cm/hr (3.5 in/hr). These rates vary significantly over the area of a single field resulting in high standard deviations, but a comparison of mean infiltration rates between the three mined areas shows much less variation. It is unlikely that the small variations seen in the infiltration rates of fields C-13 and C-24 can, by themselves, account for the large variations in resaturation rates for these fields.

Infiltration rates vary in response to changes in soil moisture content, spoil heterogeneity, soil mineralogy, and method of spoil placement. Higher values of infiltration occur when the soils are dry, generally from late spring to early fall. Differences in soil texture had less effect on infiltration rates than was hypothesized, with both coarse and fine grained soils showing similar values.

Tracer tests, using sodium bromide as a conservative tracer and the red dye Rhodamine WT, were performed to determine if channeling of water occurs in the reclaimed soils. Trenches, cut in the dyed areas, were inspected for fractures and macropores and sampled at regular intervals for analysis of bromide concentration. Rhodamine WT showed some fractures in the soil structure, but due to a chemical reaction, sorbed strongly to the soil surface with little movement into the soil column. Concentration plots of bromide proved much more useful in determining mechanisms of flow and show good vertical flow paths in fields C-13 and C-32. Lateral flow dominates in field C-24. Differences in flow mechanisms may best account of the variable resaturation rates seen in these fields.

DENITRIFICATION RATES AND ASSOCIATED SOIL CHARACTERISTICS OF WETLANDS CREATED ON OXIDIZED AND REDUCED MINE SPOIL IN EAST TEXAS

Author: Daniel T. Johns

Recovery of wetland function is the primary goal of wetland creation and restoration. Denitrification is a wetland function and part of the nitrogen (N) biogeochemical cycle in which nitrate (NO_3^-) and nitrite (NO_2^-) forms of N are converted to gaseous forms and lost to the atmosphere. Measurement of denitrification rate may therefore be an important tool for evaluating wetland function. This study examines denitrification rates and associated soil variables on wetlands created after lignite mining in East Texas. Wetlands created on four foot haul-back and mixed overburden mine spoil were selected as study sites. Soil cores were removed from recently-created (age 4-8 years), older-created (age 10 years) and reference (natural) wetlands. Denitrification was quantified using an acetylene (C_2H_2) inhibition/ gas chromatography method. Soil texture, pH, total-N, NO_3^- , cation exchange capacity (CEC), total phosphorus (P), volumetric water content and organic matter (OM) content were also measured. Soil character varied by spoil type and by age. Denitrification rate did not differ among wetlands and ranged from $0.2 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ to $105 \text{ kg N ha}^{-1} \text{ yr}^{-1}$. Older-created and recently-created wetlands on oxidized and reduced mine spoil had denitrification rates similar to natural wetlands. Denitrification potential ranged from $23 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ to $302 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ and varied by spoil type. Denitrification appears to function as well in wetlands created on mine spoil as in natural wetlands.

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NESTING AND FORAGING ECOLOGY OF INTERIOR LEAST TERNS (*Sterna antillarum athalassos*) NESTING ON RECLAIMED SURFACE COAL MINE SPOIL IN EAST-CENTRAL TEXAS

Author: Andrew C. Kasner

A thorough understanding of the breeding ecology of Interior Least Terns (*Sterna antillarum arthalassos*) is necessary for the conservation of this endangered species. Foraging ecology of the species is understudied in interior populations. Studies are lacking for interior nesting at artificial sites, which are inherently different from natural sites. This study examined the foraging and nesting ecology of Interior Least Terns nesting on reclaimed surface coal mine spoil at Big Brown Mine in Freestone County, Texas. In an experiment testing the effects of fish density on tern use, artificial stocking of sediment ponds was used to establish ponds with different fish densities, with 9 ponds used in 2000 and 12 in 2001. Fish density was not important in determining pond use by Least Terns on the mine. However, the physical characteristics of the ponds were very important in determining which ponds were used and the manner in which terns utilized them. Foraging ponds were old, clear ponds in old reclamation while loafing ponds were young, turbid ponds with mudflats or floating objects in newly reclaimed landscapes. Turbidity, wind, water surface conditions, and sky conditions, and time of day affected foraging success, with reduced effects of weather at clear ponds, suggesting that tern preference for foraging at clear ponds is reinforced by the effects of abiotic factors. Tern nest success was limited each year, with May rainfall causing egg-sticking and predation by mammals (primarily coyotes) contributing to nest failure. Sites used for nesting at Big Brown were larger in area, more recently disturbed, and had less silt in soils than unused potential sites. In 2002, 13 colonies were found around Texas on the Red River, reservoirs, and a gravel quarry. Big Brown colony sites were larger and farther from loafing sites, with more grasses present than other Texas sites. Big Brown colony sites also had less sand and gravel than other Texas sites. Big Brown and other Texas colony sites were both in very recently disturbed landscapes, with human disturbance of the landscape creating nesting habitat throughout the state.

Doctoral Dissertation
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THE SEMI-AQUATIC SNAKES OF A RECLAIMED SURFACE MINE: HABITAT UTILIZATION AND POPULATION BIOLOGY

Author: Michael B. Keck

The semi-aquatic snake population of a reclaimed surface mine in northeast Texas was studied throughout 1991 and 1992 at eight reclamation ponds and two pre-existing ponds. In descending order by abundance, the five species present were: *Nerodia rhombifer*, *N. erythrogaster*, *N. fasciata*, *Agkistrodon piscivorus*, and *Thamnophis proximus*. Neither the density of *N. erythrogaster* nor of *N. fasciata* were statistically different among the ponds. The densities of *N. rhombifer* and *A. piscivorus* were not uniform among the ponds; some ponds had significantly more captures of these species than others. The non-uniform abundance of snakes could not be explained by pond age, shoreline length, or shoreline vegetation. The two pre-existing ponds did not form a homogenous group that differed from the reclamation ponds in a quantifiable manner. Radiotelemetry revealed that *N. erythrogaster* may often utilize ephemeral streamlets between ponds.

Masters Thesis
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THERMAL AND SPATIAL ECOLOGY OF THE COTTONMOUTH, *AGKISTRODON PISCIVORUS*, AT A THERMALLY-ALTERED RESERVOIR IN EAST TEXAS

Author: Michael B. Keck

Three aspects of the biology of semi-aquatic snakes were studied at an eastern Texas reservoir, Lake Fairfield, that receives heated effluent from an industrial facility: (1) the extent of thermoregulation in *Agkistrodon piscivorus* (Viperidae); (2) the movements and total range of *A. piscivorus*; and (3) the abundance of *A. piscivorus* and *Nerodia rhombifer* (Colubridae) in thermally-altered areas of the reservoir compared to relatively unaltered areas.

Temperature has profound effects upon the physiology and ecology of reptiles. Yet the seemingly simple question "How carefully do reptiles regulate their body-temperature?" has not been addressed adequately. In the present study, the thermal ecology of a semi-aquatic snake, *A. piscivorus*, was studied to assess how carefully the species thermoregulates. Using radiotelemetry and an automated data-acquisition system, the laboratory-preferred (i.e., set-range) body temperature (T_b), field-active T_b , and range of possible field-active T_b s (i.e., operative temperatures) were examined during the late summer and early autumn (14 August to 20 September 1995). The field-active *A. piscivorus* maintained their T_b within their set-range, on average 82% of the time. They thermo-regulated more effectively than they could have by remaining above-ground in any terrestrial or aquatic habitat; they accomplished this by retreating underground during the hottest times of the day and by spending little time in the heated reservoir.

To monitor movements and total range, ten radiotagged *Agkistrodon piscivorus* (five males, five females) were tracked for period up to 14 months. Males moved 3.5 times farther between sightings and had total ranges that were 17.7 times larger than females. This intersexual difference likely was a result of mate-searching by males; however, the larger size of the males was a confounding factor.

To compare the abundance of snakes in heated versus relatively-unheated areas of the reservoir, snakes were trapped over a 4-year period. Water temperature explained the distribution of *N. rhombifer* C they were rare in the heated effluent C but not *A. piscivorus*. The more-terrestrial *A. piscivorus* appeared to be a habitat specialist, preferring a forested area. The results of this study indicate that semi-aquatic reptiles can be negatively affected by anthropogenic thermal alterations to the environment.

Doctoral Dissertation
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THE EFFECT OF COVER CROP AND FERTILIZER RATE ON THE GROWTH AND SURVIVAL OF LOBLOLLY PINE IN EAST TEXAS MINE SPOIL

Author: David Dwayne Kee

Two studies were initiated in August, 1978 at the Martin Lake lignite mine site in Panola County, Texas. The objective of these studies was to determine the effect of cover crop and N and P fertilizer rates, used to prevent soil erosion, on the survival and growth of loblolly pine planted in mine spoil. Coastal bermudagrass, fertilized with 0, 50 or 100 kg N/ha/year, was used in the N study. Dixie crimson clover, Yuchi arrowleaf clover, Mount Barker subterranean clover, Kobe lespedeza, crimson-lespedeza mix, subterranean-lespedeza mix, Gulf ryegrass, Gulf ryegrass + 100 kg N/ha/year, no cover and no cover + 100 kg N/ha/year, fertilized with 0, 25 or 50 kg P/ha, were evaluated in the P study.

Competition between cover crops and trees for light, water and nutrients influenced survival and growth of trees. Tree survival, after three years, was greatest in the subterranean clover (42%), Coastal bermudagrass + 50 kg N/ha/year (45%) and Coastal bermudagrass + 0 kg N/ha (39%) plots. The highly competitive crops, Coastal bermudagrass + 100 kg N/ha/year and arrowleaf clover, had the lowest tree survival (14% and 13%, respectively).

Mean tree height was greatest in those plots receiving applied N [ryegrass + 100 kg N/ha/year (108 cm) and no cover +100 kg N/ha/year (98 cm)] or N input from highly productive legumes such as arrowleaf clover (106 cm). These plots also had the lowest survival. Tree height was least in plots with the greatest heat and moisture stress [lespedeza (81 cm), ryegrass (81 cm) and crimson clover-lespedeza (80 cm)] in 1980 and 1981.

The regulations of the Texas Railroad Commission require a minimum of 1148 healthy trees/ha and 70% ground cover for successful reforestation of surface mineral sites. Subterranean clover + 50 kg P/ha met these requirements best with 1461 trees/ha and 91% ground cover after three years. Coastal + 50 kg N/ha/year had 1389 trees/ha and 100% ground cover. The moisture stress provided by Coastal, however, resulted in smaller and less vigorous trees.

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THERMAL STRESS EFFECTS ON THE ADENYLATE ENERGY CHARGE IN TILAPIA AUREA

Author: Kenneth Richard Kindle

Tilapia aurea (Steindachner) muscle tissue adenylate nucleotides and the adenylate energy charge (AEC) were monitored during laboratory induced hypoxia. Muscle and liver adenylates, AEC, plasma glucose, cortisol, and chloride were monitored during acute and chronic temperature stress.

ADP and AMP concentrations increase without a concomitant decrease in ATP in tilapia muscle tissue during hypoxia. This resulted in an increase in the total adenylate concentration and a significant drop in the AEC.

Muscle AEC is unaffected during acute cold water exposure but decreases significantly when tilapia are exposed to chronic, sublethal low temperature stress. The decrease in AEC is primarily the result of a decrease in ATP concentration.

Plasma glucose and cortisol increase when tilapia are exposed to 11-12^oC for 60 minutes, 11 days, and a 5-week period. Incomplete compensation is evident in 5 week-acclimated fish since glucose and cortisol levels are intermediate between controls and acutely stressed fish. Acclimation to 35^oC does not significantly affect plasma glucose and cortisol compared to controls (22^oC).

Plasma chloride is relatively unaffected by acute and chronic temperature stress. Apparently tilapia can effectively osmoregulate under a wide range of temperatures.

Liver tissue adenylates are not significantly affected when tilapia are subjected to a sudden drop in water temperature (22 to 11^oC). Liver tissue adenylate concentrations and AEC are lower than muscle.

AEC is a useful indicator of chronic temperature stress in Tilapia aurea. Plasma glucose and cortisol are useful indicators of acute and chronic temperature stress.

THE EFFECTS OF FLOODING REGIMES AND GREEN-TREE RESERVOIR MANAGEMENT ON SUCCESSION OF BOTTOMLAND HARDWOODS

Author: **Sammy Lee King**

I examined the effects of flooding regimes on bottomland hardwood (BLHW) succession by determining the effects of flooding on BLHW seed germinated, seedling growth and survival, and mature tree stress and survival in a series of greenhouse, field, and simulations modelling studies. In a greenhouse study, germination of stratified and non-stratified willow oak (*Quercus phellos*) acorns decreased following submergence for 90 d, whereas germination of the more water-tolerant overcup oak (*Q. lyrata*) peaked during this treatment.

Experimental studies on the effects of timing and duration of flooding on BLHW seedling growth and survival were conducted on Texas Utilities' Big Brown Mine in Fairfield, Texas. The order of survival within each of the three treatments was from the most to least water-tolerant species and was as follows: baldcypress (*Taxodium distichum*), overcup oak, Nuttall oak (*Q. texana*), willow oak, and Shumard oak (*Q. shumardii*). Baldcypress exhibited significantly ($P < .05$) greater growth than hardwoods in all three treatments.

Field studies conducted within two green-tree reservoirs (GTR) in east Texas indicated that overcup oak seedling establishment and survival was related negatively to duration of flooding. Stress and mortality of overstory trees differed inter- and intra-specifically. Temporal and spatial patterns of overstory mortality suggested mortality was a result of cumulative flooding events over a series of years rather than the amount of flooding in any single year. Stand-structure analyses indicated regeneration had been limited in both impoundments period.

A simulation model, GTREE, was constructed to evaluate the effects on seedling growth and survival of overcup oak, water elm (*Planera aquatica*), and willow oak. The number of seedlings reaching sapling height and the time needed to reach sapling height were dependent upon duration of time flooded during the growing season, the dormant-season flood depth, and light availability. Regeneration was limited as light availability or the duration of time flooded during the growing season approached an extreme for that species.

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**ASSESSMENT OF RADIO-TAGGED GRASS CARP
(CTENOPHARYNGODON IDELLA) DISPERSION, VEGETATION, AND
TEMPERATURE PREFERENCES IN NORTH LAKE RESERVOIR**

Author: Jason Lacewell

Twenty-nine (group One, June 8, 1995) grass carp (*Ctenopharyngodon idella*) and five (Group Two, April 18, 1996) grass carp were radio-tagged to monitor movement patterns and habitat preferences on North Lake, a 335 hectare multi-use reservoir located in Irving, Texas. Overall fish mean Average Daily Movement (ADM) rates were 49.2 meters/day (during Half One, 6/8/95-11/30/95) and 5.3 meters/day (during Half Two, 12/14/95-6/6/96). Aquatic macrophyte distribution data were obtained. Radio-tagged grass carp were located in *Hydrilla verticillata* infested areas increasingly throughout the study, however, percent frequency of *Hydrilla* along 15 transects did not decrease. Radio-transmitters were equipped with temperature-sensors (10-35E Celsius range). Results indicated that radio-tagged carp showed no avoidance of areas of North Lake with elevated water temperatures. Radio-tagged grass carp dispersed quickly from stocking point, then moved into littoral areas infested with *Hydrilla*. After an initial movement period, most fish remained in a localized area.

*Masters Thesis
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RELATION OF EOCENE DEPOSITIONAL ENVIRONMENTS TO SULFUR CONTENT AND QUALITY OF SURFACE WATERS AT LIGNITE STRIP MINES NEAR FAIRFIELD, TEXAS

Author: Robert Clark Lentz

Interpretation of facies exposed in highwalls in one of the two Big Brown lignite strip mines ("B Area") can be related to pyritic sulfur content. Acid mine waters due to oxidation of pyrite in spoil were not observed at Big Brown, although high sulfate concentrations were observed in "A Area" mine waters.

The Big Brown lignite deposit formed as a thick peat deposited in fresh-water swamps and marshes in an interlevee floodbasin between meanderbelts, low on the alluvial plain of the Mt. Pleasant Fluvial System in the Eocene Wilcox Group. Following deposition of the thick peat, two coarsening-upward facies sequences, fed by extended crevasse distributaries, initiated by overbank flooding and crevassing on trunk streams to the northeast and south, were deposited: (1) Swamp crevasse splay and distributary channel-fill, well-drained swamp, and poorly drained swamp facies form the lower sequence. (2) Lacustrine, lacustrine delta fill and distributary channel fill, and capping poorly drained swamp facies form the upper sequence.

Following burial of overburden sediments, low ferrous iron and sulfate concentrations in fresh ground waters may have been the principal factors limiting the formation of pyrite. Pyrite is concentrated in the lowest 2 centimeters of crevasse splay silty mud at the commercial lignite-sediment contact (0.68 - 3.92 percent pyritic sulfur by weight). Hydrogen sulfide was carried in ground waters from peats where organic compounds for sulfate-reducing bacterial metabolism were available, into adjacent sediments where reactive iron was present. The capping poorly drained swamp muddy lignite of the upper facies sequence contained abundant in-situ reactive iron, which resulted in high pyritic sulfur content (0.56 percent). Other facies in the two mine areas contain from 0.05 to 0.35 percent pyritic sulfur by weight. Pyrite content of overburden in the A Area is more than twice that of the B Area.

Oxidation of pyrite accounts for abnormally high sulfate concentrations (775 - 1795 mg/l) observed in A Area mine waters. These waters were obtained in springs that issue from perched ground water in reclaimed and unreclaimed spoil. Ground waters issuing from the spoil during winter, 1974-75, may be nearly saturated with gypsum, suggesting that the waters may redissolve soluble sulfate compounds formed in part during hot, low rainfall summer months, by

evaporation of ground waters within the spoil. Downstream, high sulfate surface waters are rapidly diluted. Small volumes of highly mineralized ground water in the spoil may recharge the Wilcox aquifer, but would probably significantly affect water quality only in shallow Wilcox water wells in the immediate vicinity of strip mines.

ROW SEEDING OF FOREST TREE SPECIES ON LIGNITE SPOILS IN EAST TEXAS

Author: Catherine Lundee Mask

Two study sites were delineated on freshly graded spoil material for row seeding trials. Spoil material was also moved to the greenhouse for pot experiments. One-half of each study site and one-half of the pots were mulched with hay which was mechanically tacked to the spoil.

Six tree species were chosen for seeding: Shumard oak, green ash, loblolly pine, shortleaf pine, sweetgum and autumn olive. All planting was done by hand.

Autumn olive did not emerge and was, therefore, disregarded in analysis. Loblolly pine, shortleaf pine and sweetgum seed were washed from the study areas in heavy spring rains. Thus, emergence of these species was minimal. Emergence of green ash was adequate, but herbaceous competition introduced in the hay mulch had detrimental effects on its survival and height growth. Shumard oak did well in all aspects: emergence and survival were high and vegetative competition did not adversely affect its development. This species alone appears, according to this study, to have potential for row seeding surface-mine spoil.

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ALTERATION OF EXCHANGEABLE CATION DISTRIBUTION AND ASSOCIATED CHEMICAL CHANGES IN ACIDIFYING SURFACE MINED SOILS

Author: Dennis Lee McCallister

Two mining areas of different ages, one area mined in 1972 and the other in 1977, were sampled in June and July of 1978. Twenty-five 100 cm cores were taken from each area and subdivided into 10 cm segments. Material from each segment was analyzed for pH, $\text{SO}_4\text{-S}$, and total-S, while half the total of samples from each core were analyzed for CEC, base saturation percentage, and water extractable cations.

General trends show lower pH, base saturation, and total-S in the 1972 minesoil, as well as higher $\text{SO}_4\text{-S}$ and water extractable cations. The variability of the data is extremely high as indicated by the coefficients of variability (CV), greater than 200% for some of the sulfur data. The effectiveness of the regression equations calculated to describe changes with depth and age is reduced by this variability, but the equations still suggest the presence of a weathered zone to the 20 cm depth in the 1977 minesoil.

Calculations of the minimum sampling density required to estimate the property means range from a low of 35 samples per mining area to estimate pH within ± 0.5 units to over 400 samples to estimate $\text{SO}_4\text{-S}$ within ± 100 ug/g soil.

A subsequent laboratory study involved two artificial minesoils composed of geologic materials from an area undergoing mining. This study had the principal objective of measuring changes in exchangeable cation distribution on the two artificial minesoil mixes as a function of applied acidity level, time of application, and temperature. The mixes were saturated with Na and Ca prior to acidification resulting in an approximately 1:1 distribution (equivalent basis) on the exchange sites.

Essentially all of the chemical changes measured are complete after an elapsed time of 6 days, some within 1 day. Statistical analyses generally showed significant differences due to all main effects except temperature. Values for pH, exchangeable Na and Ca, and water extractable Na and Ca are most influenced by the strongest acid treatment, whereas the effects of the two less concentrated treatments are low and nearly indistinguishable from each other. Nevertheless, the relatively small loss of exchangeable Ca, even in the most concentrated acid treatment, indicates that the base saturation of highly Ca saturated minesoils such as those at the mine site would not change greatly except under extreme acidification.

More Al was released from the oxidized mix, possibly from solubilization of Al coatings. Release of Mg and Al from both mixes indicates mineral decomposition due to acid attack. The general decrease in the ratio of the 18 Å (smectite) to 7.2 Å (kaolinite) peak heights suggests a loss of smectite minerals compared with kaolinite.

**INTERACTIONS BETWEEN THE INVASIVE FRESHWATER CLAM,
CORBICULA FLUMINEA, AND ITS FISH PREDATORS IN
LAKE FAIRFIELD, TEXAS**

Author: Ellen Joy McCrady

The effects of fish predation on *Corbicula fluminea* are explored in this research. The overall effect of fish predation is significant. The effects of predation and total clam abundance vary with time. Simulated water drawdown experiments indicate that *Corbicula* mortality would be great with a decrease in lake level and subsequent aerial exposure. Both biotic and abiotic factors are demonstrated to impact *Corbicula* population density.

Shells or shell fragments were found in the guts of two fish species. These species also ate *Corbicula* in laboratory trials. There appears to be an upper limit on the size clam that each fish will eat. Burrowing by clams reduced the number eaten by longear sunfish. A combination of increased resistance to crushing through an ontogenetic shift in shell morphology and a tendency for the more vulnerable sizes to initiate burrowing more rapidly constitute predator avoidance tactics for these clams.

*Masters Thesis
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**EFFECTS OF STOCK TYPE, FALL NURSERY FERTILIZATION AND
ECTOMYCORRHIZAL INOCULATION ON SURVIVAL OF LONGLEAF PINE
(*PINUS PALUSTRIS* MIL.) SEEDLINGS PLANTED ON LIGNITE MINESPOIL**

Author: Mary Anne McGuire

Longleaf pine (*Pinus palustris* Mill.) seedlings were planted on lignite minespoil in east Texas in 1996 and 1997. Effects of stock type, fall nursery fertilization, and ectomycorrhizal inoculation on seedling morphology, ultrastructure, mineral nutrition, physiology, and survival were assessed.

Stock type differences in root collar diameter, root weight, shoot weight, total weight, and root shoot ratio were significant. Fertilizer treatments had no significant effect on seedling morphology. No ultrastructural differences in seedling needles were evident between fertilized and control seedlings. Macronutrient and micronutrient concentrations were significantly affected by stock type and fertilizer treatments.

Root growth potential was significantly greater for container seedlings than bareroot. Water potential, leaf conductance, and transpiration tended to be greater for container seedlings and differences were significant during some measurement periods. Fertilizer treatments had no significant effects on physiological variables.

Container seedlings survived significantly better than bareroot in both years. In 1997, container seedlings grown at greenhouse facilities at Stephen F. Austin State University survived better than commercially-grown container seedlings. Based on this study, it appears that successful regeneration of longleaf pine on lignite minespoil sites can be accomplished more reliably with container seedlings than with bareroot.

ESTABLISHMENT OF WETLAND VEGETATION OF EAST TEXAS MINE SPOIL

Author: Steven Keith McKnight

Methods of establishing wetland vegetation on lignite mine spoil were studied at Big Brown Mine in northeast Texas from March 1989 to November 1990. Barnyard grass (*Echinochloa crusgalli* var. *crusgalli*), Japanese millet (*Echinochloa crusgalli* var. *frumentaceae*), and smartweed (*Polygonum punctatum*) seeds, and chufa (*Cyperus esculentus*) and arrowhead (*Sagittaria latifolia*) tubers were subjected to 4 water regimes (spring drawdown, spring flooding, fall drawdown, fall flooding). Spring drawdown was the only water regime to which all species responded. Barnyard grass produced the most ($P<0.05$) above-ground biomass, while Japanese millet produced the most ($P<0.05$) seed biomass in this water regime. Arrowhead grew under all water regimes except fall drawdown. In the remaining 3 water regimes, total tuber biomass did not differ ($P>0.05$), while tuber number was greatest ($P<0.05$) in spring drawdown. Chufa produced no seed biomass and little above-ground biomass.

Seed bank samples were collected from a shallow, reclaimed, 13-yr old, sedimentation pond (source pond), in November 1989 and subjected to 4 water regimes (unflooded, April drawdown, June drawdown, August drawdown). Nineteen species were common to both source pond point-intercept transects (24 species) and seed bank plots (41 species). April drawdown produced the greatest species richness, stem density ($P<0.05$), and above-ground biomass ($P<0.05$). June and August drawdowns produced the lowest species richness and above-ground biomass ($P<0.05$), while June drawdown produced the lowest ($P<0.05$) stem density. Mean soil moisture (percent of dry weight), differed ($P<0.05$) in all water regimes. Mean soil moisture/stem density relationships were found in only 15 of 39 taxa ($r^2= 0.08-0.36$). Muskgrass (*Chara sp.*), pondweed (*Potamogeton pusillus*), and southern naiad (*Najas guadalupensis*) grew in June and August drawdown plots prior to drawdown, with total submergent biomass greatest ($P<0.05$) in August drawdown plots. Disturbed source pond strips had 66.0% ground cover 6 months after disturbance (seed bank soil collection) compared to 96.3% in undisturbed areas.

Results of this study suggest that a combination of transplanted wetland soil and artificial planting in spring would satisfy reclamation regulations and provide a diverse wetland plant community capable of supporting waterfowl and other wildlife.

Master's Thesis
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HARVEST OF BLUE TILAPIA (TILAPIA AUREA) FROM A POWER PLANT COOLING LAKE

Author: Robert Andrew Mecum

Lake Fairfield, a 1,053 acre reservoir in north central Texas, was sampled from July 1982 through June 1983, to determine the efficiency of tilapia harvest by fyke net, gill net, and seine, considering size and condition of fish, and the relative vulnerability of tilapia compared to other species; and to determine when, where, and under which hydrological conditions tilapia are most likely to be captured.

Tilapia harvest efficiency by gill net was highest, followed by fyke net, and seine. Those caught by fyke net were relatively shorter, on average, than those gill netted or seined. Tilapia mean length and condition factor differences among sites didn't appear to be temperature-related. Condition factor values were significantly higher ($P \leq 0.0010$) from October through March than from May through September, excepting the December-May comparison.

Tilapia comprised from 24 to 48% of the catch by gill net. The percent catch of tilapia by fyke net was highest (74%) nearest the thermal effluent discharge into the warmest part of the lake, and progressively lower at sites further from the discharge, to as low as 29%. Seine percent catch of tilapia at sites 1 and 2 was 4% and 8%, respectively.

More tilapia were caught per man-hour, on average, by fyke net than by gill net or seine. Gill nets injured fish more than the other gears.

IMPACTS OF FERAL HOGS ON RECLAIMED SURFACE-MINED LANDS IN EASTERN TEXAS: A MANAGEMENT PERSPECTIVE

Author: Robert C. Mersinger

During the last decade, surface lignite mines in eastern Texas have experienced damage to reclaimed lands by feral hogs (*Sus scrofa*). Specifically, feral hogs have caused damage to vegetative plantings used in the reclamation process of surface lignite mines. In addition to vegetative losses, erosion control problems and water quality impacts have been noted. Box and corral traps were evaluated for their effectiveness in capturing feral hogs. Six male and 10 female hogs were radiomonitored from January 1998 - January 1999 at Big Brown Lignite Mine in Freestone County, Texas. Annual range size, habitat use, habitat selection, and diel movements of the feral hogs were determined using a geographic information system. Corral traps were more efficient than box traps in capturing feral hogs ($P < 0.000$). Male feral hogs had a mean annual range of 15.8 km². Female hogs had a significantly ($P < 0.02$) smaller annual range of 6.5 km². Hogs preferred reclaimed wildlife vegetation plantings and unmined riparian corridors on the mine site. Screening cover and free water were important landscape features that influenced hog movements. Feral hogs moved greater distances from free water and screening cover during nighttime hours. In addition, seasonal effects of distance from these landscape features were significant. Feral hogs traveled greater distances from both free water and screening during winter and spring, but during fall and summer months, they remained closer ($P < 0.0001$) to water and cover sources. Based on the information obtained from the data analysis, management strategies for reducing hog impacts at the mine site were developed. In order to decrease feral hog impacts on the mine site, use of corral traps, box traps, and vegetation management was recommended.

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THE INFLUENCE OF STAND DENSITY ON RATE OF CARBON SEQUESTRATION IN LOBLOLLY PINE PLANTATIONS ON MINED LANDS IN EAST TEXAS

Author: Jason D. Morton

The State of Texas emits more carbon dioxide (CO₂) into the atmosphere than any other state in the United States. With environmental concerns escalating, the U.S. may be forced to reduce its emissions of greenhouse gases. The first target of these reductions will likely be utility companies that utilize coal-fired power plants. In order to mitigate CO₂ emissions, utility companies may want to either purchase carbon credits which can be obtained through carbon sequestration on NIPF lands or manage reclaimed mined lands for maximum carbon sequestration. This study determined the financially optimal planting density and management regimes for loblolly pine (*Pinus taeda*) planted on reclaimed mined lands and NIPF lands in East Texas given the objectives of maximizing revenue from timber production and the combination of timber production and carbon sequestration. PTAEDA2, a forest stand growth simulator, was used to predict growth and yield from establishment to final harvest. Dynamic computer programming was used to perform economic analyses given current stumpage prices, management costs, and real price and cost increases. Other inputs used include planting densities 5x10, 6x10, 7x10, and 8x10 feet, site indices 50 - 90, either 0, 1, or 2 thinnings, thinning intensities of 20, 25, 30, or 35 percent of basal area removed, carbon values per ton of \$0, \$10, \$50, and \$100, and rotations of up to 60 years in length. A total of 14,084,256 operable thinning and harvest schedules were calculated for real alternative rates of return (ARR) of 2.5 to 15.0 percent. Soil expectation values (SEV) were used to select financially optimal schedules. Results indicate that when the value per ton of carbon is \$0, the 8x10 planting density provides the greatest financial returns. As the price per ton of carbon increases, the soil expectation value is maximized by utilizing higher planting densities.

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EVALUATION OF MICROBIAL POPULATIONS, RHIZOBIUM TRIFOLII AND ENDOMYCORRHIZAL ASSOCIATIONS IN RECLAMATION OF SURFACE MINE SPOILS IN TEXAS

Author: Joanna Bridget Mott

The deficiency of nitrogen and phosphorus in mixed overburden mine spoils has resulted in interest in strategies to minimize fertilizer application. In this study, the abundance of microbial populations, with emphasis on those involved in nitrogen cycle transformations was estimated in variously aged spoils. Two beneficial plant-microbe associations, the clover-Rhizobium trifolii symbiosis and endomycorrhizal associations, were investigated in field and laboratory studies.

While most groups of microorganisms regained pre-mining levels in revegetated spoils within 1.5 years after disturbance, algal populations were still reduced ten years after mining. Populations of nitrifying bacteria and a symbiotic nitrogen-fixing bacteria were as high in all spoils as in unmined soil. Microbial populations in recently levelled spoil did not show the usual decline with depth down to 90 cm.

Indigenous populations of ineffective R. trifolii were present in spoil banks and older revegetated spoil. Introduced R. trifolii strains established in spoil, nodulated subterranean and arrowleaf clovers and fixed nitrogen (acetylene reduction). Populations of Rhizobium increased during the clover growing season, and although numbers declined during summer months, they were sufficient to nodulate plants the following season. A laboratory study of survival of three commercial strains of R. trifolii for subterranean clover showed lethal effects of high temperature (45°C) especially in moist spoil, and superior survival of strain 162x95.

Endomycorrhizal associations, evaluated by assessment of root infection in bermudagrass, reached pre-mining levels by three to seven years after disturbance. Production of spores by endomycorrhizal fungi, however, was greatly reduced in all spoils.

Growth chamber studies to investigate the effects of the two symbiotic associations on subterranean clover in mine spoil at different fertility levels indicated that dual infection with Rhizobium and VAM fungi was most beneficial for plant growth, nitrogen fixation, and nitrogen and phosphorus contents. Dually infected plants grown at lower fertility levels produced as much dry matter as uninoculated plants grown at higher fertility levels. Neither symbiotic association was inhibited by the addition of 57 kg N, 25 kg P/ha and only the endomycorrhizal association was inhibited by addition of 114 kg N, and 50 kg P/ha.

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SURVIVAL OF LONGLEAF PINE (*Pinus palustris* Mill.) ON MINE RECLAMATION SITES USING DIFFERENT REGENERATION METHODS

Author: Janet R. Musgraves

Three sites were chosen to study longleaf pine regeneration on lignite minespoils in east Texas. Two different minespoils were chosen, along with an unmined site, which served as a comparison.

Three types of planting treatments were studied: direct seeding, planting bareroot stock, and planting container stock. Direct seeding was unsuccessful, and therefore, was not included in analysis.

Survival rates of longleaf pine were analyzed using planting treatment, spoil type, and length of time seedlings were planted as factors of measurement.

Results indicated no significant difference in survival between bareroot and container stock. Seedling survival on the two minespoil sites were not significantly different. However, seedling survival was significantly lower for both minespoil sites when compared to the unmined site.

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DYNAMICS OF LITTER AND SOIL MICROARTHROPOD COMMUNITIES DURING THE RECLAMATION PROCESS

Author: John Peter Nelson, Jr.

Effects of mining and time since reclamation on soil microarthropod communities were examined. Five study sites were utilized: an unmined site, an old site (reclaimed 1977), two intermediate age sites (reclaimed 1981 with different vegetation), and a new site (reclaimed 1987). Each site was divided into 100 subplots (2 by 5 m) of which six were randomly sampled (soil cores) monthly throughout 1988. In total 360 subplots were sampled and 3911 microarthropods (89% mites and collembolans) were collected.

Statistical analyses revealed significant effects of both month and site on total mites, total collembola, and total organisms. Interactions of month by site were significant for collembola and total organisms. Shannon-Weiner diversity indices increased with the time since reclamation and were maximal for the unmined site. Microarthropod communities of reclaimed sites differed from unmined sites, and reclaimed sites showed some recovery over time. Reclamation vegetation did not affect soil microarthropod communities.

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**SOME EFFECTS OF THERMAL EFFLUENTS ON
THE SECONDARY PRODUCTIVITY OF BENTHIC
MACROINVERTEBRATES OF FAIRFIELD RESERVOIR**

Author: Robert Paul Oliphint

A study of the littoral benthic macroinvertebrate community was undertaken on Fairfield Reservoir, Texas, to determine some of the effects thermal effluents from a steam electric generating station have on the secondary productivity of the benthic community. Benthic samples were collected monthly from June, 1976 through May, 1977 at five stations using an Ekman dredge and Hester-Dendy multiple plate hardboard samplers. Differential counts and drained wet-weight biomass were determined for all samples.

Thermal effluents adversely effected productivity, standing crop, density, and diversity during the summer months. Cessation of the thermal discharge during the winter months adversely effected productivity.

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A SURVEY OF THE VERTEBRATE FAUNA OF THE MONTICELLO LIGNITE MINING AREA, TITUS COUNTY, TEXAS

Author: Stephen Donlee Parris

Purpose: The purpose of this study was to determine species composition, distribution and relative abundance of vertebrates on the Monticello Lignite Mining Area, Titus County, Texas, before mining operations destroyed the habitat.

Procedure: A variety of standardized techniques were used for the observation, identification and capture of vertebrates. In addition, several quantitative techniques were used to classify the plant communities of the area.

Findings: Six different plant communities were recognized. Natural, complex communities (two types of upland forests, riparian forests and old fields) had diverse vertebrate faunas. Simplistic agrarian communities were characterized by a scarcity in kind and number of vertebrates.

Conclusions: Land reclamation practices will probably favor simplistic, agrarian communities. Recommendations for reclamation were made that would favor ecological diversity.

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DISTRIBUTION OF MERCURY IN AN EAST TEXAS LIGNITE SEAM

Author: Jason C. Paul

The focus of this study was to determine the viability of selectively mining low-Hg coal based upon mercury (Hg) distribution from within a lignite seam. This study was part of a large research effort investigating maximum attainable control technologies to be potentially implemented by power plants in order to meet near-future mandates imposed by the Clean Air Mercury Rule. Understanding the distribution of Hg throughout a coal seam is important for coal burning electrical utilities in evaluating Hg emission reduction technologies and practices. This research measured Hg concentrations in three detailed (0.10 ft. segments) and 28 regular lignite cores (sectioning based on visual mineral/lithotype content changes). ASTM Method 6414-01 was modified for a Perkin Elmer AAnalyst 700 Spectrophotometer with FIAS 100 (flow injection analysis system) to optimize instrumental sensitivity, accuracy, and precision when measuring mercury in lignite coal. Upon analysis of the lignite seam, there was no correlation of Hg concentrations with depth in any of the collected cores. Differences of over 100 $\mu\text{g}/\text{kg}$ were commonly observed in adjacent sections within detailed cores. Geospatial analysis of Hg distribution within the coal seam further illustrated heterogeneity found throughout the mining area. Comparative analyses of pyritic sulfur, total organic content (TOC), and mercury in ash were also conducted. Multiple linear regression indicates that pyrite and TOC influence the distribution of mercury. Mercury in ash was not correlated to mercury in the lignite samples, likely due to volatilization of elemental mercury during the ashing process. Additional data provided by a parallel study of the mining site performed by TXU also indicates that mercury is bound to organic sulfur. It is concluded that selective mining is not a viable option for mercury reduction in this east Texas seam. Therefore, other mercury reduction alternatives are discussed for controlling mercury emissions. These alternatives consider mercury volatility during combustion in coal-fired power plants.

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FUNCTIONAL AND TAXONOMIC DIVERSITY OF MICROBIAL COMMUNITIES IN RECLAIMED EAST TEXAS LIGNITE MINE SOILS

Author: Allen Edward Peach

A two-year study was conducted at Big Brown lignite mine in Freestone County, Texas, to determine the influence of surface mining and reclamation on the functional and taxonomic diversity in soil microbial communities. Quarterly soil samples were collected along a chronosequence including sites of 0, 1, 4, 12, and 28 years following mining and reclamation. In addition to these sites, an unmined reference site, and a tree mott (reclamation age of 20 years) were included in the study. The functional diversity of the microbial communities was assessed using the Biolog sole-carbon source utilization (SCSU) assay. Taxonomic diversity was measured using whole-soil fatty acid methyl ester (FAME) analysis. Results indicated that surface mining had a transient influence on both the functional and taxonomic diversity of the soil microbial communities reducing complexity during disturbance and early reclamation. However, the effect was reversed as the reclamation process matured. Principal component analysis (PCA) was able to separate the younger sites from the older sites in both the SCSU profiles and the FAME profiles of the soils. The separation of sites was greater, however, in the analysis of the FAME profiles suggesting a more significant change in the level of taxonomic diversity. Results from the SCSU analysis revealed a return to similarity with the reference site between one and four years. Fatty acid methyl ester profiles indicated a return to similarity with the reference site in approximately 12 years.

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SEASONAL DISTRIBUTION OF HYBRID STRIPED BASS IN A POWER PLANT COOLING RESERVOIR AND A COMPARISON TO RED DRUM

Author: Kevin Ray Piner

Palmetto bass (Morone saxatilis × M. chrysops) are the most commonly stocked hybrid striped bass in Texas. Twenty-four palmetto bass and four red drum (Sciaenops ocellatus) were monitored in 1990-1991 using ultrasonic biotelemetry in Lake Fairfield, Texas. Habitat, water temperature and dissolved oxygen level occupied were recorded for each fish located. Palmetto bass avoided heavily structured habitats, but showed a near-random distribution in non-structured habitats. Palmetto bass avoided the southern end of the reservoir throughout the entire study. Palmetto bass tolerated water temperatures above 32 C in summer to remain in water with dissolved oxygen concentrations above 4-5 mg/l. Water temperatures were important in determining palmetto bass horizontal distribution. Dissolved oxygen was more important than water temperature in determining vertical distribution of palmetto bass in the water column. Red drum seasonal distribution and habitat use were used to verify a larger 1989 red drum study. Habitat overlap between palmetto bass from the 1991 study and red drum from the 1989 study was significant in all seasons. Due to seasonal crowding in northern reservoir areas, realized habitat overlap was greatest during summer.

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NICKEL, CADMIUM AND SELENIUM LEVELS IN NATIVE SOIL, OVERBURDEN AND SPOIL MATERIALS

Author: John Lee Pitt

Overburden samples from the high wall were taken from the Big Brown mining site near Fairfield, Texas to evaluate the use of HNO_3 - HCl , HNO_3 - HC10_4 - HC10_4 DTPA-TEA and HNO_3 - HC10_4 -HF digestion mixtures in the analysis of cadmium (Cd), nickel (Ni) and selenium (Se) for applications to overburden and spoil materials. The HNO_3 - HC10_4 -HF digestion mixture was selected, because it showed excellent accuracy and precision and was the only mixture which resulted in complete dissolution of the samples. Conventional atomic absorption spectrometry (AAS) was selected for Cd and Ni analyses. Hydride generation atomic absorption was selected for the Se determinations.

The selected methods were applied to native soil, overburden core and spoil materials obtained from four surface mining operations. In general, native soil, overburden core and spoil concentrations of Ni, Cd and Se were not significantly different. Actual individual concentrations of the native soil, overburden and spoil samples ranged from 0.00 to 2.46 ppm Cd, 4.01 to 71.4 ppm Ni and 0.04 and 10.7 ppm Se.

Strong positive correlations were observed between Cd and Ni, Cd, Ni and Se with clay, and Se with total S. Cadmium and Ni concentrations decreased with depth. There was no significant relationship of Cd, Ni or Se with PH in general, but there was with the electrical conductivity.

The levels of Cd, Ni and Se were significantly different over the different geological environments of deposition. Environments with slow deposition of fine materials (backswamp, flood basin, etc.) had the highest concentrations of Cd and Ni, Selenium was highest in the lignite and deposits closely associated with the lignite.

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THE EFFECTS OF FISH DENSITY ON WADING BIRD USE OF SEDIMENT PONDS ON AN EAST TEXAS COAL MINE

Author: Donna Hubbard Renfrow

Wading bird use of sediment ponds was studied on the Big Brown Mine, located near Fairfield, Texas, from April to October of 1992. Five species of wading birds were seen regularly on ponds: Great Blue Heron (*Ardea herodias*), Great Egret (*Casmerodius albus*), Little Blue Heron (*Egretta caerulea*), Snowy Egret (*Egretta thula*), and Green-backed Heron (*butorides virescens*). Bird surveys were conducted 2-3 times per week; species and number of birds present on each pond were recorded. Eighteen habitat characteristics were determined for 32 ponds. No differences in bird use ($P \geq 0.25$) were found due to mining or grazing history of ponds. Of 16 characteristics used in multiple regression models, shoreline length and the number of perching sites over water were most related to bird use of ponds. Potential disturbances associated with mining activity did not appear to influence bird use of the study area, although they may have had a short-term effect on individual pond use. A group of nine ponds was chosen for an intensive investigation of the effects of fish density on wading bird use of ponds. Experimental design consisted of three treatments: a control and two experimental treatments of different fish density (low density, 57 kg/ha and high density, 227 kb/ka) with three ponds assigned to each treatment. The six experimental treatment ponds were cleared of fish by the application of 4 ppm rotenone and stocked with 75 mm golden shiners (*Notemigonus crysoleucas*). Through incomplete kill or re-invasion, experimental treatment ponds had multi-species fish assemblages suggest that bird use was affected by a combination of fish density and fish size.

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WATERFOWL USE OF SEDIMENT PONDS ON AN EAST TEXAS COAL MINE

Author: Larry Anthony Reynolds

Use of sediment ponds by nonbreeding waterfowl was studied on Big Brown Mine in east-central Texas during fall, winter, and early spring of 1986-87 (Year 1) and 1987-88 (Year 2). A total of 41,637 waterfowl of 21 species was seen during 25 surveys in Year 1, and 30,063 individuals of 18 species were seen on 25 surveys in Year 2. Gadwalls (*Anas strepera*), mallards (*Anas platyrhynchos*), ring-necked ducks (*Aythya collaris*), green-winged teal (*Anas crecca*), and American wigeon (*Anas americana*) accounted for 80% and 77% of the total in years 1 and 2, respectively. Over 95% of ducks were seen on sediment ponds; the remainder was seen on natural wetlands. Mallards made up 70% of ducks using natural wetlands. Fall migrants arrived in mid-November and relatively stable winter populations were maintained until mid-February, when birds began leaving the area. Blue-winged teal were fall and spring migrants but all other species wintered on the area. Waterfowl were less abundant ($P < 0.001$) in Year 2. Submergent vegetation was the primary food resource in sediment ponds and was more abundant ($P < 0.0001$) in high-use than low-use ponds. Declines in number of gadwalls, ring-necked ducks, and American coots (*Fulica americana*) suggest this resource was less abundant and/or less available in Year 2. Waterfowl use and species richness increased with pond age and surface area, but no differences ($P > 0.15$) due to grazing or mining history were found. Of 8 pond characteristics measured on all surveyed ponds in Year 2, shoreline length and submergent vegetation most influenced waterfowl use and species richness. Nonpersistent emergents, pond area with <1 m water depth, light transmission, and shoreline slope, as well as submergents, were correlated ($P < 0.05$) with waterfowl use and species richness on 15 ponds selected from high-, medium, and low-use classes. Findings from this study suggest that high quality wetland habitat can be created from mining and reclamation in this region.

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ABSORPTION OF CHLORINE AND MERCURY IN SULFITE SOLUTIONS

Author: Sharmistha Roy

The rate of chlorine absorption into aqueous sulfite/bisulfite, S(IV), was measured using a stirred cell reactor and a wetted wall column. Simultaneous absorption of Hg and Cl₂ in S(IV) solutions was also measured in the wetted wall column. The solution contained 0 to 10 mM S(IV) with pH ranging from 4.5 to 6. Experiments were performed at ambient temperature and pressure using 5 to 300 ppm Cl₂ and 46 ppb Hg. Absorption was modeled using the theory of mass transfer with chemical reaction. The rate constants for the Cl₂/S(IV) and Hg/Cl₂ reactions were determined to be 1.1×10^9 and 6.1×10^9 L/mol-s, respectively.

At the gas/liquid interface, chlorine reacts with S(IV) to form chloride and sulfate, and Hg is oxidized by Cl₂ to a more soluble form of Hg. The enhancement of the chlorine hydrolysis rate by the succinate buffer was quantified. Oxidants, such as HgCl₂ and NaOCl, enhances Hg absorption. The addition of chloride had no effect on the Hg/Cl₂/S(IV) reaction rates. However, chloride did suppress chlorine hydrolysis and significantly enhanced Hg absorption with Cl₂, when no S(IV) was present. Possible reaction pathways are discussed.

These results are relevant in the simultaneous removal of Cl₂, SO₂, and Hg from flue gas. A model was developed to predict the expected Hg removal in a limestone slurry scrubber. Mercury removal decreases with increasing SO₂/S(IV). However, with low S(IV), the Cl₂ exiting the scrubber is greater. Thus, the process feasibility depends on the amount Hg and Cl₂ which can be tolerated.

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THE EFFECTS OF THERMAL EFFLUENTS OF PHYTOPLANKTON PRODUCTIVITY IN FAIRFIELD RESERVOIR, TEXAS

Author: Kevin Clark Rudy

Phytoplankton productivity measurements were made along a thermal gradient in Fairfield Reservoir every two weeks to determine what effects, if any, the Big Brown Steam Electric Station had on the productivity. In Addition, tests for ten physical and chemical parameters were run to assess their influence, if any, upon the productivity.

Increased temperature was found to generally enhance phytoplankton productivity, with inhibition occurring at one station and only during the summer. Other physical and chemical parameters affected the productivity to a lesser degree, with a high degree of uniformity between stations for a particular parameter on a given sampling date.

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**THE EFFECTS OF NITROGEN AND PHOSPHORUS FERTILIZER
ON A YOUNG LOBLOLLY PINE PLANTATION
ON LIGNITE MINE SPOIL IN EAST TEXAS**

Author: Martin Andrew Shupe

Five levels of nitrogen fertilizer combined with three levels of phosphorus fertilizer were tested in a two year-old loblolly pine plantation on a lignite mine spoil in East Texas. Growth parameters, foliar and spoil nitrogen and phosphorus concentrations were measured after two growing seasons.

Nitrogen increased diameter growth during the first year, and foliar nitrogen increased with increasing fertilizer rates for both years. Phosphorus increased height during the first year and over both years combined and also increased diameter during the second year and over both years combined. Foliar phosphorus was increased by nitrogen in the first year. Spoil phosphorus was increased by phosphorus fertilization in both years. Spoil nitrogen was not increased by the fertilizer in either year. Attempts to correlate Munsell colors to foliar contents failed.

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SOD-SEEDING TO MODIFY COASTAL BERMUDAGRASS ON RECLAIMED LIGNITE OVERBURDEN IN TEXAS

Author: Jeffrey Grant Skousen

Introducing low-maintenance, perennial, plant species into grass pastures by sod-seeding has been identified as a method for improving forage quality and quantity with fewer cultural inputs, and for providing other plant species for alternate uses of the pasture. This study was conducted to investigate the ability of nine low-maintenance species to establish and persist with Coastal bermudagrass (*Cynodon dactylon* (L.) Pers.) established on reclaimed lignite overburden; to evaluate the establishment and persistence of seventeen low-maintenance species seeded in overburden with no vegetation cover; and to examine seeding mixtures and rates for establishing low-maintenance species into three cover types (bermudagrass, oats (*Avena fatua* L.), and no cover).

Glyphosate herbicide applied in 25-cm bands was necessary for first-year establishment of sod-seeded forbs in Coastal bermudagrass. Herbicide increased light penetration to seeded species, but was also helpful in temporarily suppressing the bermudagrass. Sod-seeding into an older sward of Coastal bermudagrass showed greater densities of seeded species than a younger sward because the lower amounts of biomass in the older sod provided more light and less competition to the seeded species. Fertilization, even at low rates, generally decreased establishment of sod-seeded species. Persistence of the seeded forbs in bermudagrass was related to growth habits (aboveground and below ground) and regenerative strategies which helped them avoid and reduce competitive interactions with Coastal bermudagrass. Strategies displayed by these species were early spring growth, extensive taproot systems, persistent rhizomes, and tall, upright growth forms.

Seventeen low-maintenance species established and persisted in overburden without fertilization during years of low precipitation. Several seeded grasses showed sufficient stand development in monoculture for erosion control. Most of the other seeded species were slower in establishment, yet persisted on the site and provided some productivity. The species showed satisfactory height, cover, and food potential for wildlife, and promoted multiple use of the reclaimed area.

Recommended seeding rates were generally adequate for seedling establishment in oat, bermudagrass, and no vegetation cover types. Sod-seeding into bermudagrass resulted in higher seedling densities than those in oats and no cover, and was apparently due to stored moisture beneath the sod during bermudagrass dormancy.

Using ¹⁵N-Labelled fertilizer, Coastal bermudagrass demonstrated the ability to rapidly recover applied N. Maximilian sunflower (Helianthus maximiliani Schrad.) was suppressed by Coastal bermudagrass in mixture at all fertilizer N rates during the sunflower's establishment phase.

BEHAVIOR OF INTRODUCED RED DRUM AND HABITAT-USE OVERLAP WITH LARGEMOUTH BASS IN A POWER-PLANT COOLING RESERVOIR

Author: Robert Clayton Smith

The introduction of a non-native species into an aquatic community is a fisheries management practice that has caused considerable debate due to concern over possible effects of interspecific competition upon resident fish populations. The recent introduction of red drum Sciaenops ocellatus into a Texas reservoir provided an opportunity to observe this euryhaline species' behavior in a freshwater system, as well as to evaluate the potential for post-stocking interspecific competition between an introduced predator and a resident predator, in this case largemouth bass Micropterus salmoides. Habitat use, temperatures occupied, and seasonal distribution of red drum and habitat-use overlap with largemouth bass were ascertained in lake Fairfield, Texas, using ultrasonic telemetry. Habitat-use overlap between the species was evaluated seasonally to determine if the potential for interspecific competition existed after the initial effects of introduction were established. Habitat use by each species varied seasonally, but tagged largemouth bass preferred the shoreline, cove, and intake canal habitats overall; utilization of open water by this species was far below expectation based upon availability. Tagged red drum preferred open water habitat throughout the study and the effluent cove during autumn and winter seasons; other habitats were used less than expected. Habitat-use overlap between the two species was minimal with the greatest overlap occurring during the winter, but overlap was probably not extensive enough to contribute to significant competitive interaction between the species. Red drum distribution varied in range and proximity to the effluent discharge with season. Red drum tended to avoid the hot-water effluent during the spring and summer; during late autumn and winter, the red drum were more closely associated with the effluent. It is hypothesized that this seasonal distribution was more prey-dependent than temperature-dependent. A temperature occupation range was determined seasonally for each species.

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THERMAL EFFECTS OF BIOLOGICAL MAGNIFICATION OF ARSENIC IN GREEN SUNFISH, LEPOMIS CYANELLUS

Author: Elsie Mae Boecker Sorensen

The pattern of heavy metal concentration in organs of both living and dead Lepomis cyanellus was measured in Section I as a function of exposure time at 10^o, 20^o, and 30^oC and 0, 30, and 60 ppm arsenic as sodium arsenate. The temperature quotient (Q_{10}) for the rate of arsenic uptake and the lethal time before 50% mortalities (LT_{50}) occurred were calculated.

Arsenic concentration in liver, gut, and muscle tissue was determined in living and dead specimens by neutron activation analysis. The occurrence of individual specimen variability in arsenic uptake data did not override general trends of increasing uptake with exposure time, temperature, and arsenic concentration. Data on the arsenic retention of fish in 10^oC and 0, 30, and 60 ppm treatments indicated that the majority of arsenic in organs is not retained after 7 days. Correlation of uptake with various specimen and tissue parameters proved inconclusive.

The mean Q_{10} value for arsenic uptake in liver was 4.5. Since the typical Q_{10} range for the genus Lepomis is 1.6 to 3.0 (O'Hara, 1968), the high mean Q_{10} for L. cyanellus seems to suggest that temperature acts synergistically with arsenic uptake.

The LT_{50} values, a measure of survival, were calculated by straight line graphic interpolation after linear regression analysis of data on % survival versus time of death. All regressions were highly significant. As temperature increased from 10^o to 20^o to 30^oC at 60 ppm arsenic, % survival decreased such that LT_{50} values were reduced from 678 to 210 to 124 hours, respectively. For an arsenic concentration of 30 ppm and temperatures of 20^o and 30^oC, LT_{50} values are 527 and 209 hours, respectively.

Since the results of Section I showed that arsenic was accumulated in organs--especially the liver--of Lepomis cyanellus and that external variations exacerbate this accumulation, an intracellular study was made in Section II to follow the appearance and rate of change of hepatocyte alterations. Hepatocyte alteration was measured as arsenic concentration (i.e., 30 and 60 ppm) and exposure time (i.e., 1, 2, and 3 weeks) varied at 20^o. As concentration and exposure time

increased, the appearance and increase in aberrant mitochondria and electron dense particles were observed. Lysosomes and smooth endoplasmic reticulum increased in number, while the number of myelin figures decreased. Hepatocyte alterations and arsenic uptake did not appear to be correlated to specimen condition.

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**THE ROLE OF TEMPERATURE AND FOOD LIMITATION
IN THE POPULATION DYNAMICS OF THE CLADOCERAN ZOOPLANKTON
IN FAIRFIELD RESERVOIR, TEXAS**

Author: Kathryn Hassell Sorensen

A One year study undertaken at Fairfield Reservoir, Texas, revealed several unique aspects in its zooplankton population dynamics. Diel sampling at six sites throughout the reservoir showed spatial heterogeneity in vertical migrations of several zooplankton, including copepoda nauplii, and the rotifers *Polyarthra* and *Brachionus*. This sampling also showed extreme clustering of various zooplankton; this clustering could not be related to the invertebrate predators, *Chaoborus* or *Asplanchna*. *Daphnia lumholtzi*, the dominant cladoceran zooplankton, was used in laboratory experiments to determine food limitation in the reservoir, and food limiting effects were evident in the winter months. The cyclomorphosis which *D. lumholtzi* experiences throughout the year is described and related to the presence of both invertebrate and vertebrate predators. The presence of *Chaoborus* had no effect on the growth of the head spine while fish did cause positive allometric growth of the head spine.

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THE LIMNOLOGY AND ICHTHYOLOGY OF FAIRFIELD RESERVOIR, TEXAS

Author: Michael Ross Speegle

The limnology and ichthyology of Fairfield Reservoir, Freestone county, Texas, which receives a heated effluent from an electric generating plant, was studied from July 1971 through August 1972. the reservoir was determined to be monomictic, to maintain an alkaline pH, and to reach high surface temperatures during summer months due to normal environmental conditions. An estimate of relative abundance of fish species present was determined by seining and gill-net data. Time of spawning and gonad development was observed in most species. A gill-net index for 11 species was computed, and length-weight regressions were determined for several species. An analysis of variance was used to analyze the gill-net catch data for the four permanent stations over an eleven month time period for the eight most numerous species of fish. The resultant data were further analyzed by the Tukey test. Even though station 4 received a heated effluent, statistical analysis proved no significant difference to exist between the four stations.

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DEVELOPMENT OF ORGANIC CARBON POOLS IN WETLANDS CREATED ON RECLAIMED LIGNITE MINE SOIL

Author: Robin E. Stapleton

Organic carbon storage and cycling is vital for the functional success of created wetlands. The purpose of this study was to examine the relationship between created wetland age and organic carbon accumulation and carbon flux through soil respiration. Seven created wetlands ranging in age from newly created to twenty-years-old were selected from the reclaimed areas at the TXU Mining Martin Lake lignite mine in Panola County, Texas. Four transects containing three plots each were placed parallel to the moisture gradient in representative locations around each wetland to facilitate sampling from the range of moisture conditions present. Organic carbon content (OC) in the water, vegetation, litter layer, and soil was analyzed to estimate carbon storage in each pool. CO₂ flux from the soil was measured with a portable infrared gas analyzer to determine mean soil respiration rate. Soil respiration and the understory vegetation, O-horizon, and water TOC were measured four times during the year to account for seasonal variation. Results indicate that as the created wetlands age, soil respiration and all the measured carbon storage pools except soil OC increased. Soil carbon to 25 cm depth decreased with wetland age at the same rate that the other carbon pools increased, such that all the wetlands had essentially the same amount of organic carbon per unit area. The decrease in soil OC is believed to be due to decomposition of incorporated lignite in the mixed overburden mine soil. Relationships between wetland age and the vegetation and detrital carbon pools, as well as between age and soil respiration appear to be stronger during the summer months. This was probably due to increased biological activity and primary production in warmer temperatures. Wetland morphology was observed to effect the duration and area of inundation in created wetlands, which in turn impacts their carbon storage potential.

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EFFECTS OF A REDUCTION OF BLUE TILAPIA OREOCHROMIS AUREUS ON THE ICHTHYOFAUNA OF A POWER-PLANT RESERVOIR

Author: Scott Michael Starling

A power-plant shutdown during December 1983 resulted in an extensive kill of blue tilapia Oreochromis aureus and provided an opportunity to examine the response of various fishes of Lake Fairfield (Texas) to the reduction of this highly successful and aggressive exotic. Gill nets, seines, and fyke nets were used to collect length, weight, and abundance data on fishes from February 1985 to January 1986, and these results were compared to data collected prior to O. aureus die-off.

The mean catch-per-unit effort (CPUE) and mean coefficient of condition (K) of gizzard shad Dorosoma cepedianum and channel catfish Ictalurus punctatus increased, and the CPUE of O. aureus decreased substantially following the partial coldkill. Feeding interactions and possible O. aureus predation on young I. punctatus may help explain these results. The seine CPUE of red shiner Notropis lutrensis and inland silverside Menidia beryllina also increased over previous results from Lake Fairfield, indicating that O. aureus may have been negatively affecting the reproductive success of these species. However, the decline in abundance of the hybrid bass Morone chrysops x M. saxatilis also probably contributed to the increased abundance of these fishes.

Largemouth bass Micropterus salmoides (CPUE) and Young-Adult Ratio (YAR) increased and Proportional Stock Density (PSD) decreased following the O. aureus reduction. These data suggest that the dense O. aureus population prior to the coldkill had suppressed the reproduction and recruitment of this species. No evidence of changes of bluegill Lepomis Macrochirus abundance was observed. Mean CPUE data indicate that the O. aureus population recovered to its former level of abundance within two years after the coldkill.

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FACTORS AFFECTING THE RATIO OF CATION EXCHANGE CAPACITY TO CLAY CONTENT IN EAST TEXAS LIGNITE OVERBURDEN

Author: William M. Stewart

Unusually high cation exchange capacity (CEC) values relative to clay content are frequently reported by commercial laboratories for lignite overburden and minesoil in Texas. The CEC:%clay ratio is commonly greater than one. Current regulatory criteria require mining companies to provide an explanation and/or reanalyze samples when the CEC:%clay ratio exceeds one. No definitive explanation for ratios greater than one has been reported.

The methods used by commercial laboratories for the determination of clay and organic C content were evaluated. A comparison of the methods of particle size distribution determination suggests that the major reason lignite overburden samples have CEC:%clay ratios greater than one is incomplete dispersion of aggregates of clay minerals or shale fragments. The method used by commercial laboratories underestimates clay content by approximately 24%. Another important factor influencing CEC:% clay ratio was the presence of organic materials (lignite) in the samples. Lignite may make a significant contribution to CEC in overburden materials. In a study designed to investigate the pH dependent charge of both the mineral and organic fractions the CEC of overburden organic constituents was determined to be approximately $158 \text{ cmol}_c \text{ kg}^{-1}$.

A mineralogical investigation that included X-ray diffraction analysis, computer simulation, identification of high charge smectites by the alkylammonium method, and scanning electron microscopy was undertaken. This investigation revealed the presence of high charge smectite in the clay fraction of lignite overburden. However, this mineral was not a major contributor to the unusually high CEC:%clay ratios. Shale fragments, smectite, and partially weathered mica were discovered in the silt fraction. The silt fraction may therefore provide a hidden source of CEC.

The high CEC:%clay ratio problem in east Texas lignite overburden and minesoils may be resolved by adjusting methods for percent clay determination to optimize dispersion and by accounting for CEC due to organic materials. An alternative approach is to use current methodology and utilize correction factors to account for incomplete dispersion of clay minerals and the charge contributions of organic materials.

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ASSESSING CONTROL STRATEGIES FOR GROUND LEVEL OZONE

Author: Neelesh Vijay Sule

Developing cost effective control strategies for ozone has been a challenge to air quality modelers. Conventionally, the control strategies are applied across-the board to the region. The main aim of this research was to develop a Decision-Making Framework (DMF) for evaluating and optimizing the selection of ozone control strategies. Conventional across-the-board reductions conduct emission reductions uniformly throughout the region and throughout the day. By contrast, this dissertation studied *targeted* reductions, in which emission sources of various types are reduced at various times and locations.

The proposed DMF comprised of four phases: (1) Initialization, (2) Mining, (3) Metamodeling, and (4) Optimization. This DMF was tested on a DFW 2009 future case episode which was based on a 10-day episode from August 13-22, 1999. 612 emission variables were identified in three source categories viz. point, area (includes non-road) and line (on-road). The emission control regions and time periods along with ozone monitoring regions and time periods were defined. The control strategy emission reductions and costs were also identified in this stage. Initially a Latin hypercube experimental design was setup to organize 30 sets of emission reduction scenarios to be modeled using the photochemical mode CAMx. Data mining reduced the number of variables to a maximum of 126. A second Latin hypercube was setup to organize another 30 emission reduction scenarios for the significant variables identified by data mining. Metamodels were developed for ozone from the 60 CAMx runs using linear regression models constructed with the stepwise model selection method. Stepwise regression further reduced the number of variables. The metamodels were implemented in optimization as a surrogate for time-intensive CAMx modeling. Appropriate constraints were calculated for each metamodel to ensure that it satisfied EPA's MAT. The optimization was formulated to find the most cost effective combination of targeted control strategies that brings the region into attainment for the 8-hour ozone. Each day was optimized individually in sequence. In order to demonstrate applicability of the DMF 5 days (August 15, 16, 17, 18 and 19) of the episode were optimized. Although the optimization identified the key sources, time periods, and control strategies, the existing controls on these sources were not adequate to bring the region in attainment. Further reductions at these sources beyond the existing list of TCEQ/NCTCOG control strategies were required. Further modifications in the DMF for DFW were suggested to improve its performance.

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PHOSPHORUS RELEASE FROM AEROBIC-SURFACED LAKE SEDIMENTS AND THE IMPORTANCE OF SULFATE REDUCTION

Author: Michael Wayne Suplee

A study was designed to determine if phosphorus (P) release from aerobic-surfaced lake sediments varies as functions of sulfate reduction rates and iron reduction. Over a one-year period, benthic chambers were used to measure soluble reactive phosphate (SRP), dissolved inorganic carbon (DIC), and oxygen fluxes of littoral sediments overlain by aerobic waters in a power-plant cooling reservoir. Sulfate reduction was measured by $^{35}\text{SO}_4^{2-}$ core injection. Measurements were made at two sites, one near the plant's effluent (A hot site), and the other near the plant's intake (A cold site). The hot site had significantly higher ($p < 0.05$) sediment SRP, DIC, and oxygen fluxes, and sediment sulfate reduction rates, than the cold site. Differences were greatest in September, when hot-site water temperature exceeded 40°C and solute fluxes rose dramatically. Relative P release (RPR) and estimates of carbon and phosphorus sediment loading were used to examine sediment P-storage. The hot site retained 65% of its annual P load, the cold site 92%. RPR data indicated sediments retained P selectively all year, except at the hot site in September when stored P was released. Overall, temperature was the only variable that significantly correlated to RPR ($R^2 = 0.53$). This was apparently due to its influence on sediment microbial metabolism and bioturbation. High temperatures diminished bioturbation at the hot site and may have decreased the sediment's ability to adsorb P. In September, high sediment oxygen demand apparently lowered hot site redox potentials sufficiently to reduce surface ferric iron, inducing the large P-flux. Total reduced inorganic sulfur (TRS) concentrations were highest when sulfate reduction rates were lowest, suggesting seasonal de-coupling of sulfur (S) oxidizers and reducers. In summer, tight coupling between reduced S oxidation and sulfate reduction decreased TRS in spite of high sulfate reduction rates. Although large variations in TRS concentrations of near-surface sediments were observed at both sites, TRS did not significantly correlate to P flux. This study's results did not support the idea that P fluxes from aerobic-surfaced sediments are controlled by sulfate reduction rates.

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SOIL MICROBIAL BIOMASS: AN ESTIMATOR OF SOIL DEVELOPMENT IN RECLAIMED LIGNITE MINE SOILS

Author: Eric Scott Swanson

A two-year study was conducted at the Big Brown lignite mine in Fairfield, Texas, to determine the rate and extent of recovery of the soil microbial biomass (SMB) in mixed overburden. The relationships between SMB carbon (SMBC), basal respiration and soil organic carbon (SOC) accretion was evaluated using the respiratory quotient ($q\text{CO}_2$) and the ratio of the SMB to SOC (SMBC:SOC ratio). Newly leveled, 1-, 3-, 5-, 10-, 15-, and 23-year-old reclaimed mixed overburden as well as an unmined soil were sampled bimonthly to measure SMBC and other parameters.

Three methods [chloroform fumigation incubation (FI), chloroform fumigation extraction (FE), and substrate-induced respiration (SIR)] were used to measure SMB and compared as estimators of SMB in reclaimed mine soils. Basal respiration (CO_2 evolved from untreated soil), metabolic quotient (i.e. specific respiratory activity; $q\text{CO}_2$; CO_2 produced per unit mass of SMB), and the SMBC:SOC ratio (the abundance of SMB relative to SOC) were used to determine trends in microbial biomass dynamics relative to SOC accumulation.

A nearly linear increase in SMB was observed over the chronosequences of mine soils ($r=0.98$ to 0.99) for each of the three biomass methods. Mean values of SMB from 12 sample dates ranged from $40 \Phi\text{g SMBC g}^{-1}$ at the 0-year site to $291 \Phi\text{g SMBC g}^{-1}$ at the 23-year site. The unmined reference soil averaged $84 \Phi\text{g SMBC g}^{-1}$ through the period of the study. The $q\text{CO}_2$ declined from 0.24 to $0.12 \text{ mg CO}_2\text{-CC mg SMBC d}^{-1}$ during the first year and tended to stabilize near 0.06 to 0.09 as reclaimed sites matured. The ratios of SMBC SOC increased linearly with age of site through 23 years ($r=0.97$).

A substantial amount of seasonal variation in SMB was observed during the two-year study. Older sites (15- and 23-years) showed significant fluctuations of SMB that correlated well with the growing season of Coastal bermudagrass. Microbial biomass peaked during mid to late summer and declined to a minimum during the cold, wet winter months. Younger sites were less affected by seasonal influences, and changes at these sites appeared more related to changes in soil moisture.

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ESTABLISHMENT OF SUBMERGENT VEGETATION AND INVERTEBRATES IN A WETLAND CONSTRUCTED ON MINE SPOIL

Author: James Alan Thomas

Because of their functions in substrate stabilization, nutrient uptake, and wildlife habitat, submerged aquatic macrophytes are essential for successful wetland restoration and creation. However, techniques for establishment of submergents have been slow to develop. Southern naiad (*Najas guadalupensis* (Spreng.) Magnus), coontail (*Ceratophyllum demersum* L.), and sago pondweed (*Potamogeton pectinatus* L.) were compared to borrowed-wetland soil during 1992 and 1993 growing seasons at three water depths (20, 50, and 80 cm) within an experimental wetland on Texas Utilities' Big Brown Mine in eastern Texas. Percent cover was determined during both seasons, and above-ground biomass (AGB) and associated macroinvertebrates were sampled at all water depths in 1993.

The borrowed-soil treatment generally had significantly ($P < 0.05$) higher total submergent AGB, percent cover, species richness, and invertebrate taxon richness than single-species treatments. Locally collected southern naiad and coontail produced greater percent cover than nursery stock. Success in submergent establishment and macroinvertebrate abundance generally increased with water depth, while emergent macrophytes establishment from borrowed soil were most successful at 20 cm. Results indicated borrowed soil by beutilized alone, or in conjunction with plantings of locally abundant species to successfully establish submergent macrophytes and associated invertebrates in wetland reclamation efforts.

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POPULATION CHARACTERISTICS AND DIETS OF TWO WHITE-TAILED DEER HERDS WITH CONTRASTING DENSITIES

Author: David Alan Tilton

Population density, diets, sex ratio, productivity estimates, and physical condition parameters were determined for a semi-confined population of white-tailed deer (Odocoileus virginianus) and for another population on a nearby control area near Fairfield, Texas. Data collected during walk-transect deer counts revealed significantly ($P < 0.05$) higher population densities on the study area. Less palatable foods were more prominent in deer diets on the study area than on the control area. For most parameters measured, analyses of nutrient levels of rumen contents produced no evidence of a statistically significant ($P < 0.05$) difference between the two areas. The sex ratio was skewed toward a predominance of females. The increased tendency of males to disperse was judged to account for this phenomenon on the study area. Fawn/doe and fetus/doe ratios suggested productivity was lower among deer on the study area than among control area deer. Kidney fat, femur marrow fat, and antler characteristics suggested deer on the study area subsisted on a low quality diet. Differences in diet, productivity, sex ratios, and physical condition between the deer on the two areas was linked to the difference in population density.

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THE FISHES OF BLUNDELL RESERVOIR MONTICELLO, TEXAS

Author: William Harry Tommey

Blundell Reservoir located in Monticello, Texas, is an 809.4 hectare (2000 acres) reservoir that receives a heated effluent. Water temperature, dissolved oxygen concentration, pH, and total alkalinity were measured at six stations in the reservoir.

The reservoir was sampled periodically from July 1974, through August 1975 to determine the ichthyofauna of the reservoir and their distribution and relative abundance. Collections were made with experimental gill-nets and a 6.1 m (20 ft.) seine.

There were significant differences in relative abundance between stations for white crappie (Pomoxis annularis), gizzard shad (Dorosoma cepedianum), channel catfish (Ictalurus punctatus), bluegills (Lepomis macrochirus), and black crappie (Pomoxis nigromaculatus). There were no significant differences in relative abundance between stations for spotted suckers (Minytrema melanops), walleye (Stizostedion vitreum vitreum), black bullheads (Ictalurus melas), and flatheads (Pylodictus olivaris).

Calculated weights of condition for six species were compared between stations and two seasons, and no significant differences were found.

Parasitism by Argulus on black bullheads (Ictalurus melas) and leeches on channel catfish (Ictalurus punctatus) decreased from January through April.

The power plant began generating December 23, 1974. Since the reservoir was receiving a thermal discharge only during the latter half of the study, it was difficult to determine any effects.

**COMPARISON OF SITE QUALITY FOR LOBLOLLY PINE
ON SELECTED MINED AND NON-MINED SOILS
IN PANOLA COUNTY, TEXAS**

Author: Bradley Gerald Toups

Non-mined Sacul soil (Aquic Hapludult) sites and reclaimed lignite mine spoil sites supporting loblolly pine plantations 2, 3, 4, 5, and 7 years of age were compared for tree total height and stem diameter (15 cm above root collar), foliar and soil nutrient content, and other soil chemical and physical properties. The non-mined site trees were generally larger in diameter and total height. The mined site yielded the larger trees of the two four-year-old plantations studied.

The mined sites had the greater abundance of soil and foliar plant nutrients, higher soil pH, greater CEC and base saturation. Soil nitrogen and occasionally phosphorus were deficient on both site types. Cumulative infiltration at 60 minutes and bulk density of the surface were similar between site types. Poor internal soil drainage and paucity of nitrogen probably accounted for generally poorer tree growth on the mined site.

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**EXPERIMENTAL TROPHIC ECOLOGY OF JUVENILE
LARGEMOUTH BASS AND BLUE TILAPIA IN LAKE FAIRFIELD, TEXAS**

Author: Stephen Louis Traxler

The potential for feeding competition between largemouth bass Micropterus salmoides and blue tilapia Oreochromis aureus in Lake Fairfield, Texas was evaluated experimentally. Largemouth bass and blue tilapia were grown in cages alone and in combination with each other. The fish were allowed to feed on the natural food of the lake. Largemouth bass grown in combination with blue tilapia were significantly shorter and weighed less than largemouth bass grown alone. Blue tilapia grown in combination with largemouth bass were significantly longer and heavier than blue tilapia grown alone. Largemouth bass grown alone had diets (volume and number of food items) significantly different than the largemouth bass grown with the blue tilapia. Largemouth bass fed primarily on chironomid larvae and pupae, and odonates, whereas blue tilapia consumed vegetable matter, detritus, and chironomid larvae. Length and weight differences between largemouth bass grown alone and in combination with blue tilapia, in conjunction with the largemouth bass diet shift, support the theory that these two species compete for food resources.

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AN ECOLOGICAL SURVEY OF THE LIGNITE MINING AREA OF THE BIG BROWN STEAM ELECTRIC STATION

Author: Dr. Joe Clyde Truett

This study provided a pre-mining (1971-72) description of the vegetation and the terrestrial vertebrate wildlife of the Big Brown mining area. A discussion of the ecological implications of pre-mining land uses was included.

Voucher specimens of approximately 200 plant species were identified and mounted on herbarium paper. Four major vegetation types--upland woods, bottomland woods, old fields, and improved pastures--occupied most of the area. White-tailed deer, bobwhite quail, mourning doves, and fox squirrels were game animals that were common on the area. During the 6-month investigation, 23 mammal species, 77 birds, 22 reptiles, and 8 amphibians were encountered.

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THE EFFECT OF STRIP-MINING AND RECLAMATION ON SMALL MAMMAL COMMUNITIES

Author: Kenneth Van Waggoner

Four habitats on and around a strip-mine in East-central Texas were sampled for small mammals by a mark-recapture grid study to determine the effect of strip-mining operations on terrestrial ecosystems. Surface vegetation and soil organic matter were also sampled and caloric values determined to identify the relationships between mammalian populations and energy availability.

Populations of each mammalian species are estimated and the Shannon-Weaver indices of species diversity plus species richness and species evenness components are computed for each month for mammals occurring in three of the four habitats. Diversity of the four areas are discussed and compared. An index of similarity is computed and intercommunity similarities of the mammal fauna are discussed.

Home range and longevity are computed for those species occurring in abundance on each of the study areas, and other life history items such as breeding season, habitat selection, and growth rates are noted.

Techniques to improve habitat quality for wildlife and grazing on strip-mined lands are proposed and discussed.

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MICROBIAL HYDROLYSIS OF UREA AND ITS SUBSEQUENT NITRIFICATION IN EAST TEXAS LIGNITE MINE SPOIL

Author: Paul James Waggoner

A functional nitrogen (N) cycle within mine spoils is necessary for successful long-term revegetation. To initiate successful revegetation of mined lands, large inputs of N fertilizers are required. Urea is gaining worldwide popularity as an N source due to its high N content (47.0%) and economical price. Since little is known about the behavior of urea in the mixed overburden mine spoils of east Texas, a two-year study was conducted to determine rates of urea hydrolysis, and its subsequent nitrification and effects on microbial activity, at reclaimed sites of varied ages.

Newly-leveled, 1-, 4-, and 8-year old spoil and an unmined soil at the Big Brown Mine in Fairfield, Texas, were fertilized with 244 kg N ha⁻¹ of (NH₄)₂SO₄ or urea. After fertilization, soils were periodically analyzed for microbial activity (arginine ammonification, AA; substrate induced respiration, SIR), ability to hydrolyze urea (UH), numbers of nitrifying bacteria, and nitrification potentials (NPs).

Only soils from the unmined and newly-leveled sites failed to show increased AA rates. Vegetated mine spoils showed AA rates ranging from 1.2 to 2.3 mg NH₄ + - N kg⁻¹ soil; h⁻¹ within seven days. Rates of AA were similar in soils fertilized with (NH₄)₂SO₄ or urea. Rates of SIR showed a similar pattern, being maximal in the 8-yr. spoil and rates were similar in soils fertilized with (NH₄)₂SO₄ or urea. Rates of AA and SIR were highly correlated ($r = 0.59$ to 0.93).

Revegetated mine spoils (4 to 8 yrs.) showed UH rates as high, or higher than those of the unmined soils. Rates of UH were greatest at the 8-yr. site (ranging from 3.0 to 3.5 mg urea-N hydrolyzed kg⁻¹ soil h⁻¹) and lowest at the newly-levelled site (maximum rate of 0.5 mg urea-N kg⁻¹ soil h⁻¹). Rates of UH were similar in soils fertilized with (NH₄)₂SO₄ or urea.

Nitrification potentials in vegetated spoil (1 to 8 yrs.) were similar to, or greater than those of the unmined soil (ranging from 2.4 to 5.2 mg NO₃⁻-N kg⁻¹ soil d⁻¹). Peak NPs were observed two weeks after fertilization and the (NH₄)₂SO₄ and urea treatments showed similar rates.

Nitrifying bacteria regained pre-mining levels within one year in revegetated sites showed numbers similar to, or greater than, numbers in the unmined soil. Numbers of NH₄ + - and NO₂⁻-oxidizing bacteria were similar in soils fertilized with either N source. Bacterial numbers increased one order of magnitude after the newly-leveled site was sprigged, suggesting an inoculation effect. Numbers of nitrifying bacteria and nitrification potentials were highly correlated ($r = 0.75$ to 0.94).

This study demonstrated the rapid recovery, to pre-mining levels, of selected soil microbial activities and populations of nitrifying bacteria in mixed overburden. Ammonium sulfate and urea produced very similar responses for the parameters measured. Urea appears to be as suitable an N source as $(\text{NH}_4)_2\text{SO}_4$ in the revegetation process.

THE EFFECTS OF AN ARTIFICIALLY ELEVATED THERMAL ENVIRONMENT AND SEASONAL ACCLIMATIZATION ON THE THERMAL TOLERANCE OF THE WESTERN MOSQUITOFISH, *GAMBUSIA AFFINIS*

Author: Rebbekah J. Watson

Gambusia affinis, the western mosquitofish, is a very hardy, live-bearing fish that has invaded freshwater habitats worldwide. The success of the western mosquitofish's invasion is due to its reproductive capabilities and ability to tolerate a wide range of temperatures. The mosquitofish can inhabit waters as low as 0°C and higher than 40°C. Because of this species' eurythermicity, questions have been raised regarding the impact of artificially heated environments on its thermal tolerance limits and whether its thermal tolerance limits are consistent across seasons. Past studies have shown that mosquitofish populations inhabiting hot ponds receiving thermal effluents at steam-electric power stations had higher upper thermal tolerance limits than populations inhabiting the associated lake's main reservoirs. This higher thermal tolerance limit was found to be heritable, pointing to fitness differences between two populations. This led to the suggestion that directional selection was occurring in the population exposed to thermal effluents, leading to a more thermally tolerant population of mosquitofish. This study examined whether the previously documented increase in upper thermal tolerance of the mosquitofish population affected by thermal effluents has continued to increase over the past five years, supporting the hypothesis of directional selection and whether a continued increase in the population's upper thermal tolerance has impacted its lower thermal tolerance limits as well. In order to determine whether thermal effluents and seasonal acclimatization affects the thermal tolerance limits of *G. affinis*, the upper and lower thermal tolerance limits were established for two populations and compared to previous research; temperature tolerance polygons were established to examine whether thermal effluents influence the degree of eurythermicity of this species; and seasonal comparisons of the upper and lower thermal tolerance limits were assessed to determine whether seasonal acclimatization has influenced the thermal tolerance limits of this species. The upper thermal tolerance limits were found to be inconsistent. Depending on the season, the population exposed to thermal effluents did not always exhibit a higher thermal tolerance than the population exposed to ambient lake waters. The lower thermal tolerance limits were more consistent, showing that the population exposed to thermal effluents were consistently less cold tolerant than the population exposed to ambient lake waters. Only female individuals exposed to thermal

effluents exhibited an increase in upper thermal tolerance compared to individuals tested five years previously. Due to the inconsistency in the upper thermal tolerance limits and the continuously varying upper and lower thermal tolerance temperatures among seasons, seasonal acclimatization was shown to heavily influence the thermal tolerance limits of *G. affinis*. Temperature tolerance polygons demonstrated that the population exposed to thermal effluents and the population exposed to ambient lake waters had similar areas of thermal tolerance, suggesting that these populations generally inhabit the same thermal niche. These polygons also supported the fact that *G. affinis* has a wide range of thermal tolerance.

THE EFFECTS OF FISH PREDATION AND THERMAL REGIME ON AN AQUATIC MACROARTHROPOD COMMUNITY

Author: Gary Allen Wellborn

The effects of vertebrate predation and thermal regime on a littoral macroarthropod community were evaluated during a one year study of Fairfield Reservoir, Freestone County, Texas. Twelve sample sites were established, with each consisting of two 2 x 4 m plots. One plot was inaccessible to fish predators, the other plot was freely accessible to fish. Artificial substrates which mimicked natural vegetation were placed in each plot to allow quantitative sampling of macrophyte-dwelling invertebrates. This design allowed assessment of the impact of vertebrate predation on invertebrate species. Half of the sample stations were located in a warm water cooling pond receiving a thermal discharge from a steam electric generating facility. The remaining stations were located in a main reservoir cove sufficiently distant from the thermal discharge to be minimally affected. Comparison of macroarthropod samples from these areas of disparate thermal conditions allowed an evaluation of the role of thermal regime in the determination of community structure.

In the main reservoir, total invertebrate abundance was significantly higher in predator exclusion plots than plots accessible to fish predators. When taxa were examined individually, *Hyaella azteca* and *Orthotrichia* sp. had significantly greater abundance in the absence of fish predation. These taxa were major components of the main reservoir fauna. Zygopteran abundance was significantly reduced in fish exclusion plots. In addition to species-specific predator susceptibility, macroarthropod response to predator density manipulation often exhibited significant spatial heterogeneity and temporal inconstancy. In contrast to results obtained under a natural thermal regime, predator exclusion plots in the cooling pond had significantly lower invertebrate abundance than predator accessible plots.

Thermal regime had a major influence on invertebrate abundance and community structure. The heated waters of the cooling pond usually supported fewer invertebrates than main reservoir locations. High water temperatures during summer months eliminated all macroarthropods in the cooling pond. As cooling pond temperatures declined in late fall, macroarthropod abundance temporarily increased to very high levels, perhaps due to an accrual of nutrients throughout the uninhabitable summer months. A further effect of the elevated thermal regime was a reduction of diversity. Chironomidae, *Hyaella*, and, to a lesser extent, *Orthotrichia* constituted the fauna of the cooling pond, while main reservoir sites supported several additional common taxa.

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COMPARISON OF AVIAN SPECIES DIVERSITY AND DENSITIES ON NON-MINED AND RECLAIMED SURFACE-MINED LAND IN EAST-CENTRAL TEXAS

Author: Dawn Nicole Wenzel

Surface mining often changes the native landscape and vegetation of an area. Reclamation is used to counter this change, with the goal of restoring the land to its original pre-mined state. The process of reclamation creates early successional-stage lands, such as grasslands, shrublands, and wetlands, attracting new plant and animal species to the area. I compared avian species density (number of individuals/ha), diversity (H'), and richness (number of species/ha) on reclaimed and non-mined lands at TXU's Big Brown Mine in Fairfield, Texas. I also compared my results to those of a previous study conducted 25 years earlier. Avian counts were conducted using a fixed-radius point-count method on 240 points placed in four different vegetation types and in four land-age groups (time since being reclaimed). Vegetation was measured both locally, and at a landscape level. Overall bird species density did not exhibit a clear relationship on non-mined versus reclaimed land. Overall bird species diversity was greater on non-mined lands, whereas overall species richness was greater on reclaimed lands. My results demonstrated a lower mean/point bird density and higher mean/point bird diversity than were found 25 years earlier. Different nesting guilds occurred on the reclaimed lands than occurred on the non-mined lands. Results suggested different species were attracted to the several successional stages of reclaimed lands over the non-mined lands, which consisted of climax vegetation. The different successional stages of reclaimed lands increased overall diversity and richness of the landscape as a whole. Five bird species of conservation concern were observed in the study, all of which occurred on reclaimed land. Four of the five species primarily occurred on reclaimed lands. Future land management should include conserving different successional-stage lands to increase overall biotic diversity and richness of mined land, preserving reclaimed habitat for species of concern, and educating future private landowners on the importance of maintaining vegetative and bird species diversity.

**SOIL PROPERTIES RELATING TO HEIGHT GROWTH OF
LOBLOLLY PINE ON SOILS OF THE BOWIE, FUQUAY,
SACUL, AND TROUP SERIES**

Author: Richard Larry Willett

Stem analysis was used to obtain age and height data for loblolly pine stands growing on Bowie, Fuquay, Sacul, and Troup soils in northeastern Texas. The soil profiles were described and bulk soil samples were taken in each sample stand. Selected physical and chemical soil properties were measured for each soil horizon. Stepwise regression analysis was used to correlate average stand height at ages five, 10, 20 and 30 years with soil properties. Strong associations were found between stand height and properties which relate to available soil moisture holding capacity, soil permeability, and soil aeration. For Bowie, Fuquay, and Troup soils, average stand height increased with increasing moisture holding capacity of the surface soil and with increasing subsoil permeability and aeration on sacul soils, height increased with better permeability and aeration of the solum.

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**TWO-YEAR SURVIVAL AND GROWTH OF LOBLOLLY
PINE SEEDLINGS FROM TWO TEXAS SEED SOURCES ON
LIGNITE MINESOILS**

Author: Gerald Allen Wood

Loblolly pine seedlings from Lost Pines (drought-hardy) and East Texas (regular) seed sources were planted in lignite minesoils in Panola County, Texas. Heights, root-collar diameters, and survival were monitored for two years. Treatments included application of Pisolithus tinctorius basidiospores immediately after planting and use of acephate for tip moth control during the second growing season. Standard foliar analyses were conducted at the end of the second growing season.

East Texas seedlings grew more in height and root-collar diameter, and had higher survival percentages than Lost Pines. No growth response from treatment with P. tinctorius was observed. Treatment with acephate resulted in 62 percent more height growth and 24 percent more diameter growth. Variations in growth or survival were not reflected in foliar nutrient content.

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EFFECTS OF COMPACTION OF RECLAMATION OF SURFACE MINED LANDS IN EAST TEXAS

Author: Li Yao

Soil compaction by reclamation vehicles is a potential constraint to the performance of reclaimed surface mine in Texas. The objective of this study were: (1) to establish a baseline study of an area, and (2) to quantify the effects of compaction on soil properties that influence the success of reclamation.

In addition to routine soil chemical and physical properties as a baseline, compaction related soil properties, such as cone index (CI), bulk density, saturated hydraulic conductivity (Ksat), micromorphological features, root density, and coastal bermudagrass yield were measured in this study.

Cone index values ranged from a few hundred KPa in reclaimed uncompacted surface soils to as high as 15 MPa in the most compacted zones under nature soil moisture conditions. Normalized CI values showed that conventionally reclaimed minesoils have compacted layers starting from 15 to 20 cm depths and the CI values in these layers were commonly as high as the induced compaction layers.

Soil compaction was also indicated by the low Ksat values in the subsurface horizons. Slow to very slow infiltration rates were observed in the compacted zones, with Ksat ranging from 0.0016 to 9.82 mm/hr and a averaged Ksat of 0.8 mm/hr. In the surface horizons for all treatments, averaged Ksat were from 5.4 to 8.5 mm/hr which corresponds to the moderately slow class of water movement. Bulk densities were generally higher in the compacted horizons than in the uncompacted ones.

A large variety of micromorphological features indicating mechanical and shear stress due to compaction, such as bent shale and stress cutans, has occurred. Macroporosity was very low and ranged from 3.1% in compacted zones to about 10% in the uncompacted surface horizons of conventionally reclaimed soil. Macropores were dominantly oriented horizontally in both compacted subsurface zones and uncompacted surface zones. High spatial variability was observed in minesoils.

This study indicated that minesoils have been subjected to compaction by the current reclamation operations. Soil physical properties and microstructure were negatively affected by compaction. These conditions decreased rates of water movement, restricted root, negatively impacted plant yield, and would be expected to enhance surface runoff and erosion.

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