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AgriLIFE EXTENSION
Texas A&M System

Education Program for Improved Water Quality in Copano Bay

Final Report

A. Berthold, E. Moench, K. Wagner, J. Paschal

Texas AgriLife Extension Service
Texas Water Resources Institute

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LIST OF ABBREVIATIONS

AU	Animal Units
BCS	Body Condition Score
BMP	Best Management Practice
BST	Bacteria Source Tracking
BW	Body Weight
CAFO	Concentrated Animal Feeding Operation
CBBEP	Coastal Bend Bays and Estuaries Program
CRP	Conservation Reserve Program
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FM	Farm Road
FSA	Farm Service Agency
I-Plan	Implementation Plan
K	Potassium
N	Nitrogen
NERR	National Estuarine Research Reserve
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
P	Phosphorus
SH	State Highway
SWCD	Soil and Water Conservation District
TAMU-CC	Texas A&M University, Corpus Christi
TCEQ	Texas Commission on Environmental Quality
TGLO	Texas General Land Office
TMDL	Total Maximum Daily Load
TSCRA	Texas and Southwestern Cattle Raisers Association
TSSWCB	Texas State Soil and Water Conservation Board
TWRI	Texas Water Resources Institute
USDA	United States Department of Agriculture
UT CRWR	Center for Research in Water Resources at the University of Texas in Austin
WQMP	Water Quality Management Plan
WWTF	Waste Water Treatment Facility

EXECUTIVE SUMMARY

The Copano Bay watershed covers approximately 1.4 million acres encompassing portions of Karnes, Bee, Goliad, Refugio, San Patricio and Aransas counties. Copano Bay and its main tributaries, the Mission and Aransas rivers, were placed on the Texas Commission on Environmental Quality (TCEQ) 303(d) list in 1998 due to levels of bacteria that exceed water quality standards established to protect oyster waters use. A Total Maximum Daily Load (TMDL) program was initiated in September 2003 to identify and assess sources of these bacteria. The Center for Research in Water Resources at the University of Texas at Austin (UT CRWR) was funded by TCEQ to conduct computer-based modeling to determine the bacterial loading and reductions necessary to attain water quality standards. Subsequently Texas A&M University-Corpus Christi (TAMU-CC) conducted bacterial source tracking (BST) with funding from Texas General Land Office (TGLO) and the Coastal Bend Bays and Estuaries Program (CBBEP) to determine actual sources of bacteria.

Due to the findings of the initial efforts of the TMDL and concerns voiced by stakeholders in the watershed, Texas AgriLife Extension Service was awarded a Clean Water Act § 319(h) Nonpoint Source Grant from the Texas State Soil and Water Conservation Board (TSSWCB) and the U.S. Environmental Protection Agency. The overall goal of this project was to improve water quality in Copano Bay and its tributaries by increasing awareness of water quality issues throughout the watershed. This increased awareness was to be accomplished by providing education and demonstrations for land and livestock owners in the watershed on best management practices (BMPs) to decrease or prevent bacteria from entering waterways.

Through creation of a project website, 52 educational programs, and nine one-on-one consultations over the span of the project, we have reached 5,408 residents in and around the Copano Bay watershed. Additionally, through this project all data collected for the initial TMDL efforts was re-evaluated and findings were presented in the “Task 2 Report.” Project members developed a curriculum for horse owners, “A Guide to Good Horsekeeping” that addressed BMPs specific to horse operations. Land and livestock owners who had already implemented BMPs or were interested in implementing BMPs were given a participation certificate.

Problem/Need Statement

Data assessed in 2002 showed that Copano Bay was not suitable for harvesting oysters because of elevated bacteria concentrations. In response to these conditions, TCEQ initiated a TMDL to determine the sources of fecal coliform bacteria and the measures necessary to restore the oyster waters use in Copano Bay. In 2004, the tidal segments of the Aransas and Mission rivers were added to the TMDL as a result of their listing on the 2004 *303(d) List* for contact recreation. The goal of the TMDL is to determine the load of bacteria that Copano Bay can receive and still support its designated uses and allocate reductions among all the potential sources of bacteria in the watershed.

TCEQ contracted with the Center for Research in Water Resources at the University of Texas at Austin to conduct computer based modeling to assess bacteria loading to Copano Bay and load reductions needed to meet the oyster water standard. Preliminary conclusions, prior to initiation of this project, from this model estimated that bacteria from livestock must be reduced 90% to meet the contact recreation standard in the tidal segment of the Mission River. The model also estimated that an 85% reduction in bacteria from livestock was needed to meet the contact recreation standard in the tidal segment of the Aransas River. Finally, the model predicted that to meet the oyster water standard in the Bay, a 15% reduction in bacteria loading from livestock was needed in the Aransas River and a 20% reduction was needed in the Mission River. Additional reductions have been proposed for wastewater treatment plant discharges and urban runoff.

Results of bacterial source tracking performed by Texas A&M University-Corpus Christi indicates that 22% of the bacteria isolates in the bay corresponded with human sources, 20% from cattle, 35% from horses, 21% from ducks, and 1% from wildlife and gulls.

As a result of these preliminary findings, a number of measures were taken by the state. First, TCEQ funded a watershed coordinator to develop a TMDL-

Implementation Plan for the Copano Bay watershed. TSSWCB is working with the Nueces River Authority and performing additional routine and targeted water quality monitoring to provide better information for the TMDL and Implementation Plan development processes. Finally, the Texas Water Resources Institute (TWRI) and AgriLife Extension, with this project, are increasing awareness of the water quality issues throughout the watershed and providing educational programs and demonstrations for landowners and livestock owners in the watershed on practices that decrease or prevent bacteria from entering waterways.

General Project Description

The goal of this project was improve the water quality in Copano Bay and its tributaries by increasing awareness of the water quality issues in the watershed and providing educational programs and demonstrations for landowners and livestock owners in the watershed on practices they can implement to decrease or prevent bacteria from entering waterways. This increased awareness of water quality issues and BMPs to address them is expected to lead to greater implementation of BMPs in the watershed.

The educational project covered all counties in the Copano Bay watershed, but focused primarily on Aransas, Bee, Goliad, Refugio and San Patricio counties. This project was coordinated with the ongoing TMDL, upcoming TMDL-Implementation Plan development, and the proposed monitoring activities to provide the necessary support to these activities as well as the most up-to-date information on these activities to landowners as part of the educational programs. This project was also coordinated with TSSWCB project 06-05, *Lone Star Healthy Streams*, to deliver educational programs and materials developed by that project to cattlemen in the watershed on measures they can take to reduce bacteria from entering streams.

TWRI led and coordinated this project. TWRI maintains excellent coordination among federal, state and local agencies and entities, ensuring effective performance. TWRI supplies all project deliverables to the TSSWCB project manager. Finally, TWRI and AgriLife Extension cooperated with and involved Soil and Water Conservation Districts (SWCDs), Natural Resource Conservation

Service (NRCS), and TSSWCB field representatives in all project activities, as appropriate.

AgriLife Extension has (1) assembled and evaluated existing information, (2) developed needed educational programs and (3) delivered educational programs to improve water quality in the watershed. Through AgriLife Extension's efforts to collect and evaluate existing information, needed data was assembled to improve the TMDL, help develop the TMDL-Implementation Plan (I-Plan), and develop needed education programs. AgriLife Extension assembled and assessed existing data on livestock, deer, and feral hog number and distribution in the watershed; investigated published bacteria loading coefficients from cattle and other livestock; performed a comparison for the bacteria levels present in Copano Bay to other coastal areas in Texas; and performed an evaluation of the historical bacterial levels in Copano Bay.

Through this project, AgriLife Extension has also developed educational curriculum for horse owners that delivers current knowledge and training on measures they can take to reduce bacteria runoff.

Finally, AgriLife Extension delivered educational programs to landowners throughout the watershed. Result demonstrations, county programs, one-on-one landowner assistance, BMP exhibits, Ag Tours, publications and other educational meetings have been used to reach the widest array of producers and residents possible in the watershed. Nontraditional audiences, including new and absentee landowners, have also been targeted by many of these programs. Specific educational programs have been targeted to small landowners (Urban Rancher), cattlemen (Lone Star Healthy Streams), horse owners (developed through this project), and the public.

TWRI and AgriLife Extension have documented project participation at all events and meetings. Selected programs have pre- and post-assessment surveys where knowledge learned was gauged. Follow-up surveys have been used to gauge implementation of BMPs.

Local media was used to promote events, and publications have promoted various BMPs to landowners and natural resource professionals. These efforts increased communication, maintaining frequent, periodic technology transfer between natural resource professionals and agricultural landowners. AgriLife Extension used its already developed resources and delivery system to educate producers on improved management and production techniques. Appropriate material resulting from this program was posted to the project website.

COPANO BAY WATERSHED EDUCATION

The Copano Bay Education Program had many avenues of distribution. A project website went online in the third quarter and can be found at http://copanobay-wq.tamu.edu. This website has currently been visited by approximately 920 unique individuals who are able to view past presentations/pictures held in watershed, quarterly reports, project description, and project personnel contact information. There have been 34 educational programs either put together by AgriLife Extension or participated in by AgriLife Extension that have reached more than 3,567 residents in and around the watershed. AgriLife Extension Agents meet daily with producers in the watershed and discuss or address a variety of issues that all have an impact on water quality.

2007 Outreach

The Nueces/San Patricio counties 2007 Advanced Beef, Pasture and Range Short Course was held in Corpus Christi on April 24, 2007. Dr. Wayne Hanselka with AgriLife Extension presented "Grazing Strategies to Improve Water Quality and Water Use Efficiency" to approximately 25 producers.

The Bee/Goliad/Refugio counties 2007 Advanced Beef, Pasture and Range Short Course was held in Blanconia on May 16, 2007. Thirty-two producers attended.

A San Patricio County Crop Tour on June 6, 2007 had 60 participants who learned about feral hog management options from Dr. Jim Gallagher with AgriLife Extension.

Forty-eight samples were taken from irrigation and domestic wells in San Patricio County during a Water Testing Program sponsored by San Patricio county office of AgriLife Extension on May 24, 2007.

In Aransas County on June 19, 2007, "Six Layers of Landscape Design" was presented to 28 people. Information on proper landscape design, emphasizing the use of native and adaptive habitats improving water quality in the bays, was given.

A Homeowner's Guide to Composting and Irrigation workshop was held in Aransas county June 19, 2007. Compost bins and irrigation audit kits were given to 25 attendees who learned how runoff pollution from homeowners can affect water quality in the bays.

A presentation on South Texas Ranching was given to 50 area ranchers in Victoria on September 28, 2007. Dr. Joe Paschal with AgriLife Extension discussed the issues surrounding the Copano Bay project and the next steps to be taken. The Coastal Bend Feral Hog Management Symposium was held October 11, 2007 at the Welder Wildlife Refuge. Information on how hogs impact water quality and methods available to reduce this problem were given to 59 participants.

More than 100 Refugio county eighth graders attended the Earth Science Field Day on October 30, 2007. The Refugio County AgriLife Extension agent and Extension assistant discussed point and nonpoint source pollution and demonstrated effects using a watershed model.

A rangeland symposium focused on watershed management was held for Refugio/Goliad/Bee counties on December 7, 2007. The AgriLife Extension assistant gave an overview of the Copano Bay project to 27 area producers.

During the fourth quarter, two horse owner programs were presented in counties surrounding the watershed. Dr. Paschal spoke about the Copano Bay project and its impact and focused on grazing management and manure management to over 150 horse owners.

2008 Outreach

In January, the Texas and Southwestern Cattle Raisers Association (TSCRA) had its annual convention in Corpus Christi. Approximately 175 attended the Range Management Track where Dr. Hanselka presented information concerning best management practices for rangeland and pastures.

In January 2008, Aransas County residents had the opportunity to conduct soil testing on their property and participate in a fertilization BMP campaign. Dr. Tony Provin discussed runoff pollution and the degradation of Little Bay and Copano Bay with 70 homeowners participating in the event.

A Tri County Blanconia Field Day was held on May 9, 2008. Several topics related to watershed management were presented to 20 attendees.

The 54th annual Beef Cattle Short Course was held August 4–6, 2008 in College Station Texas. Though this location is well outside of the Copano Bay watershed, several ranchers from the watershed attended out of the 195 people in

attendance. Topics from the short course included proper grazing and its effect on land and water.

My Piece of Texas Grazing Workshop was held October 1, 2008 in Beeville. presentations about proper grazing management were made to the 27 producers attending.

The South Texas Farm and Ranch Show was held October 22–23, 2008 in Victoria. A variety of topics were presented by AgriLife Extension and 100 brochures covering horses and water quality and an overview of the *Guide to Good Horsekeeping* publication were distributed.

Mailers addressing four different topics concerning watershed health were sent to 63 area middle school and high school agriculture, science, and biology teachers in November 2008.

Bee/Goliad/Refugio counties had a Tri County CEU day in Beeville on December 5, 2008. Forty producers listened to a PowerPoint presentation on "A Guide to Good Horsekeeping" and were introduced to the Lone Star Healthy Streams program. The publication, *Environmental Management of Grazing Lands,* was distributed as well.

A general water quality presentation was given to two Sinton High School aquatic science classes on December 12, 2008 with approximately 40 students attending.

2009 Outreach

A field day, Getting the Most from your Rangeland Watershed, was held at the Welder Wildlife Refuge March 18, 2009. Fifteen attendees listened to a variety of talks including horse manure management, proper stocking rates, prescribed burning, grazing behavior and the effect of stocking rates on bacteria runoff.

A general water quality awareness poster board was made available at the Earth Day Bay Day celebration on April 17, 2009 in Corpus Christi. The posters gave an overview of the TMDL in Copano Bay and ways the typical homeowner can improve water quality in the bays, then 100 dog feces pick up bags were distributed as a reminder.

A general water quality awareness poster board was made available at Bayfest, September 26–27, 2009 in Corpus Christi. The posters gave an overview of what bacteria in our bays means and what the typical homeowner can do to improve water quality in the Bays, then 200 dog feces pick up bags were distributed as a reminder.

The 2009 San Patricio County Ag in the Classroom was held in Sinton, on October 20–21, 2009. Approximately 950 schoolchildren attended and had a brief overview of responsible horse and cattle keeping.

Recovering from Drought for Horse Owners program was held in Beeville November 17, 2009. The 25 attendees were presented with "A Guide to Good Horsekeeping." Information on managing pastures to recover from drought was covered.

2010 Outreach

A poster board, "Take Pride in Your Projects, Take Pride in Your Pens," was taken to all junior livestock shows in the Copano Bay watershed. A variety of publications concerning water quality and how livestock owners can improve it were made available with 124 publications distributed.

A partnership was formed with the Coastal Bend Bays and Estuaries program (CBBEP) and a water quality trail talk was given to 45 middle school children in Sinton, Texas on March 8, 2010.

The Nueces/San Patricio counties Coastal Bend Pasture Symposium was held March 12, 2010 in Corpus Christi. Approximately 45 producers learned about a variety of pasture management techniques, including stocking rate determination to maintain forage stand and water quality. A Livestock and Wildlife BMP workshop was presented to 15 attendees at the Welder Wildlife Refuge on April 6, 2010. Best management practices for cattle, horses and wildlife were discussed.

On April 5–6, 2010, 175 middle school children attended a water quality trail tour at the Nueces Delta Preserve.

An educational poster board covering the impacts of excess bacteria in our bays was presented at Earth Day Bay Day in Corpus Christi on April 17, 2010 with 300 dog feces pick-up bags distributed as a reminder/promotional item.

May 5–7, 2010 125 middle school children attended a water quality trail tour at the Nueces Delta Preserve.

A tri county pasture workshop covering weed control was held in Blanconia, Texas on May 13 with approximately 40 producers attending.

A horse owner workshop was held in Sinton, Texas on May 20, 2010 with24 people attending. They learned about composting, rainwater harvesting, weed ID, pasture management and nutrition.

The Mission Aransas NERR put on a very informative “Dynamics of Copano Bay” discussion where 50 area residents discussed the bacteria issue with leading scientists working on different aspects of the bay.

Introduction

The purpose of Task 2 was to collect and evaluate existing information to improve the TMDL, help develop the TMDL-Implementation Plan, and develop needed education programs. The sub-tasks were addressed as follows:

- AgriLife Extension hired an extension assistant to compile existing information, develop education curriculum and lead all outreach program efforts.
- AgriLife Extension assembled and assessed existing data on livestock, deer, and feral hog numbers and distribution in the watershed.
- AgriLife Extension investigated published bacteria loading coefficients from cattle and other livestock to determine the most appropriate coefficients for use in the Copano Bay watershed.
- AgriLife Extension performed a comparison of the bacteria levels present in Copano Bay to other coastal areas in Texas to evaluate the most realistic endpoint.
- AgriLife Extension performed an evaluation of the historical bacterial levels in Copano Bay to assess any potential trends or changes that have occurred.

Summary of Task 2 Report

Copano Bay is a 65-square-mile estuary located northeast of Corpus Christi, Texas. Port Bay, Mission Bay, the Aransas River arm, and the eastern shoreline (Copano Creek arm) of the Bay were first identified in 1998 as impaired for elevated bacteria; they remain on the 2008 *Texas §303(d) List*. According to the 2006 Texas Water Quality Inventory – Basin Assessment Data by Segment (TCEQ 2008), the Texas water quality standard for *Enterococcus* and fecal coliform levels in bays and estuaries larger than 28 square miles are 14 and 8 cfu/100 ml, respectively. In comparison, the *Enterococcus* and fecal coliform levels in Copano Bay were 17 and 4 cfu/100 ml, respectively. No statistically significant trends were observed in fecal coliform levels at two long-term monitoring sites in Copano Bay (FM 136 and SH 35). Based on TCEQ fecal coliform data collected since 1975, the only period that Copano Bay at SH 35 has been impaired is the period of 1990–1995. However,

this is not the case for Copano Bay at FM 136. Copano Bay at FM 136 has been impaired almost continuously since monitoring began in 1973 with the exception of the periods of 1980–1985 and 1995–2000.

Livestock and wildlife populations were evaluated to assess potential sources of the fecal coliform. Deer were by far the most populous category in terms of sheer numbers. However, in terms of animal units, cattle were the most populous category. An estimated 66,348 cattle (AU) live within the watershed. As would be expected, application of published loading coefficients to the calculated animal units in the watershed indicate that as much as 86% of the livestock and wildlife bacteria production may originate from cattle and deer with cattle contributing approximately 64% and deer contributing 22%. It should be noted that all wildlife categories were not evaluated, which can have a significant impact on the findings of this study. Waterfowl (migratory and non-migratory) and other wildlife species can be a significant source of loading, especially at localized sites in the bay, and need to be included in future TMDL work.

The Task 2 Report can be found in Appendix A.

Introduction

There is a wealth of knowledge regarding management of agricultural livestock, a category that still includes horses in Texas. However, horses and their owners for the most part, exist in a space that is neither livestock nor companion animal. Therefore, owners are left without access to the educational library traditional livestock operations use and companion animal information sources. While important, this source tends to focus on management of the horse itself and not the land on which they are kept. This guide is intended to bring to light issues often overlooked by horse owners (from breeding operations to horses kept for pleasure) and provide information on best management practices that decrease their impact on natural resources.

A good percentage of people who involve themselves with horses do not start as professional horsemen and horsewomen. Many start as parents granting the wish of their children, adults who have access to discretionary income, and absentee owners who invest in the industry. Horse ownership mandates a unique set of management solutions that a person who just loaded their first purchase in the trailer may not be aware of. The following is a list of topics in which horse owners need to become proficient to do the best they can for their animals and the land they manage.

Knowledge of feeding management, manure management, pasture management facilities management and small acreage management are important because horses kept for work or pleasure are not always the “free ranging” animal of the plains where they evolved. They are often kept in a restricted area, pasture, or pen where they can develop digestive and behavioral disorders, concentrate manure, degrade pasture quality and can impact surrounding ecological areas and watersheds if care is not taken. These topics were dicussed in *A Guide to Good Horsekeeping*.

A Guide to Good Horsekeeping can be found in Appendix B.

Conclusion

Texas is projected to have exponential population growth in the near future while at the same time an adequate water supply is projected to decline. This forcast

makes water conservation and protection all the more important. As the population increases, it is logical to expect more development and fractionation of large tracts of land, which will contribute to runoff and decrease the ability of the land to filter runoff effectively. Increasing numbers of bacteria will continue to find a way into our surface waters as higher stocking rates are introduced to the land whether for recreational or commercial purposes. While this guide is solely focused on the equine contribution, it will also come from sources such as watewater treatment facilities and failing septic tanks as well as domestic pets in suburban areas. This confirms the need to educate all aspects of society on the importance of maintaining and conserving the quality of water necessary for good health.

As we have discussed, there are many important aspects to horse care that extend beyond having your hands directly on the horse. Procuring feed, managing manure, maintaining pasture, and upkeep on facilities can all take a considerable amount of time and effort. The collective impact of mismangement of equine facilities can be environmentally harmful. The management practices that minimize these impacts will result in a farm that is healthy, saves money, and is aesthetically pleasing. These qualities will pay exponentially over the years your farm operates.

CONCLUSION

During the four years of this project, much work was done in a variety of areas. Education was the biggest portion of the grant under which we reached 5,408 producers through 52 events. The residents reached in the watershed learned about the existance of the problem, measures that can be taken to fix it, and ongoing efforts being made by all participating entities.

Another portion of this grant consisted of evaluating existing programs, data obtained in initial TMDL efforts, and gathering historical information of Copano Bay and others along the gulf coast. This information is summarized in the Task 2 Final Report in Appendix A.

The publication, *A Guide to Good Horsekeeping*, was developed to provide horse owners with a combination of production and environmental training enabling them to better manage and protect their valuable land and water resources. This can be found in Appendix B.

APPENDIX A

Task 2 Report

AgriLIFE RESEARCH & EXTENSION
Texas A&M System

TEXAS A&M UNIVERSITY

COLLEGE OF AGRICULTURE AND LIFE SCIENCES

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Education Program for Improved Water Quality in Copano Bay

Task Two Report

Prepared for:
Texas State Soil and Water Conservation Board

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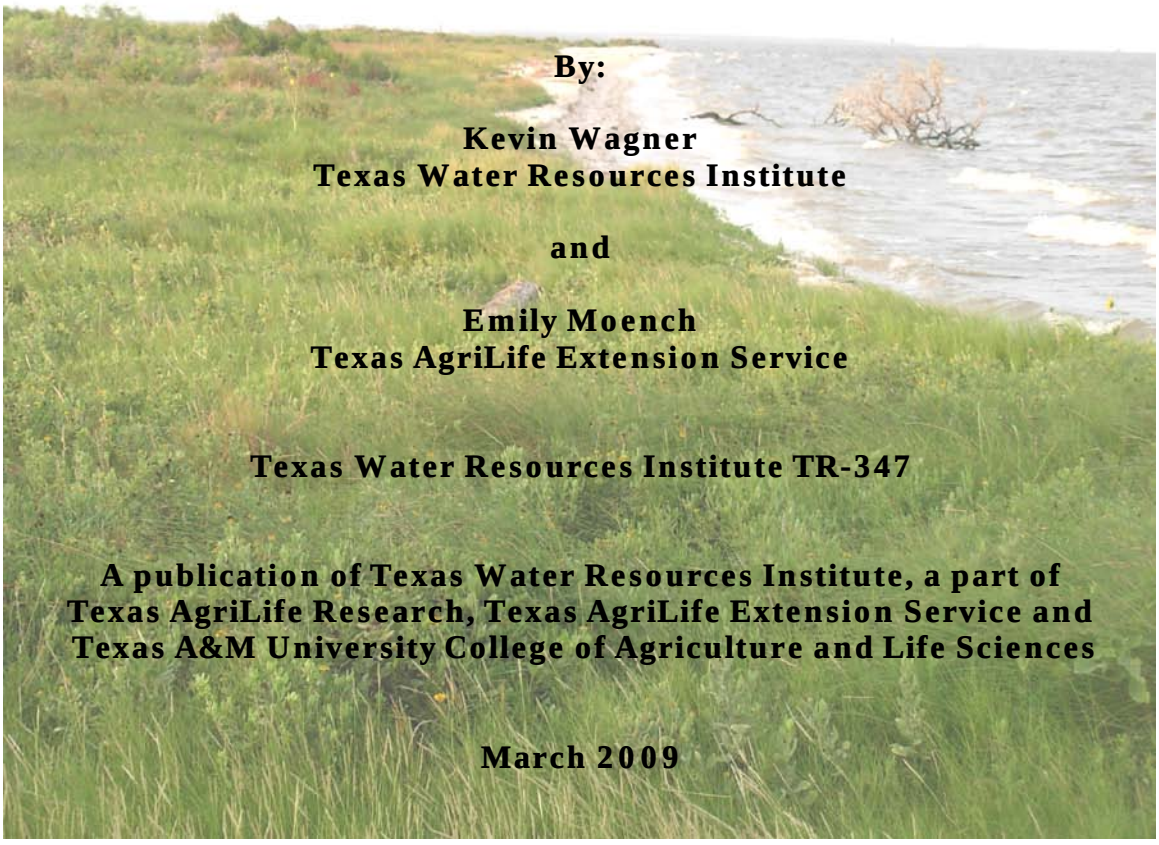

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LIST OF ABBREVIATIONS

ac.....acre
AFO.....Animal Feeding Operation
APHIS.....USDA Animal and Plant Health Inspection Service
ASAE.....American Society of Agricultural Engineers
AU.....animal units
BMPs.....best management practices
BST.....bacteria source tracking
CAFO.....Confined Animal Feeding Operation
CBBEP.....Coastal Bend Bays and Estuaries Program
cfu.....colony forming units
Co.....county
EPA.....U.S. Environmental Protection Agency
Extension.....Texas AgriLife Extension Service
GLO.....Texas General Land Office
mi^2.....square miles
mL.....milliliter
NASS.....USDA National Agricultural Statistics Service
NLCD.....National Land Cover Data
NRA.....Nueces River Authority
NRCS.....Natural Resources Conservation Service
RCAP.....Regional Coastal Assessment Program
SWCD.....Soil and Water Conservation Districts
TAMU.....Texas A&M University
TAMU-CC....Texas A&M University-Corpus Christi
TCEQ.....Texas Commission on Environmental Quality
TMDL.....Total Maximum Daily Load
TPWD.....Texas Parks and Wildlife Department
TSSWCB.....Texas State Soil and Water Conservation Board
TWRI.....Texas Water Resources Institute
USDA.....U.S. Department of Agriculture
UT-CRWR....Center for Research in Water Resources at the University of Texas - Austin
WWTF.....wastewater treatment facility

INTRODUCTION

Project Goal

The *Education Program for Improved Water Quality in Copano Bay* is funded through a Clean Water Act §319(h) Nonpoint Source Grant from the Texas State Soil and Water Conservation Board (TSSWCB) and the U.S. Environmental Protection Agency (TSSWCB Project 06-08). The goal of the project is to improve water quality in Copano Bay and its tributaries by increasing awareness of the water quality issues throughout the watershed and providing education and demonstrations for land and livestock owners on methods to decrease or prevent bacteria from entering the waterways.

Project Scope

The project focuses on the entire Copano Bay watershed, which encompasses portions of Aransas, Bee, Goliad, Karnes, Refugio, and San Patricio counties (figure 1). Although the watershed also encompasses a portion of Live Oak County, the county was excluded because it contains less than 1 percent of the watershed (table 1).

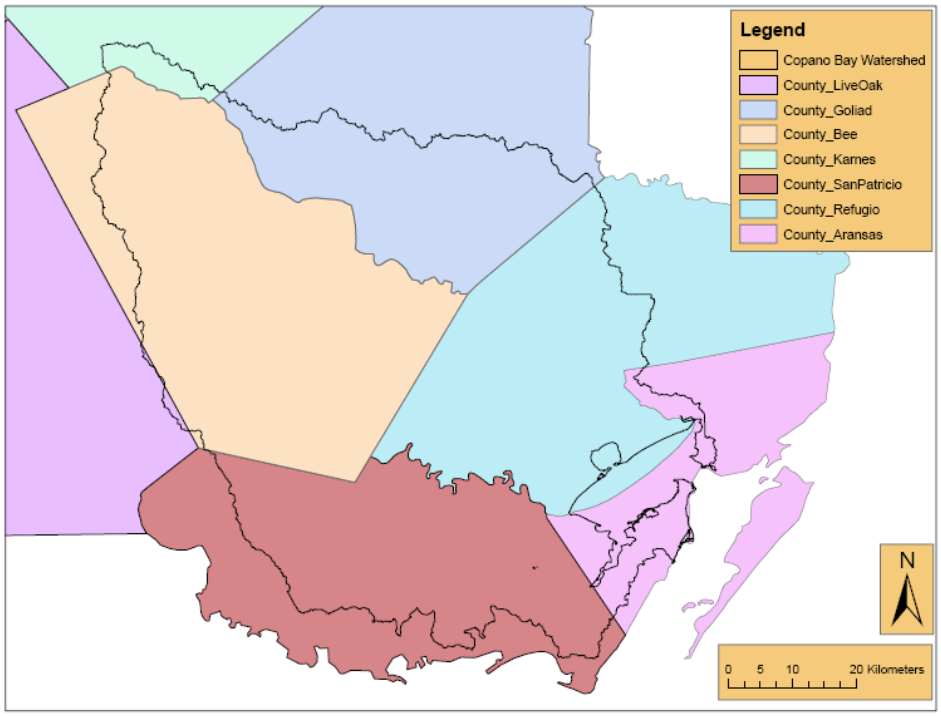

Figure 1. Counties encompassed in the Copano Bay watershed

Table 1. Number of acres and percentage of each county in the Copano Bay watershed

County	Land-Based acres by Co.	Acres of Co. in Watershed (ac)	% of Co. in Watershed	% of Watershed by Co.
Aransas	150,617	52,307	34.7%	3.7%
Bee	564,052	499,755	88.6%	36.0%
Goliad	550,124	208,049	37.8%	15.0%
Karnes	483,079	18,126	3.7%	1.3%
Live Oak	690,618	3,043	0.4%	0.2%
Refugio	504,568	316,345	62.7%	22.8%
San Patricio	452,907	291,106	64.3%	21.0%
Total	3,395,965	1,388,731	-	100.0%

According to the 2001 National Land Cover Data (NLCD) (figure 2), land use is dominated by shrub land, pastureland, and cropland. The watershed is primarily rural with only 5.5 percent of the watershed developed. The northern three-quarters of the Copano Bay watershed are dominated by rangeland, while the southern quarter of the watershed is dominated by cropland (table 2).

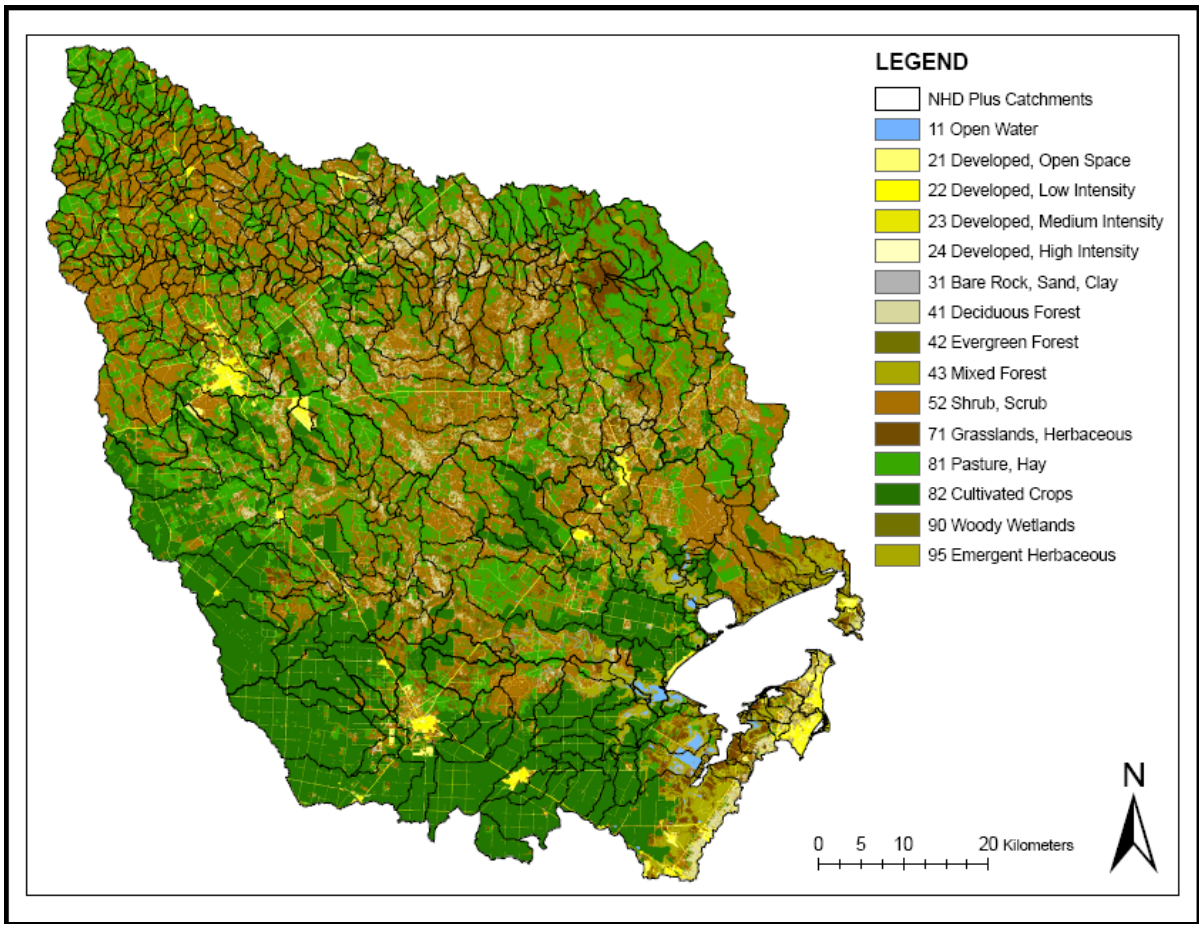

Figure 2. Land use in the Copano Bay watershed (2001 NLCD)

Table 2. Number of acres of each type of land use and corresponding percentages in the Copano Bay watershed according to the 2001 NLCD

Land use Classification	Area (ac)	% Watershed
Open Water	6,794	0.49%
Developed Open Space	53,312	3.84%
Developed Low Intensity	16,473	1.19%
Developed Medium Intensity	4,888	0.35%
Developed High Intensity	1,067	0.08%
Bare Rock/Sand/Clay	4,082	0.29%
Deciduous Forest	67,256	4.84%
Evergreen Forest	4,930	0.35%
Mixed Forest	423	0.03%
Shrub, Scrub	438,417	31.57%
Grasslands/Herbaceous	62,791	4.52%
Pasture/Hay	340,081	24.49%
Cultivated Crops	315,781	22.74%
Woody Wetlands	26,344	1.90%
Emergent Herbaceous	46,092	3.32%
Total	1,388,731	100%

Project Background

Copano Bay and its tributaries, the Mission and Aransas rivers, are identified on the *Texas §303(d) List* as impaired by elevated levels of bacteria. Copano Bay (Segment 2472) was first placed on the *Texas §303(d) List* in 1998 due to the exceedance of water quality standards established to protect oyster waters use. Water quality standards for oyster waters use are as follows:

- The median concentration of fecal coliform bacteria samples should not exceed 14 colony forming units per 100 mL of water (cfu/100 mL).
- No more than 10 percent of fecal coliform samples should exceed 43 cfu/100 mL.

Enterococcus levels in the tidal sections of the Mission and Aransas rivers exceed water quality standards established to protect swimming and other recreational activities. The tidal sections of the Mission (Segment 2001) and Aransas (Segment 2003) rivers were first placed on the *Texas §303(d) List* in 2004. Water quality standards for contact recreation use in tidal waters are as follows:

- The geometric mean of *Enterococci* samples should not exceed 35 cfu/100 mL.
- No more than 25 percent of *Enterococci* samples should exceed 89 cfu/100 mL.

While the upstream, non-tidal portions of both the Mission and Aransas rivers are not impaired, one tributary, Aransas Creek (Segment 2004A), was first placed on the *Texas §303(d) List* in 2006 for not supporting swimming and other recreational activities. Water quality standards for contact recreation in freshwater are as follows:

- The geometric mean of *E. coli* samples should not exceed 126 cfu/100 mL.
- No more than 25 percent of *E. coli* samples should exceed 394 cfu/100 mL.

All four of these water bodies (Segments 2472, 2001, 2003, and 2004A) continue to be identified as impaired for elevated bacteria on the 2008 *Texas §303(d) List*. Many steps have been taken in response to these findings. The Texas Commission on Environmental Quality (TCEQ), initiated development of a Total Maximum Daily Load (TMDL) in September 2003 to determine the sources of the bacteria and the measures needed to lower bacteria levels to those suitable for oyster harvesting/consumption in Copano Bay and contact recreation in the Mission and Aransas rivers. Many agencies, organizations, and landowners have been involved in this TMDL project.

The Center for Research in Water Resources at The University of Texas at Austin (UT-CRWR) conducted a computer modeling study, with funding from TCEQ, to determine bacterial loading in the watershed and reductions needed to attain water quality standards. Preliminary findings suggested that bacteria originating from livestock needed to be reduced by 85 percent in the tidal portion of the Aransas River and 90 percent in the tidal portion of the Mission River to achieve acceptable bacteria levels supporting contact recreation. To meet oyster water standards, the computer modeling study suggested a 15 percent reduction in bacteria originating from livestock was necessary in the Aransas River and a 20 percent reduction was needed in the Mission River. Urban runoff and wastewater treatment facility (WWTF) effluent discharge was also implicated in the computer modeling study (Gibson 2006).

Texas A&M University-Corpus Christi (TAMU-CC) conducted bacterial source tracking (BST) with funding from the Texas General Land Office (GLO) and the Coastal Bend Bays and Estuaries Program (CBBEP) to determine the source of bacteria in Copano Bay. Fourteen monitoring stations in the bay were sampled between October 2003 and May 2004. TAMU-CC found the highest numbers of bacteria were collected from stations surrounding the inflows from Copano Creek, Mission River, and Aransas River, particularly after rainfall. Additional findings indicated that 22 percent of bacteria in Copano Bay originated from human sources, 20 percent from cattle, 35 percent from horses, 21 percent from ducks, and 1 percent from nonavian wildlife and gulls (Mott and Lehman 2005).

Work continues on developing the TMDL. The Nueces River Authority (NRA) is conducting further targeted water quality monitoring with funding from the TSSWCB. UT-CRWR is conducting additional innovative computer modeling with funding from TCEQ. TAMU-CC is conducting additional BST on the tidal portions of the rivers with funding from GLO and CBBEP. The Texas Water Resources Institute (TWRI) and Texas AgriLife Extension Service (Extension) are implementing education programs to increase water quality awareness in the watershed and are also conducting demonstrations on best management practices (BMPs) to decrease or prevent bacteria from livestock from reaching waterways. Local soil and water conservation districts (SWCD) and U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) representatives are involved in all activities in the watershed.

This report summarizes the information compiled to fulfill Task 2 of the *Education Program for Improved Water Quality in Copano Bay* (TSSWCB project 06-08) including:

- existing data on livestock, deer, and feral hog numbers and distribution in the watershed;
- published bacteria loading coefficients from cattle and other livestock;
- comparison of the bacteria levels in Copano Bay to other coastal areas in Texas;
- historical bacteria levels and trends in Copano Bay.

SUBTASK 2.2
LIVESTOCK, DEER, AND FERAL HOG POPULATIONS AND DISTRIBUTION

BST has traced bacteria in Copano Bay to humans, horses, cattle, wildlife, ducks, and gulls. To better assess loading from livestock and wildlife in comparison to these preliminary findings, the number of the major livestock and wildlife categories were estimated.

There are two major sources of agriculture statistics for livestock used to obtain these estimates: the *Texas Agricultural Statistics* (NASS 2004-2008) and the federal *Census of Agriculture* (NASS 2002). Both data sets are compiled and maintained by USDA National Agricultural Statistics Service (NASS). *Texas Agricultural Statistics* are compiled yearly, or monthly, in some cases, by the NASS Texas Field Office in partnership with the Texas Department of Agriculture; the federal *Census of Agriculture* is conducted by NASS every five years. The 2002 *Census of Agriculture* is the most recent, available data; the information from the 2007 *Census of Agriculture* is not expected to be released until February 2009. Texas Parks and Wildlife Department (TPWD) biologists contributed information for deer populations. A study by USDA Animal and Plant Health Inspection Service (APHIS) Wildlife Services and Caesar Kleberg Wildlife Research Institute at Texas A&M University-Kingsville evaluating population estimation techniques for feral hogs was used for extrapolating data to estimate feral hog numbers. All population estimates were converted to animal units (AU) for comparability.

The first step to develop livestock and wildlife population estimates was to determine the number of animals in each county, then multiply that number by the percentage of each county that lies in the watershed. Finally, the estimated numbers were converted to AU to yield the total number of animal units for each livestock and wildlife category assessed. This method was applied to all livestock and deer categories; however, a different method was used to estimate feral hog populations. Additional information on population estimation methods are provided in the following sections.

Cattle

County cattle numbers (tables 3 and 4) in the watershed were estimated using the five-year average number of beef cows as published by the 2004–2008 *Texas Agricultural Statistics*. “Beef cows” are most representative of AU of cattle in watersheds like Copano Bay where cow/calf operations are predominant; thus, an AU conversion of one can be used.

Next, estimated cattle numbers from table 4 (66,348) were distributed throughout the watershed using range site stocking rate estimates from NRCS and land use (table 5).

Table 3. Estimated beef cow numbers by county (*Texas Agricultural Statistics)*

County	2004	2005	2006	2007	2008
Aransas	2,000	1,000	1,000	1,000	1,000
Bee	32,000	29,000	30,000	32,000	45,000
Goliad	39,000	37,000	39,000	45,000	44,000
Karnes	45,000	42,000	41,000	43,000	39,000
Refugio	24,000	23,000	23,000	24,000	23,000
San Patricio	7,000	7,000	7,000	7,000	7,000
Total	149,000	139,000	141,000	152,000	159,000

Table 4. Estimated beef cows in the Copano Bay watershed based on 2004 - 2008 county averages

County	County Average	Percent in Watershed	Beef Cows	AU Conversion	Cattle (AU)
Aransas	1,200	34.7%	417	1	417
Bee	33,600	88.6%	29,766	1	29,766
Goliad	40,800	37.8%	15,418	1	15,418
Karnes	42,000	3.7%	1,571	1	1,571
Refugio	23,400	62.7%	14,674	1	14,674
San Patricio	7,000	64.3%	4,502	1	4,502
Total	148,000	-	66,348	1	66,348

Table 5. Estimated cattle distribution in the Copano Bay watershed

Land Use Classification	Area (ac)	SR (ac/ AU)	Cattle (AU)
Open Water	6794		
Developed Open Space	53312		
Developed Low Intensity	16473		
Developed Medium Intensity	4888		
Developed High Intensity	1067		
Bare Rock/Sand/Clay	4082		
Deciduous Forest	67256	20.0	3,363
Evergreen Forest	4930	20.0	246
Mixed Forest	423	20.0	21
Shrub, Scrub	438417	30.0	14,614
Grasslands/Herbaceous	62791	15.4	4,066
Pasture/Hay	340081	7.7	44,038
Cultivated Crops	315781		
Woody Wetlands	26344		
Emergent Herbaceous	46092		
TOTAL	1,388,731		66,348

Horses

Because data were not available in *Texas Agricultural Statistics* for horses in the counties in the Copano Bay watershed, horse numbers are based on the 2002 USDA Census of Agriculture (table 6).

Table 6. Estimated horse numbers in the Copano Bay watershed (2002 USDA Census of Agriculture)

County	County Total	Percent in Watershed	Horses All	AU Conversion	Horses (AU)
Aransas	46	34.7%	16	1.25	20
Bee	1,391	88.6%	1,232	1.25	1,540
Goliad	887	37.8%	335	1.25	419
Karnes	973	3.7%	36	1.25	45
Refugio	692	62.7%	434	1.25	543
San Patricio	662	64.3%	426	1.25	533
Total	4,651	-	2,479	-	3,100

Goats

The 2005–2008 *Texas Agricultural Statistics* were used for estimating goat numbers. In Bee, Goliad, and Karnes Counties, the *Texas Agricultural Statistics* provided county estimates annually (table 7); however, because goat numbers for Aransas, Refugio, and San Patricio were so low, they were reported by district. District 85, which includes 5 counties, was reported to have an estimated 2,000 goats throughout the district from 2005–2008; thus, it was assumed that there were 400 goats in each county in the district.

Table 7. Estimated goat numbers in Copano Bay watershed (2005 - 2008 *Texas Agricultural Statistics*)

[1] 4 year average goat numbers in county

[2] goat numbers in county estimated from District 85 numbers

County	County Total	Percent in Watershed	Goats All	AU Conversion	Goats (AU)
Aransas[2]	400	34.7%	139	0.17	24
Bee[1]	2,775	88.6%	2,458	0.17	418
Goliad[1]	1,125	37.8%	425	0.17	72
Karnes[1]	2,175	3.7%	81	0.17	14
Refugio[2]	400	62.7%	251	0.17	43
San Patricio[2]	400	64.3%	257	0.17	44
Total	7,275	-	3,611	-	615

Sheep

Because data were not available in *Texas Agricultural Statistics* for sheep in the counties in the Copano Bay watershed, sheep numbers are based on the 2002 USDA Census of Agriculture (table 8).

Table 8. Estimated sheep numbers in the Copano Bay watershed (2002 USDA Census of Agriculture)

County	County Total	Percent in Watershed	Sheep All	AU Conversion	Sheep (AU)
Aransas	0	34.7%	0	0.2	0
Bee	670	88.6%	594	0.2	119
Goliad	162	37.8%	61	0.2	12
Karnes	327	3.7%	12	0.2	2
Refugio	71	62.7%	45	0.2	9
San Patricio	335	64.3%	215	0.2	43
Total	1,565	-	927	-	185

Domestic Hogs

Because data were not available in *Texas Agricultural Statistics* for swine in the counties in the Copano Bay watershed, hog numbers are based on the 2002 USDA Census of Agriculture (table 9).

Table 9. Estimated number of domestic hogs in the Copano Bay watershed (2002 USDA Census of Agriculture)

County	County Total	Percent in Watershed	Hogs All	AU Conversion	Hogs (AU)
Aransas	15	34.7%	5	0.25	1
Bee	113	88.6%	100	0.25	25
Goliad	69	37.8%	26	0.25	7
Karnes	21	3.7%	1	0.25	0
Refugio	22	62.7%	14	0.25	4
San Patricio	741	64.3%	477	0.25	119
Total	981	-	623	-	156

Poultry

There are no poultry CAFOs or AFOs in the watershed. Because data were not available in *Texas Agricultural Statistics* for poultry in the counties in the Copano Bay watershed, poultry numbers are based on the 2002 USDA Census of Agriculture (table 10).

Table 10. Estimated poultry numbers in the Copano Bay watershed (2002 USDA Census of Agriculture)

	Poultry	Aransas	Bee	Goliad	Karnes	Refugio	San Patricio	Total
County Totals	Layers	35	793	859	0	63	464	2214
	Pullets	0	136	75	272	0	595	1078
	Broilers	0	192	252	0	0	634	1078
	Turkeys	13	0	35	111	0	9	168
Percent in Watershed	-	34.7%	88.6 %	37.8%	3.7%	62.7%	64.3%	
Watershed Totals	Layers	12	703	325	0	40	298	1377
	Pullets	0	120	28	10	0	383	542
	Broilers	0	170	95	0	0	408	673
	Turkeys	5	0	13	4	0	6	28
AU Conversion	Layers/ Pullets/ Broilers	0.01	0.01	0.01	0.01	0.01	0.01	-
	Turkeys	0.018	0.018	0.018	0.018	0.018	0.018	-
Watershed AU	Layers	0	7	3	0	0	3	13
	Pullets	0	1	0	0	0	4	5
	Broilers	0	2	1	0	0	4	7
	Turkeys	0	0	0	0	0	0	0

Deer

TPWD county biologists contributed deer population data for each county. Average acres per deer were calculated from TPWD surveys. The deer density provided for each county was multiplied by the acres in each county to determine the total deer per county, which was then multiplied by the percent of the county in the watershed to determine the number of deer in the watershed. That final number was multiplied by 0.112 to determine the number of AUs (table 11). The overall deer density in the watershed is 15.6 ac/deer, which is comparable to the reported deer density in the Texas Hill Country of 15.4 ac/deer.

Table 11. Estimated deer numbers in the Copano Bay watershed based on Texas Parks and Wildlife Department county biologist estimates

County	Density (ac/deer)	Acres of Co. in Watershed (ac)	Total Deer	AU Conversion	Deer (AU)
Aransas	100	52,307	523	0.112	59
Bee	14.11	499,755	35,419	0.112	3,967
Goliad	12.4	208,049	16,778	0.112	1,879
Karnes	20	18,126	906	0.112	101
Refugio	20	316,345	15,817	0.112	1,771
San Patricio	15	291,106	19,407	0.112	2,174
Total			88,850	0.112	9,951

Feral Hogs

A published study (Reidy 2007) completed at the Welder Wildlife Refuge on feral hog population control estimated the density of feral hogs on the Refuge to be 33.3 acres per hog. This density was applied to all agricultural lands in the watershed to determine the total number of feral hogs in the entire watershed (table 12). It is estimated that there are **37,718 feral hogs** in the watershed. To help verify this estimate, another estimate of feral hogs was completed based on a study by the Texas A&M University Department of Veterinary Integrative Biosciences. This study (Rollo et al. 2007) estimated that there were 460,262 hogs in a 33-county area, including most of the counties in the Copano Bay watershed. It was estimated that there were 13,947 hogs per county on average (then applied to percentage of county within watershed) and **40,708 feral hogs** in the watershed. Finally in 1993, the Southeastern Cooperative Wildlife Disease Study (conducted by the College of Veterinary Medicine at the University of Georgia with funding from the USDA Animal and Plant Health Inspection Service) estimated that the feral hog density in the area was at least 10 feral hogs per square mile. Since Taylor (1991) estimated the feral hog population in Texas at approximately 1 million animals, the feral hog numbers in the state have doubled to 2 million hogs in 2004 (Mapston 2004). Based on a doubling of 10 hogs per square mile (i.e. 20 hogs per square mile) applied to 1,388,731 land acres in the watershed, it is estimated that there are **43,398 feral hogs** in the Copano Bay watershed.

Table 12. Estimated Copano Bay watershed feral hog numbers based on TAMU-Kingsville estimates

Land Use Category	Acres	Density (ac/hog)	Feral Hog Pop.	AU Conver-sion	Feral Hogs (AU)
Open Water	6,794				
Developed Open Space	53,312				
Developed Low Intensity	16,473				
Developed Medium Intensity	4,888				
Developed High Intensity	1,067				
Bare Rock/Sand/Clay	4,082				
Deciduous Forest	67,256	33.3	2,020	0.125	252
Evergreen Forest	4,930	33.3	148	0.125	18
Mixed Forest	423	33.3	13	0.125	2
Shrub, Scrub	438,417	33.3	13,166	0.125	1646
Grasslands/Herbaceous	62,791	33.3	1,885	0.125	236
Pasture/Hay	340,081	33.3	10,212	0.125	1277
Cultivated Crops	315,781	33.3	9,483	0.125	1185
Woody Wetlands	26,344	33.3	791	0.125	99
Emergent Herbaceous	46,092				
TOTAL	1,388,731		37,718		4,715

The average of the three methods is 40,608 with a standard deviation of ± 7 percent; thus, all three methods provide fairly consistent population numbers. This provides at least a marginal level of confidence in the estimated numbers of feral hogs in the watershed. For future modeling efforts in the watershed, the method using the in-watershed study results from the Welder Wildlife Refuge as shown in table 12 is recommended. To convert feral hog numbers to AU, the total feral hog population was multiplied by 0.125 AU equivalents. According to most sources, the average size of feral swine is 100-150 pounds. The middle of this range, 125 pounds, was selected as the mean weight and converted to AU by dividing by 1000 pounds.

Animal Population Estimates in the Copano Bay Watershed

Using the method described above, animal population estimates are as follows (table 13).

Table 13. Estimated numbers of livestock and wildlife in the Copano Bay watershed

	Aransas	Bee	Goliad	Karnes	Refugio	San Patricio	Total	AUs
Beef Cattle	417	29,766	15,418	1,571	14,674	4,502	66,348	66,348
Horses	16	1,232	335	36	434	426	2,479	3,100
Goats	139	2,458	425	81	251	257	3,611	615
Sheep	0	594	61	12	45	215	927	185
Hogs	5	100	26	1	14	477	623	156
Layers	12	703	325	0	40	298	1,377	13
Pullets	0	120	28	10	0	383	542	5
Broilers	0	170	95	0	0	408	673	7
Turkey	5	0	13	4	0	6	28	0
Deer	523	35,419	16,778	906	15,817	19,407	88,850	9,951
Feral Hogs	N/A	N/A	N/A	N/A	N/A	N/A	37,718	4,715

SUBTASK 2.3
BACTERIA LOADING COEFFICIENTS FOR LIVESTOCK AND WILDLIFE

Because local data are not available, published fecal coliform production values are used. Initially, Metcalf and Eddy (1991), EPA (2000), and ASAE (2003), some of the primary sources of data for estimating fecal coliform load per animal, (table 14) were evaluated; however, it was quickly observed that the publications were not directly comparable. For example, Metcalf and Eddy (1991) reports fecal coliform contributions on a per capita basis and ASAE (2003) reports on a per 1000 lb live animal mass basis.

Table 14. Daily fecal coliform production - Metcalf and Eddy (1991), EPA (2000), and ASAE (2003)

Animal	**Estimated per capita contribution of fecal coliform (cfu/day)** *Metcalf & Eddy (1991)*	**Fecal coliform (count/animal/ day)** *EPA (2000)*	**Manure characteristics per 1000 lb live animal mass (cfu/day)** *ASAE (2003)*
Beef Cattle	5.4E+09	1.04E+11	1.3E+11
Horses	N/A	4.20E+08	4.2E+08
Goats	N/A	N/A	N/A
Sheep	1.8E+10	1.20E+10	2.0E+11
Hogs	8.9E+09	1.08E+10	8.0E+10
Poultry-chicken & turkey	2.4E+08	1.36E+08 9.30E+07	3.4E+10
Human	2.0E+09	N/A	N/A
Deer	N/A	5.00E+08	N/A
Feral Hogs	N/A	1.08E+10	N/A

To better evaluate loading coefficients for the watershed, the cfu/g of manure (wet weight) was determined from the literature (table 15). Crane et al. performed an extensive review of bacteria levels in feces in 1983. These were updated with more recent publications. Many of the new publications directly report the cfu/g; however, some (i.e. ASAE) were calculated using reported daily fecal coliform and manure production. Published fecal coliform densities varied several orders of magnitude in many cases. The values published by Metcalf and Eddy (1991) were typically the most comparable to other publications and the median value; thus, the fecal coliform densities by Metcalf and Eddy (1991) are recommended for species included in that reference. It is obvious from table 15 that many of the values for Metcalf and Eddy (1991) were obtained from Geldbreich (1962, 1977, and 1978); thus, to maintain consistency, the fecal coliform densities (cfu/g) published by Geldbreich (1977 & 1978) are recommended for horses. For goats, deer, and feral hogs, it is recommended that Cox (2005) be used as this publication provides the only densities for goats and feral hogs and is the median value for deer. Recommended fecal coliform densities for the Copano Bay watershed are outlined in table 17; this data should be used until localized data is available.

Table 15. Fecal coliform densities per gram of feces.

Animal Type	Fecal coliform	Reference
Beef cattle	6.40E+03	*Yagow (2001)*
	1.80E+05	*Cox (2005)*
	2.30E+05	*Geldreich (1977)*
	2.30E+05	*Rosebury (1962)*
	2.30E+05	*Metcalf & Eddy (1991)*
	2.30E+05	*Geldreich et al. (1962)*
	3.20E+05	*Witzel et al. (1966)*
	5.30E+05	*Witzel et al. (1966)*
	6.00E+05	*Maki and Picard (1965)*
	1.36E+06	*Yagow (2001)*
(unconfined)	1.40E+06	*Hrubant et al. (1972)*
	1.87E+06	*Moyer & Hyer (2003)*
(raw waste as collected)	3.30E+06	*Hrubant et al. (1972)*
	4.90E+06	*ASAE (2003)*
Horses	1.26E+04	*Geldreich (1977)*
	1.26E+04	*Rosebury (1962)*
	1.26E+04	*Geldreich (1978)*
	1.80E+04	*ASAE (2003)*
	3.80E+04	*Cox (2005)*
	2.22E+06	*Moyer & Hyer (2003)*
Goats	1.40E+06	*Cox (2005)*
Sheep	6.60E+05	*Cox (2005)*
	1.60E+07	*Rosebury (1962)*
	1.60E+07	*Metcalf & Eddy (1991)*
	1.10E+07	*ASAE (2003)*
	1.60E+07	*Geldreich et al. (1962)*
	1.80E+07	*Moyer & Hyer (2003)*
Hogs	4.05E+05	*Yagow (2001)*
	2.10E+06	*ASAE (2003)*
	3.30E+06	*Geldreich (1977)*
	3.30E+06	*Metcalf & Eddy (1991)*
	3.30E+06	*Geldreich et al. (1962)*
	7.10E+06	*Cox (2005)*
Chicken	1.20E+06	*ASAE (2003)*
	1.30E+06	*Geldreich et al. (1962)*
	1.30E+06	*Metcalf & Eddy (1991)*
	1.30E+07	*Rosebury (1962)*
	1.10E+08	*Cox (2005)*
	1.40E+08	*Crane et al. (1980)*
	1.83E+09	*Moyer & Hyer (2003)*
Turkey	2.90E+05	*Geldreich et al. (1962)*
	2.90E+05	*Metcalf & Eddy (1991)*
	2.90E+05	*ASAE (2003)*
Deer	4.50E+05	*Yagow (2001)*
	2.20E+06	*Cox (2005)*
	4.48E+08	*Moyer & Hyer (2003)*
Feral Hogs	4.10E+04	*Cox (2005)*

Table 16. Daily fecal production (pounds per 1,000 pounds of live weight)

Animal	Fecal production	Reference
Beef Cattle	40	*Yagow (2001)*
	58	*ASAE (2003)*
	60	*PSU (2008)*
	63	*NDSU (2008)*
	66	*Pennsylvania FFA (2002)*
	82	*Mukhtar (2007)*
	104	*NRCS (2008)*
Horses	41	*Yagow (2001)*
	44	*Pennsylvania FFA (2002)*
	45	*PSU (2008)*
	50	*NDSU (2008)*
	51	*NRCS (2008)*
	51	*Mukhtar (2007)*
	51	*ASAE (2003)*
Goats	33	*Pennsylvania FFA (2002)*
	40	*Mukhtar (2007)*
	41	*ASAE (2003)*
Sheep	33	*Pennsylvania FFA (2002)*
	40	*NDSU (2008)*
	40	*NRCS (2008)*
	40	*Mukhtar (2007)*
	40	*ASAE (2003)*
Hogs	45	*Yagow (2001)*
	84	*ASAE (2003)*
	88	*Pennsylvania FFA (2002)*
Gestating sow	25	*NRCS (2008)*
	25	*Mukhtar (2007)*
	27.2	*NDSU (2008)*
Lactating sow	59	*NRCS (2008)*
	59	*Mukhtar (2007)*
	60	*NDSU (2008)*
Boars	19	*NRCS (2008)*
	20.5	*NDSU (2008)*
Nursery swine	87	*Mukhtar (2007)*
	88	*NRCS (2008)*
	106	*NDSU (2008)*
Grow/finish swine	63	*NRCS (2008)*
	63.4	*NDSU (2008)*
	65	*Mukhtar (2007)*
Poultry	25	*Pennsylvania FFA (2002)*
	57	*NRCS (2008)*
Layers	26	*PSU (2008)*
	63	*Mukhtar (2007)*
	64	*ASAE (2003)*
Pullets	48	*PSU (2008)*
Broilers	82	*Mukhtar (2007)*
	85	*ASAE (2003)*
Turkey	47	*Mukhtar (2007)*
	47	*ASAE (2003)*
Deer	15	*Yagow (2001)*

To use the fecal coliform density data, daily fecal production must be known. Although not to the extent of the fecal coliform density data, the published values of daily fecal production per 1,000 pounds of live weight (table 16) were also quite variable. Of the seven publications, Mukhtar (2007) provided the most comprehensive and up-to-date list of fecal production values; generally, his reported values were nearest to the median value of the seven publications. Mukhtar also provided multiple subcategories of domestic hogs and poultry. It was assumed that the fecal production of "grow/finish swine" were most representative of the range of both domestic and feral hogs in the watershed. Additionally, it was assumed that pullets and layers exhibited similar fecal production. Because Mukhtar (2007) did not publish fecal production values for deer, those published by Yagow (2001) were used.

Based on data in tables 15 and 16, daily fecal coliform production per AU was calculated (table 17). Calculated levels are most comparable to ASAE published values (table 14) with the exception of the Beef Cattle category. Calculations are slightly over an order of magnitude lower than ASAE *Beef Cattle* values and are most comparable to Metcalf and Eddy values. This comparability to published values helps further validate the values in table 17; thus, it is recommended that loading coefficients in table 17 be used for the Copano Bay watershed until local data is obtained.

Table 17. Recommended fecal coliform load coefficients for Copano Bay

Animal	Daily fecal production (lbs/day/AU)	Daily fecal production (g/day/AU)	Fecal coliform density (cfu/g)	Fecal coliform (cfu/AU/day)
Beef Cattle	82	37,195	2.30E+05	8.55E+09
Horses	51	23,133	1.26E+04	2.91E+08
Goats	40	18,144	1.40E+06	2.54E+10
Sheep	40	18,144	1.60E+07	2.90E+11
Hogs	65	29,484	3.30E+06	9.73E+10
Layers	63	28,576	1.30E+06	3.71E+10
Pullets	63	28,576	1.30E+06	3.71E+10
Broilers	82	37,195	1.30E+06	4.84E+10
Turkey	47	21,319	2.90E+05	6.18E+09
Deer	15	6,804	2.20E+06	1.50E+10
Feral Hogs	65	29,484	4.10E+04	1.21E+09

Based on the recommended fecal coliform loading coefficients in table 17 and the number of AU in table 13, the total daily and annual fecal coliform production was calculated (table 18). These calculations indicate that cattle and deer account for 88 percent of fecal coliform production from livestock and wildlife in the watershed. It should be stressed that other important wildlife sources such as waterfowl were not assessed by this study and could account for a significant amount of fecal coliform production in the Copano Bay watershed.

Table 18. Estimated fecal coliform production by livestock and wildlife in the Copano Bay watershed

Animal	AU in watershed	Fecal coliform (cfu/AU/day)	Fecal coliform (cfu/day)	Fecal coliform (cfu/year)	Percent of Total
Cattle	66,348	8.55E+09	5.68E+14	2.07E+17	70.2%
Horses	3,100	2.91E+08	9.04E+11	3.30E+14	0.1%
Goats	615	2.54E+10	1.56E+13	5.70E+15	1.9%
Sheep	185	2.90E+11	5.37E+13	1.96E+16	6.6%
Hogs	156	9.73E+10	1.52E+13	5.54E+15	1.9%
Layers	13	3.71E+10	5.12E+11	1.87E+14	0.1%
Pullets	5	3.71E+10	2.01E+11	7.34E+13	0.0%
Broilers	7	4.84E+10	3.25E+11	1.19E+14	0.0%
Turkey	0	6.18E+09	3.08E+09	1.12E+12	0.0%
Deer	9,951	1.50E+10	1.49E+14	5.44E+16	18.4%
Feral Hogs	4,715	1.21E+09	5.70E+12	2.08E+15	0.7%
Total	85,095		8.09E+14	2.95E+17	100%

SUBTASK 2.4
COMPARISON OF COPANO BAY BACTERIA LEVELS TO OTHER TEXAS BAYS

In 2004, the Coastal Bend Bays and Estuary Program conducted a Regional Coastal Assessment Program (RCAP) at sites throughout the Coastal Bend region. The assessment showed that *Enterococci* levels were low (<35 cfu/100 mL) throughout a majority of the Coastal Bend (figure 3), including all sites in Copano Bay.

Enterococcus and fecal coliform levels in bays and estuaries larger than 28 mi^2 from throughout Texas were also compared (table 19). Data for this comparison was derived from the *2006 Texas Water Quality Inventory – Water Body Assessments by Basin* (TCEQ 2008). The average *Enterococcus* and fecal coliform levels were 14 and 8 cfu/100 mL, respectively. In comparison, the *Enterococcus* and fecal coliform levels in Copano Bay were 17 and 4 cfu/100 mL, respectively.

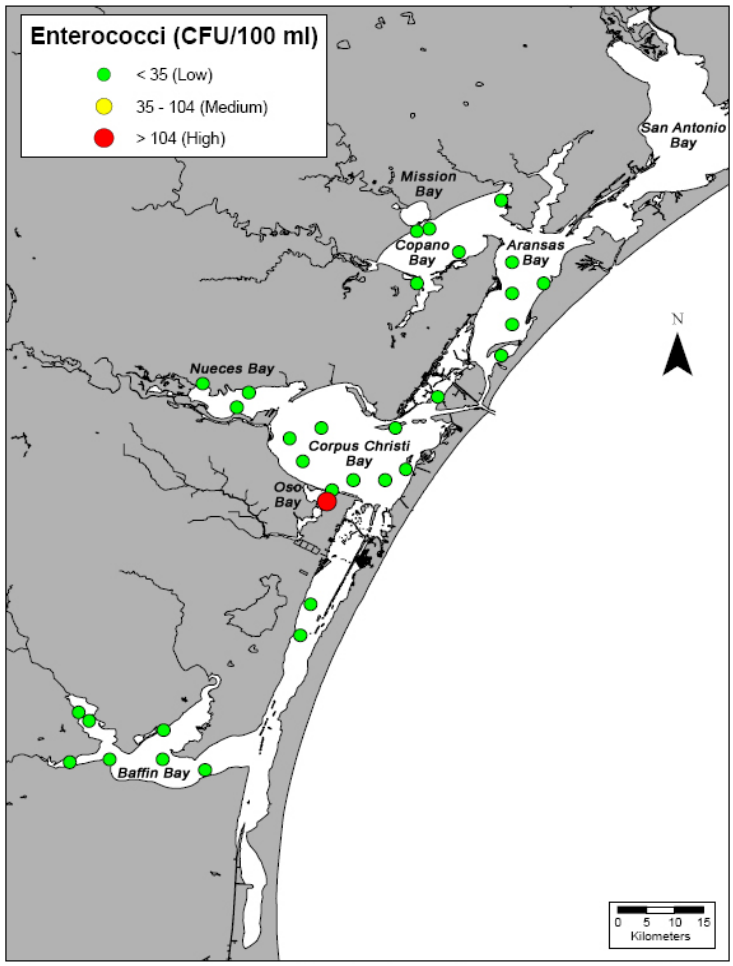

Figure 3. *Enterococci* levels (cfu/100 mL) at Regional Coastal Assessment Program (RCAP) 2004 sampling sites (Nicolau and Nunez 2006)

Thus, *Enterococcus* levels in Copano Bay were 21 percent greater than average levels observed in bays greater than 28 mi^2 in Texas, while the fecal coliform levels were half the average levels observed in bays greater than 28 mi^2 in Texas.

Table 19. Mean *Enterococcus* and fecal coliform concentrations (TCEQ 2008)

WB ID	WB Name	WB Size	*Entero-cocci*	Fecal Coliform
2412	Sabine Lake (entire waterbody)	68.7	12	14
	Upper Galveston Bay	115.7		
2421-01	Redbluff to Five Mile Cut - Houston Pt - Morgan's Pt		21	23
2421-02	West of Bay		15	10
2421-03	East of Bay		15	7
2422-01	Trinity Bay (Upper)	130.1	14	8
2422-02	Trinity Bay (Lower)		18	5
2423-01	East Bay (adjacent to Segment 0702)	52.1	10	9
2423-02	Remainder of Bay		10	4
2424-1	West Bay (main portion of waterbody)	69.3	7	6
2424-02	West Bay (adjacent to lower Galveston Island)		6	9
	Lower Galveston Bay			
2439-01	Adjacent to TX City Ship Channel & Moses Lake	139.6	11	7
2439-02	Main portion of Bay		11	7
2441-02	East Matagorda Bay (remainder of Bay)	59.1	12	4
2451-02	**Matagorda Bay/Powderdown Lake** (remainder)	261.7	12	6
	Tres Palacios/Turtle Bay	31.9		
2452-01	Main portion of Bay		17	8
2452-02	Turtle Bay			7
2452-03	Tres Palacios Creek			16
	Lavaca Bay/Chocolate Bay	59.3		
2453-01	Center portion of Bay		16	7
2453-02	Northeastern portion of Bay near Point Comfort		21	21
2453-03	Chocolate Bay Area			11
2461-01	Espiritu Santo Bay (entire segment)	60.8		2
2462-01	San Antonio Bay/Hynes Bay	119.5	12	5
2463-01	Mesquite Bay/Carlos Bay/Ayres Bay		3	2
2471-01	Aransas Bay (entire segment)	87.8	8	2
2472	**Copano Bay/Port Bay/Mission Bay**	65.2		
2472-01	Mission Bay/Aransas River arm & eastern shoreline		17	4
2472-02	Entire water body		17	4
2481-01	Corpus Christi Bay (entire segment)	123.1	11	5
2482-01	Nueces Bay (entire Bay)	28.9	13	5
2483.01	Redfish Bay (entire segment)	28.8	10	3
2491	**Laguna Madre**	347.4		
2491-01	Upper portion of Bay north of Arroyo confluence		14	24
2491-02	Area adjacent to Arroyo confluence		25	7
2491-03	Lower portion of Bay south of Arroyo Colorado confluence		23	3
2492-01	Baffin Bay/Alazan Bay/Callo de Grullo/Laguna la Salada (entire segment)	101.5	14	1
AVERAGE CONCENTRATION			**14**	**8**

SUBTASK 2.5
HISTORICAL BACTERIAL LEVELS AND TRENDS IN COPANO BAY

Copano Bay is a 65 mi^2 estuary located northeast of Corpus Christi (figure 4). Port Bay, Mission Bay, the Aransas River arm, and the eastern shoreline of Copano Bay (the Copano Creek arm) were first identified in 1998 as impaired for elevated bacteria; they remain on the 2008 *Texas §303(d) List*. To evaluate historical fecal coliform trends in Copano Bay, data were obtained from the TCEQ surface water quality monitoring Web site.

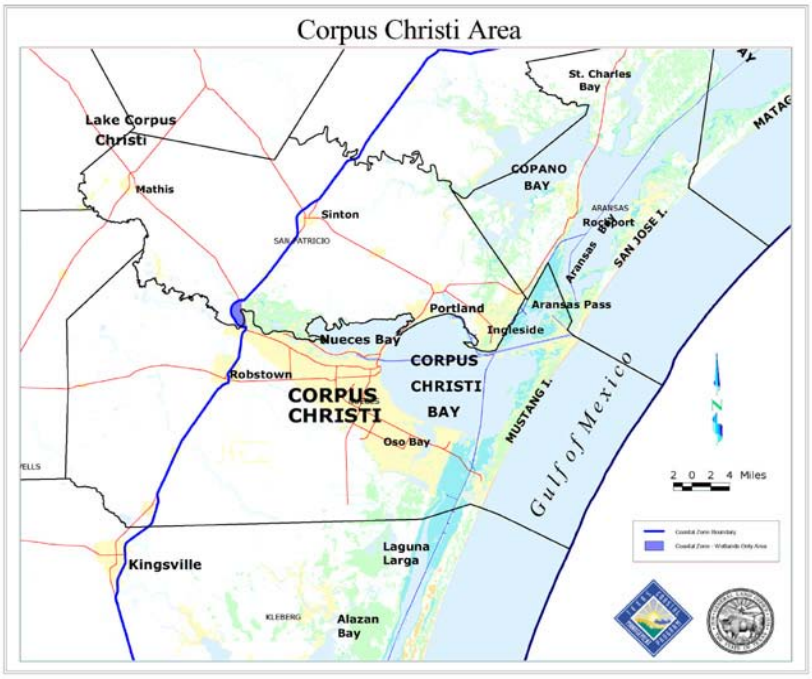

Figure 4. Copano Bay/Coastal Bend region map (GLO 2008)

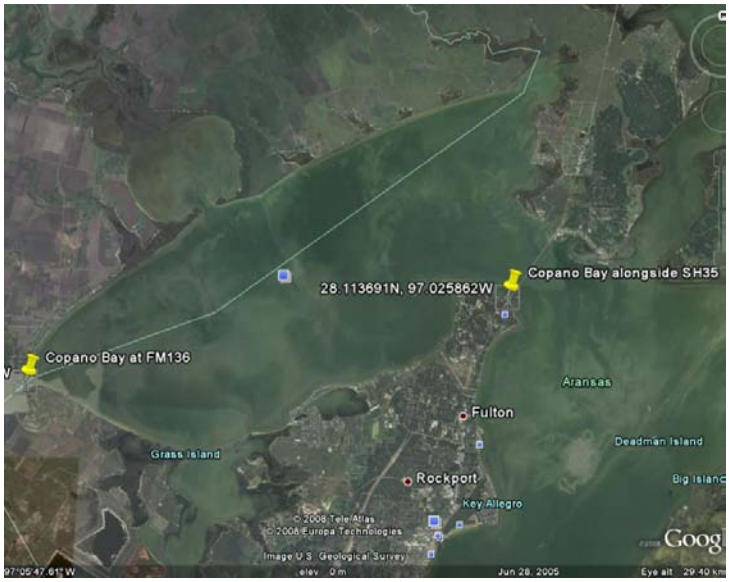

Figure 5. Map of Copano Bay sites evaluated

Two stations in the bay (figure 5) have been tested for fecal coliform since the early 1970's: Copano Bay at FM136 (Station #12945) and Copano Bay alongside SH35 (Station #13404). Fecal coliform data were obtained from Copano Bay at FM136 for the period of 1973 –2003 (appendix A). Fecal coliform data were also obtained from Copano Bay alongside SH35 for the period of 1975–2005 (appendix B). Data obtained from TCEQ were transferred to Microsoft® Excel for analysis and plotted using SPSS®.

No statistically significant trends were observed in the fecal coliform data at either FM136 or SH35 (figure 6). Fecal coliform values were highly variable, ranging from 1 to 6,000 cfu/100 mL at FM136 and from 1 to 360 cfu/100 mL at SH35.

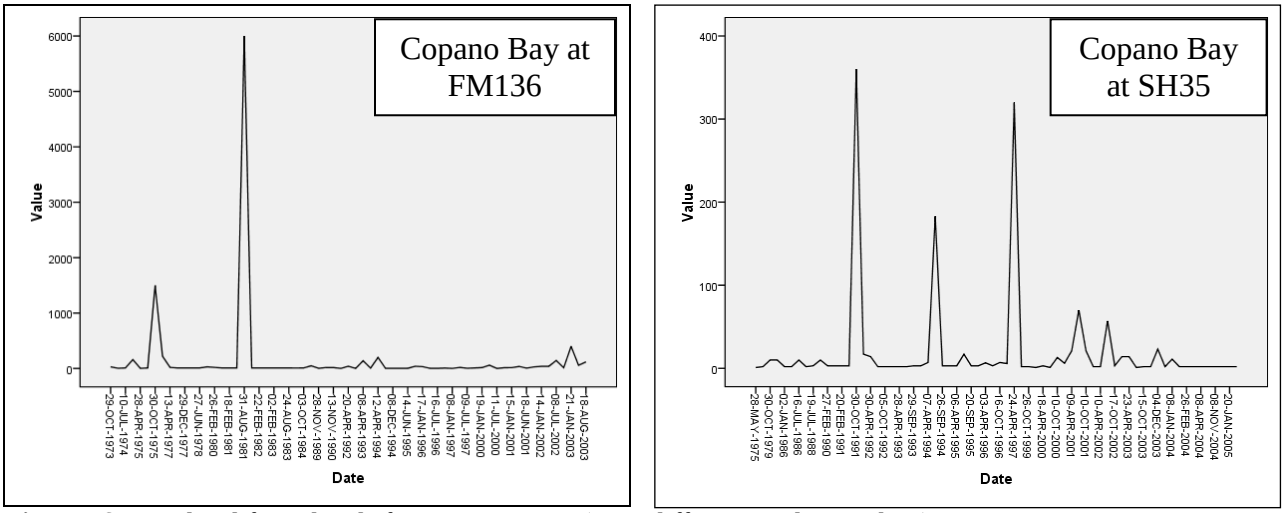

Figure 6. Fecal Coliform levels from 1973-2003 (note differing scales in plots)

To further assess any possible trends or changes in fecal coliform levels, the mean, median, and percent of samples exceeding the water quality standard (43 cfu/100 mL) were determined at five-year intervals for both sites beginning from 1970–2005 (table 20). Copano Bay at SH35 appears to have experienced an increase in fecal coliform levels between 1975 and 1995, but since 1995 the data indicates a possible downward trend. Conversely, fecal coliform levels at FM136 have been highly variable since monitoring was initiated and there is no discernable trend.

Table 20. Median, mean, and percent of fecal coliform values exceeding 43 cfu/100 mL

	Copano at SH35			Copano at FM136		
Date	**Median**	**Average**	**%>43**	**Median**	**Average**	**%>43**
1970-1975				20.0	51.0	25%
1975-1980	2.0	4.3	0%	10.0	182.3	20%
1980-1985				10.0	471.4	8%
1985-1990	3.0	5.6	0%	25.5	25.5	50%
1990-1995	3.0	34.2	11%	11.5	43.0	20%
1995-2000	3.0	31.1	8%	3.8	11.6	0%
2000-2005	2.0	10.2	7%	37.0	66.1	33%

Based on the data in table 20, the only period that Copano at SH35 has been impaired is from 1990–1995 when levels peaked. Copano Bay at FM136, however, has been impaired almost continuously since monitoring began with the exception of 1980–1985 and 1995–2000.

SUMMARY OF FINDINGS

Copano Bay is a 65 mi^2 estuary located northeast of Corpus Christi. Port Bay, Mission Bay, the Aransas River arm, and the eastern shoreline of Copano Bay (the Copano Creek arm) were first identified in 1998 as impaired for elevated bacteria; they remain on the 2008 *Texas §303(d) List*. According to the *2006 Texas Water Quality Inventory – Water Body Assessments by Basin* (TCEQ 2008), the average *Enterococcus* and fecal coliform levels in bays and estuaries larger than 28 mi^2 were 14 and 8 cfu/100 mL, respectively. In comparison, the *Enterococcus* and fecal coliform levels in Copano Bay were 17 and 4 cfu/100 mL, respectively. No statistically significant trends were observed in fecal coliform levels at two long-term monitoring sites in Copano Bay (FM136 and SH35). Based on TCEQ fecal coliform data collected since 1975, the only period that Copano Bay at SH35 has been impaired was from 1990–1995. This is not the case for Copano Bay at FM136, which has been impaired almost continuously since monitoring began in 1973 with the exception of 1980–1985 and 1995–2000.

Livestock and wildlife populations were evaluated to assess potential sources of the fecal coliform. Deer were the most populous category in terms of sheer numbers; however, in terms of AU, cattle were the most populous. An estimated 66,348 cattle (AUs) live within the watershed. As would be expected, application of published loading coefficients to the calculated AU in the watershed indicate that as much as 88 percent of the livestock and wildlife bacteria production may originate from cattle and deer with cattle contributing approximately 70 percent and deer contributing 18 percent. It should be noted that all wildlife categories were not evaluated, which can have a significant impact on the findings of this study. Waterfowl (migratory and non-migratory) and other wildlife species can be the source of a significant amount of loading, especially at localized sites in the bay, and need to be included in future TMDL work.

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APPENDIX A
HISTORICAL FECAL COLIFORM LEVELS (cfu/100 mL) COPANO BAY AT FM136

Date	Value	Date	Value
10/29/1973	30	9/29/1992	2
1/29/1974	4	4/8/1993	140
7/10/1974	10	9/29/1993	7
12/20/1974	160	4/12/1994	200
4/28/1975	3	10/4/1994	3
7/29/1975	10	12/8/1994	3
10/30/1975	1500	4/6/1995	3
1/26/1976	220	6/14/1995	3
4/13/1977	20	9/19/1995	40
9/26/1977	10	1/17/1996	33.33
12/29/1977	10	4/3/1996	3
3/30/1978	10	7/16/1996	3
6/27/1978	10	10/16/1996	7
9/27/1978	30	1/8/1997	1.4
2/26/1980	20	4/30/1997	20
5/30/1980	10	7/9/1997	3.75
2/18/1981	10	10/25/1999	10
5/20/1981	10	1/19/2000	16
8/31/1981	6000	4/17/2000	60
11/24/1981	10	7/11/2000	1
2/22/1982	10	10/9/2000	14
5/12/1982	10	1/15/2001	15
2/2/1983	10	4/10/2001	37
5/25/1983	10	6/18/2001	6
8/24/1983	10	10/8/2001	29
3/22/1984	8	1/14/2002	39
10/3/1984	10	4/9/2002	39
5/7/1986	48	7/8/2002	145
11/28/1989	3	10/15/2002	14
5/15/1990	17	1/21/2003	400
11/13/1990	16	4/22/2003	58
10/7/1991	2	8/18/2003	118
4/20/1992	40		

APPENDIX B
HISTORICAL FECAL COLIFORM LEVELS (cfu/100 mL) COPANO BAY AT SH35

Date	Value	Date	Value
5/28/1975	1	10/16/1996	7
11/3/1976	2	1/8/1997	5.7
10/30/1979	10	4/24/1997	320
3/6/1985	10	7/9/1997	2
1/2/1986	2	10/26/1999	2
4/24/1986	2	1/18/2000	1
7/16/1986	10	4/18/2000	3
10/14/1986	2	7/12/2000	1
7/19/1988	3	10/10/2000	13
4/19/1989	10	1/16/2001	6
2/27/1990	3	4/9/2001	21
8/13/1990	3	6/19/2001	70
2/20/1991	3	10/10/2001	21
8/7/1991	3	1/16/2002	2
10/30/1991	360	4/10/2002	2
1/22/1992	17	7/9/2002	57
4/30/1992	14	10/17/2002	3
8/10/1992	2	1/22/2003	14
10/5/1992	2	4/23/2003	14
12/2/1992	2	8/19/2003	1
4/28/1993	2	10/15/2003	2
7/19/1993	2	11/17/2003	2
9/29/1993	3	12/4/2003	23
2/14/1994	3	12/17/2003	2
4/7/1994	7	1/8/2004	11
6/7/1994	183	2/17/2004	2
9/26/1994	3	2/26/2004	2
12/8/1994	3	3/2/2004	2
4/6/1995	3	4/8/2004	2
6/14/1995	17	10/28/2004	2
9/20/1995	3	11/8/2004	2
1/16/1996	3	12/20/2004	2
4/3/1996	6.67	1/20/2005	2
7/16/1996	3	2/15/2005	2

APPENDIX B

A Guide to Good Horsekeeping

EM-107
2010

A Guide to Good Horsekeeping

Benefits for your horses, your land, and you

Texas Water Resources Institute
make every drop count

AgriLIFE EXTENSION
Texas A&M System

Soil Water
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Forward

This informational booklet is meant to give owners and managers an overview of the importance of different management strategies concerning the impact horse operations have on watersheds. There are various publications in existence that are how-to guides and these more in depth articles and web sites are listed at the end of this booklet for those wishing to obtain more information on any particular topic.

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Introduction

A wealth of knowledge exists regarding management of agricultural livestock, a category that includes horses in Texas. However, horses for the most part, are in a category that is neither livestock nor companion animal. Therefore, owners are left without access to the educational library traditional livestock operations use and they turn to companion animal information sources. While important, these sources tend to focus on management of the horse itself and not the land on which they are kept. This guide is intended to highlight issues often overlooked by horse owners (from breeding operations to horses kept for pleasure) and give them a choice of best management practices to decrease their impact on natural resources. For those interested in any particular best management practice, additional internet resources are listed at the end of each chapter with more detailed information on implementation.

A good percentage of people who involve themselves with horses do not start as professional horsemen and horsewomen. They start as parents granting the wish of their children, as adults who have access to discretionary income, or as absentee owners who invest in the industry. Horse ownership mandates a unique set of management solutions of which people who just loaded their first purchase in the trailer may not be aware.

Horse owners need to become proficient in the following list to do the best they can for their animals and the land they manage. Knowledge of these topics is important because horses kept for work or pleasure are not always the “free ranging” animal of the plains where they evolved. They are often kept in a restricted area, pasture, or pen where they can develop digestive and behavioral disorders, concentrate manure, degrade pasture quality, and can impact surrounding ecological areas and watersheds if care is not taken.

History of Water Quality Awareness

Water quality impacts all aspects of our lives including health, recreation, community, and industry. In Texas, the largest percentage of our water bodies are impaired due to excessive levels of bacteria. According to the Texas Commission on Environmental Quality (TCEQ) 2008 303(d) List, 57 percent of impaired waters in the state are due to fecal coliform bacteria. These bacteria naturally live in the digestive systems of all warm-blooded animals and are used as indicator organisms for fecal contamination of water bodies. Since horses are warm-blooded animals, mismanagement of a horse operation can have a potentially negative impact on surface water quality.

It is not only interesting, but important to be aware of the types of water pollution and the steps that have led us to the point where we have become specifically aware of their effects on surface water quality. The following information will raise awareness of how land management practices affect surface water quality.

Types of Water Pollution

There are two basic sources of water pollution: point source and nonpoint source.

Point Source Pollution

Point source pollution is the easiest to identify and address as it comes from a specific identifiable point. Examples of point sources are known facilities such as wastewater treatment facilities (WWTF), concentrated animal feeding operations (CAFO), and industry. These types of sources are usually heavily regulated and monitored by the U.S. Environmental Protection Agency (EPA) and TCEQ to prevent or severely reduce pollutants that are released into the environment.

Nonpoint Source Pollution (NPS)

The other type of pollution is nonpoint source pollution (NPS), which is a mix of urban and rural runoff containing roadway contaminants, lawn debris, chemicals, fertilizer, and manure. Usually NPS pollution becomes an issue after rainfall, as these pollutants are washed into water bodies by downpours. Due to its nature, NPS pollution is much more difficult to deal with as it originates from many different sources and poses varying levels of potential contaminants. A significant NPS pollution concern in Texas is bacteria from fecal contamination.

Federal Clean Water Act

The Federal Clean Water Act (CWA) was enacted in 1972 and has been amended several times. To regulate the discharge of pollutants into our waters, the act requires the implementation of pollution control programs, sets water quality standards for contaminants in surface water, and requires regulatory permits to discharge effluent from a point source. EPA is charged with implementing the CWA across the nation. In Texas, EPA has delegated the implementation of many components of the CWA to TCEQ. The CWA requires states to identify lakes, rivers, streams, and estuaries failing to meet or



Potential Sources of NPS Pollution: oil residues, horse manure, fertilizer

not expected to meet water quality standards and not supporting their designated uses (swimming, drinking, aquatic life, etc.). This list of impaired water bodies is known as the 303(d) list and must be submitted to the EPA for review and approval every two years.

Total Maximum Daily Load Program

The state must establish a Total Maximum Daily Load (TMDL) for certain water bodies identified on the 303(d) list. A TMDL defines the maximum amount of a pollutant that a water body can assimilate on a daily basis and still meet water quality standards. The pollution reduction goal set by a TMDL is necessary to restore attainment of the designated use of the impaired water body. The maximum amount of a pollutant is determined by conducting a detailed water quality assessment that provides the information for a TMDL to allocate pollutant loads between point sources and nonpoint sources. It also takes into account a margin of safety, which reflects uncertainty and future growth.

Based on the environmental target of a TMDL, an Implementation Plan (I-Plan) is then developed that prescribes the measures necessary to mitigate anthropogenic (human-caused) sources of the pollutant in that water body. The I-Plan specifies limits for point source dischargers and recommends best management practices (BMPs) for nonpoint sources. It also lays out a schedule for implementation. Together, the TMDL and the I-Plan serve as the mechanism to reduce the pollutant, restore the full use of the water body and remove it from the 303(d) list. EPA must approve the TMDL, but the I-Plan only requires state approval.

Water Quality Standards

Every two years TCEQ evaluates data on the quality of all water bodies in the state of Texas. In 2008, 925 bodies of water were assessed and 516 were impaired and placed on the *2008 Texas Water Quality Inventory and 303(d) List*. This list names impairments and levels of contaminants for any water body not meeting water quality standards.

Criteria for water bodies are based on contact and noncontact recreation, domestic water supply, oyster harvest, and aquatic life. The number of indicator organisms, which are usually harmless bacteria found in fecal matter, are measured periodically, and if found in sufficient numbers, the water body

will be placed on the 303(d) list. Because of differences in the ability of bacteria to survive in fresh water versus saltwater, different bacteria are used as standards for fresh and salt water. *Enterococcus* has the ability to survive in a saline environment and therefore is used as a saltwater indicator organism. *E. coli* are more susceptible in a saline environment, therefore are used as freshwater indicators. Oyster harvesting waters are treated differently because oysters are filter feeders and concentrate any contaminant in the water in their bodies. Compounding this trait of the oyster is that many people eat oysters raw, eliminating the chance that any harmful bacteria will be killed. These waters are held to the highest standards possible, and all fecal bacteria will be counted. On the other hand, contact recreation consists of uses such as swimming, wading, or other activities where people will be in contact with the water. The standards for contact recreation are an average of 126 *E. coli* per 100 ml of freshwater, 35 *Enterococcus* for 100 ml of saltwater, or 200 fecal coliforms per 100 ml of water. Secondary contact recreation includes boating, pier fishing, or activities where people will not be intentionally in contact with water.

Fecal Coliform Standards for Water Body Classifications

Oyster Harvesting	Contact Recreation	Non-Contact Recreation
14 cfu per 100 mL/water	200 cfu per 100 mL/water	2000 cfu per 100 mL/water

The standards for noncontact recreation are an average of 605 *E. coli* per 100 ml of freshwater, 168 *Enterococcus* per 100 ml of saltwater, or 2000 fecal coliforms per 100 ml of water. Oyster water standards are no more than 14 fecal coliforms per 100 ml of water on average.

Pollutants, which may come from horses, include bacteria, nutrients, sediment, and oxygen-demanding substances. This guide focuses on horses and their impacts to water quality due to bacteria in manure.

Texas Commission on Environmental Quality

TCEQ has general jurisdiction and primary responsibility over Texas' water quality program including water quality management planning, the issuance of permits for point source discharges, abatement of nonpoint source pollution other than from agricultural and silvicultural sources, and enforcement of water quality rules, standards, orders, and permits. TCEQ is responsible for establishing the level of quality to be maintained in, and controlling the quality of, water in the state (Texas Water Code §5.013 and 26.0136).

Texas State Soil and Water Conservation Board

The Texas State Soil and Water Conservation Board (TSSWCB) is the lead agency in Texas for planning, implementing, and managing programs and practices for preventing and abating agricultural and silvicultural (forestry) nonpoint source pollution (Texas Agriculture Code §201.026).

Community Involvement

TCEQ and TSSWCB work with watershed stakeholders to develop and implement TMDLs. Stakeholders are anyone affected by the implementation of the TMDL and can be a combination of landowners, business owners, and government representatives. The decisions made in your watershed have a direct impact on you and your business and there are many reasons for you to get involved in the process. A few reasons are:

- Ensure that state government considers the local perspective
- Promote government and community accountability
- Improve quality/quantity of ideas to the TMDL process
- Reduce the probability of one particular group dominating the process
- Lead to actions to decrease pollution

Websites of Interest

United States Environmental Protection Agency: Federal Clean Water Act
http://www.epa.gov/emergencies/content/lawsregs/cwaover.htm

Texas Commission on Environmental Quality: Total Maximum Daily Load Program
http://www.tceq.state.tx.us/implementation/water/tmdl/tmdlprogram.html

Texas Commission on Environmental Quality: Texas Water Quality Inventory and 303(d) List
http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/305_303.html

Texas State Soil and Water Conservation Board
http://www.tsswcb.state.tx.us/

Introduction

Horses have a unique ability to be detrimental to the land on which they are kept, leaving the owner with the responsibility of managing them so that they have the least impact on the surrounding environment. Considerable efforts have been made along the eastern and western coasts to stop surface water quality degradation, leading to mandatory regulations imposed on horse owners. It is our desire that these issues do not come to fruition in Texas and a proactive approach to preventing contamination makes regulation even more unlikely.

Copano Bay

There are many ways runoff from equine operations can lead to surface water quality degradation, which can have a wide range of consequences for water bodies in a watershed. Most issues stem from manure that contains bacteria and nutrients, but sedimentation from erosion and the excessive use of fertilizers and pesticides also contribute to the problem.

Bacteria

Horses and other animals contribute to the degradation of water quality in different ways, but bacterial contamination is the concern for this guide. Bacterial pollution is the number one impairment of water bodies (lakes, bays, rivers, etc.) in Texas currently accounting for over half of water bodies tested according the 2008 TCEQ 303 (d) list. The types of bacteria of concern are enteric bacteria. These are the natural bacteria that live in the digestive system of all warm-blooded animals and assist with digestion and immunity. Unfortunately, pathogenic organisms (bacteria, viruses, protozoa) such as *E. coli O157:H7*, *Salmonella*, and *Cryptosporidium parvum* inhabit our digestive systems as well. Testing for the pathogenic organisms is expensive and time consuming, therefore agencies that test water quality use indicator species to measure fecal contamination. Indicator species are bacteria such as *E. coli* and *Enterococcus* that naturally colonize in the digestive tract and are excreted in manure.

Fecal coliforms from fresh water

Horses can shed pathogenic organisms in their manure, and studies have found the following pathogens in horse manure (Quinn):

- *Clostridium tetani*
- *Cryptosporidium parvum*
- *Giardia duodenalis*
- *Campylobacter spp.*
- *Samonella spp.*
- *Escherichia coli*
- *Yersinia spp.*
- *Leptospira spp.*

Nutrients

Various nutrients, mostly from manure or fertilizer, run off into surface water and degrade water quality. These consist of nitrogen in the form of ammonia and nitrate nitrogen, phosphorus, and organic matter.

Nitrogen at high levels can be toxic to fish and a health concern for infants as it decreases the ability of red blood cells to carry oxygen (i.e. Blue Baby Syndrome).

Phosphorus is a natural fertilizer and when introduced to water bodies can cause a rapid increase in growth of aquatic vegetation and algae blooms. When the vegetation and algae die, the decomposition decreases the dissolved oxygen needed by fish to survive. Phosphorus increases algae growth leading to unsightly ponds and drops water temperature and sunlight.

Organic matter is undigested material that can include feed, bedding, and hay. As stated earlier, when these materials decompose in the water, dissolved oxygen is consumed, leading to fish kills and decreased water quality.

Erosion

Pasture health is of vital concern in preventing runoff of all varieties. As the grass is grazed down and eventually killed, what was a nice pasture is now a dirt lot, which will be washed away an inch at a time by each rain. As the topsoil is eroded from your property, aesthetic value declines and topsoil necessary for healthy plant growth is washed away. Increased sedimentation in water bodies is also a problem leading to increased turbidity, degraded water quality, and the dredging of tanks.

Pesticide Use

Pesticides include insecticides, herbicides, fungicides, and other poisons that kill and/or control unwanted pests. Our current way of life would be impossible without the judicious use of pesticides; however, if improperly used they can be very detrimental to the aquatic environment. Many pesticides are used on horse farms, including fly spray for the barn, herbicides for the weeds in the pasture, and fungicides/insecticides for the feed bin.

The proper use of these chemicals is very important for the health of your horse, your family, and aquatic life. There have been instances where improper amounts of insecticides were used to fumigate the feed bin, which resulted in horses being killed after eating contaminated feed. Small amounts of some herbicides can be lethal to fish and other amphibians in your stock tank. As stated before, pesticides provide safety and comfort if used properly, according to the guidelines below.

Pesticide spray nozzle

- Read all product labels and follow label directions
- Don't apply pesticides with conditions that promote runoff
- Store water pollutants away from water sources
- Don't spray pesticides on windy days
- Leave buffer zones around water bodies
- Don't dispose of excess materials down drains or on the ground
- Use low toxicity products

Copano Bay Watershed

An example of issues currently faced by horse owners is happening in the Copano Bay Watershed. Bacteria Source Tracking conducted by Texas A&M University–Corpus Christi determined that a slight majority of bacteria in the bay originated from horses. An education program is underway to educate owners on best management practices they can implement to reduce bacteria runoff. Similar measures will be undertaken in the areas surrounding all impaired water bodies to try to bring them back to their classified usage. Additionally, in an attempt to be proactive, we may be able to avoid the regulations being imposed on the east and west coasts.

The Copano Bay Watershed is approximately 1.4 million acres and includes significant portions of Aransas, Bee, Goliad, Refugio, and San Patricio counties. A watershed is an area of land that drains to a main water body, which in this case is Copano Bay. The management practices of homeowners, livestock owners, and businesses in these counties all contribute in varying degrees to the water quality in this bay. It is important to recognize factors that are beyond our control, such as the contributions of wildlife and weather fluctuations that impact the bay. While attempting to completely rid our waterways of every pollutant is an unattainable goal, we can take steps to minimize the impact of our practices that increase water pollution and degrade water quality.

Copano Bay Watershed
Source: TCEQ

Websites of Interest

Bacteria Source Tracking in Copano Bay: Phase II Final Report
http://www.tceq.state.tx.us/assets/public/implementation/water/tmdl/42copano/42-bst-phase2finalrpt.pdf

Bacteria Source Tracking on the Mission and Aransas Rivers
http://www.cbbep.org/publications/virtuallibrary/0630final.pdf

Texas Commission on Environmental Quality Sampling Data Query, Surface Water Quality Monitoring
http://www.tceq.state.tx.us/compliance/monitoring/crp/data/samplequery.html

National Livestock and Poultry Environmental Learning Center
http://www.extension.org/animal+manure+management

Texas Watershed Steward
http://tws.tamu.edu/

Texas Commission on Environmental Quality: Copano Bay, A TMDL Project for Bacteria in Oyster-Harvesting Waters
http://www.tceq.state.tx.us/implementation/water/tmdl/42-copano.html

Introduction

An understanding of basic feeding guidelines is an important component of on-farm nutrient management. Implemented correctly, these practices can increase horse health and decrease feed costs.

Horses eat approximately 1.5 percent to 3 percent of their total body weight per day, on average, depending on the type and quality of feed and the amount of work imposed on the horse. Many prepared feeds have the appropriate feeding directions on the back of the feed bag. Horse feeds are considered complete feeds if fed with the right amount of hay. No additional supplements should be necessary with commercially prepared horse feed.

The most important aspect of your horse's diet is proper forage intake. Horses naturally graze forage continuously so it is important to provide adequate amounts of long-stemmed forage spread throughout the day if possible. A minimum of at least 1 percent of the body weight in forage per day will usually meet their dietary requirements. The benefits of feeding adequate amounts of forage result in good dietary and mental health. Some adverse behaviors seen in horses without access to enough forage are listed below (Householder et al.).

- Chewing wood
- Eating bedding
- Eating manure
- Chewing manes and tails
- Cribbing

Before discussing the second most important aspect of your horse's diet, body condition scoring and classification of the horse based on use need to be reviewed. Understanding these two concepts is critical when determining if and with what grain to supplement your horse's diet.

Body Condition Scoring (BCS)

Body condition scoring is a way of determining the amount of fat on a horse by observing various areas of the horse's body. These areas are typically the back, ribs at midbarrel, neck, behind the shoulders at forerib, withers and tailhead (Householder et al.). When evaluating these areas, it is important not to confuse long hair coats and bulky muscles as fat. After observing the target areas, horses are assigned a number from 1 (emaciated) to 9 (obese), with 5 being an optimal condition for your horse. The following chart contains a description for each body condition score (Gibbs).

Score Description

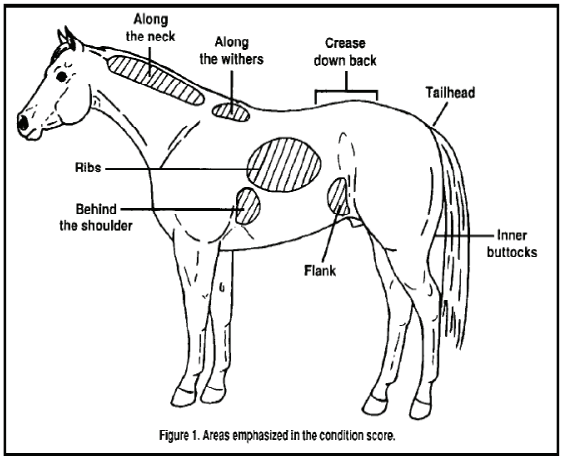


Figure 1. Areas emphasized in the condition score.

Source: Nutritional Management of Pregnant and Lactating Mares (Gibbs)

1 Poor. The horse is emaciated. The spinous processes (backbone), ribs, tailhead, and hooks and pins all project prominently. The bone structures of the withers, shoulders, and neck are easily noticeable, and no fat can be felt anywhere.

2 Very Thin. The spinous processes are prominent. The ribs, tailhead, and pelvic bones stand out, and bone structures of the withers, neck, and shoulders are faintly discernable.

3 Thin. The spinous processes stand out, but fat covers them to midpoint. Very slight fat cover can be felt over the ribs, but the spinous processes and ribs are easily discernable. The tailhead is prominent, but individual vertebrae cannot be seen. Hook bones are visible but appear rounded. Pin bones cannot be seen. The withers, shoulders, and neck are accentuated.

4 Moderately Thin. The horse has a negative crease along its back and the outline of the ribs can just be seen. Fat can be felt around the tailhead. The hook bones cannot be seen and the withers, neck, and shoulders do not look obviously thin.

5 Moderate. The back is level. Ribs cannot be seen but can be easily felt. Fat around the tailhead feels slightly spongy.

6 Moderate to Fleshy. There may be a slight crease down the back. Fat around the tailhead feels soft and fat over the ribs feels spongy. There are small deposits along the sides of the withers, behind the shoulders, and along the sides of the neck.

7 Fleshy. There may be a crease down the back. Individual ribs can be felt, but there is noticeable fat between the ribs. Fat around the tailhead is soft. Fat is noticeable in the withers, the neck, and behind the shoulders.

8 Fat. The horse has a crease down the back. Spaces between ribs are so filled with fat that the ribs are difficult to feel. The area along the withers is filled with fat, and fat around the tailhead feels very soft. The space behind the shoulders is filled in flush and some fat is deposited along the inner buttocks.

9 Extremely Fat. The crease down the back is very obvious. Fat appears in patches over the ribs and there is bulging fat around the tailhead, withers, shoulders, and neck. Fat along the inner buttocks may cause buttocks to rub together, and the flank is filled in flush.

Horse Classification by Use

Classification of horses by use is extremely helpful when deciding nutritional requirements since horses in different stages of life and levels of competition have different needs. The following chart is a good starting point to combine with feed bag instructions when determining the amount of forage and grain to feed per day as a percentage of body weight (BW) (Householder).

Class	Forage (%BW)	Concentrate (%BW)	Total (%BW)
Mature (Idle)	1.5-2.0	0-0.5	1.5-2.0
Late Gestation (Mares)	1.0-1.5	0.5-1.0	1.5-2.0
Lactation (Mares)	1.0-2.0	1.0-2.0	2.0-3.0
Working Horses	0.8-2.0	0.5-2.0	1.5-3.0
Growing (Weanlings)	0.5-1.0	1.5-3.0	2.0-3.0
Growing (Yearlings)	1.0-1.5	1.0-2.0	1.8-3.0

Source: Feeding Management Points for Texas Horse Owners (Householder)

Concentrates

There are many concentrates to choose from when supplementing your horse's forage intake. The choice between sweet feed, pelleted, and "complete" feeds can only be compounded by further division into different percentages of crude protein and fat. Generally, mature idle horses can be maintained on 10 percent crude protein, but as physical demand on the horse increases so does the amount of protein that needs to be fed. Some horse owners choose to add fat to every feeding instead of relying on what is commercially prepared. The choice between sweet feed and pelleted feed is primarily personal preference or the preference of your horse, as some tend to be picky. Complete feeds are designed to contain all the concentrate and forage needs of the horse and are primarily marketed towards the geriatric horse. These horses need more fats and are able to digest pelleted feeds more efficiently. Additionally, they may have dental issues preventing the efficient consumption of hay, though it is important to allow access to forage even when feeding complete feeds.

Pelleted feed (top) and sweet feed

Feeding Methods

It is important to follow some basic storage and feeding rules to maintain the safety and health of your horse (Householder).

- Protect stored hay and concentrates from moisture, insects, and rodents
- Do not store concentrates for more than one month
- Feed by weight and not volume
- Do not feed more than .75 percent of body weight in concentrate at one feeding
- Space multiple feedings equally throughout the day
- Feed at the same time every day
- Do not abruptly change amount or type of feed
- Check for feed that was not consumed
- Allow access to salt
- Do not mix commercially balanced feed (for example: oats and sweet feed)

Pasture Feeding

When feeding horses in the pasture, most of the rules above apply, but there are other guidelines as well. If more than one horse is being fed in the pasture at the same time, it is important to space feeders at least 10 feet apart. Some horses may require more space or removal altogether so that other horses may finish their feed. Horses tend to congregate at feeding time around their feeders, which can cause excessive trampling and erosion of pasture; therefore, if you notice the area around your feeders becoming damaged, moving the feeders to different locations periodically can assist in allowing the grass to recover. Feeding hay in a feeder instead of on the ground can also assist in preventing damage. This also has pasture health benefits, which will be discussed further in pasture management.

Trampled feeding area

Nutrient Management

Nutrient inputs on a farm consist of feed, animals, irrigation water, fertilizer, legume nitrogen, etc. Outputs are meat, milk, animals, crops, and manure. When inputs exceed outputs, losses will be present in feed or barnyard waste, in manure, and in field runoff (Westendorf). These losses can lead to wasted feed, money, and animal inefficiency.

Over-feeding your horse can lead to a multitude of physical effects for the horse, excess nutrients being shed in the manure, and wasted money on more feed than is necessary. The environmental effects of the nutrients will be discussed in the section on manure production and characteristics. However, an overview of the initial source of nitrogen and phosphorus is important to understand.

Protein is the chief nitrogen source in the diet, and nitrogen is the nutrient that we are most concerned with (Westendorf). If you have ever compared feed prices, you have noticed that as the percentage of crude protein increases, so does the price of the bag. A mature, idle horse can be maintained on a 10 percent crude protein feed, though feed companies market feeds up to 16 percent crude protein for certain other categories. By buying a feed with the correct percentage of crude protein for your horse, you will save money, and your horse will use the feed more efficiently with less nitrogen excreted in the manure.

Phosphorus management in horses has its own unique set of criteria, which requires a ratio of calcium to phosphorus of 2:1. Typical horse diets approach two to three times the required level of phosphorus, which can be detrimental to the environment (Westendorf). Due to the necessary calcium/phosphorus ratio, there are not many ways to effectively reduce the excess amounts of phosphorus in the diet. However, commercial feeds are still the best option for horse owners.

One other way to save money and improve efficiency is to make an attempt to cut the amount of feed wasted by the horse. Some of the ways horses waste feed and methods to prevent it include the following:

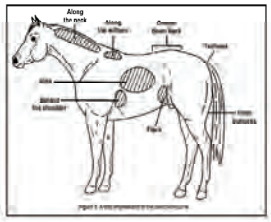
- Shoveling the feed onto the ground with their nose
  Correction: Feed them from a steep-sided feed or water bucket
- Dropping mouthfuls of feed while they chew
  Correction: Have an equine dentist check their teeth
- Turning over ground feeders
  Correction: Feed from a feeder or in a bucket on the fence

Conclusion

Many aspects need to be considered when feeding horses. The guidelines above are a place to start. Some horses are termed “easy keepers” and will manage to “get fat on a pasture of dead weeds” while others may need an alarming amount of concentrate just to keep weight on. The best strategy is to evaluate the classification and body condition score to determine where your horse is currently and where you would like him to be in the future. Then pick a plan to start with and periodically evaluate how your horse is gaining, losing, or maintaining his current weight and adjust accordingly.

Step 1. Hungry horse

Step 2. Evaluate BCS



Step 3. Identify class

Class	Forage (%BW)	Concentrate (%BW)	Total (%BW)
Mature (Idle)	1.5-2.0	0-0.5	1.5-2.o
Late Gestation (Mares)	1.0-1.5	0.5-1.0	1.5-2.0
Lactation (Mares)	1.0-2.0	1.0-2.0	2.0-3.0
Working Horses	0.8-2.0	0.5-2.0	1.5-3.0
Growing (Weanlings)	0.5-1.0	1.5-3.0	2.0-3.0
Growing (Yearlings)	1.0-1.5	1.0-2.0	1.8-3.0

Source: Feeding Management Points for Texas Horse Owners (Householder)

Step 4. Meet minimum 1% of BW forage requirement

Step 5. Choose type and amount of concentrate needed

Step 6. Periodically observe horse BCS for necessary adjustments to feed schedule

Websites of Interest

Texas A&M University: Department of Animal Science, Equine Science Web Page
http://animalscience.tamu.edu/academics/equine/index.htm

Rutgers: Equine Science Center
http://www.esc.rutgers.edu/

Introduction

Understanding the production and components of the manure your horse generates every day will help you develop a better understanding of why managing this "resource" is so important.

Production

An average 1,100-pound horse produces approximately 56 pounds of manure per day. Of those 56 pounds, approximately 85 percent is moisture, which results in eight pounds of manure per day, dry weight (Mukhtar). The numbers do not provoke much thought until you calculate how much manure is produced per year. In an average year, one horse produces approximately 10 tons of manure, or 1.5 tons on a dry matter basis.

Characteristics

The manure your horse generates every day contains many different components. Important chemical and biological elements that are components of manure include nitrogen, phosphorus, potassium, and bacteria. The horse excretes 99 pounds of nitrogen, 18 pounds of phosphorus, and 51 pounds of potassium per year (Mukhtar). Ammonia is excreted in urine and manure as a form of nitrogen. Fecal coliform production, according the American Society of Agricultural Engineers, is 402 million bacteria per day.

Implications

You may have noticed that the nutrients nitrogen, phosphorus, and potassium (N, P, and K) in horse manure match those nutrients contained in the fertilizer you buy at the store. Managed correctly, your manure pile can be a very valuable asset, especially since you already paid for it. Mismanaged, those nutrients and bacteria can be very detrimental to the environment. The following chart contains the effects of excessive contamination of water bodies with manure (Sciarappa).

Nitrate	 Health
Ammonia	 Fish Kills
Phosphorus	 Algae Blooms
Bacteria	 Health
Organic	 O_2 Depletion

Potential Effects of Contaminants
Source: Adapted from environmental concerns with equine operations (Sciarappa)

Management

Managing your manure can range from maximum labor and costs to minimal labor, and costs. Our goal is to give you a variety of tools to find the choice that fits your needs and resources the best.

Composting

Composting is the controlled breakdown or degradation of organic material into a stable product known as humus (Auvermann). Compost can be used to enrich pastures and gardens by improving soil structure, fertility, texture, aeration, and water retention. It can also help control erosion and balance pH (Horse Outreach Workgroup). Additional advantages to choosing this method of manure management include:

- Kills internal parasites, bacteria, fungi in manure
- Discourages external pest colonization in manure
- Kills weed seeds in manure
- Will reduce volume of manure up to 50 percent
- Manure from one horse is equivalent to approximately $150 worth of fertilizer per year (Blickle)

Some disadvantages to choosing this method are:

- Initial investment can be expensive
- Can require extra time depending on the intensity of your management choice
- Large numbers of horses require more resources

There are three important inputs in composting and the proper maintenance of all three is crucial to the process. Composting must be an aerobic process, use naturally occurring aerobic microbes to digest organic material, and be thermophilic, thus reaching temperatures between 130 and 160 degrees F, ensuring the neutralization of pathogens and weed seeds.

Maturity of your compost pile is an important endpoint to realize, depending on what you are going to do with the pile after composting. Compost that is done will not compete with plants for nutrients and will supply the plant with necessary nutrients that are needed to grow. Therefore, if you plan on marketing your compost to nurseries or avid gardeners, special attention needs to be given so that they receive a consistent and quality product. Temperature and commercial tests are good indicators of when a compost pile is ready for appropriate usages.

Composting temperatures


Proper composting barn

The correct mixture of moisture, carbon to nitrogen ratio, and oxygen saturation all play a big role in the success of your composting efforts. Moisture contents between 45 and 55 percent water usually suffice for efficient quality composting. An easy test for this percentage is the amount of moisture left after a handful of compost has been squeezed. Your hand should be left damp, but no water should come from your hand. Manure is generally this percentage when excreted, but will dry out over time; therefore, the compost pile will need to be watered as time passes. Optimal carbon to nitrogen ratios for composting ranges from 25:1 to 30:1 by weight. Most agricultural manure has a C:N ratio of 15:1 or 10:1 so wood chips or sawdust would be a good addition for the best compost. Keeping your pile oxygenated is crucial to success. This can be done actively by turning the pile weekly or every few weeks, or passively by inserting PVC pipes with holes into various places in the pile.

Keeping a temperature log of your compost pile will give you clues to how the process is going and a heads up for any troubleshooting that needs to be performed. Temperatures between 130 and 160 degrees F are optimal, but the pile will cool when it needs to be turned and immediately after turning. The temperature should be back up to the optimal range within 24 hours. When the compost is done, it will not heat up after turning again.

Since our overall goal is to improve the land on which we keep our horses and in a broader sense, the environment, you should keep in mind a few things if you choose to compost your horse manure. The size of your manure storage site is important and should be calculated carefully before implementing your plan. Most people who purchase one horse usually find that their herds multiply exponentially. Your holding structures should have some type of cover that will prevent runoff during rain events, and the storage site should not be close to any water body, water well, or drainage area. Always consider your storage site for placement of a compost pile because of the possibility that bacteria may enter a water body if placed to closely.

Removal from Premises

This choice is probably the most easily managed, provided you have the financial resources to pay for container rental and hauling fees. For example, waste from one horse picked up once a week would cost approximately $310 per month. However, the major advantages are the limited number of times manure is handled and no need for disposal on your property.

Compost pile (straw bedding)

The disadvantage to this method of manure disposal is the landfill aspect. These facilities dispose of wastes that cannot be recycled and are buried. Since they are considered eyesores and bring down property values, it is in an operator's best interest to ensure the longest functional life possible. Therefore, if a waste can be recycled in any way instead of being dumped at the landfill, it will increase the longevity of that facility. Some establishments may even charge an extra fee for allowing disposal of manure.

Spread Fresh on Pasture (Not composted)

Spreading the manure fresh on a pasture is the most popular choice for manure disposal. It has some time management advantages, but unfortunately has some serious drawbacks on pasture, environmental, and herd health. The result of a recent study in Florida suggests that spreading unprocessed horse stall material on pastures can inhibit the productivity and quality of forage (Dilling). Some other disadvantages are listed below.

- Parasite eggs, bacteria, and viruses distributed on pasture
- Nitrogen depletion of soil (occurs during the breakdown of bedding by microorganisms)
- Extremely heavy application will kill forage
- Inadequate acreage for spreading
- Introduces weed seeds to your pasture

The important points above make it imperative that proper application of manure be followed. Many significant points should be considered before spreading manure on your property, such as proper application rates, pasture characteristics where application will occur, timing of application, soil/manure nutrient testing results, and record keeping.

Manure storage container

Manure spreader

According to the Natural Resources Conservation Service (NRCS) practice standards, application rates should be based on soil and manure (composted or not) nutrient evaluations. The amount applied should match as closely as possible to the nutrient uptake of the forage planted. Manure should only be applied to pastures that are flat or gently sloped and that are not close to any water body. Timing of application is an important consideration and should be done when plants are growing and not when plants are dormant, such as during winter. Manure should also not be applied during wet weather or when heavy rainfall is forecasted to occur in the next 24 hours, as this will contribute to runoff. To optimize the results of your manure-spreading venture, records should be kept for at least five years and include quantities distributed, soil test results, dates distributed, climate conditions on application days, and application methods.

Keeping Horses Exclusively on Pasture

Just because you don't have stalls to clean does not mean you are absolved of responsibility for the manure generated on your land. If you have an ideal stocking rate on your property, you have less to worry about than those who are supporting more horses than the land is intended to support. Regardless of your stocking rate, it is a good idea to periodically rake, aerate, or disk your pastures to break up the manure piles. Doing so will allow the manure to decompose faster, kill pathogenic microorganisms more quickly, and supply nutrients to the soils that are readily available to growing forages.

Raking or harrowing your pasture on a periodic basis does not require an investment in expensive equipment. Any device that will aid in the destruction of manure piles will do. A few examples are listed below and can be pulled by hand, horse, four wheeler, tractor, or utility vehicle.

- A segment of chain link fence with weights on top
- An arena rake (will aerate the soil as well)

Conclusion

Horses produce a large amount of manure that contains a variety of components. In reviewing manure management choices there are advantages and disadvantages to any method you choose. The only constant of manure management is a steadily growing pile that you can't ignore and **will** have to deal with at some point.

Websites of Interest

Texas A&M University System: Texas Animal Manure Management Issues
http://tammi.tamu.edu/pubs.html

Composting Horse Manure
http://tammi.tamu.edu/pdf%20pubs/compostinghorsemanure.pdf

Composting: Recycling the Feed You Have Paid For
ftp://ftp-fc.sc.egov.usda.gov/CT/kmrc&d/heap_composting.pdf

Manure Storage: Containing the HEAP
ftp://ftp-fc.sc.egov.usda.gov/CT/kmrc&d/heap_storage.pdf

Manure Utilization: Conquering the HEAP
ftp://ftp-fc.sc.egov.usda.gov/CT/kmrc&d/heap_utilization.pdf

Rutgers: Equine Science Center, Stable Management Publications
http://www.esc.rutgers.edu/publications/management.htm

Natural Resources Conservation Service Practice Standards
http://www.nrcs.usda.gov/technical/standards/nhcp.html

Pasture Management

Introduction

Most horse owners who have the illusion that grass will not die under any circumstances lack an adequate knowledge of proper pasture use and maintenance. While initially a daunting subject, pasture management is a skill that must be learned and practiced so that your horses and your land stay optimally productive. The following are all important topics in pasture management.

- Stocking rates
- Soil evaluation
- Weed control and identification
- Forage cultivation
- Grazing management

Pasture Importance

Pasture is important to horses for many reasons that sometimes are lost in our, "feed them twice a day and ride for an hour" mantra. Horses naturally graze continuously and the effects of attempting to adapt their needs to our convenience are often seen. A good quality pasture alone will maintain a mature idle horse and contains carbohydrates, fats, proteins, vitamins, minerals, and water (Williams). Effectively using your pastures will allow your horse to spend time in his natural habitat while having a positive effect on your budget as listed below. Horses should consume at least one percent of their body weight daily in long stemmed forage regardless of whether they are in pastures or stalls. This practice decreases the incidence of colic, gastric ulcers, and boredom. The pasture is also a place where horses can socialize and exercise, which decreases the incidence of numerous vices we try so creatively to eliminate.

Additional benefits in allowing your horses to graze pasture are listed below (Williams).

- Reduces hay costs by $60-100 per month
- Reduces fertilizer costs when spreading manure (if composted)
- Aesthetically pleasing for horse owners and neighbors
- Less time spent cleaning stalls
- Reduction in bedding costs
- Reduce parasite problems such as worm and fly infestations (if composted)

What more can a good pasture do? Plenty! A pasture plays many roles in environmental health as well (Williams).

- Reduction in erosion
- Nutrient recycling
- Groundwater recharge
- Filter surface water runoff
- Control dust and odor

Stocking Rates

One of the complexities encountered while raising/owning horses is the emotional attachment most of us experience. This makes it difficult to part with the older "starter" horses or foals that were bred as an "investment." Consequently, we may end up with a stocking rate that is less than ideal.

The stocking rate can be affected by your geographic region, soil type, management practices (past and present), total acreage, average rainfall, and forage variety (Hanselka). After land purchase, the only aspect mentioned above in your control is management practices and forage variety that will be discussed as we proceed. In general, the U.S. Department of Agriculture recommends seven acres per animal in excellent condition to greater than 19 acres per animal in extremely adverse conditions.

These guidelines can be manipulated by more intensive management however; this usually leads to higher costs elsewhere. Since there are a variety of soil types and geographic regions compounded by the unpredictability of rainfall amounts, finding the perfect stocking rate can be a daunting task. It will require close monitoring of your pasture conditions and addressing any adverse reactions that occur before the pasture is permanently damaged. The last chapter of this guide discusses various organizations that can provide free expertise relative to your area.

Soil Evaluation

Think of soil as an equivalent to the 50-pound feed sacks or bales of hay you cart to the barn every week. Similar to the way that feed and forage supplies your horse with essential nutrients, the soil provides essential nutrients to the grasses you want to keep healthy. A soil evaluation is a necessity before fertilization or deciding to plant new forage species. This low cost test can save you thousands in wasted time and money in the event of a failed re-seeding.

Stocking rate

=

Acres per horse

All that needs to be done is to take multiple samples from the pastures you want tested and put the mix in a bag along with a completed questionnaire. More specific instructions may be obtained from the testing laboratory. In one to two weeks the results of the test are returned along with detailed instructions for fertilizer application if needed. These tests can be obtained from your county extension agent or from the Texas A&M University Soil, Water & Forage Testing Laboratory.

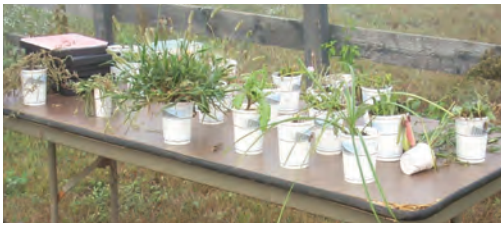
Soil sample collection

Weed Identification and Control

Weed control ties very closely to soil fertility and stocking rate. Weeds are opportunistic, meaning they usually move in during adverse conditions. If you have overstocked your pastures and all the forage has been removed, resulting in a change in soil pH and bare spots, you have just handed out an invitation for weed invasion. In addition to decreased nutrition and palatability, some weeds can be toxic to your horse and have a wide variety of effects on your animals.

Identification

The ability to become proficient at undesirable plant identification will save a lot of time, aggravation, and money. If you wait until a weed has taken over three-quarters of your pasture before trying to eliminate it, it's too late. On the contrary, if you identify the presence of a weed while it only inhabits one square foot of your pasture, you can spot spray or dig it up, which costs significantly less than applying herbicide to your entire pasture. There are several weed and toxic plant guides available in addition to your county extension agents or NRCS field staff to assist in identifying what is growing in your pasture.



Plant identification

Control

Methods for control of weeds can be offensive or defensive. Taking an offensive stance on weed control is less costly and aggravating than being forced into defense. Some methods considered to be offensive are just good management practices and are as follows:

- Don't over or under graze your pastures
- Select forage species recommended for your area
- Use early weed control

Methods to be taken once spot control is no longer an economically viable option can include:

- Mechanical – mowing, disking, or burning
- Chemical – herbicides
- Biological

Mechanical weed control

The importance of plant identification plays a role in control as well. Herbicides can be selective or can kill anything the spray might land on. Carefully read the label and make sure you know what you are trying to eliminate before spraying to avoid disastrous consequences. If you plan to graze your animals or cut the pasture for hay, you also need to pay careful attention to the restrictions to determine when it will be safe to do so. Restrictions can range from weeks to no time restriction for allowing livestock back on the pasture or cutting hay. In addition, the classification of animals as lactating may also have an impact on restriction time for grazing on treated pasture.

Chemical weed control

Forage Cultivation

The purposes for cultivating forages, according the NRCS practice standards, are as follows.

- Establish adapted and compatible species for forage production
- Improve or maintain livestock nutrition and health
- Balance forage supply and demand during low production times
- Reduce soil erosion and improve water quality

Many considerations need addressing when deciding to renovate or improve a pasture. The plant species selected depends on your particular climate, soil condition/type, and resistance to disease or insects that may be prevalent in your area. After deciding on the species, proper planting is essential and seeding rates, time of planting, depth of planting, and the necessity of fertilizer use are key to your success. Remember that livestock must be removed during renovation or improvement and not allowed back on the pasture until plants are well established.

The most important aspect of forage cultivation is choosing the plant species that grows best where you intend to grow it. For instance, some owners like to feed their horses alfalfa, but your attempt to grow it in South Texas probably will not be successful. Contact your county agent or seed store for assistance in choosing the right forage and establishment plan for your area and livestock goals.

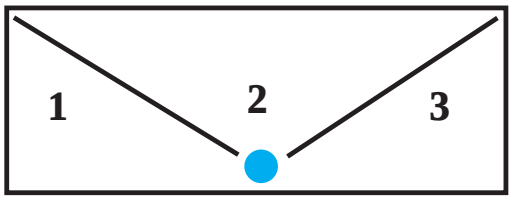
Grazing Management

Importance

We have talked about the things that pastures do for us and our horses. Improperly managing the animals' access to this resource can have deleterious effects in a very short time that can take a very long time to recover. Different management techniques can be employed to optimize the health of the pasture and the access horses have to it.

Rotational Grazing

The management system of rotational grazing involves a few rules of thumb. You should graze your animals when the grass is 6 inches to 8 inches high and rest the pasture when it is 1.5 inches to two inches high (Horse Environmental Awareness Workgroup). This is not always possible and depends on the forage being grown, so if all you can manage is one pasture and a sacrifice lot, that will be better than one pasture that is turned into a sacrifice lot. It is also important to remember that recovery times for pastures grazed down can range from ten to 60 days, depending of course on the amount of available water. Before you start calculating the expense of fence per foot, remember that electric fencing is cheap and portable!



The figure above is an example of a rotational grazing system that utilizes one common watering system.

Sacrifice Lot

Sacrifice lot is an important management option you can choose if you have a high density-stocking rate and involves fencing off a section of your property, knowing that pasture quality will be reduced or destroyed. The idea of the sacrifice lot was developed to protect pastures from overuse at critical times such as winter, summer, periods of heavy rainfall, rejuvenation time, preventing over-consumption, drought, and managing horses that don't get along (Connecticut Horse Environmental Awareness Program).

Sacrifice lot

Keep in mind that this is not where your horses will primarily be living, so being generous in size with a sacrifice lot will defeat the purpose. A minimum size for a sacrifice lot will allow for at least 600 square feet or a 20'x 30' foot area per horse (Horse Outreach Workgroup). Remember, this area does not have to be totally sacrificial: it can double as an arena, turnout, or storage area when not in use.

Mowing

Not all parts of grazing management involve your grass-powered animal, and occasionally you will have to get out your gas-powered animal! Some horses tend to mark out one portion of the pasture as the communal manure pile where the extra fertilization of that particular area results in healthy growth that is never grazed. However, this trait can become frustrating when you notice the area 3 feet away is chewed down to the dirt. Mowing your pastures occasionally will prevent weed seeds

from coming to a head, discourage weed growth, spur new grass growth, encourage horses to eat in a more uniform fashion, and prevent grass from becoming too mature.


Example of manure concentration

Burning

Before discussing the benefits of burning pastures, it is imperative that any plans to burn are only conducted by those who have the experience and knowledge necessary to maintain the safety of people involved. There are many reasons to burn pastures, including control of undesirable vegetation, prepare for harvesting or seeding, control plant disease, reduce wildfire hazard, improve wildlife habitat, improve plant production, remove debris, and enhance seed production.

A plan should be in place before the burn ever begins and should include the location/description of the burn area, pre-burn vegetation cover, management objectives, required weather conditions, notification list, equipment list, personnel assignments, post burn evaluation criteria, firing sequence, ignition method, and all necessary approval signatures.

Conclusion

Each of the topics discussed have their own impact on the horses and land on which they live. Proactive management will save time and money when compared with reactive management.

Websites of Interest

Horse Pastures for Texas
http://animalscience.tamu.edu/images/pdf/equine/equine-horse-pastures-texas.pdf

Stocking Rate: The Key Grazing Management Decision
http://repository.tamu.edu/bitstream/handle/1969.1/86995/pdf_1417.pdf?sequence=1

Reading Your Landscape: Are Your Pastures Healthy (Publication#E-107)
http://tcebookstore.org/

Do You Have Enough Forage?
http://cnrit.tamu.edu/ganlab/docs/EnoughForage.pdf

Know Your Plants to Protect Your Watershed (Publication #E-105)
http://tcebookstore.org/

Common Range Plants of Texas
http://essmextension.tamu.edu/plants/

Testing Your Soil: How to Collect and Send Samples (Publication #L-1793)
http://tcebookstore.org/

Introduction

Your barnyard area has the potential to be environmentally harmful if proper management measures are not taken. For this section, we will include barns, sacrifice areas, pasture shelters, manure storage areas, watering areas, and feeding areas in our definition of a barnyard. Animals tend to concentrate or spend a significant amount of time in these areas, and consequently, tend to have more manure deposition and greater forage destruction leading to increased runoff of pollutants. Facilitating good drainage away from heavy-use areas to keep water clean is a key management practice when attempting to reduce the effect of a barnyard on the environment. A few ways to facilitate drainage include the following (Sciarappa):

- Building location
- Gutter systems
- Harvesting rainwater
- Natural filters

Rainwater harvesting system

Building Location

If you have the luxury of planning your facility from the ground up, you should keep in mind a few things when planning the location of your barns, storage areas, and compost piles. It is best to place these structures on higher topographical areas with well-drained soils and avoid building close to streams, ponds, and wetlands (Banka). All efforts should be made to direct stormwater away from the structures toward filter strips or vegetated water retention systems by constructing berms, terraces, and grading.

Gutter Systems

Placing gutters on the buildings in your barnyard and on your pasture shelters is an effective way to divert large amounts of water away from high-use areas where large amounts of manure is deposited and there is lots of bare ground. However, it is important not to allow the water to run out at the base of your structure as it does in traditional gutter systems. It is best to continue diverting the water underground, past the high-use area to a common filtration site such as a rain garden or vegetated buffer. Water can also be retained and stored for later use by horses or their owners.

Rainwater Harvesting

Horses typically drink three to eight gallons of water per day. When you factor in water used for baths, cleaning water buckets, landscaping, or other activities, a large amount of water is used on your farm

every day. A great way to conserve water and prevent runoff from traveling through your barnyard is to harvest rainwater. For instance, one inch of rain can yield .6 gallons of water for every square foot of collecting surface. The roof of a 2,000-square-foot house can collect 1,200 gallons of water from a one-inch rain and can be stored and used as needed.

There are many different designs of rainwater harvesting systems ranging from small wildlife watering structures to roof catchments with filters and treatment systems for uses throughout the whole home or barn.

Natural Filters

Rain Gardens

A rain garden is an aesthetically pleasing and artistic version of a bio-retention system. A bio-retention system is a scientific name for a depression that catches and filters water. The depression is about six inches deep and landscaped with a variety of plants that catch contaminated water runoff and filter it naturally. This type of system is best implemented on the down-slope of sacrifice areas, manure storage areas, arenas, or other areas where there is bare earth and heavy animal congregation.

Vegetative Buffer Strips

Vegetative buffer strips are natural filters. A California study showed that a 15-foot-wide vegetated buffer strip can remove 74 percent of the total suspended solids, which are organic and nonorganic solids that bacteria and other nutrients can adhere to. However, the NRCS stipulates that filter strips should have at least 20 feet of flow length. This type of natural filter is not a bio-retention system or landscaped; it is just a strip of grass. It should be placed where runoff will be distributed evenly over the buffer strip. If runoff does not flow uniformly, gullies will form and the buffer strip will become useless. If you choose to implement a vegetative buffer strip around your barnyard, the horses will not understand its significance and probably think it is more valuable as a snack, so fencing is also a key consideration. It is important that the filter strip not be used as a traffic lane for livestock or heavy equipment and that you choose plants and vegetation wisely. Some species can be toxic to horses and others may be hardier during drought conditions.

Example of a rain garden

Example of a vegetated buffer strip with pasture on one side and a creek on the other side of the trees.

Conclusion

Keeping drainage from going through the high-use areas on your farm is a key management system to reduce nonpoint source pollutants and can be accomplished with the methods described above. Remember, grazing management and associated cross fencing is a key part of success with your natural buffer systems.

Websites of Interest

Rutgers: Equine Barnyard Management
http://www.esc.rutgers.edu/publications/stablemgt/FS618.htm

Slowing the Flow With Vegetated Buffers
ftp://ftp-fc.sc.egov.usda.gov/CT/kmrc&d/heap_buffers.pdf

Keeping Clean and Dry With Water Diversions
ftp://ftp-fc.sc.egov.usda.gov/CT/kmrc&d/heap_diversions.pdf

Texas AgriLife Extension Rainwater Harvesting Website
http://rainwaterharvesting.tamu.edu/

Small Acreages

Overview

A small 20-acre farm

Unfortunately, small acreage tracts are some of the most overused lands in Texas (McGinty). The most prevalent reason is overgrazing, which usually results from overstocking. An understanding and implementation of the best management practices in this guide are crucial if you have a limited amount of land. Small acreage properties collectively comprise a significant portion of land in Texas and mismanagement of most small acreages can have huge impacts on the environment, especially when theses small acreage properties are clustered near water bodies.

Another inadvertent consequence of small land ownership is your new role as agricultural ambassador to the urban population. These small pockets of agriculture might be the only example of farming or livestock an urban dweller may see. Therefore, it is extremely important that you uphold your responsibility as an animal owner to provide for their basic needs, including food, shelter, health, and welfare (McGinty). Well-kept facilities with healthy horses are considered aesthetically pleasing and will be welcomed or, at the very least, met with less opposition from a community.

Websites of Interest

Managing Small-acreage Horse Farms
http://extension.oregonstate.edu/catalog/pdf/ec/ec1558.pdf

Livestock and Poultry Environmental Stewardship Curriculum: Small Farm Fact Sheets
http://www.extension.org/pages/Livestock_and_Poultry_Environmental_Stewardship_Curriculum

Technical Assistance

Many agencies are available to you for consultations on issues you may be facing or plans you would like to implement. These agencies also routinely conduct short courses and seminars at little or no cost on current information and management practices in agriculture. They include the Texas AgriLife Extension Service, Natural Resources Conservation Service, Texas State Soil and Water Conservation Board, and your local Soil and Water Conservation District.

Texas AgriLife Extension Service

Texas AgriLife Extension Service has many responsibilities in the state of Texas, all based on community education. Each county has one or more county agents in the areas of agriculture/natural resources, family/consumer sciences, community development, and 4-H/youth development. These agents oversee programs that concern research, Better Living for Texans, the vast 4-H program, Master Gardeners, The Urban Rancher, and many more.

Texas State Soil and Water Conservation Board

The Texas State Soil and Water Conservation Board (TSSWCB) is the state's leading agency for the planning, management, and abatement of agricultural and forestry nonpoint source pollution. The agency is steered by two governor appointees and five elected landowners from across the state of Texas. 216 soil and water conservation districts (SWCD) across the state obtain technical assistance from the TSSWCB regarding nonpoint source pollution. A certified Water Quality Management Plan (WQMP) is the first line of defense again nonpoint source pollution. These plans include appropriate land treatment practices, production practices, management measures, and technologies.

Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) is an agency of the U.S. Department of Agriculture (USDA), which assists landowners and land managers with conserving soil, water, and other natural resources. Service centers in each county provide technical assistance to owners in initiating and maintaining various conservation practices. Two main programs that may be available to horse owners are the Environmental Quality Incentives Program (EQIP) and the Conservation Reserve Program (CRP).

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a more flexible, short-term contract that helps agricultural producers who have issues with the quality of soil, water, air, or other natural resources on their land. The goal of EQIP is to provide a voluntary conservation program for farmers and ranchers that promotes both agricultural production and environmental quality. The amount of funding available for EQIP can vary from county to county. To be eligible for this program, you must

be involved in livestock or agricultural production and develop a plan of operations. This plan defines the objective by the conservation practice proposed and a schedule of practice implementation. Applications will then be ranked by environmental benefits achieved and the cost effectiveness of the proposed plan.

- Grassed Waterways
- Filter Strips/Riparian Buffers
- Manure Management Facilities
- Capping Abandoned Wells
- Nutrient Management
- Integrated Pest Management
- Wildlife Habitat Management

Manure storage area

Conservation Reserve Program

Wildlife

The Conservation Reserve Program (CRP) is administered through the USDA Farm Service Agency (FSA). This program helps agricultural producers safeguard environmentally sensitive land through practices that improve the quality of water, control soil erosion, and enhance wildlife habitat. Owners of large ranches close to sensitive water bodies or owners interested in restoration of degraded land should consider this program. After enrollment, the FSA will pay an annual per acre rental rate and provide up to 50 percent cost share assistance for practices that accomplish the above goals. The portions of property to be submitted to the program will be under contract for 10 to 15 years and cannot be grazed or farmed. To be eligible for the program, you must have owned or leased the land for one year prior to application. In addition, the land submitted for the program must be suitable for the following practices.

- Riparian Buffers
- Wildlife Habitat Buffers
- Wetland Buffers
- Filter Strips
- Wetland Restoration
- Grass Waterways
- Contour Grass Strips
- Salt-Tolerant Vegetation
- Shallow Water Areas for Wildlife

For the Small Acreage Landowner

Acreages less than 10 acres generally have problems receiving funding. These problems can be because of a variety of logistical issues. When improving pasture, you will need to remove livestock. However, many small acreages have nowhere else to put them for the time required to establish growth. For professionals who have the equipment for re-seeding and brush control, it may not be cost effective to take on small acreages. These are a few reasons small landowners may not be able to receive financial assistance for property improvements that will beneficially impact the environment.

Websites of Interest

Natural Resources Conservation Service
http://www.nrcs.usda.gov/

Texas State Soil and Water Conservation Board
http://www.tsswcb.state.tx.us/

Texas AgriLife Extension
http://texasextension.tamu.edu/

Conclusion

Texas is projected to have exponential population growth in the near future. Concurrently our water supply is projected to decline, making water conservation and protection all the more important. As the population increases, more development and fractionation of large tracts of land is expected. This trend will contribute to runoff and decrease the ability of our land to filter it effectively. Increasing numbers of bacteria will continue to find a way into our surface waters as more livestock are applied to the land whether for recreational or commercial purposes.

This guide is primarily focused on the equine contribution to nonpoint source pollution, but there are other sources such as wastewater treatment facilities, failing septic systems, and urban runoff that contribute to water quality impairments as well. This confirms the need to educate all aspects of society on the importance of maintaining and conserving the quality of water necessary for good health.

As we have discussed, there are many important aspects to horse care that extend beyond having your hands directly on the horse. Procuring feed, managing manure, and maintaining pasture and facilities can take a considerable amount of time and effort. The collective impact of mismanagement of equine facilities can be environmentally harmful. The management practices that minimize these impacts will result in a farm that is healthy, saves money, and is aesthetically pleasing.

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http://www.mda.state.md.us/pdf/sacrifice07.pdf

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