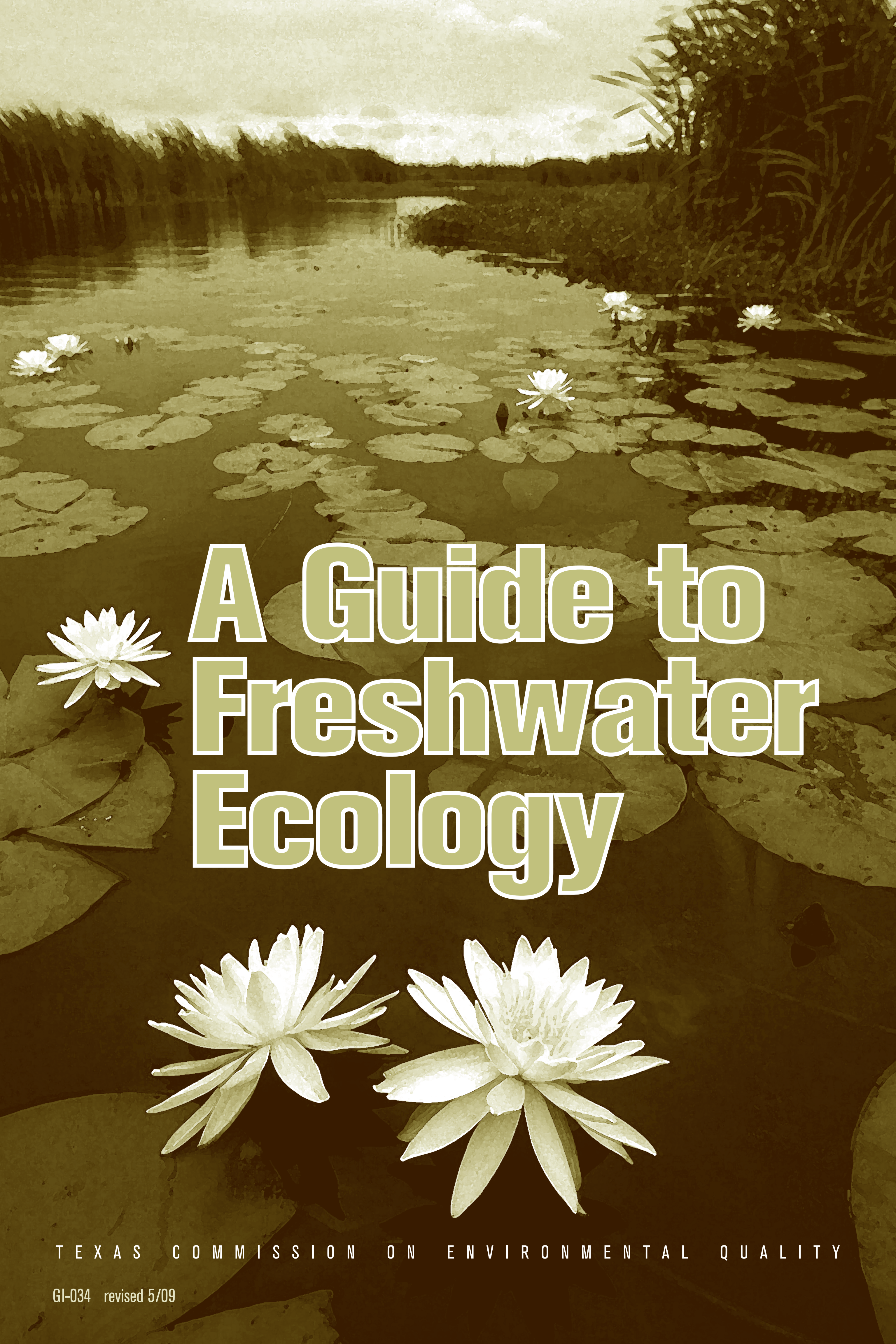

A Guide to Freshwater Ecology

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

GI-034 revised 5/09

October 2016 Addendum:

In 2011, the TCEQ updated its web domain to tceq.texas.gov.

So for any links to the TCEQ website included in this publication, please substitute this new domain in place of tceq.state.tx.us.

TCEQ

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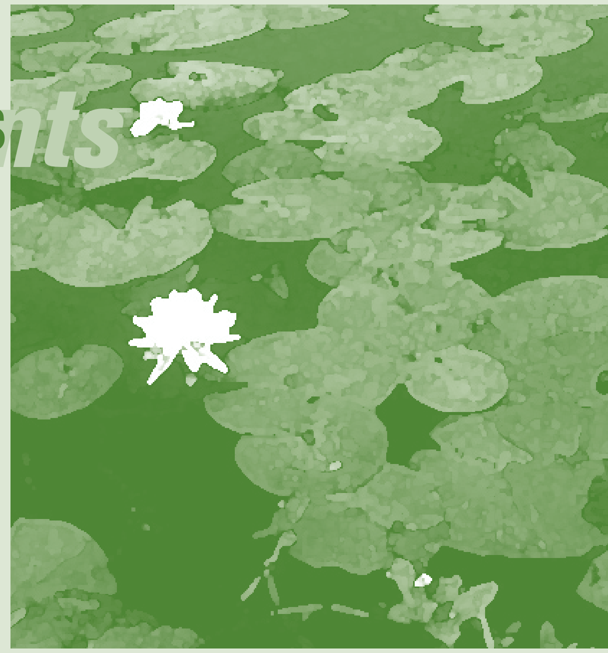
Preface and Acknowledgments



This freshwater guide was authored by Christine M. Kolbe of the Texas Commission on Environmental Quality (TCEQ) and Mark Luedke of the Texas Parks and Wildlife Department (TPWD). Illustrations, unless otherwise noted, were created by Christine M. Kolbe.

The purpose of this manual is to familiarize individuals with a variety of topics related to freshwater ecosystems. It is intended to be user friendly and should therefore be beneficial to individuals with a wide range of expertise. If you come across a term you don't understand, there is a glossary near the end of the book. The information on freshwater invertebrates, fish, reptiles, amphibians, birds, and plants is meant to familiarize the user with only the most common groups in Texas lakes and streams. Although this document contains the most current information available, keep in mind that the classification of plants and animals is always being evaluated. A reference list is included at the end of the manual to provide individuals with sources of more detailed information and complete keys.

The authors would like to thank staff from TCEQ and TPWD for reviewing this document.

Contents

List of Tables

List of Figures

List of Abbreviations Used

BOD	biochemical oxygen demand
°C	degrees Celsius
CFR	Code of Federal Regulation
CG	collector-gatherer
cfs or ft^3/s	cubic feet per second
Cl^{-1}	chloride
DO	dissolved oxygen
EPT	Ephemeroptera-Trichoptera- Plecoptera Index
°F	degrees Fahrenheit
FFG	functional feeding groups
ft/s	feet per second
FC	filterer-collector
H^+	hydrogen ion
H_2O	water
km	kilometer
µg/L	micrograms per liter
m	meter
mg/L	milligrams per liter
mL	milliliter
mm	millimeter
NH_3	ammonia-nitrogen
NO_3	nitrate-nitrogen
NO_2	nitrite-nitrogen
OH^-	hydroxide ion
PPM	parts per million
PPT	parts per thousand
PI	piercers
P	predator
RBA	rapid bioassessment assessment protocols
SCR	scraper
SHR	shredder
SO_4^{-2}	sulfate
TDS	total dissolved solids
TCEQ	Texas Commission on Environmental Quality
TNRCC	Texas Natural Resource Conservation Commission
TPWD	Texas Parks and Wildlife Department
TSS	total suspended solids
TSWQS	Texas Surface Water Quality Standards
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WWTP	wastewater treatment plant

CHAPTER

1 Introduction

Texas covers an area of 267,277 square miles varying from desert mountains in the west to the pine forests in the east. The differences in land form from north to south range from the flat, treeless high plains in the Panhandle region to the flat Lower Rio Grande Valley and the coastal plain.

Texas has a large number of water bodies, with 11,247 streams and rivers large enough to be named. Surface water in Texas covers 5,363 square miles. The total length of all streams and rivers combined is 191,228 miles. However, only 40,194 miles of streams and rivers are considered perennial, meaning that they have sustained flow throughout the year. Sections of rivers form parts of borders and are resources shared with Oklahoma (Red River), Louisiana (Sabine River), and Mexico (Rio Grande).

The state has 10,196 reservoirs larger than 10 acres which cover more than 3.5 million surface acres. Another 6.3 million acres are freshwater wetlands. There are also thousands of smaller reservoirs, private ponds, and stock tanks throughout the state. Several large springs (groundwater) and thousands of smaller springs are scattered throughout the state. These various types of freshwater habitat provide for a diverse array of aquatic life.

Distinct differences in land form, soil types, natural vegetation, climate, and land use are evident when traveling across Texas from east to west. The Piney Woods of east Texas slowly transform to Post Oak and Blackland Prairie areas, where richer, deeper soils promote agricultural activities. In sharp contrast to these areas, the rolling, rough topography and thin rocky soils to the west are characteristic of the Edwards Plateau or the Hill Country. The Trans-Pecos area of far west Texas, with its arid climate and harsh terrain, produces only sparse, drought-resistant vegetation without irrigation.

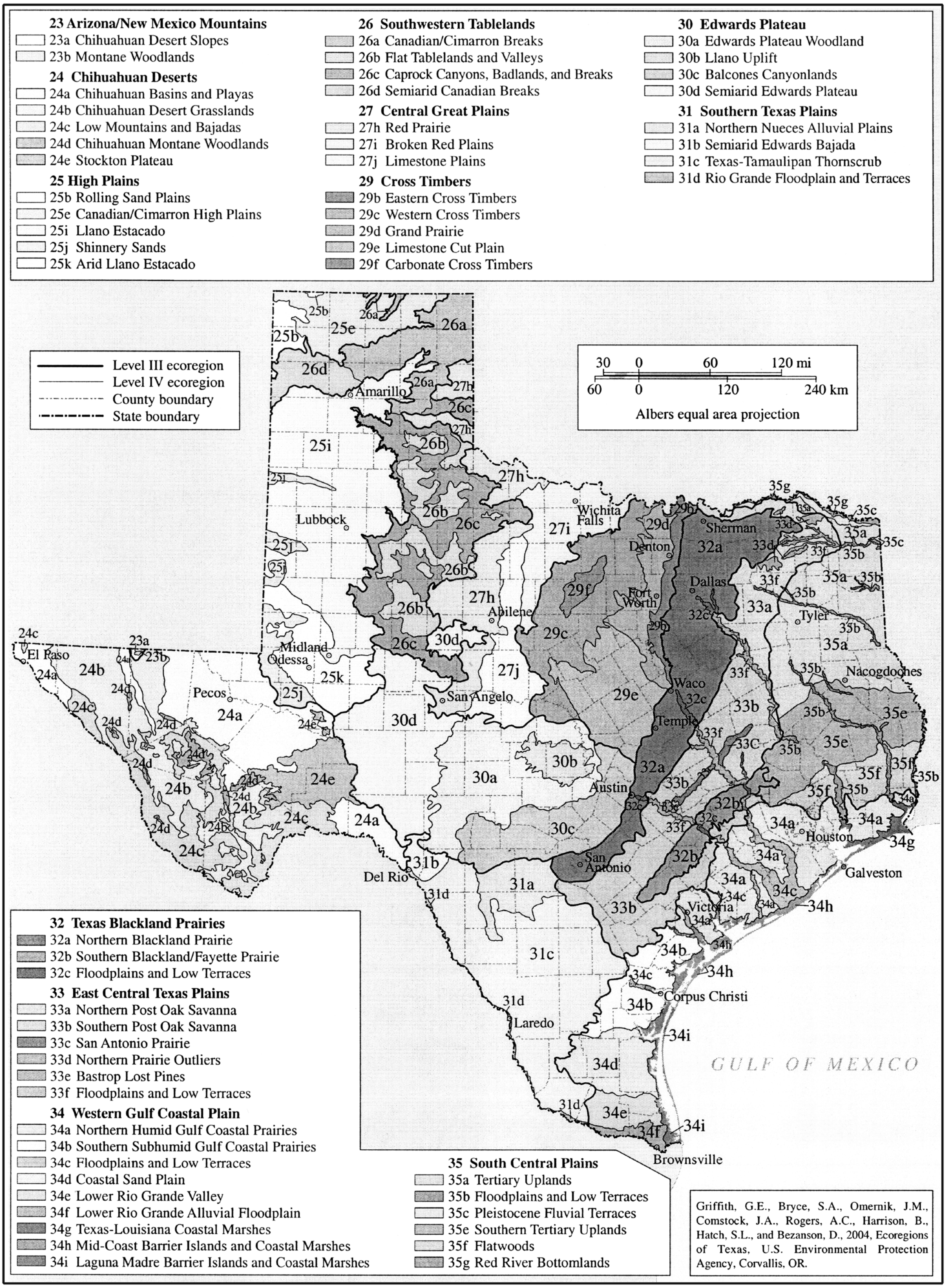
Streams that cross these natural areas and the reservoirs found within them are just as distinct. As water flows over and through the land and stream channels, it acquires and integrates characteristics from the land, especially from the soils, topography, and vegetation. The bayous, streams, and sloughs in the Piney Woods typically have sluggish flow due to flat terrain with little change in slope. These streams generally have highly colored, dark brown to black water due to abundant natural organic matter. Streams that traverse the Post Oak Savanna and Blackland Prairie areas, while faster flowing, tend to carry higher suspended inorganic sediment loads due to the erosion of deep soils. The rocky terrain of the Hill Country tends to produce fast-flowing, clear streams due to high stream slopes and thin soils. As a result of the arid climate of the Trans-Pecos, few streams cross the western portion of the state. Those that do resemble Hill Country streams, but often have elevated salt content due to high evaporation rates.

The USEPA has developed a system for classifying ecological regions called ecoregions. *Ecoregions* define areas of general ecosystem similarity and in the type, quality, and quantity of environmental resources. Ecoregions are based on geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology.

There are four ecoregion levels. Level I, the most general level, divides North America into 15 ecoregions. Level II divides the continent into 52 ecoregions. Level III further defines the continental US into 104 ecoregions. There are 12 Level III ecoregions in Texas—Arizona/New Mexico Mountains, Chihuahuan Deserts, High Plains, Southwest Tablelands, Central Great Plains, Cross Timbers, Edwards Plateau, Southern Texas Plains, Texas Blackland Prairies, East Central Texas Plains, Western Gulf Coastal Plain, and South Central Plains (see Figure 1-1). In 2004, Texas ecoregions were further defined to Level IV.

A map detailing Level III and IV ecoregions of Texas can be found on the Web at **www.epa.gov/wed/pages/ecoregions/tx_eco.htm**.

Figure 1-1
Ecoregions of Texas



CHAPTER

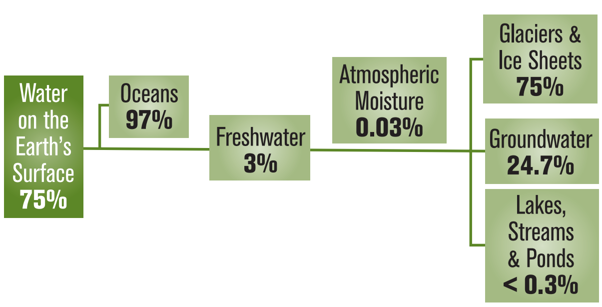
2 The Basics of Water

A GUIDE TO FRESHWATER ECOLOGY

Water, essential to the survival of all living things, is one of the most abundant and important substances on earth. Humans cannot go for more than several days without water. No living organism on earth can survive without water. Some may be better adapted to survival in areas with minimal water sources, but they still need it.

Water covers about 75 percent of the earth's surface (see Figure 2-1). Ninety-seven percent of all water on earth is saltwater in the oceans. Only three percent is freshwater, found in the form of glaciers, ice sheets, surface water, groundwater, and in the atmosphere. The majority of freshwater is found in glaciers and ice sheets. Most of the remaining freshwater is found as groundwater. Only a small fraction of all freshwater on earth is found as surface water in lakes, ponds, rivers, and streams. The remaining fraction of freshwater is found in the atmosphere.

Figure 2-1
Water on the Earth's Surface



What Is Water?

The Water Molecule

Water is defined chemically as H_2O. This notation means a molecule of water is made up of two atoms of hydrogen (H) attached or bonded to one atom of oxygen (O) as illustrated in Figure 2-2. Atoms carry either a positive or a negative electrical charge. In the case of water, the hydrogen atoms carry a positive charge, and the oxygen atom, a negative charge. The two hydrogen atoms are located on one side of the oxygen atom. This causes that side of the water molecule to carry a positive charge, while

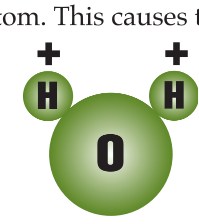


Figure 2-2
Water Molecule

the side with the oxygen atom has a negative charge.

The water molecule illustrates the old saying "opposites attract." The positive hydrogen side of a water molecule will bond with the negative oxygen side of another water molecule (see Figure 2-3). Water molecules tend to cluster together as drops instead of spreading out in thin layers. Without gravity, a water drop would be a perfect sphere.

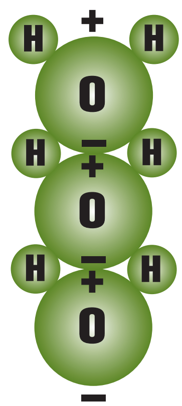


Figure 2-3
Bonded Water Molecules

Physical and Chemical Properties of Water

These simple molecules have some unique physical and chemical properties.

Water is a universal solvent. About half of all the natural elements on earth can dissolve in water. Most substances required for life are found dissolved in water. Many of the nutrients and minerals required by plants and animals are carried by water. Water is also an inert solvent, meaning that it is not altered by any substance it dissolves, and in turn those substances are not altered by water.

Water is the only naturally occurring substance that can exist in all three physical states. Water can be a solid (ice), a liquid (water), or a gas (water vapor).

Water is colorless, tasteless, odorless, and transparent in its pure liquid state.

Pure water has a neutral pH. This means that water has a pH of 7.0, and is neither acidic nor basic.

Water has a very high surface tension. Have you ever wondered how a water strider (insect) can skate across the water surface without sinking, or why a leaf floats? The water surface is the point where liquid water meets water vapor (air). At this point water molecules and water vapor molecules form an attraction. The attraction of the water molecules is the strongest, creating *surface tension*. Surface tension is basically a "water membrane," which allows things heavier than water to float on the surface without breaking through. Surface tension, also known as capillary action, is responsible for the movement of water through plant roots in a manner similar to a paper towel or sponge soaking up water.

Water is the basis for temperature measurement. The boiling and freezing points of water are the basis for temperature measurement. On the Celsius scale, 0°C is the freezing point of water and 100°C is the boiling point, at sea level. Water freezes at 32 degrees Fahrenheit (°F) and boils at 212°F, at sea level.

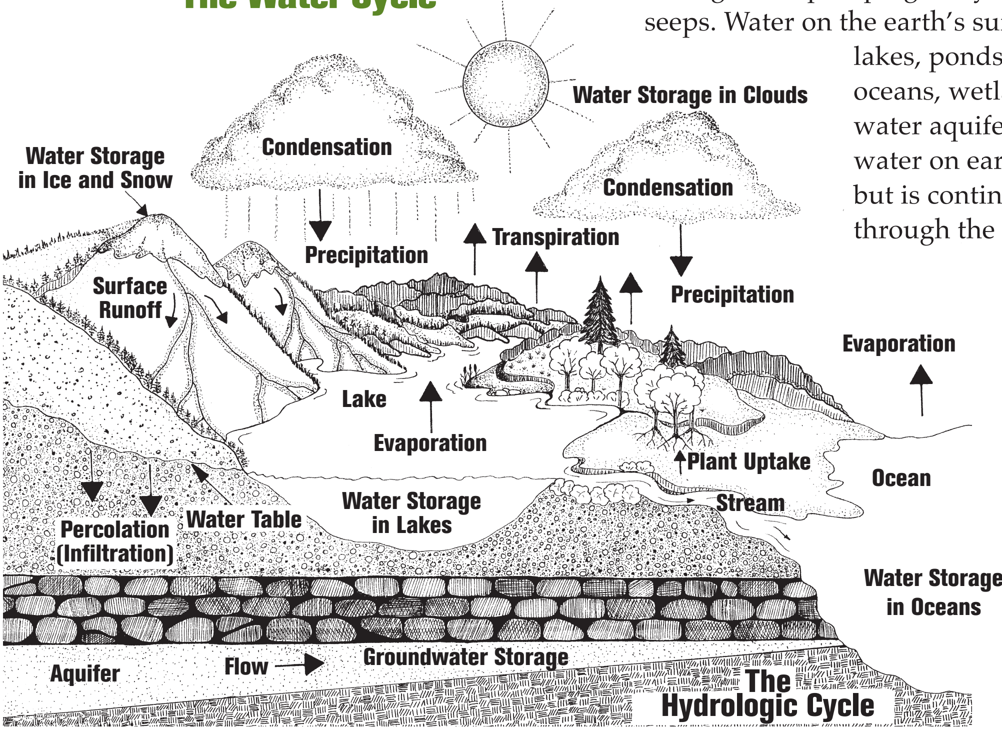
Water has unique properties relative to heat. The specific heat of water is defined as one, and the specific heat of all other substances is measured in relation to water. Specific heat is defined as the calories required to raise the temperature of one gram of water by one degree Celsius (°C).

Water can absorb a great amount of heat with a relatively small increase in temperature. Water is commonly used as a coolant, as in a car radiator. Water can absorb large amounts of heat energy before getting hot. Water is also slow to cool when the source of heat energy is removed or decreased. It is this property that moderates the earth's climate and helps organisms regulate body temperature.

Water, like other solids and liquids, becomes denser as it cools up to a point. So why does ice float? Water gets heavier as temperatures drop to about 4°C (39°F). Below 4°C water becomes less dense. When water freezes at 0°C (32°F) it expands causing pipes to burst, glass containers to break, and ice to float on the surface. This property is especially important to the protection of aquatic life from extreme temperatures in areas where water bodies freeze over in winter. Water in its solid form is less dense than the liquid state which allows ice to float on the water surface, trapping warmer water underneath.

Figure 2-4

The Water Cycle



The Water Cycle

The *water cycle* or *hydrologic cycle* is a model that describes continuous movement of water, through storage and transfer, between the atmosphere, land, and water bodies (see Figure 2-4). The transfer of water occurs in several different ways. *Evapotranspiration* refers to the two ways of moving water from the land to the atmosphere, *evaporation* and *transpiration*. Powered by the sun, *transpiration* releases water to the atmosphere from plant tissue that loses moisture absorbed from the soil through the leaves. *Evaporation* moves water from oceans, lakes, streams, and other surface water bodies (storage).

The sun causes water to evaporate (convert to vapor) and rise to the atmosphere, where it can be carried long distances before cooling, condensing (reduction to a denser form) in clouds, and falling back to earth as *precipitation* (dew, rain, sleet, hail, or snow). When precipitation falls back to earth it drains across the land as surface *runoff*. Most runoff follows the drainage patterns of a watershed and enters lakes, streams, and other water bodies. A portion of the runoff replenishes groundwater through *infiltration* (or percolation).

Groundwater is stored in *aquifers*. Aquifers are water-bearing layers of permeable rock, sand, or gravel. Groundwater is discharged to the surface through well pumping or by natural springs and seeps. Water on the earth's surface is stored in lakes, ponds, streams, rivers, oceans, wetlands, and groundwater aquifers. The amount of water on earth never changes but is continually moving through the water cycle. While drought may cause a shortage of water in one location, another place will be getting more water than it needs.

CHAPTER

3 Surface Water Quality

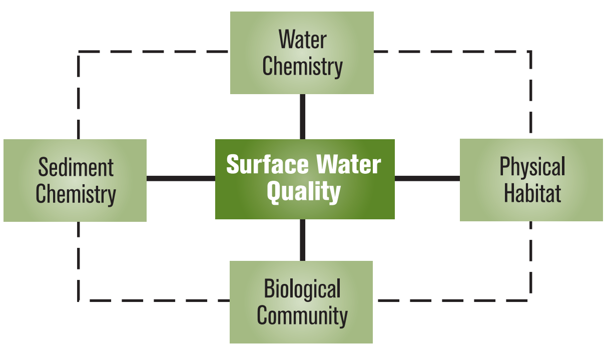
What is surface water quality? *Surface water quality* is a term used to describe the chemical, physical, and biological characteristics of water in lakes, streams, rivers, estuaries, and bays.

What Affects the Quality of Surface Water?

The overall quality in a given water body is determined by a combination of four categories:

▼ Water chemistry
▼ Sediment chemistry
▼ Physical habitat
▼ Biological community

Figure 3-1
Categories Used to Define Water Quality



The physical and chemical parameters and biological communities present in a water body are useful tools in determining the overall quality of a stream or lake. Each category should be considered a piece of a puzzle—without all the pieces the picture is incomplete. Historically, water chemistry has been used to determine water quality. The most common physical water quality indicators are dissolved oxygen (DO), water temperature, pH, and specific conductance. Common chemical indicators include nutrients, chloride, sulfate, total suspended solids, and total dissolved solids. The health of the biological community is directly affected by more than just water chemistry and can be an effective indicator of degraded water and sediment quality, and degraded physical habitats. The following sections will include basic information about pollution sources, common pollutants, and the use of biological indicators to determine the quality of a water body.

Pollution Versus Pollutants

What is the difference between a pollutant and pollution? *Pollution* is defined as the man-made or man-induced alteration of the chemical, physical, and biological integrity of water. Pollution is caused by activities that affect overall water quality. A few examples of pollution are the damming of rivers to create reservoirs, channelization and levee construction for flood control, or impacts from recreational activities or urban development.

A *pollutant* is a substance that can cause pollution. Heavy metals, pesticides, and nutrients are examples of pollutant categories. Elevated levels of one pollutant alone or in conjunction with other pollutants can cause adverse effects to the quality of the aquatic environment. Although some pollutants are from natural sources, most originate from man-made sources.

Pollutant Concentration Versus Pollutant Loading

Most water quality data collected is based on pollutant concentration and not pollutant loading. A pollutant concentration is measured in units like milligrams per liter (mg/L) or parts per million (ppm), while pollutant loads are measured in pounds per day. In other words, concentration measures a pollutant at a specific time, while loads measures a pollutant over a period of time.

Pollutant loadings are generally calculated when determining how much wastewater effluent can be discharged to a stream and be assimilated by it without becoming polluted. The pollutant load is often a better indicator of water quality than the pollutant concentration.

The difference between a pollutant concentration and a pollutant load. The following is an example of the way a pollutant load is calculated. If 5 tablespoons of salt are added to a gallon of water (A), the concentration would be 5 tablespoons per gallon (5 Tbsp/gallon). If 10 tablespoons of salt are added to two gallons of water (B), the concentration would still be 5 Tbsp/gallon. The concentration of salt in both containers is the same. However, even though the concentration is the same in both containers, the total amount of salt, or the load, is twice as high in B as it is in A.

The effect of pollutant levels on water quality in a stream varies with the amount of flow. Suppose scientists collected water quality data from a stream during fall and summer. Ammonia concentrations were the same for both seasons. Based on the concentrations, it might be concluded that there was no difference in pollutant levels. However, flows during each season are not the same because summer tends to be dry, and fall rainy. If the flow during the fall is 10 times greater than the summer, then the stream carries ten times more ammonia during the fall, even though the concentrations are the same.

Water Pollution Sources

There are two general categories for water pollution sources: *point source* and *nonpoint source*. *Point source* refers to a specific location where pollutants are discharged, like a wastewater treatment plant, outfall, a ship, or a pipe.

Nonpoint source refers to pollutants that do not have a single point of origin or a specific outfall. These pollutants are generally carried by stormwater runoff. The major categories for nonpoint source pollution are agriculture, forestry, urban, mining, construction, and land disposal.

Each of the sources of pollution are generally associated with certain types of pollutants.

Point Sources of Pollution and Associated Pollutants

Municipal wastewater treatment plants. Biochemical oxygen demand (BOD), nutrients, ammonia, bacteria, chlorine, total dissolved solids (TDS), chloride, and sulfate.

Industrial facilities. BOD and chemical oxygen demands (COD), and toxic substances.

Sewage bypasses. BOD, bacteria, nutrients, total suspended solids (TSS), turbidity, TDS, and ammonia.

Oil production areas. Oil, brine water.

Nonpoint Sources of Pollution and Associated Pollutants

Agricultural runoff from crops, feedlots, and pastures. Nutrients, TSS, turbidity, TDS, chloride, sulfate, bacteria, ammonia, pesticides.

Urban runoff. TSS, turbidity, bacteria, nutrients, TDS, oil and grease, pesticides, and trash (cans, bottles, other debris).

Construction runoff. TSS, turbidity, and nutrients.

Septic systems. Bacteria, and nutrients.

Landfills and spills. Substances present vary with type of landfill and material spilled.

Common Pollutants

Some common conventional pollutants are:

- ▼ Nutrients (nitrogen and phosphorus)
- ▼ Oxygen-demanding substances
- ▼ Temperature
- ▼ Salinity
- ▼ Suspended solids

Each of these common pollutants is discussed in greater detail in the following sections.

In general, the effects of common pollutant types on aquatic ecosystems are chronic and cause deterioration over time. These pollutants also have the potential to cause acute effects (immediate damage) to an aquatic community. Large volumes of raw sewage, or concentrated fertilizer, or a rapid increase or decrease in water temperature can cause immediate and often lethal effects on an aquatic community.

Plant Nutrients

Nutrients, primarily *nitrogen* and *phosphorus*, are essential for plant growth, though they can become pollutants in certain circumstances. The rate of plant growth is often controlled by a *limiting nutrient*, typically nitrogen or phosphorus, although it can be any of the essential minerals needed for growth. The limiting nutrient is the one available in quantities smaller than necessary for aquatic plants to reach maximum abundance.

When a limiting nutrient is depleted, growth stops even if there is an adequate supply of other nutrients available. Water bodies with high levels of nutrients and therefore capable of supporting abundant algae and aquatic plant growth, are referred to as *eutrophic*. The prefix "eu" means good or sufficient and *trophic* refers to nutrient requirements. The addition of nutrients into surface waters from human activities is referred to as *cultural eutrophication*.

Major sources of nutrients include fertilizers and manure from agricultural activities, urban runoff containing fertilizer from lawns and golf courses, and domestic and industrial wastewater effluent.

Ammonia, nitrite, and nitrate are related by the process of *nitrification*, which is the oxidation of ammonia and nitrate. In the presence of oxygen, ammonia is oxidized by specialized bacteria (*Nitrosomonas*) to nitrite, an intermediate product.

Nitrite is then oxidized by another specialized bacteria, *Nitrobacter,* to form nitrate.

Nitrite (NO_2^-), like ammonia, is extremely toxic to aquatic life, but is not considered an environmental problem because it occurs in relatively low concentrations. *Nitrate* (NO_3^-) is relatively nontoxic to aquatic organisms but is a common plant nutrient.

Ammonia occurs naturally in surface water and is produced by the breakdown and decay of organic materials. It can also enter surface water from manmade sources like raw sewage bypasses, fertilizer use, or animal feed lot runoff. Ammonia fits into several categories: oxygen-demanding substance, plant nutrient, and toxic substance. As a common pollutant, ammonia is one of the most toxic to aquatic life. See the "Toxic Substances" section for additional information on ammonia.

Effects of Nutrients on Water Quality

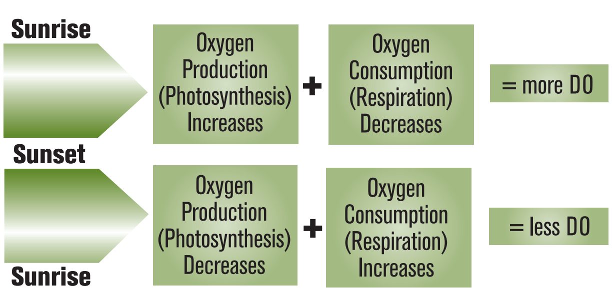
Plant nutrients where essential to plant growth, can have a negative impact on water quality and the aquatic environment. Too many nutrients entering a water body can trigger a series of events that results in a reduction of oxygen in the water.

Natural variation. Over a 24-hour period, DO levels fluctuate naturally in most water bodies. Oxygen production—or *photosynthesis*—normally varies because it is light dependent. As the sun rises, aquatic plants and algae—or *photosynthetic organisms*—begin to produce oxygen, which increases in concentration throughout the day. Production of oxygen is greater than consumption. Around sunset, photosynthesis essentially ceases, and DO levels begin to drop due to respiration and consumption by fish and other aquatic organisms is greater than production (see Figure 3-2). The lowest DO levels usually occur just before dawn. In addition to photosynthesis, oxygen is added to a water body by natural aeration (wind, rain, and water currents).

In general, oxygen consumption (*respiration*) can be considered a constant drain on the aquatic system, day and night. The introduction of oxygen-demanding substances—substances that demand oxygen because of their chemical nature—increases the drain on the aquatic system. For example, as organic substances decompose, oxygen in the system is consumed. Oxygen deficiency is common in water bodies, especially during warm, dry, summer months.

Figure 3-2

Natural Fluctuations in Dissolved Oxygen



Dissolved oxygen reduction. The reduction of DO is commonly associated with excessive nutrients and oxygen-demanding waste. Low DO levels result when the balance is disrupted between oxygen production and its physical, chemical, and biological processes.

Algal blooms. Elevated plant nutrients can cause uncontrolled plant growth or *algal blooms*. An increase in nutrients can cause algae growth and reproduction to increase dramatically into a bloom, just as fertilizing a lawn makes the grass grow faster.

Algae are microscopic plants that are usually aquatic, unicellular, and lack true stems, roots, and leaves. In most cases algal blooms are formed by phytoplankton or large mats of filamentous algae that float on the surface or attached to rocks, logs, or other objects in the water. Phytoplankton are a type of microscopic algae that float suspended in the water column.

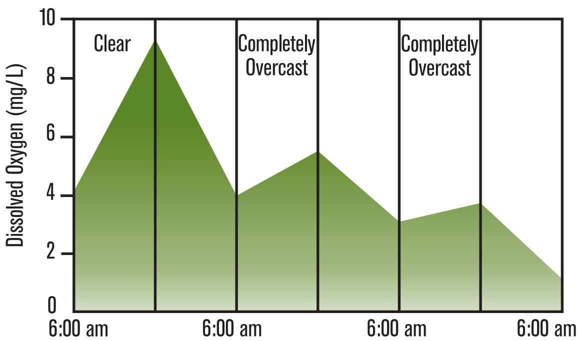
During an algal bloom, the population grows beyond the capacity of the system. An algal bloom can discolor the water due to the large number of algal cells. A water body with a bloom often takes on the appearance of pea soup, but in general, the color depends on the dominant species of algae present.

Effects of an algae bloom. During blooms, DO levels during daylight hours can be very high, often greater than 10 milligrams per liter (mg/L) or parts per million (ppm). However, during the night, when oxygen production ceases and respiration begins, the DO can drop to lethal levels. Algal blooms can cause stress and in severe cases, death for fish and other aquatic organisms.

The effect of an algae bloom can be compounded on overcast days. Decreased sunlight causes a reduction in oxygen production, which results in a net loss of DO (see Figure 3-3). Warm summer temperatures compound the effects of a bloom.

Dense mats of filamentous algae or floating aquatic plants can also prevent sunlight from reaching submerged plants and can interfere with oxygen production. As plants and algal blooms die they sink to the bottom of a water body and decompose, creating another source of oxygen depletion.

Figure 3-3
Effects of an Algal Bloom



Harmful Algal Blooms

What are harmful algal blooms? A harmful algal bloom (HAB) is a specific type of bloom that produces toxins which are detrimental to plants and animals. While any algae bloom can kill fish by depriving them of oxygen, the toxins produced during a HAB are often lethal to aquatic organisms.

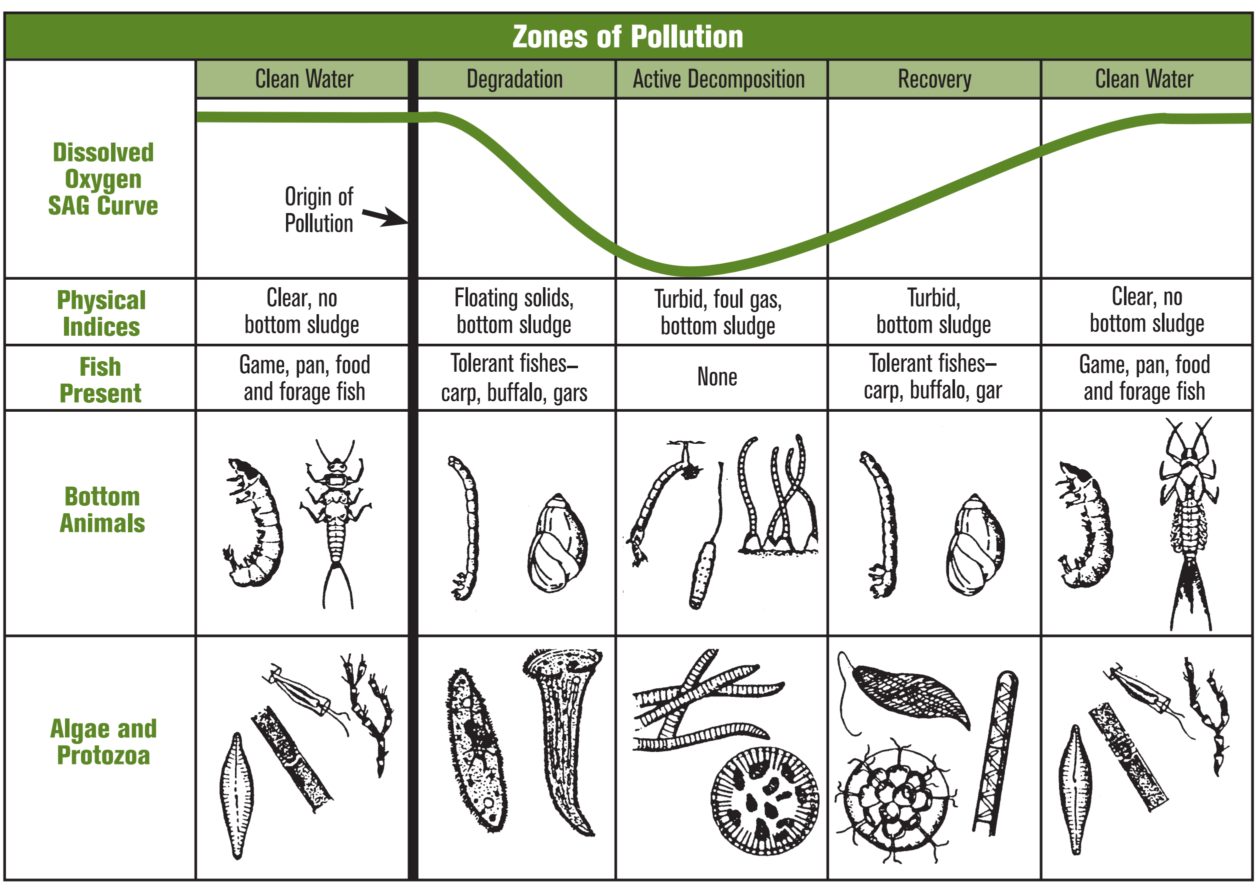
Fish kills from the golden alga, *Prymnesium parvum*, have been found in freshwater in Texas since 1985. While originally noted in the Pecos River, the alga has progressively spread to and caused fish kills in numerous other river basins. *Prymnesium parvum* is found worldwide in estuaries (estuaries are mixing zones between freshwater from rivers and seawater) and in some freshwater bodies that have relatively high salt content. Texas Parks and Wildlife Department (TPWD) biologists were the first to note the occurrence of this alga in freshwater bodies in the Western Hemisphere. Subsequently, other states have reported its occurrence or possible occurrence. Fish kills caused by *Prymnesium parvum* can be significant. Though there are no dangers to human health from the toxins that produce these fish kills, there are effects on the environment and economy of the area (Information from **www.tpwd.state.tx.us/hab/ga/**).

Oxygen-Demanding Substances

Oxygen-demanding substances include organic materials that can indirectly cause the decrease of DO in surface waters. Organisms involved in the decomposition of these organic materials actually cause the oxygen depletion by respiration (oxygen consumption).

Examples of oxygen-demanding substances include raw sewage, food processing plant wastes, and animal feedlot wastes. The effects of organic waste are generally chronic, with a gradual deterioration of an aquatic ecosystem over time. The amount of oxygen required to decompose organic materials is called *biochemical oxygen demand* (BOD).

Figure 3-4
Recovery of a Stream



Water Bodies Receiving Oxygen-Demanding Waste—Can They Recover?

What would happen if a normally clean and well-balanced stream suddenly received thousands of gallons of raw sewage? Rivers and streams have a natural ability to recover from the introduction of oxygen-demanding substances through physical, biological, and chemical processes. The same basic processes occur in lakes, but follow less distinct patterns due to the variability of water movement in a stream as compared to a lake.

For example, Stream "A" normally receives effluent from a wastewater treatment plant. The amount of effluent discharged is easily handled by processes in the stream. This *clean* stream is well balanced, with a wide variety of aquatic species present. Organisms are adjusted to the natural physical and chemical characteristics of the area. DO is well balanced and the BOD is low. An accident causes the release of 50,000 gallons of raw sewage. Can the stream recover?

Degradation begins when this large amount of raw sewage is introduced into the stream. The organic matter in the sewage is a source of food for many organisms, causing the rapid growth of bacteria and other microorganisms. Plants and aquatic animals may be affected by increased turbidity. Predator species that are intolerant of pollution are replaced by scavengers. A population explosion of fungi and bacteria creates a severe demand on the available oxygen. The number of species present is reduced with the less pollution-tolerant forms being replaced by a few very tolerant forms (see Figure 3-4 and Table 3-1).

After the initial degradation, *active decomposition* begins. The area is now *anoxic* (lacking DO). Weather conditions, such as heat and sunlight, can enhance the oxygen demand caused by the decomposition of the organic material. In Texas, more fish kills occur in the summer months from the lack of DO than during any other part of the year.

The reduced oxygen levels in an anoxic area can kill off most of the organisms present, thereby adding to the organic material. Organisms that can live without oxygen (anaerobic) or those with alternative ways to get oxygen (for example, rat tail maggots use a breathing tube) thrive. The number of species present is low, but the number of individuals is usually high because there is less competition. The organisms present will feed on the organic material as long as it is present.

Active decomposition gradually merges into *recovery*. This recovery is characterized by extreme

Table 3-1

The Pollution Recovery Cycle of a Stream Impacted by Organic Pollutants

Zones	Dissolved Oxygen	Biochemical Oxygen Demand	Turbidity	Organic Content	Biological Characteristics
Clean	high	low	low	low	•Number of different species is high •Number of individuals of each species is moderate to low •Variety of benthic macro-invertebrates and fish present •Usually a mixture of sensitive and tolerant species
Degradation (origin of pollution)	low	high	high	very high	•Number of tolerant individuals high •Number of tolerant species increases •Sewage fungus present
Active Decomposition (anoxic)	zero	moderate-high	high [a]	moderate-high	•Number of species low •Number of individuals high (less competition) •Pollution-tolerant macroinvertebrates present •Fish absent
Recovery	moderate-high	moderate	moderate [b]	low-moderate [c]	•Number of species increasing •Number of individuals per species decreasing (more competition) •Extremely tolerant species will be replaced by those more moderately tolerant of pollution
Clean	high	low	low	low	•Same as above

[a] *water dark with strong hydrogen sulfide or sewage odor* [b] *reduced odor* [c] *starting to decrease*

daily (diurnal) fluctuations in DO. The amount of organic material decreases along with pollution-tolerant organisms. The oxygen demand from bacteria and fungi is reduced, DO levels begin to rise, and oxygen-requiring organisms begin to appear. Suspended material is reduced and algal growth is often abundant, causing high productivity. Heavy algal growth increases DO during the day, but also causes the oxygen to drop at night.

After recovery, the stream begins to regain the majority of its original characteristics. Some streams may never fully recover if the source of pollutants is chronic. The water body will continue the cleansing process, but will maintain characteristics of the recovery phase.

Water Temperature

Water temperature, one of the simplest water quality measurements, is one of the most important to the health of an aquatic ecosystem. Water temperature can also cause pollution.

Temperature characteristics of an aquatic environment affect the composition of its biological community. In general, aquatic organisms are cold-blooded and have body temperatures that fluctuate with the water temperature.

Each aquatic species has an optimum temperature at which it functions the best. Most fish and other aquatic species in Texas are among those that can tolerate warmer water temperatures.

Effects of water temperature increases. Elevated temperatures reduce the solubility of DO and decrease the amount of oxygen in a water body. For example, at 0°Celsius (C), water can hold approximately 14.6 mg/L of oxygen at the saturation point, while at 30°C, the amount decreases to 7.5 mg/L. High temperatures increase metabolism, respiration, and the demand for oxygen by fish and other aquatic organisms. In general, metabolic rates in aquatic organisms double with every rise of 10°C in temperature. Under normal weather conditions, water temperatures tend to increase during the warm summer months.

How does water temperature affect water quality? The effects of oxygen-demanding wastes (sewage, food process waste, feedlot waste) and nutrients are intensified by temperature increases. The main sources of heated water are discharges from power plants and some industries. Development in a watershed can also affect temperatures in nearby streams. For example, clearing bank vegetation exposes a stream to warming from increased exposure to the sun.

Although it does occur, temperature alone is not a common cause of the death of aquatic organisms. The most common result of increased water temperature is lower oxygen levels and aquatic communities dominated by tolerant organisms.

Acidity–Alkalinity Scale (pH)

What is pH? Although not a pollutant, pH plays a key role in the health of an aquatic ecosystem. What exactly is pH? The term *pH* refers to a scale of numbers from 0 to 14, used to measure the acidity of liquids (see Figure 3-5). Pure water has a pH value of 7.0, which is neutral, meaning neither acidic nor basic. When the pH is less than 7.0, water is considered acidic; at a pH greater than 7.0, water is basic or alkaline.

Generally, the ability of aquatic organisms to complete a life cycle greatly diminishes as pH becomes greater than 9.0 or less than 5.0.

Figure 3-5

pH Scale

Increasing Acidity ↑	pH=0	Battery Acid
	pH=1	Sulfuric Acid
	pH=2	Lemon Juice, Vinegar
	pH=3	Orange Juice, Soda
	pH=4	Acid Rain (4.2-4.4)
	pH=5	Clean Rain (5.6)
	pH=6	Milk (6.5-6.8)
Neutral	pH=7	Pure Water
	pH=8	Sea Water, Eggs
	pH=9	Baking Soda
	pH=10	Milk of Magnesia
	pH=11	Ammonia
	pH=12	Soapy Water
	pH=13	Bleach
Increasing Alkalinity ↓	pH=14	Liquid Drain Cleaner

The scientific definition of pH. The scientific definition of pH is the negative logarithm of the hydrogen ion (H^+) concentration, which means that the concentration of hydrogen ions does not increase or decrease in a linear fashion. As a result, a pH of 3 is not twice as acidic as a pH of 6. Increases are in powers of 10. For example, a pH of 6 is 10 times more acidic than a pH of 7, and 100 times more acidic than a pH of 8. A pH shift of one whole number is therefore quite a large change.

Whether water is acidic or basic is determined by the balance of positive hydrogen (H^+) ions and negative hydroxide (OH^-) ions (see Table 3-2). *Ions* are positively or negatively charged particles. Pure water has an equal number of OH^- ions and H^+ ions. Acidic water has more H^+ ions than OH^- ions, and the reverse is true for alkaline water.

Table 3-2
Scientific Definition of pH

Type of Water	Buffering Capacity		pH
ACIDIC	$H^+ > OH^-$	LOW	< 7.0
NEUTRAL	$H^+ = OH^-$	MEDIUM	7.0
BASIC	$H^+ < OH^-$	HIGH	> 7.0

What factors influence the pH of surface water? The pH of an aquatic system is determined by a number of factors. Water dissolves mineral substances it comes in contact with, picks up aerosols and dust from the air, receives man-made wastes, and supports photosynthetic organisms—all of which affect pH. The buffering capacity of water is critical to aquatic life because it determines the pH range. Alkalinity is commonly used to measure the *buffering capacity* of water—or the ability to neutralize acid.

Geology. The underlying rock and soil type in a watershed determines the general pH in an aquatic system. A water body in a drainage basin that is largely limestone tends to be more alkaline. The slightly acidic nature of rain causes soft rock, like limestone, to weather more rapidly than other harder rock types. The weathering of limestone releases minerals that buffer the water, causing slight increases in pH.

Mineral-rich waters are considered *hard water* and typically have pH values greater than 7.0 (high buffering capacity). Water bodies in drainage basins with harder igneous bedrock tend to be more acidic. Hard rock weathers more slowly, releasing few minerals. Water bodies with a low mineral content and a limited ability to buffer rainfall are considered *soft water*. Soft water tends to have pH values less than 7.0. basic (low buffering capacity).

Photosynthesis. Photosynthesis by aquatic plants removes carbon dioxide (CO_2) from the water, which can significantly increase pH. Therefore, in waters with abundant plant life (including planktonic algae), an increase in pH can be expected during a sunny afternoon, especially in low-velocity or still waters. During plankton blooms, it is not uncommon to see pH values in the 8 to 9 range.

Human activities. Human activities in a watershed may also affect pH. Water flowing through mine tailings (waste from mining operations) can become acidic due to the presence of minerals containing sulfide, which under the right conditions can become sulfuric acid. Drainage from these areas into soft-water streams can cause the pH to decrease. Emissions from power plants and car exhausts containing nitrogen oxides and sulphur dioxide can react with moisture in the atmosphere to form nitric and sulphuric acids, more commonly known as *acid rain*. Acid rain has a pH less than 5.6, while normal rain is generally greater than 5.6. Accidental spills, urban runoff, agricultural runoff (pesticides, fertilizers), or sewage overflows are other examples of activities or events that can alter pH in a water body.

Effects of pH. Toxicity of certain chemicals, especially metals, can change dramatically with pH. When this happens, the chemical is usually more toxic at lower—that is, more acidic—pH.

Salinity

Water quality is also affected by elevated salinity levels. Elevated salinity is more common in the more arid parts of the state. From both natural and human activities, increased salinity can make a water body unsuitable for aquatic species that are not tolerant of brackish water, for use in agriculture (livestock and crops), and for use as a drinking water source.

In general, rainwater has a very low specific conductance. However, as runoff flows over land, the slighty acidic nature of rainwater can release ions from soil and rock, causing an increase in the specific conductance. These ions are commonly referred to as *inorganic salts* (salinity).

The most common inorganic salts are bicarbonate, calcium, carbonate, chloride, magnesium, potassium, sodium, and sulfate. They are discussed in greater detail in sections that follow.

Salinity differs from one watershed to another and is highly dependent on the underlying rock type. Arid areas of the state tend to have salt buildup in the soil due to the high rate of evaporation. Runoff from these areas carries salts back into a stream or reservoir.

Salinity is often increased by irrigation return flow or domestic wastewater discharges. Runoff from areas with production oil wells can have very high salinity due to brine water associated with oil extraction. Reduced instream flows and high evaporation during drought conditions can also increase salt levels.

According to the U.S. Geological Survey (USGS)—water is divided into the following categories based on the amount of dissolved solids:

- ▼ Freshwater—
  less than 1,000 parts per million (ppm)
- ▼ Slightly saline water—
  from 1,000 ppm to 3,000 ppm
- ▼ Moderately saline water—
  from 3,000 ppm to 10,000 ppm
- ▼ Highly saline water—
  from 10,000 ppm to 35,000 ppm

How is salinity commonly measured? The method commonly used to indirectly measure the salt concentration in water is *specific conductance*. It is a measure of the ability of water to carry an electric current and is dependent on the amount of dissolved solids in water. Specific conductance increases when salinity increases. For example, specific conductance in distilled water is very low, and in sea water, is very high.

Salinity is also measured using *chloride*, *sulfate*, and *total dissolved solids* (TDS). As an indication of how variable salinity is in the state, water quality criteria for TDS in Texas freshwater bodies range from 150 to 46,200 mg/L. A specific conductance measurement can be multiplied by a factor to estimate the total dissolved solids concentration. The TCEQ currently uses a factor of 0.65 to estimate TDS.

Common Inorganic Salts

The following section provides information on some of the common inorganic salts that affect the salinity and quality of water.

Chloride and sulfate. *Chloride* (Cl) is a substance found in all water. Chloride compounds are used extensively in industrial operations and agriculture (the potash in fertilizers is potassium chloride). Chloride is found in all human and animal waste. Common sources of chloride are wastewater, septic tanks, animal feed lots, and irrigation return flow. Although chloride is not considered a health risk for humans, it can disrupt the aquatic community in water bodies that are not normally saline.

Sulfate (SO_4) is derived from rocks and soils containing gypsum, iron sulfide and other sulfur compounds. Sulfur changes from one form to another in a complex cycle depending on conditions. For example, if oxygen is lacking, bacteria can convert sulfate to hydrogen sulfide gas. This gas has a distinctive rotten-egg smell, and high concentrations can be toxic to aquatic life. Sulfate is widely distributed in nature and is used by all aquatic organisms to build proteins. It is also widely used in industry and agriculture.

Sodium and potassium. *Sodium* (Na), the sixth most abundant element on earth, is essential to all animals. All waters contain sodium. Sodium is most often associated with chloride. Areas with high sodium levels are often associated with arid climate, agricultural runoff containing fertilizer residue, and discharges of human or animal waste.

Potassium (K) is an important mineral and nutrient necessary for plant growth. It makes up over two percent of the earth's crust. Potassium finds its way into surface water from many natural sources. Man-made sources include agricultural runoff (potassium is a key component of fertilizers and is abundant in animal waste) and industrial wastewater effluent.

Levels of sodium and potassium in water are naturally very low. Their presence is often an indicator of pollution linked to human activities. Over time, increasing levels of sodium and potassium can indicate long-term pollution effects.

Calcium and magnesium. *Calcium* (Ca) is one of the most abundant substances in surface water because it dissolves easily. The main source of calcium in surface water is from the weathering of rocks, like limestone, that are primarily comprised of calcium compounds. However, calcium can also be added to water as the result of the extensive use of calcium-containing compounds in industry and agriculture.

Magnesium (Mg) is the eighth most abundant element on earth. It is a common component of all surface water, making contributions of magnesium from natural sources greater than all other human activities combined.

Calcium and magnesium are the causes of hard water. When hard water is used for agriculture, domestic, and industrial purposes, these minerals leave crusty accumulations or "scale" buildup in pipes and hot water heaters.

Suspended Solids

Suspended solids is a common term used for the mineral and organic particles suspended in the water column. Most often, they are small clay and silt particles held in suspension by water currents.

The most common sources of suspended solids are construction activities (buildings, roads, bridges), the erosion of agricultural lands, and surface mining such as sand and gravel operations. Waters with heavy sediment loads are very obvious because of their muddy appearance. This is especially evident in rivers during high flows, when the force of the water keeps the solids suspended, rather than allowing them to settle on the bottom.

Why are suspended solids a concern? Suspended solids reduce the penetration of sunlight into the water column making it less clear. The reduction of light affects aquatic life in several ways.

- ▼ Primary producers (phytoplankton, algae, and other aquatic plants) are less able to produce oxygen.
- ▼ Fish and predators feed less efficiently in turbid waters.
- ▼ Suspended sediments settle to the bottom and cover up aquatic habitats. Over a period of time, this reduces the amount of invertebrate food available for fish and other predators.
- ▼ If the sediment load is too high, fish gills can become clogged.
- ▼ Suspended solids carry plant nutrients and also provide attachment places for other pollutants, such as metals and bacteria.
- ▼ Water clarity affects the human perception of water quality. Decreased water clarity often causes water to be seen as dirty or polluted.

Natural variation. Heavy rains erode soils, and fast-moving water tends to scour a stream or river bottom. The geological characteristics of the watershed can determine the amount of erosion that occurs.

This natural variation can also be enhanced by human activities in a watershed. The removal of vegetation along stream banks can result in increased bank erosion. Road construction and clearing land for development, agriculture, and logging are just a few other examples of activities that can enhance the natural erosion potential and increase the turbidity of a stream or river. In lakes and reservoirs, the major source affecting water clarity is free-floating algae (phytoplankton).

Algae can also cause seasonal increases in turbidity. *Turbidity* refers to the amount of light blocked by water due to the presence of suspended solids. As turbidity increases, the amount of light penetrating the water column is reduced. During the summer months when the water is warm and flow is low, plankton blooms are frequent in nutrient rich streams. Suspended planktonic algae can give the water a variety of colors such as pea green, bright green, yellow, brown, brown-green, brown-yellow, or blue-green.

Bacteria

Bacteria have long served as an indicator of drinking water and recreational water quality. Their presence is extremely significant. Historically, *fecal coliform* bacteria has been the most widely used *indicator bacteria* in surface waters. Fecal coliforms are commonly found in the small intestines of humans and other warm-blooded animals. They are not necessarily harmful, but may indicate the presence of harmful bacteria and viruses found in raw sewage. *E. coli*, more commonly associated with human waste only, has replaced fecal coliform as the indicator bacteria for freshwater bodies in Texas.

The presence of fecal coliform or *E. coli* is usually associated with inadequately treated sewage, improperly managed animal waste from livestock, failing septic systems, pets in urban areas, and wildlife—birds and mammals, either aquatic or living near water (for example, birds nesting under a bridge).

Toxic Substances

Substances that are considered toxic are distinct from the other pollutants because of the acute effect they can have on aquatic ecosystems. These are substances that can kill organisms directly and in a relatively short period of time. *Acute toxicity* results when high concentrations of a substance cause immediate danger or death. Toxins generally disrupt an entire ecosystem, severely reducing the stream's natural ability to recover.

Toxic substances include substances such as metals (arsenic, cadmium, mercury), cyanide, acids, alkalines, ammonia, chlorine, and pesticides. These substances, in sublethal concentrations can also produce chronic effects. *Chronic toxicity* is the long-term effect of sublethal levels of a substance which alters growth, reproduction, or development of aquatic organisms.

The following sections focus on several common toxic substances: ammonia, chlorine, and pesticides.

Ammonia

Ammonia is one of the most common aquatic pollutants. It is highly toxic in nature and is widespread in surface waters. Ammonia enters surface water in varying quantities from industrial and municipal wastewater discharges, agricultural runoff (fertilizers, confined animal feeding operations), leaking septic systems, raw sewage spills, urban runoff (fertilizers, cleaners), and accidental spills. The most common sources of elevated ammonia are raw or partially treated sewage and runoff from animal feeding operations.

Ammonia is also nitrogen rich, making it a valuable component of fertilizer. When mixed with water, ammonia creates a powerful cleaner, making it one of the most common household and industrial chemicals.

How toxic is ammonia? The toxicity of ammonia depends on the pH and temperature of the water body. As pH and water temperature increase, so does ammonia toxicity.

Chlorine

The common sources of chlorine in the aquatic environment are the disinfection of treated domestic wastewater, use as an antifouling agent in cooling towers, and as a bleaching agent in textile and paper mills. Chlorine is a chronic source of stress on the aquatic environment, especially in streams where flow is dominated by treated domestic wastewater discharges.

The presence of chlorine can alter the fish population downstream of an wastewater outfall. Larger wastewater treatment plants are required to remove chlorine from the wastewater effluent before it is discharged. However, smaller wastewater treatment plants are not required to remove chlorine. Evidence of this can be observed when aquatic plants near an outfall have a bleached appearance.

How toxic is chlorine? If free chlorine residuals can be measured in surface water, it is not considered safe for fish. Chlorine becomes more toxic as pH decreases.

Pesticides

There are dozens of pesticides in use on agricultural crops and on lawns and gardens. These pesticides have various effects on the aquatic environment and enter rivers, streams, and lakes through runoff. Organophosphates are more toxic to fish than to any other organism because the pesticides are absorbed into the blood through the gill tissue. High concentrations will have an immediate and deadly effect on aquatic organisms. Long-term exposure to lower concentrations can damage fish populations causing declines in growth and reproduction and a decrease in available food organisms.

Sediment

What exactly is sediment? *Sediment* is mostly a mixture of loose inorganic particles (sand, silt, and clay) and organic substances (decomposing plants and animals) that settle to the bottom of a water body. The quantity and quality of sediment plays a key role in the makeup of the biological community.

How sedimentation occurs. What happens once flow can no longer keep particles suspended in the water column? As flow decreases and water loses speed, suspended materials drop to the bottom—a process called *sedimentation*. The sedimentation process is pronounced after periods of high flow. In addition, as a river reaches a reservoir, the water loses speed and sediment drops to the bottom. Increased sedimentation is a major effect of reservoir construction.

Reservoirs are built for water storage and flood control. With the exception of major flood events, reservoirs severely limit the ability of a stream to remove sediment. In a natural river system, high flows scour the bottom, carrying sediments downstream. During periods of flooding, water leaves the river channel and flows out over the floodplain; river sediment is then deposited.

Sediment buildup creates problems for aquatic organisms by covering up habitat and filling in lakes and slow-moving areas of streams. The reduction of aquatic habitat results in a change in the types of aquatic plants and animals living in a stream. As sediment settles out, what was once a sandy or clay bottom becomes a *mucky* bottom, where different and possibly fewer organisms can live. An abundance of suspended solids in flowing water can affect fish by clogging their gills. Sediments can cover their breeding areas and smother their eggs.

Sediment chemistry. In addition to the effects of large amounts of sediment on the biological community, the quality of sediment is also very important. Sediment acts as a sink, or collection site, for many contaminants such as metals, pesticides, and polyaromatic hydrocarbons (PAHs)—a group that contains petroleum products and byproducts.

Industrial and municipal wastewater discharges and stormwater runoff from urban, industrial, and agricultural areas are some of the most common sources of contaminants. Some contaminants become airborne and may be found in water bodies miles from original sources—factories, power plants, refineries. Pesticides such as DDT and the industrial chemical known as polychlorinated biphenyl (PCB) were released into the environment for years. Even though these chemicals were banned by the USEPA, they are still found in some sediment. These types of contaminants are commonly referred to as *legacy pollutants*.

Physical Habitat Alteration

Changes in the physical habitat of a stream often lead to changes in the biological community, regardless of water quality. Assessing the biological community and habitat is important in determining the quality of a stream.

Channelization

Channelization is one of the major causes of the decreasing health of the biological community. It is the process of straightening a stream's channel by removing its natural meanders and is used to control flooding; however, this change can cause a stream to become nearly lifeless. Channelization typically involves removal of large trees and natural bank vegetation which provided shading and stream cover—resulting in high, steep, exposed banks. While most channelized streams have grass-covered banks, some in urban areas are lined with concrete. Bottom sediments are disturbed, and important habitats such as logs, rocks, tree stumps, and root masses are removed.

Effects of Channelization

Following are some of the effects of channelization on biological community health.

Water Temperature. The removal of stream bank vegetation reduces shading to almost zero. The lack of shading and increased exposure to sunlight causes increased water temperature. See the section on water temperature for additional discussion.

Increased Turbidity. Erosion of exposed banks during storms and high flows increases turbidity. Turbidity can also aid in the increase of water temperature by absorbing the sun's rays.

Changes in Flow. The removal of natural stream channel characteristics and straightening the channels to accommodate flood waters increase the velocity of the water and increases the potential for downstream flooding. The high banks created by channelization also remove the stream's natural ability to decrease the velocity of flood waters.

Under normal conditions, the flow in a stream will leave the stream channel and move out and over the floodplain. A *floodplain* is the area adjacent to the channel which is occasionally submerged under water. The floodplain is usually a low-gradient area, well covered by various types of vegetation. The floodplain allows the force of the water to be displaced over a larger area. With flows confined to a straight and narrow channel, the stream loses its ability to reduce the force of the water. Restricting flow within a channel also eliminates the ability of a stream to deposit part of its sediment load onto the floodplain.

Dams also alter the flow of rivers. Rivers that can no longer flush sediment begin to accumulate it. The same is true for reservoirs. A heavy sediment load being carried by a river is deposited in a reservoir with nowhere to go. Many reservoirs in Texas begin to fill with sediment, reducing the volume of water in the reservoir.

Bottom Substrate. Channelized stream bottoms tend to be unstable, muddy, and unsuitable for many bottom dwelling organisms.

Organisms Used as Indicators of Pollution

Biological communities (fish and freshwater macroinvertebrates) can be used to evaluate short- and long-term trends in water quality and can be used to determine the overall quality of an aquatic ecosystem. Short-term trends show the existing status of a water body—whether it is clean or polluted. Long-term trends show if conditions are getting better or worse over time.

Fish and benthic macroinvertebrates are placed into categories based on their tolerance to pollution and are used as indicator organisms in evaluating the health of streams. See Chapters 6 and 7 for additional information on freshwater macroinvertebrates and fish.

The three main categories of pollution tolerance are:

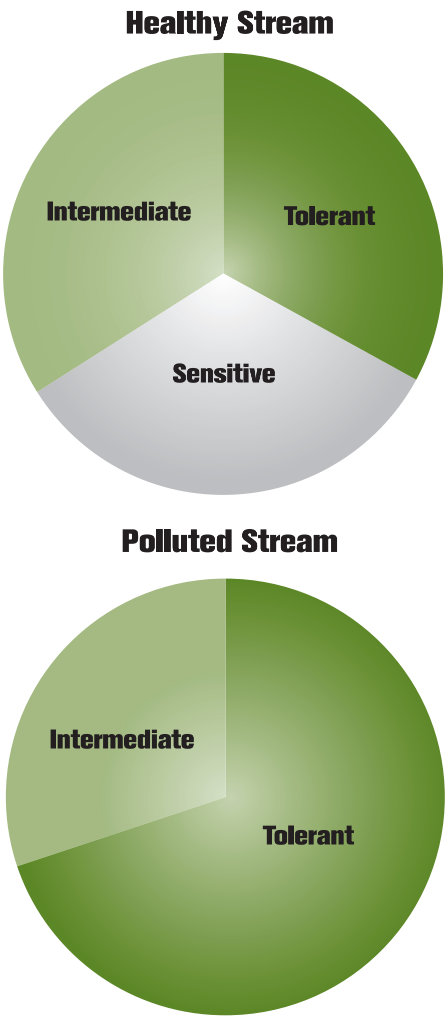
- **Intolerant**—Sensitive to poor stream conditions.
- **Intermediate**—Moderately tolerant to degraded habitat and water quality.
- **Tolerant**—Most tolerant to degraded habitat and water quality.

As a general rule, in streams with limited impact, intolerant organisms will be present along with intermediate and tolerant organisms.

Water quality is not always the limiting factor in the presence or absence of aquatic organisms. Physical habitat also plays a key role in the whether an organism inhabits a water body. The lack of physical habitat can be just as limiting as poor water quality.

The type and number of organisms present can tell a lot about a stream. If the aquatic community is made up of more intolerant species and a few intermediate and tolerant forms, the stream can be considered healthy (see Figure 3-6). The presence of intolerant and intermediate species generally means that no significant pollution exists. Poor water quality is indicated when the number of tolerant organisms exceed that of intermediate species and intolerant species are absent. The number of individuals of any one species is also an indicator of quality. A good quality stream will have a larger number of species with fewer individuals per species, increased variety, and a balanced system. An unhealthy community includes a few species with numerous individuals, lacks variety, and is unbalanced.

Figure 3-6
General Comparison of Indicator Organisms



Freshwater Macroinvertebrates Used as Indicators of Water Pollution

Freshwater macroinvertebrates are used as indicators of water quality for the following reasons:

- ▼ Important component of virtually all aquatic ecosystems.
- ▼ Found in all types of aquatic habitats.
- ▼ Relatively easy to collect.
- ▼ Have different levels of tolerance to environmental disturbance.
- ▼ Most are sedentary or move over a small area.
- ▼ The kind of organisms and number present in a stream is well correlated with recent past and present conditions.
- ▼ Life cycles and taxonomy of most groups are well documented.

Freshwater macroinvertebrates can indicate the following:

- ▼ Long-term water quality trends.
- ▼ Impacts of various pollutants.
- ▼ Impact of changes to the physical habitat.
- ▼ Improvements or declines in water quality.

Freshwater Fish Used as Indicators of Water Pollution

Freshwater fish are used as indicators of water pollution for the following reasons:

- ▼ Live in water for entire life and have long life spans (2 to10+ years).
- ▼ Easy to identify in the field because of established key characteristics of fish species.
- ▼ Relatively easy to collect with the proper equipment.
- ▼ Wide range of tolerance levels, from very sensitive to very tolerant of environmental disturbance.
- ▼ Distribution, life histories, and pollution tolerances for many North American fish species are well documented.
- ▼ Fish communities are persistent and can recover from natural disturbances.

Freshwater fish can indicate the following about water pollution:

- ▼ Long-term and short-term water quality trends.
- ▼ Impacts of various pollutants.
- ▼ Impact of changes to the physical habitat.
- ▼ Improvements or declines in water quality

See the “Feeding Groups and Pollution Tolerance” sections in Chapter 7 for more information on the use of fish as indicators of pollution.

Rapid Bioassessment

Rapid bioassessment, a relatively inexpensive screening tool, uses freshwater macroinvertebrates, fish, and habitat, to determine the quality of a stream. These protocols are often used to characterize the existence and severity of pollution, to identify causes and sources of impairment, and to establish conditions in least-impacted streams. These protocols were developed by the USEPA.

Physical Water Quality Indicators

Water color and odors are often key indicators of water quality problems. Many water quality problems have similar characteristics, so it is important to collect as much information as possible. It is easy to mistake one thing for another if important pieces of information are missing. Simple visual observations can be very helpful in interpreting other water quality data.

For example, a 2-mile stretch of stream has turned a bright green color in a short period of time. Was something dumped in the creek? It's common to assume something was dumped in the stream because it doesn't look normal. If a few additional pieces of information are added, the assumption changes.

1. The pH is normal to slightly elevated.
2. The DO levels are elevated in the afternoon.
3. Fish are not showing signs of stress or strange behavior.
4. There is little flow.
5. The affected area is located downstream of a small tributary that drains a golf course pond.

What Does the Extra Data Indicate?

1. pH is normally elevated when there is a plankton bloom.
2. Plankton blooms cause an increase in oxygen production.
3. There is nothing in the water that is causing adverse affects to fish. If the condition continues low DO may become an issue.
4. Low flow provides ideal conditions for plankton by creating a quiet area to establish populations.
5. The pond was designed to hold runoff from the golf course and keep nutrients (from fertilizers) out of the creek. Pond water was released during maintenance on the pond's dam.

Physical Water Quality Indicators—Color, Odor, and Surface Film

The following tables include common physical indicators used in assessing water quality. They include color, odor, surface film, and land use.

Color

Muddy-Tan to Light-Brown

▼ Suspended sediments are common after rainfall.

▼ Runoff from construction, roads, agriculture, or rangeland.

▼ Soil erosion caused by vegetation removal from riparian zone, overgrazing of rangeland, agriculture, and logging.

Pea-Green, Bright-Green, Yellow, Brown, Brown-Green, Brown-Yellow, Blue-Green

▼ These colors can be key indicators of a plankton bloom.

▼ Water color is dependent on dominant plankton type present.

Tea or Coffee

▼ Dissolved decaying matter originating from organic portion of soil.

▼ Usually associated with woodlands or swampy areas.

Milky-White

▼ Paint (construction), milk (food processing).

Dark-Red, Purple, Blue, or Black

▼ Fabric dyes, inks from paper and cardboard manufacturers.

Milky-Gray or Black

▼ Raw sewage discharge or other oxygen-demanding waste; a rotten-egg or hydrogen sulfide odor may be present.

Clear Black

▼ Turnover of oxygen-depleted bottom waters or sulfuric acid spill.

Orange-Red

▼ Deposits on stream beds associated with oil production areas, but not always; check for petroleum odor.

▼ Can be due to iron; an oily sheen or residue present, which can occur naturally—not oil or petroleum; no petroleum odor.

White Crusty Deposits

▼ Common in dry or arid areas where the evaporation of water leaves behind salt deposits; for example, chloride or sulfate.

▼ Associated with brine water discharge (from oil production areas); a petroleum odor, and an oily sheen may be present along the banks.

Odors

Rotten Eggs or Hydrogen Sulfide

▼ Raw sewage (septic)

▼ Oxygen-poor sediment (anoxic)

Chlorine

▼ Wastewater treatment plant discharges, swimming pool overflow, or industrial discharges.

Sharp, Pungent Odor

▼ Chemicals or pesticides.

Musty Odor

▼ Presence of raw or partially treated sewage, livestock waste, or algae.

Petroleum Odor

May be present after a spill, near oil and gas production areas, or from road runoff.

Surface Scum

Tan Foam

▼ High flow or wave action: Wind action plus flow churns water containing organic materials (increased with rainfall runoff), creating harmless foam, producing small patches to very large clumps.

White Foam

▼ Sometimes patchy or covering wide area around wastewater outfall. Usually thin or billowy and mostly due to soap.

Yellow, Brown, Black Film

▼ Pine, cedar and oak pollens form film on surface, especially in ponds, backwater areas, or slow moving water of streams.

Rainbow Film

▼ Oil or other fuel type; sheens are common after rains when oil and gas residue wash off streets. Other sources include spills, pipelines, and oil and gas production areas.

Note: Check for a petroleum odor which may be present if there is a large sheen. Some bacteria can cause a natural sheen. See information under orange-red. The distinction between a petroleum sheen and a natural sheen can be made by the detection of a petroleum odor.

Surrounding Land Use

Characteristics and activities within the watershed of a stream, river, or lake affect water quality, so information about them is important for assessing water quality. Different land uses have different potential impacts to water quality.

Woodland

▼ Erosion from logging, road construction, or clear cutting may cause muddy water.

Agricultural Land

▼ Fertilizers or manure from crops, pastures, or feedlots draining into a stream may cause excessive algal and aquatic plant growth; streams may also receive pesticides and herbicides in runoff; sedimentation may occur from soil erosion.

Cities and Towns

▼ Urban runoff carries with it a variety of contaminants such as oil, pesticides, metals, and chemicals, depending on dominant area activities in the area.

Industry

▼ Numerous types of chemicals and products, depending on the industry, which may cause color changes, excessive algae, odors, absence of aquatic life, fish kills, elevated BOD, and sewage fungus.

Wastewater Treatment Plants

▼ Organic pollution common at outfalls (typically associated with effluent of poor quality); effects may include excessive algal growth, white foam, sludge deposits (fluffy dark-brown or gray solids), absence of fish and insects, or the abundance of tolerant forms (mosquitofish), variable DO levels, chlorine odor, high BOD, sewage fungus (slimy growth, white, and gray-brown). In the absence of chlorination, elevated levels of bacterial indicators, fecal coliform or *E. coli* may be present; excessive chlorine can cause the bleaching of aquatic vegetation

Construction

▼ Runoff from construction can cause water to become muddy and turbid.

Residential

▼ Lawn fertilizers, oil drained from cars, septic tank overflows, detergents used to wash cars, trash (cans, bottles, paper).

Fish Kills

All fish kills have a cause; however, determining that cause can be difficult and more often than not, unsuccessful. Fish kills may be caused by a wide variety of factors, both natural and man-made. Natural causes—such as low DO, infectious diseases, high water temperature, toxic algal blooms, and parasitic, bacterial, or viral infections have the potential to cause widespread fish kills.

Oxygen depletion is a common natural cause of fish kills, but is often enhanced by human activities (Meyer and Barclay 1990). Tables 3-3 and 3-4 are summaries of general water chemistry, fish behavior, and possible causes associated with fish kills.

If you have a water quality concern contact the local TCEQ field office. A list of TCEQ field offices can be found on the Web at **www.tceq.org/about/directory/maps_index.html**.

If you observe a fish kill, contact the local TPWD Kills and Spills biologist. A list of TPWD regional biologists can be found on the Web at **www.twpd.state.tx.us/conserve/private_lands/resource/kills_spills.phtml**.

Table 3-3

Water Chemistry and Possible Causes Associated with Fish Kills

Observations and Water Chemistry	Possible Causes
Large fish coming to surface, gulping air, low DO, small fish alive and normal	Oxygen depletion caused by excessive organic matter; look for a sewage treatment plant, livestock feedlot, irrigation runoff, decaying plant material, or dying algal bloom after several days of hot, calm, cloudy weather
Large fish coming to surface and gulping air	May be same as above but enough time in the presence of adequate oxygen has passed to allow for reoxygenation of water; ammonia kills may also have these characteristics; look for possible drainage from feedlot or wastewater treatment plant
Fish swimming erratically and moving up tributary streams to avoid pollution	Usually a heavy metal or chemical waste discharged from a chemical complex or through a wastewater treatment plant
Fish dying after heavy rain	Pesticide or herbicide that has washed off adjacent agricultural fields or runoff of chemicals from an aerial spraying operation
Oil sheen on water	Drilling and refinery operations; ruptured pipeline in the area; wash water discharged from oil barges or a leaking barge; or a gas station
Streambanks and bottom covered with orange substance; high conductivity readings in water samples	Drilling operations; look for discharge of brine water into stream
Low pH, orange discoloration of water but good water clarity	Acid water discharge from coal mining operation
Fish hyperexcitable, rapid movements followed by death, fish may attempt to swim onto shore	High levels of ammonia from raw sewage or animal feed lot runoff; low pH from a spill
Bleeding from the gills, schooling near shore, sluggish behavior, bleach odor	High levels of chlorine; look for wastewater treatment plant or swimming pool overflow

Reference: Meyer and Barclay 1990 with modifications

Table 3-4

Physical Signs Associated with Common Causes of Fish Kills

Physical Signs	Oxygen Depletion	Algal Bloom	Pesticide Toxicity
Fish behavior	Gasping and swimming at surface	Convulsive, erratic swimming, lethargy	Convulsive, erratic swimming, lethargy; pectoral fins extended forward
Selected species in fish kill	All species affected. Some species can tolerate low DO levels	All species affected	Usually one species killed before others, depending on fish sensitivity and pesticide level encountered
Size of fish	Large fish killed first, eventually may kill all sizes and species	Small fish killed first, eventually all sizes	Small fish killed first, eventually may kill all size fish
Time of fish kill	Night and early hours	Only during hours of bright sunlight, about 9:00 am to 5:00 pm	Any hour, day or night
Plankton abundance	Algae dying, little zooplankton present	Abundance of one algal species, few zooplankton present	If insecticide, no zooplankton present, but algae normal; if herbicide, algae may be absent
Dissolved oxygen	Less than 2 ppm	Very high, often saturated or super saturated near surface	Normal range
Water pH	6.0–7.5	9.5 and above	7.5–9.0
Water color	Brown, gray, or black	Dark green, brown, or golden, sometimes with musty odor	Normal color and little or no unusual odor
Algal bloom	Many dead and dying cells	Abundant algae, majority of one species	Normal plankton bloom of mixed species unless a herbicide is involved, then algae is absent or reduced

Reference: Meyer and Barclay 1990 with modifications

CHAPTER 4

The Basics of Freshwater Ecosystems

What Is a Freshwater Ecosystem?

A freshwater or aquatic ecosystem is defined as the organisms (*biotic*) and the non-living (*abiotic*) environment they inhabit.

Drainage Basins

A freshwater ecosystem—whether it be a pond, lake, stream, or river—is defined by the *drainage* or *catchment basin* in which it exists. The United States Environmental Protection Agency (USEPA) defines a drainage basin as “a geographic area in which water, sediments, and dissolved materials drain into a common outlet” (see Figure 4-1). This outlet can be a stream, lake, estuary, aquifer, or ocean. The dividing line between two drainage basins is the highest point of land between them. This dividing line, or divide, causes each basin to be drained by a different river system.

In Texas, there are 23 major river basins that drain into the Gulf of Mexico as illustrated in Figure 4-2. Maps of the river basins can be found in the *Atlas of Texas Surface Waters* at **www.tceq.state.tx.us/comm_exec/forms_pubs/pubs/gi/gi-316/index.html**

Defining a Drainage Basin

A drainage basin can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. The topographic dividing line or ridge causes streams on either side to flow in different directions.

Watersheds

The word *watershed* is more commonly used when discussing drainage basins, but it has a much broader meaning than drainage basin. Where drainage basin defines the physical transport of water, sediment, and dissolved minerals into the common outlet, watershed is a term that defines a complex system of components that affect water bodies in a given drainage basin.

Each watershed includes a variety of factors that interact with the water in the system, including climate, amount of rainfall, geology and geography of an area (rocks, soil, hills, lowlands, forests), and human activities (urban and industrial development, agriculture).

When it rains, water flows overland and through soils, recharging groundwater supplies and draining into nearby streams. Consequently, everything that happens in a watershed can contribute to what ends up in a stream. Impurities such as oil and grease (from road runoff) or bacteria (from untreated wastewater, septic tanks, or other sources) are picked up in the water flow and deposited in a nearby stream.

Figure 4-1
A Drainage Basin

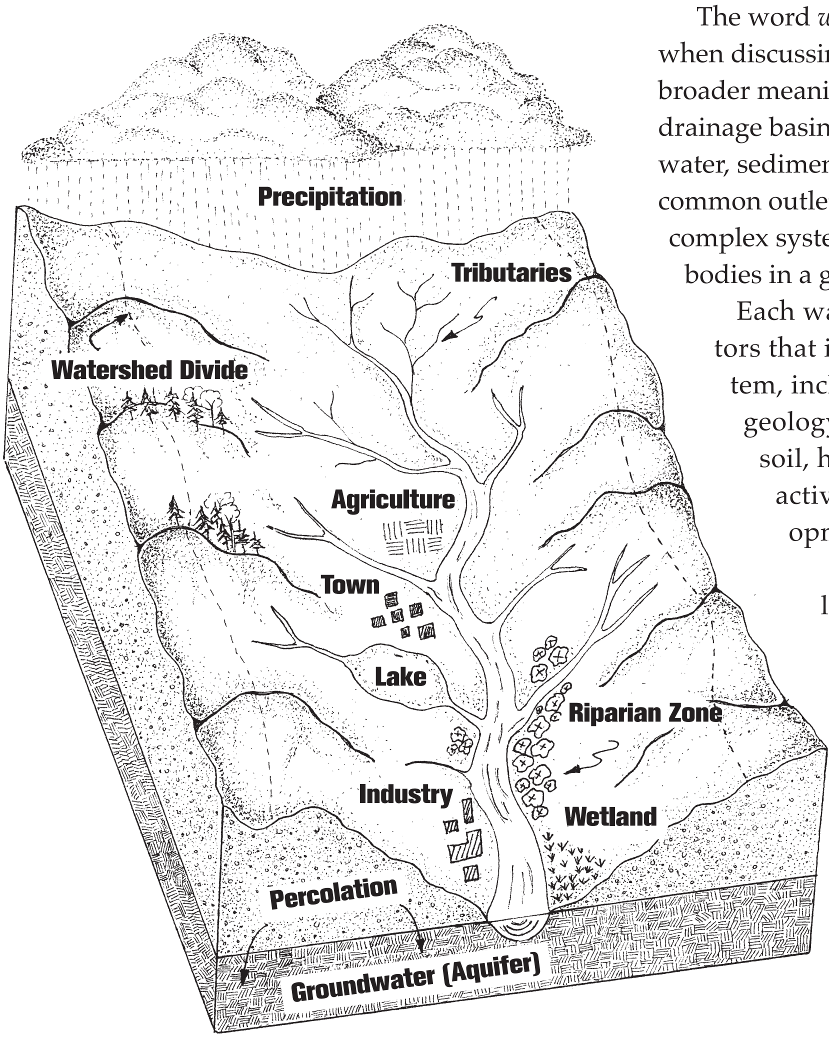
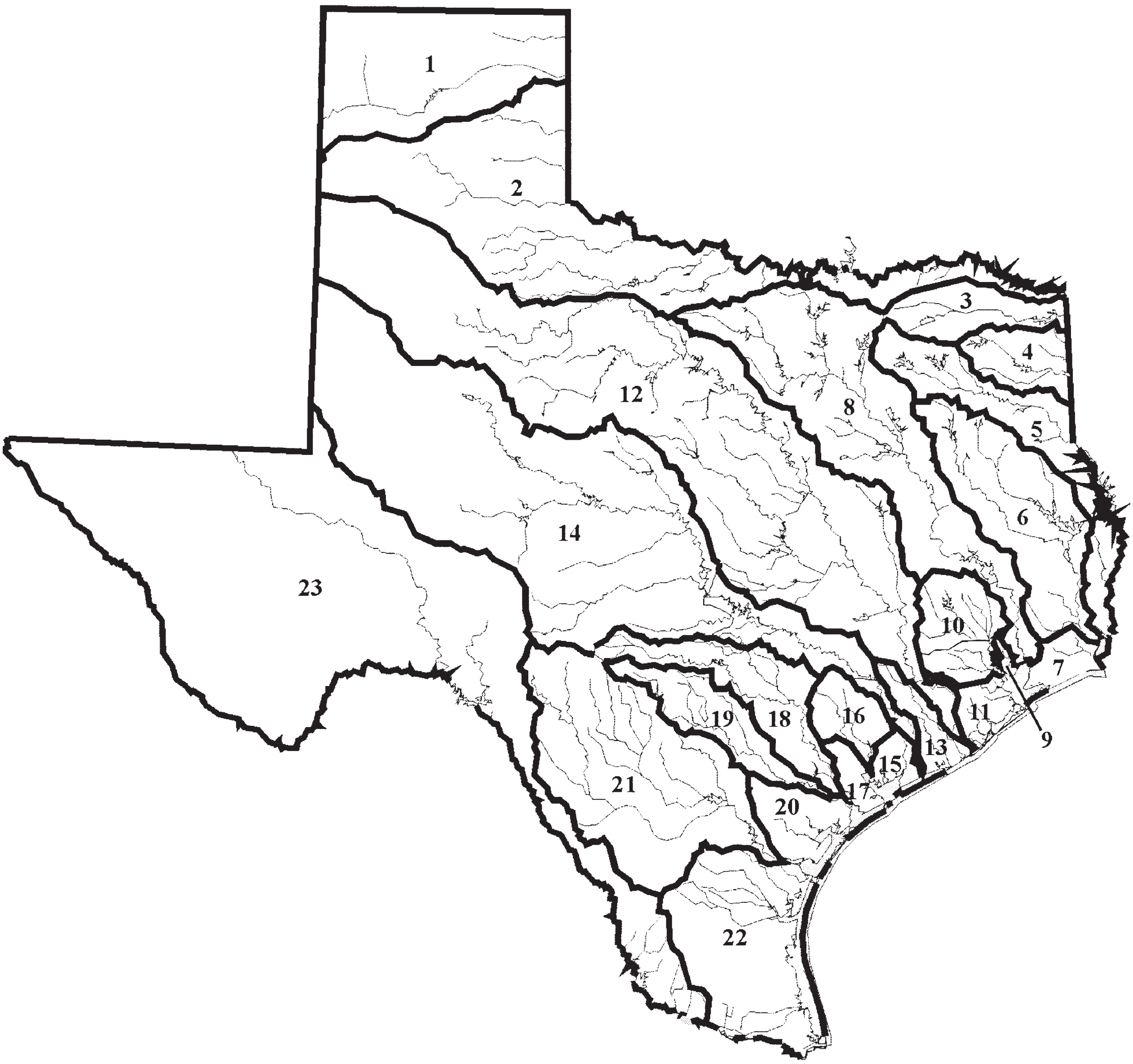


Figure 4-2

Major Texas River Basins



1 - Canadian River Basin

2 - Red River Basin

3 - Sulphur River Basin

4 - Cypress Creek Basin

5 - Sabine River Basin

6 - Neches River Basin

7 - Neches–Trinity Coastal Basin

8 - Trinity River Basin

9 - Trinity–San Jacinto Coastal Basin

10 - San Jacinto River Basin

11 - San Jacinto–Brazos Coastal Basin

12 - Brazos River Basin

13 - Brazos–Colorado Coastal Basin

14 - Colorado River Basin

15 - Colorado–Lavaca Coastal Basin

16 - Lavaca River Basin

17 - Lavaca–Guadalupe Coastal Basin

18 - Guadalupe River Basin

19 - San Antonio River Basin

20 - San Antonio–Nueces Coastal Basin

21 - Nueces River Basin

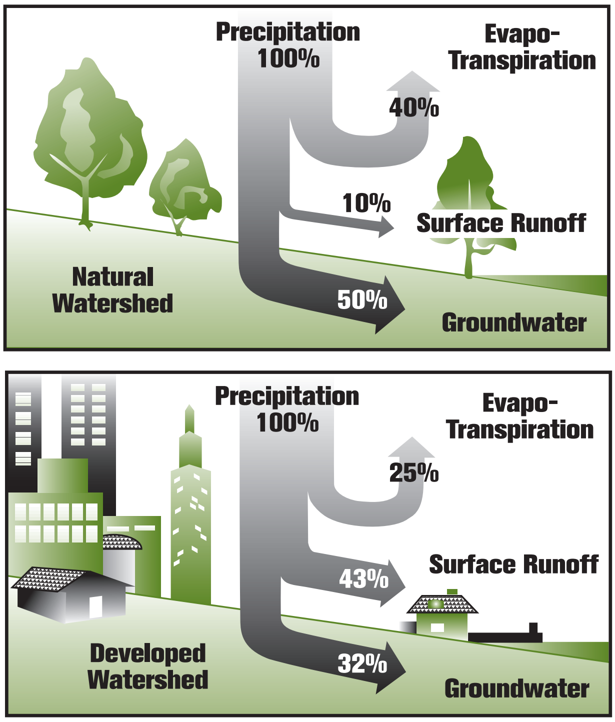
22 - Nueces–Rio Grande Coastal Basin

23 - Rio Grande River Basin

The concentration of these impurities and the speed and the amount of water flowing to the stream can affect a stream's water quality.

In natural areas, such as forests, vegetation slows the flow of water over the land, filtering some impurities and decreasing erosion. In these areas as much as half of all rainfall is absorbed into the ground, becoming groundwater. In urban areas, many vegetated surfaces are replaced with impervious cover, like concrete, which does not allow water to soak into the ground. Instead, water flows more swiftly downhill. This increased flow can lead to flooding and erosion and allows more pollutants to reach surface waters. In many urban areas, less than one third of all rainfall is absorbed into the ground (see Figure 4-3).

Figure 4-3
Fate of Precipitation



Large watersheds, like the Mississippi River basin, contain thousands of smaller watersheds with many different land uses. Information on defining a watershed can be found in the TCEQ publication, *Conducting a Watershed Survey*, Report No. GI-232, **www.tceq.state.tx.us/comm_exec/forms_pubs/gi/gi-232_168024.pdf**

Major Freshwater Ecosystems

Freshwater ecosystems are divided into two general categories, *running water* or *lotic* (rivers and streams) and *standing water* or *lentic* (ponds and lakes).

General Differences Between Streams and Lakes

The following table shows the distinct physical differences between streams and lakes. The physical characteristics of running or standing water directly affect water quality and the ability of a water body to assimilate pollutants.

Table 4-1
General Differences Between Streams and Lakes

Streams (Lotic)	Lakes (Lentic)
One direction of flow, upstream to downstream	Various flows, no particular direction
Normally oxygen rich	Oxygen depletion exists at times in deeper water
Shallower	Deeper
Narrower and longer	Wider and shorter
Various effects from different terrestrial environments along the stream's course. The shoreline has more potential to affect water quality because a larger portion of the water body is near shore.	Terrestrial environment similar all around the lake shore. A smaller portion of the water is in close proximity to the shore.
Stream continually cuts into the channel, making it longer, wider, and deeper	Lakes become shallower over time from depositing sediments
Age progression of a stream goes from young stream, narrow and shallow, to mature stream, wider and deeper	Age progression of a lake or pond goes from lake to marsh or swamp to land
Shorter retention time for water	Longer retention time for water
Top and bottom waters generally have the same temperature	May have different temperatures from the top to bottom

Lotic System

This section covers stream types and the habitats found in a lotic system. This section also includes animals common to this type of system. Finally, the importance of habitat to the health of lotic systems is described.

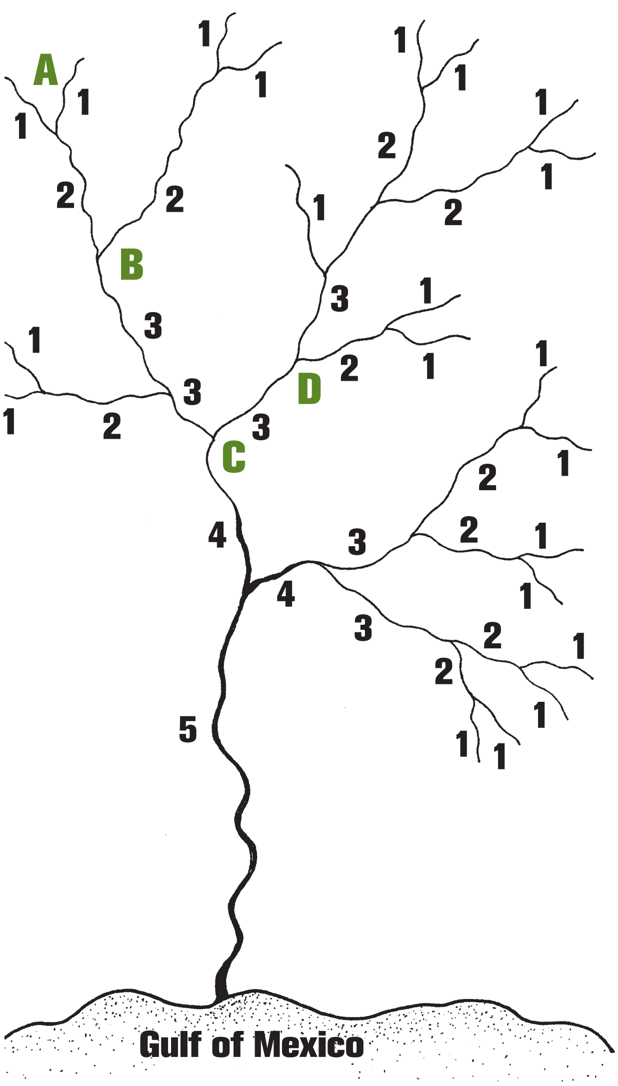
Lotic environments include streams and rivers. Flowing waters are very diverse, not only in size but in characteristics. Streams and rivers are defined by things like surrounding land use (urban, agricultural, natural), size of the watershed, stream order, geology, soils, topography, flow, and vegetation.

Stream Order

A simple method has been developed to categorize streams in a watershed (see Figure 4-4). Streams that have no tributaries flowing into them are called *first-order streams* or *headwater streams*. These streams typically begin as a spring, or as an outlet from a lake, pond, or wetland.

A first-order stream joined by another first-order stream becomes a *second-order stream* (labeled "A" in Figure 4-4). When two second-order streams join, the result is a *third-order stream* (labeled B). Two third-order streams result in a fourth-order stream (labeled C), and so on. This process continues until all the streams in a watershed merge into the largest river, which ultimately drains into a lake or ocean. The Mississippi River, near its mouth, is a twelfth-order stream. Keep in mind that two like streams must join to form the next highest stream order. For example, if a second-order stream flows into a third-order stream. The joined flow is still a third-order stream (labeled D).

Figure 4-4
Stream Order



Stream Types

Streams and rivers are primarily characterized by flow. There are three main types of streams: *perennial*, *intermittent*, and *ephemeral*. Perennial streams and rivers are those that flow year-round. Some perennial streams and rivers in Texas are fed by large springs (Comal River, San Felipe Creek, San Marcos River, or Devils River). Due to the intermittent nature of most streams in Texas, the headwaters of many streams are effluent discharges from wastewater treatment plants. These discharges create artificial *perennial* streams. Many urban streams are considered *effluent dominated*.

Intermittent streams and rivers are those that become dry for a period of a week or longer each year. Over 76 percent of the streams in Texas fall into the intermittent category. These water bodies are generally associated with arid or semiarid areas or areas of average rainfall that are experiencing especially dry conditions, but intermittent streams can be found throughout Texas. During times of extreme drought, even perennial streams can become intermittent. Although shallow sections of intermittent streams and rivers can dry up, perennial pools are often maintained in the deeper sections of a stream channel. Large pools can often sustain aquatic life through the hot summer months.

Intermittent streams that regularly exist for only a short period of time are classified as *ephemeral* streams. Ephemeral streams are best illustrated by the dry stream beds in west Texas, called *arroyos*, that flow only following rainfall and cease to flow soon after.

Gaining and Losing Streams

What makes a stream perennial or intermittent? An important factor that allows some streams to maintain flow during dry weather is the *water table*. As rain falls or snow melts, some water percolates through the soil until it reaches an area where the pores and cracks in rock are saturated with water. This subsurface saturated zone is called an *aquifer*.

An aquifer stores *groundwater*. The upper area near the surface of the aquifer is called the *water table*. When the water table is at or very close to the surface of the earth, groundwater can be discharged into a stream as a *spring*. This type of stream is called a *gaining stream* (see Figure 4-5A).

When the water table falls below the stream channel, some water moves away from the surface to the aquifer. This type of stream is a *losing stream* (see Figure 4-5B). This concept is important in understanding how groundwater and surface water interact, and how one can influence the quality of the other.

Stream Habitat Types

There are two lotic habitats, *lotic erosional*, characterized by fast-running water, and *lotic depositional*, characterized by areas of slow-moving water (see Figure 4-6). The type of stream habitat, sediment, and substrate depends largely on the area of the state (see Table 4-2).

Rivers and streams flow downhill seeking a path of least resistance. Changing terrain alters the course of a river or stream creating bends called *meanders*. These meanders move over time through the processes of *erosion* and *deposition*.

Figure 4-5(A)
Gaining Stream

Figure 4-5(B)
Losing Stream

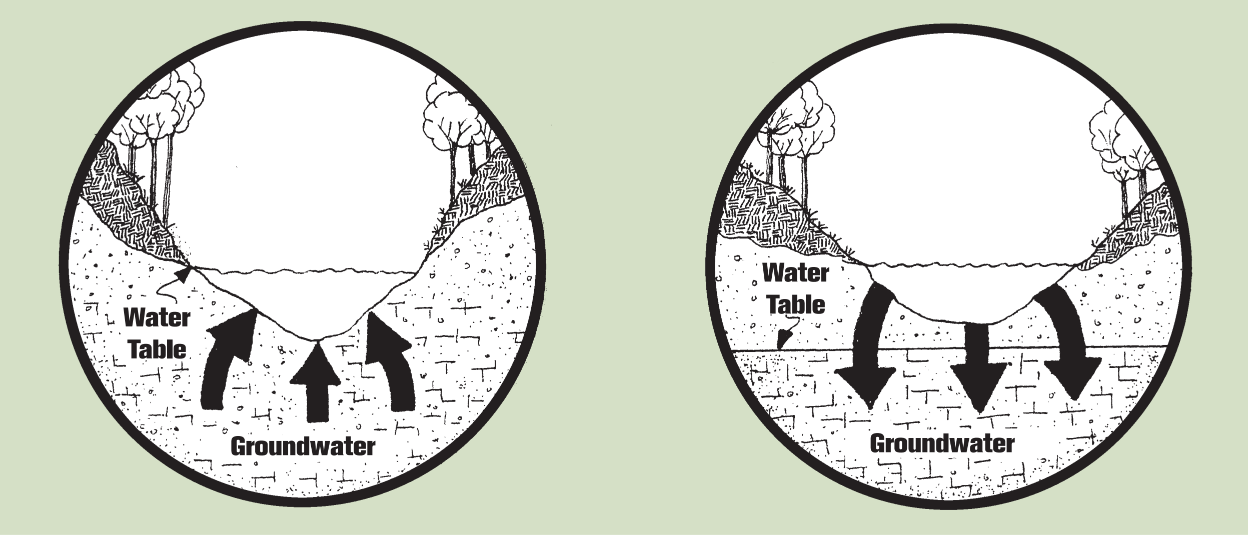


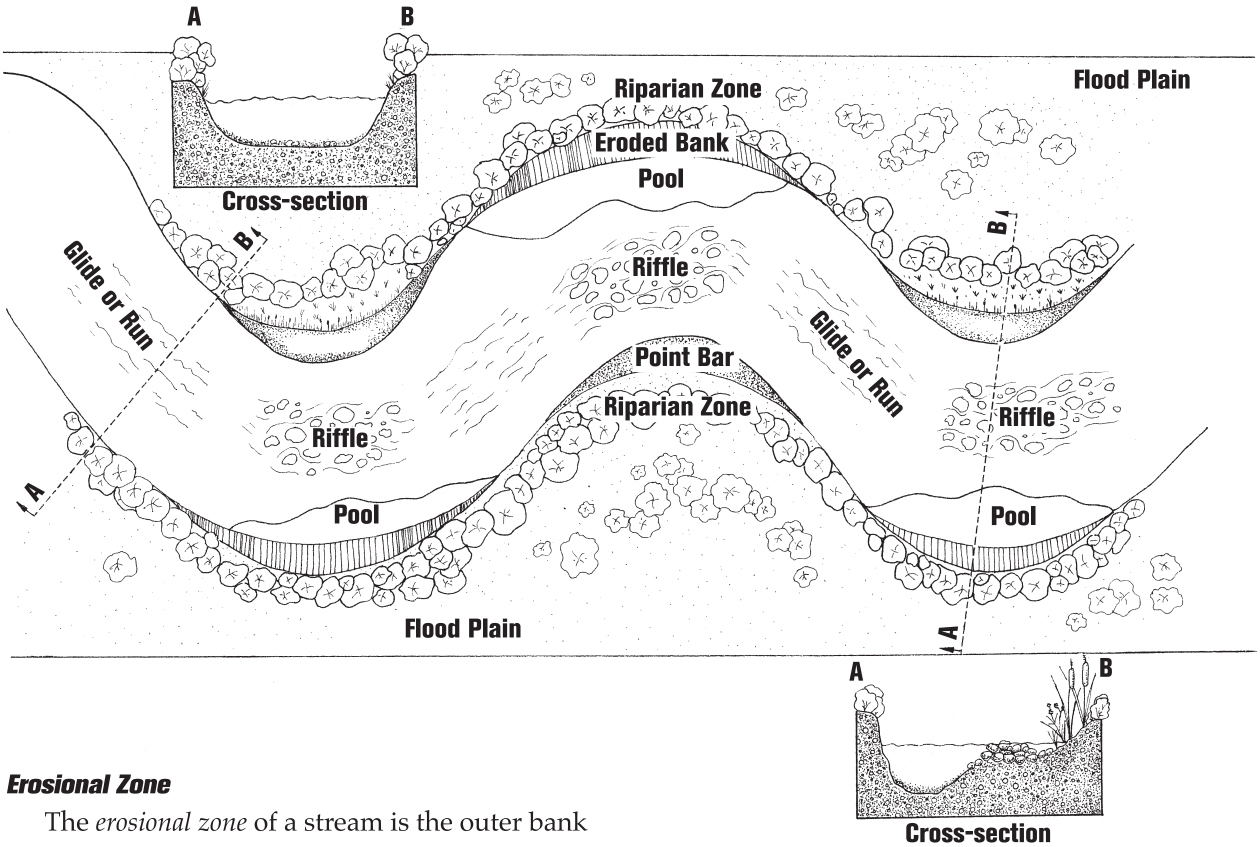
Table 4-2
Aquatic Stream Habitats

General Aquatic Habitat Types	Characteristics	Description
Lotic–erosional	Flow	Relatively shallow area of a stream. Three areas defined by flow: Riffle–fast-moving, turbulent water Run–fast-moving, nonturbulent water Glide–slow-moving water
	Sediment	Coarse sediment comprised of cobble, pebble, and gravel
	Aquatic plants (macrophytes)	Plants typically grow on or in coarse sediment (pondweed)
	Aquatic animals	Aquatic insects and small fish that require high oxygen levels, flowing water for feeding, and are adapted to living in swift water through the ability to swim or cling to rocks in riffle areas
	Organic materials (detritus)	Comprised of leaf litter, twigs, and other coarse particulate matter, usually trapped in stream riffles behind large rocks or logs; also known as *leaf packs*
Lotic–depositional	Flow	Relatively deep and wide with slow moving water compared to riffles, runs, or glides
	Sediment	• Primarily found in pools and backwater areas of streams • Fine sediment comprised of sand and silt
	Aquatic plants (macrophytes)	Submergent vegetation growing in fine sediment *(Hydrilla, Potamogeton)*
	Aquatic animals	• Organisms similar to those found in lakes and pond systems (dragonflies, damselflies, water striders) • Many fish use the deeper water of the pools and areas along the banks for cover and find food easier to catch in slower moving water
	Organic materials (detritus)	Comprised of leaf litter and other particulate matter found at the bottom of pools and backwater areas of streams

Adapted from Merritt and Cummins, 1995.

Figure 4-6

Stream Habitats



Erosional Zone

The *erosional zone* of a stream is the outer bank where flow velocities and bank erosion are high (see Figure 4-6). *Riffles* are the shallow portions of a stream characterized by relatively

fast-moving, turbulent water with bottom materials composed of cobble, gravel, or bedrock.

There are two other areas associated with flowing water: glides and runs. Glides and runs are intermediate habitat types that fall between riffles and pools.

A *glide* is an area where the flow is characterized by slow-moving, nonturbulent flow referred to as *laminar*, similar to that in a shallow canal. A glide is too shallow to be a pool, but the water velocity is too slow to be a run.

A *run* is a relatively shallow portion of a stream characterized by relatively fast-moving, nonturbulent flow. A run is usually too deep to be considered a riffle and too shallow to be considered a pool.

Riffle areas of streams are important habitats for many aquatic insects and small fish that require flowing water for feeding and high oxygen levels (see Figure 4-6). Few plants grow in the fast-moving water of a stream, but some may be adapted for living in the current of smaller streams. Riffle areas commonly support those organisms adapted to life in fast-moving waters, such as algae, plants, and invertebrates (mayflies, caddisflies, riffle beetles, water pennies) that can anchor themselves to rocks, logs, and other stream debris. Some fish prefer the fastest part of a stream (darters). Many fish spawn in the riffles of streams.

Depositional Zone

The *depositional zone* refers to the inner bank of a stream where velocity is at a minimum (see Figure 4-6). The slower velocities allow for the deposition of suspended sediment and bed materials (gravel, pebbles), which form bars. These bars often support emergent aquatic vegetation.

A *pool* is relatively deep and wide with slow-moving water compared to riffle, run, or glide areas. Pools often contain large eddies with widely varying directions of flow compared to riffles, glides, and runs, where flow is nearly all downstream. *Eddies* are currents that move in a direction other than downstream, usually in a circular motion. Pool areas support fish, aquatic invertebrates, and aquatic plants (see Figure 4-6).

Sediment in most pooled areas of streams and rivers is composed of sand, silt, clay, and organic matter, compared to the coarser sediment of riffles, runs, and glides. Reduced velocity allows suspended materials to settle to the bottom. The slower-moving water supports organisms similar to those found in lakes and pond systems (dragonflies, damselflies, water striders). For descriptions and illustrations of common freshwater macroinvertebrates, see Chapter 6.

Riparian Zone

The *riparian zone* is a vegetated buffer between nearby lands and a stream or river (see Figure 4-6). These areas are important in controlling the introduction of sediment and nutrients into a river or stream channel. The riparian zone includes the stream bank and portions of the floodplain that are periodically covered by flood waters.

Interaction between the riparian zone and a stream is vital for the health of the stream. For example, in flood-prone areas where streams are channelized for flood control, vegetation, with the exception of grasses, is removed from the banks. The riparian zone of a channelized stream does not offer much in the way of protection from surrounding land uses, in contrast to a riparian zone retaining a wide band of native vegetation.

Importance of In-Stream Habitats

In-stream habitats include pools, riffles, root mats, aquatic plants, undercut banks, submerged rocks and logs, overhanging vegetation, and leaf litter. A combination of these, along with the depth and flow of the water, are key factors in determining the type of aquatic organisms found in a stream.

Under natural conditions, a wider variety of habitats equals greater aquatic life diversity. Low diversity of aquatic life is often caused by poor quality of in-stream habitats rather than by poor water quality. Historically, the quality of a stream has always been determined by water chemistry and physical parameters (DO, pH, temperature) alone. Recently, the use of biological community and habitat assessments has become very important in determining the quality of a stream.

Lentic System

This section covers the habitats found in a lentic system and the plants and animals common to this type of system. It also includes the concept of biological productivity and the stratification in lakes. Finally, the aging process of lentic systems is described.

Lentic environments include lakes, ponds, and wetlands. Lakes and ponds are formed in a variety of ways. In the northern part of the United States and Canada, many of the lakes and ponds were formed by glacial activity. Glaciers created gouged-out depressions that eventually filled with water.

Lakes that are formed by meanders in rivers that flow over floodplains and low valleys are called *oxbow lakes*. These meanders are snake-like loops that are eventually cut off from the rest of the river forming oxbow lakes that are long, narrow, and crescent or U-shaped. Such lakes are common in the mature segments of rivers in Texas, especially in the flat coastal areas. Oxbow lakes formed in the Lower Rio Grande Valley are called *resacas*.

Another kind of lake, called a *playa*, appears in the Southern High Plains of Texas (Panhandle). Small, shallow, and circular, playa lakes are generally less than 1.6 km (1 mile) in diameter and 20 m (65 ft) in depth. There are numerous theories on the origin of playa lakes but the generally accepted theory is that multiple factors contributed to their formation, including soil erosion, winds, salt and carbonate dissolution, and even herds of bison (Gustavson *et al*. 1995).

With the exception of playa lakes, oxbow lakes, and Caddo Lake in East Texas, lakes in Texas are man-made reservoirs, remnants of quarry and mining operations, or agricultural stock ponds. Reservoirs are formed by damming rivers. The Rio Grande–Amistad and Falcon International Reservoirs, the Brazos River–Possum Kingdom Reservoir and Lake Whitney, the Guadalupe River–Canyon Lake, and the Sabine River–Toledo Bend Reservoir are all examples of reservoirs formed by damming rivers. Texas has approximately 10,196 reservoirs and lakes that cover 10 surface acres or more, for a total of approximately 2 million acres covered by reservoirs and lakes.

Wetlands are basically transition zones between water and land. There are four basic categories of wetlands,

- ▼ **Marshes**—Seasonal or permanent shallow water originating from surface water runoff and floodwaters. The marsh is dominated by soft-stem woody vegetation.
- ▼ **Swamps**—Areas characterized by very wet soils during the growing season and standing water during certain times of the year. Swamps are dominated by trees and scrubs. Swamps occur in freshwater or saltwater floodplains.
- ▼ **Bogs**—Characterized by floating, spongy peat deposits covered by a thick layer of sphagnum moss with evergreen trees and shrubs. Bog ecosystems support carnivorous plants like pitcher plants. Bogs, more acidic than fens, are typically found in the northern US.
- ▼ **Fens**—Groundwater-fed, peat-forming wetlands that are covered by grasses, sedges, and reeds with willow and birch trees. Fens, more alkaline than bogs, are typically found in the northern US.

Additional information on wetlands can be found at **www.epa.gov/owow/wetlands/types**.

Habitats

Habitats within a lentic ecosystem are characterized by well-defined boundaries: the shoreline, the sides of the basin, the surface of the water, and the bottom sediments (see Figure 4-7). Lentic environments are divided into three major zones, or habitats.

- ▼ **Littoral zone**—shallow vegetated and wave-swept, near-shore areas with coarse sediment (cobble, pebbles, gravel). The majority of aquatic plant growth occurs in this area, where light penetrates to the bottom.
- ▼ **Limnetic zone**—open water area too deep to support rooted aquatic plants but shallow enough for light to penetrate into the water column.
- ▼ **Profundal zone**—deep, bottom-water area of little or no light penetration. Fine bottom sediments consist of fine sand, silt, and clay mixed with organic matter.

In the *littoral zone* the water is shallow enough for light penetration to the bottom, allowing for rooted plant growth. Wave-swept shores have coarse sediments (rocks, cobble, pebbles, gravel, or sand) and may be inhabited by invertebrates common to flowing water. Sheltered areas generally have finer sediments like silt and clay. Aquatic plants are generally associated with sheltered areas and provide habitat for a variety of invertebrates and small fish.

The *limnetic zone*—the open water of a pond, lake, or reservoir—is characterized by the lack of rooted plants and limited light penetration. This area is normally inhabited by plankton and fish.

The *profundal zone* or bottom is generally characterized by the lack of light penetration, lack of rooted aquatic plants, and the absence of photosynthesis. The sediments are generally silt and clay mixed with organic matter. Oxygen levels in this zone tend to be extremely low. Organisms that rest or burrow on the bottom and that are tolerant of little or no oxygen are common.

Aquatic Plant Categories

In the littoral zone, three general categories of aquatic plants are common.

- ▼ **Emergent**—rooted plants growing near the shore with lower portion submerged and upper portions above the surface (cattails, bullrush, sedges).
- ▼ **Floating**—rooted plants (some free floating) with leaves floating on the surface (water lilies, water hyacinth, duckweed).
- ▼ **Submerged**—rooted plants with nearly all leaves below the surface (eel grass, elodea, hydrilla).

Additional information on aquatic plants can be found in Chapter 11.

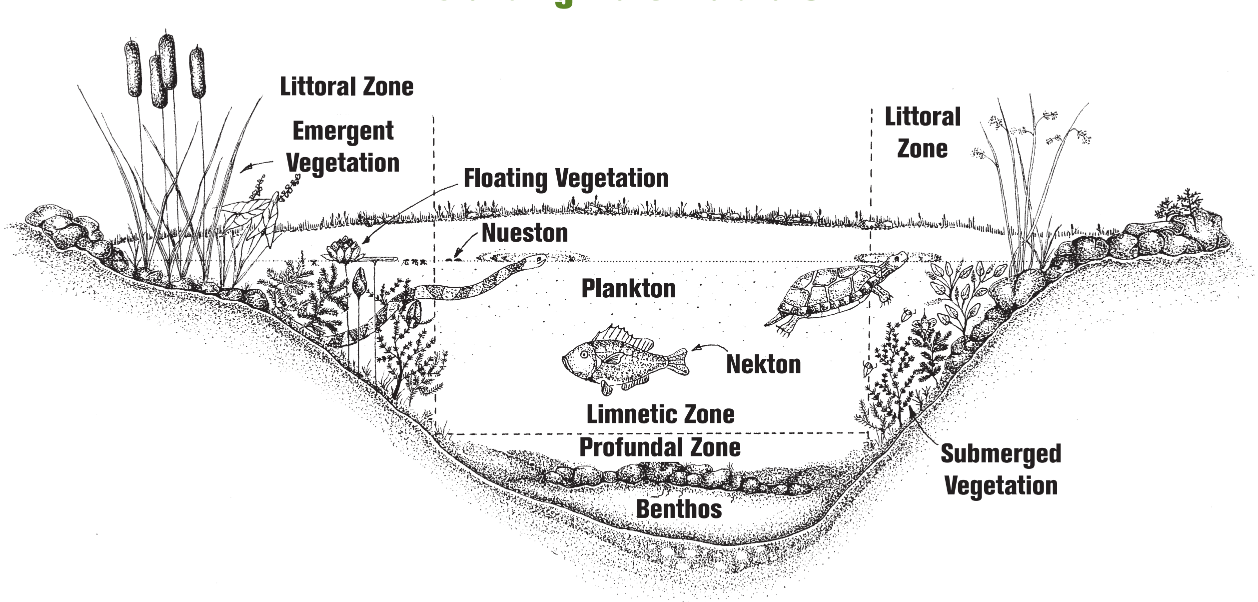
Aquatic Animals

Organisms inhabiting ponds and lakes of the littoral zone are put into five general categories based on their physical adaptations.

- ▼ **Neuston**—organisms resting at or near the surface (mosquito larvae, water striders, whirligig beetles).
- ▼ **Nekton**—free-swimming organisms (fish, predaceous diving beetles).

Figure 4-7

Standing Water Habitats



▼ **Periphyton**—organisms that cling to rocks, logs, and other debris (including algae).

▼ **Benthos**—organisms living on and in the bottom sediments (worms, snails, clams).

▼ **Plankton**—microscopic plants (phytoplankton) and animals (zooplankton) that are suspended in the water column.

Biological Productivity

Biological productivity, or *trophic state*, is defined as the amount of plankton, algae, aquatic plants, aquatic macroinvertebrates, and fish that a water body can produce and sustain. Biological productivity in a lentic system such as a lake or pond is usually limited to the depth of light penetration into the water column, in both the littoral and limnetic areas. The depth of light penetration is limited by the water color, and by the amount of suspended solids. A pond is usually defined as a body of water where light penetrates to the bottom. In a lake, the depth of light penetration can vary from several inches to many feet in the open water.

The four traditional categories of biological productivity from lowest to highest are *oligotrophic*, *mesotrophic*, *eutrophic*, and *hypereutrophic*. These categories are defined in Table 4-3.

Determining the Trophic State

The three common water quality parameters used to determine the trophic state are total phosphorus (plant nutrient), chlorophyll *a* (a measure of the algae population), and Secchi disk transparency (a measure of water clarity). The use of these three indicators is based on the fact that changes in nutrient levels cause changes in chlorophyll *a*, which in turn produces a change in water clarity.

Plant nutrients are necessary for the growth and maintenance of plants. The proper level of nutrients is important in limiting growth of algae and other aquatic vegetation. High nutrient levels often trigger *algae blooms*. Algae blooms result in increased turbidity, lower oxygen levels, and decreased water clarity. The effects of nutrients on the aquatic environment are discussed in the "Plant Nutrients" section in Chapter 3.

Chlorophyll *a* is the dominant green pigment found in algae and plants; it allows plants to convert solar energy into chemical energy through photosynthesis. Chemical energy is used to change carbon dioxide and water into the carbohydrates needed for the growth and maintenance of plants. Elevated chlorophyll *a* levels indicate an increase in productivity.

Water clarity gives an idea of how far light will penetrate into the water column or how much light is available to algae, phytoplankton, and other aquatic plants. The limit of light penetration is the limit of plant growth. Reduction in water clarity is often the result of large algae populations in the water column. The effects of water clarity on water quality are discussed in the "Suspended Solids" section in Chapter 3.

Table 4-3

Summary of Biological Productivity Characteristics

Lake Trophic Classification	Biological Productivity	Nutrient Concentration	Typical Characteristics
Oligotrophic oligo = scant or lacking	Low	Low	Clear water, low aquatic plant and plankton populations, few fish, low nutrient supplies, sandy bottoms with little organic material
Mesotrophic meso = mid-range	Moderate	Moderate	Water bodies with a moderate amount of nutrients, aquatic plants, and water clarity in transition from oligotrophic to eutrophic
Eutrophic eu = good or sufficient	High	High	Lakes, ponds (slow-moving streams and rivers also) that typically have large populations of algae, plankton, plants, fish, and aquatic macroinvertebrates; high nutrient supplies and frequent plankton blooms; and sediments with more organic matter and water that is commonly colored and turbid
Hypereutrophic hyper = overabundant	Very high	Very high	Water bodies that are highly productive with low water clarity; have large populations of plants and aquatic animals, very high nutrient supplies and frequent plankton blooms; and have sediments with more organic matter

References: Florida LAKEWATCH 1999.

Water Stratification in Lakes

In lentic systems, ponds and lakes have similar physical characteristics, like temperature and dissolved oxygen, from top to bottom. The water is generally well mixed by wind. When a water body is well mixed, the physical characteristics vary little with depth. If light can penetrate to the bottom, photosynthesis and plant growth can occur throughout the water column.

Larger, deeper lakes become layered during warm summer months. This layering is known as *stratification*. During summer months increased sunlight and warm winds heat the surface water, trapping colder water at the bottom. Differences in the densities of warm and cold water resist mixing by wind.

In the fall months, cooler air temperatures decrease the surface water temperature of a lake. The densities of the upper and lower waters become similar, and the wind mixes the layers of water together. When the water temperature in the lake becomes uniform, this is known as *fall turnover*. Oxygen levels are replenished in the deep water. In Texas, there is generally one turnover per year in the fall (*monomictic*).

In the northern climates, lakes become stratified in summer and winter. Turnovers occur twice a year (*dimictic*), in the spring and fall. The variation in the northern turnover comes during the winter, when the stratification of warm water over cold is reversed. Colder water, usually in the form of ice, lies over warmer water during the winter, creating what is known as *inverse stratification*. For information on why cold water rises to the surface see the "Physical and Chemical Properties of Water" in Chapter 2.

Unlike shallow lakes and ponds, the physical characteristics of a deep lake vary from top to bottom. Stratification creates three different zones, the *epilimnion, metalimnion, and hypolimnion* (see Figure 4-8).

Epilimnion. The warmest zone near the water surface. The surface water area circulates freely and has variable temperatures. Mixing of the surface water is caused by wind, water currents, and both heating and cooling. This is usually the area where the majority of organisms are found. It is the area of greatest productivity and light penetration; the oxygen concentration is also usually greatest in this zone.

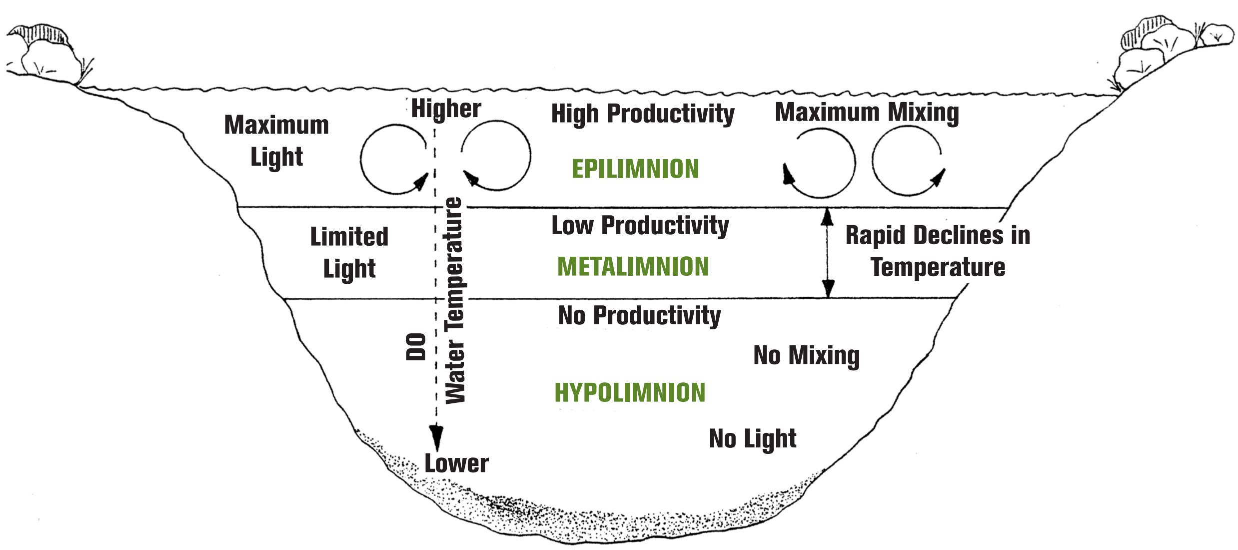
Metalimnion. The middle layer is characterized by steep and rapid declines in temperature. The *thermocline* is found in this zone—an area of the most rapid temperature decrease at 1°C per each meter of depth. Warm water is much lighter than cold water, which is heavy and tends to sink to the bottom of the lake.

Hypolimnion. The third layer is deep and cold with little temperature change and low oxygen due to little or no production of oxygen by plants. This water does not come into contact with air, and there is no mixing. The quantity of oxygen decreases with depth, the farther the distance from the boundary between the air and water, and from mixing by the wind. Oxygen is further depleted by bottom-dwelling organisms and bacteria feeding on organic matter. Little or no light penetrates the hypolimnion.

The Aging Process

Lakes and ponds go through a natural aging process called *succession*. Marshes, swamps, and bogs are generally the mature stages of succession

Figure 4-8
Lake Stratification



for lakes and ponds. Over time, sediments fill up ponds and lakes. As the depth decreases, the number of aquatic plants increases. Emergent aquatic like plants, cattails, sedges, and rushes begin to move out from the shoreline areas. These plants start to build a soil base where water-tolerant shrubs, grasses, and other plants start to move in. If left undisturbed, grasses and shrubs will eventually be replaced by larger trees and forest.

Aquatic Food Chain

Food chains are simplified models that describe the general flow of energy and food pathways that link different species in an ecosystem. At the base of the aquatic food chain are the *primary producers*—aquatic plants, algae, and phytoplankton. Primary producers are known as *autotrophs*, or organisms that can produce their own food.

Energy from the sun is the driving force of any ecosystem. Light energy, carbon dioxide, and water are converted to chemical energy (carbohydrates) by primary producers through a process called *photosynthesis*. This chemical reaction is described in Figure 4-9.

Figure 4-9
Photosynthesis

$6CO_2$ +	$6H_2O$ +	light energy =	$C_6H_{12}O_6$ +	$6O_2$
carbon dioxide	water		carbohydrate	oxygen

Plants use a portion of the chemical energy produced during primary production along with plant nutrients in a process called *respiration*. Respiration provides the plant with the energy needed for growth and reproduction (see Figure 4-10).

Figure 4-10
Plant Respiration

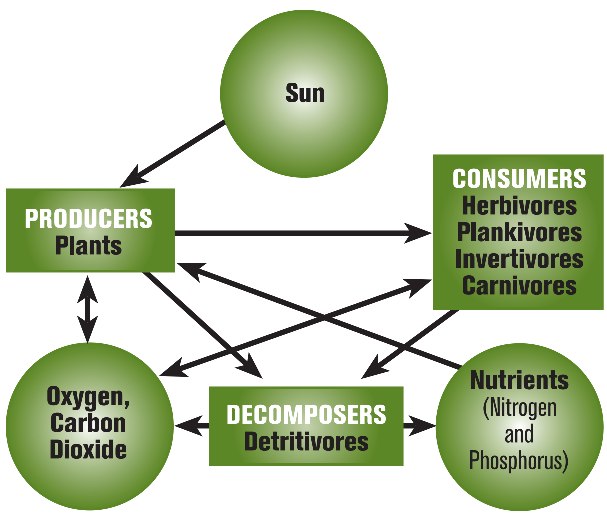
$C_6H_{12}O_6$ +	$6O_2$ =	$6CO_2$ +	$6H_2O$ +	released energy
carbohydrate	oxygen	carbon dioxide	water	

Since animals cannot produce energy, they must eat either plants, other animals, or dead organic material (*detritus*) to get the energy and nutrients they require. The pathways in which energy and nutrients are transferred from plants to animals are known as *food chains*.

Consumers are known as *heterotrophs*, or organisms that rely on organic matter as a source of food. *Primary consumers*—zooplankton and certain aquatic invertebrates and some fish—feed on the primary producers (see Figure 4-11). These are *herbivores*, or plant eaters. *Secondary consumers* feed on the primary consumers. In the aquatic environment, secondary consumers are generally *invertivores* (feed on invertebrates), planktivores (feed on zooplankton), small *carnivores* (flesh eaters), and *omnivores* (feed on a variety of things).

The secondary consumer group may contain more than one level of carnivore. Top carnivores (bass, turtles, snakes, alligators) form a *tertiary consumer* group. In summary, primary consumers eat primary producers, secondary consumers eat primary consumers, tertiary consumers eat secondary consumers, and so on.

Figure 4-11
Major Ecosystem Components



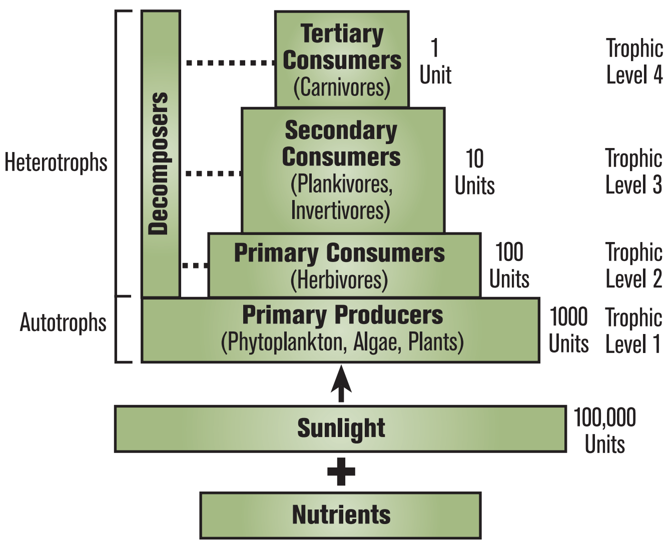
Detritivores (scavengers) are an important part of the food chain. Detritivores shred and eat detritus that contains fungi, algae, and bacteria. The final link in the food chain are *decomposers* (bacteria and fungi). By breaking down dead tissues and cells, decomposers release nutrients for use by primary producers.

The levels of a food chain are called *trophic levels*. These trophic levels describe the passage of energy through a food chain. Any ecosystem includes a finite number of trophic levels. A limit is reached when consumers cannot consume enough energy to balance energy lost during normal physiological functions (growth, reproduction). Most ecosystems have about four to five trophic levels.

Food Pyramid

The food pyramid is a simple way to demonstrate *biomass* (weight of living matter) relative to the number of organisms and amount of energy found at each trophic level. Figure 4-12 illustrates a food pyramid for an aquatic ecosystem. At each trophic level, the size of the box shows the relative number of organisms or biomass. The amount of biomass decreases from bottom to top. Primary producers make up the majority of biomass in a food pyramid. At each trophic level, the organisms become larger and the populations become smaller than at the previous level. Figure 4-12 shows the movement of energy, relative biomass, and trophic levels.

Figure 4-12
An Aquatic Ecosystem Food Pyramid



With every increasing trophic level, the use of energy becomes less efficient. This means that the amount of energy available at each successive trophic level becomes progressively less. Figure 4-13 shows a simplified example of energy movement. The original source of energy for a food chain, the sun, provides about 100,000 units of energy that plants capture and use for photosynthesis.

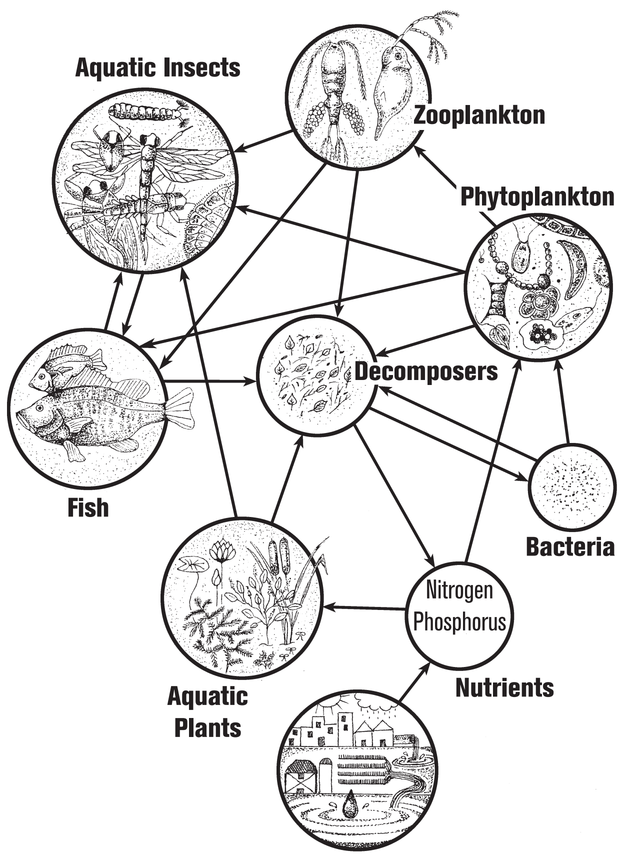
Plants are able to capture about 1 percent of the light energy (1,000 units). Primary consumers use about 10 percent of the plant biomass produced (100 units of energy). Secondary consumers capture and consume about 10 percent of the energy stored by primary consumers (10 units of energy). Finally, the tertiary consumers capture and consume about 10 percent of the energy stored by the secondary consumers (1 unit of energy). As the individuals increase in size, the amount of energy required for body maintenance, growth, reproduction, and locomotion also increases.

Food Web

In any ecosystem, most organisms have more than one source of food. For example, a large fish may feed on smaller fish, crayfish, and insects. This process results in an organism being part of more than one food chain. The complex overlapping of food chains is known as a *food web* (see Figure 4-13).

Keep in mind that food chains, food webs, and food pyramids are ways to generalize and simplify what are, in reality, very complex systems.

Figure 4-13
General Aquatic Food Web



CHAPTER

5 The Basics of Biological Classification

This chapter covers the basic taxonomy of freshwater macroinvertebrates and fish. It also includes information on the identification of aquatic organisms and the use of taxonomic keys.

Freshwater Macroinvertebrate Taxonomy

Taxonomy is the classification of all living things into related groups (or *taxa*), according to similar characteristics (see Figure 5-1). Macroinvertebrates are members of Kingdom Animalia, which is the largest taxonomic grouping. The taxa below kingdom, from general to specific, are *phylum*, *class*, *order*, *family*, *genus*, and *species*. Genus and species are a specific organism's scientific name.

For example, the classification of a mayfly is: kingdom Animalia; phylum Arthropoda; class Insecta; order Ephemeroptera; family Isonychidae; genus *Isonychia*; species *sicca*. Figure 5-1 illustrates the classification structure for benthic macroinvertebrates found in Texas.

Figure 5-1
Freshwater Macroinvertibrate Taxonomy

Kingdom	Phylum	Class	Order
Animalia	Platyhelminthes	Turbellaria Flatworms	
Animalia	Annelida	Hirudinea Leeches	
Animalia	Annelida	Oligochaeta Aquatic Earthworms	
Animalia	Arthropoda	Arachnida Water Mites	
Animalia	Arthropoda	Insecta	**Ephemeroptera** (Mayflies) **Plecoptera** (Stoneflies) **Trichoptera** (Caddisflies) **Odonata** (Dragonflies & Damselflies) **Diptera** (True Flies) **Coleoptera** (Beetles) **Lepidoptera** (Aquatic Caterpillars) **Megaloptera** (Dobsonflies & Alderflies) **Hemiptera** (True Bugs)
Animalia	Arthropoda	Crustacea	**Isopoda** (Sowbugs) **Amphipoda** (Scuds & Sideswimmers) **Decapoda** (Crayfish & Prawns) **Ostracoda** (Seed Shrimp) **Cladocera** (Water Fleas) **Anostraca** (Fairy Shrimp) **Notostraca** (Tadpole Shrimp)
Animalia	Mollusca	Pelecypoda Clams and Mussels	
Animalia	Mollusca	Gastropoda Snails	

Example:

ORDER: Ephemeroptera
FAMILY: Isonychidae
GENUS: *Isonychia*
SPECIES: *sicca*

Freshwater Fish Taxonomy

Fish are also members of Kingdom Animalia. The classification of a channel catfish is: kingdom, Animalia; phylum Chordata; class Osteichthyes, order Siluriformes; family Ictaluridae; genus *Ictalurus*; species *punctatus*. Figure 5-2 illustrates the classification structure for freshwater fishes found in Texas. The classification follows that of the American Fisheries Society (Nelson *et al*. 2004).

Figure 5-2
Freshwater Fish Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	**Chordata**	**Cephalaspidomorphi** (Lampreys)	**Petromyzontiformes**	**Petromyzontidae** (Lampreys)
		Actinopterygii (Ray-Finned Fishes)	**Acipenseriformes**	**Acipenseridae** (Sturgeons) **Polyodontidae** (Paddlefish)
			Lepisosteiformes	**Lepisosteidae** (Gars)
			Amiiformes	**Amiidae** (Bowfins)
			Hiodontiformes	**Hiodontidae** (Mooneyes)
			Anguilliformes	**Anguillidae** (Freshwater Eels)
			Clupeiformes	**Clupeidae** (Herrings)
			Cypriniformes	**Cyprinidae** (Carp & Minnows) **Catostomidae** (Suckers)
			Characiformes	**Characidae** (Characins)
			Siluriformes	**Ictaluridae** (N. American Catfish) **Loricariidae** (Suckermouth Armored Catfish)
			Esociformes	**Esocidae** (Pike)
			Salmoniformes	**Salmonidae** (Trout & Salmon)
			Percopsiformes	**Aphredoderidae** (Pirate Perch)
			Mugiliformes	**Mugilidae** (Mullet)
			Atheriniformes	**Atherinopsidae** (New World Silversides)
			Cyprinodontiformes	**Fundulidae** (Topminnows) **Poeciliidae** (Livebearers) **Cyprinodontidae** (Pupfish)
			Perciformes	**Moronidae** (Temperate Basses) **Centrarchidae** (Sunfish) **Percidae** (Perch) **Sciaenidae** (Drum & Croakers) **Elassomatidae** (Pygmy Sunfish) **Cichlidae** (Cichlid)

ORDER: Siluriformes
FAMILY: Ictaluridae
GENUS: ***Ictalurus***
SPECIES: ***punctatus***

Identifying Aquatic Organisms

Taxonomic Keys

The "keys" provided in this document are general and are meant to familiarize the user with different types of organisms living in the aquatic environment. If advanced identification is desired, then use a more traditional taxonomic key.

What is a Taxonomic Key?

A *taxonomic key* is used to simplify the identification of an unfamiliar organism. Most taxonomic keys are dichotomous keys. A *dichotomous key* uses successive choices of two pairs or *couplets* of contrasting characteristics. These contrasting characteristics help narrow the possibilities down to smaller and smaller groups.

Example of a Simple Dichotomous Key

Figure 5-3 illustrates a very simple dichotomous key. The numbers on the left side of the key, usually 1a and 1b, or 1 and 1′, are used to identify the members of each couplet. To the right of each pair there will be either a number or a name. The number means that additional characteristics are needed to make an identification. The number points to the next couplet needed. Many organisms share similar characteristics and it often takes a series of couplets to reveal more specific characteristics. The numbers in ( ) on the left side allow the user to keep track of past selections and to backtrack when necessary. Eventually an end point is reached, and a name will be listed on the right side of the key.

Guidelines for Using a Taxonomic Key

To use a taxonomic key, a certain amount of knowledge is necessary to correctly identify an organism. One must have some knowledge of the organism's basic anatomy and the associated anatomical terms. Most keys have helpful information that includes illustrations, a glossary, and other important life history information that aids in the identification process.

When using a taxonomic key, read the companion information that comes with the key. There are many keys available, so it is important to find a current version. In many cases, keys are available that are specific to certain areas of the U.S.

Read both choices in each successive couplet carefully and pick the closest, but be aware of natural variability. Some specimens may be incomplete or immature, and preserved specimens lose natural coloring. Finally, make sure to check both choices again if there is any doubt. Back-tracking is not uncommon and often necessary to verify the correct choices that were made.

Figure 5-3

A Simple Dichotomous Key

A Key to Things Found in a Desk Drawer			
Pair or couplet	1a	Non-metallic	2
	1b	Metallic	3
	2a (1a)	Contains rubber	rubber band
	2b	Contains no rubber	post-it notes
	3a (1b)	All metal and flat	4
	3b	All or partially metal and not flat	5
	4a (3a)	Disk-shaped and solid	quarter
	4b	Not disc shaped	paper clip
	5a (3b)	Sharp point at one end	tack 6
	5b	Both ends blunt	binder clip
	6a (5a)	Nonsharp end spherical in shape, may be plastic	map tack
	6b	Nonsharp end looks like a flat disk	thumb tack

Example key by M. Worthen, 2001.

CHAPTER

6 Freshwater Macroinvertebrates

This chapter includes general information on environmental adaptations, feeding habits, and other more detailed information on the most common aquatic insect families found in Texas.

Introduction

Freshwater macroinvertebrates are animals without backbones that live in or near the bottom of freshwater ponds, lakes, streams, and rivers for some or all of their life cycle. Freshwater macroinvertebrates inhabit all types of freshwater ecosystems. They are very important indicators of the health of streams and rivers reflecting water quality and habitat conditions.

Historically, water chemistry and physical parameters, such as DO, were used to determine the quality of a stream. However, these types of indicators provide only a "snapshot" of water quality in a stream, not a comprehensive view of conditions over time. Biological communities and in-stream habitat give better overall pictures of conditions in a stream by showing changes in physical and chemical parameters.

Freshwater insects shape a large part of the freshwater macroinvertebrate community, accounting for up to 90 percent of the bottom organisms in a stream. Non-insect benthic macroinvertebrates include crayfish, clams, snails, worms, and leeches.

Of the two million known insects, 80,000 species depend on the freshwater environment for all or part of their life cycle; approximately 5,000 freshwater species have been described in North America. In general, the majority of freshwater insects live in the aquatic environment during the immature stages of their lives and emerge as terrestrial adults. A few live their entire lives in water—for example, aquatic Hemipterans (true bugs) and aquatic Coleopterans (beetles).

Adaptations to the Aquatic Environment

Freshwater macroinvertebrates are generally grouped by two characteristics: how they feed and how they move within the aquatic environment. In addition, macroinvertebrates are also categorized by their tolerance to pollution.

General Environmental Adaptations

Freshwater macroinvertebrates, in order to adapt to the aquatic environment, have to be able to move or maintain their position in the water. The water penny (Coleoptera–Psephenidae) is an example of a *clinger*. It has a flattened body structure that allows it to remain close to a rock surface and avoid being swept away by the current. Water pennies are usually found in riffles, where water velocity and turbulence are high.

Burrowers and *sprawlers* are adapted to inhabit sediments comprised mainly of sand and silt. Burrowing mayflies (Ephemeroptera–Ephemeridae) have large, spade-shaped leg parts and tusk-like mouth parts to assist in digging. Sprawlers have adaptations for staying on top of the substrate, such as long legs. *Climbers*, as the name implies, are adapted for climbing plants or debris.

Table 6-1 summarizes the general environmental adaptations of aquatic insects. In some instances, more than one adaptation is listed for a certain family. This means that not every genus in this family has the same environmental adaptations.

Functional Feeding Groups

Freshwater macroinvertebrates are divided into various groups based on feeding habits, called *functional feeding groups*. The classification of a functional feeding group is based on food preference and how an organism eats. Table 6-2 summarizes general functional feeding groups. For example, predators feed by either eating prey whole or by piercing into their prey. Collectors feed on small bits of organic matter by either gathering deposits from the substrate or by filtering particles out of flowing water. In some instances there is more than one functional feeding group listed for a certain family. This means that not all genera in this family have the same food preferences.

Pollution Tolerance

Aquatic organisms are also put into categories based on their tolerance to pollution. Tolerance values range from 0 to 10 with 0 being least tolerant and 10 most tolerant. Like functional feeding groups and general adaptations, tolerance values apply to the family level and may vary depending on the genus. Tolerance values are assigned to organisms that are used as pollution indicators. In some instances there is more than one tolerance value listed for a certain family. See Chapter 3 for more information on the use of freshwater macroinvertebrates as indicators of pollution.

See the "Organisms Used as Indicators of Pollution" section in Chapter 3 for more information on the use of freshwater macroinvertebrates as indicators of pollution.

Table 6-1

General Environmental Adaptations of Freshwater Macroinvertebrates

Type	Description
Skaters (sk)	• Adapted for movement on the water's surface • Scavenge on organisms caught in the surface film
Planktonic (pl)	• Inhabit open water (limnetic zone) of lakes, ponds, bogs (lentic) • May float and swim in open water or float at the surface to get oxygen or food; can dive when alarmed
Divers (dv)	• Can swim by rowing with the hind legs in lentic habitats and lotic pools • Some come to surface to get oxygen; dive and swim when alarmed • Some cling to or crawl on submerged objects
Swimmers (sw)	• Adapted for fish-like swimming in lotic and lentic habitats • Cling to submerged objects–rocks (lotic riffles) and vegetation (lentic)–following short bursts of swimming
Clingers (cn)	• Construct shelters, have long tarsal claws and flattened bodies for attaching to surfaces in lotic riffles and wave-swept rocky littoral zones
Sprawlers (sp)	• Live on the surface of floating aquatic plants or fine sediments • Usually have modifications for staying on top of substrate and keeping respiratory surfaces free of silt
Climbers (cb)	• Live on overhanging branches, logs, roots, or aquatic macrophytes
Burrowers (bu)	• Inhabit fine sediments of streams (pools) and lakes

adapted from Merritt and Cummins 1995

Table 6-2

Functional Feeding Group Classification of Freshwater Macroinvertebrates

Functional Feeding Groups	Food Preference	Feeding Habits
Shredders (SHR)	Live aquatic plants, or dead and dying plants, such as leaves and wood, where fungus, bacteria, and algae (periphyton) are closely attached to the substrate	Chew, bore, or gouge plant material
Collector-gatherers (CG)	Small bits of decomposed organic matter, also known as fine particulate organic matter (FPOM)	Gather deposits from the bottom
Collector-filterers (CF)	Small bits of decomposed organic matter	Filter matter out of the water
Scrapers (SCR)	Periphyton–algae, diatoms, bacteria, and fungi attached to rocks and plants–also known as coarse particulate organic matter (CPOM)	Scrape food from rock, plant, and other hard surfaces
Piercers (PI)	Live aquatic plants	Pierce into the plants and suck fluids out
Predators (P)	Live animals	Engulf whole animals, or pierce into the animals and suck fluids out

adapted from Merritt and Cummins 1995

General Freshwater Macroinvertebrate Key

The general freshwater macroinvertebrate key that follows is made up of the most common freshwater orders. The main purpose of the key is to familiarize the reader with the different orders and their key characteristics.

The first part is a general insect key, which can be used to find the order in which an insect belongs. The second part lists the common families of each order and gives the key characteristics of that family.

References for this section include McCafferty 1983, Merritt and Cummins 1995, and Thorp and Covich 2001. Advanced taxonomic keys to freshwater macroinvertebrates are listed in Chapter 14.

Definitions of Scientific Terms

Aquatic organisms are identified by physical characteristics. The following is a list of definitions which will help explain the scientific terms used in identifying benthic macroinvertebrates.

Basic Terms

Basic terms are used to describe:

Orientation or location. Used to refer to the location of a body structure; front, back, top, or bottom.

General body divisions. Head, thorax, or abdomen.

Body structure. Gills, antenna, legs, claws, wings, or mouth parts. There may be additional terms used to further describe body structures. For example, mayflies are identified by the presence of gills. Specific families of mayflies are identified by the shape and location of their gills.

Orientation

anal. Refers to last abdominal segment, posterior end.

anterior. Near or toward the head.

basal. Base or point of attachment.

caudal. Posterior part of body or tail.

distal. Refers to a part farthest from the body.

dorsal. Refers to back or uppermost side.

lateral. Refers to sides (left or right).

posterior. Hind or rear end.

terminal. Forms located at the end of a structure.

ventral. Underside

General Body Divisions

abdomen. The posterior section of the body behind the thorax.

head. Bears the eyes, antennae, and mouth parts.

thorax. Body region behind the head that has the legs and wings, divided into three segments, (1) prothorax, (2) mesothorax, and (3) metathorax.

Body Structure

antennae. Long sensory appendage found on the head of insects and crustaceans. The singular is antenna.

anus. Posterior opening of the digestive system.

carapace. Hard dorsal covering in shellfish.

cerci. Pair of dorsal appendages at the posterior end of the abdomen. The singular is cercus.

chelate. Claw-like.

coxa. The segment of the leg at the point of attachment to the body.

compressed. Flattened from side to side or top to bottom.

epiproct. A short projection located just above the anus on the 10th segment in dragonflies–Odonata.

exoskeleton. A supporting structure found outside of the body; for example, the shell of a crayfish.

femur. Long leg segment, located between the trochanter and tibia.

lamellate. Thin, flat membrane.

labium. Lower lip or posterior mouth part.

labrum. Upper lip or anterior mouth part.

mandibles. Pair of hard (sclerotized) unsegmented jaws. Located between the labrum (upper lip) and maxillae (secondary jaw).

maxillae. Secondary jaws that are paired and segmented and used to aid in chewing and holding food. Located between the mandibles and labium (lower lip).

prementum. Part of labium (lip). When the labium is not in use, it lies against the ventral side of the head and thorax. The prementum—either broad, thin, or spoon shaped—conceals or partially conceals the lower face.

notum. Hard plate-like areas (sclerites) on the dorsal surface of a thoracic segment; each segment of the thorax has a notum, prothorax-pronotum, metathorax-metanotum and mesothorax-mesonotum. The plural is nota.

ocelli. Simple eye. The singular is ocellus.

paraprocts. A pair of projections located to the left and right of the anus (dragonflies–Odonata).

proleg. A fleshy leg on the abdomen of some insect larvae.

raptorial legs. Front legs modified for grabbing and holding prey.

sclerite. Hard plate-like areas, often bordered by sutures or a membranous area.

sclerotized. Hardened.

scutellum. A triangular sclerite between the pronotum and the wings

setae. Thin bristle-like projections.

sutures. Line-like grooves in the body wall.

spiracle. External opening for respiratory system.

sternum. A hard plate (sclerite) on the ventral or lower region of the thorax.

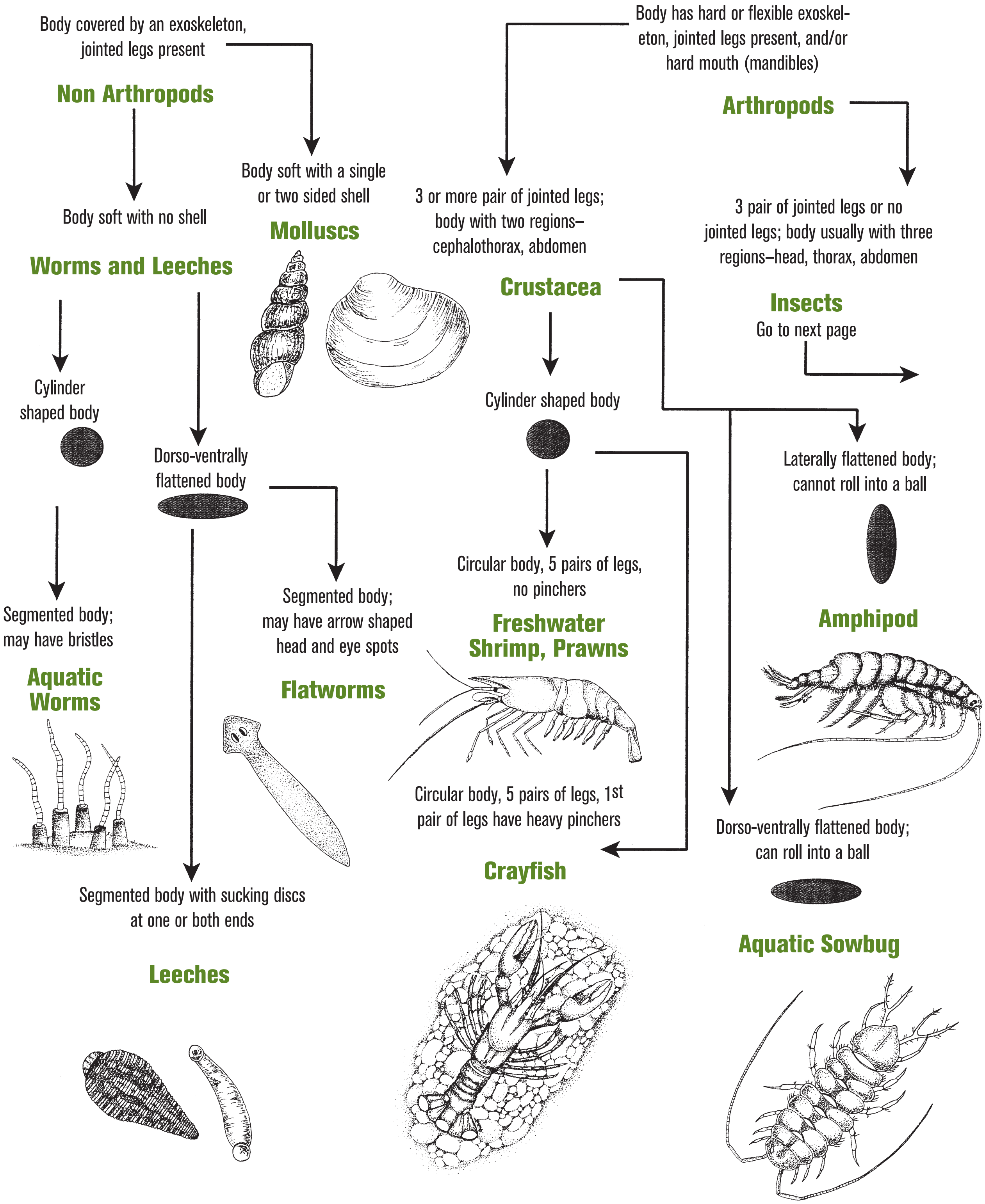
tarsus. The final leg segment next to the tibia, generally bears the claws.

tibia. Leg segment between the femur and tarsus.

trochanter. Small leg segment between the base segment (coxa) and the middle leg segment (femur).

wing pads. Developing external wings.

Key to Common Freshwater Macroinvertebrates

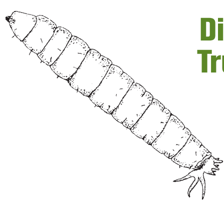


Key to Common Freshwater Macroinvertebrates (cont.)

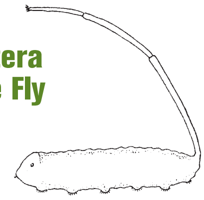
Aquatic Insect Orders

Thorax lacks jointed legs; may have prolegs

Head is indistinct, entirely or partly lacking

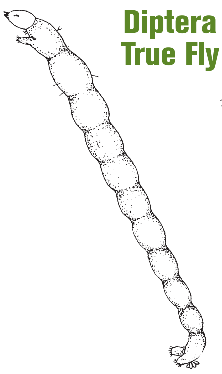


Diptera
True Fly

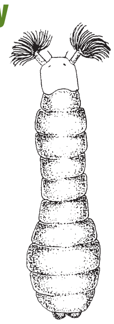


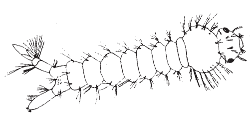
Head distinct and well developed

Prolegs are often present at the thorax, end of abdomen or both; obvious hairs and/or processes at the end of the abdomen



Diptera
True Fly





Thorax has 3 pairs of jointed legs

External wings or wing pads absent

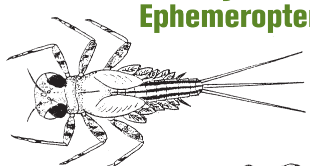
Go to next page

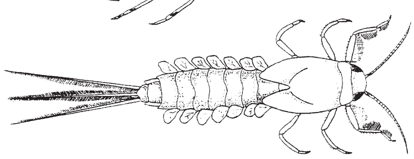
Wings or wing pads present

Abdomen ends 2 to 3 tails (caudal cerci)

Feet (tarsi) with <u>1 claw</u>; abdomen ends in 2 to 3 tails (caudal cerci); wing pads and lateral gills present; many abdominal segments may have lateral gills

Mayflies
Ephemeroptera

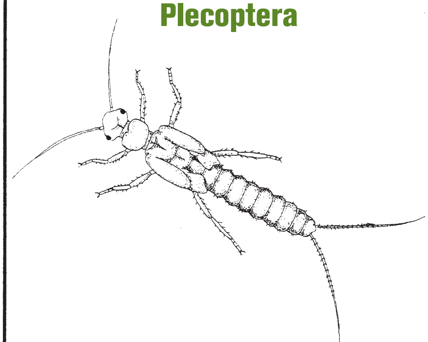




Abdomen ends in 1, 2, or no tails (caudal cerci)

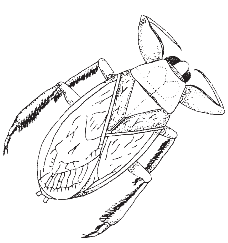
Feet (tarsi) with <u>2 claws</u>; abdomen ends in a 2 cerci; abdominal gills usually absent; if present filaments found on the first few abdominal segments

Stoneflies
Plecoptera



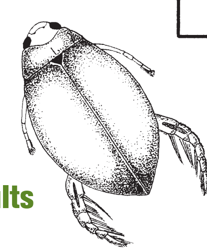
Mouth is beak shaped which projects beneath the head; adult has leathery wings

Hemiptera True Bugs



Thorax with hard wings creating platelike covering

Coleoptera
Aquatic Beetle Adults



Mouth is not beak shaped; mouth parts are for chewing or grasping prey

Go to next page

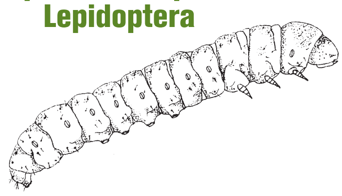
Key to Common Freshwater Macroinvertebrates (cont.)

Aquatic Insect Orders (cont.)

External wings or wing pads absent

→ Pairs of short, fleshy prolegs on the underside of the abdomen that end in a series of tiny hooks are <u>present</u>

Aquatic Caterpillar
Lepidoptera



↓ Pairs of short, fleshy prolegs on the underside of the abdomen that end in a series of tiny hooks are <u>absent</u>

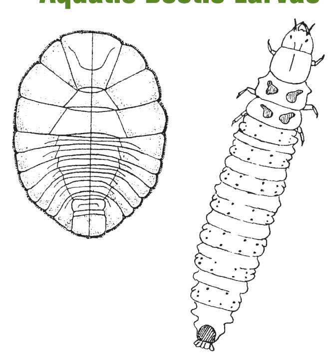
→ Thoracic segments often with developed hard exoskeleton, or fleshy; abdomen ends in a pair of anal prolegs (size varies) usually with a single hook at the end

Cadddisfly Larvae
Trichoptera

↓ Abdomen never ends in pair of prolegs with a single hook; if terminal hooks are present there will be 4

→ Abdomen lacks well-developed lateral filaments

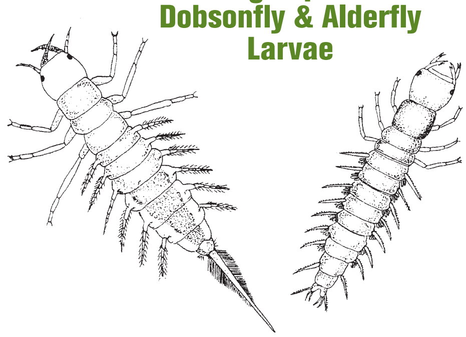
Coleoptera
Aquatic Beetle Larvae



↓ Abdomen has well defined lateral filaments

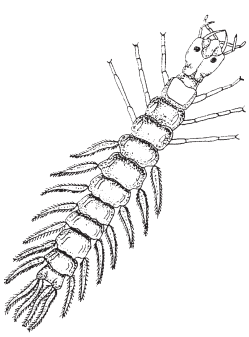
→ Abdomen ends in a single, unforked long filament or in a pair of prolegs, each with 2 hooks

Megaloptera
Dobsonfly & Alderfly
Larvae



↓ Abdomen usually does not end in a single, unforked, long filament and never with a pair of hooked prolegs; structures at the end of the abdomen vary

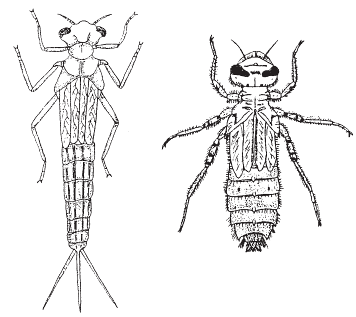
Coleoptera
Aquatic Beetle Larvae



Mouth is not beak shaped; mouth parts are for chewing or grasping prey

↓ Extendable lower lip (labium) present; may look like a large mask or lie flat under the head. At rest, the labium covers the mouth parts.

Damselfly & Dragonfly
Odonata



Common Texas Freshwater Macroinvertebrates

Freshwater Insects

Dobsonflies and Alderflies—Order Megaloptera

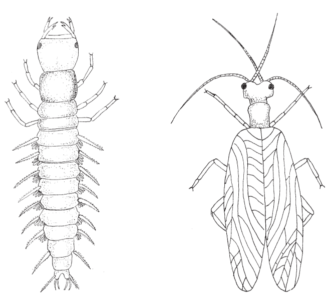
Dobsonflies–Family Corydalidae

▼ Larvae live under rocks in riffle areas and fast-moving water of streams (lotic)
▼ Intolerant of pollution and low oxygen
▼ Aggressive stream predators
▼ Common genus and species found in Texas—*Corydalus cornutus* and *Chauliodes*
▼ General feeding group(s)—predator
▼ General habitat(s)—clinger and climber
▼ Pollution tolerance—generally sensitive to moderately tolerant

Key characteristics:

▼ large mandibles
▼ a pair of hooked anal prolegs
▼ 8 pairs of lateral filaments
▼ no terminal filament

Figure 6-1



Adult

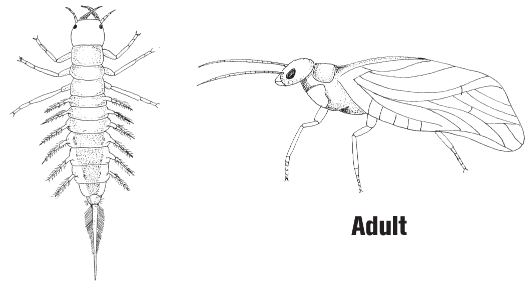
Alderflies–Family Sialidae

▼ Similar to the dobsonfly larvae but smaller; predators
▼ Live mostly in deposited sediments of streams (lotic), permanent ponds and lakes (lentic)
▼ Common genus found in Texas—*Sialis*
▼ General feeding group(s)—predator
▼ General habitat(s)—burrower, clinger
▼ Pollution tolerance—generally sensitive

Key characteristics:

▼ long, single tail filament (separates alderfly larvae from all other aquatic insects)
▼ 7 pairs of lateral filaments
▼ no hooked anal prolegs

Figure 6-2



Adult

Mayflies—Order Ephemeroptera

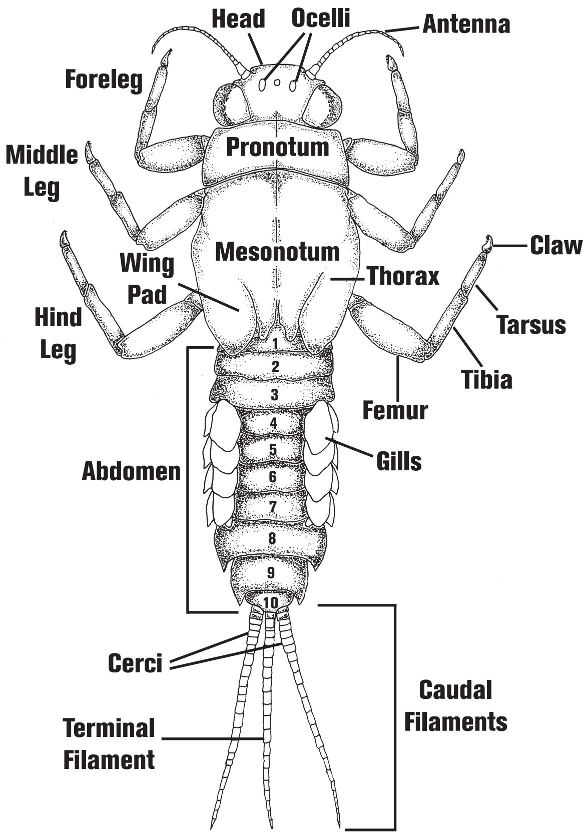
▼ Widespread and abundant in most regions; occur in a wide variety of habitats
▼ All larvae are aquatic; majority live in streams, a few live in ponds, and lakes
▼ Majority of life cycle is spent in the water
▼ Adults have no functional mouth parts and live less than 24 hours as an adult
▼ Important food source for fish in streams
▼ Wide range of DO requirements
▼ Very important in the biological monitoring of streams
▼ Most crawl on substrate, but many are good and fast swimmers
▼ Swim by moving abdomen and caudal filaments up and down
▼ Can adapt to less oxygen-rich environments and can increase water circulation by moving gills
▼ Most are herbivores (feed on plant material) or detritivores (feed on organic matter, leaf litter)

Pollution indicator role: Mayflies display a wide range of pollution tolerance, but are generally associated with good water quality. Mayflies are one of three key indicator organisms used in biological assessments. Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are used to calculate the *EPT Index*.

General characteristics:

▼ filamentous antennae
▼ 1 tarsal claw
▼ presence of lateral or ventrolateral gills on most of the first 7 segments
▼ majority have 3 caudal filaments (2 cerci and 1 median filament); only a few have 2 caudal filaments
▼ closely resemble stonefly larvae, which have only 2 cerci, lack gills on middle abdominal segments, and have 2 tarsal claws
▼ wing pads are present

Figure 6-3



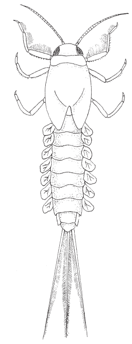
Family Baetidae

- ▼ Small but active swimmers
- ▼ Widespread; occur in variety of streams, permanent and temporary ponds, and littoral zones of lakes
- ▼ Common genera found in Texas—*Baetis*, *Baetodes*, *Callibaetis*, *Centroptilum*, *Cloeon*, *Camelobaetidius*, *Fallceon*, *Paracloeodes*, *Pseudocloeon*
- ▼ General feeding group(s)—collector-gatherer, scraper
- ▼ General habitat(s)—swimmer
- ▼ Pollution tolerance—generally sensitive to moderately tolerant

Key characteristics:

- ▼ torpedo shaped body
- ▼ lamellate abdominal gills
- ▼ long antennae (twice the length of the head)
- ▼ median caudal filament often shorter than the cerci

Figure 6-4



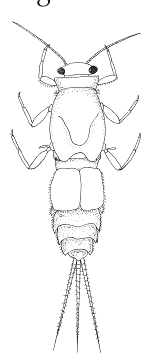
Family Caenidae

- ▼ Widespread and common in a variety of lentic and lotic habitats, in streams (all sizes), swamps, spring seeps, marshes, lakes, and ponds
- ▼ Often partially covered with silt because they frequent the sediment
- ▼ More tolerant of low DO levels than any other mayfly family
- ▼ Adults live only a few hours and mate shortly after emerging
- ▼ Common genera found in Texas—*Caenis*, *Brachycercus*
- ▼ General feeding group(s)—collector-gatherer, filter-collector
- ▼ General habitat(s)—sprawler
- ▼ Pollution tolerance—generally sensitive to moderately tolerant

Key characteristics:

- ▼ small in size
- ▼ easy to recognize by nearly square operculate gills
- ▼ gills have fringed margins

Figure 6-5



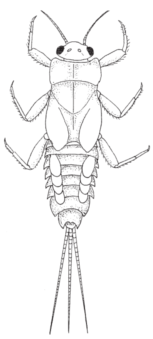
Family Ephemerellidae

- ▼ Common in United States
- ▼ Most species inhabit clean streams; often abundant in leaf litter, eddies, or near bank areas
- ▼ Some species can be found along wave-swept lake shores and organically enriched streams

▼ Most larvae are herbivores or detritivores; a few are omnivores and feed on small invertebrates
▼ Common genus found in Texas—*Eurylophella*
▼ General feeding group(s)—collector-gatherer, scraper
▼ General habitat(s)—clinger, sprawler, swimmer
▼ Pollution tolerance—generally sensitive

Key characteristics:
▼ gills absent on abdominal segment 2
▼ lamellate or operculate gills on segments 3 to 7 or 4 to 7

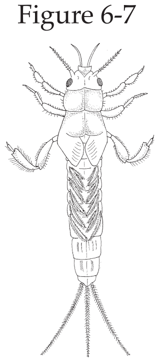
Figure 6-6



Family Ephemeridae
▼ Burrow into sand or eddies in riffle areas of small to medium-sized streams; inhabit silt bottoms of medium to large streams, as well as sand or silt bottoms of clean lakes
▼ Primarily filter feeders; circulate water through their burrows; also graze on algae and detritus from bottom
▼ Common genus found in Texas—*Hexagenia*
▼ General feeding group(s)—collector-gatherer, scraper
▼ General habitat(s)—burrower
▼ Pollution tolerance—moderately tolerant

Key characteristics:
▼ large body size
▼ filamentous gills extending upward over the back
▼ tusks curving upward and outward from the mouth

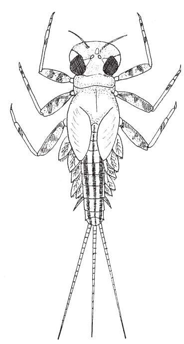
Figure 6-7



Family Heptageniidae
▼ Widespread and abundant in lotic habitats (streams); also found in wave-swept shorelines of lakes
▼ Inhabit rocks, wood, debris, and other materials where they can cling
▼ Common genera found in Texas—*Stenacron*, *Stenonema*
▼ General feeding group(s)—scraper, collector-gatherer
▼ General habitat(s)—clinger
▼ Pollution tolerance—generally sensitive to moderately tolerant

Key characteristics:
▼ body flattened top to bottom (dorsoventrally)
▼ eyes and antennae located dorsally (further back on head)
▼ may lack median caudal filament
▼ oval gills in a single plate, usually with tufts near the base

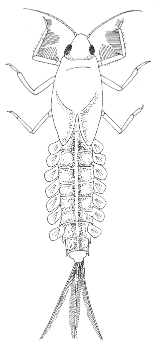
Figure 6-8



Family Isonychiidae
▼ Large in size and excellent swimmers
▼ Feed on algae and diatoms; use long hairs on forelegs to filter food out of water
▼ Found in riffles or sandy bottoms of streams
▼ Common genus and species found in Texas—*Isonychia sicca* (used to be in the family Oligoneuridae)
▼ General feeding group(s)—filter-collector
▼ General habitat(s)—swimmer, clinger
▼ Pollution tolerance—generally sensitive

Key characteristics:
▼ front legs have two rows of setae (long hairs)
▼ torpedo-shaped body
▼ rounded gills
▼ lower part of abdomen curves upward when not swimming
▼ outer caudal filaments fringed on both sides

Figure 6-9



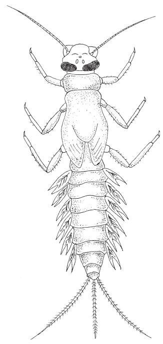
Family Leptophlebiidae

- ▼ Found in many stream habitats including cobble substrates, debris dams, and leaf packs
- ▼ Common genera found in Texas—*Leptophlebia*, *Choroterpes*, *Farrodes texanus*, *Paraleptophlebia*, *Thraulodes*, *Traverella*
- ▼ General feeding group(s)—collector-gatherer, scraper, filter-collector, shredder
- ▼ General habitat(s)—swimmer, clinger
- ▼ Pollution tolerance—sensitive

Key characteristics:

- ▼ Abdominal gills on segments 2 to 7 either forked with fringed margins

Figure 6-10



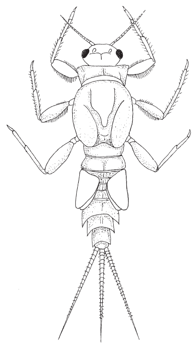
Family Tricorythidae

- ▼ Larvae are widespread
- ▼ Inhabit detritus, silt, and gravel in streams of all sizes
- ▼ Some species are resistant to low DO levels
- ▼ Common genera found in Texas—*Leptohyphes*, *Tricorythodes*
- ▼ General feeding group(s)—collector-gatherer
- ▼ General habitat(s)—clinger, sprawler
- ▼ Pollution tolerance—generally sensitive to moderately tolerant

Key characteristics:

- ▼ triangular or oval operculate gills on abdominal segment 2

Figure 6-11



Caddisflies—Order Trichoptera

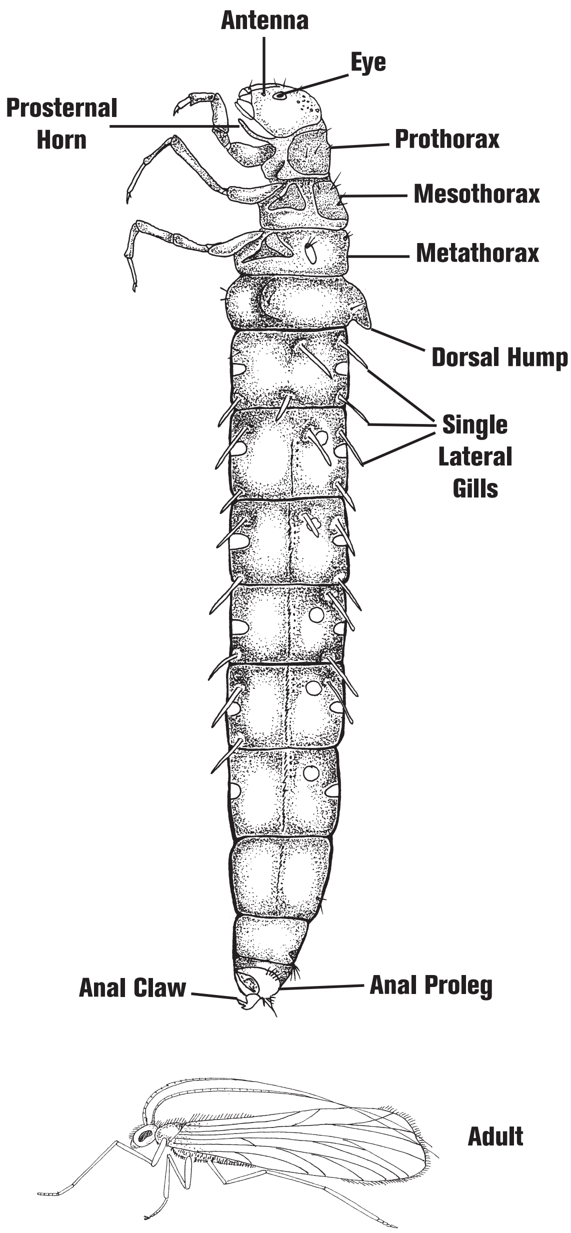
- ▼ All but a few are aquatic
- ▼ Most are found in streams and rivers, with a few inhabiting ponds and lakes
- ▼ Very important part of the stream community, sometimes dominating the insect community of a stream
- ▼ Important in biological monitoring of streams
- ▼ Important food source for fish
- ▼ Three major groups: (1) free-living (predators), (2) case-building (scrappers/shredders), and (3) net-spinning (algae, detritus, macroinvertebrates)
- ▼ Undergo complete metamorphosis (larvae, pupae, and adult), which allows them to spin silk used to build nets and cases
- ▼ Case materials are either organic (leaf, sticks, pine needles, or bark) or mineral (sand, fine gravel)

Pollution indicator role: Caddisflies display a wide range of pollution tolerance but are generally associated with good water quality. One of three key indicator organisms used in biological assessments: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are used to calculate the EPT Index.

General characteristics:

- ▼ 3 pairs of thoracic legs (near head)
- ▼ single tarsal claw
- ▼ abdominal gills
- ▼ head subdivided into 3 parts by Y-shaped lines
- ▼ short anal prolegs (no joint) at the end of the abdomen, with pointed anal claws
- ▼ no wing pads

Figure 6-12



Case-Building Caddisflies

FAMILY HELICOPSYCHIDAE

▼ Use sand grains to build small snail-like cases; very distinctive and the larvae never abandon the case

▼ Mainly lotic, but can be found along lake margins and sometimes in deep water; tolerate warm temperatures, found in thermal springs

▼ Widespread; inhabit rocks or wood

▼ Feed by scrapping periphyton off of substrate

▼ Common genus found in Texas—*Helicopsyche*

▼ General feeding group(s)—scraper

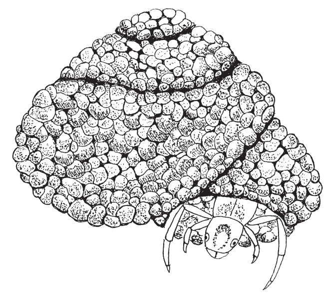
▼ General habitat(s)—clingers

▼ Pollution tolerance—sensitive

Key characteristics:

▼ never leave snail-like case; hard to remove

Figure 6-13



FAMILY LEPTOCERIDAE

▼ Larvae construct a wide variety of cases; some genera build long cases built with vegetation, vegetation and sand, or pure silk, and have fringes of long setae on the legs for swimming; other genera build shorter, stouter cases of plant or mineral materials and are unable to swim

▼ Found in a variety of permanent habitats: lotic (slow water) and lentic (littoral zone and far from shore)

▼ Common genera found in Texas—*Setodes*, *Triaenodes*, *Nectopsyche*, *Oecetis*

▼ General feeding group(s)—shredder, collector-gatherer, predator

▼ General habitat(s)—climber, sprawler, clinger, swimmer

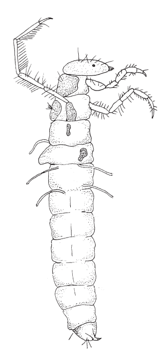
▼ Pollution tolerance—generally sensitive

Key characteristics:

▼ long antennae (much longer than other caddisflies)

▼ long metathoracic legs

Figure 6-14



Case-Building Microcaddisflies

FAMILY HYDROPTILIDAE

▼ Found in lotic (erosional) and lentic (littoral) environments

▼ Purse-shaped case made out of fine sand grains

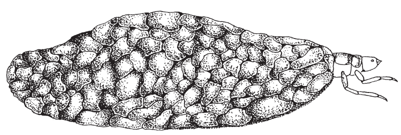
▼ Common genera found in Texas—*Hydroptila*, *Leucotrichia*, *Mayatrichia*, *Ochrotrichia*, *Oxyethira*, *Stactobiella*

- General feeding group(s)—scraper, collector-gatherer, piercer
- General habitat(s)—clinger, climber
- Pollution tolerance—sensitive to moderately tolerant

Key characteristics:

- lack branched ventral gills
- very small larvae
- completely sclerotized thoracic nota

Figure 6-15



Net Spinning Caddisflies

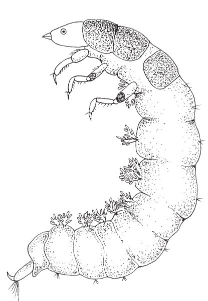
Family Hydropsychidae

- Important caddisfly family; frequently represent a large portion of the stream macroinvertebrate community in streams of all sizes, temperatures, and currents
- Most are omnivores, feeding on algae, crustaceans, and insects captured in their nets
- Widespread, abundant; tolerance to organic pollution varies by species; very important in the biological monitoring of streams
- Build net retreats on rocks, logs, and other substrate
- Common genera found in Texas—*Cheumatopsyche*, *Diplectrona*, *Hydropsyche*, *Smicridea*, *Macronema*, *Macrostemum*, *Potamyia*
- General feeding group(s)—filter-collector
- General habitat(s)—clinger
- Pollution tolerance—sensitive to moderately tolerant

Key characteristics:

- larvae are very large
- numerous, branched filamentous gills on ventral side of abdomen

Figure 6-16



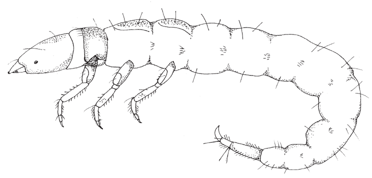
Family Polycentropodidae

- Majority found in streams, but also inhabit littoral areas of lakes and temporary ponds
- A few species are herbivores and build trumpet-shaped capture nets; most species are predators with tubular-shaped retreats
- Tubular retreats aid in respiration; larvae circulate water through them by moving their body; important in habitats that are occasionally oxygen deficient
- Common genera found in Texas—*Cernotina*, *Neureclipsis*, *Nyctiophylax*, *Phylocentropus*, *Polycentropus*, *Polplectropus*
- General feeding group(s)—filter-collector, predator
- General habitat(s)—clinger
- Pollution tolerance—sensitive to moderately tolerant

Key characteristics:

- unmodified tarsi (legs)
- presence of dark or light spots (muscle scars) on head

Figure 6-17



Damselflies and Dragonflies—Order Odonata

- All larvae aquatic
- Tolerate some pollution
- Often top predators in the invertebrate community
- Prey on other insects and small minnow-size fish
- Adults also predators; highly beneficial insects
- Two-thirds live in ponds and lakes, and one-third in streams; mosquitoes make up a large part of the diet for adult and nymph stages
- Pollution tolerance—moderately tolerant although variable (some species less tolerant than others), generally indicators of water with lower DO levels

General characteristics:

- easily distinguished from all other aquatic insects
- large body size

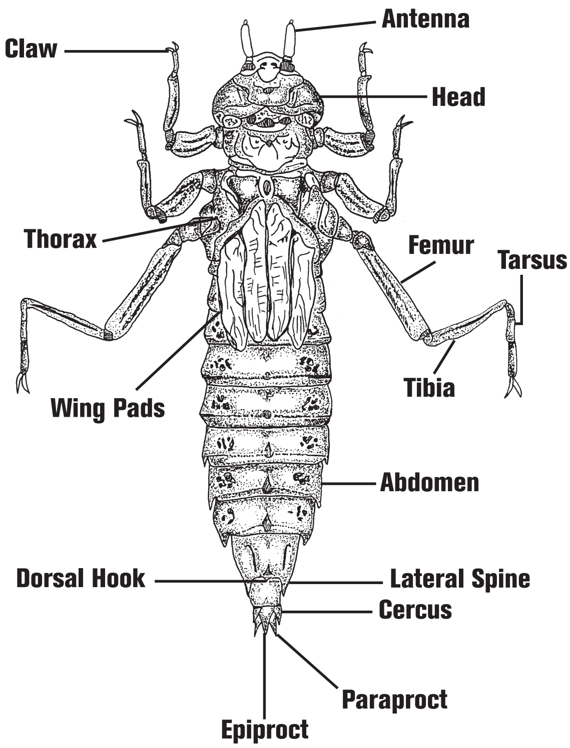
- ▼ elongate, hinged lower lip (labium) modified for seizing prey
- ▼ wing pads

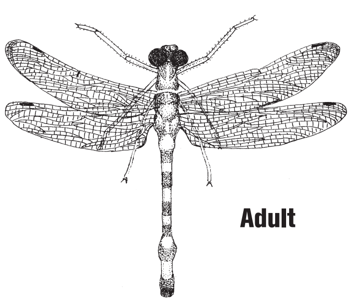
Dragonflies–Suborder Anisoptera

General characteristics:

- ▼ abdomen relatively broad and terminates in three triangular-shaped cerci
- ▼ some move by rapidly expelling water through rectal chamber (burrowers)
- ▼ most are burrowers and clingers
- ▼ lower lip (labium) forms spoon-shaped mask fitting over the lower part of the head and mouth parts; others have a flat labium

Figure 6-18





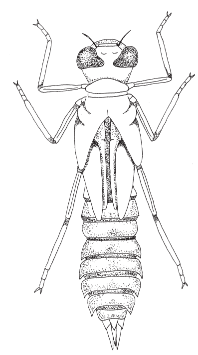
Family Aeshnidae

- ▼ Climb actively in vegetation of shallow waters; cling to and move around on vegetation to stalk prey
- ▼ Voracious predators; feed on invertebrates and small vertebrates (minnows)
- ▼ Most are found in lentic (standing water) habitats like weedy permanent marshes, ponds, and littoral areas (shallow water of lakes)
- ▼ A few species found in pool areas of streams
- ▼ Common genera found in Texas—*Aeshna, Basiaeschna, Boyeria, Epiaeschna*
- ▼ General feeding group(s)—predator
- ▼ General habitat(s)—climber
- ▼ Pollution tolerance—generally sensitive

Key characteristics:

- ▼ nymphs have large body size
- ▼ flat prementum
- ▼ antennae slender, bristle like, with 6 to 7 segments
- ▼ body cylindrical with long tapered abdomen
- ▼ head slightly flattened
- ▼ abdomen has lateral spines on segments 8 and 9, (and/or sometimes on segments 5 to 7)

Figure 6-19



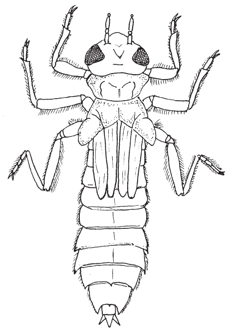
Family Gomphidae

- ▼ Nymphs inhabit streams and riffles and often burrow into silt or sand in slower-moving water; some may inhabit small permanent ponds and littoral areas of lakes
- ▼ Common genera found in Texas—*Dromogomphus*, *Erpetogomphus*, *Gomphus*, *Hagenius*, *Ophiogomphus*, *Phyllogomphoides*, *Progomphus*
- ▼ General feeding group(s)—predator
- ▼ General habitat(s)—burrower
- ▼ Pollution tolerance—sensitive to moderately tolerant

Key characteristics:

- ▼ flat prementum
- ▼ nymphs are shorter and broader than Aeshnidae
- ▼ antenna has 4 segments; short and thick
- ▼ front of head flat and wedge shaped

Figure 6-20



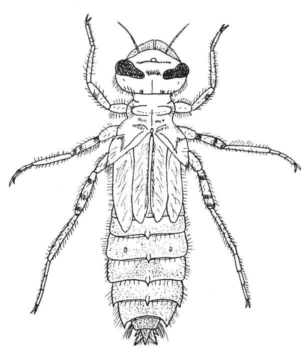
Family Libelluidae

▼ Sprawl on bottom, but some crawl on debris and vegetation
▼ Inhabit slow-moving waters of streams and vegetated zones of ponds and lakes
▼ Common genera found in Texas—*Brechmorhoga, Erythemis*, *Erythrodiplax*, *Libellula, Orthemis, Perithemis*
▼ General feeding group(s)—predator
▼ General habitat(s)—sprawler
▼ Pollution tolerance—tolerant

Key characteristics:

▼ prementum spoon shaped (fits over face like a mask)
▼ large body; narrower than Macromiidae
▼ frontal horn on head *absent* (between antennae)
▼ looks hairy

Figure 6-21



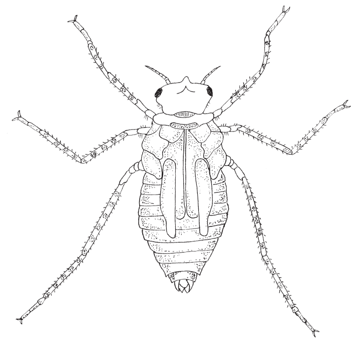
Family Corduliidae

▼ Found with debris in currents of medium to large streams or lake margins exposed to wave action
▼ Sedentary, often covered with silt
▼ Common genus found in Texas—*Macromia*
▼ General feeding group(s)—predator
▼ General habitat(s)—sprawler
▼ Pollution tolerance—sensitive

Key characteristics:

▼ prementum spoon shaped
▼ frontal horn on head
▼ abdomen flat, broad
▼ long, sprawling legs

Figure 6-22

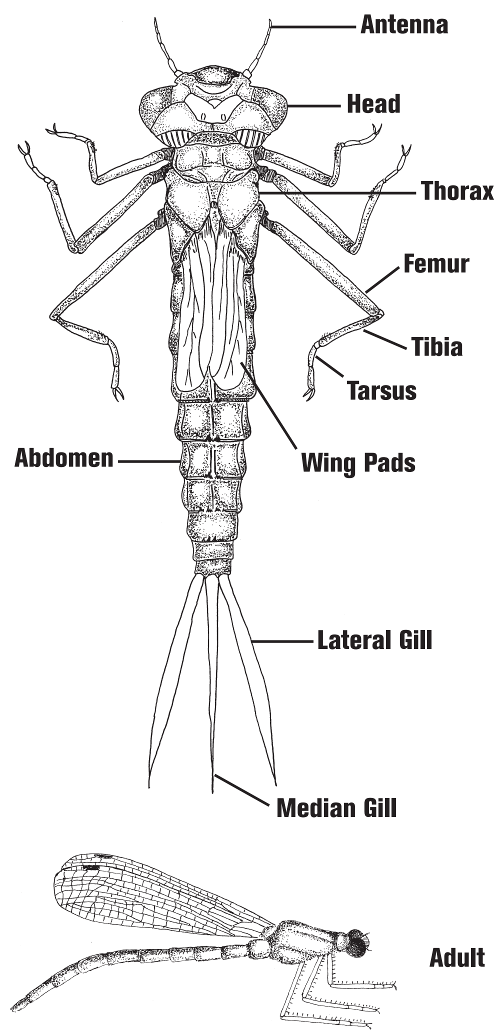


Damselflies–Suborder Zygoptera

Key characteristics:

▼ abdomen long and thin, ending in 3 long vertically oriented external gills (caudal lamellae: flattened leaf-like structures at posterior end)
▼ swim by moving abdomen from side to side
▼ most cling to plants and other objects
▼ lower lip (labium) longer and narrower than the dragonfly's

Figure 6-23



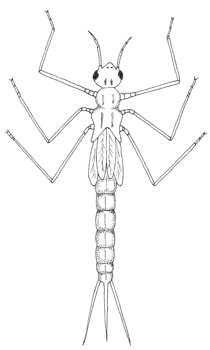
Family Calopterygidae

- ▼ All species are lotic, living in running water habitats (in streams of all sizes); found among bank vegetation and accumulating debris
- ▼ Common genera found in Texas—*Calopteryx*, *Hetaerina*
- ▼ General feeding group(s)—predator, scraper
- ▼ General habitat(s)—climber
- ▼ Pollution tolerance—moderately tolerant to tolerant

Key characteristics:

- ▼ large body
- ▼ very long first antennal segment

Figure 6-24



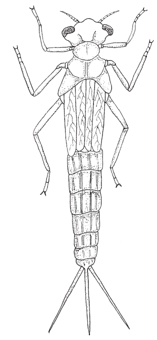
Family Coenagrionidae

- ▼ Mainly found in lentic (standing-water) habitats; in permanent ponds, marshes, swamps and littoral (shallow-water) areas of lakes; sometimes in stream vegetation in areas of little or no current
- ▼ A few species inhabit riffle areas of streams and along stream banks
- ▼ Climb on vegetation where they stalk prey; feed on small invertebrates
- ▼ Common genera found in Texas—*Argia*, *Chromagrion*, *Enallagma*, *Ischnura*
- ▼ General feeding group(s)—predator
- ▼ General habitat(s)—climber
- ▼ Pollution tolerance—moderately tolerant

Key characteristics:

- ▼ small size
- ▼ antenna segments equal
- ▼ base of prementum *not* greatly narrowed

Figure 6-25



Stoneflies—Order Plecoptera

- ▼ Intolerant to pollution
- ▼ Important food source for fish and invertebrate predators
- ▼ Important in biological monitoring of streams
- ▼ All but a few live in streams
- ▼ Need oxygen-rich environment due to the lack of extensive gills
- ▼ Some nymphs are plant feeders, others are predators
- ▼ Most are adapted to cool temperatures of clear mountain streams, but a few species are found in Texas
- ▼ Found under rocks, in debris, and in thick mats of algae
- ▼ Common families and genera found in Texas—Capniidae, *Allocapnia*; Leuctridae, *Zealeuctra*; Perlidae, *Perlesta*, *Perlinella*; Perlodidae, *Isoperla*; Taeniopterygidae, *Taeniopteryx*
- ▼ General feeding group(s)—predator, shredder, collector-gatherer, scraper
- ▼ General habitat(s)—clinger, sprawler

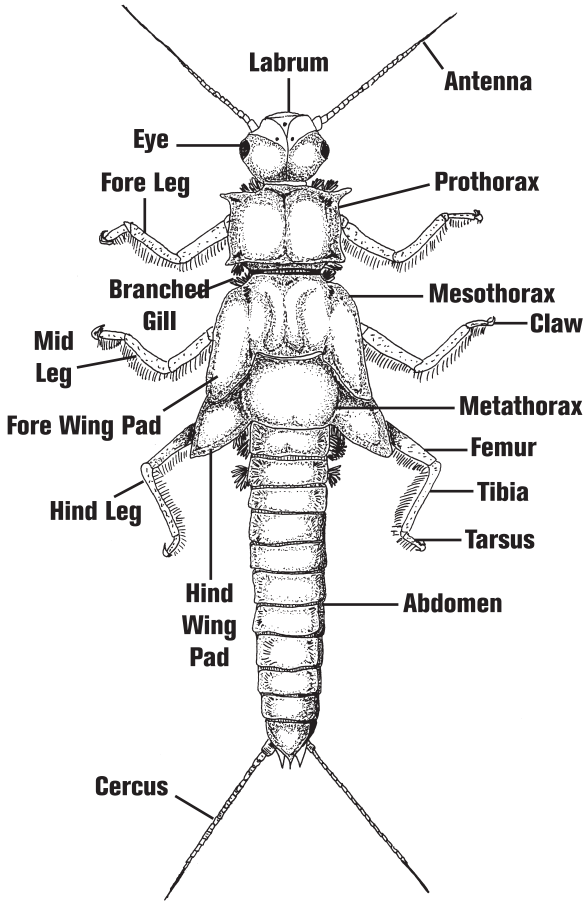
Pollution indicator role: Stoneflies are associated with good water quality and a good supply of oxygen, and are generally considered sensitive to pollution. One of three key indicator organisms used in biological assessments: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are used to calculate the *EPT Index*.

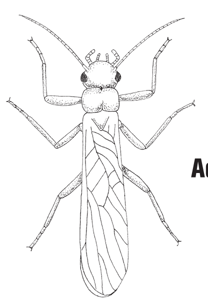
General characteristics:

- ▼ long antennae
- ▼ 2 claws on each tarsus
- ▼ gills, if present, on head, thorax, or basal segments of the abdomen

▼ 2 long caudal filaments (cerci)
▼ wing pads

Figure 6-26





True Flies—Order Diptera

▼ Larvae are legless (prolegs may be present) and worm-like
▼ Often lack a well-developed head
▼ Commonly called maggots
▼ Found in all freshwater environments; in a variety of other habitats (soil, decaying materials, and animal and plant tissue)
▼ Can be very tolerant of poor water quality and low-oxygen (anoxic) conditions (rat-tail maggot)
▼ Adults have 1 pair of wings
▼ 18 to 22 aquatic families

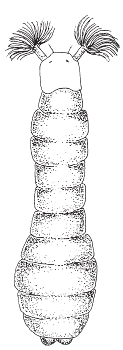
Black Flies—Family Simulidae

▼ Common and widespread
▼ Inhabit a wide variety of lotic (running water) habitats
▼ Often abundant on rocks, submerged wood, or vegetation in fast- to slow-moving currents
▼ Adults are small in size; female adults have a painful bite and are considered serious pests in some parts of the country; blood meal is needed to mature eggs
▼ Common genera found in Texas—*Cnephia*, *Prosimulium*, *Simulium*
▼ General feeding group(s)—filter-collector
▼ General habitat(s)—clinger
▼ Pollution tolerance—moderately tolerant to tolerant, usually found in swift-moving streams, but can also indicate elevated nutrients (nitrogen and/or phosphorus) in the water

Key characteristics:

▼ uniquely shaped: swollen abdomen that is attached to rocks and other debris by a caudal (posterior end) sucker
▼ relatively large head
▼ single ventral proleg on the thorax

Figure 6-27



Craneflies—Family Tipulidae

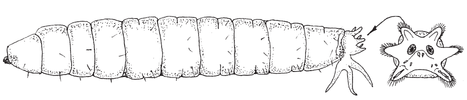
▼ Adults have a large mosquito-like body with long legs; sometimes referred to as mosquito hawks
▼ Aquatic larvae are widespread and abundant
▼ Adult craneflies do not bite; they are harmless
▼ Larvae live in water or moist soil
▼ Most aquatic species found in lotic (running-water) habitats; a few found in shallow, lentic (standing-water) habitats
▼ Feeding habits vary; all feeding groups are included—omnivores, herbivores, carnivores, and detritivores; most feed on plants and plant debris, some are predators
▼ Common genera found in Texas—*Antocha*, *Erioptera*, *Helius*, *Hexatoma*, *Limnophila*, *Lipsothrix*, *Psuedolimnophila*, *Tipula*

- General feeding group(s)—shredder, collector-gatherer
- General habitat(s)—burrower
- Pollution tolerance—moderately tolerant, indicating moderately clean water; rare in polluted water

Key characteristics:

- head capsule has a partial hard covering and is retracted into the thorax
- size is large, 10 to 25 mm long
- easily recognized by lobes on the posterior end, which stretch out to form a terminal disk that has 2 conspicuous eye-like spiracles
- spiracles are characteristic of a species
- caudal spiracles (external opening for breathing system) are used to get oxygen from the surface; in well-oxygenated streams most oxygen is obtained through the cuticle (outer covering)
- Body is worm-like and thick skinned
- Colors range from brownish-green to somewhat transparent white

Figure 6-28



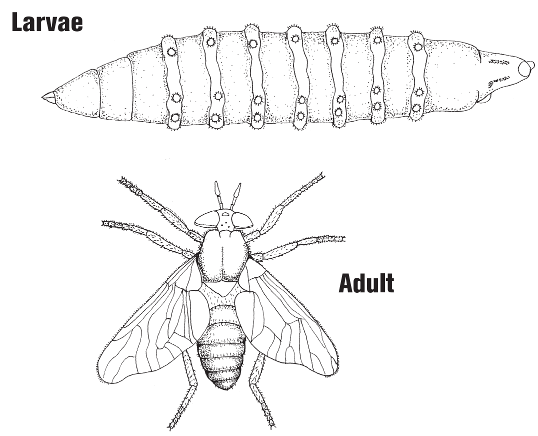
Deerflies or Horseflies–Family Tabanidae

- Most larvae develop in semiaquatic habitats that may be closely associated with aquatic habitats; some species are entirely aquatic
- Aquatic larvae are found in stream riffles, shallow stream margins, and shallow vegetated habitats
- Larvae are predators feeding on other aquatic macroinvertebrates
- Most adult females feed on the blood of humans, livestock, and other animals; bites are painful
- Common genera found in Texas—*Chlorotabanus*, *Chrysops*, *Tabanus*
- General feeding group(s)— predator, collector-gatherer
- General habitat(s)—sprawler, burrower
- Pollution tolerance—moderately tolerant

Key characteristics:

- distinct prolegs absent
- girdle of six or more pseudopods (false feet) on most abdominal segments
- 10 to 25 mm long

Figure 6-29



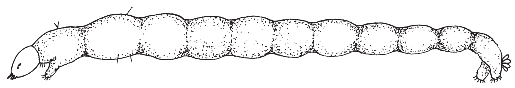
Midges–Family Chironomidae

- The largest family of aquatic insects; 30,000 species
- Inhabit all types of temporary and permanent aquatic habitats
- Larvae are dominant in the profundal (bottom) and sublittoral (area between littoral and profundal) zones
- Larvae are extremely important part of aquatic food chain; eaten by other insects and fish
- Many species are free living (predators); most species build cases made of bottom (substrate) material cemented together with saliva
- Herbivores and detritivores feed on fine bottom particles; some are filter feeders that build cases to collect food
- Tolerant species are usually red and called bloodworms; they contain a hemoglobin-like pigment that holds oxygen
- Bloodworms are often abundant in sewage lagoons or organically polluted areas of lakes and streams
- Adults do not feed, and live no more than two weeks; seen in swarms over water and by light at night
- Look like small pale mosquitoes, but do not bite
- Common genera found in Texas—61 common genera; difficult to identify to genus and species; most identify to the family level only
- General feeding group(s)—collector-gatherer, filter-collector, predator
- General habitat(s)—burrower
- Pollution tolerance—tolerant, indicators of poor water quality; extremely tolerant of low oxygen

Key characteristics:

- pairs of anterior and posterior prolegs
- sizes vary from 2 to 30 mm long
- narrow bodies

Figure 6-30



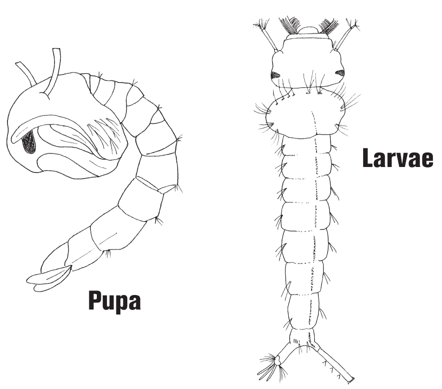
Mosquitoes–Family Culicidae

- Common and widespread
- Serve as transporters of serious diseases: yellow fever, encephalitis, and malaria
- All larvae are aquatic; pupae are generally aquatic
- Occur in a variety of places, such as pools, ponds, lakes, swamps, or any object or container holding water; not found in areas with current or wave action
- Larvae feed on organic debris and microorganisms
- Only a few larvae genera are predators, mostly on other mosquitoes
- Male adults feed on nectar from plants; females, on blood from mammals, birds, reptiles, or amphibians
- Depending on the species females may live several weeks or months
- Larvae breathe at the surface
- Common genera found in Texas—*Culex*, *Anopheles*
- General feeding group(s)—filter-collector, collector-gatherer
- General habitat(s)—swimmer, planktonic
- Pollution tolerance—tolerant; indicator of poor water quality and low DO

Key characteristics:

- *Culex* mosquito has a breathing tube at the posterior end; seen hanging from the water surface
- *Anopheles* mosquito lacks a breathing tube and spends most of the time floating at the surface
- have a flip-flop swimming motion; very active swimmers
- pupae have a large head and thorax
- 3 to 15 mm long

Figure 6-31



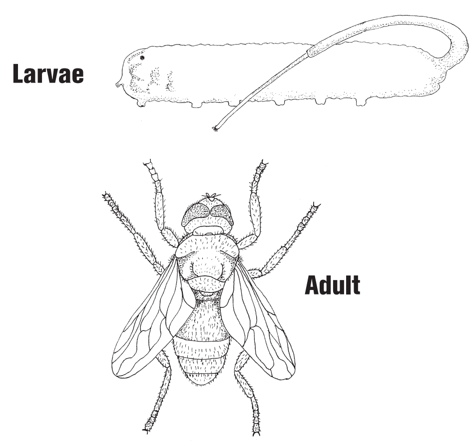
Rat-tail Maggots–Family Syrphidae

- Inhabit shallow lentic (standing-water) habitats, margins of lotic (running-water) habitats, and sewage lagoons; common in areas with large amounts of decomposing organic matter and sludge
- Very tolerant of pollution, low DO, and poor water quality; use breathing tube to get oxygen from the air
- Feed on detritus and microorganisms
- General feeding group(s)—collector-gatherer
- General habitat(s)—burrower
- Pollution tolerance—tolerant, indicator of poor water quality and low DO

Key characteristics:

- large body
- broad and blunt shape
- a very long segmented extendible breathing tube (siphon); can be extended 3 to 4 times the body length
- ventral (underside) prolegs

Figure 6-32



True Bugs—Order Hemiptera

- Adults and immature stages are aquatic
- Modified mouth parts form a beak with piercing sucking mouth parts
- Anterior (front) portion of first wing hard and leathery; posterior (back) portion membranous
- Some aquatic adults can fly, but not well

Backswimmers–Family Notonectidae

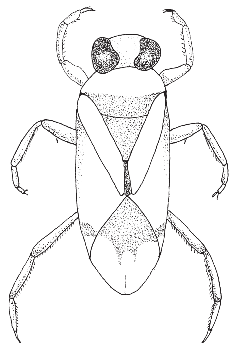
- Most species breed in littoral areas of lakes and permanent ponds; some breed in stream pools
- Resemble water boatman (Corixidae)
- Swim ventral (bottom) side up, but orient themselves dorsal (back) side up when not in the water

- Feed on other aquatic insects, sometimes small vertebrates
- Bite if mishandled; not painful
- Common genus found in Texas—*Notonecta*
- General feeding group(s)—predator
- General habitat(s)—swimmer

Key characteristics:

- elongate segmented rostrum (beak)
- deep bodied and not flattened
- front legs not scoop shaped
- back legs long with fringe-like hairs

Figure 6-33



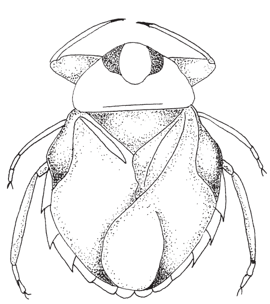
Creeping Waterbugs–Family Naucoridae

- Common in the southern U.S.; rarely as far north as Canada
- Usually associated with lotic habitats, living in streams, spring ponds, or impoundments
- Fully developed wings, but rarely fly
- Live in well-oxygenated water
- Feed on a variety of aquatic organisms
- Common genera found in Texas—*Ambrysus*, *Cryphocricos*, *Limnocoris*, *Pelocoris*
- General feeding group(s)—predator
- General habitat(s)—clingers, swimmer

Key characteristics:

- dorsoventrally (top to bottom) flattened
- rounded appearance when viewed from above
- front femur thickened
- margins of head, eyes, and pronotum continuous

Figure 6-34



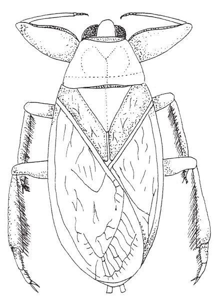
Giant Water Bugs–Family Belostomatidae

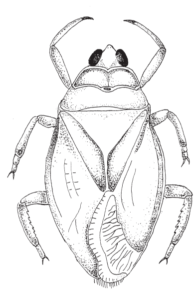
- Large size
- Powerful predators; capture and kill anything they can handle, including fish, frogs, tadpoles, and other insects; important invertebrate predator
- Inhabit permanent lentic (standing water) habitats: margins of ponds, lakes, and marshes, especially weedy areas
- Can fly and are attracted by lights
- Also known as toe biters, can inflict a painful bite
- Lay large masses of eggs on vegetation above the water surface or carry eggs on the backs of males
- Common genera found in Texas—*Abedus*, *Belostoma*, *Lethocerus*
- General feeding group(s)—predator
- General habitat(s)—climber, swimmer
- Pollution tolerance—tolerant

Key characteristics:

- large body, oval and flattened
- raptorial front legs for grasping prey
- a pair of short, strap-like posterior respiratory appendages (retractable)
- obvious beak-like mouth

Figure 6-35





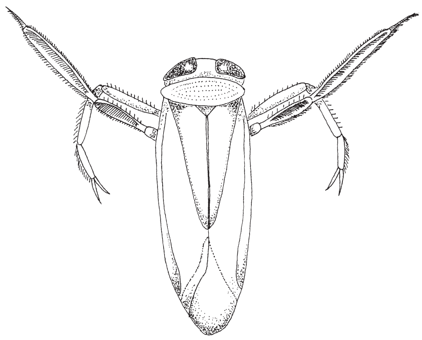
Water Boatmen–Family Corixidae

- Abundant; common insects in ponds
- Some occur in streams or brackish pools along seashore above high tide line
- Erratic but fast swimmers
- Spend most of time clinging to submerged vegetation
- Do not bite
- Feed on algae and other minute organisms
- Common genera found in Texas—*Trichocorixa*
- General feeding group(s)—predator, piercer
- General habitat(s)—swimmer

Key characteristics:

- ▼ body elongate and oval shaped
- ▼ back legs elongate and serve as oars
- ▼ front legs short, single-segmented tarsi, and scoop shaped
- ▼ dorsal surface of body is flattened

Figure 6-36



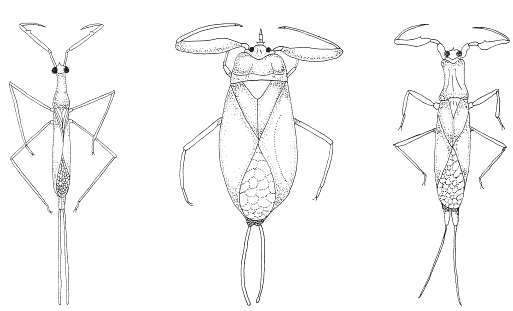
Water Scorpions—Family Nepidae

- ▼ Common in ponds
- ▼ Predators; feed on other insects
- ▼ Poor swimmers; usually cling to vegetation or other objects in the water
- ▼ Breed in permanent lentic (standing water) habitats, especially shallow areas with a lot of vegetation
- ▼ Can bite if handled carelessly
- ▼ Resemble terrestrial walking sticks
- ▼ General feeding group(s)—predator
- ▼ General habitat(s)—climber
- ▼ Pollution tolerance—moderately tolerant

Key characteristics:

- ▼ long, slender body (*Ranatra*); long oval shape (*Nepa*); narrow and short (*Curicta*)
- ▼ long, slender legs
- ▼ raptorial front legs (used to hold prey)
- ▼ pair of long, slender abdominal appendages that form a nonretractable breathing tube
- ▼ mouth beak-shaped

Figure 6-37



Ranatra **Nepa** **Curicta**

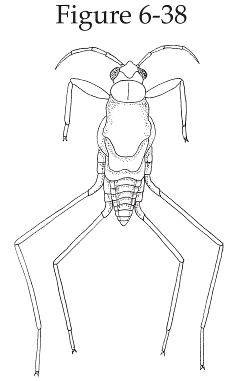
Water Striders—Family Gerridae

- ▼ Semiaquatic; live on surface of water
- ▼ Seen moving on the water surface, often in large groups
- ▼ Feed on small insects that fall on water surface or aquatic insects living just beneath the surface
- ▼ Found in a variety of aquatic habitats; areas with little wave action or current are preferred
- ▼ Lotic species inhabit streams of all sizes
- ▼ Lentic species inhabit swamps, marshes, permanent and temporary ponds, shoreline areas, and the ocean
- ▼ Lotic species can be found in lentic areas and vice versa
- ▼ Most species are commonly associated with emergent vegetation
- ▼ Common genera found in Texas—*Rheumatobates*, *Trepobates*
- ▼ General feeding group(s)—predator
- ▼ General habitat(s)—skater

Key characteristics:

- ▼ body long and slender
- ▼ front legs are short
- ▼ middle and back legs are long and slender
- ▼ joint of the back legs extends beyond the tip of a short abdomen

Figure 6-38



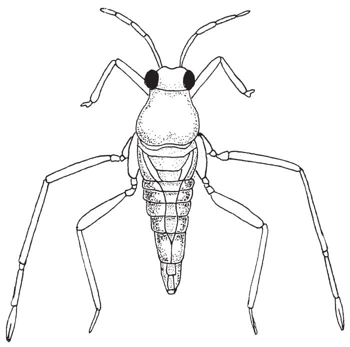
Broad-Shouldered or Short-legged Water Striders—Family Veliidae

- ▼ Abundant in a wide variety of aquatic habitats: streams near riffles or under cut banks, swamps, ponds, marshes, or margins of lakes
- ▼ Common genera found in Texas—*Microvelia*, *Rhagovelia*
- ▼ General feeding group(s)—predator
- ▼ General habitat(s)—skater

Key characteristics:

- ▼ smaller, and with shorter legs, than Gerridae
- ▼ joints of the back legs *do not* extend beyond the abdomen

Figure 6-39



Beetles—Order Coleoptera

- Largest insect order, with 3 percent having an aquatic stage; represent a significant portion of the aquatic insect community
- 1,100 aquatic species with 18 families in North America
- Both larvae and adults may be aquatic in some species
- Adults range in size from 1 to 40 mm long
- No piercing and sucking mouth parts; chewing mouth parts are present
- Entire forewing is hardened and shell-like in adults
- Larvae have no distinguishing characteristics; vary greatly in size and general morphology

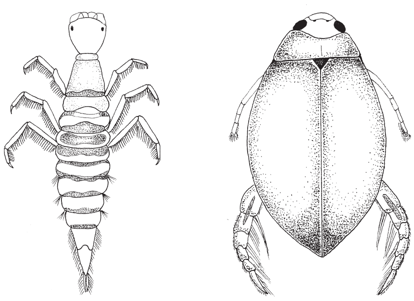
Predaceous Diving Beetles—Family Dytiscidae

- Larvae and adults both aquatic and predators
- Largest family of water beetle
- Adults range in size from 2 to 40 mm long
- Most species are lentic in all types of temporary and permanent habitats but prefer shallow vegetated areas of swamps, marshes, bogs, and ponds
- Most abundant in areas that lack insectivorous fish
- Adults can fly
- Common genera found in Texas—*Agabus*, *Bidessonotus*, *Brachyvatus*, *Hydaticus*, *Hydroporus*, *Hydrovatus*, *Liodessus*, *Oreodytes*
- General feeding group(s)—predator
- General habitat(s)—diver, swimmer
- Pollution tolerance—moderately tolerant

Key characteristics:

- oval, convex body shape
- hind legs flattened with fringe-like hairs
- brown or black color
- antennae threadlike
- distinct scutellum (triangular patch behind pronotum which is the section between head and thorax)
- head narrower than posterior portion

Figure 6-40



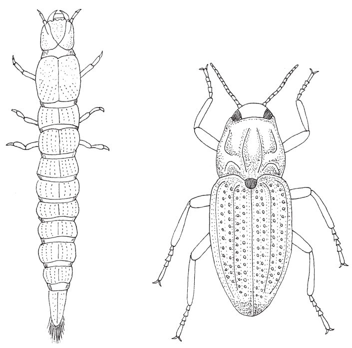
Riffle Beetles—Family Elmidae

- Larvae and adults are aquatic herbivore-detritivores, feeding on algae, decaying wood, and detritus
- Pupae are terrestrial; adults will fly to a suitable habitat, but rarely fly again
- Live in oxygen-rich water
- Found on stones, logs, and other debris in the swiftest-moving water of a stream or on a wave-swept shore
- Widespread and abundant
- Adults less than 4.5 mm long
- Common genera found in Texas—*Ancyronyx*, *Dubiraphia*, *Macrelmis*, *Heterelmis*, *Hexacylloepus*, *Macronychus*, *Microcylloepus*, *Narpus*, *Neoelmis*, *Stenelmis* (tolerant)
- General feeding group(s)—collector-gatherer, scraper
- General habitat(s)—clingers
- Pollution tolerance—mostly sensitive, with a few species more moderately tolerant; indicators of good water quality

Key characteristics:

- body distinctive, oval to cylindrical
- small size
- brown or black color
- long legs with 2 long tarsal claws
- larvae are generally long and slender

Figure 6-41



Larvae Adult

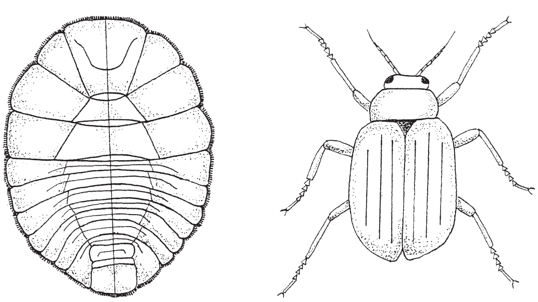
Water Pennies–Family Psephenidae

- ▼ Larvae and adults feed on plants
- ▼ Adults live in vegetation along shore and are terrestrial
- ▼ Larvae are found on the underside of rocks in fast-moving water, but may be found on wave-swept shores
- ▼ Common genera found in Texas—*Eubrianax*, *Psephenus*
- ▼ General feeding group(s)—scraper
- ▼ General habitat(s)—clingers
- ▼ Pollution tolerance—mostly sensitive, with a few species more moderately tolerant; indicators of good water quality

Key characteristics:

- ▼ flat, round body
- ▼ brownish color
- ▼ legs underneath

Figure 6-42



Larvae Adult

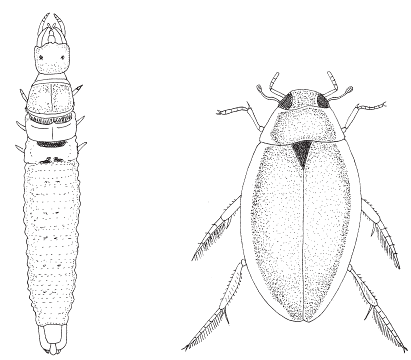
Water Scavenger Beetles–Family Hydrophilidae

- ▼ Common in vegetated areas of quiet, shallow pools and ponds
- ▼ A few are good swimmers, but most are crawlers
- ▼ Feed on decaying vegetation, but also on living plant material, especially algae
- ▼ Larvae are voracious predators, feeding on a variety of aquatic animals
- ▼ Common genera found in Texas—*Berosus*, *Enochrus*, *Helochares*, *Helophorus*, *Hydrochus*, *Lacobius*
- ▼ General feeding group(s)—collector-gatherer
- ▼ General habitat(s)—diver, swimmer
- ▼ Pollution tolerance—moderately tolerant

Key characteristics:

- ▼ size range: 1 to 40 mm long
- ▼ black; some are yellow or brown
- ▼ short, clubbed antennae, usually concealed beneath head
- ▼ maxillary palp (feeler-like structure) larger than antennae
- ▼ hind legs flattened, usually with fringe-like hair
- ▼ similar to predaceous diving beetle (Dytiscidae)

Figure 6-43



Larvae Adult

Whirligig Beetles–Family Gyrinidae

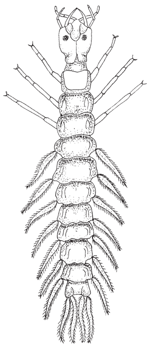
- ▼ Seen swimming or resting on the water surface in groups of a few or several hundred, especially in protected areas (out of wind and current)
- ▼ Widespread and abundant
- ▼ Often swim under the surface
- ▼ Most species are lentic with a few lotic species; adults are found in depositional areas, while larvae live among aquatic macrophytes
- ▼ Common genera found in Texas—*Dineutus*, *Gyretes*, *Gyrinus*
- ▼ General feeding group(s)—predator (engulfer), surface-film (nueston) scavenger
- ▼ General habitat(s)—swimmers, divers
- ▼ Pollution tolerance—moderately tolerant

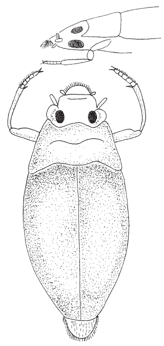
Key characteristics (adult):

- ▼ 2 pairs of eyes; 1 for looking up, the other for looking down
- ▼ greatly flattened legs

▼ elongate, oval body (similar to predaceous diving beetle), 3.5 to 14 mm long
▼ larvae distinctive; fringed lateral projections on all abdominal segments and posterior

Figure 6-44


Larvae


Adult

Aquatic Caterpillars—Order Lepidoptera

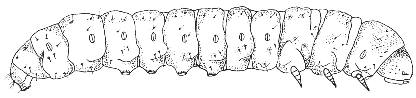
Family Pyralidae

▼ Largely terrestrial with a few associated with aquatic habitats
▼ Feed on plants
▼ Some species become so abundant they affect the surrounding aquatic plant community
▼ Inhabit a wide variety of permanent aquatic habitats
▼ Easy to distinguish from other aquatic insect larvae
▼ Difficult to tell aquatic and terrestrial apart; only those that build cases out of aquatic vegetation and those with numerous filamentous gills covering their body can be recognized as aquatic
▼ Common genera found in Texas—*Crambus*, *Parapanyx*, *Petrophila*
▼ General feeding group(s)—shredder, scraper
▼ General habitat(s)—climber, swimmer, clinger
▼ Pollution tolerance—moderately tolerant

Key characteristics:

▼ 3 pairs of thoracic legs
▼ pairs of prolegs ringed with hooks on abdominal segments 3-7

Figure 6-45



Other Freshwater Invertebrates

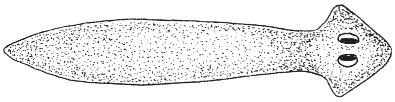
The following section contains information on the most common non-insect freshwater invertebrates found in Texas.

Unsegmented Worms—Phylum Platyhelminthes

Flat Worms–Class Turbellaria

▼ Flattened or cylindrical unsegmented worms
▼ Gray, brown, or black in color
▼ Most common and familiar are the planaria
▼ Common taxa—order Tricladida (planarians), family Planariidae, genus *Dugesia*
▼ Predators or scavengers

Figure 6-46



Segmented Worms—Phylum Annelida

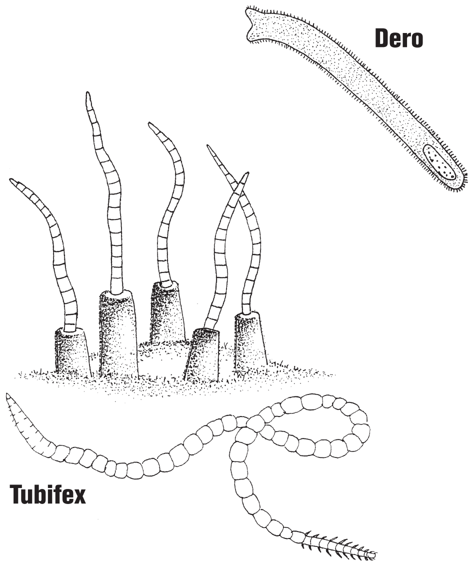
Bristle Worms–Class Oligochaeta

▼ Common in soft mud bottoms; widespread
▼ May live in tubes, within mats of filamentous algae, or on aquatic vegetation
▼ Feed on organic material obtained by ingesting large quantities of sediment as they move, extracting organic material in the digestive tract and discarding the rest through the anus
▼ Important in cleaning up dead and decaying vegetation
▼ Common bristle worms are *Dero*, which is found on the underside of duckweed, and *Tubifex*, found in the deepest parts of lakes and in stagnated waters
▼ *Tubifex* worms can live without oxygen for certain periods of time and are often abundant; the bright red color of *Tubifex* worms (blood worms) comes from an oxygen-bearing pigment; often associated with very polluted waters
▼ Pollution tolerance—tolerant, high numbers considered indicator of very poor water quality

Key characteristics:

▼ cylindrical and segmented
▼ bundles of bristle (setae) on sides of each segment after the first
▼ size range: 1 mm to 122 cm long
▼ distinct head region

Figure 6-47



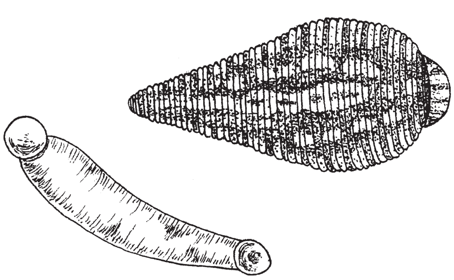
Leeches—Class Hirudinea

- ▼ Found mostly in freshwater
- ▼ Use an inchworm-type motion and creep along the substrate
- ▼ When not moving, all leeches use at least one sucker to hang on to vegetation, rocks, or other substrate
- ▼ Leeches are predators (snails, insect larvae, crustaceans, and worms) or scavengers; a few are the bloodsucking type (also feed on vertebrates)
- ▼ Pollution tolerance—tolerant; high numbers considered indicator of very poor water quality

Key characteristics:

- ▼ dorsoventrally flattened (top to bottom)
- ▼ anterior and posterior suckers

Figure 6-48



Crustaceans—Class Crustacea

- ▼ All have hard exoskeleton
- ▼ Appendages are modified for a variety of functions: walking, swimming, feeding, respiration, grooming, sensory reception, reproduction, and defense
- ▼ Carnivores and scavengers; some filter algae and detritus
- ▼ Live in a variety of habitats
- ▼ Mostly aquatic gill breathers

General characteristics:

- ▼ usually at least 5 pairs of leg-like appendages
- ▼ 2 pairs of antennae; 1 pair may be small
- ▼ a pair of appendages on each segment of the cephalothorax (fused head and thorax)
- ▼ may have appendages on the abdominal segment
- ▼ 2 distinct body regions: cephalothorax and abdomen
- ▼ cephalothorax covered by hard covering (carapace)

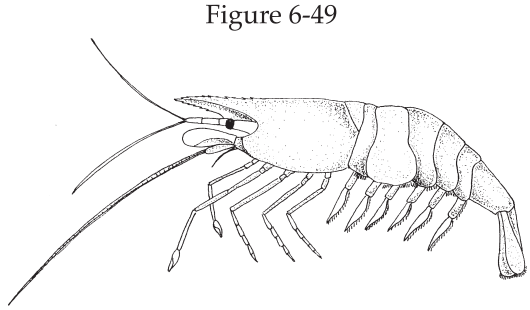
Southeastern River Shrimp, Southern or Eastern Prawns, and Grass Shrimp—Order Decapoda

- ▼ Southeastern river shrimp, *Macrobrachium*: 9 to 240 mm long.
- ▼ Southern and eastern prawns and grass shrimp, *Palaemonetes*: 25 to 55 mm long
- ▼ Edwards Aquifer has a blind shrimp; San Marcos River has very large prawns
- ▼ Commonly found in ponds and lakes, especially around vegetation; also found in ditches

General characteristics:

- ▼ first 2 pairs of legs are chelate (claw-like)
- ▼ second chelate leg larger than first
- ▼ no spine above the eye
- ▼ body laterally compressed

Figure 6-49



Crayfish—Family Cambaridae

- ▼ Move by swimming, walking and crawling, and can move backwards quickly when disturbed
- ▼ Omnivorous predators and scavengers that also eat vegetation
- ▼ Food for fish, wading birds, frogs, turtles, raccoons
- ▼ Some crayfish burrow in wet areas without ever going into water, while others are found in

muddy ponds and ditches or slow-moving areas of streams and rivers

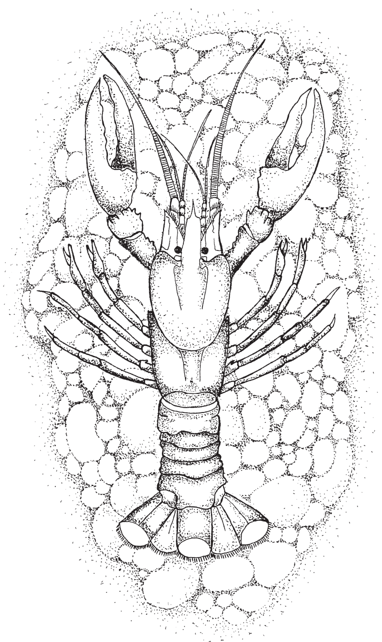
- Burrows vary in size and depth (8-10 ft, depending on water level); excavated soil is piled outside the hole, forming a chimney-shaped structure
- Common genera found in Texas—*Cambarellus*, *Procambarus*

Pollution indicator role: Moderately tolerant, rarely found in polluted water.

Key characteristics:

- entire head and thorax (cephalothorax) covered by a carapace
- 5 pairs of leg-like appendages on the cephalothorax
- first pair of legs has large claws (chelate)
- decapod (10 legs)

Figure 6-50



Aquatic Sowbugs–Order Isopoda

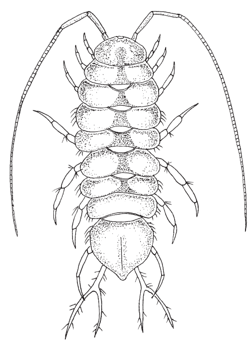
Family Asellidae

- Primarily marine and terrestrial; about 50 species are aquatic
- Crawl slowly over bottom or vegetation; found in vegetation, under logs and rocks in shallow-water areas
- Majority are scavengers, feeding on dead and injured organisms
- Resemble terrestrial sowbug, but legs are longer and more extended
- Blind species found in caves, wells, and springs (Edwards Aquifer); white or cream colored
- A few species can tolerate polluted water with low oxygen
- Little importance as food source for fish
- Common genera found in Texas—*Asellus*, *Lirceus*
- Pollution tolerance—moderately tolerant to tolerant, generally an indicator of poorer water quality

Key characteristics:

- lack a carapace
- dorsoventrally flattened (top to bottom)
- 7 pairs of leg-like appendages (cephalothoracic)

Figure 6-51



Sideswimmers or Scuds–Order Amphipoda

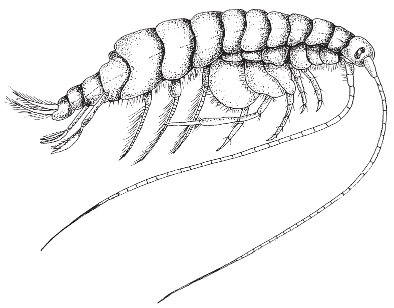
Family Gammaridae and Hyalellidae

- Mostly marine; about 50 species live in freshwater
- Omnivorous scavengers feeding on plant and animal material
- Prey of fish, birds, insects, and amphibians
- Move actively at night by swimming or crawling on side by flexing and extending entire body
- Common and widespread; large numbers live in clear unpolluted waters
- Found in lakes streams, ponds, springs, and subterranean waters
- Blind species can be found in caves and underground springs (Edwards Aquifer)
- Common genera found in Texas—*Gammarus* (sensitive), *Hyalella* (tolerant)
- General feeding group(s)—gatherer, shredder
- General habitat(s)—swimmer
- Pollution tolerance—wide range, generally moderately tolerant to sensitive; rarely found in severely polluted water

Key characteristics:

- laterally (side to side) flattened body
- no carapace
- 7 pairs of leg-like appendages (cephalothoracic: head and thorax)

Figure 6-52



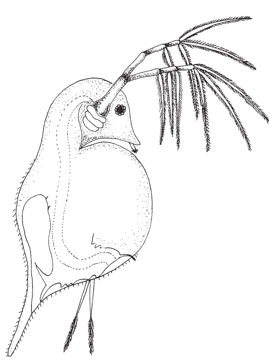
Microscopic Crustaceans—Order Cladocera

- ▼ Common and widespread in freshwater
- ▼ Found everywhere, with the exception of fast-moving streams and extremely polluted waters; a few species can handle low oxygen levels
- ▼ Important part of the zooplankton community
- ▼ Water fleas (*Ceriodaphnia*) are used in bioassays to check for toxicity in water
- ▼ Majority feed on organic detritus, bacteria, and protozoans; two common species, *Daphnia* and *Bosmina*, are algae eaters
- ▼ Important in the food chain; they are the prey of insects, wading birds, and fish
- ▼ Move by using a long second antenna, which is fringed for swimming

Key characteristics:

- ▼ 4 to 6 pairs of thoracic legs
- ▼ head outside of carapace
- ▼ laterally compressed (side to side)
- ▼ visible to naked eye, but need microscope to view up close; 0.2 to 3.0 mm long
- ▼ oval shaped with posterior spine

Figure 6-53



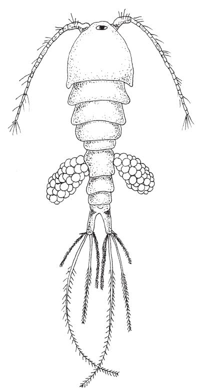
Free-Living Copepods—Order Copepoda

- ▼ Abundant and common, they are an important part of the zooplankton community and the aquatic food chain; provide a link between bacteria, algae, protozoans, and large planktivores (mainly fish)
- ▼ Very important food for fish
- ▼ Found in a variety of habitats; most common in lakes and littoral areas
- ▼ More tolerant of low oxygen than water fleas
- ▼ Common genera—*Cyclops* (single eye and 2 egg sacs) and *Diaptomus* (long antennae and single egg sac)
- ▼ Collect with a plankton net

Key characteristics:

- ▼ cylindrical shape
- ▼ greatly narrowed abdomen
- ▼ 2 caudal branches (rami) with setae
- ▼ antennae hang down, giving a droopy appearance
- ▼ less than 2 mm long, visible but need microscope to view
- ▼ carry 1 to 2 egg sacs, posterior end

Figure 6-54



Molluscs—Phylum Mollusca

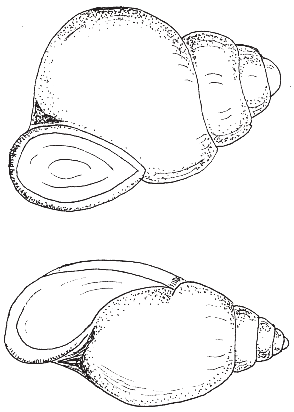
Snails and Limpets—Class Gastropoda

- ▼ Found in every freshwater environment, from the smallest ponds and ditches to the largest lakes and rivers
- ▼ The genus *Physa* (pouch snail) is very pollution tolerant, while most gastropods need high oxygen concentrations
- ▼ Creep along any substrate (rocks, plants, man-made debris), generally in water up to 2 meters deep
- ▼ Feed on microscopic algae on submerged substrate, filamentous algae, aquatic plants, and dead organic matter

Key characteristics:

- ▼ most snails have shells that are coiled, which are spiral or discoidal (disk-like)
- ▼ limpets have low, cone-shaped shells
- ▼ spiral shells are either dextral (curving to the right) or sinistral (curving to the left)

Figure 6-55



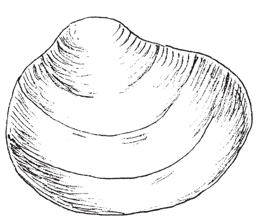
Clams—Class Pelecypoda

- ▼ Known as bivalves because of the two-sided shell
- ▼ Found in all types of freshwater environments, but are most common in the muddy bottoms of rivers; smaller clams, like fingernail clams and the introduced Asian clam (*Corbicula*), live in streams and lakes
- ▼ Feed on microscopic plankton and organic debris (filter feeders)
- ▼ Spend all the time on the bottom; move with a pseudopod (false foot)

Key characteristic:

- ▼ 2-sided shell

Figure 6-56



Water Mites—Class Arachnida

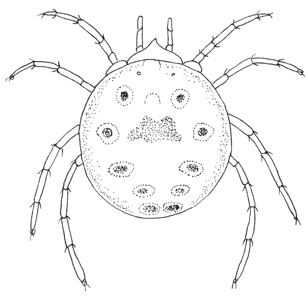
Order Acarina (mites and ticks), Suborder Hydracarina

- ▼ Found in all types of freshwater habitats; most common and abundant in ponds and littoral areas of lakes; especially in areas with a lot of rooted aquatic vegetation
- ▼ Preyed on by a variety of aquatic invertebrates

Key characteristics:

- ▼ look like tiny spiders, but body is fused into a single mass
- ▼ no segmentation; look like little ball with legs
- ▼ 6 pairs of spider-like legs
- ▼ variety of bright colors: red, blue, yellow, tan, brown, or combinations of colors

Figure 6-57



CHAPTER 7

Freshwater Fish

Introduction

Fish are cold-blooded animals with backbones (vertebrates) that live their entire lives in water, breathing by means of gills, and moving by means of fins.

There are 45 families and 247 species of fishes found in the freshwaters of Texas (Hubbs *et al*. 1991). More than two-thirds of the 247 species are recognized as exclusively freshwater fishes; the remaining 78 species are estuarine. However, some of these estuarine species can be found in the freshwater portions of streams many miles upstream from the coast (for example, striped mullet).

The fish species in Texas vary greatly in size, shape, color, behavior, feeding habits, and habitat. Some species of fish provide economically valuable recreational and commercial fisheries. However, all fish species play an important role in the aquatic ecosystem.

Fish Habitat

Although fish inhabit nearly every permanent water body, each species has its own distribution and range. The basic requirements for a fish's survival include prey, cover, suitable water temperature, and DO levels.

Species such as common carp and channel catfish can survive in a variety of habitats and are found throughout the state. Others, like sunfish, prefer calm, quieter waters, while darters prefer very swift flowing streams with riffles. Some species have a very limited geographical distribution in the state. For example, the Devils River minnow is found in only a few streams in southwest Texas, the Mexican stoneroller is only found in the Big Bend region of the state, and the fountain darter and Comanche Springs pupfish are only found in specific springs in the state.

Other species have specific water quality criteria for survival, such as the rainbow trout (nonnative species), which is restricted to the cold water of the Guadalupe River below Canyon Lake dam. Some fish such as the Red River pupfish and plains killifish are better suited for streams with a higher salinity, such as the Red River and Canadian River. However, some generalizations can be made about the particular fish species that are typically associated with the various habitat types in streams and reservoirs (see Table 7-1).

Feeding Groups

Fish feed at all levels of the food chain, from bottom scavengers to top-level predators. Fish can be categorized into groups based on food preferences: *piscivores*, *invertivores*, *omnivores*, and *herbivores*. The groups are referred to as *trophic guilds* (see Table 7-2).

Fish in each of the trophic guilds have *morphological* (form and structure of an organism) adaptations to allow more efficient feeding. For example, piscivores generally have large eyes for better sight and a well-developed lateral line to detect the vibrations of prey in the water. Omnivores and invertivores feeding on the bottom usually have fleshy lips (suckers) or taste buds on their barbels (catfish) to aid in detecting prey. Herbivores use pharyngeal teeth (a modified gill arch in the throat) for crushing plant material (minnows).

Table 7-1

Habitat Types with Representative Fish Species

Habitat Types	Fish Species
Streams	
Riffles (high DO)	Darters, shiners
Pools	Sunfish, bass, catfish, suckers
Backwater areas (low DO)	Gar, bowfin, pirate perch
Reservoirs	
Open Water	Shad, white bass, striped bass
Shorelines with aquatic vegetation	Sunfish, bass, shiners
Quiet Coves	Gar, suckers

Freshwater fish in Texas have been classified into trophic guilds. For this information refer to *Regionalization of the Index of Biotic Integrity for Texas Streams*, TPWD River Studies Report No. 17 located on the Web at **www.tpwd.state.tx.us/texaswater/river_studies/index.phtml**.

Table 7-2
Food Preferences of Fish

Trophic Guild	Food Preference	Examples
Predators (P) (Piscivores)	Fish that eat other fish	Largemouth bass, smallmouth bass, flathead catfish, spotted gar, alligator gar, white bass, crappie (black and white)
Invertivores (IF)	Fish that eat invertebrates; insects, worms, crayfish and other crustaceans, molluscs	Tadpole madtom, blue sucker, bullhead minnow, red shiner, bluegill, longear sunfish
Omnivores (O)	Fish that eat any available food	Smallmouth buffalo, gizzard shad, threadfin shad, common carp, fathead minnow, black bullhead, channel catfish
Herbivores (H)	Fish that eat plant material	Central stoneroller, Mexican stoneroller, grass carp

Pollution Tolerance

Fish can be used to evaluate the water quality and health of an aquatic ecosystem. As part of this evaluation fish are placed into categories based on their tolerance to pollution.

The three general categories are intolerant, tolerant, and intermediate. Freshwater fish in Texas have been classified into pollution tolerance groups. For this information refer to *Regionalization of the Index of Biotic Integrity for Texas Streams*, TPWD River Studies Report No. 17 located on the Web at **www.tpwd.state.tx.us/texaswater/river_studies/index.phtml**.

See the "Organisms Used as Indicators of Pollution" section in Chapter 3 for more information on the use of fish as indicators of pollution.

Fish Identification

The objective of this section is to describe some of the most common freshwater fish in Texas through illustrations and short descriptions. This section features 16 families and 42 species and includes two parts. The first part provides information to identify the fish to family. The second part provides information about each family and a description of the most common species within that family.

Like the benthic macroinvertebrate identification section, the information provided in this section is general and meant to familiarize the user with the most common fish species. The characteristics for each fish relate only to adult specimens because the young of some species may differ from the adults in appearance.

If advanced identification is necessary, a more traditional taxonomic key should be used. Suggested keys for fish identification are listed in the reference section. To assist in fish identification, a list of fish species found in each river basin, "Fish Species Common to Major Texas River Basins," is presented on the Web at **www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/mtr/swqm_links.html**.

The common and scientific names used follow Nelson *et al*. (2004). Fish key characteristics and information were taken from Pflieger (1997), Eddy and Underhill (1978), Robison and Buchanan (1988), and Tomerlleri and Eberle (1990). For additional information, see selected references on freshwater fish listed in Chapter 14.

Fish Structures Used in Identification

The first step in the identification of fish is learning about the anatomical structure of a fish, specifically those structures which are the basis for classification. Fish structures used in identification are also referred to as *key characteristics*. Key characteristics include things such as body shape and size; tail shape; shape or position of the mouth; location, shape, and size of fins; coloration; markings; and presence or absence of scales.

The terms provided below are those needed to do basic fish identification. They do not represent a complete list of terms related to fish anatomy and physiology needed for advanced work. The terms defined in the following section are illustrated in Figure 7-1.

Fish Structure Terms

General Terms

anterior. Before or to the front part of the body or structure.

dorsal. Back or upper surface.

lateral. Sides or toward the sides.

medial. Central part or middle of body or structure.

posterior. Behind or back end of body or structure.

ventral. Underside or lower surface.

Common Fish Structure Terms

adipose fin. A single small, soft, fleshy structure without rays or spines, located behind the dorsal fin. Adipose fins are a key characteristic of the catfish family, trout family, and Mexican tetras.

air bladder. A gas-filled sac lying above the intestine.

anal fin. A single median (middle) ventral (underside) fin located posterior (behind) to the anus.

anus. Waste elimination opening of the digestive tract, located at the posterior end of the body on the ventral (under) side. The location of the anus is a key characteristic of the pirate perch (*Aphredoderus sayanus*).

barbels. Fleshy, whisker-like sensory structures located on the head and around the mouth. Barbels are a prominent characteristic of catfish.

caudal fin. The tail fin; the term tail alone generally refers to that part of a fish posterior (behind) to the anus. The caudal fin is located at the end of the tail. The shape of the caudal fin (rounded, forked, square) is a common characteristic used in identification.

dorsal fin. A median fin along the back that is supported by spines and/or rays. There may be two dorsal fins, in which case the most anterior (closest to the head) is designated as the first.

lateral line. A sensory organ, consisting of a canal running along the side of the body under the skin, which communicates via sensory pores (one on each scale) through scales to the exterior; functions in perceiving low-frequency vibrations and pressure differences in general. This means that fish can swim blindly without hitting objects, which helps in capturing prey. The presence, absence, and other characteristics of the lateral line are commonly used in fish identification. For example, a Rio Grande cichlid has an interrupted or broken lateral line, while a freshwater drum has a lateral line that extends from the head out onto the caudal fin.

opercle (gill cover). A bony gill cover that lies between the cheek and the posterior border of the head. The skin covering the opercle is usually without scales. Some species have scales covering or partially covering the opercle, for example pickerels, *Esox*.

opercular (ear) flap. A flattened, flexible structure that extends off the rear end of the opercle (gill cover) on some fish. The opercular flap is used in the identification of sunfish species that have distinctive flaps.

pectoral fin. A pair of soft-rayed fins located laterally (side) and posterior (behind) to the opercle. Pectoral fins are present on most fishes but may be absent or reduced on a few. The primary functions of pectoral fins are locomotion, turning, making sudden stops, and aggressive displays.

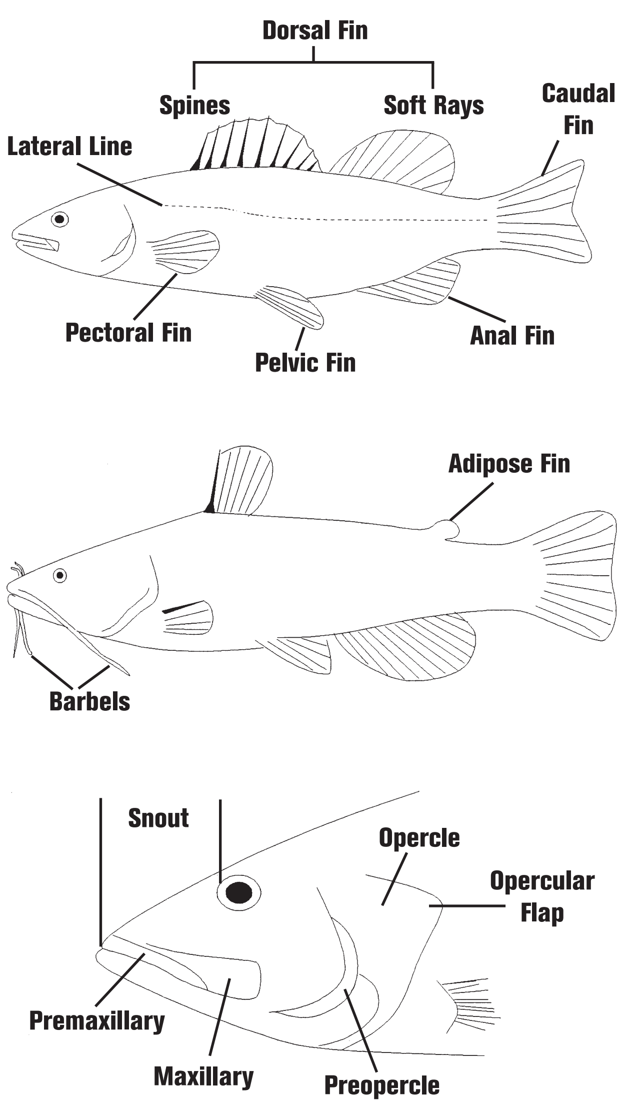
pelvic fin. A pair of soft-rayed fins, generally smaller than pectoral fins, that have limited function and vary in placement on the ventral (bottom) side of a fish. Pelvic fins are used to steady a fish and for breaking, but they are not used much for locomotion.

pharyngeal teeth. A modified gill arch in the throat.

premaxillary. Part of upper jaw; make up the anterior (front) end of the upper jaw.

preopercle. A boomerang-shaped bone, the edges of which form the posterior (back) and lower

Figure 7-1
Fish Structures



margins of the cheek region; it is the most anterior (front) of the bones comprising the gill cover. The shape of the preopercle is a common characteristic used in identification.

mandible. Lower jaw.

maxillary. Part of upper jaw. The maxillary usually marks the posterior (back) end of the jaw. The posterior end of the maxillary in relation to the eye is often used in identification.

snout. The part of the head that extends from the anterior (front) tip of the upper jaw to the eye.

soft ray. A soft, segmented fin support that is usually branched. The number of rays in dorsal and anal fins are commonly used in fish identification.

spines. Sharp, hard, solid structures that are unbranched and unsegmented. The presence and number of spines in dorsal and anal fins are common characteristics used in fish identification.

spinous soft ray. Unbranched, hardened spine-like structures found on catfish (dorsal and pectoral fins) and common carp (dorsal and anal fins).

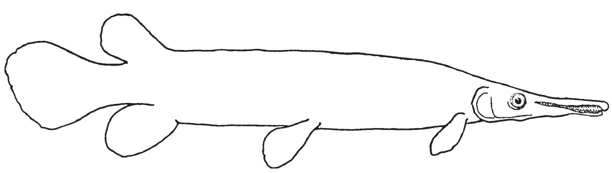
Key to the Families

Gar Family—Lepisosteidae

- ▼ long cylindrical body
- ▼ long jaws with sharp teeth
- ▼ hardened scales cover body

Go to Figures 7-18 to 7-20

Figure 7-2

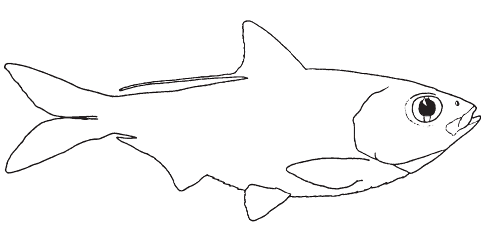


Herring Family—Clupeidae

- ▼ thin fish with silvery scales
- ▼ lateral line absent
- ▼ saw-toothed keel on belly

Go to Figures 7-21 to 7-22

Figure 7-3

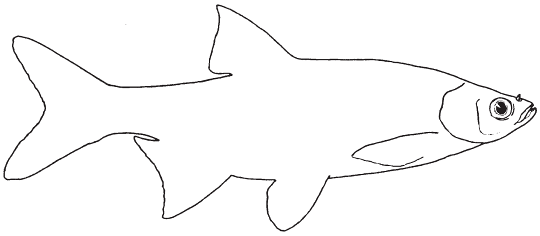


Carp and Minnow Family—Cyprinidae

- ▼ lips not sucker-like
- ▼ usually not more than 10 dorsal rays
- ▼ largest family of freshwater fishes

Go to Figures 7-23 to 7-28

Figure 7-4

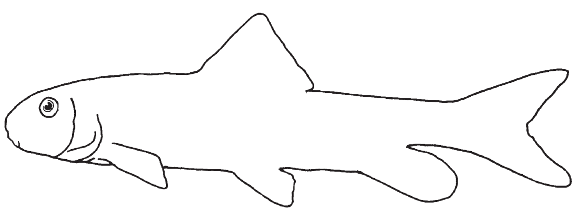


Sucker Family—Catostomidae

- ▼ sucker-like mouth with thick lips
- ▼ body with large, smooth, simple scales
- ▼ usually more than 10 dorsal rays

Go to Figures 7-29 to 7-31

Figure 7-5

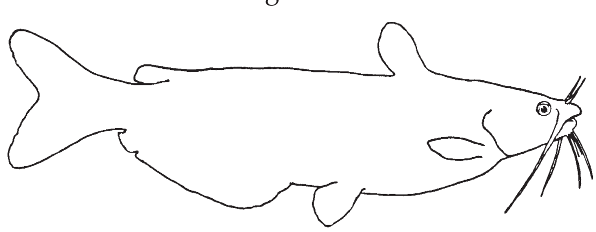


North American Catfish Family—Ictaluridae

- ▼ scaleless body
- ▼ barbels present around mouth
- ▼ adipose fin present
- ▼ sharp, heavy pectoral and dorsal spines

Go to Figures 7-32 to 7-35

Figure 7-6

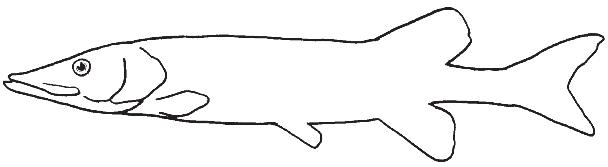


Pike Family—Esocidae

- ▼ long, cylindrical body
- ▼ both jaws extend forward, shaped like a duck-bill

Go to Figures 7-36 to 7-37

Figure 7-7



Pirate Perch Family—Aphredoderidae

- ▼ dark olive, somewhat speckled
- ▼ anus under throat
- ▼ large mouth

Go to Figure 7-38

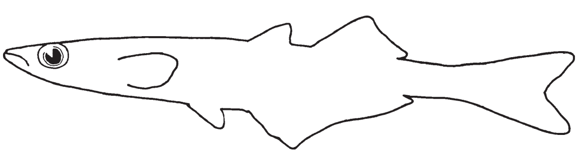
Figure 7-8

New World Silverside Family—Atherinopsidae

- ▼ slender fish with silvery band on sides
- ▼ snout flattened
- ▼ lower jaw extending before upper jaw

Go to Figures 7-39 to 7-40

Figure 7-9

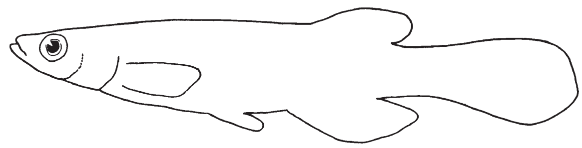


Topminnow Family—Fundulidae

- ▼ top of head and back flattened
- ▼ mouth upturned
- ▼ body elongated
- ▼ lateral line absent

Go to Figure 7-41

Figure 7-10

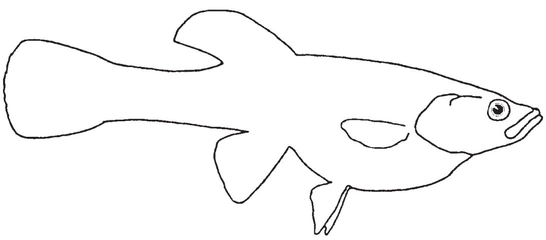


Livebearer Family—Poeciliidae

- ▼ similar in appearance to topminnows
- ▼ third anal ray not branched

Go to Figures 7-42 to 7-43

Figure 7-11

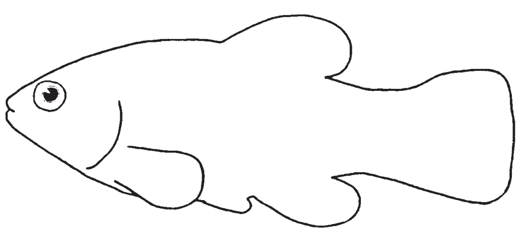


Pupfish Family—Cyprinodontidae

- ▼ deep rounded body
- ▼ mouth upturned
- ▼ head is flattened but back is usually highly arched
- ▼ lateral line absent

Go to Figures 7-44

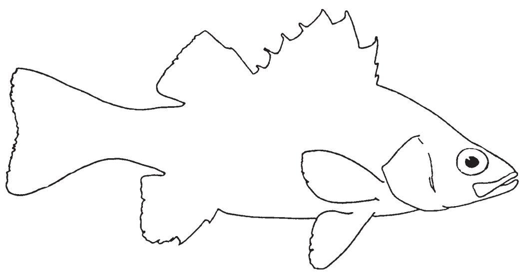
Figure 7-12



Temperate Bass Family—Moronidae

▼ body with obvious stripes
▼ opercle with well-developed spine
▼ dorsal fin is almost completely divided
Go to Figures 7-45 to 7-47

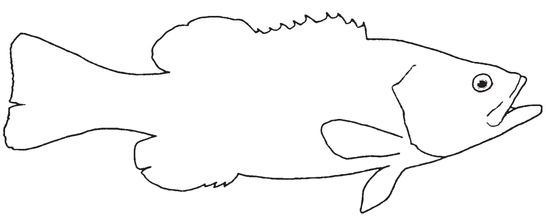
Figure 7-13



Sunfish Family—Centrarchidae

▼ dorsal fin is united and confluent
▼ anal fin with 3-8 spines
▼ opercle without well-developed spine
▼ thoracic pelvic fins present
Go to Figures 7-48 to 7-53

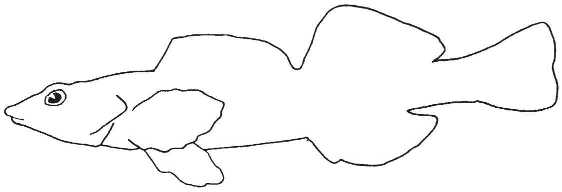
Figure 7-14



Perch Family—Percidae

▼ dorsal fin completely divided
▼ anal fin with 1 or 2 spines
Go to Figures 7-54 to 7-56

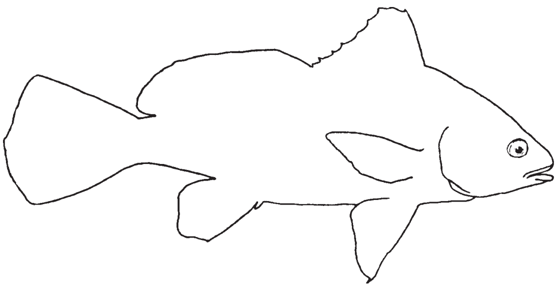
Figure 7-15



Drum and Croaker Family—Sciaenidae

▼ deep bodied silvery fish
▼ high back and long dorsal fin
▼ lateral line extends onto caudal fin
Go to Figure 7-56

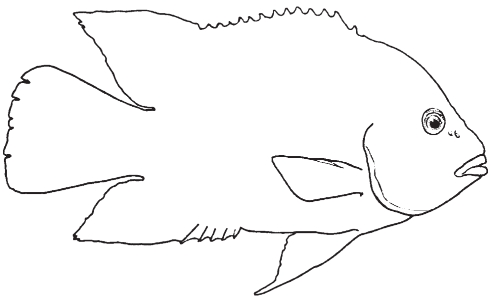
Figure 7-16



Cichlid Family—Cichlidae

▼ lateral line broken under dorsal fin
▼ one nostril on each side of head
Go to Figures 7-58 to 7-59

Figure 7-17



Key to the Species

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Gar Family—Lepisosteidae

The gar family is a primitive group of fish containing seven species that are native to the fresh and brackish waters of Central and North America and the West Indies. Five species are found in the United States east of the Rockies. Their bodies are covered with an array of enamel-hard, diamond-shaped plates called *ganoid scales*.

Gars are especially designed for backwater areas because they can breathe with gills or a special lung-like air bladder. The air bladder is connected to the throat, allowing the gar to breathe air. This allows gars to survive in stagnant waters that might not have sufficient oxygen for most other species of fish. Gar eggs are quite toxic and cause great distress if eaten by warm-blooded vertebrates.

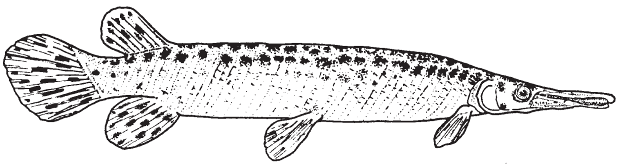
Gars are sometimes blamed for poor fishing because of their voracious consumption of small fish, and sometimes game fish. However, the majority of a gar's diet consists of gizzard shad. Gars actually may serve as a natural control in preventing over-population and unbalanced fish populations.

Spotted Gar—*Lepisosteus oculatus*

- ▼ snout short and broad
- ▼ top of head with large spots
- ▼ one row of teeth in upper jaw
- ▼ length up to 4 feet

Pollution tolerance: tolerant

Figure 7-18

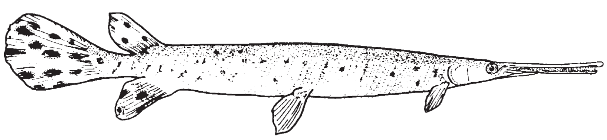


Longnose Gar—*Lepisosteus osseus*

- ▼ snout very long and slender
- ▼ one row of teeth in upper jaw
- ▼ length up to 5 feet

Pollution tolerance: tolerant

Figure 7-19

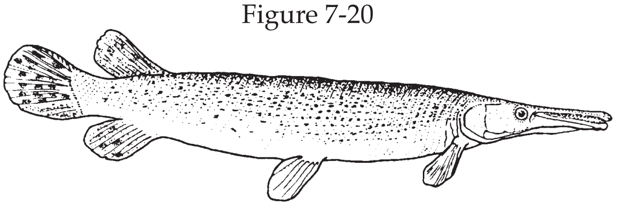


Alligator Gar—*Lepisosteus spatula*

- ▼ snout broad and blunt
- ▼ two rows of teeth in upper jaw
- ▼ length up to 12 feet

Pollution tolerance: tolerant

Figure 7-20



Herring Family–Clupeidae

Herrings are a large (about 200 species), principally marine group that is found worldwide. The freshwater herrings are bright, silvery, flat-sided fish that typically feed on plankton. The herring's belly has a sharp "sawtoothed" keel, formed by a row of specially modified scales. Herrings also have transparent adipose (fleshy) eyelids that cover the eye. The two common freshwater herring species are the threadfin shad and gizzard shad.

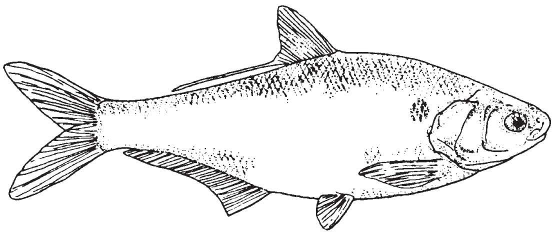
Herrings are one of the most important families of food fish in the world, and much of the commercial catch is processed into fish meal, a major source of protein in livestock feed and pet food. Gizzard and threadfin shad are among the most widely stocked prey fish in United States reservoirs and ponds.

Gizzard Shad—*Dorosoma cepedianum*

- ▼ sharp "sawtoothed" edge (keel) on belly
- ▼ last ray of dorsal fin greatly elongated, forming a long filament
- ▼ upper jaw slightly overhangs lower jaw (cannot catch lower jaw by running hand down snout)
- ▼ anal fin with 30 to 33 rays
- ▼ length up to 22 inches

Pollution tolerance: tolerant

Figure 7-21

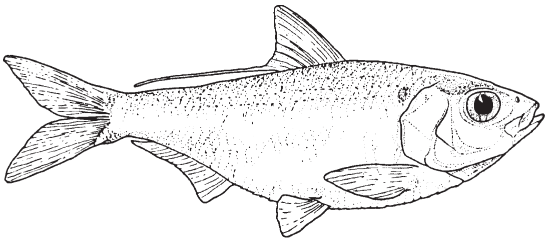


Threadfin Shad—*Dorosoma petenense*

- ▼ sharp "sawtoothed' edge (keel) on belly
- ▼ last ray of dorsal fin greatly elongated forming a long filament
- ▼ more superior mouth (can catch lower jaw by running finger down snout)
- ▼ anal fin with 20 to 25 rays
- ▼ length up to 6 inches

Pollution tolerance: intermediate

Figure 7-22



Carp and Minnow Family–Cyprinidae

The minnow family is the largest family of fish with 1500 species worldwide. About 280 species are found in North America. Most minnows are small. As a group, minnows live almost anywhere, and eat almost anything. Males of some species develop brilliant breeding colors. Minnows lack teeth in the mouth, but have well-developed teeth on the last or modified fifth gill arch, called *pharyngeal teeth*. The pharyngeal teeth are often used in the advanced identification of minnow species.

Minnows also have well-developed *Weberian ossicles*, a series of small bones connecting the inner ear to the swim bladder. The membranous wall of the swim bladder picks up vibrations in the water and transmits them to the ear, giving minnows a keen sense of hearing. When injured, minnows also secrete chemical substances called *pheromones* to signal danger to other minnows.

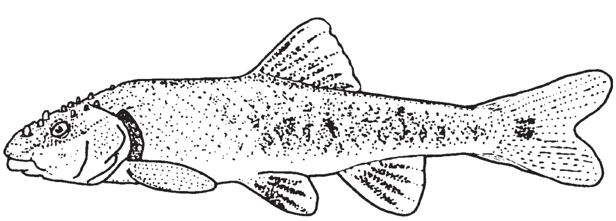
Minnows are important as prey for other fish and as bait for fishing. One of the largest minnow species is the common carp, introduced in North America from Europe. The grass carp, another large minnow species, was introduced from Asia for vegetation control in many southern states, including Texas, and is commercially important in some states. However, grass carp are on the Harmful or Potentially Harmful Exotic Fish List of the Texas Parks and Wildlife Department (TPWD), and are regulated by that agency.

Central Stoneroller—*Campostoma anomalum*

- ▼ thick, slightly compressed body
- ▼ hard ridge on lower jaw of subterminal mouth
- ▼ brown above; often dark stripe along side, dark caudal spot on young; irregular dark blotches on back and side of large individuals
- ▼ breeding males have orange fins, white lips, bright red iris
- ▼ length up to 9 inches

Pollution tolerance: intermediate

Figure 7-23

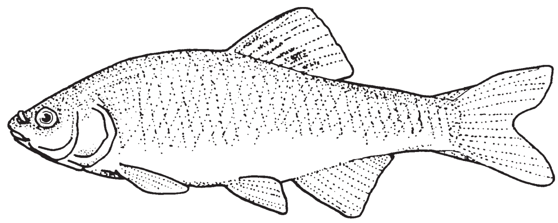


Red Shiner—*Cyprinella lutrensis*

- ▼ steel blue in color, males with red on fins
- ▼ lateral band starts on back half of body
- ▼ faint vertical bar on shoulder
- ▼ anal fin with 8 or 9 rays
- ▼ length up to 4 inches

Pollution tolerance: tolerant

Figure 7-24

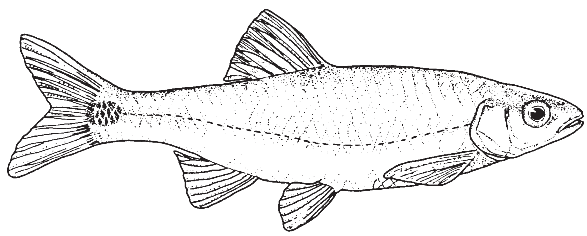


Blacktail Shiner—*Cyprinella venusta*

- ▼ large black spot at base of caudal fin
- ▼ body steel blue with slight dusky band
- ▼ anal fin with 7 or 8 rays
- ▼ length up to 5 inches

Pollution tolerance: intermediate

Figure 7-25

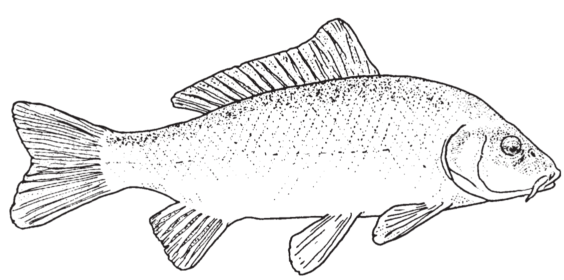


Common Carp—*Cyprinus carpio*

- ▼ 2 barbels on each side of upper jaw
- ▼ anterior spine in dorsal and anal fin
- ▼ body color reddish
- ▼ more than 12 dorsal rays
- ▼ length up to 30 inches

Pollution tolerance: tolerant

Figure 7-26



Golden Shiner—*Notemigonus crysoleucas*

▼ deep body; silvery gold color

▼ lateral line deeply curved

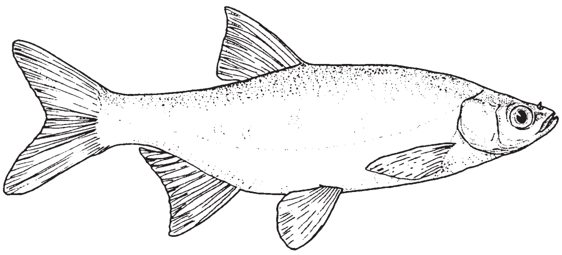
▼ falcate-shaped anal fin

▼ belly behind pelvic fin with a sharp naked keel

▼ length up to 10 inches

Pollution tolerance: tolerant

Figure 7-27



Bullhead Minnow—*Pimephales vigilax*

▼ dark lateral band present

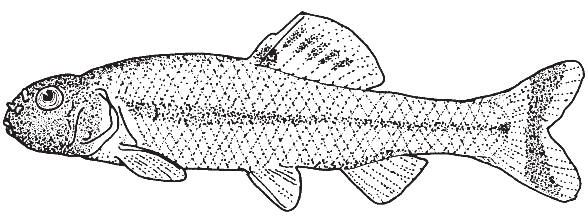
▼ dark spot on first four dorsal rays

▼ small spot at base of caudal fin

▼ length up to 4 inches

Pollution tolerance: intermediate

Figure 7-28



Sucker Family—Catostomidae

The suckers are close relatives of the minnow family. They are primarily a North American family, with 59 species and 11 genera in the United States and Canada. The suckers are soft-rayed fish, and possess a toothless and more-or-less sucker-like mouth with thick lips.

The pharyngeal teeth are numerous (20) and in a single row, whereas minnows have either two rows of teeth, or one row with only a few (5) teeth. Suckers usually have more than 10 dorsal rays, whereas most native minnows have no more than 10 dorsal rays.

Suckers are mostly omnivorous, feeding on the bottom where they eat a large variety of animal matter, as well as some plant material. Small suckers are valuable prey for large predator species. Large suckers, like buffalo fish, redhorses, and carpsuckers are commercially important. Suckers are extremely bony. Ribs, including a set of accessory ribs, are distributed from the head to the tip of the tail.

River Carpsucker—*Carpiodes carpio*

▼ body goldish color tinged with red

▼ nipple-like structure on lower lip

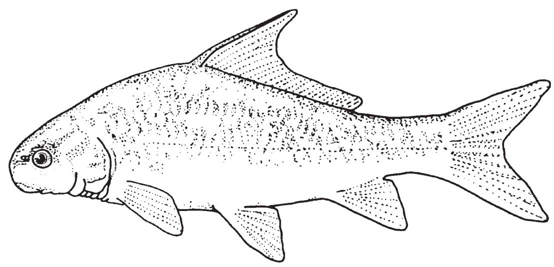
▼ triangular shaped preopercle

▼ dorsal fin long with 25 to 40 rays

▼ length up to 2 feet

Pollution tolerance: tolerant

Figure 7-29



Smallmouth Buffalo—*Ictiobus bubalus*

▼ deep body and steel blue in color

▼ circular-shaped preopercle

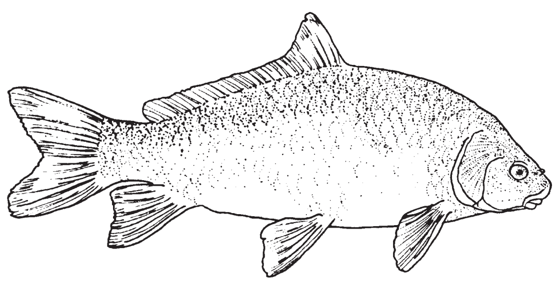
▼ mouth small

▼ dorsal fin long with 25 to 40 rays

▼ length up to 3 feet

Pollution tolerance: intermediate

Figure 7-30



Gray Redhorse—*Moxostoma congestum*

▼ broad, U-shaped head (from above)

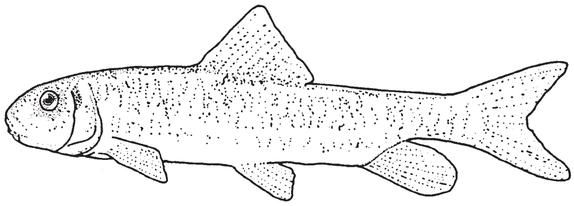
▼ long pectoral fin, slightly concave dorsal fin, slightly forked caudal fin

▼ olive to yellow above, gray dorsal and caudal fins, yellow anal and paired fins

▼ length up to 26 inches

Pollution tolerance: intermediate

Figure 7-31



North American Catfish Family—Ictaluridae

Most catfish families around the world are restricted to freshwater, with 39 species in the United States and Canada. Catfish are easily recognizable by their scaleless bodies, broad flat head, sharp pectoral and dorsal spines, and long barbels around the mouth. The catfish takes its name from the barbels or "cat whiskers" on its head. The barbels possess taste buds which help them to locate and taste food, especially in turbid water and at night.

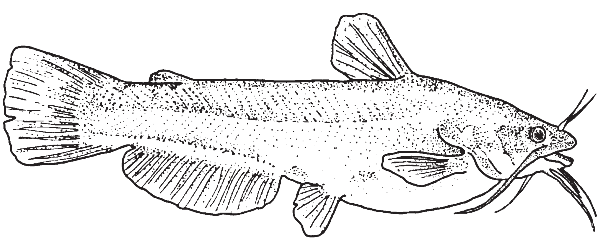
Catfish possess venomous spines at the origins of the dorsal and pectoral fins and can inflict a painful wound. The toxicity is thought to be caused by poisonous secretions of cells from the sheath covering the spine. Their stings probably are a defense mechanism to reduce predation.

Yellow Bullhead—*Ameiurus natalis*

- ▼ caudal fin rounded or squared
- ▼ barbels under jaw white
- ▼ anal fin with more than 16 rays
- ▼ length up to 18 inches

Pollution tolerance: intermediate

Figure 7-32

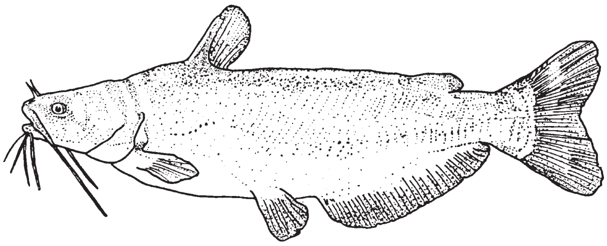


Blue Catfish—*Ictalurus furcatus*

- ▼ caudal fin deeply forked
- ▼ body dusky blue
- ▼ anal fin with 30 or more rays
- ▼ length up to 5 feet

Pollution tolerance: intermediate

Figure 7-33

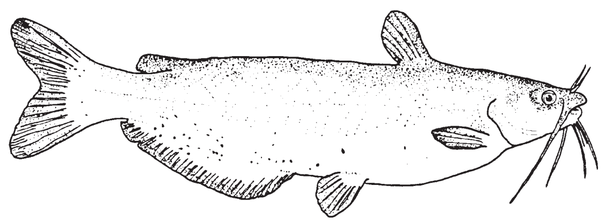


Channel Catfish—*Ictalurus punctatus*

- ▼ caudal fin deeply forked
- ▼ body bluish with small black spots
- ▼ anal fin with 24 to 29 rays
- ▼ length up to 3 feet

Pollution tolerance: tolerant

Figure 7-34

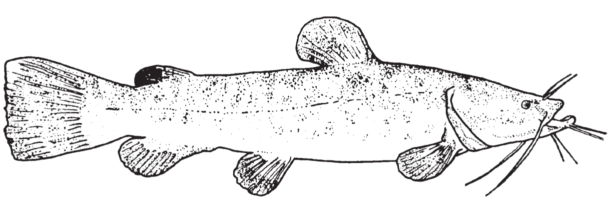


Flathead Catfish—*Pylodictis olivaris*

- ▼ caudal fin rounded or squared
- ▼ head flattened
- ▼ body yellowish brown in color
- ▼ anal fin rays, less than 16
- ▼ length up to 5 feet

Pollution tolerance: intermediate

Figure 7-35



Pike Family—Escocidae

The pike family includes five species, which are found in North America, Europe and Asia. Four species are native to North America. Pike are easily recognized by the "duck-bill" shape of their snout, which is large and lined with numerous sharp teeth.

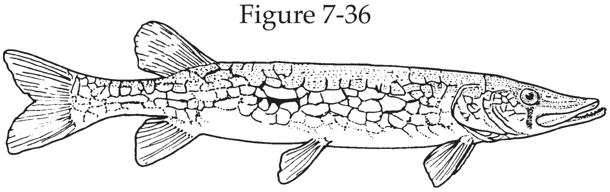
Pike are normally associated with cover, especially weed beds, in which they lay in wait to ambush their prey, usually small fish. Pike are sometimes stocked to control the overpopulation of shad and other nongame fish. Pike grow very rapidly, and some species reach a large size. The larger species are popular game fish.

Chain Pickerel—*Esox niger*

- ▼ sides and back marked with dark network of horizontal chain-like lines
- ▼ opercle entirely scaled
- ▼ length up to 24 inches

Pollution tolerance: intolerant

Figure 7-36

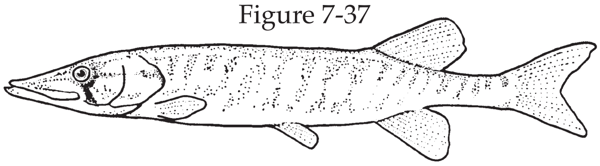


Redfin Pickerel—*Esox americanus*

- ▼ sides and back marked with dark, wavy, vertical streaks
- ▼ opercle entirely scaled
- ▼ length up to 12 inches

Pollution tolerance: intolerant

Figure 7-37



Pirate Perch Family–Aphredoderidae

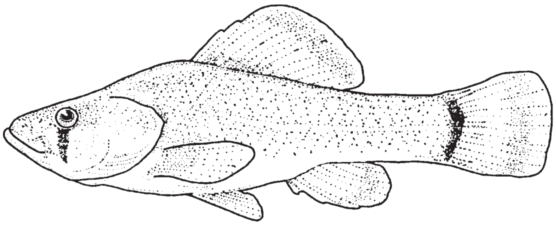
This family contains only one living representative species, confined to the eastern United States. The most unusual characteristic is the position of the anus. The anus moves forward as the fish grows until it is located under the throat of the adults. Pirate perch are nocturnal and predaceous, feeding mostly on aquatic insects and other small aquatic animals. The pirate perch is tolerant of high water temperatures and low DO. This family inhabits swamps, and other quiet backwaters, preferring areas of abundant vegetation or other cover.

Pirate Perch—*Aphredoderus sayanus*

- ▼ dark olive, somewhat speckled
- ▼ anus located under the throat
- ▼ two dark bars at base of caudal fin
- ▼ length up to 5 inches

Pollution tolerance: intermediate

Figure 7-38



New World Silverside Family–Atherinopsidae

Silversides are found worldwide and are primarily marine, with 12 species in the United States and Canada. One of the best known members of the silverside family, the California grunion (*Leuresthes tenuis*), attracts attention when it spawns on sandy beaches during high tides.

The freshwater species are pale in color with a wide, horizontal, silvery band on each side of the body and an upturned mouth. Their dorsal fins are divided into a small spiny portion and a larger soft-rayed portion, which are widely separated.

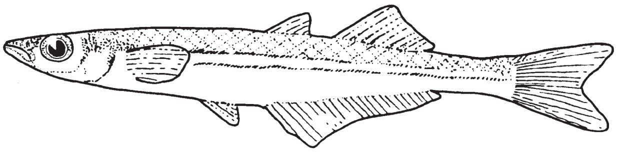
Silversides swim in schools at the surface, and sometimes skip across the surface. They feed on a variety of invertebrates. Schools of silversides are common around pier lights at night. Silversides serve as a prey species for many sport fish, birds, and other animals. Silverside eggs have a sticky thread enabling them to float until the thread becomes attached to some object.

Brook Silverside—*Labidesthes sicculus*

- ▼ body pale with wide silvery band on side
- ▼ snout longer than diameter of eye
- ▼ small scales
- ▼ length up to 4 inches

Pollution tolerance: intolerant

Figure 7-39

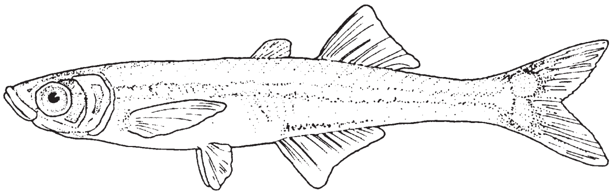


Inland Silverside—*Menidia beryllina*

- ▼ body pale with wide silvery band on side
- ▼ snout equal to diameter of eye
- ▼ large scales
- ▼ length up to 4 inches

Pollution tolerance: intermediate

Figure 7-40



Topminnow Family—Fundulidae

Topminnows are small, brightly colored fish (particularly mature males) that inhabit fresh, estuarine, and marine waters. The family contains 40 species in North America and most members in this family are in the genus Fundulus. Members of this family are also called "killifish" which is derived from a Dutch word for creek or channel in reference to their habitat. Topminnows have previously been included in the Family Cyprinodontidae but were recently reclassified based on differences in bony structures.

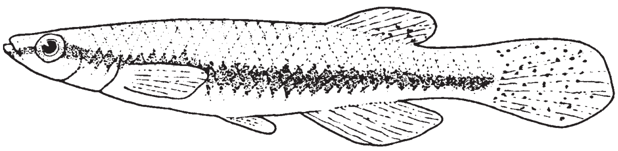
Topminnows, as their name implies, spend most their time at the water surface. Feeding with their upturned mouths and flattened heads just beneath the surface of the water causes noticeable ripples. Their upturned mouth and flattened head may allow topminnows to utilize a thin layer of oxygen-rich water at the surface which could allow them to occupy areas of depressed oxygen levels. Many tropical species in this family are popular aquarium fish. Some of the species in this family are used as experimental animals in laboratory behavioral and genetic studies.

Blackstripe Topminnow—*Fundulus notatus*

- ▼ dark, lateral band extends through eye
- ▼ body marked with random black spots
- ▼ upturned mouth
- ▼ length up to 4 inches

Pollution tolerance: intermediate

Figure 7-41



Livebearer Family—Poeciliidae

The livebearer family has about 160 species that are restricted to the southern part of the United States and farther south. They are close relatives to the killifish family and are difficult to differentiate by structural characteristics. The family is one of the few freshwater fish of the United States in which the female gives birth to living young.

The males possess an anal fin modified into a long, slender structure for transfer of the sperm called a *gonopodium*. The females carry the developing eggs until they hatch internally and the young emerge alive. The females are able to store sperm for over 10 months in their reproductive tracts, and several successive broods may be fertilized from one mating.

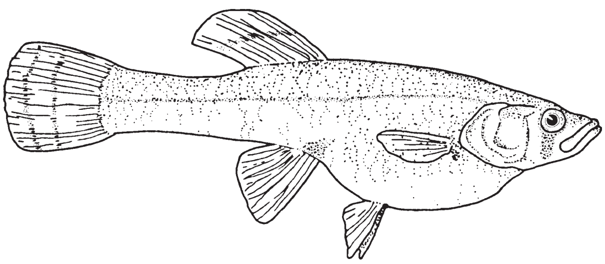
The mosquitofish has been widely stocked for mosquito control and serves as prey for a variety of predators. Many tropical species are popular in the aquarium trade.

Western Mosquitofish—*Gambusia affinis*

- ▼ body light olive, each scale dark edged
- ▼ length up to 2 inches

Pollution tolerance: tolerant

Figure 7-42

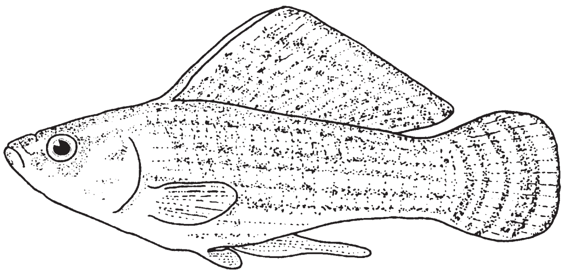


Sailfin Molly—*Poecilia latipinna*

- ▼ longitudinal row of black spots
- ▼ dorsal fin long and high
- ▼ caudal fin with black margin
- ▼ length up to 3 inches

Pollution tolerance: tolerant

Figure 7-43



Pupfish Family—Cyprinodontidae

Most species in this family inhabit water bodies in the desert areas of the southwestern United States and northern Mexico, but they can be found in estuarine waters. The family contains 44 species in North America. Most members are in the genus Cyprinidon, meaning "tooth carp" in reference to the many small teeth on the jaws; their roundish body shape also resembles a carp. This family no longer includes the topminnows. Topminnows were recently reclassified into the Family Fundulidae based on differences in bony structures.

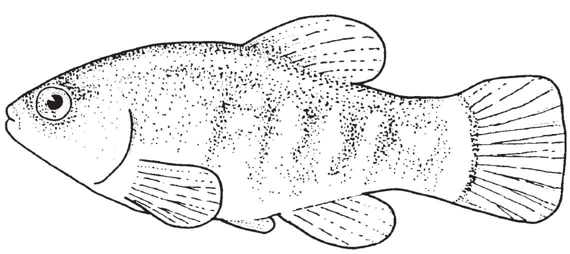
Pupfish are very tolerant of environmental conditions such as high water temperatures and low dissolved oxygen. They are among the most heat tolerant of all fishes and some species live in pools several times the salinity of sea water. The males are brilliantly colored during the mating season and become quite territorial. They feed primarily on insects, snails, and crustaceans. Most pupfish species are either threatened or endangered due to factors such as habitat loss resulting from surface and groundwater pumping, urban development, or hybridization and predation from the introduction of nonnative species.

Sheepshead Minnow—*Cyprinodon variegatus*

- ▼ olive-colored; deep bodied with hump back
- ▼ males have salmon-color belly; orange margin on dorsal and pelvic fins
- ▼ females have numerous crossbars
- ▼ length up to 3 inches

Pollution tolerance: tolerant

Figure 7-44



Temperate Bass Family—Moronidae

This family includes the true freshwater basses and several of their *anadromous* (fish that inhabit seas but go up streams to spawn) relatives. Temperate basses are represented in the United States by four species and one artificially-bred hybrid.

Two species, white and yellow basses, are strictly freshwater fish. The other two, white perch and striped bass, are anadromous, but can live their entire lives in fresh water and have been transplanted to inland reservoirs and lakes. The hybrid striped bass, a cross between a female striped bass and a male white bass, has been introduced into inland reservoirs and lakes.

Temperate basses are moderately deep bodied fish, with two entirely separate or only slightly connected dorsal fins, the first containing nine stiff spines. White bass, striped bass, and yellow bass have prominent dark, horizontal streaks along each side.

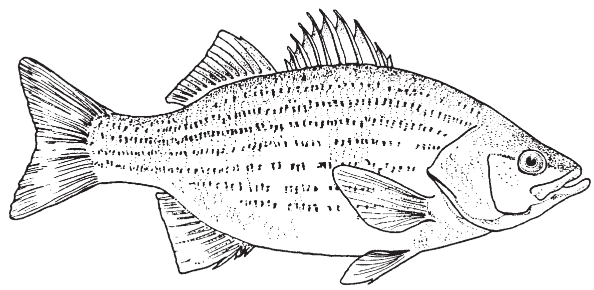
Temperate basses are *pelagic* (open water) fish, often traveling in schools where they feed upon small schooling fish, especially shad. During spring, the temperate basses make spawning runs in large schools from open lake water into tributary streams, or from large rivers into lesser tributaries.

White Bass—*Morone chrysops*

- ▼ deep bodied with silvery color
- ▼ sides with dark longitudinal stripes
- ▼ teeth on tongue in a single patch
- ▼ length up to 18 inches

Pollution tolerance: intermediate

Figure 7-45

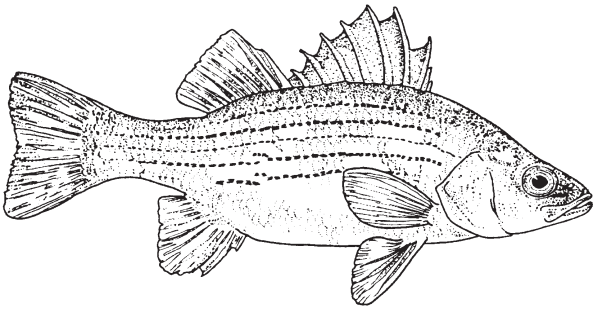


Yellow Bass—*Morone mississippiensis*

- ▼ deep bodied with yellow color
- ▼ sides with dark longitudinal stripes which are broken below lateral line
- ▼ no teeth on tongue
- ▼ length up to 10 inches

Pollution tolerance: intermediate

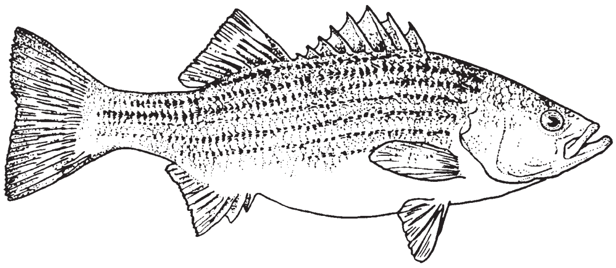
Figure 7-46



Striped Bass—*Morone saxatilis*

▼ slender bodied with silvery color
▼ sides with dark longitudinal stripes
▼ teeth on tongue in two patches
▼ length up to 4 feet
Pollution tolerance: intermediate

Figure 7-47



Sunfish Family—Centrarchidae

The sunfish family contains a total of 31 species, including sunfish, as well as crappies and black basses. The members of this family were not originally found west of the Rocky Mountains, except for the Sacramento perch in the central valley of California. Many species of this family have been introduced all over the world.

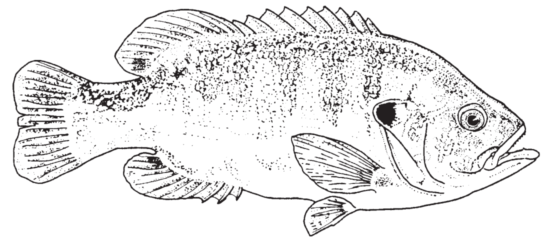
The members of this family closely resemble those of the perch family and the temperate bass family. They differ in that the spinous and soft portions of the dorsal fin are united and confluent, except in the largemouth bass (sunfish), where a deep notch almost separates the two parts. Natural hybridization between species is common, with the offspring showing characteristics of both parents.

Most sunfish are rather sedentary, remaining near submerged cover. They do not form schools, but they can occur in small groups or aggregations. Individuals of most species show definite attachment to a particular pool or stretch of stream. They feed primarily on insects, crustaceans, or small fish.

Green Sunfish—*Lepomis cyanellus*

▼ body short and deep
▼ base of dorsal fin much longer than base of anal fin
▼ dark spot at base of soft dorsal fin
▼ large mouth, maxillary extending to middle of eye
▼ dorsal, anal, and caudal fins edged with orange
▼ length up to 8 inches
Pollution tolerance: tolerant

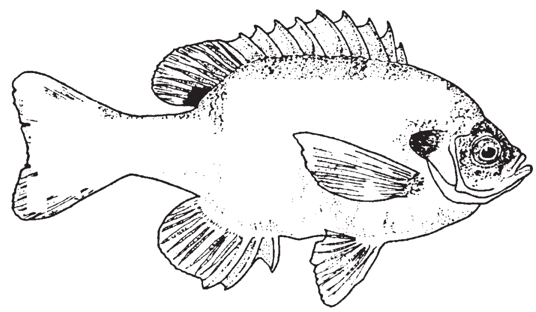
Figure 7-48



Bluegill—*Lepomis macrochirus*

▼ body short and deep
▼ small mouth, maxillary extending to front of eye
▼ dark spot at base of soft dorsal fin
▼ vertical bars on sides
▼ length up to 10 inches
Pollution tolerance: tolerant

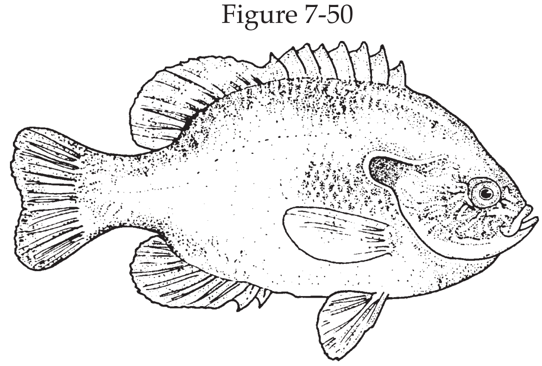
Figure 7-49



Longear Sunfish—*Lepomis megalotis*

▼ body short and deep
▼ base of dorsal fin much longer than base of anal fin
▼ small mouth, maxillary extending to front of eye
▼ opercle flap with white fringe
▼ brightly colored with orange spots and blue streaks
▼ length up to 8 inches
Pollution tolerance: intermediate

Figure 7-50

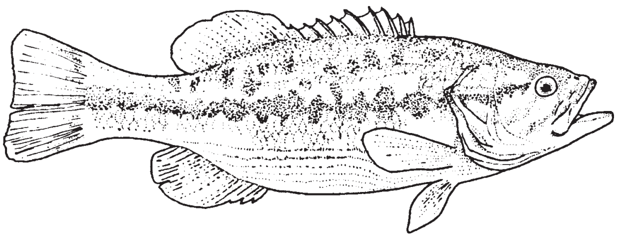


Spotted Bass—*Micropterus punctulatus*

▼ body elongate, dark green with lateral band
▼ spinous dorsal fin separated from soft dorsal fin by a small notch

▼ upper jaw does not extend beyond eye
▼ rows of spots along sides below lateral line
▼ length up to 17 inches
Pollution Tolerance: intermediate

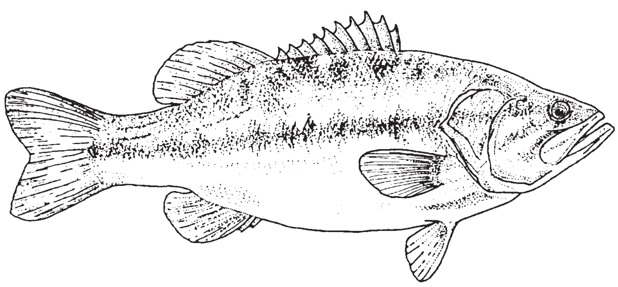
Figure 7-51



Largemouth Bass—*Micropterus salmoides*

▼ body elongate, dark green with lateral band
▼ spinous dorsal fin separated from soft dorsal fin by a deep notch
▼ upper jaw extends beyond eye
▼ length up to 28 inches
Pollution Tolerance: intermediate

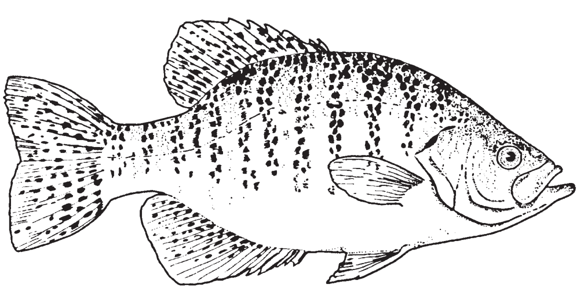
Figure 7-52



White Crappie—*Pomoxis annularis*

▼ body short, deep with faint vertical bars
▼ base of dorsal fin slightly longer than base of anal fin
▼ dorsal fin with 5 or 6 spines
▼ length up to 15 inches
Pollution Tolerance: intermediate

Figure 7-53



Perch Family—Percidae

Perch are a diverse family with about 150 species widely distributed in the North Temperate Zone in North America, Europe, and Asia. The perch family has three popular game fish: walleye, sauger, and yellow perch. Also included in the perch family are a number of small, lesser-known fish, referred to as darters. Darters, a strictly North American group, are native only to those regions east of the Rocky Mountains.

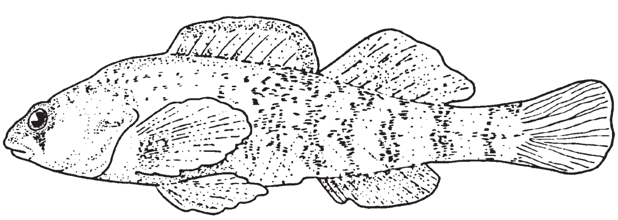
Perch taxonomy is difficult. This family of fish is characterized by a dorsal fin that is completely divided into two separate portions, one spiny and one soft-rayed portion. All members are predaceous, with the larger species being piscivorous, and the smaller darters preying on insects and crustaceans.

Darters are adapted for life in swift-flowing, rocky streams. Darters spend most of the time beneath or between rocks. When moving from place to place, darters proceed by a series of short, quick dashes, which is the origin of their name.

Orangethroat Darter—*Etheostoma spectabile*

▼ arched body, deepest at nape or front of dorsal fin
▼ body with variable colors, often dark bars (blue between orange on male, brown between yellow-white on female) on side
▼ fins with blue edge, red on dorsal and caudal fins
▼ length up to 3 inches
Pollution tolerance: intermediate

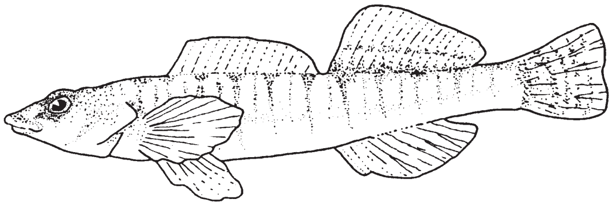
Figure 7-54



Bigscale Logperch—*Percina macrolepida*

▼ yellowish with sides marked by many vertical bars
▼ dark spot at base of caudal fin
▼ belly naked with a mid-ventral row of modified scales
▼ length up to 6 inches
Pollution tolerance: intolerant

Figure 7-55

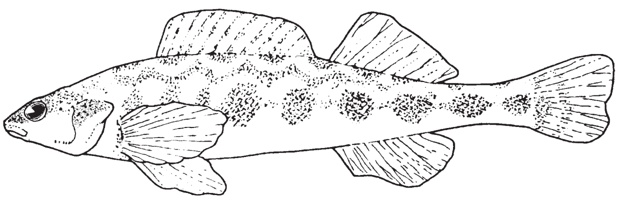


Dusky Darter—*Percina sciera*

- yellowish olive
- sides with about 7 confluent blotches
- length up to 5 inches

Pollution tolerance: intolerant

Figure 7-56



Drum and Croaker Family—Sciaenidae

The drum family is a largely marine or estuarine family found on the continental shelves of tropical and temperate seas worldwide. Only one of the 254 species in this family lives strictly in freshwater. It is the freshwater drum, a deep-bodied silvery fish with a high back. The lateral line extends out onto the caudal fin.

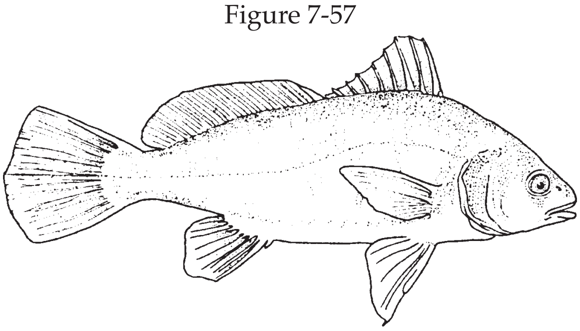
Many of the members of this family, including the freshwater drum, make a rumbling or grunting sound by way of a complicated swim bladder with special muscles and tendons. Drum feed mostly on the bottom, grinding their food with a powerful set of pharyngeal teeth.

Freshwater Drum—*Aplodinotus grunniens*

- deep bodied and silvery
- high back and a long dorsal fin
- lateral line extends out onto the caudal fin
- length up to 3 feet

Pollution tolerance: tolerant

Figure 7-57



Cichlid Family—Cichlidae

Cichlids are a large family native to rivers and lakes in Africa, and Central and South America. One species, the Rio Grande cichlid, ranges from Central America northward into Texas and has been introduced into other areas. Members in this family crossbreed or hybridize readily, making taxonomy difficult.

Members of this family are characterized by a broken lateral line and only one aperture for each nostril. The Rio Grande cichlid has a deep body that is brownish and speckled all over.

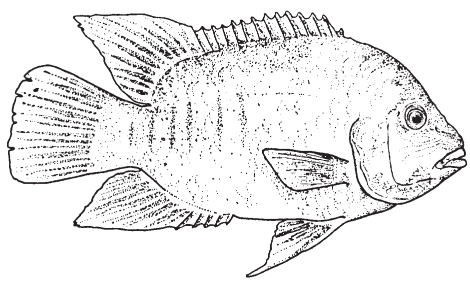
Cichlids are popular aquarium fish because of their brilliant colors. At least eight species have been established in North America. Some members of this family have been raised commercially by aquaculturists as food fish. Certain species in this family are on the Texas Parks and Wildlife Prohibitive Fish List because as predators, they compete with our native basses and sunfish.

Rio Grande Cichlid—*Cichlasoma cyanoguttatum*

- brownish in color and speckled all over
- lateral line broken under dorsal fin
- length up to 8 inches
- five or six anal fin spines

Pollution tolerance: intermediate

Figure 7-58

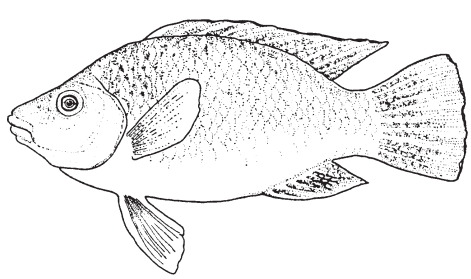


Blue Tilapia—*Oreochromis aurea*

- fewer than five anal spines
- sides unmarked or with vague, irregular dark markings
- caudal fin often has a broad red distal margin
- length up to 15 inches

Pollution tolerance: tolerant

Figure 7-59



CHAPTER

8 Common Reptiles

The most familiar groups of reptiles include crocodilians, turtles, lizards, and snakes. Reptiles are easily distinguished from amphibians by the scales, shields, or plates covering their bodies. Another difference is claws on the toes of alligators, lizards, and turtles.

Reptiles are air-breathing vertebrates that are cold-blooded, meaning their body heat is determined by the surrounding environment. Reptiles control their body temperature by moving to warmer or cooler areas as necessary. Young reptiles resemble their parents in appearance, if not always in coloration and pattern.

This section contains information on the more common reptiles found in or near aquatic habitats in Texas and was taken from Contant and Collins 1998; Dixon 2000; Garrett and Barker 1987; and Tennant *et al*. 1985. For detailed information and figures of reptiles associated with the aquatic environment, try one of the field guides listed in Chapter 14. Illustrations used in this chapter are the copyright property of Dover Publications and are reprinted with permission.

Crocodilians—Family Crocodilidae

There are 21 known species of crocodilians (alligators, crocodiles, and caimans) worldwide, but only two are native to the United States—American alligator and American crocodile.

The American alligator—*Alligator mississippiensis*—is the only native representative of the crocodilians in Texas. The American crocodile is also native to the southern-most tip of Florida.

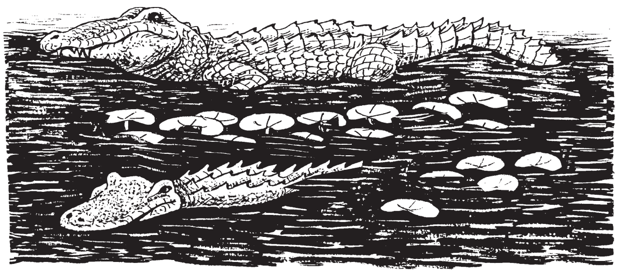
The American alligator is the largest reptile in North America, growing to more than 19 feet long as an adult. Alligators inhabit the eastern, east-central, and southeastern part of the state, and most of the Gulf of Mexico coast to the extreme southern tip of Texas near Brownsville.

Alligators are found in rivers, swamps, lakes, and bayous, and can tolerate the brackish water of coastal marshes. They are semiaquatic, spending much time basking on land. However, during the coldest months and in dry seasons, they dig deep holes in muddy banks, where they hibernate.

Alligators are carnivorous predators that feed primarily on fish, snakes, turtles, small mammals, and waterfowl. When a larger prey is captured, the alligator will twist underwater until the prey drowns. The alligator can chew underwater but must surface to swallow. Alligators produce a hissing sound when disturbed.

When breeding, the female alligator builds a large mound of mud and leaves about 6 feet across and 2 or 3 feet high. She excavates the center, where up to 60 hard-shell oval eggs about 3 inches long are deposited. During the nine-week incubation period, the female stays near the nest and is extremely protective. The call of the hatchlings prompts the female to scratch open the nest. The hatchlings are about 9 inches long and stay with the female for a year or more.

Figure 8-1



Turtles

Turtles are the oldest living reptiles. Freshwater turtles have a toothless, horny beak and a shell of bony dermal plates, usually covered with horny shields, enclosing the soft body. The head, limbs, and tail may be drawn into the shell when necessary.

Turtles have scaly skin and are often seen basking on rocks and logs. Turtles exhibit a wide variety of color and patterns, and identification often requires close examination. Turtles lay eggs in cavities dug out by the female.

Texas is home to 35 species, with about 240 species found worldwide. Information on the more common turtles found in or near aquatic habitats in Texas is listed in the following sections.

Snapping Turtles—Family Chelydridae

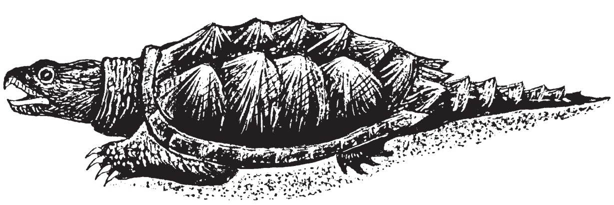
Two species of snapping turtles are found in Texas: the common snapping turtle—*Chelydra serpentina serpentina* and the alligator snapping turtle—*Macrolemys temminckii*. Snapping turtles inhabit freshwater, but may enter brackish waters. They feed on a variety of food, including aquatic plants, invertebrates, fish, carrion (dead animals), waterfowl, other reptiles, and mammals.

Snapping turtles rarely bask in the sun as most other turtles do. In shallow water, they often bury themselves in mud with only their eyes and nostrils visible. Differences between the two species of snapping turtles are their size and where they are found. The common snapping turtle can be found statewide, except for the western Trans-Pecos region and the Lower Rio Grande Valley. The alligator snapping turtle, the largest freshwater turtle in North America, is found in the eastern one-third of the state.

The two species of snapping turtles are both large and similar in appearance:

- ▼ huge head, powerful jaws with a strongly hooked beak
- ▼ shell with prominent keels (ridge)
- ▼ long tail
- ▼ alligator snapping turtle (up to 2 feet long and up to 300 pounds) is larger than the common snapping turtle (up to 19 inches long and up to 50 pounds)
- ▼ distinguishing characteristics between the two species: saw-toothed tail of the common snapping turtle; presence of extra rows of *scutes* (horny plates) on the shell of the alligator snapping turtle

Figure 8-2



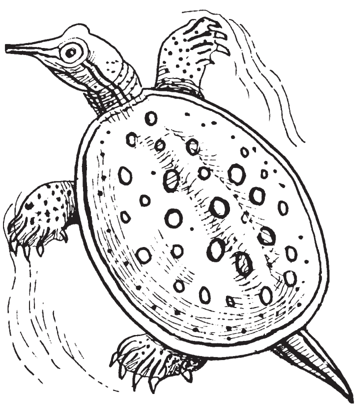
Soft-Shelled Turtles–Family Trionychidae

Two species of soft-shelled turtles are common in Texas: the smooth soft-shelled turtle—*Trionyx muticus muticus*, and the spiny soft-shelled turtle—*Trionyx spiniferus.* Soft-shelled turtles may bask onshore, but are very agile on land and quickly slide into the water when disturbed. The smooth soft-shelled turtle is found throughout the state. There are four subspecies of the spiny soft-shelled turtle, with each subspecies having its own distinct geographical distribution.

The two species of soft-shelled turtles are similar in appearance:

- ▼ reach up to 14 inches in length
- ▼ long neck
- ▼ olive-gray, leathery carapace marked with dots and dashes slightly darker than the background color
- ▼ distinguishing characteristics between the two species: spiny soft-shelled turtle has spines or bumps on its carapace; ridges on the nostrils; strongly spotted or streaked feet

Figure 8-3



Box and Water Turtles–Family Emydidae

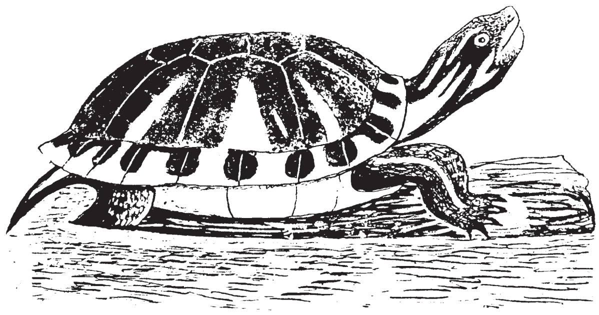
The largest of all turtle families has two common species in Texas: the red-eared slider— *Trachemys scripta elegans* and the Texas river cooter—*Pseudemys texana*. Both species are commonly seen basking on logs, rocks, or other objects sticking out of the water. However, both are very wary and will slip into the water when approached.

Red-Eared Slider—*Trachemys scripta elegans*

The red-eared slider prefers quiet water with a muddy bottom and abundant vegetation. This is the turtle that dime stores once commonly sold as pets. These turtles are found statewide, except in far west Texas and along the New Mexico border. They feed mostly on aquatic plants.

- ▼ length up to 11 inches
- ▼ unique broad, reddish stripe behind the eye
- ▼ rather flat shell; dark green with light and dark markings in the form of bars, stripes, whorls, and circles

Figure 8-4

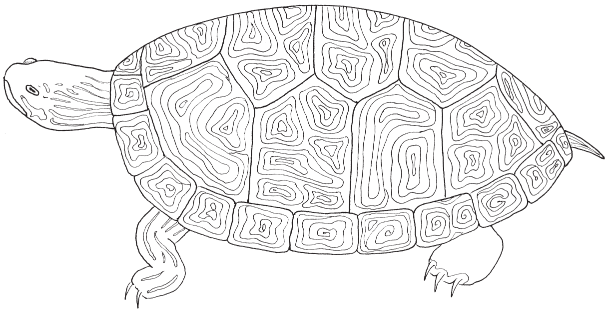


Texas River Cooter—*Pseudemys texana*

Usually found in rivers, the Texas River cooter may also inhabit ditches and stock tanks. These turtles are found in a broad area extending from the northwest-central part of the state and down to the coast south of Freeport in the watersheds of the Colorado, Brazos, Guadalupe, and San Antonio Rivers.

▼ length up to 12 inches
▼ variable head markings, with many lateral stripes
▼ short, broad shell; slightly rough; dark olive-brown and marked with yellow whorls created by thin curving lines

Figure 8-5



Musk and Mud Turtles—Family Kinosternidae

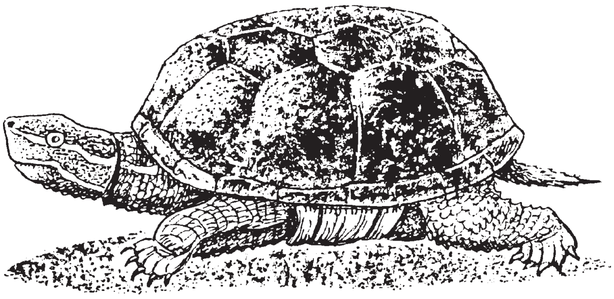
The Family Kinosternidae is often referred to as the "stinkpot." The name is derived from a musky secretion exuded from glandular openings on the side of the body when the turtle is alarmed. Turtles in this family rarely leave the water and bask mainly in shallow water with only a portion of their shell exposed. The more common representative of the species found in Texas is the yellow mud turtle—*Kinosternon flavescens flavescens*.

Yellow Mud Turtle—*Kinosternon flavescens flavescens*

Found statewide, the yellow mud turtle inhabits a variety of aquatic habitats except for the eastern third of the state. It feeds on aquatic invertebrates, worms, and tadpoles, and can be seen foraging on land during rains.

▼ length up to 6 inches
▼ yellowish chin and throat visible from a distance
▼ usually flat shell; smooth on top; olive-brown to olive-green

Figure 8-6



Snakes

Snakes are easily recognizable as a limbless, scaled reptile with a long tapering body. Over 2,300 species of snakes are known worldwide. Snakes are spread throughout the world, but are notably absent from many islands, including Ireland, New Zealand, and numerous South Sea archipelagos. Some species have salivary glands modified to produce venom that is injected through grooved or tubular fangs.

Vipers—Family Viperidae

The viper family contains all of the poisonous snakes found in Texas (copperhead, cottonmouth, and rattlesnakes) except coral snakes. The pit viper common name comes from the facial pit on each side of the head midway between the eye and nostril. The pit is a sensory organ that helps detect warm-blooded prey. General characteristics of the family include a head wider than the neck and vertically elliptical pupils. The most common viper found in Texas aquatic habitats is the western cottonmouth—*Agkistrodon piscivorus leucostoma*.

Western Cottonmouth—*Agkistrodon piscivorus leucostoma*

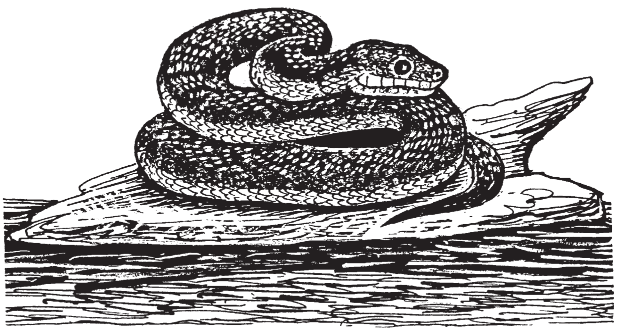
Cottonmouths often stand their ground or crawl slowly away. A cottonmouth vibrates its tail when excited and throws its head upward and backward, and holds its mouth wide open to reveal a whitish interior. This behavior is the origin of the name cottonmouth. In contrast, water snakes usually flee quickly and do not vibrate their tails when excited. Cottonmouths are found in a variety of habitats including central, south-central, and east Texas. Prey consists of fish, frogs, salamanders, birds, and small mammals.

▼ length up to 4 feet

▼ short, heavy body; sometimes a dark, dorsal crossband; many specimens are plain black or dark brown with no pattern

▼ closely resembles the nonpoisonous water snakes (*Nerodia*)

Figure 8-7



Colubrids—Family Colubridae

This large family of nonpoisonous snakes contains 75 percent of the genera and 78 percent of the species of snakes in the world. Three representatives of this family are common in aquatic habitats in Texas: the diamondback water snake—*Nerodia rhombifer rhombifer*, the blotched water snake—*Nerodia erythrogaster transversa*, and the ribbon snake—*Thamnophis proximus* var.

Diamondback Water Snake—*Nerodia rhombifer rhombifer*

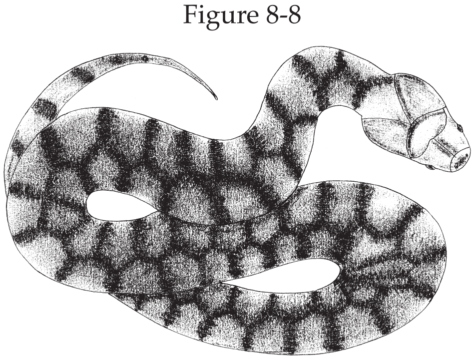
The diamond back water snake is consistently mistaken for the cottonmouth snake. It is found in many habitats, from lakes and rivers to ditches. This snake is a vigorous biter with an extraordinary musking ability when molested. It is found in most areas of the state, except for the western third. Prey consists of carrion, frogs, and fish.

▼ length up to 4 feet

▼ dark, heavy body

▼ color pattern on back: dark-brown, chain-like markings on a background color of lighter brown or dirty-yellow

Figure 8-8



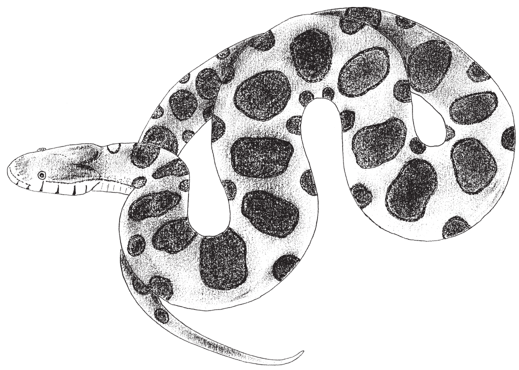
Blotched Water Snake—*Nerodia erythrogaster transversa*

The blotched water snake is found in a variety of aquatic habitats. They may venture some distance from water after dark to feed, especially after rainfall. If unable to escape, this snake may flatten its head and neck and strike several times in succession. This snake is found statewide, except in the far eastern, southern, and western regions. Prey consists of fish, frogs, tadpoles, and crustaceans.

▼ length up to 4.5 feet

▼ chocolate brown with a blotched pattern; color may vary from gray to brown with markings darker than background

Figure 8-9



Ribbon Snake—*Thamnophis proximus* var.

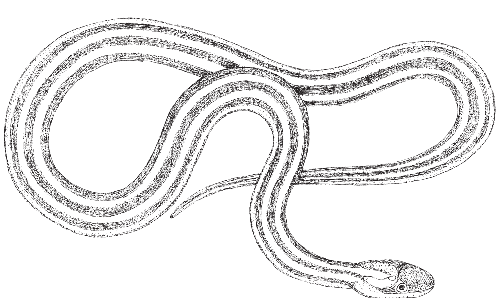
Four subspecies of ribbon snakes are found in Texas, each with its own distinct geographical distribution. Ribbon snakes are likely to be found near a variety of aquatic habitats. They are also found in brush country, though seldom far from water. They swim on the water surface instead of diving, as water snakes do. Prey consists of fish, frogs, lizards, and toads.

▼ length up to 3 feet

▼ slim, agile, and nervous

▼ marked with three stripes, normally yellow or orange with a greenish tinge

Figure 8-10



CHAPTER

9 Common Amphibians

Amphibians have many characteristics that are intermediate between fish and reptiles. The word amphibian derives from Greek and means "living a double life." Larvae of amphibians have gills and live in water, while adults breath air.

Amphibians, like reptiles, are vertebrates that are cold-blooded, drawing their body heat from outside sources and controlling their body temperature by moving to warmer or cooler areas as necessary. Amphibians have moist, glandular skin, and their toes are devoid of claws. Amphibians lay gelatinous-covered eggs in moist areas. Their young pass through a larval, usually aquatic, stage (tadpoles) before they metamorphose into the adult form. The young metamorphose into miniature adult look-a-likes. The most familiar groups of amphibians include the frogs, toads, and salamanders.

The information in this section is from Contant and Collins (1998), Dixon (2000), Garrett and Barker (1987), and Tennant *et al*. (1985). For detailed information and figures of amphibians associated with the aquatic environment, try one of the field guides listed in Chapter 14.

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Frogs

Frogs are largely aquatic amphibians that have smooth skin, webbed feet, no tail, and are agile leapers. The typical frog has a relatively smooth skin and long legs for leaping, while the typical toad has a warty skin and short legs for hopping. Each species has its own distinctive call for announcing its presence and for mating.

While the females of most species lay egg masses on the surface of the water, the eggs may adhere to vegetation or woody debris. The tadpoles of frogs transform generally within weeks. In arid regions or during prolonged droughts, these amphibians may estivate (go dormant) for months at a time.

Frogs feed on insects, crayfish, minnows, and on almost anything smaller than themselves.

True Frogs—Family Ranidae

Many members of this family have the characteristics of the typical frog, such as long legs, narrow waist, smooth skin, and webbed toes. The most common members of this family in Texas aquatic habitats are the bullfrog (*Rana catesbeiana*), and the three species of leopard frog (*Rana* sp.).

The three species of leopard frogs look similar and are difficult to identify to individual species. The males of some species have paired vocal pouches at the sides of the throat. However, females of some species can vocalize when alarmed. These frogs feed on insects, crayfish, and minnows.

Bullfrog—*Rana catesbeiana*

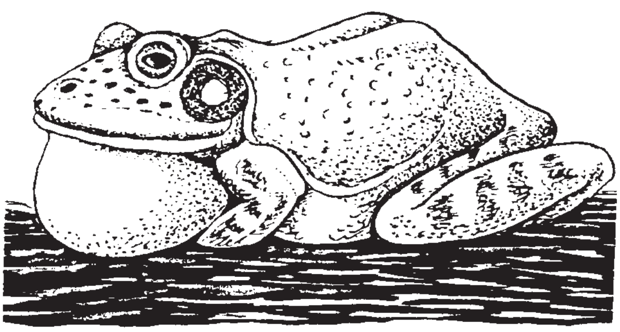
The bullfrog has a vocal sac which inflates to enormous size during calls, which are commonly heard in the evenings of early summer. When deflated, the sac forms a flat pouch under the chin.

This voracious frog will eat nearly anything that moves and can swallow. Prey consists of insects, crayfish, minnows, other frogs, and small snakes.

Bullfrogs are found statewide, except in mountain ranges of west Texas. They have had their range extended in the U.S. by people. Frogs are commonly removed from the wild to become "pets" and are often released or escape from their new location. Once established in new habitats, bullfrogs have reduced the local populations of native amphibians.

- ▼ length up to 8 inches
- ▼ large (largest frog in Texas), broad body with plain or nearly plain green color above, or a net-like pattern of gray or brown on a green background
- ▼ prefers larger bodies of water than most frogs

Figure 9-1

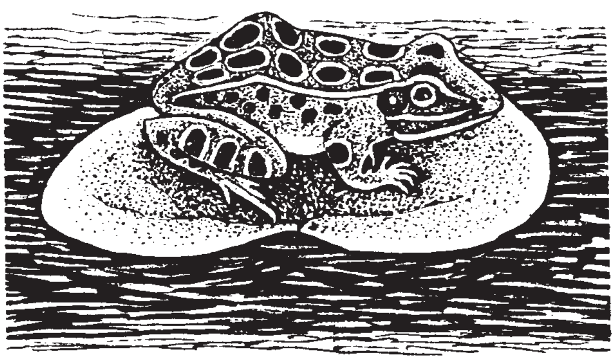


Leopard Frog—*Rana*

There are three species of leopard frogs in Texas, each with their own distinctive geographic distribution: plains leopard frog (north-central region and panhandle of Texas), southern leopard frog (central and west Texas), and Rio Grande leopard frog (central, far west, and south Texas). The southern leopard frog is found in all aquatic habitat types, even entering brackish marshes along coasts. The plains leopard frog and Rio Grande leopard frog are adapted to dry conditions but are also found along streams and pond edges.

- ▼ length up to 5 inches
- ▼ brown or green with 2 or 3 rows of irregularly placed dark spots between prominent yellowish ridges on back
- ▼ numerous additional rounded dark spots on sides

Figure 9-2



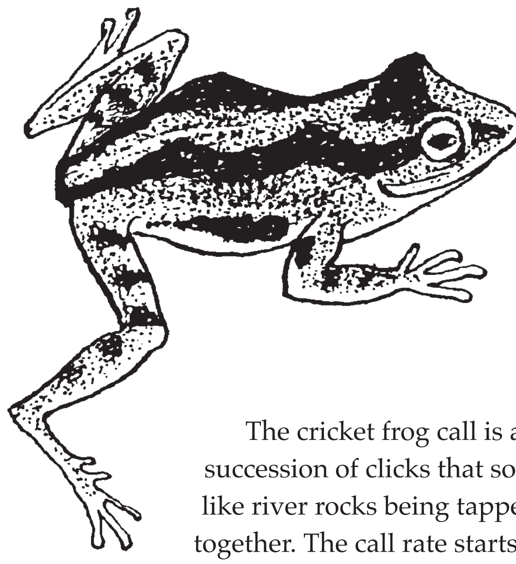
Tree Frogs—Family Hylidae

The tree frog family is large, with approximately 635 species. Members in this family are generally small with slim waists and long limbs. The most common species found in Texas aquatic habitats is the cricket frog (*Acris crepitans*).

Cricket Frog–Acris creptians

- ▼ length up to 2 inches
- ▼ generally, light gray to greenish brown, with indistinct dark markings on its back and dark bands on its legs
- ▼ line along the upper jaw is not as distinct as in other species

Figure 9-3



The cricket frog call is a succession of clicks that sound like river rocks being tapped together. The call rate starts at about one per second and gradually increases. This species prefers shallow water ponds with plenty of vegetation in the water.

Three subspecies of cricket frogs live in Texas: Blanchard's cricket frog (*Acris crepitans blanchardi*), northern cricket frog (*Acris crepitans crepitans*), and the coastal cricket frog (*Acris crepitans paludicola*). The coastal cricket frog is found along the coast near Beaumont. The northern cricket frog is found in the eastern one-fourth of the state. Blanchard's cricket frog is found statewide except for far east Texas, the western Panhandle, and the extreme western tip.

Prey includes insects and most anything smaller than itself.

CHAPTER

10 Common Birds

Of all 50 states, Texas has the largest number of bird species. More than 540 species have been recorded in this state. This is three-quarters of all the species known to occur between Mexico and the Canadian border. A large percentage of those North American birds that spend the winter in the tropics pass through Texas on their migrations. This section only lists a few of the more common birds associated with the aquatic environment.

For detailed information and figures of birds associated with the aquatic environment, consult one of the many available field guides to birds. Several of the more common field guides available are listed in the Chapter 14.

Information in this section was taken from Peterson 1988 and Rappole and Blacklock 1994.

Note: The bird illustrations used in this chapter are the copyright property of Dover Publications and are reprinted with permission.

Anhingas—Family Anhingidae

Members of the anhinga family are large, blackish, slender-billed, birds that eat fish. The only representative of the species found in Texas is the *Anhinga anhinga*.

Figure 10-1

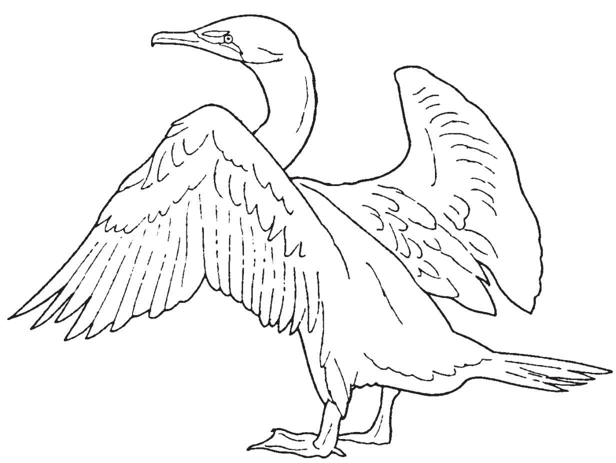
The anhinga is similar in appearance to the cormorant, but the anhinga has a much larger, longer fan-shaped tail, a pointed straight bill, and a long, snake-like neck. For this reason they are also known as the "snakebird." Anhingas dive from the water surface using their sharply pointed bill to spear fish. At times they are observed swimming with only their head and neck above the water.

Anhinga prefer freshwater habitats and are often seen perched on branches or stumps with wings spread to dry because they lack oil glands. In flight, their profile looks headless. Slow, regular wingbeats alternate with high soaring on flat wings. Anhingas reach a length of 36 inches, with a wingspan of 45 inches.

Cormorants—Family Phalacrocoracidae

Like the anhingas, members of the cormorant family are large, blackish, slender-billed birds that eat fish. However, the cormorant has a smaller tail and a hooked bill.

Figure 10-2



Two species are found in Texas: the neotropic cormorant (*Phalacrocorax brasilianus*) and the double-crested cormorant (*Phalacrocorax auritus*). The two species of cormorants are difficult to distinguish. Cormorants reach lengths up to 32 inches, with a wingspan up to 63 inches.

Cormorants dive from the water surface, using their sharply pointed bill to spear fish. They soar high on flat wings and may swim submerged to the neck. They can be found at marshy ponds or shallow inlets perching on stumps and snags.

In flight, cormorant flocks fly high in a line or wedge formation very much like geese, but they are silent. Cormorants often perch in an upright position on posts with their necks in an "S," and with wings spread to dry because they lack oil glands.

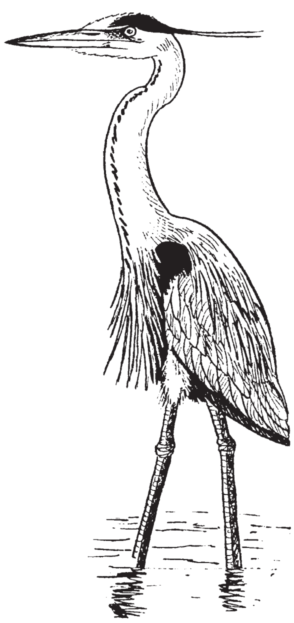
Herons—Family Ardeidae

Herons are wading birds that have long legs, long necks, and dagger-like bills used for stalking food in shallow water. Graceful crests and plumes adorn some species in breeding season. Thirteen species are found in Texas. Herons feed on a variety of aquatic life, including fish and frogs.

Great Blue Heron—*Ardea herodias*

The great blue heron stands approximately 4 feet high with a wingspan of 6 feet. They have characteristically long legs, long necks, and dagger-shaped bill. The most distinguishing feature is their blue-gray plumage. They are commonly found along lakes, ponds, marshes, swamps, rice fields, and rivers. They feed alone in shallow water, stalking for fish, frogs, and crayfish. Great blue herons are often seen standing motionless on the banks of water bodies.

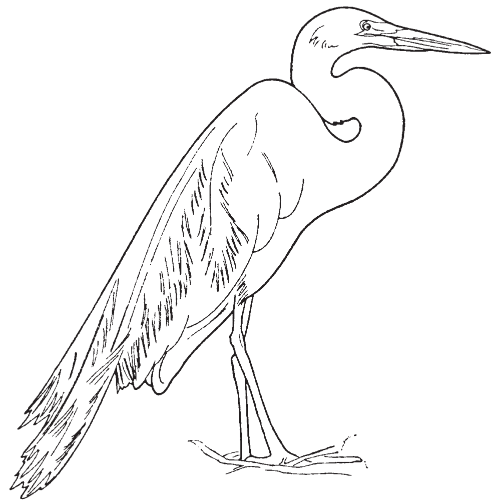
Figure 10-3



Great Egret—*Casmerodius albus*

The great egret is a large heron with pure white feathers, a heavy yellow bill, and blackish legs and feet. During breeding, long plumes trail from its back, extending beyond the tail. The great egret can reach a height of 3.25 ft with a wingspan of 5 feet. They are commonly seen in marshes, ponds, and coastal mud flats, and are partial to open habitats for feeding, where they slowly and methodically stalk prey. Once greatly reduced in numbers by plume hunters at the turn of the century, their populations are now mostly recovered.

Figure 10-4

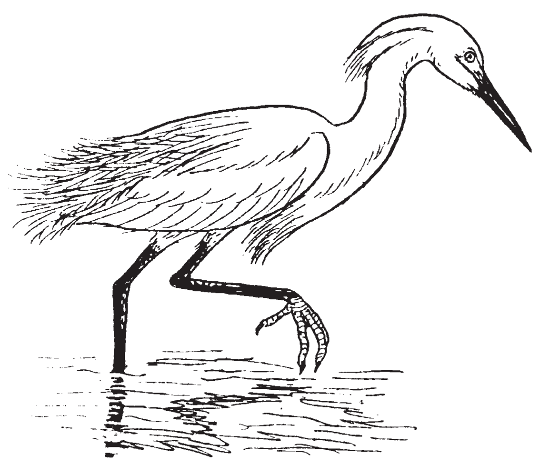


Snowy Egret—*Egretta thula*

The snowy egret is a rather small white heron with a slender black bill, yellow eyes, black legs, and yellow feet. It reaches a height of 27 inches, with a wingspan of 3 feet. Snowy egrets are common in marshes, swamps, ponds, and along shorelines. Their unique feeding habit involves sprinting rapidly through shallow water, chasing schools of bait.

The snowy egret was once hunted extensively for its plumes. Now protected, its populations have recovered. The cattle egret is very similar in appearance but has yellow legs instead of black. Cattle egrets, as their name implies, are found near cattle.

Figure 10-5



Kingfishers—Family Alcedinidae

Kingfishers are stocky and short-legged, with a large head, a large bill, and ragged crests. They are seen near streams, ponds, and in coastal areas. Kingfishers feed mainly on fish, but some prefer insects and lizards. They hover over water or watch from low perches, then plunge headfirst to catch a fish.

The kingfisher's heavy bill and strong feet serve for digging long nest burrows in stream banks. Three species of kingfishers are found in Texas. The two more common species are the belted kingfisher—*Ceryle alcyon,* and the green kingfisher—*Chloroceryle americana*.

Belted Kingfisher—*Ceryle alcyon*

The belted kingfisher is larger than the green kingfisher, reaching a height of 14 inches; they have blue-gray feathers above with a ragged, bushy crest and a broad gray breastband. Both male and female have a slate-blue breast band. The belted kingfisher is common and conspicuous along rivers, ponds, lakes, and estuaries.

Figure 10-6

Green Kingfisher—*Chloroceryle americana*

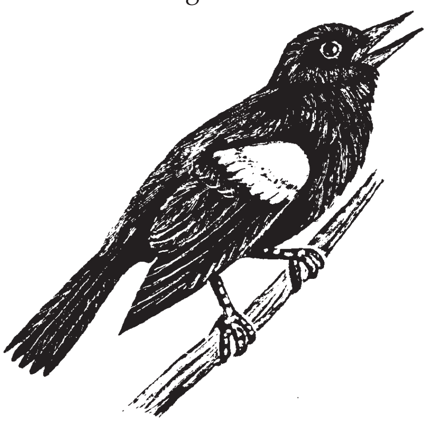
The green kingfisher reaches a height of up to 8 inches and has greenish feathers with white on the underside. Their flight is direct and very fast. Often perching on low, sheltered branches, the green kingfisher is a fairly common resident of lower Rio Grande Valley. The male has a broad reddish breastband, the female has two greenish bands, and both have a white collar.

Redwinged Blackbirds–Family Icteridae

Strong, direct flight and pointed bills mark this diverse and familiar group. There are 18 species found in Texas. The more common member found in Texas is the redwinged blackbird—*Agelaius phoeniceus*. The male redwinged blackbird is a glossy black color with a red and yellow shoulder patch. The females are brownish with well-defined black striping.

Redwinged blackbirds reach lengths up to 9 inches. This abundant, aggressive bird is often found in immense flocks in winter and generally nests in thick vegetation of freshwater marshes and sloughs. They frequent a wide variety of habitats and feed on insects, small fruit seeds, and small aquatic animals.

Figure 10-7



CHAPTER

11 Common Aquatic Plants

Introduction

Aquatic plants are often referred to as *macrophytes,* or large plants. Numerous species of aquatic plants are found in and around ponds, reservoirs, and streams. Aquatic plants have adapted to living in a variety of water conditions ranging from swift-flowing to stagnant. Aquatic plants are an important part of an aquatic ecosystem. Plants affect water quality by adding oxygen to the water column and by stabilizing bottom sediments and shorelines to reduce turbidity. They also provide protection, feeding areas, and spawning areas for fish, invertebrates, and waterfowl.

Aquatic plants are grouped in three general categories according to their growth habits (Figure 11-1).

Floating plants. Plants that float freely on the surface and plants that are rooted on the bottom with their leaves floating on the surface.

Emergent plants. Plants that are rooted to the bottom and grow above the water along shorelines and in shallow water areas.

Submerged plants. Plants that are generally rooted at the bottom and are completely underwater, except for seed heads or flowers.

Nearly all aquatic plants inhabit the littoral zone, or near-shore area. The extent to which they move away from shore depends on the depth that light penetrates into the water column. In large lakes, plants may inhabit only shallow near-shore areas. In shallow lakes, ponds, and slower-moving streams and rivers, aquatic plants may inhabit the entire water body. Free-floating plants, such as water hyacinth, cause problems by covering a water body and reducing the amount of light available to other aquatic organisms.

The following section includes drawings and short descriptions to help identifying the common aquatic plants. Information in this section is from Hotchkiss (1972), Tarver *et al*. (1986), and Westerdahl and Getsinger (1988).

Note: Aquatic plant line drawings used in the sections on floating, emergent, and submerged plants are the copyright property of the University of Florida Center for Aquatic Plants in Gainesville, Florida, and are used with permission.

Floating Plants

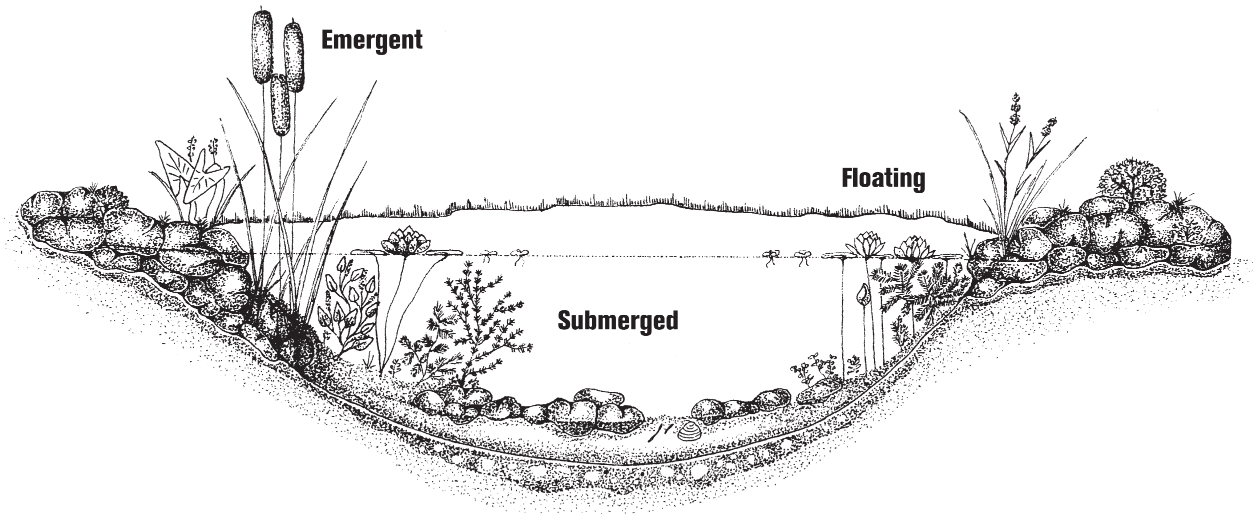
Common Duckweed—*Lemna*

Small, free-floating, green frond with one root per frond. Fronds may occur singly or in groups.

Occurs throughout most of the world with seven species in North America. Duckweed, which is eaten by waterfowl, is usually found in ponds, backwater areas of lakes, along slow-moving rivers, and in ditches. Duckweed can occur in large

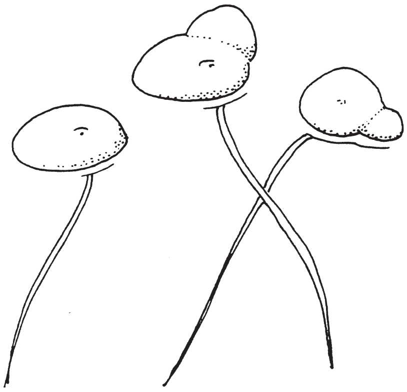
Figure 11-1

Aquatic Plant Habitats in Freshwater Lakes and Ponds



enough numbers to form a green blanket over the water surface.

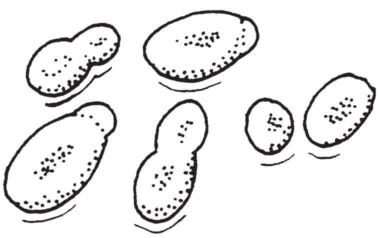
Figure 11-2



Watermeal—*Wolffia*

Very small, free-floating, bright-green plant without rootlets. Fronds often occur in pairs. Three species occur in the United States. Watermeal, which is eaten by waterfowl, usually grows with other duckweed in backwater areas.

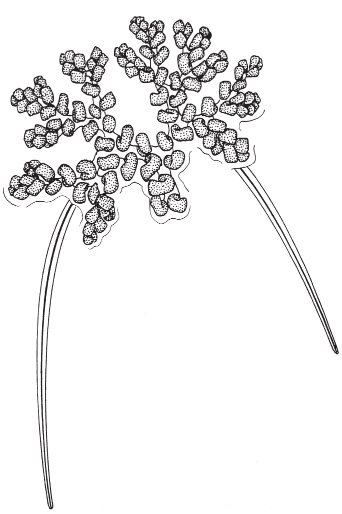
Figure 11-3



Water Fern—*Azolla*

Small, free-floating fern often reddish in color. Three species occur in the United States and Canada. The individual fronds usually grow grouped together and inhabit still-water areas. Water fern typically cover the entire water surface.

Figure 11-4



Water Hyacinth—*Eichhornia crassipes*

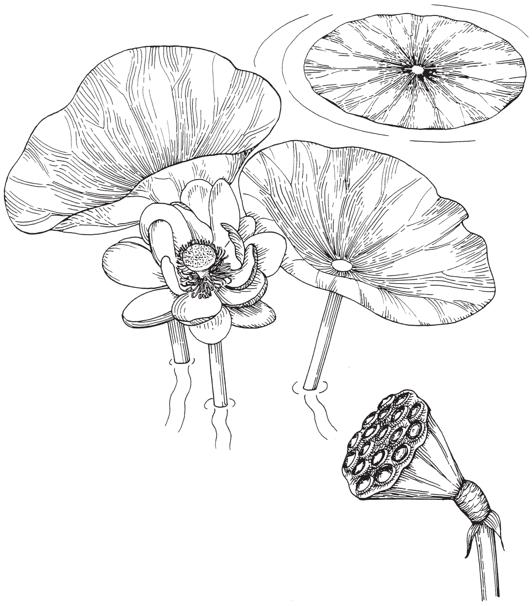
Somewhat tall, free-floating plant with spongy stems and a light-blue to violet flower. Numerous dark fibrous roots are located beneath the plant. The seeds can remain dormant in the sediment for years until reflooding occurs. This plant can form extensive mats and can clog waterways. Water hyacinth inhabits inland and coastal freshwater bays and lakes. It has been used in municipal wastewater treatment facilities because of its pollutant absorption capabilities. The five species of water hyacinth are native to Central and South America. See Chapter 12 for information on nonnative species.

Figure 11-5

American Lotus—*Nelumbo lutea*

A rooted plant with circular leaves, up to 2 feet across, floating on or above the water surface. Plant stem attaches to center of a floating leaf. The flower is solitary, pale-yellow, and up to 10 inches across. The acorn-like seeds are in individual pits in a flat-topped receptacle. Dried seed pods are commonly used in flower arrangements. Inhabits lakes and quiet streams, often forming extensive colonies.

Figure 11-6



Water Shield—*Brasenia schreberi*

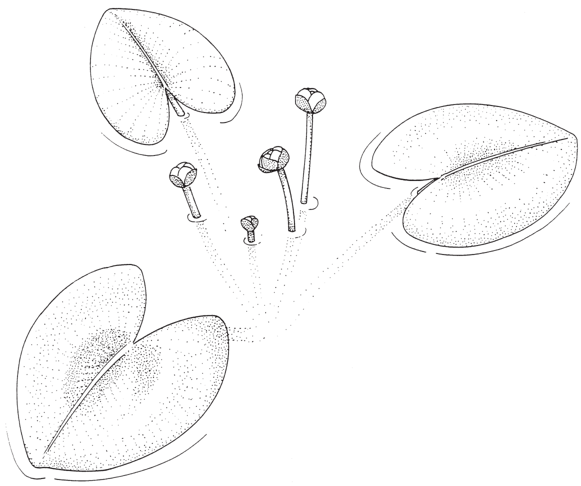
A plant with floating leaves and creeping roots covered with thick gelatinous coating. Leaves are green on the upper surface, purple on the lower surface, 5 inches long, and 3 inches broad. Flowers are purplish. Inhabits shallow water areas. The seeds, leaves, and underwater portions are eaten by waterfowl.

Figure 11-7

Cow Lily or Spatterdock—*Nuphar*

A plant with ovate (egg-shaped) leaves, heart-shaped at the base, shiny, smooth, and approximately 16 inches long. Some of the leaves float, but most of them stand above the water. Solitary flower is yellow and 1 to 3 inches in diameter. Lateral leaf veins arise from a central vein. Inhabits water up to 5 feet in depth, often forming extensive colonies. The seeds are eaten by waterfowl, and the rootstocks are eaten by rodents.

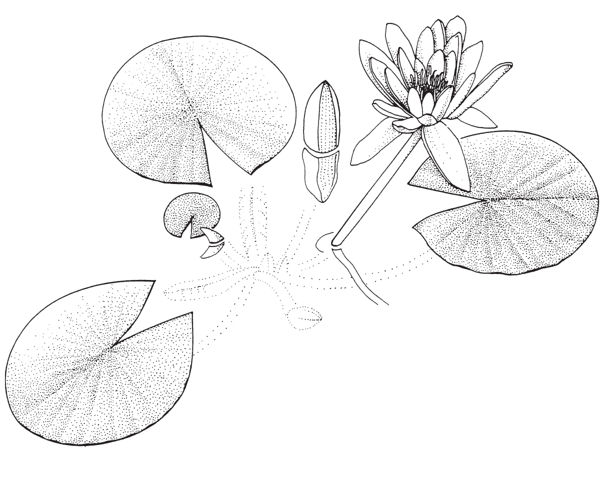
Figure 11-8



Waterlily—*Nymphaea*

Leaves circular, cleft at the base, up to 10 inches broad, and mostly floating. Solitary flower is white, fragrant, and 5 inches in diameter. Leaf veins branch outward like a fan from the stem top. Inhabits water up to 5 feet in depth, often forming extensive colonies. The roots are eaten by rodents.

Figure 11-9



Submerged Plants

Coontail—*Ceratophyllum*

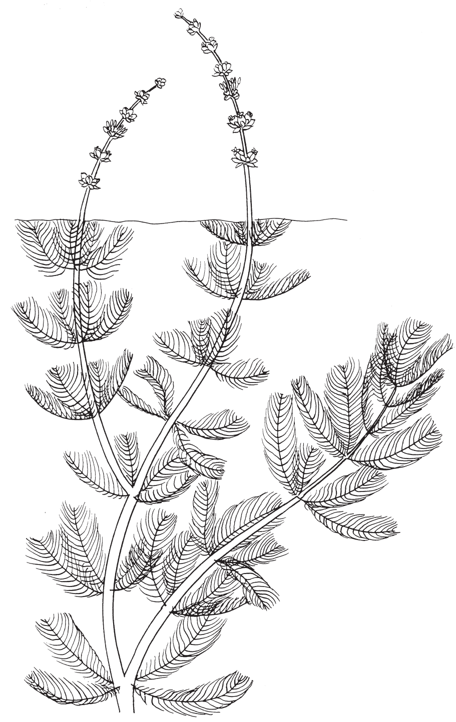
Olive to dark-green plant with many branched stems and no roots. Leaves with many divisions into narrow segments. Inhabits standing water, often forming dense colonies. One of the most abundant freshwater plants. The seeds and foliage are eaten by waterfowl.

Figure 11-10

Water Milfoil—*Myriophyllum*

Reddish-brown stems with olive-green leaves in a whorl and divided into feather-like segments, often extending above the water surface approximately 4 inches. Inhabits a variety of water body types. The fruits are eaten by waterfowl. Native to South America. Common aquarium plant. Sometimes referred to as parrot feather.

Figure 11-11



Hydrilla—*Hydrilla verticillata*

Dark-green plant with long branching stems. Leaves are whorled with toothed margins and midrib spines. Flowers are inconspicuous and white on long stalks. Found in most water habitats. Native to Africa, introduced in North America from aquaria trade. Causes problems because it forms dense mats and can interfere with navigation, water flow, and recreational activities. See Chapter 12 for information on nonnative species.

Figure 11-12

Southern Naiad or Bushy Pondweed—*Naja*

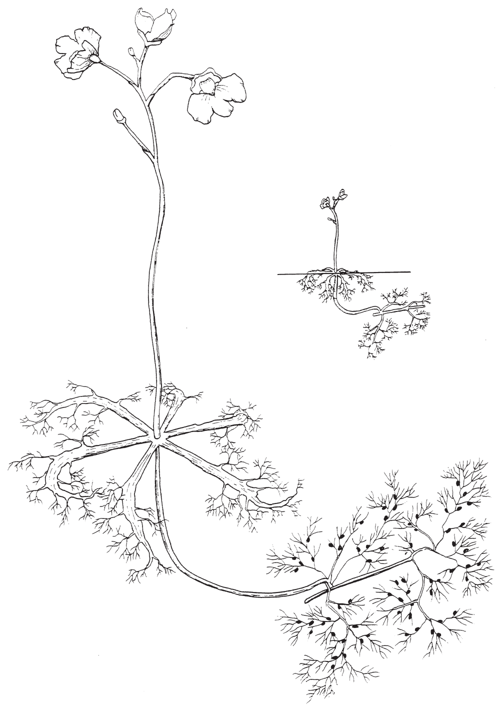
Slender plant possessing linear, deep-green or greenish-purple leaves. Inhabits a variety of water habitats. The entire plant serves as food for waterfowl. Very common plant in Texas ponds.

Figure 11-13

Bladderwort—*Utricularia*

A rootless plant with threadlike leaves and bearing bladders. The bladders act as traps for small aquatic invertebrates and fish. They possess small flowers in a cluster that extends upright above the water. Flowers are yellow in two species and purple in another. Inhabits ponds and lakes. Very limited use by waterfowl as a food source.

Figure 11-14



Pondweed—*Potamogeton*

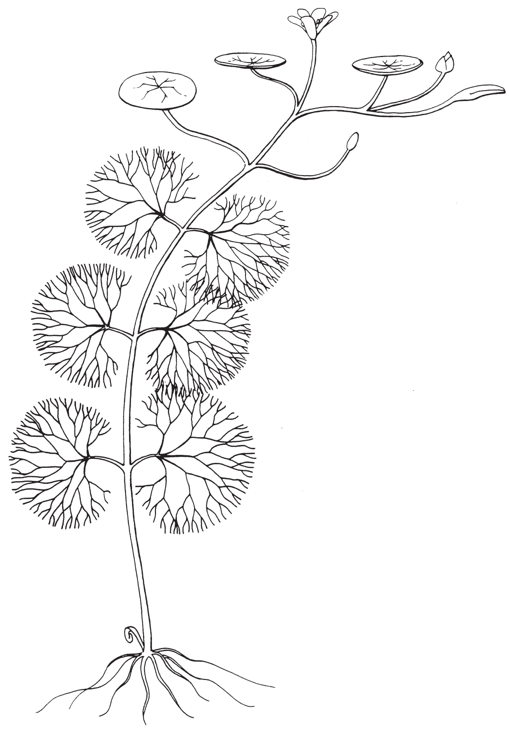
A plant with floating, elliptical leaves approximately 6 inches long and 3 inches broad. Seeds on cylindrical spikes extending above the water 3 inches. Found in a variety of water habitats. The seed heads are eaten by waterfowl. The leaf shape of *Potamogeton* species are variable, but the most common species in Texas have a leaf shape similar to the example shown Figure 11-15.

Figure 11-15

Cabomba or Fanwort—*Cabomba*

The submerged leaves (1 to 2 inches wide) are opposite or whorled, green colored, and are finely dissected in the general shape of a fan. The floating leaves are few in number, linear-elliptical in shape, and 0.5 to 1 inch in width. Cabomba is a popular aquarium plant and has become widely distributed through discarded aquarium plants. Typically found in quiet streams and ponds. The seeds are occasionally consumed by waterfowl.

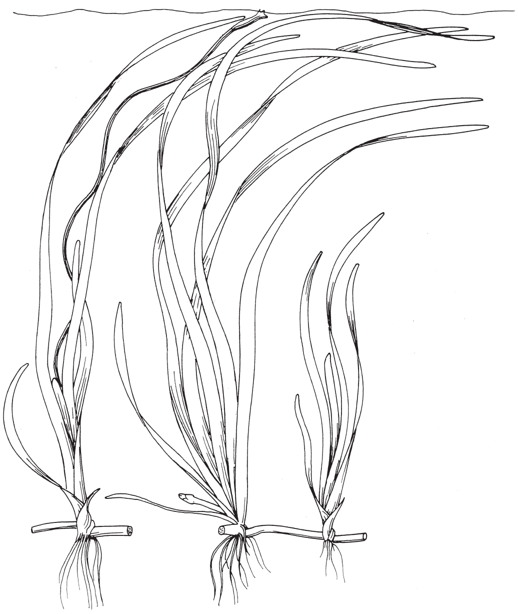
Figure 11-16



Eel-Grass or Tape Grass—*Vallisneria americana*

Submerged plant with dark-green ribbon-like leaves 1 to 1.5 inches wide, and several feet long. It is entirely submerged, or sometimes the upper portion is floating. Eel-grass is found in lakes and swift-flowing spring-fed streams. Eel-grass is a valuable waterfowl food.

Figure 11-17



Emergent Plants

Alligator Weed—*Alternanthera philoxeroides*

A plant with upright stems and elliptical leaves, approximately 4 inches long. Plants have small white flowers. Inhabits water or very wet soil, often forming dense mats. Deer and cattle browse on the plants. Native of South America. See Chapter 12 for information on nonnative species.

Figure 11-18

Bullrush—*Scirpus*

Light-green plant with triangular or round stems as tall as 6 feet. Fruit is in a terminal spikelet in a drooping cluster a few inches from the tip. Inhabits mud banks or standing water up to several feet in depth. The fruit are eaten by waterfowl.

Figure 11-19

Cattail—*Typha*

Elongated plant with flat leaves, standing up to 10 feet tall. Has thickened, cylindrical seed spikes. Found growing in saturated habitats and in water up to a few feet deep. Four species occur in the United States. The use of cattail as a food source by wildlife is minimal.

Figure 11-20

Spike Rush—*Eleocharis*

Slender plant that grows in clumps up to 8 inches. Stems have dark-brown, scaly lance-shaped spikelet at the tip. Commonly grows in mud and shallow water up to 2 feet. The entire plant is eaten by waterfowl.

Figure 11-21

Soft Rush—*Juncus effusus*

A pale-green plant with hollow stems up to 3 feet tall, usually growing in large clumps along shorelines. It can also grow in wet soil or dry ground. The flowers are usually grouped near tip of the stem. The seeds are eaten by waterfowl.

Figure 11-22

Flat Sedge—*Cyperus*

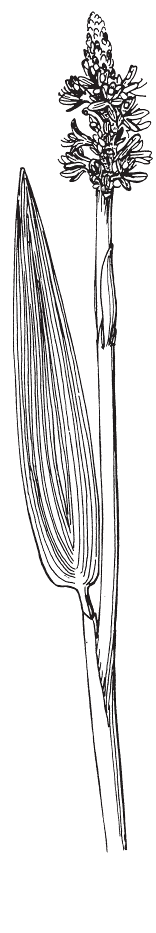
A plant with triangular stems up to 2 feet, usually solitary or growing in clumps of two to six. Large golden-brown seed heads are located terminally on the stem. This plant is suited for wetland and marsh areas. The seeds are eaten by rodents and birds.

Figure 11-23

Pickerel Weed—*Pontederia cordata*

Leaves ovate (egg-shaped), heart-shaped at base, and approximately 8 inches long. Leaves have considerable variation. Flowers blue-purple, crowded in elongated terminal spikes. Inhabits shorelines of standing water. The seeds are eaten by waterfowl.

Figure 11-24



Water Primrose—*Ludwigia*

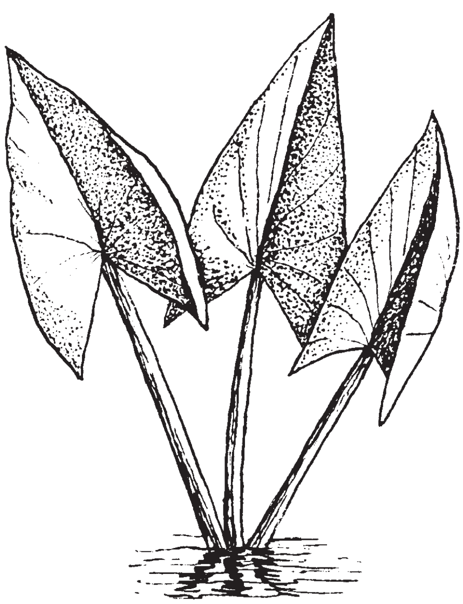
A plant with stems floating, or upright if terrestrial, and covered with long hairs. Leaves lance shaped, hairy, and approximately 2 inches long and 1 inch broad. Small yellow flower. They can form extensive mats in lakes, ponds, and slow streams. Waterfowl occasionally eat the seeds.

Figure 11-25

Arrowhead—*Sagittaria latifolia*

A plant with arrowhead-shaped leaves approximately 8 inches long and 4 inches broad. Has stout stem and reaches 3 feet in height. Has as many as ten whorls of small white flowers. Inhabits shallow water areas. The seeds are eaten by waterfowl.

Figure 11-26



Smartweed—*Polygonum*

Smartweed has creeping rhizomes and hairy stems that are often swollen at the nodes. It produces small pinkish-white flowers commonly over 2 inches long. The plant is very common in irrigation ditches, marshes, and along streams and lakes. The seeds are heavily utilized by songbirds, marsh birds, waterfowl, and several small mammals.

Figure 11-27

Algae

Algae are small plants or plant-like organisms that live primarily in water. Algae is plural, pronounced AL-jee. Alga is singular, pronounced AL-gah. Most algae are microscopic, but a few genera are individually large enough to be seen without the aid of a microscope. Like other plants containing chlorophyll, they can manufacture their own food through the process of photosynthesis.

Algae are the simplest of chlorophyll-bearing organisms, the entire plant being but a single cell. Algae are found in a wide variety of habitats, including freshwater, oceans, deserts, hot springs, and snow fields. The amount and type of algae in a water body depends on the amount of nutrients present, such as nitrogen, phosphorus. These plant are primarily identified by colors and shapes.

Algae are primary producers which means they are the base of the aquatic food chain. Algae also provide oxygen for other aquatic life, serve as indicators of water pollution, determine the toxicity of specific pollutants, and treat raw sewage (oxidation). However, when some species of algae bloom (grow rapidly in numbers, usually due to the presence of high nutrients), they can cause taste and odor problems in drinking water supplies, and some species can be lethal to fish and other wildlife.

For additional information on the role of algae in aquatic ecosystems see Chapter 3.

Characteristics of Algae

The most common forms of algae can be characterized by either basic physical structure, habitat, or color, as detailed in the following sections:

Basic Physical Structure

Algae falls into four basic physical structures.

- ▼ **Single-celled**.
- ▼ **Colonial**. Groups of single algae cells.
- ▼ **Filamentou**s. Algae are made up of single cells arranged end to end, either in a straight line or branched.
- ▼ **Plant-like**. Large algae that resemble vascular plants.

Habitat

- ▼ **Planktonic**. Free-floating, unattached plants that are generally single cells or colonies of single cells, which may or may not have *flagella* (whip-like tail structures used in movement). Commonly referred to as *phytoplankton*.
- ▼ **Periphyton**. Attached to substrate—rocks, logs, and other structures.
- ▼ **Floating mats**. Large quantities of filamentous algae floating on the surface.
- ▼ **Benthic**. Growing on sediment or bottom substrate.

Color

The colors of algae are:

- ▼ Green
- ▼ Blue-green
- ▼ Golden
- ▼ Brown
- ▼ Red

Grouping of Algae

Currently there are eight commonly recognized groups (phyla) of algae: *green* (Chlorophyta), *blue-green* (Cyanobacteria), *diatoms* (Bacillariophyta), *stoneworts* (Charophyta), *golden* (Chrysophyta), *dinoflagellates* (Dinophyta), *brown* (Phaeophyta), and *red* (Rhodophyta). Brown and red algae are almost entirely marine and will not be discussed.

Information for the following section is from Prescott (1978), Sze (1986) and the National Museum of Natural History, Smithsonian Institution Web page at **www.nmnh.si.edu/botany/projects/algae/AlgIntro.htm**.

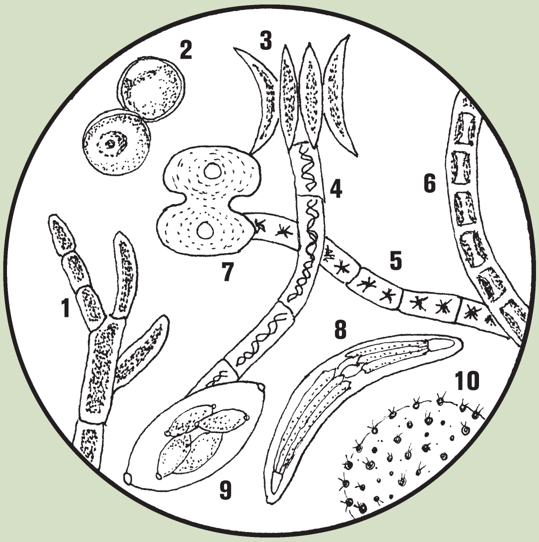
Green Algae—Chlorophyta

Green algae (chlorophytes) make up the most diverse group of algae at approximately 8,000 species. The green algae range in size from microscopic to quite large. The typical green color of algae, resulting from the dominant chlorophyll pigments, is some shade of apple- or grass-green, although certain species may appear yellow-green or blackish-green due to the presence of other pigments.

Pithophora sp. and *Spirogyra* sp. are two examples of filamentous green algae that are common in ponds and slow-moving streams. Dense growths of these algae can result in floating mats that are referred to as "pond scum." These floating mats can deplete oxygen, clog water intake filters, taint the taste of water supplies, and interfere with recreational activities.

Calcified green algae are especially important as major contributors of marine sediments. The sparkling white sand beaches of the Caribbean and many other areas in the world are largely the sun-bleached and eroded calcium-carbonate remains of green algae.

Figure 11-28



GREEN ALGAE

1 - Cladophora
2 - Chlorella
3 - Scenedesmus
4 - Spirogyra
5 - Zygnema
6 - Ulothrix
7 - Cosmarium
8 - Closterium
9 - Oocystis
10 - Volvox

Blue-Green Algae—Cyanobacteria

Blue-green algae are related to bacteria (lacking a membrane-bound nucleus); however, because they are photosynthetic and aquatic, cyanobacteria are often called "blue-green algae." Although this grouping is convenient for discussing photosynthetic aquatic organisms, it does not reflect a relationship between cyanobacteria and other algae.

Blue-green algae typically are quite small, with a fairly uniform cell structure. They often grow in colonies large enough to view without a microscope, and are found in a wide variety of habitats—especially warm, slow-moving, or still waters. Blue-green algae can use sunlight more efficiently than most algae. Some species have air pockets that allow them to float on the surface.

Blue-green algae played an important role in the past and continue to play a role in the present. They were critical in the forming of the early earth's atmosphere because blue-greens can fix nitrogen (use atmospheric nitrogen), as well as use carbon dioxide (photosynthesis) to create carbohydrates and produce oxygen. Many current oil deposits are attributed to the activity of blue-green algae. Currently they are used as nitrogen fertilizers in the cultivation of crops and some species, such as *Spirulina*, are grown commercially and marketed as a high-protein dietary supplement.

Blue-green algae are divided into filamentous and nonfilamentous types. Flagella are not found on any blue-green algae. Three species of blue-green algae common in freshwater ecosystems are *Anabaena*, *Oscillatoria*, and *Microcystis*. All three of these blue-green algae can produce blooms which can form pond scum, can produce toxins that can spoil the taste of water, and can be lethal to fish and to cattle or birds that drink the water.

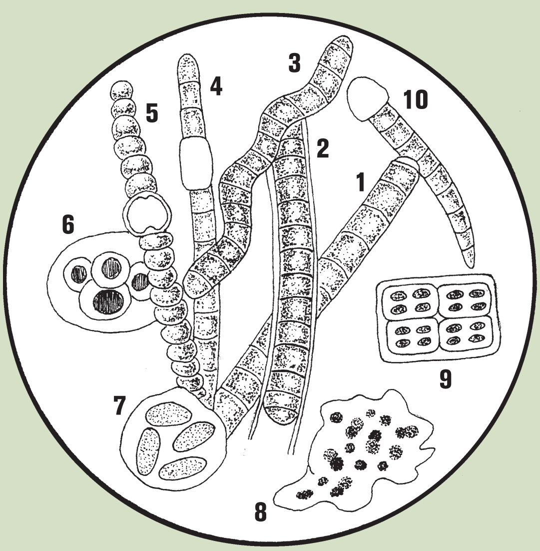
Microcystis sp. is a nonfilamentous colonial blue-green algae made up of hundreds of spherical cells arranged in a row and surrounded by a gel-like coating or sheath. *Oscillatoria* sp. is an unbranched filament with disk-shaped cells arranged in a row. Like the colonial blue-green, the filament is enclosed in a gel-like coating, or sheath.

Diatoms—Bacillariophyta

Diatoms are unicellular organisms found in both marine and freshwater ecosystems. Most diatoms are planktonic, but some are bottom dwellers or grow on other algae or plants. Diatoms have unique and intricate shells that serve as their cell walls. The overlapping shells, or *frustules*, that surround the diatom protoplasm are made of silica. Identification of diatom species is based on the delicate markings on their frustules, which include a large number of tiny, intricately-shaped depressions, pores, and passageways that bring the diatom cell membrane in contact with the environment.

Diatoms occur as single cells or as members of small colonies. The phyla is divided into two groups based on the symmetry of their markings:

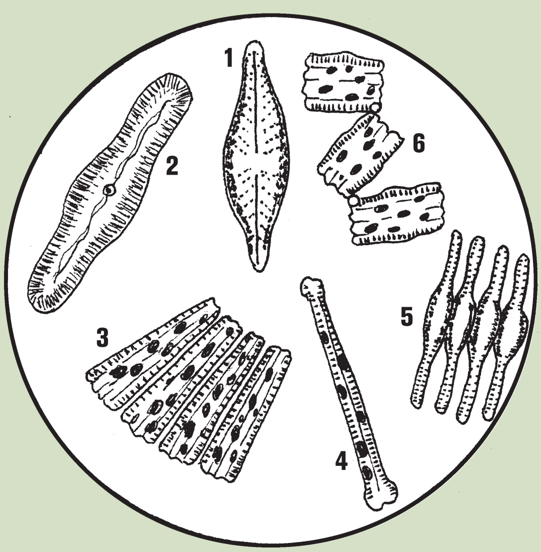
Figure 11-29



BLUE GREEN ALGAE

1 - Oscillatoria
2 - Lyngbya
3 - Arthrospira
4 - Apanizomenon
5 - Anabaena
6 - Anacystis
7 - Coccochloris
8 - Anacystis (Microscystis)
9 - Agmenellum
10 - Calothrix

Figure 11-30



DIATOMS

1 - Navicula
2 - Pinnularia
3 - Meridion
4 - Asterionella
5 - Tabellaria
6 - Fragilaria

centric diatoms (*Centronella* sp.) are circular with markings that are radial; and **pennate diatoms** (*Navicula* sp.) are long with the markings arranged on either side of a line running down its length.

Diatoms are an abundant component of phytoplankton that serve as a primary source of food for zooplankton in both freshwater and marine ecosystems. Diatom frustules have accumulated over millions of years to form the fine, crumbly, rocky substance known as diatomaceous earth, which has a variety of uses (for example, for abrasives, filtration, and insulation). Additionally, diatom remains in both marine and freshwater sediments are important as indicators of environmental conditions at the time the sediments were formed.

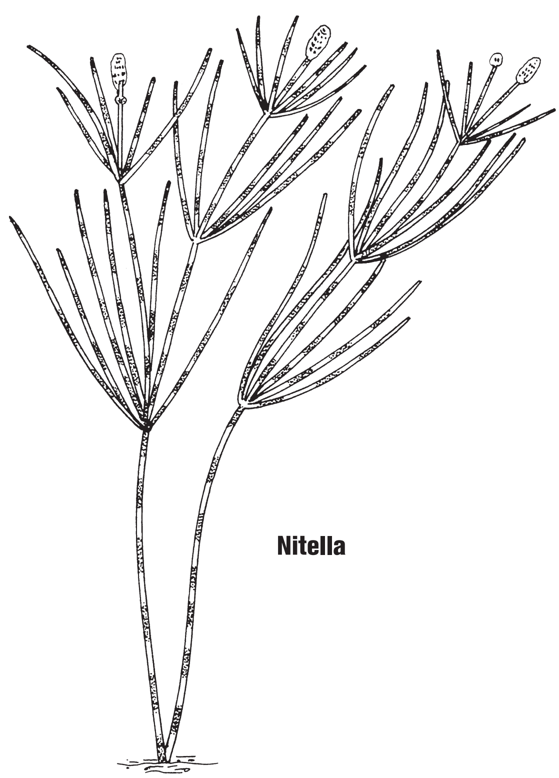
Stoneworts—Charophyta

Stoneworts are freshwater plant-like algae, ranging in size from a few inches to 3 feet, which generally grow anchored to substrate. Typically, stoneworts grow erect with stem-like structures referred to as a *thallus*. The green color of stoneworts comes from chlorophyll.

Two of the more common freshwater species of this group are *Chara* sp. and *Nitella* sp. *Chara* varies in length from several inches to 3 feet. They are found mostly in hard-water (or alkaline) lakes and slowly flowing streams in which calcium is abundant. Calcium carbonate or lime deposits on the stems and leaves are responsible for the common name "stonewort."

Chara has a musky, skunk-like odor and is often referred to as "musk-grass." *Nitella* usually grow in soft (acidic) water. Some species occur in bog lakes that are darkly stained with humic acid or tannic acids. *Nitella* are not foul-smelling and are greener than *Chara* because they are not encrusted with lime.

Figure 11-31



Golden Algae—Chrysophyta

Golden algae are single-celled organisms that are abundant in freshwater and marine environments. Golden algae are biochemically and structurally similar to brown algae. Most species of golden algae are planktonic, but some are filamentous and colonial forms. Golden algae may turn predator, feeding on bacteria and diatoms in the absence of light or in the presence of abundant dissolved food.

Large blooms of *Prymnesium parvum* can cause discoloration of water from yellow to coppery brown and can be toxic to fish. *Prymnesium parvum* has been the suspected cause of large Texas fish kills in the Pecos River, Lake Granbury, Possum Kingdom Reservoir, and in the upper portions of the Brazos River. For additional information on *Pyrmnesium parvum* see the "Harmful Algal Blooms" section in Chapter 3.

Golden algae are important as a food source for zooplankton in aquatic ecosystems. Additionally, the fossils of golden algae, like those of diatoms, are often used as indicators to reconstruct ancient environments.

Dinoflagellates—Dinophyta

Dinoflagellates are a diverse and confusing group. Dinoflagellates are part plant and part animal because they produce chlorophyll and they also swim rapidly, using their two flagella, or whip-like tails. The name "dinoflagellate" refers to the forward-spiraling movement of these organisms.

Dinoflagellates commonly have a cell-covering structure called a *theca*. This structure differentiates them from other algal groups. Cells are either armored or unarmored. Armored species have theca divided into plates that are key features used in their identification. The theca can be smooth and simple, or laced with spines, pores, and/or grooves, and can be highly ornamented.

Dinoflagellates are planktonic, as well as attached to substrate, and are found in freshwater and marine ecosystems. Dinoflagellates produce their own nutrition from photosynthesis but also feed on organic matter and other organisms.

Some marine species of dinoflagellates are harmful to the environment when they bloom in warm summer months. Blooms of *Gymnodinium breve* can cause the water to turn a reddish-brown color known as "red tide." Red tides produce a neurotoxin that affects muscle function. This toxin can be lethal to fish and can even affect humans exposed to blooms. Symptoms in humans include watery eyes and a burning feeling in air passages.

Humans may also be affected by eating fish or shellfish containing the toxins produced by dinoflagellates. Two examples of such diseases affecting humans are ciguatera, transmitted by eating affected fish; and paralytic shellfish poisoning (PSP), transmitted by eating affected shellfish such as clams, mussels, and oysters. These diseases can be serious but are not usually fatal.

Additionally, blooms of a relatively new species, *Pfiesteria* sp., have caused numerous fish kills in the coastal areas of North Carolina. *Pfiesteria*, just like *Gymnodinium breve*, also produces a neurotoxin that essentially suffocates the fish. However, *Pfiesteria* do something unusual—feed on the flesh of fish, causing sores.

Concerns over toxic effects on both humans and fish have resulted in a great deal of *Pfiesteria* research along the eastern coast of the U.S. Neither *Gymnodinium* or *Pfiesteria* are thought to be a problem in freshwater.

CHAPTER 12 Nonnative Species

Most Texas streams or reservoirs are home to at least one nonnative species. Nonnative species are those (fish, shellfish, or aquatic plants) that enter an ecosystem beyond their historic ranges.

Other names for nonnative species include *introduced*, *foreign*, *exotic*, *alien*, *nonindigenous*, and *transplants*. In Texas, at least 35 nonnative species have become established in aquatic habitats (Table 12-1).

How Did They Get Here?

Nonnative species have been introduced both intentionally and unintentionally. Reasons for purposely introducing nonnative species include:

- increasing local food supplies
- authorized enhancement of sport and commercial fisheries
- manipulating aquatic ecosystems to control pests or nuisance plants
- improving aesthetics

Nonnative species have also been unintentionally introduced into ecosystems by

- canal systems
- unauthorized stocking by anglers
- hitchhiking on boats—snails, plants
- angler bait buckets
- releases from personal aquariums
- dumping of ballast water
- escape from aquaculture facilities

Adverse Environmental and Economical Impacts

The introduction of harmful nonnative species may alter established ecosystems, although it is difficult to predict the exact changes. Their introduction can cause both adverse environmental and economical impacts. Examples of possible adverse environmental effects include:

- preying on native fish
- altering established aquatic food webs
- introducing new parasites or diseases
- altering habitats
- damaging the genetic integrity of native species by hybridization
- out-competing native species for resources

Examples of possible adverse economical effects include:

- clogging intake pipes of municipal or industrial water users
- clogging irrigation canals
- interfering with water-based recreational activities
- endangering commercial and recreational fishing because of diminished numbers of native species

In response to the adverse effects of harmful nonnative species on native species, laws have been enacted to prevent and regulate their introductions. In Texas, the Texas Parks and Wildlife Department (TPWD) has the authority to determine which species are potentially harmful and to regulate them. In addition, TPWD carefully reviews the proposed introduction of nonnative species, and identifies possible negative effects before introduction to prevent irreversible damage to natural ecosystems.

Fortunately, the majority of nonnative species fail to become established. However, if nonnative species do become established, they are almost impossible to remove. Citizens should do their part to make sure nonnative species are not intentionally or unintentionally released into Texas waters. Prevention can be as simple as not releasing fish from bait buckets, or removing plant fragments from the boat trailer before leaving the lake. Additional information on harmful nonnative species is listed in the reference section.

Examples of Nonnative Species in Texas

Examples of nonnative species that *have* caused problems:

Plants. *Hydrilla and water hyacinth*. When they get out of control, these plants can clog canals used for irrigation, reduce cooling capacity of power plant reservoirs, alter predator-prey interactions, and interfere with water-based recreational activities (fishing, swimming, skiing, boating).

Fish. *Common carp and tilapia*. Common carp can uproot aquatic plants and increase turbidity. Tilapia can out-compete the native sunfish populations, and can affect largemouth bass reproduction.

Invertebrates. *Corbicula*. This small clam can clog power plant pipes located on cooling water reservoirs and can out-compete native mollusk populations.

Examples of nonnative species that have proven beneficial with *no known* problems are:

Fish. *Striped bass, rainbow trout, and walleye*. Introductions of these species into streams and reservoirs have greatly increased recreational angling opportunities.

Table 12-1

List of Nonnative Species Found in Texas Aquatic Habitats

Group	Common Name	Scientific Name
Plants	Elephant ear	*Colocasia esculenta*
	Water lettuce	*Pistia stratiotes*
	Parrotfeather	*Myriophyllum brasiliense*
	Eurasian watermilfoil	*Myriophyllum spicatum*
	Giant waterweed	*Egeria densa*
	Hydrilla	*Hydrilla verticillata*
	Water hyacinth	*Eichhornia crassipes*
	Curly pondweed	*Potamogeton crispus*
	Giant salvinia	*Salvinia molesta*
	Salt cedar	*Tamarix sp.*
	Floating fern	*Ceratopteris thalictroides*
	Alligatorweed	*Alternanthera sp.*
Fish	Rainbow trout	*Oncorhynchus mykiss*
	Northern pike	*Esox lucius*
	Goldfish	*Carassius auratus*
	Grass carp	*Ctenopharyngodon idella*
	Common carp	*Cyprinus carpio*
	Rudd	*Scardinius erythrophthalmus*
	Suckermouth catfish	*Hypostomus plecostomus*
	Guppy	*Poecilia reticulata*
	Striped bass	*Morone saxatilis*
	Rock bass	*Ambloplites rupestris*
	Redbreast sunfish	*Lepomis auritus*
	Smallmouth bass	*Micropterus dolomieu*
	Yellow perch	*Perca flavescens*
	Sauger	*Sander canadensis*
	Walleye	*Sander vitreus*
	Blue tilapia	*Oreochromis aurea*
	Mozambique tilapia	*Oreochromis mossambicus*
	Redbelly tilapia	*Tilapia zillii*
	Pacu	*Colossoma*
Molluscs	Asiatic clam	*Corbicula fluminaea*
	Giant ramshorn snail	*Marisa cornuarietis*
Mammals	Nutria	*Myocastor coypus*
Reptiles	Florida water snake	*Nerodia fasciata pictiventris*

References: Bowles and Arsuffi 1993; Howells 1999; Hubbs et al. 1991; and USFWS 1995

CHAPTER

13 Glossary

A

acclimation. An organism's ability to adjust to a changing environment.

acute toxicity. The ability of a substance to cause poisonous effects resulting in severe biological harm or death soon after a single exposure or dose. Also, any severe poisonous effect resulting from a single short-term exposure to a toxic substance.

adaptation. Adjustments made by animals in respect to their environments. The adjustments may occur by natural selection, as individuals with favorable genetically acquired traits breed more prolifically than those lacking these traits (genotypic adaptation), or they may involve non-genetic changes in individuals, such as physiological modification (for example, acclimatization) or behavioral changes (phenotypic adaptation).

aerobic. Life forms or processes that require the presence of oxygen.

algae. Plants that lack true roots, stems, and leaves. For the physical assessment described here, algae consist of nonvascular plants that attach to rocks and debris, or are free floating in the water.

algae bloom. The effect of excessive nutrients on the algal populations in a lake, pond, river, or stream. Excessive nutrients cause the prolific growth of algae and phytoplankton referred to as a "bloom". The result of an algae bloom is the depletion of dissolved oxygen.

alkalinity. A measure of the acid-neutralizing capacity of water. Bicarbonate, carbonate, and hydroxide are the primary cause of alkalinity in natural waters. Concentrations are expressed as mg/L of $CaCO_3$.

ammonia-nitrogen (NH_3-N). Ammonia, naturally occurring in surface and wastewaters, is produced by the breakdown of compounds containing organic nitrogen.

anaerobic. Lifeforms or processes that occur in the absence of oxygen.

anthropogenic. Relates to the influence of human activities on the natural environment.

aquatic macrophyte. Vascular plants that usually are arranged in zones corresponding closely to successively greater depths in shallow water. The characteristic plant forms that dominate these gradients (listed in order farthest to nearest to the surface) are: (1) submerged, (2) floating-leaved, and (3) emergent. Some vascular plants like duckweed may live unattached in the water and may occur anywhere on the water surface.

autotrophic. Self-nourishing organisms; green plants and forms of bacteria that do not require organic carbon or nitrogen and produce their own food out of inorganic salts, carbon dioxide, and energy.

autotrophic organism. An organism capable of constructing organic matter from inorganic substances.

B

bank. The portion of the stream channel that tends to restrict lateral movement of water. It often has a slope of less than 90° and exhibits a distinct break in slope from the stream bottom.

benthic region. The bottom of all water bodies; supports the benthos.

benthos. Aquatic bottom dwelling organisms that include: worms, leeches, snails, flatworms, burrowing mayflies, clams. Also referred to as benthic macroinvertebrates, infauna, or macrobenthos.

bioaccumulation. The process in which a chemical is moved through the biological food chain by being passed from one organism to another as the contaminated organism is preyed upon by another organism.

bioassay. The use of living organisms to measure the effect of a substance, factor, or condition by comparing before-and-after data.

biochemical oxygen demand (BOD). A measure of the amount of oxygen consumed in the biological processes that break down organic matter in water. The greater the BOD, the greater the degree of pollution.

biodiversity. Refers to the variety and variability among living organisms and the ecosystems in which they occur.

biological integrity. The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region.

biological magnification. The process by which certain pollutants (for example pesticides or heavy metals) become very concentrated, above their normal concentrations, in water or mud. The concentration of pollutants occurs as organisms that take the pollutants from the water or mud are consumed by other organisms higher in the food chain. The substances become concentrated in tissues or internal organs as they move up the chain.

biomass (or standing crop). The total mass or weight of a given population of plant or animal. For example, the weight of all life in a square foot of stream bottom. Biomass is calculated by taking a count of individuals in a population, for example large mouth bass, multiplied by the weight of an average-sized individual in that population. The result is an estimate of the population weight.

biota. All living organisms of a region.

bloom. The accelerated growth of algae and/or higher aquatic plants in a body of water. This is often related to pollutants that increase the rate of growth.

BOD5. The amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter.

C

carcinogen. A substance that causes cancer.

carnivore. Flesh eater.

channel. The portion of the landscape containing the bank and the stream bottom. It is distinct from the surrounding area due to breaks in the general slope of the land, lack of terrestrial vegetation, and changes in the composition of substrate (bottom) materials.

channelization. Straightening and deepening streams so water will move faster. A method of flood control that disturbs fish and wildlife habitats and can interfere with a water body's ability to assimilate waste.

chemical oxygen demand (COD). A measure of the oxygen required to oxidize all compounds in the water, both organic (living) and inorganic (nonliving).

chloride (Cl). One of the major inorganic ions in water and wastewater. Concentrations can be increased by industrial processes. High chloride concentrations can affect metallic objects and growing plants.

chlorophyll *a*. Photosynthetic pigment that is found in all green plants. The concentration of chlorophyll *a* is used to estimate phytoplankton biomass (all of the phytoplankton in a given area) in surface water.

chronic toxicity. The capacity of a substance to cause long-term health effects (see acute toxicity).

cold-blooded animals. Organisms that lack a temperature-regulating mechanism that offsets external temperature changes. The body temperature of these organisms fluctuates with that of the surrounding environment (for example, fish, turtles, and aquatic insects).

community. All the groups of organisms living together in the same area, usually interacting or depending on each other for existence.

conductivity. A measure of the electrical current-carrying capacity, in micromhos/cm, of 1 cm^3 of water at 25°C. Dissolved substances in water dissociate into ions with the ability to conduct electrical current. Conductivity is a measure of how salty the water is; salty water has high conductivity.

consumers. Organisms that consume solid particles of organic material.

contact recreation. Recreational activities involving a significant risk of ingestion of water, including wading by children, swimming, water skiing, diving, and surfing.

contaminant (aquatic). Any physical, chemical, or biological substance or matter that has an adverse effect on the quality of water, sediment, and the biological community.

criteria. Water quality conditions that are to be met in order to support and protect desired use.

cubic feet per second(cfs). A commonly-used measure of the rate of flow where a 1-cubic-foot volume of water travels 1 foot in 1 second or ft^3/s.

cultural eutrophication. The aging process of a water body accelerated by human activities. See eutrophication.

cut bank. The outside (concave) bank of a stream channel bend characterized by high erosion. Stream flow usually increases along the cut-bank side of the channel.

D

decomposition. The breakdown of organic material by bacteria and fungi.

detritus. Decaying organic material (leaves, plants).

detritivore. Animal that feeds on decaying organic matter.

dissolved oxygen (DO). The oxygen freely available in water. DO is vital to fish and other aquatic life and for the prevention of odors. Traditionally, the level of DO has been accepted as the single most important indicator of a water body's ability to support desirable aquatic life.

dissolved oxygen sag. Refers to the reduction of DO levels below the point of a wastewater discharge. Relates to the effects of organic wastes on the water downstream of a wastewater discharge. Oxygen-demanding waste discharged into a stream causes a zone of degradation downstream of the discharge point. The time and distance a sag moves downstream and the point of recovery (increases in DO) depend on various factors, which include: the volume of the discharge and the flow in the creek, concentrations of pollutants in the discharge, temperature, and reaeration capabilities. Most streams have the ability to recover. DO sags also occur naturally during the early morning hours before sunrise.

E

ecological impact. The effect that a man-made or natural activity has on living organisms and their abiotic (nonliving) environment.

ecology. The relationship of living things to one another and their environment, or the study of such relationships.

ecosystem. The interaction of a biological community and its nonliving environment.

eddy current. A circular water movement formed on the side of a main current. Eddies may be formed where the main stream passes obstructions such as logs and rocks.

effluent. Wastewater (treated or untreated) that flows out of a treatment plant or industrial outfall and into a water body.

emergent vegetation. Aquatic macrophytes (plants) that are rooted in the sediment, near shore, or in marshes, with nearly all of the leaves above the water surface (cattails).

epilimnion. The warmer oxygen-rich region of a lake or reservoir that extends from the surface to the thermocline.

erosion. The process in which a material is worn away by flowing water, wave action, or wind. Erosion is often intensified by human activities, such as land clearing and channelization.

Escherichia coli (*E. Coli*). *E. coli*, a bacteria species more commonly associated with human waste only, has replaced fecal coliform as the indicator bacteria for freshwater bodies in Texas.

The presence of fecal coliform or *E. coli* indicates the presence of inadequately treated sewage, improperly managed animal waste from livestock, pets in urban areas, wildlife (birds and mammals either aquatic or living near water; for example, birds nesting under a bridge), or failing septic systems.

estuary. Region of interaction between rivers and near-shore ocean waters, where tidal action and river flow create a mixing of fresh and salt water.

euphotic zone. The zone of water from the surface to the depth of light penetration. Photosynthesis $\geq$ respiration in this zone.

eutrophic. Water bodies with high levels of nutrients capable of supporting abundant algae and/or aquatic plant growth. Able to support an abundance of living organisms. The prefix "eu" means good or sufficient. Algal blooms and resulting fish kills can occur in eutrophic water bodies.

eutrophication. The slow aging process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears.

F

fall overturn. A physical phenomenon that usually takes place in a lake or reservoir during the early autumn. Fall overturn includes the following: (1) cooling of the surface water; (2) density change in surface waters, producing convection currents, top to bottom; (3) circulation of the total water volume by wind action; and (4) vertical temperature equality. The overturn results in the uniformity of the physical and chemical properties of the water from top to bottom. Southern lakes usually experience fall overturn only, while northern lakes will turn over in both the spring and fall.

family. A group of related plants or animals forming a category ranking above a genus and below an order and usually comprising several to many genera.

fecal coliform bacteria. Bacteria found in the intestinal tracts of warm-blooded animals.

Organisms used as an indicator of pollution and possible presence of waterborne pathogens.

floating vegetation. Rooted plants (some free floating) with leaves floating on the surface. For example, water lily, water shield, duck weed, and water hyacinths.

floodplain. The area adjacent to the channel that is occasionally submerged under water. Usually the floodplain is a low-gradient area well covered by various types of riparian vegetation.

food chain. The dependence of organisms upon others in a series for food. The chain begins with producers (plants) and ends with the largest of the consumers (carnivores).

food web. An interlocking pattern of several to many food chains.

freshwater. Water with less than 1,000 parts per million (ppm) of dissolved solids. See saline water.

G

genus. A category of biological classification ranking between the family and the species, comprising structurally or phylogenetically (evolutionary relationship) related species and being designated by a Latin or latinized capitalized singular noun.

glide. Portion of the water column in which the flow is characterized by slow-moving laminar flow, similar to that found in a shallow canal. Water surface gradient over a glide is nearly zero, so velocity is slow, but flow is shore to shore without eddy development. A glide is too shallow to be a pool, but the water velocity is too slow to be a run.

H

habitat. A place where the physical and biological elements of ecosystems provide a suitable environment including the food, cover, and space resources needed for plant and animal livelihood.

herbivore. An animal that feeds on plants.

heterotrophic. Organisms that are dependent on organic matter for food.

hydrologic cycle. A model that describes the movement of all water on earth, in all of its phases (solid, liquid, and gas).

hypereutrophic. Water bodies with extremely high levels of nutrients, capable of supporting abundant algae or aquatic plant growth. Able to support an abundance of living organisms. The prefix "hyper" means over abundant.

hypolimnion. The cold, oxygen-poor region of a lake or reservoir that extends from the thermocline to the bottom, and is not influenced by surface conditions.

I

impact. Change in the chemical, physical, or biological quality of a water body, caused by outside sources.

impoundment. A body of water confined by a dam, dike, floodgate, or other barrier.

index of biotic integrity (IBI). A method used to describe the biological condition of a site. The IBI uses a series of metrics (terms used to represent varying aspects of a biological community— benthic macroinvertebrates or fish) to calculate a score. This score relates to the overall quality of a biological community. The IBI is only one of many indices used to evaluate the condition of a biological community.

indicator organisms. An organism, species, or community that indicates the presence of a certain environmental condition or conditions.

inorganic. Any compound lacking carbon. Not living.

intolerant organism. Organisms that are sensitive to degradation in water quality and habitat. Sensitive organisms are usually driven from an area or killed as the result of some contaminant, especially organic pollution (for example, sewage, feedlot runoff, food waste).

invertebrate. Animal lacking a backbone.

L

laminar flow. Flow that moves in parallel layers. A stream with laminar flow is like a shallow canal. The bottom substrate, depth, stream slope, and flow direction are uniform. Laminar is the opposite of turbulent.

lentic. Standing water systems such as lakes, ponds, or bogs.

limnetic zone. The open water portion of a pond, lake, or bog that is too deep for rooted plants, but with enough light penetration for photosynthetic activity.

limnology. The study of the physical, chemical, and biological aspects of inland waters.

littoral zone. Area of shallow water where light penetrates to the bottom, allowing for rooted plant growth (lake or pond).

lotic. Running or flowing water systems; rivers and streams.

M

macrophyte. Any large vascular plant that can be seen without the aid of a microscope or magnifying device (cattails, rushes, arrowhead, waterlily).

mesotrophic. A term used to classify bodies of water that fall midway between oligotrophic and eutrophic; characterized by moderate amounts of nutrients entering the water body and moderate shoreline aquatic vegetation and occasional plankton blooms. The prefix "meso" means mid-range.

N

natural vegetative buffer. An area of either natural or native vegetation that buffers the water body from terrestrial runoff and the activities of man. In natural areas, it may be much greater than the riparian zone width. In man-altered settings, the natural vegetative buffer limit would be at the point of man's influence in the riparian zone, such as a road, parking lot, pasture, or crop field. It is the width of this buffer that is measured for purposes of quantifying potential stream impairments.

nekton. Free-swimming organism (for example, fish).

neuston. Organism resting on or swimming at the surface (for example, water striders, whirligig beetles).

niche. The functional role of a species in a community.

nitrate-nitrogen (NO_3-N). A compound containing nitrogen that can exist as a dissolved solid in water. Excessive amounts can have harmful effects on humans and animals (>10 mg/L).

nitrification. The process where ammonia in water and wastewater is oxidized to nitrite and then to nitrate by bacterial and chemical reactions.

nitrite-nitrogen (NO_2-N). An intermediate oxidation state in the nitrification process (ammonia, nitrite, nitrate).

nonpoint source. Pollution sources that are diffuse and do not have a single point of origin, or are not introduced into a receiving stream from a specific outfall. The pollutants are generally carried off the land by stormwater runoff. The commonly used categories for nonpoint sources are agriculture, forestry, urban, mining, construction, dams and channels, land disposal, and saltwater intrusion.

nutrient. Any substance used by living things to promote growth. The term is generally applied to nitrogen and phosphorus in water and wastewater, but is also applied to other essential and trace elements.

O

oligotrophic. A water body characterized by clear water, few nutrients entering the water body, and capable of only supporting small populations or plants, invertebrates, fish, and wildlife. The prefix "oligo" means scant or lacking.

omnivore. Feeding on both plant and animal substances.

organophosphate pesticides. Pesticides that contain phosphorus; short-lived, but some can be toxic when first applied.

orthophosphate (O-P). Nearly all phosphorus exists in water in the phosphate form. The most important form of inorganic phosphorus is orthophosphate, making up 90 percent of the total. Orthophosphate, the only form of soluble inorganic phosphorus that can be directly used as a nutrient, is the least abundant of any nutrient and therefore is commonly the limiting factor in plant growth.

outfall. A designated point of effluent discharge.

overhanging vegetation. Vegetation that overhangs the water column and provides food and cover for fish and benthic macroinvertebrates, and shades the water from solar radiation.

P

parasites. Organisms that live off other organisms and gain nourishment from them.

periphyton. Organism that cling to surfaces such as rocks, plants, logs, tires, or other structures in water.

pH. The measure of the hydrogen-ion activity of water and the presence of dissolved acids and bases.

phosphorus. Essential nutrient to the growth of organisms, and can be the nutrient that limits the primary productivity of water. In excessive amounts—from wastewater, agricultural drainage and certain industrial wastes— it also contributes to the eutrophication of lakes and other water bodies.

photosynthesis. The manufacture by plants of carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll, using sunlight as an energy source.

piscivore. An organism that feeds on fish.

plankton. Organisms (plants and animals) that live in open water, either suspended or floating.

Characteristics of *phytoplankton* (plants) are: (1) microscopic, (2) movement dependent on currents, (3) primary producers (solar radiation and nutrients used for growth), and (4) have effect on water quality. Characteristics of *zooplankton* (animals) are: (1) microscopic, but some can be seen by the naked eye, (2) capable of movement, and (3) secondary producers that feed on phytoplankton, bacteria, and detritus (dead organic matter).

point bar. A stream channel bend characterized by high deposition of sand, gravel, or cobble. Point bars are built up during periods of flooding and are usually devoid of woody vegetation.

point source. A specific location from which pollutants are discharged. It can also be defined as a single identifiable source of pollution (for example, pipe or ship).

pool. In a stream, an area that is relatively deep and wide with slow-moving water compared to the riffle, run, or glide areas. The substrate is usually composed of silt and sand. Pools and riffles usually follow in sequence along the water course (riffle to pool to glide to pool). Pools often contain large eddies with widely varying directions of flow, compared to riffles and runs where flow is nearly exclusively downstream.

predators. Life forms that attack, kill, and feed on living organisms.

primary producers. Life forms at the lowest level of the food chain comprised of green plants. Also referred to as the first trophic level.

profundal zone. Area of a pond or lake lacking light penetration and photosynthesis.

R

receiving water. A river, stream, lake, or other body of surface water into which wastewater or treated effluent is discharged.

reducer. Organisms (bacteria and some fungi) that convert dead organic material back to inorganic material, which is then usable by other organisms.

reservoir. Any natural or artificial holding area used to store, regulate, or control water.

respiration. Exchange of carbon dioxide with oxygen by plants or animals.

richness. The number of species present in a habitat or ecosystem. The number of species is a part of the measure of species diversity. The diversity of species within an ecosystem is typically associated with the health of the biological community.

riffle. A shallow portion of the stream extending across a stream bed, characterized by relatively fast-moving, turbulent water. The water column in a riffle is usually constricted, and water velocity is fast due to a change in surface gradient. The channel profile in a riffle is usually straight to convex. The substrate is usually cobble, gravel, or rock.

riparian zone. An area adjacent to and along a stream or river, which is often vegetated, and which constitutes a buffer zone between nearby lands and the river or stream. The area is considered to be important in controlling sediment and nutrient delivery into the channel. It generally includes the area of the stream bank and out onto the floodplain that is periodically inundated by the flood waters from the stream. The limit of the zone depends on many factors, including native plant community makeup, soil moisture levels, and distance from the stream (or the limit of interaction between land and stream processes). Interaction between this terrestrial zone and the stream is vital for the health of the stream.

risk management. The process of evaluating alternative regulatory and nonregulatory response to risk and selecting among them. The selection process necessarily requires the consideration of legal, economic, and social factors.

river basin. The land area drained by a river and its tributaries.

run. A relatively shallow portion of a stream characterized by fast-moving nonturbulent flow. A run is usually too deep to be considered a riffle and too shallow to be considered a pool. The channel profile under a run is usually a uniform flat plane.

runoff. The part of precipitation or irrigation water that runs off land into streams and other surface water.

S

salinity. The amount of dissolved salts in water, generally expressed in parts per thousand (ppt).

scavengers. Organisms that feed on dead and decaying plant and animal materials.

sediment. Bottom layers composed of particles of sand, clay, silt, and plant or animal matter carried in water which are deposited in reservoirs and slow-moving areas of streams and rivers.

sedimentation. The process by which suspended solids enter, accumulate, and settle to the bottom, forming sediment.

segment. Waters designated by the TCEQ in the Texas Surface Water Quality Standards (TSWQS) that include most rivers and their major tributaries, major reservoirs, and lakes, and marine waters. Segmented waters have designated physical boundaries, specific uses, and numerical physicochemical criteria (for example, dissolved oxygen, temperature, fecal coliform, chloride, sulfate) in the state's water quality standards.

septic odor. Rotten-egg smell produced by decomposing organic matter and the lack of oxygen.

species. A category of biological classification ranking immediately below the genus, comprising related organisms potentially capable of interbreeding. A species is identified by a two part name; the name of the genus followed by a Latin or latinized uncapitalized noun agreeing grammatically with the genus name.

species diversity. The variability of plant and animal species within habitats or ecosystems.

spring overturn. A physical phenomenon that may take place in a body of water during the early spring (northern lakes). The sequence of events leading to spring overturn include: (1) melting of ice cover; (2) warming of surface waters; (3) density change in surface water producing convection currents from top to bottom; (4) circulation of the total water volume by wind action; and (5) vertical temperature equality, 4°C. The overturn results in a uniformity of the physical and chemical properties of the water from top to bottom.

submerged vegetation. Rooted plants with almost all leaves below the water surface (for example, alligator weed, hydrilla, or elodea).

substrate. Bottom of an aquatic system. Substrates can be composed of clay, silt, sand, gravel, bed rock, or a mixture of materials.

sulfate (SO4). Sulfate is derived from rocks and soils containing gypsum, iron sulfide, and other sulfur compounds. Sulfate is widely distributed in nature.

T

tolerant organism. Organism that has the capacity to grow and thrive when subjected to unfavorable environmental factors.

total dissolved solids (TDS). The amount of material (inorganic salts and small amounts of organic material) dissolved in water.

total hardness. The sum of the calcium and magnesium concentration in water, expressed as calcium carbonate in mg/L.

total suspended solids (TSS). A measure of the total suspended solids in water, both organic and inorganic. Reported in mg/L.

tree canopy. The uppermost spreading branching layer of stream side trees that shades the water surface. Tree canopy is reported as percent cover and is measured with a canopy densiometer. Possible measurement range is from 0 percent (totally open) to 100 percent (totally closed canopy cover).

trophic. Relating to nutrition.

trophic level. A component that makes up a food chain with plants (primary producers) making up the first trophic level, or base of the food chain. The second trophic level would consist of herbivores or plant eaters. The third trophic level would be predators, feeding on herbivores, and so on. See Chapter 4.

tributary. A stream or river that flows into a larger stream or river.

V

volatile suspended solids (VSS). The portion of the total suspended solids (TSS) that is lost after ignition. This represents the organic part of the TSS.

W

water cycle. See hydrologic cycle.

water pollution. The addition of harmful or objectionable materials, such as sewage or industrial wastes, to a water body in concentrations or quantities that cause the degradation of water quality.

water quality standards. The designation of water bodies for desirable uses and the narrative and numerical criteria considered necessary to protect those uses.

watershed. The area of land from which precipitation drains to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge, which form the topographic dividing line from which surface streams flow in two different directions. Large watersheds, like the Mississippi River or the Chesapeake Bay, contain thousands of smaller watersheds.

water table. The upper level of groundwater.

wetlands. An area that is regularly saturated by surface or ground water and characterized by vegetation adapted for life in saturated soil conditions. Wetlands are divided into four general categories—marshes, swamps, bogs, and fens.

CHAPTER

14 Bibliography

Following is a bibliography of materials used to develop this guide. Materials that will assist in further study of freshwater systems, such as in the advanced identification of freshwater benthic macroinvertebrates, fish, plants, and other animals associated with the freshwater environment, are also included. Noted Internet sources were available at the time of this publication (May 2005).

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Reptiles, Amphibians, Mammals, and Birds

Reptiles and Amphibians

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CHAPTER

15 Internet Resources

Internet sources were available at the time of this publication (August 2005).

Water Quality

Water Science for Schools—U.S. Geological Survey
//ga.water.usgs.gov/edu/
A Primer on Water Quality—U.S. Geological Survey
//water.usgs.gov/pubs/fs/fs-027-01/index.html
Water on the Web
//waterontheweb.org/under/waterquality/index.html

Pollutants

US Environmental Protection Agency
www.epa.gov/ebtpages/pollutants.html

Biological Indicators of Watershed Health

U.S. Environmental Protection Agency
www.epa.gov/bioindicators/

Biological Assessment Information

www.epa.gov/owow/monitoring/bioassess.html

Freshwater Ecosystems

U.S. Environmental Protection Agency
www.epa.gov/bioindicators/aquatic/freshwater.html
Water on the Web
www.waterontheweb.org/under/lakeecology/
U.S. Environmental Protection Agency
www.epa.gov/bioindicators/aquatic/lake-r.html
Missouri Botanical Garden
www.mbgnet.mobot.org/fresh/rivers/
U.S. Environmental Protection Agency
www.epa.gov/bioindicators/aquatic/river-r.html

Freshwater Macroinvertebrates

Soil & Water Conservation Society of Metro Halifax (SWCSMH) Freshwater Benthic Ecology and Aquatic Entomology Homepage
//lakes.chebucto.org/ZOOBENTH/BENTHOS/benthos.html

Freshwater Macroinvertebrate Identification

University of Virginia
www.people.virginia.edu/~sos-iwla/Stream-Study/StreamStudyHomePage/StreamStudy.HTML
New York State Department of Environmental Conservation—Photo Key
http://www.dec.ny.gov/animals/35772.html
U.S. Environmental Protection Agency
www.epa.gov/bioindicators/html/invertebrate.html
Kentucky Division of Water
kywater.org/ww/bugs/intro.htm
Connecticut Department of Environmental Protection
www.ct.gov/dep/lib/dep/water/volunteer_monitoring/rbvcards.pdf

Freshwater Fish

U.S. Environmental Protection Agency
www.epa.gov/bioindicators/
Fish Data Base
www.fishbase.org/search.cfm
Texas Memorial Museum at the University of Texas at Austin
www.tmm.utexas.edu/tnhc/
Texas Parks and Wildlife Department
www.tpwd.state.tx.us/fish/infish/species/index.phtml
U.S. Environmental Protection Agency
www.epa.gov/bioindicators/html/fish.html
Texas Parks and Wildlife Department
Fish Kill Information
www.tpwd.state.tx.us/landwater/water/environconcerns/kills_and_spills/index.phtml

Reptiles and Amphibians

Texas Memorial Museum at the University of Texas at Austin
www.zo.utexas.edu/research/txherps/

Aquatic Plants

University of Florida Center for Aquatic and Invasive Plants

//plants.ifas.ufl.edu/

Harmful Algae Blooms—Golden Alga

www.tpwd.state.tx.us/hab/ga/

Nonnative Species

National Invasive Species Information Center

www.invasivespeciesinfo.gov/

National Nonindigenous Aquatic Species Database—U.S. Geological Survey

//nas.er.usgs.gov/queries/default.asp

Glossaries

U.S. Geological Survey

//ga.water.usgs.gov/edu/dictionary.html

U.S. Environmental Protection Agency

www.epa.gov/bioindicators/aquatic/glossary.html

www.epa.gov/OCEPAterms/aterms.html

Analyzing Data

Basic Statistics

U.S. Environmental Protection Agency

www.epa.gov/bioindicators/statprimer/index.html

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