Test Document P02: Pollinators and Ocean Acidification Fact Sheets

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Pollinators (USDA, US Forest Service)

Pollinator Syndromes

Plants and pollinators have co-evolved physical characteristics that make them more likely to interact successfully. The plants benefit from attracting a particular type of pollinator to its flower, ensuring that its pollen will be carried to another flower of the same species and hopefully resulting in successful reproduction.

The pollinator benefits from its adaptation to a particular flower type by ensuring that it will be able to find and access important food resources - nectar and pollen. Such relationships are considered mutualistic.

Animals, wind, and water can all be vectors for pollen. The flower type, shape, color, odor, nectar, and structure vary by the type of pollinator that visits them. Such characteristics are considered pollination syndromes and can be used to predict the type of pollinator that will aid the flower in successful reproduction.

Use the pollinator syndrome table to help you identify the potential pollinators you may associate with different flower types.

Pollinator Syndrome Traits

Trait	Bats	Bees	Beetles	Birds
Color	Dull white, green or purple	Bright white, yellow, blue, or UV	Dull white or green	Scarlet, orange, red or white
Nectar Guides	Absent	Present	Absent	Absent
Odor	Strong musty; emitted at night	Fresh, mild, pleasant	None to strongly fruity or fetid	None
Nectar	Abundant; somewhat hidden	Usually present	Sometimes present; not hidden	Ample; deeply hidden
Pollen	Ample	Limited; often sticky and scented	Ample	Modest
Flower Shape	Regular; bowl shaped - closed during day	Shallow; have landing platform; tubular	Large bowl-like, Magnolia	Large funnel like; cups, strong perch support

Pollinator Syndrome Traits

Trait	Butterflies	Flies	Moths	Wind
Color	Bright, including red and purple	Pale and dull to dark brown or purple; flecked with translucent patches	Pale and dull red, purple, pink or white	Dull green, brown, or colorless; petals absent or reduced
Nectar Guides	Present	Absent	Absent	Absent
Odor	Faint but fresh	Putrid	Strong sweet; emitted at night	None
Nectar	Ample; deeply hidden	Usually absent	Ample; deeply hidden	None
Pollen	Limited	Modest in amount	Limited	Abundant; small, smooth, and not sticky
Flower Shape	Narrow tube with spur; wide landing pad	Shallow; funnel like or complex and trap-like	Regular; tubular without a lip	Regular: small and stigmas exerted

Source: U.S. Forest Service, "Pollinator Syndromes", https://www.fs.usda.gov/managing-land/wildflowers/pollinators/syndromes, last updated May 9, 2023.

Pollinators

Each of us depends on pollinators in a practical way to provide us with the wide range of foods we eat.

Pollination services from honey bees and other insects provide the backbone to ensuring our diets are diverse and plentiful with fruits, nuts, and vegetables. In all, there are over 100 crops grown in the United States that depend on pollination. USDA supports the critical role pollinators play in agriculture through research and data collections, diagnostic services and pollinator health monitoring, pollinator habitat enhancement programs, and pollinator health grants.

2022 Annual Strategic Pollinator Priorities Report is now available!

annual-pollinator-report-2022.pdf (1.82 MB)

USDA Pollinator Offices and Initiatives

Agricultural Marketing Service (AMS) conducts a monthly National Honey Report, which collects prices paid of extracted and unprocessed honey, price by honey type, primary nectar source visited, and estimates the export and import of honey with major trading partners. Animal Plant Health Inspection Service (APHIS) safeguards honey bees against the entry, establishment, and spread of economically and environmentally significant pests, and facilitates the safe trade of agricultural product.

Information on the National Honey Bee Pests and Diseases Survey, Exotic Bee and Bee Mite ID guides, outreach videos on the parasitic Varroa mite and introductions to beekeeping can be found at this site.

- Identification Technology Program

Agricultural Research Service (ARS) Bee Research Laboratories are located across the country. These labs look at a wide range of issues that impact bee health.

The primary labs include:

- Beltsville, Maryland Bee Lab focuses on a wide range of bee pests and diseases, and offers a free Bee Disease Diagnosis Service of pests and diseases for beekeepers across the United States.
- Baton Rouge, Louisiana Bee Lab focuses on honey bee breeding, genetics, and physiology research.
- Logan, Utah Bee Lab studies the biology, management, and systematics of pollinating insects.
- Tucson, Arizona Bee Lab focuses on improved nutrition and Varroa control.

USDA Climate Hubs develop and deliver science-based information and technologies to natural resource and agricultural managers, enabling climate-informed decision making, reducing agricultural risk, and building resilience to climate change. Some examples of how the Climate Hubs support pollinators and their stakeholders include collaborative research and outreach on soil health practices that support pollinator forage and habitat, research on how climate may

impact the pollination of pollinator-dependent crops, and adaptation guides to support beekeepers' resilience to hurricanes.

Farm Service Agency (FSA) administers the Conservation Reserve Program (CRP), which implements long-term rental contracts with growers to voluntarily remove environmentally sensitive land from agricultural production, and to plant species that will improve environmental health and quality, such as for pollinator and wildlife habitat. Further, it administers the Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) program which provides financial assistance to eligible producers of honey bees due to eligible adverse weather events and loss conditions events.

ELAP assistance is provided for losses not covered by other disaster assistance programs authorized by the 2014 Farm Bill and the Bipartisan Budget Act of 2018. National Agricultural Library (NAL) is a source for a variety of agricultural resources devoted to pollinators and honey bees. National Agricultural Statistics Service (NASS) conducts statistically based surveys of beekeepers, including the Bee and Honey Inquiry Survey and the Colony Loss Survey.

National Institute for Food and Agriculture (NIFA) provides grants to universities, including Land-Grant institutions, to address high priority pollinator research. They also work to provide funding to U.S. Land-Grant institutions and counties through the Cooperative Extension System to conduct information and technology transfer to stakeholders on pollinator health. Natural Resources Conservation Service (NRCS) offers more than three dozen conservation practices that can benefit pollinators.

Although many of these practices target improving grazing lands or reducing soil erosion, small modifications to the practices can yield benefits to pollinator species. The shared link provides an overview of NRCS conservation work for pollinators and pollinator conservation and habitat enhancement resources. Office of Pest Management Policy (OPMP) analyses policy questions that address questions related to the interface of crop pest management and pollinator health and works closely with the USDA's National Agricultural Statistic Service on data collections to better understand pollinator Best Management Practices.

The link provides an exhaustive summary of crops that are attractive and/or pollinated by both honey bees and other bees in the United States. Risk Management Agency (RMA) administers the Apiculture Pilot Insurance Program (API) to provide a safety net for beekeepers' primary income sources – honey, pollen collection, wax, and breeding stock.

Additionally, RMA manages the Apiculture Rainfall Index (RI), which insurance programs utilize as an indexing system to assess plant growth and vigor, which correlates to honey production. U.S. Forest Service (USFS) is highly engaged in the protection of pollinators via sound management of and research to support managed lands. This link provides information on topics such as pollination, plant pollination strategies, types of pollinators, pollinator friendly practices, and gardening for pollinators.

Pollinator Fact Sheets, News and Blogs

2022 Annual Strategic Pollinator Priorities Report

A report on federally-led efforts to address factors impacting pollinator health.

annual-pollinator-report-2022.pdf (1.82 MB)

Beekeeper Resources Fact Sheet

Programs and Resources that support Beekeepers

usda-programs-resources-support-beekeepers.pdf (193.44 KB)

The Buzz About Pollinators

Protecting and supporting pollinators is key to maintaining U.S. agriculture.

What's All the Buzz About?

See the impact of USDA's efforts focusing on pollinator health, crop production, and conservation.

pollinator-week-infographic-06.25.2020.pdf (1.5 MB)

Native Plants for Pollinators

Use this resource to learn about pollinator-attractive plants.

native-pollinator-plants-infographic.pdf (1.14 MB)

Meeting Honey Demand in the U.S.

This USDA dashboard helps visualize pollinator data and provides a clearer picture of trends.

More Pollinator Stories

Pollinator Facts

An overview of why pollinators are so important to our agricultural industry and our lives.

pollinator_week_factsheet_06.25.2020.pdf (1.54 MB)

Farmers are Helping to Protect Working Wings

Fruits and veggies provide us the well-balanced diet for healthy lifestyles.

Honey Bee Highlights

Overview of major statistics on honey bees collected by NASS, USDA’s statistical service.

Read the factsheet

Pollinators at a Crossroads

Bees and other pollinators, including birds, bats, butterflies, moths, flies, wasps, beetles, and small mammals, play a critical role in our food production system.

Horned-Face Bees Sublet in a Honey Bee Colony

Shedding new light on strategies used to ensure survival of two very different pollinators.

Read the news release

Helping Honey Bees Make It Through Winter With Early Cold Storage

Putting honey bees into early indoor cold storage in October rather than November increases their chances of surviving the winter.

Read the news release

The Value of Birds and Bees

Pollinators benefit America’s working forests, farms, and ranches.

Read the blog

Protecting Pollinators from a New Threat – First-Ever U.S. Sightings of Asian Giant Hornet

Asian giant hornets are extremely large and equipped with relatively massive mandibles (teeth).

Read the blog

Scientists Probe Pollinator Survival

Shedding new light on strategies used to ensure survival of two very different pollinators.

Highlights

Access USDA resources on enhancing agricultural pollinator health and conservation.

- How Farmers Can Help Pollinators
- Online Identification Tools
- Bee Disease Diagnosis Service
- Attractiveness of Agricultural Crops
- Honey Bee Surveys
- Cold Storage Overwintering Tool
- Establishing Pollinator Habitats
- Honey Bees on the Move

More Highlights

Introduction to Beekeeping

Source: U.S. Department of Agriculture, "Pollinators", https://www.usda.gov/farming-and-ranching/plants-and-crops/plant-breeding/pollinators.

Bee Pollination

Bees are the champion pollinators!

In the United States, there are over 4,000 species of native bees. Familiar bees visiting garden flowers are the colorful, fuzzy, yellow-and-black striped bumblebees, metallic-green sweat bees, squash bees, and imported honeybee. These flower-seeking pollen magnets purposefully visit flowers to collect pollen and nectar for food for themselves and their young.

Energy Needs

All bees have very high-energy needs that must be met for their survival. Bees need key resources such as pollen and nectar from a variety of flowers. Bees need these resources for themselves and their progeny. Many bees need water in addition to nectar.

Nesting Habitat

Bee nesting habits vary greatly. For example:

- Mason bees construct nests from mud.
- Leafcutter bees use a "wrapper" of leaves, resin and sand.
- Carder bees harvest plant fibers.

Most bees excavate their nest tunnels in sunny patches of bare ground, while others seek out abandoned beetle burrows in dead tree trunks or branches. The majority of bees are solitary,

but a few, like sweat bees, bumblebees, and honeybees, are social, living in colonies that consist of a queen, her worker bee daughters and a few males, the drones.

Bee Flowers

The flowers that are visited by bees are typically:

- Full of nectar
- Brightly colored with petals that are usually blue or yellow or a mixture of these (bees cannot see red)
- Sweetly aromatic or have a minty fragrance
- Open in daytime
- Provide landing platforms
- Often bilaterally symmetrical (one side of the flower is a mirror image of the other)
- Flowers are often tubular with nectar at base of tube

An example of a bee-pollinated flower is a snapdragon or Penstemon (pictured right). Snapdragon flowers have sturdy, irregular shaped flowers with landing platform. Only bees of the right size and weight can trigger the flower to open. Other bee species or other insects that are too small or too large are excluded.

Nectar Guides

Many of the flowers pollinated by bees have a region of low ultraviolet reflectance near the center of each petal. This region appears invisible to humans because our visual spectrum does not extend into the ultraviolet. However, bees can detect ultraviolet light. The contrasting ultraviolet pattern called a nectar guide. This guide helps a bee quickly locate the flower's center.

This adaptation benefits both the flower and the bee. The bee can more rapidly collect nectar and the flower is more effectively pollinated.

Bee Mimics

Many insects such as flies and wasps mimic true bees. True bees have two sets of wings. Flies have only two wings. Wasps although they look like are only closely related to bees. Next time you see a pollinator in your garden check to see if it is a bee. Check out “Is it or isn't it a bee?”

Source: U.S. Forest Service, "Bee Pollination", https://www.fs.usda.gov/wildflowers/pollinators/animals/bees.shtml.

Gardening for Pollinators

Follow these simple steps to create a pollinator-friendly landscape around your home or workplace.

- Use a wide variety of plants that bloom from early spring into late fall.

  Help pollinators find and use them by planting in clumps, rather than single plants. Include plants native to your region. Natives are adapted to your local climate, soil and native pollinators. Do not forget that night-blooming flowers will support moths and bats.

- Avoid modern hybrid flowers, especially those with "doubled" flowers.

Often plant breeders have unwittingly left the pollen, nectar, and fragrance out of these blossoms while creating the "perfect" blooms for us.

- Eliminate pesticides whenever possible.

  If you must use a pesticide, use the least-toxic material possible. Read labels carefully before purchasing, as many pesticides are especially dangerous for bees. Use the product properly. Spray at night when bees and other pollinators are not active.

- Include larval host plants in your landscape.

  If you want colorful butterflies, grow plants for their caterpillars. They WILL eat them, so place them where unsightly leaf damage can be tolerated. Accept that some host plants are less than ornamental if not outright weeds. A butterfly guide will help you determine the plants you need to include. Plant a butterfly garden!

- Create a damp salt lick for butterflies and bees.

  Use a dripping hose, drip irrigation line, or place your bird bath on bare soil to create a damp area. Mix a small bit of table salt (sea salt is better!) or wood ashes into the mud.

- Spare that limb!

  By leaving dead trees, or at least an occasional dead limb, you provide essential nesting sites for native bees. Make sure these are not a safety hazard for people walking below. You can also build a bee condo by drilling holes of varying diameter about 3 to 5 inches deep in a piece of scrap lumber mounted to a post or under eaves.

- You can add to nectar resources by providing a hummingbird feeder.

  To make artificial nectar, use four parts water to one part table sugar. Never use artificial sweeteners, honey, or fruit juices. Place something red on the feeder. Clean your feeder with hot soapy water at least twice a week to keep it free of mold.

- Butterflies need resources other than nectar.

  They are attracted to unsavory foodstuffs, such as moist animal droppings, urine and rotting fruits. Try putting out slices of overripe bananas, oranges and other fruits, or a sponge in a dish of lightly salted water to see which butterflies come to investigate. Sea salt provides a broader range of micronutrients than regular table salt.

- Learn more about pollinators

  Get some guidebooks and learn to recognize the pollinators in your neighborhood. Experiment with a pair of close-focusing binoculars for butterflies, bees and hummingbirds.

Learn How You Can Use Agroforestry to Help Pollinators

The April 2015 issue of the Inside Agroforestry Newsletter has hit the streets on the National Agroforestry Center website. This issue of Agroforestry Center's Inside Agroforestry highlights ways that agroforestry has supported pollinator conservation and management as well as efforts that have also served to educate the public.

- Learn How You Can Use Agroforestry to Help Pollinators (PDF, 6.35 MB)
- Also take a look a the Agroforestry Center's Pollinators Issue web page…

Pawnee National Grassland Receives Its First Pollinator Garden

Noble Energy established a pollinator garden on the Lillifield Pipeline as part of their restoration work last fall. The fenced area was hydro-seeded with plant species native bees and butterflies favor and will help provide a space for these pollinators to thrive.

Pollinators are an important part of plant reproduction. Large game animals, migratory songbirds and livestock feast on plants dependent on pollinators for propagation. Pollinators also benefit the agricultural community by proliferating important crop species. Many native bees and butterflies are declining due to the decline of pollinator plants they need to survive.

The Pawnee National Grassland (PNG) is located in northeast Colorado east of Fort Collins, Colorado, and serves as an important reserve of native short-grass prairie formerly abundant along Colorado's Front Range. This project was a cooperative effort between the oil and gas industry and federal agencies. Pawnee National Grassland employees consulted with the USDA Natural Resources Conservation Service (NRCS), as they recently installed several large pollinator gardens on lands managed under the Cropland Reserve Program (CRP).

These areas are located on farms and ranches near the Grassland. The PNG Planner, Biologist, and Rangeland Specialist suggested prime locations and added fencing to keep livestock out while allowing birds easy access to the garden. NRCS staff created a seed mix for the project, and Noble Energy installed the garden this fall at the direction of the PNG Lands and Minerals Specialist.

"Everyone is excited to see the pollinator garden this spring. The Pawnee National Grassland is always looking for partnership opportunities such as this to expand our ability to manage the Grassland resources for long-term, public benefit," Acting District Ranger Ken Tu said.

Source: U.S. Forest Service, "Gardening for Pollinators", https://www.fs.usda.gov/managing-land/wildflowers/pollinators/gardening.

Insect Basics

Six legs, three body parts (HEAD, THORAX, and ABDOMEN), a hard EXOSKELETON, and compound eyes characterize insects. Most insects have a pair of antennae and two pairs of wings.

Insects grow by MOLTING, shedding their old exoskeleton, and growing a new, roomier one. After molting, and before the new exoskeleton hardens, insect bodies are soft and vulnerable.

Insects go through COMPLETE METAMORPHOSIS. Life cycle stages are EGG, LARVA, PUPA, and ADULT.

Butterflies, bees and beetles are insects whose larval forms are distinctly different from the adult form. Insects whose larval form resembles the adult, such as crickets and cockroaches, go through INCOMPLETE METAMORPHOSIS.

Spiders are NOT insects, but like insects spiders are arthropods (jointed legs, hard outer layer). They have eight legs, compound eyes and an exoskeleton. Some spiders have defensive URTICATING HAIRS which when thrown temporarily blind a predator’s eyes.

Insects can be HERBIVORES or CARNIVORES, and some are PESTS to humans. Mosquitoes feed on mammalian blood, aphids and scale insects infest our gardens, and wasps produce a nasty sting.

Most insects are BENEFICIAL. Bees, beetles, and butterflies POLLINATE our gardens and crops, making possible such foods as chocolate, nuts, and most fruits. Some insects are DECOMPOSERS, helping to breakdown dead material. Other insects, like ladybugs and praying mantis, feed on pest insects.

Flowers have adapted various attributes (COLOR, SCENT, SHAPE, SIZE) to attract specific pollinators such as bees, butterflies, and hummingbirds. See pollinator syndromes for more information.

These pollinators sip NECTAR from the flower, collect POLLEN and carry this pollen to the next flower of the same species (or in some cases, the pollinator moves the pollen within the same flower), thus fertilizing the flower.

Source: U.S. Forest Service, "Insect Basics", https://www.fs.usda.gov/wildflowers/pollinators/animals/insectbasics.shtml.

Migration and Overwintering

The annual migration of North America's monarch butterfly is a unique and amazing phenomenon. The monarch is the only butterfly known to make a two-way migration as birds do. Unlike other butterflies that can overwinter as larvae, pupae, or even as adults in some species, monarchs cannot survive the cold winters of northern climates. Using environmental cues, the monarchs know when it is time to travel south for the winter. Monarchs use a combination of air currents and thermals to travel long distances. Some fly as far as 3,000 miles to reach their winter home!

Where Do Monarchs Go?

Monarchs in Eastern North America have a second home in the Sierra Madre Mountains of Mexico. Monarchs in Western North America overwinter in California.

Eastern North American Population

Overwintering in Mexico

The eastern population of North America's monarchs overwinters in the same 11 to 12 mountain areas in the States of Mexico and Michoacan from October to late March.

Monarchs roost for the winter in oyamel fir forests at an elevation of 2,400 to 3,600 meters (nearly 2 miles above sea level). The mountain hillsides of oyamel forest provide an ideal microclimate for the butterflies. Here temperatures range from 0 to 15 degrees Celsius. If the temperature is lower, the monarchs will be forced to use their fat reserves. The humidity in the oyamel forest assures the monarchs won't dry out allowing them to conserve their energy.

Directional Aids

Researchers are still investigating what directional aids monarchs use to find their overwintering location. It appears to be a combination of directional aids such as the magnetic pull of the earth and the position of the sun among others, not one in particular.

Clustering in Colonies

Monarchs cluster together to stay warm. Tens of thousands of monarchs can cluster on a single tree. Although monarchs alone weigh less than a gram, tens of thousands of them weigh a lot. Oyamel trees are generally able to support the clustering butterflies, but sometimes branches break.

Protection of Oyamel Forest

Conservation of overwintering habitat is very important to the survival of monarchs. The Mexican Government recognized the importance of oyamel forests to monarch butterflies and created the Monarch Butterfly Biosphere Reserve in 1986.

Monarchs can travel between 50-100 miles a day; it can take up to two months to complete their journey. The farthest ranging monarch butterfly recorded traveled 265 miles in one day.

Monarch butterflies are called Mariposa monarca in Mexico.

Western North American Population

Monarchs living west of the Rocky Mountain range in North America overwinter in California along the Pacific coast near Santa Cruz and San Diego. Here microclimatic conditions are very similar to that in central Mexico. Monarchs roost in eucalyptus, Monterey pines, and Monterey cypresses in California.

Flyways

Traveling South

Eastern North American monarchs fly south using several flyways then merge into a single flyway in Central Texas. It is truly amazing that these monarchs know the way to the overwintering sites even though this migrating generation has never before been to Mexico!

Congregation Sites

Monarchs only travel during the day and need to find a roost at night. Monarchs gather close together during the cool autumn evenings. Roost sites are important to the monarch migration. Many of these locations are used year after year. Often pine, fir and cedar trees are chosen for roosting. These trees have thick canopies that moderate the temperature and humidity at the roost site. In the mornings, monarchs bask in the sunlight to warm themselves.

Use of Peninsulas

Monarchs traveling south congregate on peninsulas. The shape of the peninsula funnels the migrating butterflies. At its tip, the monarchs find the shortest distance across open water. They congregate along the shore to wait for a gentle breeze to help them across.

Traveling North

As warm temperatures and lengthening days arrive, the migratory generation of monarchs finishes the development they halted prior to their migration. They become reproductive, breed and lay the eggs of the new generation. This starts the northern journey back to North America. Unlike the generation before them, who made a one-generation journey south, successive generations make the journey north.

Multiple Generations

Generation 1 monarchs are the offspring of the monarchs who overwintered in Mexico. Each successive generation travels farther north. It will take 3-4 generations to reach the northern United States and Canada.

Tracking Migration

The northern migration is tracked by an organization called Journey North. You can help track the migration of the monarch butterfly by visiting this site.

Report your sightings!

The Western Monarch Milkweed Mapper project is part of a collaborative effort to map and better understand monarch butterflies and their host plants across the Western U.S. Data compiled through this project will improve our understanding of the distribution and phenology of monarchs and milkweeds, identify important breeding areas, and help us better understand monarch conservation needs.

Help us track monarchs and milkweed across the West!

You can learn more about a project to track the southern migration at Papalotzin, The Journey of the Monarch Butterfly.

Report Your Sightings!

Help us track monarchs and milkweed across the West!

Source: U.S. Forest Service, "Monarch Butterfly Migration and Overwintering", https://www.fs.usda.gov/wildflowers/pollinators/Monarch_Butterfly/migration/index.shtml.

Ocean acidification (NOAA)

Ocean acidification

In the 200-plus years since the industrial revolution began, the concentration of carbon dioxide (CO_2) in the atmosphere has increased due to human actions. During this time, the pH of surface ocean waters has fallen by 0.1 pH units. This might not sound like much, but the pH scale is logarithmic, so this change represents approximately a 30 percent increase in acidity.

The ocean absorbs about 30% of the carbon dioxide (CO_2) that is released in the atmosphere. As levels of atmospheric CO_2 increase from human activity such as burning fossil fuels (e.g., car emissions) and changing land use (e.g., deforestation), the amount of carbon dioxide absorbed by the ocean also increases. When CO_2 is absorbed by seawater, a series of chemical reactions occur resulting in the increased concentration of hydrogen ions. This process has far reaching implications for the ocean and the creatures that live there.

The pH scale

The pH scale runs from 0 to 14, with 7 being a neutral pH. Anything higher than 7 is basic (or alkaline) and anything lower than 7 is acidic. The pH scale is an inverse of hydrogen ion concentration, so more hydrogen ions translates to higher acidity and a lower pH.

Carbon dioxide and seawater

Carbon dioxide, which is naturally in the atmosphere, dissolves into seawater. Water and carbon dioxide combine to form carbonic acid (H_2CO_3), a weak acid that breaks (or “dissociates”) into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-).

Because of human-driven increased levels of carbon dioxide in the atmosphere, there is more CO_2 dissolving into the ocean. The ocean’s average pH is now around 8.1, which is basic (or alkaline), but as the ocean continues to absorb more CO_2, the pH decreases and the ocean becomes more acidic.

Impacts of ocean acidification on shell builders

Ocean acidification is already impacting many ocean species, especially organisms like oysters and corals that make hard shells and skeletons by combining calcium and carbonate from seawater. However, as ocean acidification increases, available carbonate ions (CO_3^{2-}) bond with excess hydrogen, resulting in fewer carbonate ions available for calcifying organisms to build and maintain their shells, skeletons, and other calcium carbonate structures. If the pH gets too low, shells and skeletons can even begin to dissolve.

The pteropod, or "sea butterfly," is a tiny sea snail about the size of a small pea. Pteropods are an important part of many food webs and eaten by organisms ranging in size from tiny krill to whales. When pteropod shells were placed in sea water with pH and carbonate levels projected for the year 2100, the shells slowly dissolved after 45 days. Researchers have already discovered severe levels of pteropod shell dissolution in the Southern Ocean, which encircles Antarctica.

Ocean acidification impacts on fish and seaweeds

Changes in ocean chemistry can affect the behavior of non-calcifying organisms as well. The ability of some fish, like clownfish, to detect predators is decreased in more acidic waters. Studies have shown that decreased pH levels also affect the ability of larval clownfish to locate suitable habitat. When these organisms are at risk, the entire food web may also be at risk.

While some species will be harmed by ocean acidification, algae and seagrasses may benefit from higher CO_2 conditions in the ocean, as they require CO_2 for photosynthesis just like plants on land. There are some ongoing studies examining if growing seaweed can help slow ocean acidification.

Our changing ocean

Estimates of future carbon dioxide levels, based on business-as-usual emission scenarios, indicate that by the end of this century the surface waters of the ocean could have a pH around 7.8 The last time the ocean pH was this low was during the middle Miocene, 14-17 million years ago. The Earth was several degrees warmer and a major extinction event was occurring.

Ocean acidification is currently affecting the entire ocean, including coastal estuaries and waterways. Billions of people worldwide rely on food from the ocean as their primary source of protein. Many jobs and economies in the U.S. and around the world depend on the fish and shellfish that live in the ocean.

Current research

Ocean acidification is one aspect of global climate change. Anything we do to mitigate climate change today will benefit the future of the ocean as well. Over the last decade, there has been much focus in the ocean science community on studying the potential impacts of ocean acidification. NOAA's Ocean Acidification Program serves to build relationships between scientists, resource managers, policy makers, and the public in order to research and monitor the effects of changing ocean chemistry on economically and ecologically important ecosystems such as fisheries and coral reefs.

Because sustained efforts to monitor ocean acidification worldwide are only beginning, it is currently impossible to predict exactly how ocean acidification impacts will cascade throughout the marine food web and affect the overall structure of marine ecosystems. With the pace of

ocean acidification accelerating, scientists, resource managers, and policymakers recognize the urgent need to strengthen the science as a basis for sound decision making and action.

EDUCATION CONNECTION

Ocean acidification is a problem that impacts the ocean ecosystem as well as commercial industries like oyster farms. This topic can be taught in conjunction with lessons about food webs and ecosystems, the environmental impacts of climate change and CO_2 emissions, and chemistry lessons concerning real-life applications. Students can explore data, including real-time information about carbon dioxide levels in seawater and in the atmosphere.

Source: National Oceanic and Atmospheric Administration, "Ocean acidification", https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification, last updated October 7, 2026.

What is Ocean Acidification?

Ocean acidification refers to a reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO_2) from the atmosphere.

For more than 200 years, or since the industrial revolution, the concentration of carbon dioxide (CO_2) in the atmosphere has increased due to the burning of fossil fuels and land use change. The ocean absorbs about 30 percent of the CO_2 that is released in the atmosphere, and as levels of atmospheric CO_2 increase, so do the levels in the ocean.

When CO_2 is absorbed by seawater, a series of chemical reactions occur resulting in the increased concentration of hydrogen ions. This increase causes the seawater to become more acidic and causes carbonate ions to be relatively less abundant.

Carbonate ions are an important building block of structures such as sea shells and coral skeletons. Decreases in carbonate ions can make building and maintaining shells and other calcium carbonate structures difficult for calcifying organisms such as oysters, clams, sea urchins, shallow water corals, deep sea corals, and calcareous plankton.

These changes in ocean chemistry can affect the behavior of non-calcifying organisms as well. Certain fish's ability to detect predators is decreased in more acidic waters. When these organisms are at risk, the entire food web may also be at risk.

Ocean acidification is affecting the entire world’s oceans, including coastal estuaries and waterways. Many economies are dependent on fish and shellfish and people worldwide rely on food from the ocean as their primary source of protein.

Source: NOAA National Ocean Service, "What is Ocean Acidification?", https://oceanservice.noaa.gov/facts/acidification.html, last updated September 23, 2026.

Sources

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