MINISTRY OF PLANNING AND DEVELOPMENT

BESNet
Biodiversity and Ecosystem Services Network

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MULTILATERAL ENVIRONMENTAL AGREEMENTS

BES-Net TT Project

Pollinators in Secondary Science

Teacher Resource Book (CAPE)

BES-Net TT Project - Pollinators in Secondary Science

The United Nations Development Programme (UNDP) implemented the two-year project – Biodiversity and Ecosystem Services Network Trinidad and Tobago project (BES-Net TT) - on behalf of the Government of the Republic of Trinidad and Tobago (2021-2023). The overall project goal was to conserve globally important biodiversity in Trinidad and Tobago by addressing the science, policy and practice of pollination and pollinator management. Three major outcomes of the project were:

1. Improved scientific knowledge of pollinators and pollination services in Trinidad and Tobago;
2. Improved conservation of pollinators and pollination services through improved plans and policies;
3. The provision of education, tools and support to improve the practice and application of pollinator and pollination science in multiple contexts.

Further background information on the project is available at http://biodiversity.gov.tt/index.php/bes-net/bes-net-tt.html

One key project output under Outcome 1 was building public awareness and knowledge of pollinators and pollination. Students in local secondary schools were identified as a main audience with which such knowledge should be built. A Communication Working Group reviewed the Science curriculum at that educational level and selected topics for which information on pollinators would be relevant. The team brainstormed on ideas to develop content for incorporation in curriculum delivery while adding information to inspire students to value and conserve our local biodiversity.

This resource was based on selected topics in the Biology and Environmental Science curricula at the CAPE level, which are clearly indicated at the start of each section of this booklet. As far as possible, sections incorporate a basic introduction, a hands-on activity and links to additional resources that can be used in curriculum delivery.

If any sections of the booklet are used, your feedback on the resource is welcomed. Please complete the Feedback Questionnaire at the back of the booklet and send to the Environmental Policy and Planning Division, Ministry of Planning (lena.dempewolf@planning.gov.tt). We hope you find these resources to be useful and that your students enjoy using them!

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CAPE Biology

Unit 1, Module 3 – Reproductive Biology
General Objective: Understand sexual reproduction in plants.
Specific Objective: 1.3 Explain the sequence of events from pollination to fertilization.
1.4 Explain how cross fertilization is promoted.

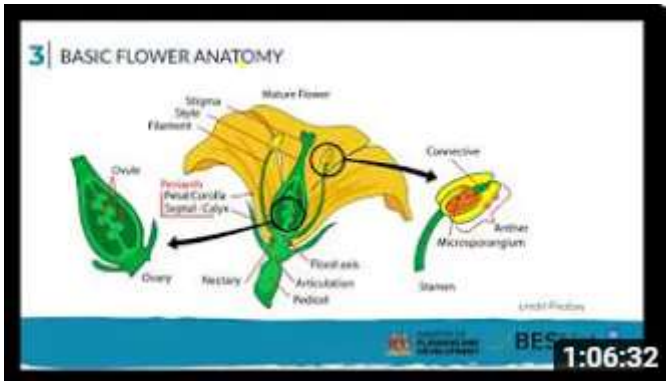
Pollination

Pollination is the act of transfer of pollen grains from one flower to the stigma of a flower of the same species. When the pollen transfer occurs on the same flower or flowers of the same plant, this is called self-pollination. Transfer of grains between two plants is referred to as cross pollination.

Cross pollination is carried out by wind currents or by animals. In many cases, animal pollination is carried out by insect species. These include bees, butterflies, flies and beetles. Other animals involved in pollination include bats, birds and even some reptiles.

Pollination is an essential process as two thirds of the world's plant species depend on pollination by animals and one-third of the foods we eat are produced from plants that are pollinated by animals.

A brief introduction to pollination is provided in the BES-Net TT webinar recording, *Pollinators and Pollination* [1]. (A screenshot from the video is at right)



Pollinator-Flower associations

Scientists have determined that the shape, colour and sometimes scent of some flowers have attractions for particular types of pollinators.

Scent is a powerful signal which draws some pollinators to particular flowers. No two flowers have exactly the same scent. Bees and flies are generally attracted to flowers with sweet scents and beetles to flowers with musty or fruity scents. The scent level is highest when the pollinators are active: bees and butterflies are attracted to flowers whose scent is highest in the daytime while bats and moths are attracted to flowers whose scent is highest at night.

[1] https://www.youtube.com/watch?v=0GSML5AATHo

Birds have no sense of smell and flowers those they pollinate generally are unscented. Birds are, however, attracted by colour and visit mainly red and yellow flowers, as do butterflies. Bees are believed to be attracted to flowers that are white, yellow or blue in colour. Some flowers also have nectar guides that direct pollinators, mainly bees, to the location of nectar.

Flower shape and size also provide visual cues to pollinators and scientists also say that a coevolution is represented between flowers and pollinators in this regard. Beetles and butterflies pollinate flowers that open widely and provide a 'landing pad' for the insect. Trumpet-shaped flowers are pollinated by hummingbirds, which are able to reach deep into the flower to obtain nectar because of their long, narrow beaks.

Video Resources

Plant-pollinator attractions are explored in segments of BES-Net TT webinar recordings as follows:

- *Native plants that attract pollinators*[2] - Time code: 47:50 to 1:01:00
- *Bat pollinated plants*[3]*:* Time code: 35:50 to 53:35
- *Bird pollinated plants*[4] Time code: 24:42 to 41:50
- *Plants visited by stingless bees*[5] Time code: 41:20 to 1:01:00

Follow-up activity

1. Take students on a field trip to an outdoor garden (e.g. Botanic Gardens, farm area, home garden) to observe pollinator-plant interactions.
2. Let them individually record observations over several minutes: organisms seen visiting flowers; name of pollinator (e.g. hummingbird, butterfly, beetle, bee, fly) and colour (blue, lilac/purple, orange, pink, red, white, yellow) and shape (e.g. flat, tubular) of flower.
3. Allow students to compile their data after returning to the classroom: list of flower-visiting organisms; pollinators visiting flowers of a particular colour; pollinators visiting flowers of a particular shape.
4. Discuss results and determine whether any conclusions can be drawn about plant-pollinator interactions on the basis of flower shape and colour. (n.b. scent is not considered here to reduce risk in the field to students).

[2] https://www.youtube.com/watch?v=3EFoTUPqdms
[3] https://www.youtube.com/watch?v=PqRhj4sWm3s
[4] https://www.youtube.com/watch?v=3Z68YgGQXjw
[5] https://www.youtube.com/watch?v=4HegiqPygv0

Pollinator feature: An introduction to stingless bees

When considering the importance of our local biodiversity, stingless bees are a specific group of insects that play a key role in the pollination of native plant species. Honey bees are their perhaps more well-known relatives, owing to the wide use of honey, a major hive product. Many persons are not aware that honey bees are in fact exotic species in Trinidad and Tobago, in that they did not originate here, but were imported to this region to develop the honey industry. While honey bees also provide pollination services, native bees, particularly native stingless bees, have co-evolved with native plants and therefore serve as more effective and efficient pollinators.

Stingless bees belong to the family Meliponini and like honey bees are social insects, living together in colonies. Whereas honey bees belong to one genus, *Apis*, stingless bees belong to several genera and there are close to 500 species of stingless bees globally. In Trinidad and Tobago, at least eleven (11) species of stingless bees have been recorded.

Table 1. A list of the stingless bee species (Meliponini) recorded in Trinidad and Tobago

Scientific name	Common name
Cephalotrigona capitata	Mombucão
Frieseomelitta paupera	Petite angel
Lestrimelitta limao	Lemon cab
Lestrimelitta spinosa	
Melipona favosa	Erik, Moko chiquita
Melipona trinitatis	Guanot, Moko grande
Nannotrigona testaceicornis	Irai
Partamona nigrior	Petit pegone
Plebeia tobagonensis	Mirim
Plebeia sp.	(believed to be different from *P. tobagoensis*)
Trigona amalthea	Pegone
Trigonisca sp.	

Conserving bees in nature means allowing the bees to thrive in their chosen habitats. Stingless bee colonies found in trees should ideally be left there to thrive. When conditions can possibly be enhanced to support the colony, such as planting preferred plants that are known sources of nectar and pollen for the bee species or which supply resins which they need for construction of the hive.

Stingless bees are not nomadic but generally stay in a fixed place. The ideal situation is to maintain bees in their natural habitat, however, for bees which have established colonies within the built environment or within trees that are to be removed, boxing is advised to sustain the life of the colony.

Follow-up activity

A slide show of the locally documented stingless bees is available online at the following link: https://www.youtube.com/watch?v=_xIv4ycqulE

This can be shown to students to introduce them to the stingless bees of Trinidad and Tobago.

Citizen Science

The iNaturalist platform is a global service which provides any person an opportunity to be engaged in citizen science, contributing to a body of knowledge of biodiversity worldwide and for local benefit. Persons can photograph living organisms and upload these photographs to iNaturalist where a team of experts from around the world will propose and agree on the identity of the organism.

A Trinidad and Tobago species listing on iNaturalist was created to capture information from the two islands, and a project which captures a listing of pests and pollinators of Trinidad and Tobago. 711 species have been identified through the project and the platform is sustained to increase data collection locally.

iNaturalist is a useful platform to engage students to contribute voluntarily as citizen scientists to the development of a local biodiversity database. You may also incorporate observations and identifications into school based assessments/internal assessments. The steps to follow are simple, and student contributions can make a big difference in documenting our biodiversity.

Instructions – Preparation Phase

1. The BES-Net TT project posted a webinar that gives a guided tour of the iNaturalist platform.[6] You can view the recording on You Tube with your students.

2. Visit iNaturalist at https://www.inaturalist.org/ to explore the platform.

3. The student/teacher can then sign up to the platform.

4. Go to the Community Tab in the menu and click on Projects. Use the Search function on this page to look for: Pollinators and Pests of Trinidad and Tobago. When the user is ready to post images to the platform, please click on the blue tab which reads "Add Observations to This Project". This will add new observations to build our database of pollinator/pest species in Trinidad and Tobago.

[6] https://www.youtube.com/watch?v=PqRhj4sWm3s

Instructions - In the field

The activity can be done by a group or individuals in the school garden, in an at-home garden, or in a public garden or farm.

1 Use a record sheet during this activity so that each time you go out to the field, you can document the date of the activity, the location, and general notes about the animals/plants seen. A simple template is provided (below) but you can also draw up records in a notebook.

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2 Conduct observation of the flowers in the chosen area to determine which flowers are being visited by possible pollinators.

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3 Note the particular type of flower-visiting organisms present. This can include bees, wasps, butterflies, ants, other types of insects, birds and even lizards.

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4 Take a good photograph of the flower visitor when at the flower. A good photograph will have the following elements:

a. The entire body of the organism is captured within the frame of the photograph.
b. When the photograph is taken, the true colours of the organism are captured; adjust angle of camera as needed so that the lighting of the image does not alter colour.
c. As far as possible, capture a dorsal (overhead) shot and a lateral (side) image of the organism, and if possible, a photograph of the underside (in butterflies) as there may be colour differences at each angle that may help in identification of the organism.

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5 It is useful to capture as many photographs of the organism as possible in the field from which the best can later be selected.

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6 For safety reasons, it is not recommended that organisms are captured. However, if appropriate equipment is available, under an adult's supervision the organism can be captured, photographed against a plain background, and then released back into the environment (may be best to limit this to butterflies captured with a sweep/butterfly net which will cause little injury to the insect).

Student iNaturalist Record Sheet

Date	Location	Flower Visitors Observed	Photographs selected

Instructions - After field visit

1. After returning from the field, it is advisable that the photographs are quickly downloaded to a computer/laptop/hard drive.

2. Review the images captured and select those that meet the requirements of a good photograph.

3. *Optional:* You may decide to rename the file names of each of these selected photographs using a code that gives the general name of the organism and the date of capture. For example, a butterfly photographed on November 5th 2022 can be recorded as 1_Butterfly_001_051122. A different angle of the same butterfly can be recorded as 1_Butterfly_002_051122. Then, if a different butterfly was recorded on the same day at the same location, that photograph can be recorded as 2_Butterfly_001_051122. A photograph of a bee can be renamed 1_Bee_001_051122.

4. When you have made your selection of images, you can begin to upload these to iNaturalist. Log in to the platform and follow Step 4 in the first section, that is, go to the Community tab, select Projects, search for Pollinators and Pests of Trinidad and Tobago, then add observations (upload your images) to the project.

5. You will need to put in a name for your observation. If you know this is a butterfly, you can put 'butterfly' in as the name, but you can also put in 'insect' if you are unsure; this is because some bees may look like wasps, some make look like a fly. When unsure, use a more generic term like 'insect'.

6. You will need to add a location for your observation. There is a map to guide your selection of location, but you may also just put in a main town or village, like California, but ensure that the country is also put in: Trinidad and Tobago.

7. You will receive an e-mail notification when an identification is proposed by one of the many experts around the world that view your photograph. When three experts agree on the identification, you have greater certainty of the identification. If your photograph is of good value as a reference image for future research or identification, you will see the tag "research grade" added to your observation!

8. Send an e-mail message to BES-Net TT at besnet.tt@gmail.com to let us know of your progress on this activity. We especially would like to know how many photographs you have uploaded and how many identifications were made, and if you received any Research Grade designations for your images.

Enjoy this short, animated clip on the BES-Net TT project's TikTok channel, on why using iNaturalist is so useful.

Follow Up Actions

Every observation made of pollinators which is upload to the iNaturalist Pollinators and Pests of Trinidad and Tobago project helps to build a local biodiversity data base. Apart from your contribution to this national data set, there are other ways in which the iNaturalist output can be used. Here are a few ideas:

1. Let students create a poster of their observations and identified organisms to put up in the classroom wall/ notice board. Based on the group's diligence, a new poster can be created every month with new observations!

2. If the group is doing observations in the school garden, a checklist of pollinator species for the garden can be created and perhaps PowerPoint or any other presentation programme can be used to create a slideshow to share with the rest of the school!

3. Let the students conduct research on the identified species to see if these visit other flowers (Generalists) or just the particular plant/flower on which it was photographed (specialist). Find out also if the pollinator is rare or common, or endangered; this will enable them to learn more about the animal and perhaps encourage conservation of the particular species.

Remember that iNaturalist can be used to identify any living organism, so apart from this BES-Net TT activity, encourage the students to use their photography skills and iNaturalist to help explore and build their knowledge of our rich biodiversity in Trinidad and Tobago!

Hands-on Activity: Pollinator exclusion experiment

SO2 – Reproduction in the flowering plant

A simple experiment, and one that yields considerable data, much of which is lacking in Trinidad and Tobago, is assessing the contribution of pollinators to the production of fruits and seeds. The experiment compares the fruit development of flowers that are open to animal pollinations and flowers that are only able to receive pollen via wind. What would happen to plant species if all pollinators were to disappear? How dependent are these plants on pollinators? This experiment will help to answer these questions; it also is a useful idea for the SBA Investigative Project.

Materials needed:

- 30 fine mesh bags (not plastic or cloth)
- String/Ribbon
- Flagging tape
- Pencil/pen and paper/notebook

Optional: Equipment to measure abiotic data:

○ Rainfall ○ Temperature ○ Relative humidity ○ Light intensity

Method:

1. Choose a plant or crop to work with on this experiment.
2. Identify 60 **unopened** female or hermaphrodite flowers on the same species of plant. It is useful to choose more than one flower per plant, but also use more than one plant.
3. Place a bag over each of 30 unopened flowers and secure the opening of the bag with string/ribbon.
4. Multiple unopened flowers can be bagged at a time, but ensure that all flowers are closed, and that there are no male flowers included. Make sure to note how many flowers are contained within each bag.
5. Tag an additional 30 unopened flowers, which are not bagged, with flagging tape.
6. For each plant that is used, bag and tag at least three **open** flowers each on that plant. (Optional: Take photographs of the tagged and bagged flowers for your records)

Photographs at right:
A. Bagged seim flowers
B. Tagged pepper flowers

7. Check on the plants used for the experiment regularly to ensure that bags and tags are in place.
8. As days go by (20 days experiment duration), make the following observations:
    a. How many of the buds that have been bagged have developed into flowers?
    b. How many of the buds that have been flagged but are open to pollinators have developed into flowers?
    c. How many of the flowers of the bagged flowers and the flagged but open flowers have developed into fruit?

A suggested data collection sheet is given as follows:

DATA COLLECTION SHEET FOR POLLINATOR EXCLUSION EXPERIMENT

Day	30 Bagged Buds	Fruit Y/N	30 Tagged Buds	Fruit Y/N	Bagged open flowers	Fruit Y/N	Tagged open flowers	Fruit Y/N
1	*30 Unopened 0 open*	*N*	*30 Unopened 0 open*	*N*	*0 Unopened [X] Open*	*N*	*O Unopened [X] Open*	*N*
2								
3								
4								
20								

Analysis and Discussion

After recording observations, consider the following questions for analysis of the results of this experiment.

- Was there a difference between bagged and open flowers? What were those differences?
- What do you think contributes to the presence or absence of pollinators?
- What can be put in place additionally to prevent animals from entering the bags (e.g. ants that walk along the stalks)?
- Why do we have to place the bags over unopened flowers?
- How do you think your results might change if you selected a different plant species?
- Do you think your results would change if you tried the experiment with the same plant species but at a different location? Why?
- What were some of the challenges faced in this experiment?
- How can the experiment be improved?
- What does this experiment tell you about the pollination needs of your plant species?

Report

Share your findings by writing up a formal report.

Additional options:

1. Compare seed set. In plants where you can tell easily that the fruit has ripened (e.g. by colour change), collect the fruits, cut them open and count the fully developed seeds for each fruit. How do they compare between flowers that were not accessible by pollinators to those that had ample pollinator supply?

2. Choose a time of day (mornings are best for most plants – read up on your plant species to see what time of day flowers usually open and what they might be pollinated by) and observe pollinators. What kind of pollinators visited the flowers? What kind of animals did you see?

3. Visit the plants on multiple days at the same time and for the same amount of time so that you can make comparisons. How many times were the flowers that you observed visited? Does this change from one day to the next? How does the weather affect this (here, you can use any abiotic data that you collect to compare)?

4. Compare multiple plant species. How do your results differ between species? Which plant species are more reliant on pollinators, and which require fewer pollinators to produce fruits and seeds?

5. Optional: Statistics. A very simple way of comparing the data of bagged and open flowers is by using a simple Chi-square test[7]. This tests whether the differences that you saw are statistically significant, or likely just due to chance. You use a Chi-square test for hypothesis tests about whether your data is as expected. The basic idea behind the test is to compare the observed values in your data to the expected values that you would see if the null hypothesis is true.

[7] https://www.simplilearn.com/tutorials/statistics-tutorial/chi-square-test

CAPE Environmental Science

Unit 1, Module 1 – Sustainable Fundamental ecological principles
Specific Objective 2. Explain the relationship between living organisms and their environment.
Specific Objective 6. Discuss types of interactions between organisms in communities.

Unit 1, Module 3 – Sustainable Use of Natural Resources
Specific Objective 6 - Assess the importance of natural resources in the Caribbean.
Specific Objective 10 - Describe measures and tools available for natural resource management and conservation.

Biodiversity assets

The biological diversity of the Caribbean is perhaps the most valuable asset of the region. The flora and fauna, as well as the natural landscapes in which they are found provide key services to the people of the region, from ecosystem services, to intrinsic and cultural, to unique food and nutritional services, as well as educational, scientific and livelihood values.

A stinkbug and a butterfly both carrying out duties as pollinators.

Pollinator species are important facets of biodiversity, and while the organisms that participate in this ecosystem function are often small and overlooked, their absence would create a major negative impact.

Inspite of their importance, these species face several threats to their existence and therefore require concerted efforts by people to be maintained and sustained in the natural environment.

Importance of pollinator species

It is said that pollinators are responsible for one-third of the food that humans eat and that two-thirds of the world's entire species of plants depend on animal pollination. In this regard, our food security is quite dependent upon the sustainability of our pollinator populations, and the maintenance of our floral diversity is especially dependent upon pollinators.

Stingless bees sitting on a honey pot in the hive.

When one considers that our floral diversity itself provisions many ecological services – such as a habitat for wildlife, stabilization and enrichment of soils, support of the water cycle, regulation of temperature, source of medicinal materials, capture of carbon, release of oxygen – then the role of pollinators in initiating the reproductive processes of many plants is quite critical.

In terms of human livelihoods, several persons depend upon successful pollination action in order to obtain the products of plants including plants themselves. Farmers are an obvious beneficiary group, but so are consumers; horticulturalists and those managing flower/plant shops will also benefit from pollinators. Tour guides and those associated with the tourism industry will also benefit from pollination which maintains the landscape of trees, shrubs, vines and other flora with aesthetic value.

Researchers also benefit from pollinators which maintain the floral diversity which is still being investigated, to reveal bioactive properties that can assist in development of natural products for treatment of illnesses and disease, as well as improving crop varieties for various uses. Some pollinators – particularly, bees – also create hive products that have nutritional and medicinal value and are traded commercially (honey, pollen, beeswax etc).

Apart from the land-based plants, pollination activity by animals also takes place in the marine environment. Here, pollination of seagrasses assists in the maintenance of these coastal, submerged plants, which are important in protection of the coastal zone during storm surges. Seagrass meadows also form important nursery habitats for juvenile marine organisms, including commercially important fish and shellfish species captured and sold in the fishing industry.

Threats faced by pollinators

Animal species which carry out pollination vary in size, however several pollinators are insect species which tend to be small and are therefore not always noticeable. It is easy to overlook these organisms and because of this, there is a need to build awareness of their value and take action to address the threats they may face. Key threats to pollinator species are climate change, habitat destruction, pollution and unregulated pesticide use among others.

With the changing climate, weather patterns have changed and there is unpredictability associated with seasons – in Trinidad and Tobago there may be extremely dry conditions in the dry season, and equally extreme weather events during the wet season. These extremes impact many animals whose reproductive cycles are influenced by certain abiotic conditions. Other animals may be impacted by a lack of access to water which may influence movement patterns. When flora is negatively impacted, for instance by drought conditions, pollinators may not have adequate sources of nectar as a main food; this will impact their nutrition and viability.

If pollinator habitats are destroyed – for example through land clearance and tree felling for development – pollinators such as bats and birds will be challenged to find new niches to occupy. Stingless bees are non-nomadic, and destruction of habitats such as hollow logs and trees where their hives are found, will lead to the demise of these colonies. Similarly, pollution in the coastal zone can impair the optimal conditions for growth and survival of seagrass species and their pollinators.

Bats roosting among leaves of a palm tree.

Efforts in conservation

Globally, countries have been taking steps to address the pollinator crisis in several ways, from the complex to the simple. One key action is building awareness of the important role of pollinators and helping persons to identify the species of animals that are involved in pollination. Locally, the BES-Net TT project has contributed to this effort through its online information pages[8] and promotion of the iNaturalist[9] platform. Other international agencies that are also assisting in this area include the Xerces Society[10] and the Pollinator Partnership[11].

Practical action can also improve the survival of pollinators. The establishment of pollinator gardens to create habitat for shelter and food supplies for pollinators is an activity which can be undertaken at a large or small scale using a sizeable piece of land or yard space or simply using a collection of specially curated plants in flowerpots. Bee hotels can be included in domestic or urban settings to facilitate solitary bees. Bat houses allow safe refuges for bats. Management of stingless bees in hive boxes enables security of colonies and at the same time, may provide hive products that can be harvested for human use. Some of these activities were undertaken in Trinidad and Tobago, with practical training in stingless bee management and pollinator garden design offered through a workshop series in 2022. Video recordings of these training sessions are available on the BES-Net TT You Tube channel[12]

In September 2023, Trinidad and Tobago became the 32nd member of The Coalition of the Willing on Pollinators[13] signaling the country's commitment to protection of local pollinator species.

Follow-up activities on pollinator conservation

1. Encourage students to research local action being undertaken to facilitate pollinator conservation. (n.b. interviews, newspaper articles, web searches should provide key points)
2. Assign students to prepare posters on the steps involved in creating one of the following: (i) a pollinator garden; (ii) a bee hotel; (iii) a bat house.
3. Arrange a visit to (i) the Royal Botanic Gardens in Port of Spain, Trinidad to view the *Garden with Wings* butterfly garden; (ii) Wa Samaki Ecosystems pollinator garden in Freeport, Trinidad. Let students makes notes on the types of pollinator species observed and the plants they frequent. Pose questions to the facilitators on the choice of plants for the gardens.
4. Request a Zoom interview with the Biodiversity Specialist, Environmental Policy and Planning Division, Ministry of Planning and Development to find out about Trinidad and Tobago's official efforts in pollinator/biodiversity management, then write a report to document findings.
5. Ask students to research local activities in habitat restoration in Trinidad and Tobago and comment on how these activities may assist in pollinator management (e.g. Fondes Amandes Community Reforestation Project in Fondes Amandes, St. Ann's; Vetiver TT; Protectors of the Environment [Surrey/Lopinot]).

[8] http://www.biodiversity.gov.tt/index.php/bes-net/resources.html
[9] https://www.inaturalist.org/projects/pollinators-and-pests-of-trinidad-and-tobago
[10] https://xerces.org/protecting-pollinators
[11] https://pollinator.org/
[12] https://www.youtube.com/@bes-net_tt/videos
[13] Protecting Pollinators, TTT news

The need for natural resource conservation

SO9 – Justify the need for natural resource conservation; policies, UNCBD

Our natural resources provide several ecosystem services which facilitate our human living. While these resources have the capacity to reproduce, their existence is not dependent only on this capacity, but also on the efforts made by man to allow them to flourish and continue to provide their services.

In this regard, care and conservation of natural resources is imperative. Conservation is often described as 'wise use' of resources. Whereby man has and continues to have extractive use of natural resources, this needs to be done in a judicious manner, so as not to deplete these resources. Care of resources is more of an attitudinal action, whereby decisions are made from a position of emotional intelligence, recognizing that the management of these resources impacts on long-term availability of the resources.

Sustainable Development Goals

Care and conservation of our natural resources in our terrestrial and aquatic environment are referenced several times under the United Nations Sustainable Development Goals[14] as noted directly and/or indirectly in the following descriptions:

Goal 14	**Life Below Water:** Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
Goal 15	**Life on Land:** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
Goal 3	**Good health and well-being:** Ensure healthy lives and promote well-being for all at all ages
Goal 6	**Clean water and sanitation:** Ensure availability and sustainable management of water and sanitation for all
Goal 12	**Responsible consumption and production:** Ensure sustainable consumption and production patterns

Beyond these clear connections, the pursuit and achievement of these goals also impacts positively on achievement of all 17 Sustainable Development Goals (SDGs).

The SDGs had its genesis in the United Nations Conference on Sustainable Development in Rio de Janeiro, Brazil in 2012, with the intention to come up with post-2015 goals, following targets set by the Millenium Development Goals to 2015.

Follow up activity:

The SDGs build upon many actions, plans and programmes that have incorporated efforts in environmental conservation. Have students work in groups to research and prepare posters providing details on some of these prior events:

i. 1972 – The United Nations Conference on the Human Environment
ii. 1992 - The Earth Summit and Agenda 21
iii. 2000 - The Millenium Summit and Millenium Development Goals
iv. 2012 - The United Nations Conference on Sustainable Development (Rio+20)

[14] https://www.youtube.com/watch?v=0XTBYMfZyrM

Trinidad and Tobago's Multilateral Environmental Agreements

A Multilateral Environmental Agreement (MEA) is a legally binding agreement between three or more states relating to the environment. These international treaties are predominantly established by the United Nations (UN). In Trinidad and Tobago, MEAs are coordinated by the MEA Unit (MEAU) which falls within the Environmental Policy and Planning Division (EPPD) of the Ministry of Planning and Development (MPD). There are three general categories of MEAs: Climate change and ozone, biodiversity and waste. Some of the MEAs under the purview of the MEAU are:

- United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol
- Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol
- United Nations Convention on Biological Diversity and its Cartgena Protocol on Biosafety
- Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)
- Ramsar Convention on Wetlands
- United Nations Convention to Combat Desertification and Land Degradation
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
- Rotterdam Convention on the Prior Informed Consent Procedure for certain hazardous chemicals and pesticides in International Trade
- Stockholm Convention on Persistent Organic Pollutants (POPs)

United Nations Convention on Biological Diversity

The United Nations Convention on Biological Diversity (CBD)[15] entered into force on 29 December 1993. It has 3 main objectives:

- The conservation of biological diversity
- The sustainable use of the components of biological diversity
- Fair and equitable sharing of the benefits arising out of the utilization of genetic resources.

The Convention was developed over a period of time from as early as 1988 and was presented at the UN Conference on Sustainable Development (The Rio "Earth Summit") in 1992.

Nagoya Protocol

The *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utlilization to the Convention on Biological Diversity* is an international agreement which aims at sharing the benefits arising from the utilization of genetic resources in a fair and equitable way. It entered into force on 12 October 2014. Trinidad and Tobago is not currently party to the Nagoya Protocol.

Land Degradation and Desertification

Land degradation is an important environmental issue in Trinidad and Tobago; it is brought on by unregulated deforestation, pollution, soil salinization and other actions. The United Nations Convention to Combat Desertification (UNCCD) was established in 1994 to address desertification and the effects of drought on the environment, so that food, water, shelter and economic opportunity can be secured for all. For more information, visit: https://meastt.gov.tt/mea-focal-areas/land-degradation-and-desertification/

[15] https://www.cbd.int/intro/

IPBES

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is an independent intergovernmental body established by States to strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development. It was established in Panama City, on 21 April 2012 by 94 Governments. The United Nations Environment Programme (UNEP) provides secretariat services to IPBES.

The work of IPBES can be broadly grouped into four complementary areas:

- **Assessments**: On specific themes (e.g. "Pollinators, Pollination and Food Production"); methodological issues (e.g. "Scenarios and Modelling); and at both the regional and global levels (e.g. "Global Assessment of Biodiversity and Ecosystem Services").
- **Policy Support**: Identifying policy-relevant tools and methodologies, facilitating their use, and catalyzing their further development.
- **Building Capacity & Knowledge**: Identifying and meeting the priority capacity, knowledge and data needs of member States, experts and stakeholders.
- **Communications & Outreach**: Ensuring the widest reach and impact of the work of IPBES.

For more information on IPBES, visit: https://www.ipbes.net/about

More information on Trinidad and Tobago's actions and participation is available at this link:

- Multilateral Environmental Agreements (Trinidad and Tobago) page - https://meastt.gov.tt/mea-focal-areas/biodiversity/conventions/#1631651074878-90aa9cd3-6b7f

Follow up activity:

The United Nations Convention on Biological Diversity and associated protocols are important mechanisms for global action on biodiversity conservation. Apart from Governmental action, needed work is also conducted by various non-governmental organizations (NGOs) in Trinidad and Tobago to safeguard and ensure sustainable and non-extractive use of local biodiversity: Have students investigate some of the work done by NGOs in environmental conservation, by conducting research on the following:

- Environment Tobago
- Nature Seekers
- Pointe a Pierre Wild Fowl Trust
- Trinidad and Tobago Field Naturalists' Club
- UWI Biological Society

Consider inviting a representative from a local environmental NGO to speak to the students and answer questions about activity in environmental conservation in this country.

Unit 2, Module 1 – Agriculture and the Environment

SO3 – Assess the impact of agriculture on the environment
SO6 – Evaluate environmentally sustainable practices in agricultural systems

Agriculture and the Environment

Agriculture as a human activity that cultivates soil and land, rears livestock and harvests aquatic systems to obtain food, is often associated with changes to or disturbance of a natural landscape. The extent to which these changes or disturbances are persistently impactful on the natural system determines whether they are reversible or allow the natural system to bounce back from these impacts.

Pollination is of central importance to food production, with the transfer of male reproductive cells to female reproductive structures being a key precursor to fertilization and fruit and seed development. Pollinator species which aid in the food production process are found in the natural landscape, however if conditions in agricultural landscapes are not conducive, they may not be as numerous and they may even be cast out or killed when improper agricultural practices are prominent.

Here is a short activity that can be carried out with student groups to underscore the importance of the connectedness of biodiversity and human activities.

Follow-up activity: The Connectedness of Biodiversity

Materials:

- Biodiversity story (see on next page)
- Yarn/ String (at least 6 metres in length)
- Cue cards: laminated photos and/or text (see on following pages)
- Floor space to act roles in the story, which is visible to the whole group

Instructions:

1. Appoint a narrator to read the Biodiversity story. The narrator will stand at the front of the gathering of students where he/she can be seen and heard.
2. Assign a group of volunteers. Each of the volunteers will be assigned a character role during the reading of the story.
3. Each volunteer on cue will come to the front of the gathering in the assigned acting space and collect an appropriate cue card for their role, as well as hold on to a piece of yarn/string.
4. The narrator will continue to read the story as the volunteers one by one come to the acting space on cue, each taking up position along the length of yarn/string.
5. When all volunteers have been added to the story, they should all be holding on to a portion of the length of yarn/string.
6. At the appropriate time in the reading of the story, the narrator will indicate that a character leaves and hand over a cue card. At that time, the specific volunteer acting that role, will remain in position, but release the yard/string he/she is holding, allowing it to fall to the floor.
7. At the end of the story, all volunteers can rejoin their seats (the other students can applaud their efforts). The cue cards and yarn/string should be collected and secured. The class can then get ready to discuss questions based on what was shared in the story.

Biodiversity Story

Farmer Joe manages a small farm north of the Matura Forest in north-east Trinidad. He farms in the most "organic" way possible, not using any pesticides and just using some simple fertilizers. (FARMER character comes forward)

"Short crops" such as peppers, tomatoes and eggplant – solanaceous cops – are popular among farmers in the area. Farmer Joe ensures that he, at all times, has a field under short crops as a sure income earner for his family. Many of these crops at one time evolved from an original, wild species, before becoming the domesticated variety we know today. (CROP PLANTS character comes forward)

Pollinators, among them bees, butterflies and ladybird beetles, ensure that Farmer Joe's crops are productive. Wild pollinators are essential to agriculture and maintaining biodiversity. Some of these pollinators are themselves natural predators of other pests, and their presence on the crops manages the potential impacts of these pests. (BEES character comes forward)

Alongside his farm, Farmer Joe has planted a few fruit trees as a windbreak around his farm in the event of heavy wind. Additionally, when a large harvest comes in, Farmer Joe can obtain a extra income from the sale of the fruit. The trees also provide shade and Farmer Joe had a little respite from the sun when working on the farm in the shade of the trees. (TREES character comes forward)

The fruit trees also serve as a habitat for a colony of frugivorous (fruit-eating) bats. The bats are nocturnal and do all their feeding at night. The bats find a home in the trees and because they feed on the wing, they are also important as seed dispersers and spread the seeds of the fruits throughout the area they forage, increasing the trees for Farmer Joe and for the neighbouring Matura Forest. (BATS character comes forward)

Over time, Farmer Joe saw a new farmer move into the community. That farmer put down some "short crops" also, but he had a different agricultural tradition to Farmer Joe. The new farmer used a cocktail of herbicides, pesticides and other chemicals on his farm. He was accustomed to having a pest-free farm and "the quicker I can kill them, the better for me". (PESTICIDES – give to BEES character and let BEES character drop the yarn/string)

Farmer Joe noticed that as the neighbouring farmer sprayed his crops with chemicals, his crops started to fail. The production was lower than in times past, and he saw a range of new pests on his crops which he had not seen before. Caterpillars were all over his plants, eating the foliage. After a week or two in which this persisted, Farmer Joe was faced with the temptation of using the chemicals himself. (LOSS OF CROPS – give to CROP PLANTS character who drops the yarn/string)

Farmer Joe asked for advice on the chemical cocktail. The chemicals were costly and he noticed that the labels of the chemical containers had warning red bands. He remembered that an Agricultural Officer advised that red and yellow bands on chemical containers indicated toxic chemicals and blue and green bands signaled lower toxicity. Farmer Joe decided not to use the chemicals. At first he decided to wait it out till the next growing season. What Farmer Joe did not know, was that pesticide drift from his neighbour's farm had impacted the pollinators and reduced the production potential of the farm. Other non-target pests became opportunistic, their populations grew and they ravaged his crops. (LOSS OF POLLINATORS + INCREASE IN OPPORUNISTIC PESTS)

As the crops declined, so did the productivity of Farmer Joe's fruit trees. When in the past these trees afforded him an additional income, he was not getting a large harvest anymore to sell in the market. Farmer Joe decided that he needed a break from this farm and opted to go to another area to plant his crops, where the influence of chemicals from another farm would be less. He sold the farm and moved on. (Departure of FARMER character – let FARMER character drop the yarn/string)

With Farmer Joe's departure, in moved a land developer, who wanted to build a holiday home in this picturesque corner of Trinidad. The new owner cleared the now fallow farm, removed the fruit trees and put in a hedge of ornamental plants to establish a boundary between his site and the neighbouring farm. (LOSS OF FRUIT TREES – let TREES character drop the yarn/string)

As the trees were removed, all the bats that lived in them were disturbed. They flew out quickly and made their way into the Matura Forest to find new homes. No longer could they find a food source at the site of the old farm, nor could they assist in seed dispersal in this area. (REMOVAL OF TREES – let BATS character drop the yarn/string)

The landscape of Farmer Joe's farm had now changed. No crops, no pollinators, no fruit trees, no bats, no Farmer Joe. But the land developer now had a home under construction and the new farmer was pumping chemicals onto the land to get his food production going. Is this a happy ever after for biodiversity?

Follow-up questions for discussion

1. What is/are the value/s of maintaining naturally exisiting fauna within the crop system?
2. What advantages does organic farming bring to the natural environment?
3. What are the factors that may have caused a decline in Farmer Joe's crops even though his farming practices were more environmentally sound than his neighbour's?
4. What advice can be given to farmers to assist them in managing pests in an environmentally friendly manner?

Cue cards (Print, cut out and laminate)

FARMER	
CROP PLANT	
BEES	
TREES	
BATS	

PESTICIDES
LOSS OF CROPS
LOSS OF POLLINATORS
DEPARTURE OF FARMER
REMOVAL OF TREES

Natural pest control

Within ecosystems, natural enemies are present among the wide variety of organisms which live and feed in a common space, each occupying their own habitat and feeding niches. The disruption of natural ecosystems for development offsets the natural balance that may have existed originally.

Often the use of synthetic chemicals is a knee-jerk response to pest control in agricultural systems and indeed if pest levels are high, some chemical use is expected. The chemicals used in control of issues in crop systems (pesticides, nematicides, fungicides etc.) however have been grouped into ***four classes of pesticides*** with two classes being highly toxic and two classes being less toxic to the environment and the beneficial organisms like pollinators that are not targeted as pests.

As well, over time researchers and farmers themselves have noted that pest control is possible by the introduction of ***natural enemies*** of pests, other natural organisms, and ***materials extracted naturally from plants*** to the crop system. These efforts reduce the amount of synthetic chemicals introduced to the crop ecosystem, thus minimizing health and human risk, issues pertaining to development of pest resistance to these chemicals, and negative impacts on pollinators.

Agronomical techniques and integrated pest management (IPM) approaches also aid in this type of pest control, such as the use of ***barrier crops*** and growing ***pest repelling plants*** near to the main crop. ***Permaculture***, described as a land management approach which uses a set of design principles to maintain ground cover can also be applied to agricultural systems to manage or reduce pests in a system and consequently reduces the need for pest control through non-natural means.

Follow-up Activity

As a follow-up activity, students can pursue research on some of pest-control techniques listed below, which are pollinator friendly. For each technique ensure that students provide examples.

Pollinator-friendly pest control options:

- Natural enemies
- Barrier crops
- Pest-repelling plants
- Use of natural products derived from plants
- Integrated pest management
- Permaculture

Suggested local information sources:

- Extension services of the Ministry of Agriculture, Land and Fisheries
- Wa Samaki Ecosystems Limited

Feedback Questionnaire

Teacher Resource Book Form 6/CAPE

1. At what school do you teach? _____

2. What level do you teach? Lower 6th Form □ Upper 6th Form □ Other _____

3. Did you enjoy using the activities in this booklet? Yes □ No □

   Explain your answer _____

   _____

4. How many of the booklet's activities for your class level have you used?
   Approximately 25% □ 50% □ 75% □ 100% □

5. Did you find the content to be relevant to the curriculum? Yes □ No □

6. Was it easy or difficult to integrate content in your teaching? Easy □ Difficult □

7. Describe the experience the students had while taking part in these activities.

   _____

   _____

8. What did you like best about this resource? _____

9. What did you like least about this resource? _____

10. Were there other aspects of pollinators you would have liked to see in this booklet? If yes, please share these, below.

    _____

    _____

11. If you have any recommendations about how this resource may be improved, please share below.

    _____

    _____

    _____

Thank you for your feedback. Kindly send your completed form to bes-net.tt@gmail.com

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