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Human-Environment Relations: A Case Study of Donana National Park, Andalucia, Spain and the Los Frailes Mine Toxic Spill of 1998

Curriculum Unit 99.06.01
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Introduction.

This curriculum unit on contemporary human-environment relations focuses on the interplay of cultural, ecological, environmental, and human health issues. It is a case study of an environmental disaster near Donana National Park, Andalucia, Spain. Donana is considered the most important wetland in Europe. Its marshes, mobile dunes, and forests are unique. In April 1998, a sudden burst in a zinc mine waste reservoir released a billion gallons of heavy metal contaminants into the Guadiamar River, a tributary of the Guadalquivir River, which forms the eastern boundary of Donana National Park. The toxic spill quickly was regarded as a national disaster in Spain, and it received extensive coverage in the press and in science journals. The highly acidic sludge, zinc, cadmium, arsenic, and lead pollutants that were released into the environment continue to threaten the ecology and the biota of this internationally significant wetland.

I had the opportunity to visit Spain in the summer of 1998, just several months after the toxic spill occurred. The trip started and ended in Madrid, but the majority of time was spent traveling through the southern and southwestern regions of Spain, in Andalucia and Extremadura. A day excursion to Donana National Park gave me a chance to make first hand observations of the wetland (albeit during the dry season), to discuss ecological and environmental issues with park and tour group representatives, and to obtain some highly informative literature on the region. Having a highly current environmental problem of international importance and some direct experience with the setting for the problem, I quickly developed a desire to collect additional information and develop a curriculum unit in environmental science.

The unit is intended for high school juniors and seniors in a year-long environmental science elective, and for juniors and seniors in an honors anatomy and physiology elective. For the environmental science students, I intend the unit to raise topics relating to groundwater contamination, the threatened loss of biological diversity, land management, and risks to human health. For the anatomy and physiology students, the unit will introduce subjects that lead to further study of environmental/human health problems. My primary purpose in developing the unit, however, is to show all my students how they might undertake a broad-based investigation into a contemporary environmental issue.

The classroom activities which are presented in the unit follow from the development of an historical narrative

about Coto Donana, the name for this long time nature preserve, and they include cultural, ecological, environmental, and land management components. Students' research skills are developed in an attempt to develop an understanding of a complex set of issues. The unit considers the geography of Spain, the historical and cultural heritage of Andalucia Province, the biogeographical province in which Donana is found, and the legal protections that are afforded Donana by national governance and international designation. It is my hope that the case study presented here will lead to the development of similar teaching units focusing on regional environmental problems (such as groundwater contamination at Massachusetts Military Reservation/Otis Air Force Base, Cape Cod, Massachusetts), and local environmental problems (such as pollution of the Quinnipiac River marshes of Greater New Haven, Connecticut). Future refinement of the unit also will lead to further exploration of the following related topics: (1) people's attitudes toward nature and wildlife; (2) the broad range of interests that different individuals, groups, organizations, and political groups maintain concerning the environment; (3) the management implications of people's attitudes toward and values assigned to nature; (4) the interrelations among sustainable resource development, human health, and ecosystem management; (5) the ethical issues which arise from human actions that cause damage to human health and diminished environmental health; (6) the development of mapping skills, using a variety of maps and photographs to track the distributions of natural resources, human population, and health impacts. Several of these topics have been central to the Teachers Institute seminar that has given rise to this unit.

The unit has been developed in the 1999Yale-New Haven Teachers Institute, where I have been a fellow in the seminar, "Human-Environment Relations: International Perspectives from History, Science, Politics, and Ethics," led by John P. Wargo, Associate Professor of Environmental Risk Analysis and Policy. This seminar has engaged its participants in challenging discussions about the effects of human actions on the environment and human health. The several purposes of the seminar include identification of environmental issues of importance, disciplinary and interdisciplinary analyses, interrelations among ecosystem management, human health, and sustainable resource development, values and ideology, and questions of ethics. In the seminar, Institute fellows have looked at the following topics in human-environment relations: population growth; agriculture; land use and infectious disease; ecosystem management; watershed management; land use and environmental health; biodiversity loss; ecosystem fragmentation and landscape planning; wildlands, parks, and protected areas. (A more comprehensive treatment of seminar purposes and topics is available in the seminar description.)

I have become a strong believer in the use of current event topics in the teaching of science. Television is without a doubt the medium of choice for young people. At times in my teaching, I make use of some of the excellent life science (natural history, ecological, medical) and physical science programs that appear on television. However, my medium of choice for launching into current events is the newspaper. I tend to use articles from the New York Times. The NYT recently has expanded its Tuesday Science Times section, and an increasing number of Section A articles appear through the week. These are useful, accessible articles that can be incorporated into the science curriculum. I have found three New York Times articles on Donana National Park which have appeared in the last two years. I use them in a non-chronological order to frame sections of this unit. They are an April 1998 announcement of the zinc mine toxic spill near Donana National Park, a 1997 travel article encouraging a visit to Donana, and a 1999 article updating the public on the effects of the toxic spill.

The Problem - Disastrous Sludge Spill in Southern Spain.

I begin the unit by presenting my students with an environment/health problem, a toxic chemical spill at Aznalcollar, Spain, as reported in the May 2, 1998 issue of the New York Times. The article, entitled "Big sludge spill poisons land in southern Spain," announces what some call the most serious environmental disaster to occur in Europe. To my students, I state that this is an issue of concern to our study of environmental science and human health. We are now beginning a several week study of the topics which emerge from this article, and from other written and visual materials which will become available to us. The article is read aloud in class by a succession of student readers. Following completion of the reading, discussion ensues. I pose several questions to guide the discussion. Where does the news event take place? (Wall maps are available in the room.) What is the specific incidence that threatens the environment? What are the potential consequences of the event? How might the natural environment be affected? What are the short term and the long term impacts of this toxic spill? What might be the consequences to people living in or visiting the region? Do you foresee any short term or long term health consequences for people? Who do you think the principal players will be as this story unfolds? How would you go about investigating the story further?

The following issues should emerge directly from the article in the class discussion:

1. A large zinc mine in southern Spain has experienced a break in its mine tailings sedimentation basin, and at least 150 million cubic feet (a billion gallons) of toxic industrial sludge has contaminated previously pristine lands;
2. The waste consists of acid sludge and heavy metals, particularly zinc, cadmium, and arsenic;
3. There is an immediate impact on at least 15,000 acres of farmland;
4. The mine is owned by a Canadian company, Boliden Ltd, part of a larger, multinational corporation;
5. Local rice, cotton, and fruit tree farmers, such as Jose Antonio Alvarez, are in a state of shock;
6. People in a nearby village are experiencing burning sensations in eyes and throats;
7. The river that received the sludge connects via a larger river to Donana National Park, a wetland environment of international significance;
8. The spill occurred during the spring breeding season, and a large number of birds, some of them rare and endangered, are threatened as the heavy metal pollution enters the food web;
9. Spain's Environment Minister, Isabel Tocino, terms the waste spill a "terrible catastrophe";
10. Many environmental threats to Donana existed prior to the disaster, including fertilizer and pesticide seepage into groundwater, expansion of agricultural fields, and increased development of land for a new tourism industry;
11. Environmentalists have been concerned a long time about Spain's lack of interest in environmental protection;
12. The owners of the mining company have agreed to pay for the cleanup; they have begun an assessment of the spill.

I state that this New York Times article is the starting point for student research into historical and cultural, biogeographical, ecological, environmental, and human health issues. After presenting the central problem of the case study, I inform the students that we will put aside the story of the toxic spill for awhile, and we will begin to consider the broader context for the environmental problem. I believe that some historical and cultural context needs to be developed to understand the problem and to allow it to take on a human dimension for my students. The following questions come to mind. What does a chemical spill in Spain have to do with us? How does it affect the livelihoods of people? What is the cultural background, the socioeconomic level, the method of employment of the Spanish people living near Donana? Did they bring this environmental disaster on themselves? What were the environmental and health risks that were being taken at the mine, and what were the potential and actual benefits to the local people for having the mine in operation? How long has mining been practiced here? What parallels might there be for residents of the United States, of Connecticut, of New Haven? Are there any other issues that the students feel should be investigated?

The next step in the process of student research is to develop background information on the region of Spain where the toxic spill has occurred. The environmental disaster that occurred will have little meaning to students if they have no understanding of the country where the pollution occurred. While I do not suggest conducting an in-depth study of Spain, its history and culture, I do want to construct an image of the southern European country where Donana National Park and the zinc mine are located. As a tourist who recently visited Spain, I began my learning process about Donana National Park and southern Spain by reading travel guides. My students will do the same. There are many excellent travel guides on Spain, and the two guides I have selected for use are Rick Steve's Spain & Portugal 1998 (John Muir Publications), which describes itself as a distillation of essential travel knowledge, and Lonely Planet Spain (Lonely Planet Publications, 1997), a more comprehensive guide for the traveler. Students are presented with copies of these two guides, and they are asked to gather information on pertinent geography, history, and culture of the region. They will in effect plan a trip through southern Spain within some guidelines that I present. Rick Steve has information on Andalusia, the region of southern Spain where the spill occurred, and three of its major cities, Granada, Sevilla, and Cadiz. Lonely Planet has 150 pages of travel information on Andalusia, presented by province. Granada, Sevilla, and Cadiz are the principal cities of the three provinces of the same names.

Assignments relating to the Andalucian region of Spain.

Assignment #1.

Use the Michelin map provided to plan a two week car trip through Andalusia, Spain. Plot the course of your trip on the map, identify highways and secondary roads, and develop a list of the route numbers you need to follow. Your trip should begin in Granada (an hour or so north of the Spanish resort region on the Mediterranean Sea), then proceed to Antequera, Ronda, Arcos de la Frontera, and Sevilla, with side trips to Cadiz and Huelva. (Keeping track of anticipated expenses for lodging, food, and excursions would bring a greater touch of reality to the travel plan.)

Assignment #2.

Develop an outline of the principal overnight stops you would make along the trip, the landmarks you would visit and the activities you would expect to pursue during your travel. Each student is responsible for

collecting and sharing information on an aspect of the trip. Several students will be assigned a particular town or area of Andalucia to research. Following sufficient time for collecting information and a day devoted to brief student presentations, I give color slide presentations on Andalusia, Spain, focusing on Granada, Ronda, Arcos de la Frontera, Sevilla, Cadiz, and Huelva. One section of the presentation addresses the significant locations and events in the life of Christopher Columbus, from his arrival in Spain and efforts to convince the Spanish monarchy to bankroll his voyages of exploration, to his completion of four New World trips, his death, and his modern legacy. While not essential, the presentation of this information can be timed with the occurrence of Columbus Day, a regularly scheduled school holiday in New Haven.

Assignment #3.

Pursue research on the geography, history, and culture of the Andalusian region. (These student activities are stated in objectives form.)

Objectives.

1. Develop some familiarity with the basic geography of Spain (southwestern Europe) and its Andalucia region, including Andalucia's two mountain ranges, the Andalucian plain, and the Atlantic Ocean and Mediterranean Sea coastlines.
2. Associate Andalucia with a dry Mediterranean climate.
3. Become familiar with the several contributing cultures of Andalucia - Islamic (Moorish), Jewish, and Christian. Important elements of these cultures include: Muslim and Christian architecture (palace fortresses, cathedrals, churches, plazas, gardens), visual and performing arts (painting, flamenco music, singing, and dance), foods (tapas, gazpacho, etc.), festivals (including bull fighting), customs, and religious observances.
4. Recognize key events and locations in the life of Christopher Columbus (ports from which he sailed, monasteries and churches where he worshiped, present day monuments and attractions).

Andalucia Region of southern Spain.

The following thumbnail sketches cover the information I expect my students to review in their research on southern Spain. General information. This is a large region which stretches across the south of Spain. It is defined geographically by two east-west oriented mountain ranges, the Sierra Morena and the Sistema Penibetico, lying on either side of the Guadalquivir River Valley. A narrow plain of Mediterranean coastline, the Andalucian plain, is found here. Portions of Andalucia are very wet (Sierra de Grazalema, in the southwest), and portions are very dry (deserts of Almeria). Eight provinces and the British colony of Gibraltar (under British sovereignty) make up Andalucia. Five provinces (Granada, Malaga, Cadiz, Huelva, and Sevilla) are considered here.

Muslim invaders from North Africa first arrived in Spain in the 8th century. Muslim-occupied Spain was known as Al-Andalus, hence the later name Andalucia. The largest cities are Granada, Sevilla (Seville, the regional capital), and Cordoba, all of them formerly Muslim cities. The Reyes Catolicos (Catholic King Fernando and Queen Isabel) conquered Granada in 1492, shortly before Columbus set sail to the Americas. Following Columbus' return to Andalusia and subsequent voyages by him and others, the large city of Sevilla became extremely wealthy. Much of the subsequent trade with the New World took place through the ports of Sevilla and Cadiz.

Andalucia is known for bullfights, flamenco guitar music and dancing, fiestas and spectacles, foods such as gazpacho and tapas plates (and beverages such as sherry), white-washed hill towns, (many of the buildings are painted white), Mediterranean and Atlantic Ocean resorts (Costa del Sol), equestrian horses, castle ruins, and strong Moorish influence. The Romeria del Rocio is an annual festive pilgrimage occurring in Andalucia each year, the largest religious (or semi-religious) event in Europe. The pilgrimage, which is organized by nearly 100 brotherhoods (hermandades) and attracts nearly 1 million pilgrims, converges on the village of Rocio (near Donana National Park) during the 7th weekend after Easter (the Pentecost). Pilgrims travel by foot, on horseback, and in covered wagons, camping along the way. The modern tourist in southern Spain stays in hotels, or paradors. Flamenco, the music and dance art form, derives from Moorish and gypsy cultures. It includes guitar, castanets, and hand-clapping (palmas). Another recognizable feature of Andalucia is the extensive use of colorful azulejo tiles in building and patio construction.

Granada Province (and the city of Granada). Granada is located in the Darro River Valley, with the Sierra Nevada mountains in the background. The population of the city is approximately 250,000. Granada was the last stronghold of the Moorish kingdom in Spain. The most famous and beautiful example of Moorish architecture is the Alhambra fortress, positioned high on a hill in town. The name means pomegranate. It has been occupied at various times in the past by Iberian tribes (5th century B.C.), the Romans (3rd century B.C.), the Visigoths (following Roman rule), Muslims (conquering the city in 711 A.D.), and Christians. After the 13th century fall of Cordoba and Sevilla from Muslim rule, the Muslims remained in Spain only in Granada. Moorish domination of the city peaked in the 14th century, when trade, artistic and scientific contributions were made under the rule of Yousouf I and Mohammed V. In the late 1400s, the Moorish dynasty was in major decline, and the fortress palace, the Alhambra, became a place of retreat into a life of pleasure-seeking. An invasion of the Alhambra was begun by Christian armies in 1482. Castilla and Aragon became unified with the marriage of Ferdinand and Isabella. Christians again laid siege to Granada in 1491, and the Reyes Catolicos were successful in retaking Granada in 1492. Ferdinand and Isabella set up court in the Alhambra for several years thereafter. Jews were forced to convert to Catholicism or were expelled from Spain in 1492. Muslims were forced to convert to Catholicism in 1502 or they, too, were forced to leave Spain. Muslim converts became known as moriscos. By the second third of the 19th century, there was a restored recognition and appreciation of Granada's Islamic heritage. Tourism became a major industry by the end of the 19th century.

Malaga Province and Cadiz Province (cities and towns of Ronda; Arcos de la Frontera, Jerez de la Frontera, Sanlucar de Barrameda, Cadiz). The Spanish province of Malaga, located in southcentral Andalucia, is known for its Mediterranean resort beaches and its beautiful hill country. Its main city, Malaga, east of Gibraltar on the Costa del Sol, was established as a Phoenician trading post in the 8th century. The town of Ronda is due west of Malaga and about an hour north of the Costa del Sol coastline. The province of Cadiz lies west of Malaga, stretching from the Strait of Gibraltar to the eastern side of the Guadalquivir River and inland to the Sierra de Grazalema. Its main city is the Atlantic Ocean port of Cadiz, which is located on a prominent peninsula and today combines beautiful resort beaches with extremely heavy industrialization. Cadiz Province has a number of small towns, including Jerez de la Frontera and Sanlucar de Barrameda, two of the so-called

sherry-making towns.

Ronda. Ronda is one of the largest of the white-washed towns. Its population is 35,000 - 40,000. Ronda is known for its old (14th century and 17th century) and new (18th century) bridges spanning the 100 meter deep gorge of the Rio Guadavin. Ronda was Muslim territory until 1485. It has the oldest bull ring in Spain, the Plaza de Toros, built in the 18th century. One can visit a bullfighting museum (Museo Taurino) here.

Arcos de la Frontera. Towns carrying the ending "de la Frontera" are those historically Christian towns which were on the front line in the efforts to recapture Spain from Muslims. Over a 200 year period, from the late 13th to the late 15th centuries, the Muslims were slowly pushed back into North Africa. The countryside surrounding Arcos de la Frontera, perhaps the most beautiful of the white towns of Andalucia, has sunflower and wheat fields, vineyards, and olive groves. Arcos is perched on a high promontory, and it retains a medieval street plan, winding and narrow. Some of its building-lined streets are barely able to accommodate automobiles. The most narrow streets in the old part of town can be driven in compact cars only, and side mirrors must be folded in so as not to scrape against the outer walls of buildings. On one street near the summit of this town, it is necessary for cars to do back and forth maneuvers in order to negotiate a hairpin turn. Pedestrians frequently have to step inside recesses when cars pass by. The two most significant churches historically are the Basilica Parroquia de Santa Maria, begun in the 15th century, and the Iglesia de San Pedro, a 15th century Gothic church with bell tower.

Cadiz. The population of this heavily industrialized and large seaport is 155,000. Cadiz was at its peak of grandeur in the 1700s, when it accounted for 75% of Spanish trade with the Americas. Cadiz was founded in 1100 B.C. by Phoenicians, who traded in Baltic amber and precious metals. Christopher Columbus set sail from Cadiz on his 2nd and 4th voyages to the New World. Cadiz' most notable landmark is the large, yellow-domed Cathedral, completed in 1838. Cadiz was a frontier of Christian held territory during the Reconquista, the 250 year period of warfare between Muslim and Christian rulers. Today, Europeans on holiday flock to Cadiz' beautiful Atlantic Ocean resort beaches.

Sanlucar de Barrameda. Columbus sailed from here in 1498 on his third voyage to the New World. Ferdinand Magellan's (Portuguese) 1519-1522 circumnavigation of the world began here. The circumnavigation was not completed by Magellan, who died in the Philippine Islands, but rather by the Basque pilot Sebastian Elcano.

Huelva Province (Huelva, El Rocio, Parque Nacional de Donana, Rio Tinto). The province of Huelva, westernmost of Andalucia's provinces, stretches from the west bank of the Guadalquivir River to the border with Portugal. It contains most of the Donana National Park. The beaches of Costa de la Luz are located here. Columbus first arrived in Huelva in 1485, after his failure to convince the Portuguese to support him in his search for a western passage to the East Indies. Columbus set sail from Huelva on August 3, 1492 on the first of four voyages to the New World. A number of historical sites in the vicinity of Huelva relating to the life of Columbus are visited annually by pilgrims. Most important of these are La Rabida (the 14th century Franciscan monastery where Columbus prayed before his departure), Palos de la Frontera (with its Iglesia de San Jorge, where Columbus and crew attended mass prior to their departure - here Columbus returned in March 1493 to give thanks for his safe return) and Moguer (where Columbus visited the 14th century Convento de Santa Clara numerous times). At Punto del Sebo there is a 34 meter statue to Columbus, the Monumento a Colon. A new attraction in Huelva is the Muelle de las Carabelas (Wharf of the Caravels), with full-scale reconstructions of Columbus' three ships, the Santa Maria, the Nina, and the Pinta. I first saw these ships in San Juan, Puerto Rico, in December 1991, where they had arrived after sailing across the Atlantic from Spain. They were in America for the 500th anniversary of Columbus' voyage to the New World.

Sevilla Province (Sevilla, Italica). Sevilla, the fourth largest city in Spain, has a population of 700,000. It is the leading city of Andalucia. Bullfighting and flamenco are important here. Sevilla is called the gateway to the New World, for it is from this area that Columbus sailed to the Americas. While its large harbor silted up several centuries ago, the Rio Guadalquivir which flows through Sevilla remains navigable to the Atlantic Ocean over a distance of more than 100 kilometers. Amerigo Vespucci, for whom America is named, sailed from the river harbor of Sevilla. Sevilla became a major cultural center through the artistic efforts of Velazquez, Murillo, and Zurbaran. The people of Sevilla have a custom of taking an early evening stroll, or paseo. The old Jewish Quarter, also called the Barrio de Santa Cruz, is a frequently visited part of Sevilla. Major monuments in the city are the gothic Cathedral (completed in 1507), La Giralda tower (constructed during the period 1184-1195 and considered Spain's most perfect Islamic building), and the Alcazar fortress palace (originally constructed in the early 10th century, added to in the 11th and 12th centuries). The present mudejar palace, the Palacio de Don Pedro, was built by Pedro I during the period 1364-1366. Its palace gardens approach those of the Alhambra in beauty. The Cathedral is the third largest in Europe, behind St. Peter's in the Vatican State and St. Paul's in London, and it is the largest Gothic church in Europe. Called the Catedral de Santa Maria de la Sede, it has the purported tomb of Christopher Columbus, whose body was transported here from Cuba in 1899. (As he died in Spain, it's unclear to me how his body got to Cuba.) The tomb consists of four crowned sepulcre-bearers representing the four Spanish cities of Castilla, Leon, Aragon, and Navarra. The cathedral has a huge main altarpiece. The Giralda Tower is attached to the cathedral. It was originally built as a Moorish minaret, constructed by Yousouf Yacoub al-Mansour, and it was modified later to become the Christian cathedral's bell tower. The Alcazar is a palace of Muslim design in which Al-Mutamid and Yousouf Yacoub were 12th century Muslim rulers. The Alcazar was expanded by Moorish workmen for the Christian King Pedro I. Fernando III El Santo (the Saint) recaptured Sevilla from the Moors in 1248. Sevilla remained a leading city for the next 200 years, although nearly half its population died during a major outbreak of the plague in 1649. A subsequent plague in 1600 killed off another large percentage of the population. The town has a number of plazas, or town squares. The Plaza de Espana was constructed in 1929 for an Iberian-American fair. It is constructed in a neo-Renaissance and neo-mudejar style. One of the most impressive churches in Sevilla is the Basilica Macarena (dedicated to the Virgen de la Macarena, or the Weeping Virgin). Holy Week processions are a major religious festival in Sevilla..

Italica. This is the first Roman town in Spain. It was founded in 206 B.C. as a retirement village for veterans of the Punic Wars. The Roman emperors Trajan and Hadrian were born here. Italica has been abandoned since the time of the Visigoths. In recent years it has become a significant archaeological site and tourist stop for travelers studying the Roman period of dominion in Spain. The partially reconstructed ruins consist of theater, amphitheater, and extensive use of mosaic tiles in homes and baths.

Classroom Activity - Slide Presentation on Spain, with emphasis on the province of Andalusia. (Slides were taken by me on my travels through Spain. Complete sets are on file at the Yale-New Haven Teachers Institute office. Consultation with one of the above-mentioned travel guides will help place the photos in context.)

A. Granada: tile scene of Granada (Plaza de Espana, Sevilla); Alhambra: panoramic view of the Alhambra and the Sierra Nevada mountains; general view of the Alhambra; the Alhambra from Paseo del Padre Manjon; Alhambra parador; (1) Royal Palace (Casa Real, or Palacio Nazaries): Serrallo (official residence of the sultan): detail of the façade; Hall of Ambassadors (Salon de Embajadores); Patio of the Myrtles, or Arrayanes Court (Patio de los Arrayanes); Court of the Lions (Patio de los Leones), columns, arcades, and fountain; Sala de los Abencerrajes, ceiling with stalactite vaulting (nobles of the Abencerraj family were murdered here); Patio of the Cypresses (Patio de los Cipreses); Lindaraja's belvedere (Mirador de Lindaraja, patio and fountain); Royal Baths (Banos Reales); Granada, from the Alhambra. (2) Gardens of the Partal (Jardines del Partal) and Tower

of the Ladies (Torre de las Damas), terraces, walkways, and pools. (3) Generalife (Garden of the Architect) and the Summer Palace: Court of the Long Pond (Patio de la Acequia); Patio de la Sultana (Court of the Sultana); Jardines Altos (old, or upper gardens); Jardines Nuevos (new gardens). (4) Palace of Carlos V (Casa Real Nueva), circular courtyard with columns in two tiers. (5) Alcazaba: ramparts, 13th-14th centuries, Nasrid Dynasty; watchtower (Torre de la Vela). (6) Cathedral (Catedral), gothic/renaissance, 1521-1700s; exterior and interior views; main chapel (Capilla Mayor); Royal Chapel (Capilla Real); cathedral museum.

B. Ronda: El Tajo gorge and Rio Guadalevin; Puente Nuevo bridge; Iglesia de Santa Maria La Mayor; Plaza de Toros, bull ring and seating; bull fighting scenes; sculpture, matadors; surrounding countryside.

C. Arcos de la Frontera: views of the city and pastoral countryside; Basilica-Parroquia de Santa Maria; Iglesia de San Pedro; Rio Guadalete.

D. Sevilla: Palace fortress (Alcazar): Patio del Rey Don Pedro (mudejar palace); Hall of Ambassadors (Salon de Embajadores); Patio de las Munecas; gardens, Pavilion of Carlos V; Cathedral of Sevilla (Catedral), exterior and interior scenes - Patio de los Naranjos, royal chapel, organ, stained glass windows, Sacristia Mayor; Giralda Tower (La Giralda), view of Sevilla from Giralda Tower; Plaza de Espana; Basilica de la Macarena; flamenco scenes (Bailes Flamencos)

E. Cadiz: excavations of Roman theatre; yellow-domed Cathedral; Cadiz beach (Playa de la Caleta); castle (Castillo de Santa Catalina); central market (Mercado Central); equestrian statue of Simon Bolivar.

F. Huelva: (see Columbus and Donana National Park slides)

G. Italica (oldest Roman town in Spain): amphitheatre; statuary; series of mosaic tile floors

H. Christopher Columbus: Granada: Plaza de Isabel La Catolica, statue of Isabel and Columbus; Royal Chapel (Capilla Real); marble monuments to Fernando and Isabel; marble monuments to King Philip (Felipe El Hermoso) and Queen Juana (Juana La Loca); crypt with lead coffins. Sevilla: Tomb of Columbus, Catedral de Sevilla; monument to Isabel, near Alcazar gardens. Huelva and vicinity: tile scene of Columbus at Huelva with the caravel, from Plaza de Espana, Sevilla; monument to Columbus at Punta del Sebo (Monumento a Colon); La Rabida (14th century Franciscan monastery - exterior, courtyard, and chapel; Wharf of the Caravels (Muelle de las Carabelas) - Santa Maria, Nina, Pinta

Parque Nacional de Donana (Donana National Park).

Donana National Park is located in the Andalucian province of southern Spain. It is a UNESCO-MAB (Man and the Biosphere) Biosphere Reserve, and it is also recognized as a Ramsar site (a wetland of international importance) and a Natural World Heritage Site. I visited Donana in July 1998, when I participated in an ecotourism view of the park. July is in the middle of the dry period in this seasonal wetland, when 1-2 meter deep wetland marshes have given way to dry, cracked mudflats, and abundant migratory bird species have already departed for other breeding grounds. While in Donana, I learned of current land and wildlife management issues, observed and photographed representative habitats, plants and animals. La Donana is adjacent to the coastal port of Huelva and lies not far from the major seaport of Cadiz. It is from these parts of southern Spain that Columbus began his four voyages to the New World. Because of the historical and ecological importance of Donana, as well as the recent environmental disaster which occurred there, it lends

itself well to the topics with which we have been concerned in the Institute seminar.

Following our introduction to the Andalusian region of southern Spain, its geography, history, and culture, we turn our attention to the ecology of Coto Donana (or Donana game preserve), which consists of Donana National Park, the adjacent Donana Natural Park (which is regional), and surrounding lands developed primarily for agriculture. The entry point for this part of the unit is another New York Times article, from the Sunday, June 15, 1997 travel section. It is entitled, "Amid the wild grandeur of a Spanish sanctuary", and it is written by Christopher Clarey. The article identifies Donana as "one of the world's great wildfowl sanctuaries." Students reading the article (aloud in class) should recognize the following points:

1. The Coto Donana wetlands are reduced in size from their original expanse due to human activities, including the encroachment of human settlements and agriculture.
2. Donana is a 200 square mile park located between the coastal ports of Huelva and Cadiz in southern Spain.
3. Donana is home to a wide variety of mammals, including otters, weasels, badgers, red deer, wild boars, wild horses, and the endangered Iberian lynx.
4. The avifauna of Donana is similarly diverse, consisting of 250 resident and migratory bird species. They include herons, egrets, and ibises, flamingos, storks, kites, harriers, stilts, and avocets. Three rare or endangered species are the Marbled Teal, Crested Coot, and Spanish Imperial Eagle.
5. Donana National Park receives full protection, and the adjacent Donana Natural Park serves as an important buffer zone around the former.
6. Details are given for commercial all terrain vehicle tours through Donana National Park, leaving from the park visitor center at El Acebuche, for boat tours on the Rio Guadalquivir, and for guided horseback tours. Lodging, dining, and other information is given for the interested traveler.

Having read a current event newspaper article introducing the reader to this coastal wetland environment, comparable in global significance to the Florida Everglades, students begin a study of the ecology of Donana. There are three major text references available to them: (1) Ministerio de Agricultura Pesca y Alimentacion. 1990. Donana National Park: nature in Spain. Barcelona: Lunwerg Editores, S.A., 249pp.; (2) Larramendi, Alberto. 1994. Donana: patrimonio de la humanidad. Madrid: Repsol, S.A./Incafo, 189pp.; (3) Novo, F. Garcia. C1999. The ecosystems of Donana National Park, from Internet Website http://www.enveng.ufl.edu/wetlands/donana.html. The first two references were obtained by me during my July 1998 visit to Donana National Park (available through the park bookstore, or via Internet booksellers). The third reference comes up from an Internet search engine using the key words "Donana National Park." Reference #1 is a coffee table-sized publication with excellent photographs of Donana beach, marsh, fixed and mobile dunes, woodland scenes, trees and flowering plants, birds, mammals, and cultural sites. A number of photographs have greater artistic merit than scientific value. Of significance are the articles, published in English and Spanish, which comprise the text of the book. They cover such topics as the origins of the Donana

ecosystems, the natural environment of the Park, the history and culture of Donana, establishment of Donana as a national park, and current scientific research within the park. These book chapters are written by some of the foremost ecologists and social scientists of this region. Reference #2 is written entirely in Spanish. Book chapters treat the history of this region as a game preserve for Spanish kings and dukes, historical and cultural features of Donana, the geological and ecological origins of the present Donana ecosystems, descripions of the marshlands, forests, and dunes, and the establishment of Donana as a national park. There is an excellent map of Donana National Park, easier to read than the various other maps I have obtained. Numerous high quality photographs of Donana ecosystems and organisms (amphibians, grebes, herons, flamingos, waterfowl, gulls and terns, Spanish Imperial Eagle, red deer, wild boar, Iberian lynx) are far more informative than the photos in reference #1. The Internet website information on Donana, written by F. Garcia Novo of the Department of Ecology, University of Sevilla, has comprehensive sections on geology, climate, land units and ecosystems (beach, stationary dunes, mobile dunes, forests, Mediterranean scrublands, grasslands, marsh, ponds), representative plants and animals, and conservation. Taken together, these three references provide an excellent overview of Donana in an historical, cultural, ecological, and environmental context.

Class Assignment.

Investigate the climate, geology, historical and cultural significance, and ecology of Donana National Park, using the references provided. Students are divided into four groups to conduct 3-4 days of research into these subjects. They are responsible for developing notes, producing summary handout sheets for other class members, and brief oral presentations on their assigned topic. As part of this investigation, I show slides of Donana National Park, taken in summer 1998.

Slides of La Donana: Rio Guadalquivir (in Sevilla); ecotourism buses; fixed dunes; mobile dunes and umbrella pine forests; low strips between dunes (las corrales); marshes of the Guadalquivir River (las marismas); dried mud flats; Spanish Imperial Eagle; wild boars; huts of indigenous farmers; scenes of charcoal-making; ecotourists at mouth of Rio Guadalquivir.

Summary of subject matter on Donana National Park.

Location: Donana is a 7500 square mile lowland habitat found on the southwestern coast of Spain (Atlantic Ocean portion) on the Gulf of Cadiz. It extends east from the border between Spain and Portugual to the western part of the province of Cadiz, and it incorporates parts of three provinces, Huelva, Sevilla, and Cadiz. The two large rivers which flow through Donana are the Rio Guadalquivir (which forms its eastern boundary) and the Rio Guadiamar, a tributary of the Guadalquivir.

Climate and Geology: The climate of this southern region of Spain is temperate. Donana has been shaped in different ways in the last 18,000 years, depending on the persistence of wet or dry periods. Extended wet periods led to the establishment of estuarine marshes, lagoons, and braided river systems, while arid periods encouraged the deposition and reshaping of wind-blown (aeolian) dunes, with their greater elevational relief. Changing sea levels resulted variously in expansion of marshland (regressions) or silting up of estuaries (transgressions). Donana has taken on its present look in the last 2000 years. The current system of dunes,

described below, are an estimated 500 to 700 years old.

Ecology: Donana is a complex combination of estuarine environment, marshes, lakes, salt ponds (lucios), sand dunes, scrubland and wooded habitat, shaped by Atlantic waves, blowing winds, and transporting river waters. Its principal ecosystems are tidal flats and beaches, marshland (originating from the Rio Guadalquivir estuary, but today of continental character rather than tidal), stationary dunes (on sands of marine origin), multiple chains of mobile dunes (aeolian, or windblown sands), pine forests (such as El Faro pine forest in the south, separated from the coast by a zone of dunes), and Mediterranean scrub woodland. Intensive human activity over a period of centuries has had an impact on virtually every ecological system found in Donana, creating what can be referred to as a "humanized landscape." Today Donana is bordered on the south by the Atlantic Ocean, tidal flats, beach, and a prominent band of dunes known as El Asperillo. Inside the zone of dunes are the Donana marshes, also called the Guadalquivir marshes. Covering 27,000 hectares, they are considered the most distinctive feature of Donana. They are comparable in significance to the Florida Everglades, but they go through considerable seasonal change. Half the input of water comes from the Guadiamar, the Guadalquivir, and associated rivers, but half comes from rainwater, accounting for the seasonality of Donana's marshes. The present marshland, formerly a heavily channeled tidal marsh but now cut off from the coastal estuary, is blanketed by 1-2 meters of water in the wet season and is reduced to cracked mudflat in the dry season. Stream flow is minor, and water is nearly brackish. Ponds, basins, pools, and grooves are scattered through portions of the marshland. Subtle changes in topographic relief and in substrate give rise to different patches of marshland, different levels of pH and mineral content, and different water depths. The changing levels of water produce the saltpools, or lucios. While the Florida Everglades consist of 50 mile wide, one foot deep sheet flow of water, Donana marshes circulate north to south, drain into the Guadalquivir River, and dry up nearly completely by the end of spring. Summer drought and cracked mudflat surfaces present a totally different picture from that of spring.

The coastline at Donana has more than 30 kilometers of sandy beach and setback dunes. Sea sands that wash up on the beach are the source of the sand fields and dune trains here. The two basic types of sand sheets are fixed or arrested dunes and mobile dunes. Each dune system is fairly parallel to the coast, extending several kilometers inland. Fixed dunes are located on the upper beach, held down by a cover of vegetation, and mobile dunes are continually moved and reshaped by prevailing coastal winds. The moving dunes take on parabolic shapes (best seen in the El Asperillo dunes), with the coast-facing surfaces having a gentle slope and the parabolas facing inland with a slope of more than 30 degrees. The parabolic dunes assume different heights and migrate inland at different rates, but they move on average 5-6 meters per year and achieve a maximum rate of migration of 30 meters per year. Sand is removed from the trailing edge of the dune and is redeposited on the parabolic face during migration. The present dynamic system of dune migration has persisted nearly for 400 years. These dunes bear a resemblance to the dune systems of the Provincelands of Outer Cape Cod in their mobility and their ability to bury and kill large trees. The hollows that form between bands of dunes are called corrales. They are the sites of springs, pools, and lagoons, with their higher water table. Some lagoons connect to the marsh via small creeks.

A more detailed ecological examination of Donana's arid scrubland recognizes three types of scrub: (1) monte negro, consisting of low-lying, moist lands with heathland plants; (2) monte blanco, which occurs at intermediate elevations and is dominated by helianthemum; (3) xerophilous Mediterranean scrub, occurring on the highest and driest lands, vegetated with rosemary, rockrose, lavendar, and marjoram. The monte negro lands bear similarity to Cape Cod's coastal heathland critical habitat.

Stone pine forested regions of Donana are low and dense, and they support little wildlife. Cork oak forests are

more open, and they have abundant wildlife.

Representative Trees and Wildlife: Donana's marshland plants include grasses, rushes, and salt-loving plants such as saltwort. The dry, open country of Donana is characterized as dune scrub, heathland, and fire-loving helianthemum scrub. Understory plants include savin, lentisk, rosemary, and rockrose - all xerophytic, or dry soil plants. The most widely represented genera of trees in Donana's forested regions are Quercus (oak), Pinus (pine), Juniperus (Juniper), Fraxinus (ash), and Populus (poplar). Cork oak and Umbrella oak are the two most common trees in this genus, and the most common species of Pinus is stone pine, originally a native species, extirpated by 500 years ago and subsequently reintroduced. Ash and poplar are found along marsh edges and flowing waters. Juniper has grown historically along coastal regions, as it does in Connecticut. Donana is rich in invertebrate and vertebrate life, and it is particularly known for its resident and migratory birds and its mammals. Approximately 250 bird species are considered residents or common migrants, and an additional 100 species are rare species, transients, or vagrants. These numbers are fairly comparable to the numbers of bird species in Connecticut (approximately 400), but the abundance and diversity of Donana birds and the size of the migration make this region special. An estimated one million birds spend the winter at Donana. The major aviaries and heronries of Donana are found around marsh lagoons. Ecotones, the contact zones between the marshes and the sandbanks, are very species rich. Bird life has been reduced in richness in historic times by the conversion of tidal wetland to continental marsh. Fallow deer have been introduced, and they number about 2000 within the park, as do the red deer. Wild boar are abundant, and they have long been a preferred species for hunting. There are 30-40 Iberian lynx in the park. Their principal food items are rabbits, the primary consumers near the base of the food web. Coastal and inland waters have diverse species of native and introduced fishes.

Land management: Information on the ecological conditions of Donana extends back to the 13th century, as this area was long used as a hunting preserve for Christian monarchs and aristocrats. The Spanish word Coto refers to the preserve, but also to the sand sheets of Donana. Much of the eastern boundary of Donana has been given over to agricultural fields through drainage and filling of marshland. Grazing animals (introduced livestock - cattle, horses, pigs, sheep) have reduced the extent of forested land and favored development of scrubland. Overgrazing continues to be a problem. The religious pilgrimage that annually traverses the park occurs along a 20 meter wide livestock trail, the Sanlucar de Barrameda - Almonte path. Charcoal-making has been common for a long time, also contributing to the loss of forested land and the development of fire-dependent scrub. National Park ecotours take visitors to several villagers' huts where charcoal-making is practiced. There is a long history of logging of pine trees for charcoal-making, timber, firewood, and ships' masts. Reforestation efforts in some regions of the park have been attempted for at least 300 years. The National Park is carrying out a reforestation program using cork oak trees, with the aim of doubling the number of these trees in Donana. Commercial fishing for shellfish and fish occurs in the marsh system. The Guadalquivir River experiences substantial water pollution, which poses a continuing threat to aquatic and terrestrial life. Industry continues to crowd the Donana reserve, with open pit mining for heavy metals, especially in the Rio Tinto area, being a major threat to the larger region. Introduction of exotic tree species, such as eucalyptus, has caused disruption of some expanses of mobile dunes, especially in the northern part of the park. The National Park is attempting to remove some of the invasive eucalyptus plantations here. Tourism has existed for a hundred years, and there is a concerted effort within and outside the national park to extend tourism opportunities, including the construction of major coastal resorts and real estate developments. Disparate groups of people, including members of industry, agriculture, conservationists, and local villagers, have recognized the importance of protecting the remaining wetlands and dune systems of Donana. Today, the National Park is administered by the Spanish Ministry of Agriculture, Fishing and Food, and the Higher Council for Scientific Research.

Boliden Ltd, the Los Frailes Zinc Mine and the Disastrous Spill of April 25, 1998.

A number of Internet news releases and websites are available describing the Los Frailes mine waste reservoir spill. Those sites which I found most useful are: (1) Environmental News Network (ENN), with articles published on April 30, 1998, October 21, 1998, January 7, 1999, and March 16, 1999; (2) World Wildlife Fund (WWF), particularly its articles of April 27, 1998, May 4, 1998, and June 1998; (3) CNN Interactive, using Reuters News Service (cnn.com), with news releases of April 25, 1998, April 26, 1998, May 16, 1998, and January 12, 1999; (4) a Dutch site with the Internet address antenna.nl; (5) Boliden Limited. The Boliden homepage provides an overview of this multinational mining company, established in Sweden and now based in Canada. Its subsidiary company, Boliden Apirsa, owns and operates the Los Frailes mine. A news release describes the waste reservoir spill from the company's point of view. Additional 1998 and 1999 news releases appearing in an Investor Relations section provide useful background information but appear not to be readily printable from the computer screen. CNN Interactive was first to communicate the toxic spill story. The World Wildlife Fund played a key role in raising national and international concern about the spill, calling for a quick response by the Spanish government, assigning culpability for the spill, and promoting long term ecological restoration of the Donana. Environmental News Network, which maintains a subscription environmental news service drawing on Reuters, Associated Press, and Knight-Ridder/Tribune, provides comprehensive news stories with links to related stories and related sites. The Dutch website antenna.nl provides the best technical discussion of the Los Frailes waste reservoir failure I have found.

Additional websites that can be used include the United Nations Environment Programme (UNEP), with a section discussing financial and legal ramifications of the spill, Greenpeace, with a list of international mining industry accidents involving waste reservoir dam failures, Lycos Environment News Service, describing the efforts of WWF to keep Los Frailes mine closed, and EnviroNews Service, "a project of the EnviroLink Network." An article by Gary Gallon, President of the Canadian Institute for Business and the Environment, available at sentex.net (see bibliography) is of interest. Undoubtedly, there are numerous additional references available on the Internet.

Summary of news releases: April 25, 1998: The waste reservoir or tailings dam dike of the Los Frailes zinc mine, (Aznalcollar, Andalucia, Spain) operated by Boliden Ltd of Canada, burst in the early morning hours of Saturday, April 25, 1998, releasing at least five million cubic meters of acidic, toxic heavy metals sludge into the Guadiamar River south of Sevilla. The spill threatens the ecology of Europe's largest nature reserve, Donana National Park. Donana lies 60 kilometers, or 37 miles, south of Los Frailes. A 50 meter section of the dike failed, apparently the result of shifting substrate. Makeshift retaining walls appear to be protecting Donana from the toxic waste water. At least 10,000 hectares of farmland have been covered by the spill. While no one was injured in the accident, residents were urged not to use their wells and to keep grazing animals away from the river. The spill advanced south at a rate of 1 kilometer per hour, and it posed the threat of entering the Donana National Park within a day and a half of the accident. Efforts to reroute the Guadiamar River through a man-made canal were intended to take the sludge into the Guadalquivir River outside the Park. The accident was quickly regarded as a major environmental disaster. Donana is identified as a globally significant ecosystem of dunes, marshes, and forest.

April 26: Successful diversion of the toxic sludge into the Guadalquivir River, which flows into the Gulf of Cadiz, appears to have prevented a major environmental disaster in Donana. Environment Minister Isabel Tocino viewed the damage by helicopter and declared that Donana has been saved. The toxic sludge deposited on

farmland is identified as consisting of minerals of zinc, lead, copper, and silver. The concern was expressed that tidal waters would draw the contaminated Guadiamar waters into the Park, but the closing of flood gates between the river and the park prevented this from happening. The national government called for action to be taken against those responsible for the spill, as did environmental organizations. Boliden Ltd indicated that a recent inspection of the dam disclosed no apparent weaknesses prior to the spill. The company initiated dam repairs to prevent further leakage from the waste reservoir.

April 27: The Secretary General of World Wildlife Fund/ADENA, Juan Carlos del Olmo, asked for a meeting of the Patron Board of Donana National Park to assess the damage and to coordinate a response to the crisis. He also called for relief assistance from the national government. The spill began as a fast-flowing stream of acidic water, followed by a slow- moving stream of viscous, acidic mud loaded with hydrocarbons and heavy metals. The blackened waters of the Guadiamar River now extend for 40 kilometers from the accident site, spanning either side of the riverbed for 200 meters. While the National Park has not been invaded by the sludge, the Natural Park buffer zone has been affected extensively. A huge die off of fishes and aquatic invertebrates is noted. An important population of Purple Gallinules (a member of the rail family) is threatened. It is feared that the toxic substances will enter the food chain, as dead organisms are eaten by higher order consumers. WWF assigns blame for the spill to the Andalusian regional government and the Ministry of the Environment, and the international conservation organization states that a clear danger of a toxic spill had been recognized since 1995. WWF questions the effectiveness of efforts by the two Donana administrations (national park and natural park) to coordinate emergency activities. Del Olmo predicted that Donana will suffer long-term effects from the spill. The aquifer has been contaminated, and forthcoming rains will continue to redistribute toxic substances. The contaminated land must be cleared of toxic soils, and these soils must be dumped elsewhere. The company responsible for the spill must pay for damages and restoration. A call was made for a comprehensive recovery program for the entire Guadiamar river system, providing a green belt corridor for the long term protection of Donana. May 4: The toxic spill was described as having occurred late in the evening of Friday, April 24. WWF called for the Spanish Army to join the emergency effort and for Spanish authorities to do a better job of alerting the populations of seven nearby towns to the dangers to human health. WWF questioned the ability of Boliden to pay for damages or environmental restoration, and contradicted the position of the Spanish government that everything is under control. The magnitude of the environmental disaster is considered unprecedented. WWF felt that Boliden was being treated with kid gloves. Government officials publicly dining on Gulf of Cadiz shrimp won't lessen the extent of the disaster. A call was made for permanent closure of the mine and alternative employment opportunities for the region's residents. NGOs (non-governmental organizations) must have a say in the decision-making about Donana during the crisis. May 16: Some experts now feel that environmental damage from the spill is limited, particularly within Donana National Park. Park spokesmen took a similar position. An opposing view is that the extent of damage to Donana will not be known for years. Boliden claimed no responsibility for the disaster, but it pledged to pay out millions of dollars to farmers for loss of crops. The national government also pledged millions, and some estimated a price tag of US$100 million for damages and cleanup. The hotel industry feared a falloff in tourism. Cleanup will take at least three months.

June 1998: The volume of toxic sludge spilled from the Los Frailes (Apirsa) waste lagoon was equivalent to 500 Exxon-Valdez oil tankers. Approximately 46,000 people were directly affected. Donana was identified as WWF's first conservation project, for WWF spearheaded a 1959 effort to save the Donana habitats from imminent development. WWF continued to call the spill something other than an accident, as it had been known for several years that the reservoir was leaking. All agricultural and fishing activity in the area has ceased. The breeding seasons of birds and fishes have been disrupted. The effects on the endangered Iberian lynx and the Spanish Imperial Eagle were of special concern. WWF foresaw a cleanup effort requiring at least

three years. Toxic waste will be disposed of in an abandoned portion of the mine. WWF called for a legal inquiry and full accountability for the spill. It feared the occurrence of numerous spills of a similar type throughout Europe.

October 21: The amount of zinc spilled into the Guadiamar River in April, estimated to be 120,000 tons, nearly equaled the annual output of zinc from the mine. Agricultural crops are particularly sensitive to zinc poisoning. Thousands of fishes and shorebirds were killed as a result of the spill. A study of river bank sediments six miles downstream of the mine disclosed zinc contamination 100 times that of uncontaminated soils. Further downstream, zinc contamination was less than expected. Chemical precipitation of zinc was suspected of lessening the contamination.

Classroom Activities.

In pursuing the Donana National Park/Los Frailes mining accident as a case study, I have my students read and analyse the news releases (listed under Student reading) at three different stages in time. The first set of news releases comes from the period late April to mid-May 1998, when the spill was announced and the initial government response to the disaster took place. The second set dates to the summer and fall of 1998 (spanning the time that I was in Andalucia, Spain), when various opinions were expressed about the spill and assessments had been made about its severity. The third set comes from the period January 1999, when the Donana National Park management board and the WWF recommended the permanent closing of the mine, to April 1999, when Boliden sought to reopen the mine and subsequently did so, and to the most recent past, including the latest information available about the spill. I summarize the first set of news releases above. I have summaries of the main aspects of the second and third time periods, although they are not published here.

Follow-up on the Disaster.

The third New York Times article, published in the Monday, May 24, 1999 issue, is entitled Aznalcazar journal: year-old spill poisons farms and wild food chain." Written by Marlise Simons, writer of the 1998 New York Times article announcing the spill, it presents an assessment of the Los Frailes zinc mine disaster thirteen months after the spill occurred, and after the first studies of short-term impacts of the spill had been published. Students read this article aloud in class, and they discuss the content of the article.

Summary of the article.

1. The fruit and vegetable farmer Jose Antonio Alvarez is interviewed about the impact of the zinc mine waste reservoir spill on his livelihood. He was previously interviewed by Ms. Simons for the 1998 NYT article. He surveys his barren farmland and states, "we're forbidden to grow anything." He refers to his land and the land of hundreds of other farmers in the Aznalcazar area. He also fears that he and the other farmers will lose possession of their land as a result of the spill.
2. The flow of acid sludge and heavy metal compounds was diverted from Donana National Park by the fast construction of dikes, but it poisoned the waters of the Guadiamar River, the Natural

Park which serves as a buffer zone to the National Park, and the Guadalquivir River
3. Spain's environmental conscience is called into question, with the writer's tempering words that this was nonetheless considered a major environmental disaster.
4. Boliden Ltd of Canada has made available an abandoned open pit mine on the Los Frailes property for receiving 12 million tons of acidic, contaminated mud from the spill. The US$52 million they have spent thus far has gone toward cleanup of the spill, repair of damaged landscapes, and compensation to farmers for crops and income lost.
5. Superficially, the area looks fairly clean. But, acidic materials and heavy metals have contaminated the agricultural fields and marshlands (mistakenly called swamps by Ms. Simons) and entered the food chain, beginning with aquatic plants, continuing through fishes, amphibians, and birds. In a study conducted by the Council for Scientific Investigations, forty four per cent of Greylag Geese sampled had high levels of cadmium and lead in their body tissues, and 22% of the contaminated birds were severely affected. Cesar Nombela is director of the Council.
6. Donana biologist Miguel Ferrer cautions that geese are a main food source for the endangered Spanish Imperial Eagle and the endangered Iberian lynx. These geese are hunted by peoples of Scandinavian countries following their northerly spring migrations, and by North African peoples following the fall migration south. The heavy metal poisoning thus spreads to other parts of Europe and to Africa.
7. Local farmers and fishermen are concerned about their livelihoods, fearing arsenic poisoning the most.
8. Chemical and biological treatments are being considered as ways to arrest the contamination.
9. The Andalusian regional government states its intention to expropriate land from farmers (a list of affected farms has been published) and establish a green belt that is reforested along the 70 mile long spill site and dedicated to recreational use. US$160 million will be used for the land buyout, and the plan calls for a third of this sum to come from the European Union. Four hundred families will be affected.
10. Some farmers say they will fight the regional government's green belt plan in court. Local farmer Carmen Moraira leads the protest, and she charges the regional government with hypocrisy. "Since when did they become environmental converts?," she questions.
11. The Guadiamar River has long been the dumping ground of untreated sewage from surrounding towns. Nobody ever swims in this river.
12. The Los Frailes zinc mine has just reopened. It provides 500 jobs for local villagers, and the reopening of the mine was supported by them. The Donana National Park board called for the permanent closure of the mine, however.
13. This complex environmental and health issue is in the hands of a local judge, who tries to assign responsibility for the spill. Boliden Ltd, another company which previously owned the waste reservoir, the engineers who designed the reservoir, and the government inspectors who regularly found nothing wrong with it are among the suspects. The court lacks money for an in-depth investigation.

The following questions should guide class discussion: One year after the spill, what has happened to Donana National Park? What has happened to the Guadalquivir River Valley? What has been the impact on local villagers? What is the position of the villagers concerning the environment? What is their economic position? Which group is taking a strong stance for protection of the environment? Which group or groups take a strong stance in favor of economic issues? How can these positions be resolved to the satisfaction of those concerned?

Additional references.

I have prepared this unit to show, in part, the process by which one might research a current event topic connecting environmental science and human health. I am also interested in showing students how a search for information might turn up examples of scientific research being conducted at Donana National Park, and other references in international scientific publications. Two additional references of interest to this topic come from two of the science journals to which I subscribe, the journal Nature and the Ecological Society of America's journal, Ecological Monographs. The 10 September 1998 issue of Nature (page 110) has a letter in the correspondence section that relates to Donana and the toxic spill. In the letter, four researchers (in university or institute departments of ecology, geology and geophysics, and astrophysics) call for Spain to coordinate better communications between central and regional governments, secure experts in science, engineering, and management, and pay closer attention to its natural resources. They also call for Cesar Nombela's National Research Council-created commission to prepare a report on the impact of the mine spill, its damage to Donana ecosystems and threats to public health. The report should be available to the citizens of Spain and to the international scientific community. They cite public distrust of the Spanish authorities and charge that government decisions have been made for political purposes at the expense of environmental and health considerations. Donana National Park also receives criticism for its decision-making weaknesses. Finally, the authors foresee long term persistence of toxic chemicals and ecological damage and the need for long term response to the disaster. They call for "rigorous problem analysis, professional implementation of solutions and transparent decision-making."

The Ecological Monographs article makes use of field work and computer modeling of a metapopulation of the Iberian lynx. This rare species of lynx is found only in Iberia. The world population is 1000 individuals, of which approximately 60 cats live in Donana National Park. Metapopulations consist of a series of smaller, fragmented and isolated populations that experience some connection through dispersing individuals. This technical article uses elements of wildlife, reproductive, and conservation biology, and ecological theory to consider the likelihood that the donana lynx population goes extinct in the next 100 years. It contains current information on Donana's lynxes, a map showing the distribution of the lynx populations, and extensive consideration of reproductive biology of the lynx. Most significantly, it discusses the threats faced by endangered species due primarily to habitat loss and human-induced mortality.

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Student Reading List.

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