Environmental Problems of the Danube Delta

Europe depends on the Danube River for shipping, power, agriculture and municipal water; downstream, the river's delta reflects the environmental problems of the entire region

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Environmental problems routinely disregard national boundaries, but scientists seeking solutions to such problems cannot. Whether pollution takes the form of a plume billowing from a smokestack or nutrients entering a river from agricultural runoff, the effects may be experienced both locally and at great distance from the source. Thus efforts to restore and manage damaged ecosystems require an interdisciplinary approach to understanding the events and processes that have led to current environmental problems. Often these are intricately tied to national politics and economic strategies, requiring the collaborative efforts of ecologists, agriculturalists, resource managers, economists and other specialists to work toward solutions.

As Europe's largest wetland, the Danube Delta provides a case in point. Fed by the Danube River, which stretches 2,860 kilometers through nine nations and serves the watersheds of four more, the delta receives the drainage from 810,000 square kilometers—about 70 percent of the area of Central Europe. On average the Danube delivers 6,300 cubic meters of water per second through the delta and into the Black Sea.

Among European rivers the Volga is longer, but the Danube carries more navigation, making it one of the world's busiest rivers. The Danube River provides the only access to the sea for Austria, Slovakia and Hungary, and it links four national capitals: Vienna, Budapest, Belgrade and Bratislava. With the recent completion of the Main-Danube Canal, which has been under construction for 30 years, the Black Sea and the North Sea are now linked through the Main (a tributary of the Rhine) and the Danube.

The Danube's vital role in Central European economies, however, has been a major source of environmental problems in its delta. In addition to providing transportation and drinking water for inhabitants along its course, the Danube's waters are tapped for hydroelectric power, industrial processes, irrigation of agricultural land, and disposal of municipal and industrial waste. Production-oriented strategies in former socialist countries often failed to incorporate into management practices science-based environmental protection and conservation. The effects of these uses upstream have fallen heavily on the Danube Delta and its inhabitants.

Figure 1. Danube Delta, Europe's largest wetland, is a nesting area for mute swans *(Cygnus olor)* and more than 160 other species of birds, many of which migrate on European flyways.

Formed nearly 8,000 years ago, the Danube Delta exhibits the classic delta form—a broad, flattened cone with its apex at the point where the river's main channel divides into three main branches: the Bratul Chilia, the Bratul Sulina and the Bratul Sfintu Gheorghe. Between these branches lies a mosaic of shallow lakes and channels, rooted

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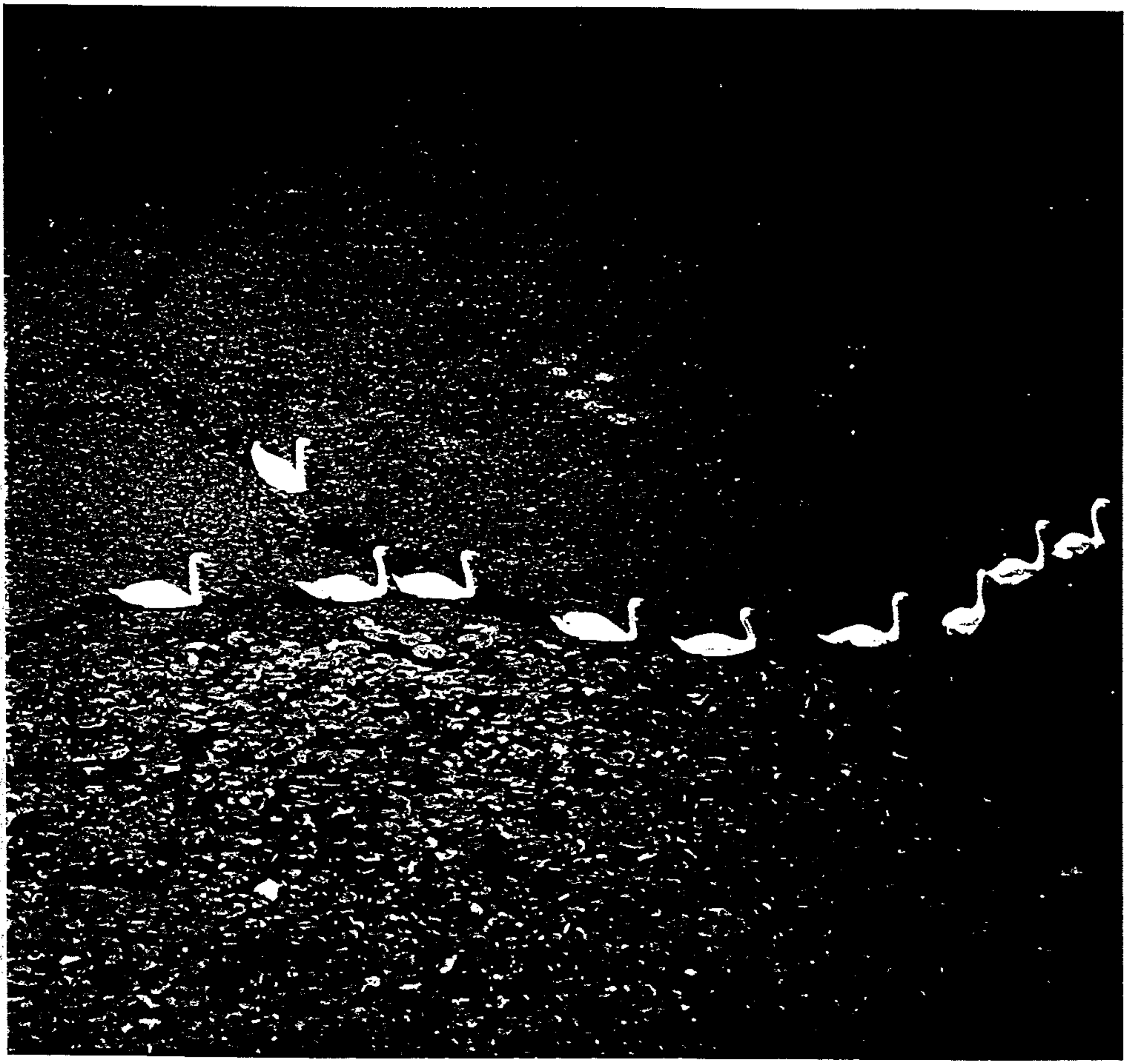

Threats to their habitat include water-quality deterioration from heavy nutrient loads, pesticides and engineering works; the drainage of wetlands for agricultural production and aquaculture; coastal erosion; and predation from feral animals. The plight of birds is one of the most visible of the delta's environmental problems, which are a result of influences both within its confines and far upstream. The problems actually reflect those of the area the Danube River drains—much of Central and Eastern Europe. (Photo courtesy of The Cousteau Society, copyright 1991.)

emergent vegetation, and natural and artificial levees. During times of very high flow, the branches lack sufficient capacity, and the entire delta floods.

Almost 80 percent of the delta's area (580,700 hectares) is located within Romania (459,000 hectares); the remaining portion (121,700 hectares) is in Ukrainian territory. Romanian geographers divide the delta into three zones: the lake complex (Lakes Razim, Colvita, Zmeica and Sinoe); the fluvial (river-deposited sediment) zone stretching from the lakes to the Letea-Caraorman-Crasnicol sand dunes, which originated as barrier islands around 3,500 B.C.E.; and the maritime zone, extending from the dunes to the Black Sea.

The delta contains a variety of habitats and species, many of which are seriously threatened throughout the rest of Europe, making it an area of unique ecological significance. Fisheries in the delta have long played a pivotal role in the Romanian economy. Many birds that migrate on European flyways stop at the delta. One of the delta's most distinctive habitats is its reed beds, the largest single area of reeds in Europe, covering 284,000 hectares in Romania alone.

Environmental stresses on delta wetlands have increased markedly in the

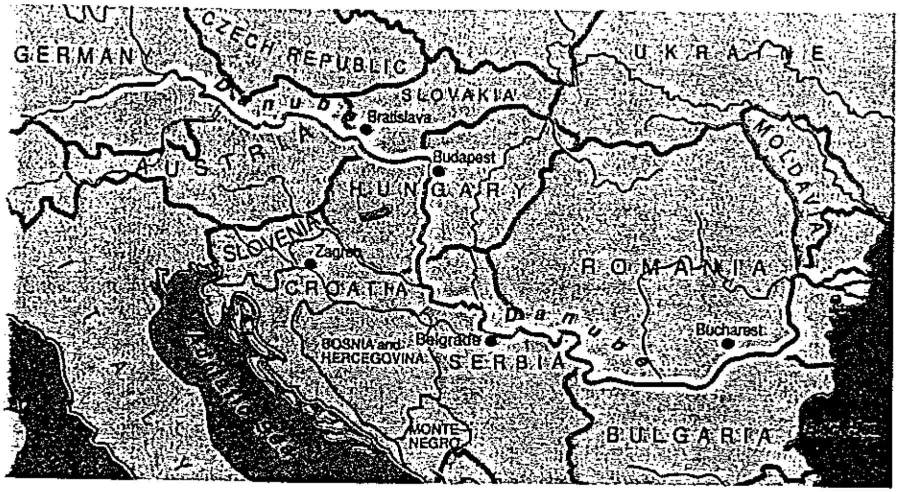

Figure 2. Danube River runs through nine Central European nations and serves the watersheds of four more. The river offers access to the Black Sea for the land locked nations of Austria, Czechoslovakia and Hungary and is linked to the North Sea through the Rhine-Main Canal.

past few decades. The volume of agricultural runoff and municipal waste flowing into the Danube River upstream from the delta has increased, and engineering works have reduced the river's ability to retain those effluents along its course. As the river has delivered greater loads of plant nutrients to the delta, the wetlands' ability to cycle these materials has been compromised by development. Efforts to exploit the delta for mechanized agriculture and aquaculture have reduced or eliminated natural water flow in many areas, severely disturbing aquatic ecosystems. The delta has become physically smaller as well, owing to severe coastal erosion.

Romanian scientists began documenting delta environmental problems more than a decade ago, but few data have been published outside Romania. As a first step toward making those data more generally available and developing new wetlands research and restoration efforts, a U.S.–Romanian collaboration was launched in 1991. Under the joint sponsorship of the U.S. and Romanian National Academies of Sciences, 10 U.S. and 11 Romanian ecologists, agricultural engineers, biogeochemists, biologists, entomologists, ichthyologists and restoration biologists lived and worked for three weeks on a river barge towed to various research locations in the delta. In the second phase of the exchange program in 1992, Romanian scientists visited the United States to continue research collaborations and proposal writing, and to examine analogous environmental problems in the Mississippi Delta. This article is one result of the collaboration.

The Roots of Environmental Decline

The complex and varied ecosystems of the Danube Delta have deteriorated dramatically over the past few decades. Studies have identified four primary causes of this decline: high nutrient loads in the Danube River as it enters the delta; hydrologic changes in the Danube River—primarily the elimination of the river's floodplain in the nine nations that abut it; hydrologic changes within the delta resulting from engineering works such as drainage programs, dikes, impoundments and channel dredging; and nutrient and pesticide loading from agricultural activities inside the delta.

Pollutant loadings in the Danube River are very high. The human population within the river basin is roughly 86 million, about 12 percent of all Europeans, and many major cities and small towns along the river lack even primary sewage treatment facilities for domestic and industrial waste. Budapest, the capital of Hungary, for example, empties an estimated three-quarters of its sewage untreated into the Danube.

At the same time that contamination has increased in the Danube, hydrologic modifications along the river's course have compromised its capacity for self-purification. Numerous hydroelectric projects have sprung up along the river, bringing with them channel diversions and impoundments. Currently more than 30 dams span the Danube before it reaches the delta.

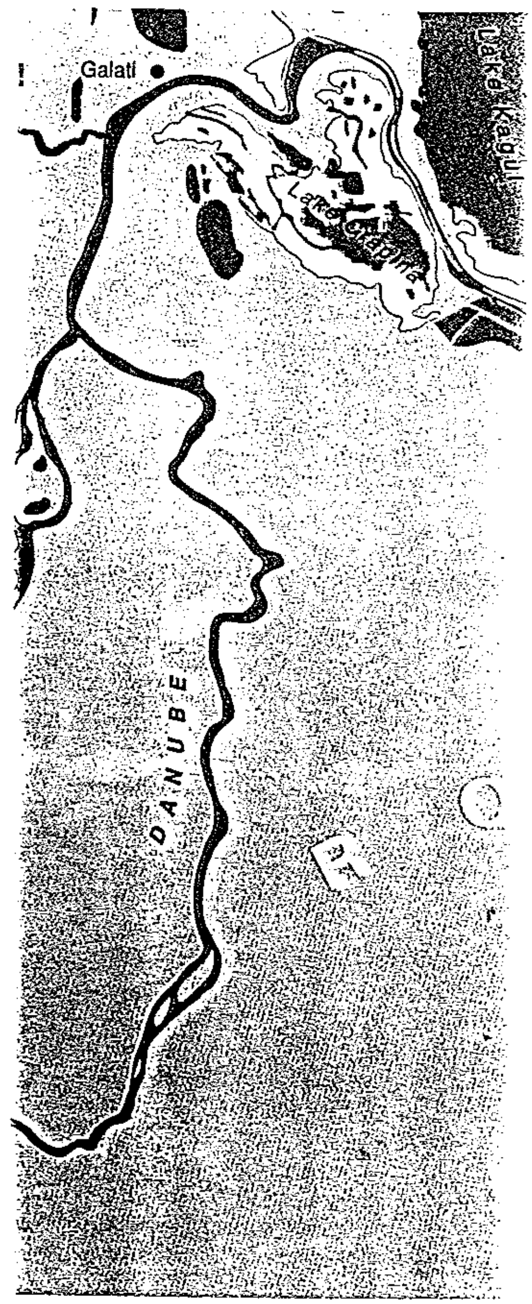

Figure 3. Romanian geographers divide the Danube Delta into three regions: The lake complex (Lakes Razim, Golovita, Zmeica and

These and other engineering activities along the Danube's main channel have disconnected the river from its usual floodplain. Within the Romanian stretch of the river, embankments built between 1963 and 1967 reduced the floodplain by 290,000 hectares, which corresponds to a loss of 4.3 cubic kilometers of water-retention capacity. As a result, the Danube has lost a portion of its capacity to retain nutrients and heavy metals locally; they are now carried in the river to the delta.

Another negative effect of hydrologic modifications in the river system is

Sinoe) south of the city of Tulcea; the fluvial (river-deposited sediment) zone stretching from Tulcea and the lakes to the Letea-Caraorman-Crasnicol sand dunes *(areas in tan)*; and the maritime zone, extending from the dunes to the Black Sea. North of the Danube River, in Ukraine, lie several lakes that have been hydrologically isolated from the Danube River by engineering works.

coastal erosion. The natural accretion of sediment on the Black Sea coast near the mouths of the Danube branches has ended, and severe coastal erosion is taking place. The shoreline is receding at a rate of up to 17 meters per year, threatening tourism and the economic base of coastal cities such as Constanta. Coastal erosion is a natural and inevitable process as waves pound against the shoreline, but in the past it was offset by sediments dropped from the river at its outlets and pushed ashore by the Black Sea. Dam construction and other hydrologic changes have reduced the transport of sediments, disturbing the balance between erosion and accretion.

Exploitation of the Delta

Traditionally, the Danube Delta was the least-populated and least-developed region of Romania because of its harsh climate, its inaccessibility, and spring and winter floods. In 1983, however, the leadership of the former communist regime implemented a plan for the management and exploitation of the delta. This plan envisioned large-scale changes in the wetland that would make the region a center for agricultural production. In fact, however, the economic exploitation of the delta began much earlier and can be segmented into five distinct phases, of which former President Nicolae Ceausescu's program is only one.

The Romanian naturalist Grigore Antipa recognized the economic potential of the delta's natural reed beds (*Phragmites australis*) as far back as the turn of the century. Commercial exploitation of the reed beds for high-grade cellulose and for sugar for yeast production began in 1908 and continued at a sustainable pace until the mid-

Figure 4. Broad beach-barrier complexes grow through the action of current and waves transporting sand southward along the Danube Delta's coastline. In addition to building subdeltas of the Danube branches, these beach-barrier islands are important breeding grounds for many species of birds, including terns and gulls. (Photo courtesy of the Cousteau Society, copyright 1991.)

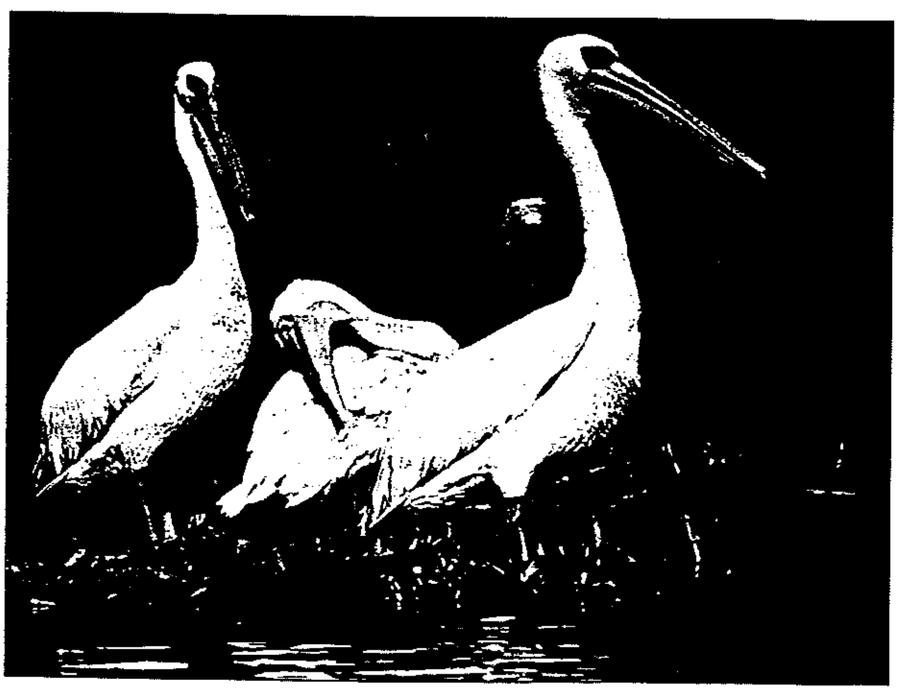

Figure 5. Half of the Palearctic population of the white pelicans (*Pelecanus onocrotalus*) nests in the Danube Delta. The drainage of wetlands and the construction of dikes have destroyed much valuable habitat for these birds, which were common in the delta's Pardina region (Figure 7) until the area was drained. At the beginning of this century reported numbers were at least ten times higher than at present. (Photo courtesy of The Cousteau Society, copyright 1991.)

1950s. In 1958 a new cellulose factory doubled the demand for reeds from the delta, and an intensive program of reed cultivation was undertaken within specially constructed, diked polders (areas separated from normal water circulation by manmade embankments). Production reached a peak of 226,000 tons from 213,000 hectares in 1965, of which 136,000 hectares were in managed polders.

This high productivity was short-lived, however, as the reed harvest plummeted to 40,000 tons over the next decade, owing to a lack of seed regeneration in the polderized areas. Regeneration was hampered by the design of the polders, which limit water flow and exclude sediments and nutrients usually supplied to the reed beds by flood water. Reed marshes require a free flow of river water through them, especially during the crucial periods of plant development during spring and early summer. Standing water can produce soil conditions that are toxic to the reeds in their budding phase, when they depend on a slightly oxidized upper soil layer. Also, the poor nutritional status of the reeds provided the opportunity for other plants, such as reedmace (*Typha*), to replace them. As reed production failed in the polders, they were converted to aquaculture or drained for conventional agricultural production or for cellulose production from fast-growing trees.

Attempts to improve fisheries in the delta began as early as 1903, when two small river courses were excavated to bring Danube water to Lake Razim. Extensive further efforts to increase water circulation and oxygen content in smaller lakes were undertaken between 1930 and 1965. Fish-polder construction began in the 1950s, and the area dedicated to polders grew steadily until 1970, when aquaculture became the focus of the government's economic strategy in the delta. Between 1970 and 1990, the area in fish polders nearly doubled to 53,007 hectares.

Despite the commitment, aquaculture was not successful in the delta, and many polders were abandoned. Shortages of basic materials—such as feed for the fish and spare parts for the pumps—inadequately trained personnel and the introduction of fish species ill-suited to the delta contributed to low yields, which averaged 23,000 tons per year. During the same period, catches by local fishermen plunged from 7,000 to 9,000 tons per year to 4,000 to 5,000 tons per year. This decline has been attributed to the loss of fish habitat and the general deterioration of water quality in the delta. Although the Danube still accounts for 50 percent of freshwater fish production in Romania, the drop in catches has affected food supplies and the livelihood of the 500 to 600 fishermen who live in the delta.

Traditional small-scale agriculture has long been practiced in the delta. Subsistence farmers cultivate small (up to one-quarter hectare) plots carved from silt deposits along the smaller river channels around their villages. Large-scale agriculture came only recently. As fish and reed polders failed, they were drained and converted to forestry or conventional mechanized agriculture as part of the complex plan for the economic development of the delta. These plots range from 2,800 to 28,000 hectares, and the primary crops are barley, corn, wheat, flax and sunflowers (for oil) and various fruits. With the arrival of mechanized agriculture, the amount of land under cultivation grew tremendously. In 1970, 35,355 hectares (7.7 percent of the delta) were in production; by 1990 the area had grown to 61,604 hectares (13.4 percent of the area). Under former President Ceausescu's regime, an unsuccessful attempt was made to turn 100,000 hectares of the delta into farmland.

The Danube Delta is not ideally suited to large-scale, intensive agriculture. Production from polders is hindered by low rainfall, sandy soils, dropping water tables from lack of replenishment, soil salinization from evaporation, wind erosion, soil acidification, peat fires and intense competition from reeds that grow from residual rhizomes and seed banks in the soil. Overcoming these limitations has required energy-intensive practices that demand fuel for mechanical cultivation, planting, harvesting and irrigation and heavy use of fertilizers and pesticides. Because of severe shortages of these materials, as well as what appears to be a conscious decision by the post-communist government to reduce the intensity of agriculture in the delta, large-scale agriculture there faces an uncertain future.

From 1990 to 1991 the delta area devoted to intensive agricultural production dropped from 38,394 hectares to 36,800 hectares. Since the fall of the Ceausescu government in 1989, large tracts are being converted to silviculture, and others are being completely abandoned. Production seems to be shifting back toward traditional labor-intensive practices, but the economic and environmental effects of these changes have not been quantified.

The Ukrainian portions of the Danube Delta have also seen economic-development efforts that have changed hydrology and had detrimental effects on water quality. The four largest Danubian lakes north of the Chilia Channel (Kagul, Yalpug, Katlabikh and Kitai) originated as lagoons of the Danube River. They were cut off from the river between 1940 and 1960 by a series of dams constructed primarily to eliminate seasonal water-level fluctuations that limited irrigation supplies to the nearby Odessky region.

As a consequence, annual water exchange between the lakes and the river is now one-third to one-half what it was, causing major increases in salinity and other forms of mineralization. Scientists have documented a dramatic deterioration of floral and faunal habitats over the past decade. Nutrient loads

Figure 6. Intense competition from native reeds (*Phragmites australis*) is one of the main reasons that attempts to convert Danube Delta wetlands to conventional agricultural production have been unsuccessful. Here corn seedlings are being overwhelmed by reed shoots growing from residual rhizomes. Heavy applications of herbicides have failed to hold back the reeds. (Photo by George Vellidis.)

Figure 7. Dikes and drainage canals such as those in the Danube Delta's 28,000 hectare Pardina polder were used to convert wetlands to agricultural crop and forage production. The need for intensive fertilization and pesticide use has made such efforts at agriculture in the Danube Delta uneconomic, and the damage to sensitive delta ecosystems has been extensive. (Photo by George Vellidis.)

Figure 8. Traditional delta agriculture in the Danube region consists of small (up to one-quarter hectare) plots in silt deposits along river channels. This sustainable approach has supported small delta communities for centuries. (Photo by Catherine Pringle.)

from agricultural activity in the lakes' watersheds have led to high levels of eutrophication, or lake enrichment. In a eutrophic lake a few plant and animal species become dominant, and the oxygen content of subsurface waters may drop to levels lethal to aquatic life. This, combined with influxes of agricultural chemicals and heavy metals from industrial waste, has made the water in three of the four lakes unsuitable for human consumption. It can be used for irrigation only after extensive and expensive treatment. Despite these problems, agricultural and industrial development has intensified in the surrounding watersheds over the past decade.

The Delta Today

Increasing nutrient, heavy-metal and pesticide inputs into the Danube and its delta, in combination with changes in surface water flow and sediment loading, have increased the eutrophication and turbidity of the water serving the delta's aquatic ecosystems. This degradation of water quality has led to reductions in biodiversity, major shifts in the structure of ecosystem primary productivity—from rooted aquatic plants to phytoplankton (floating algae)—and large economic losses from declining fish yields.

Anthropogenically produced loads of nitrogen and phosphorus in the Danube River have increased steadily since 1980. Chemical oxygen demand (a measure of the potential for oxidizing reactions to use up the dissolved oxygen in water) has increased sharply. A corresponding increase in hydrogen-sulfide concentration indicates the existence of anaerobic conditions in river sediments.

Over the past decade large influxes of nitrogen and phosphorus into the delta have overwhelmed its ability to cycle these plant nutrients, producing eutrophic or polluted conditions in many lakes and associated nuisance blooms of algae. These blooms deplete oxygen, typically consist of algal species unsuitable as food sources for fish, and shade out submerged rooted plants that are important habitat for species such as pike.

Within the delta, regular sampling along the Sulina Branch shows little reduction in nutrient, metal and pesticide concentrations compared to the Danube River above it. This reflects the fact that channels such as the Sulina, which have been straightened and dredged, are bypassing the filtering capacity of the wetlands. Instead, the branches have become conduits for the delivery of concentrated pollutants to the Black Sea. Levels of dissolved nitrogen and phosphorus in lakes and secondary channels of the delta are lower than those measured in the main channels but have

Figure 9. Large-scale aquaculture became the goal of the Romanian government's plans for the Danube Delta beginning in 1970. Despite a major commitment to construction of new polders, the effort was a failure, largely because of shortages of fish feed and fuels to run equipment. Shown here is an abandoned aquaculture operation in a polder. (Photo by Catherine Pringle.)

been increasing at the same rate over the past 10 to 20 years. Already those levels are well above the threshold for algal growth and for the decline of larger aquatic plants.

Studies indicate that the delta's waters are in an advanced state of eutrophication. Most lakes and secondary channels show a marked decrease in rooted aquatic-plant density and an increase in algal blooms—primarily blue-green algae (Cyanophyta)—over the past decade. The diversity of bottom-dwelling macroinvertebrates such as shellfish has dropped dramatically over the same period, and in one lake, numbers of midge larvae (Chironomidae) have decreased by 90 percent. Although it is difficult to assess the effects of pesticides on the delta ecosystem, data suggest that the aquatic food web is affected by pesticide runoff from sources both inside the delta and upstream in the Danube River. Residues of the insecticides HCH (also known as lindane) and DDT are present at significant levels in polder soils in the delta, and in the sediment, plankton and fish of delta lakes.

The Danube Delta supports large populations of bird species that are generally widespread across Europe. More than 160 bird species breed in the delta, including pelicans, herons, ibises and terns. The drainage of wetlands, river channelization, impoundments, pollution and feral livestock have degraded the habitat quality to the point where bird populations are a fraction of their historical numbers.

Beyond the delta, the eutrophication of the Danube has been responsible, at least in part, for declining water quality in the Black Sea. The Sea is currently in a very eutrophic state and was described as being "within an inch of falling into a coma" by specialists who attended the Ecoforum Peace Conference in Moscow in 1990. Its waters are highly stratified, and the chemocline (the depth below which water is stagnant and very low in dissolved oxygen) has risen from 170 meters to 110 meters below the surface over the past few years. Because few fish can live below the chemocline, its rise has destroyed valuable fisheries.

The Outlook for Improvement

There is some hope that the rate of environmental degradation in the delta is easing. Political changes in Romania following the revolution of 1989 have given the Romanian portion of the delta a reprieve. In February 1990 President Ion Iliescu decreed a halt to all agricultural and hydrologic development in the delta, and the area was made a Biosphere Reserve by national decree in August 1990. More than 50 percent of the

Figure 10. Fish harvests by the 500 to 600 Danube Delta fishermen who use traditional methods dropped by nearly half, severely affecting their livelihood, at the same time that aquaculture efforts failed in the delta. (Photo by Catherine Pringle.)

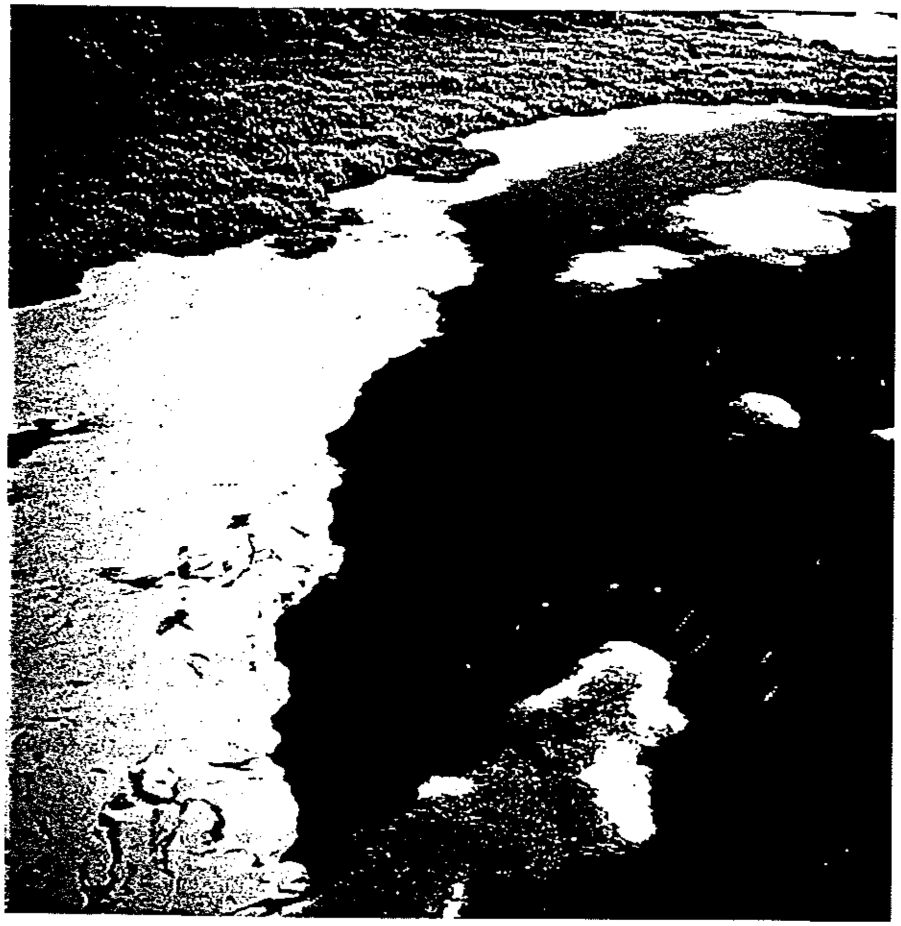

Figure 11. Intense algal blooms have become common in the Danube Delta as nutrient loads have increased over the past two decades. These and other threats to water quality in delta wetlands and lakes have accompanied significant declines in populations of rooted plants, shellfish and fish. (Photo courtesy of The Cousteau Society, copyright 1991.)

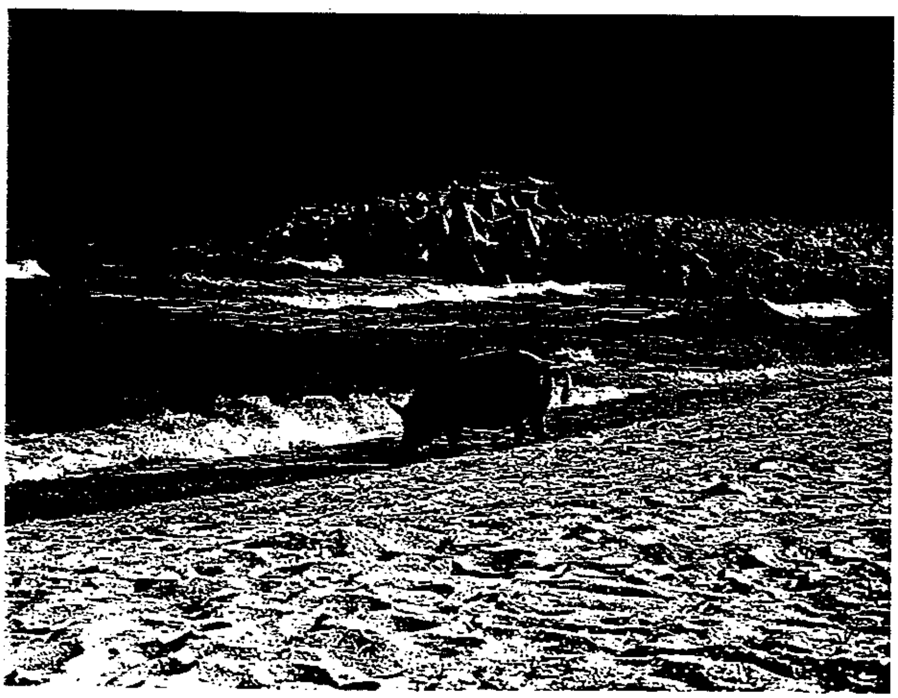

Figure 13. Feral livestock often disturb bird-nesting areas along the Black Sea. In the background, erosion-control engineering works have been installed to help slow the recession of the coastline, which is eroding as rapidly as 17 meters per year. (Photo by Catherine Pringle.)

reserve was declared a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in late 1991. As a result, the surface area of the delta within Romania devoted to agriculture is no longer increasing. Furthermore, pesticide use is restricted through the Danube Delta Biosphere Reserve Authority, a management and research unit established in 1990 by the Ministry of Environment.

Upstream from the delta, hydroelectric projects now under construction, such as the Bos-Nagymaros dam, have proved highly controversial and have been delayed because of public concern about deleterious environmental effects. Measures to reduce the introduction of untreated waste and agricultural runoff to the Danube River and to restore its floodplains, however, have been limited. In 1985 the nine nations through which the Danube River passes signed the Bucharest Declaration, an agreement to cooperate on water management and pollution control, but socioeconomic and political problems in the nations of the Danube basin have stifled progress.

Although it is clear that water-quality issues in the entire Danube River watershed must eventually be addressed if the environmental decline of the delta is to be reversed, current efforts focus on the more practical matter of restoring aquatic ecosystems within the delta itself.

The World Bank, through the Global Environment Facility (GEF), has recently approved an advance to provide technical assistance and equipment to the Romanian government to prepare for a project on biodiversity conservation in the delta. The $4.2 million (U.S.) project, Danube Delta Biodiversity, will support local authorities in their efforts to manage the delta as an ecological system, including the development of environmentally sustainable economic activities such as fisheries, small-scale agriculture and tourism. Divided into Romanian and Ukrainian subprojects, these efforts will be connected to two regional GEF projects, Environmental Problems of the Danube River Basin, and the Black Sea Environmental Program.

One goal of the preparation phase of the Romanian phase of the biodiversity project is to identify two medium-scale (100 to 500 hectares) restoration sites for converting deserted agricultural polders or fish ponds into wetlands. Plans will also include a program to monitor changes in the rehabilitated areas and the surrounding environment.

Another important goal of the project's preparation phase will be to increase the control of human activities in the delta. The Danube Delta Ecological Guards (Corps) was established in November 1990 to protect the Danube Delta Biosphere Reserve. The Corps is responsible for enforcing harvest regulations, eradicating domestic and feral animals from protected areas, excluding people from sensitive bird-nesting areas and educating the people who live in the delta about environmental concerns. Unfortunately, there is little money to support this fledgling program. Thus cadets are under-trained, under-equipped and underpaid. The World Wildlife Fund International has provided some basic equipment for the Corps, but the most crucial need is financial support to train and pay the wages of cadets, who currently earn the equivalent of only $20 per month.

Research into Wetlands Restoration

Local restoration is crucial for delta rehabilitation. Both the Romanian government and local inhabitants have begun to acknowledge that large-scale agricultural production in most of the polderized areas is not sustainable and that restoring such areas to wetlands will have substantial benefits. Research has shown that drained wetlands in the delta are probably the major cause of both its inability to handle nutrient loads and its declining fisheries. These findings prompted Marin Gomoiu, governor of the Danube Delta Biosphere Reserve, to give high priority to restoration of reed beds in selected areas.

The ideal way to return polderized land to a condition suitable for natural reed beds would be to raze completely the retaining dikes, restoring original water depths and flow patterns. In reality, however, fiscal constraints will drive restoration efforts, and polder dikes likely will be breached in strategic locations to establish the necessary hydrologic conditions. High flow rates will require more openings in the dikes and significantly larger budgets. Water-depth regulation may require supplementary excavation or water-level control structures to accommodate elevation changes from earth moving or soil subsidence.

Because the science of wetland creation and restoration is in an early stage of development, the knowledge necessary to make informed management decisions is not currently available. To avoid the mistakes of the past, therefore, it is important that we gain fundamental information about restoration before attempting the large-scale reconversion of polders to wetlands. The best way to acquire such information is through experiments that allow manipulation of key environmental variables.

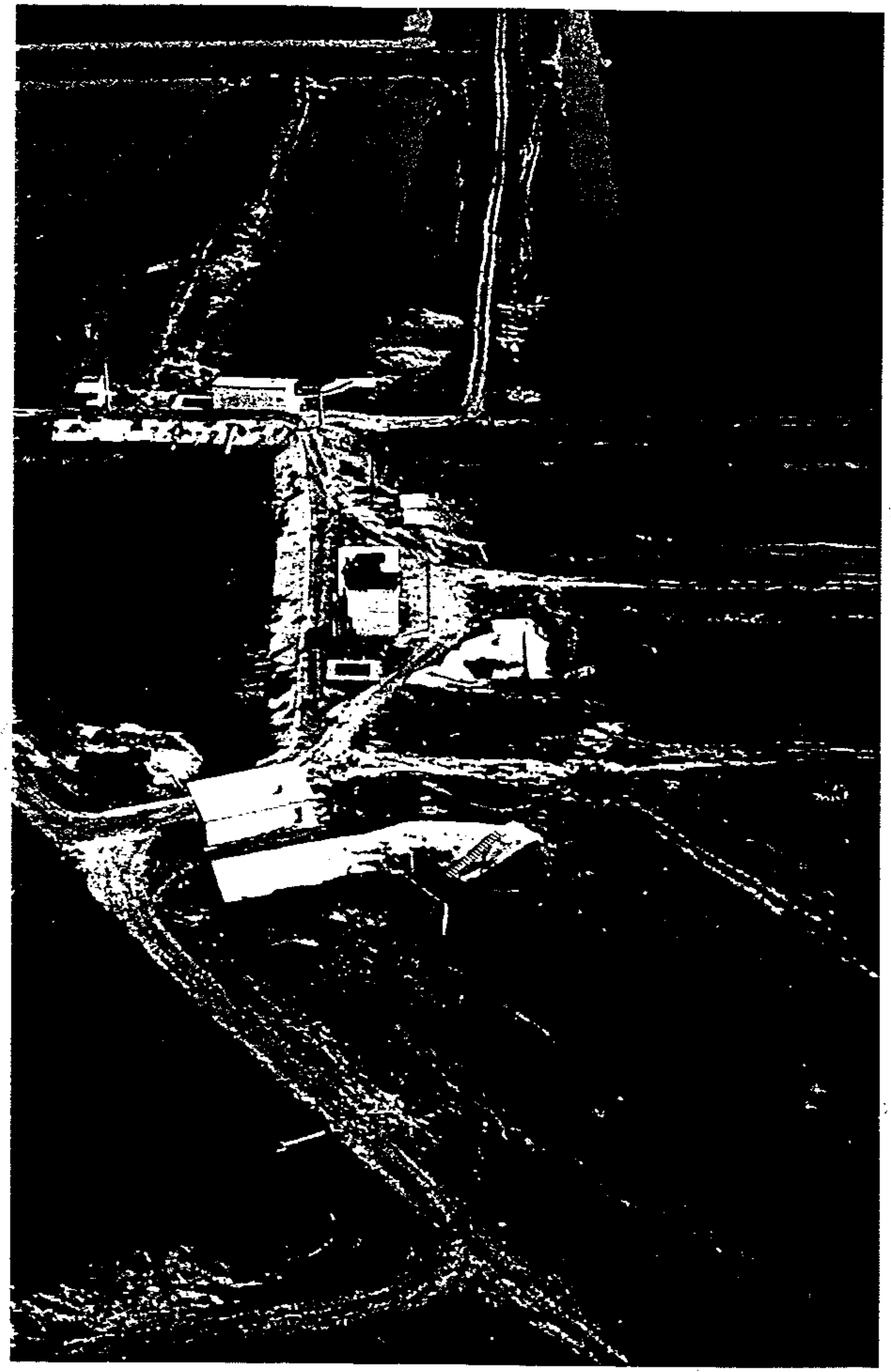

Figure 13. Abandoned aquaculture and sand-mining and processing complexes at Caraorman in the Danube Delta demonstrate the degree to which delta wetlands geography has been changed by human activities. More than 23,000 hectares of fish polders have been constructed in the delta since 1970. (Photo courtesy of The Cousteau Society, copyright 1991.)

The technical problems of restoring reed beds converted to agricultural land are not insurmountable. Such areas generally retain their seed banks, and the dispersal of plant species is facilitated by waterfowl that use these wetlands. As long as there are no other severe disturbances, reed beds recover naturally once crop planting stops and the natural water flows are restored. It is

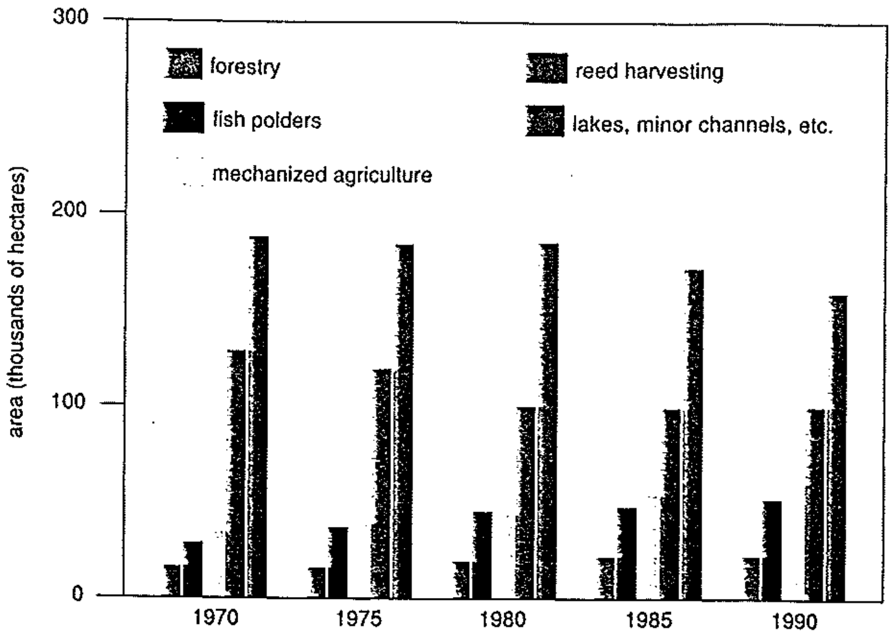

Figure 14. Changing patterns of land use over the last two decades show clearly the conversion of lakes and minor channels in the Danube Delta to agricultural and aquacultural uses. Increased forestry is largely in abandoned reed polders.

not known, however, which hydrologic regime will most effectively bring about rapid establishment of highly productive reed stands; natural reed stands in the delta have many natural hydrologic conditions.

Scientists of the Danube Delta Research Group, consisting of the 21 participants of the 1991 and 1992 workshops sponsored by the U.S. and Romanian National Academies of Sciences, have proposed a dual experimental approach for determining feasible restoration techniques for drained lands currently in unsustainable agricultural production.

The first approach, currently being implemented by scientists from the Danube Delta Research Institute, involves flooding selected small polders (4.9 hectares of agricultural polders and 10.2 hectares of fish polders) by breaching the retaining dikes in one or two locations without any other hydrologic modification. Over the next two to three years, periodic measurements will be made to determine the recovery of wetland functions.

The second approach, a rigorous experimental study by Romanian and U.S. scientists, is still in the formative stage. Experimental plots will be established in a series of large earthen basins, and various water depths and flow-through velocities will be tested. In addition, some elements of the natural hydrologic cycle will be replicated within the experimental basins. Nonfloating reed beds in the delta are typically inundated for several months each year when the river rises from mid-April through the first week of June and again from mid-November through the first week of December. During the spring flood—which lasts longer and has greater volume, making it more important for reed growth and regeneration—the Danube River discharges a third of its annual flow.

The success of restoration efforts will be assessed with intensive water-quality, soil, vegetation and aquatic-biota sampling. To better understand how the quality of Danube River water influences restoration success, simplified nutrient budgets will be developed by estimating, based on collected data, annual nutrient inputs, outputs and sinks for each basin. Results from both studies will be used to establish guidelines for the successful implementation of the large-scale restoration projects anticipated in the Danube Delta Biosphere Reserve in the coming years.

Restoration will provide benefits at both the population and ecosystem levels. At the population level, flora and fauna that require a wetland habitat will be re-established. Many of these species—reeds, for example—have economic value. At the ecosystem level, restored wetlands will provide spawning and nursery habitat for fish and shellfish, which will support commercial, recreational and subsistence fisheries in the delta and in the Black Sea.

Restoring Danube Delta wetlands and associated ecosystems is a necessary first step toward achieving environmental security for the entire Danube Basin. By showing that environmental restoration can provide direct and indirect economic, environmental and social benefits—not only to the delta but also to the nine nations the Danube River runs through, as well as other nations dependent on the Black Sea for fisheries, tourism and other economic activities—it may provide the catalyst that leads regions to tackle environmental problems on an ecological, rather than a national, scale.

Acknowledgements

The authors gratefully acknowledge the support of the U.S. National Academy of Sciences and the Romanian Academy of Sciences and the participation of other members of the Danube Delta Research Group in the U.S.–Romanian workshop: A. Chiorascu, R. Dorel, I. Gheorghe, C. Griffin, L. Guta, B. Harvey, B. Howes, J. Hanganu, D. Kogalniceanu, K. Lajtha, B. McKee, V. Mitache, M. Palmer, L. Platica, G. Risnoveanu, G. Ruzsa, M. Staras, A. Zale and M. Zamfir. We would like to extend special thanks to Stephen Deets of the National Research Council's Office of Central and Eastern European Affairs, who played a key role in facilitating and organizing both phases of the U.S.–Romanian Young Investigators Program.

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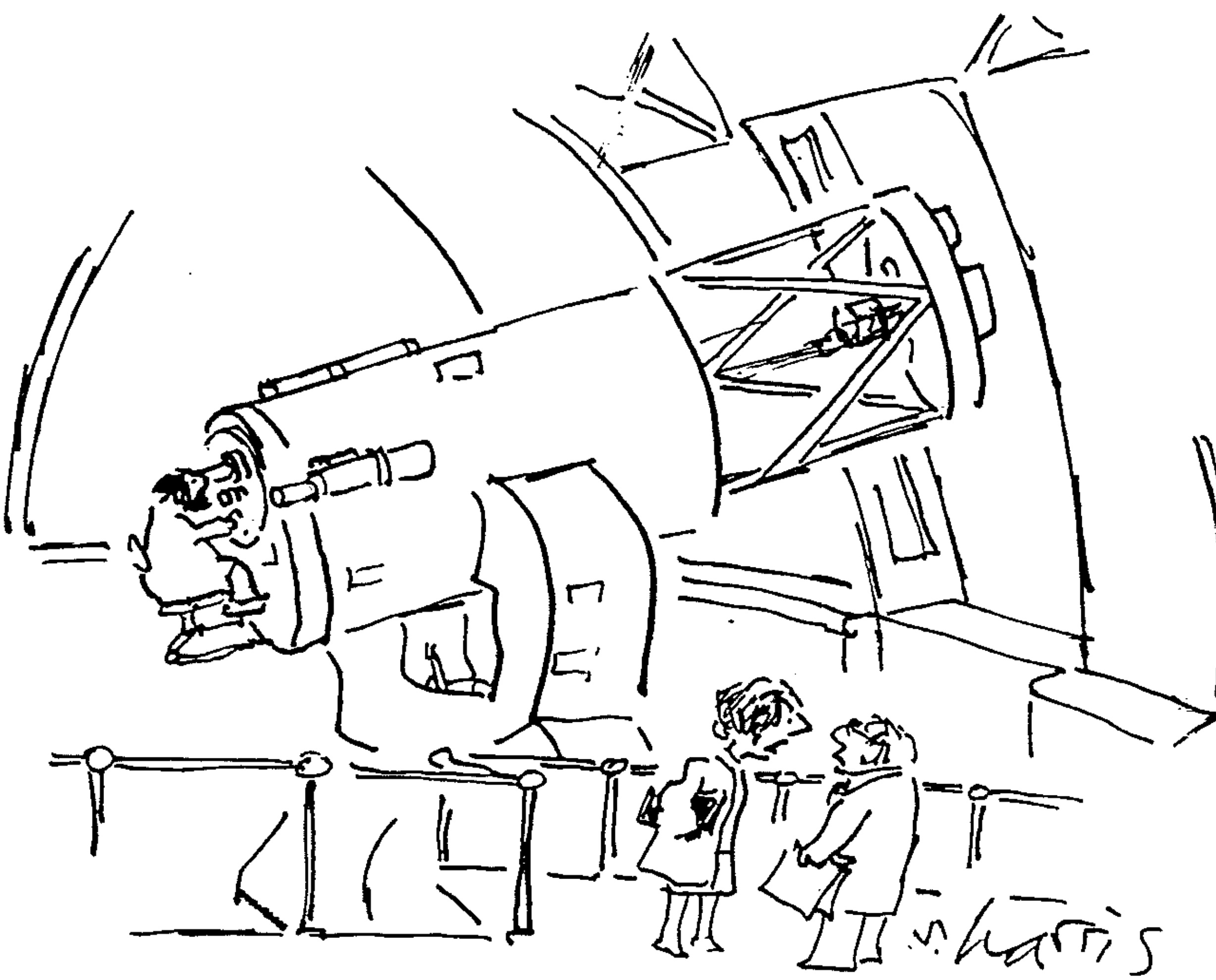

"THE REASON HE'S NEVER SEEN A CONSTELLATION IS HE'S CONVINCED THERE REALLY ARE WHITE LINES CONNECTING THE STARS."