"Operation RubyThroat: The Hummingbird Project"
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ABSTRACT

"Operation RubyThroat: The Hummingbird Project" is a cross-disciplinary project in which K-12 students in North America and Central America collaborate to study behavior and distribution of Ruby-throated Hummingbirds (*Archilochus colubris*). Operation RubyThroat and its award-winning Web site at www.rubythroat.org are outreach initiatives of Hilton Pond Center for Piedmont Natural History, a non-profit research, education, and conservation organization in York, South Carolina (see www.hiltonpond.org).

In 2000-2001, Operation RubyThroat principles were field tested successfully by six K-12 educators, one of whom who reported the project "aligns perfectly with state and local curriculum standards." As a next step, the project was piloted in 2001-2002 by more than 4,000 students in the Carolinas and New York. In 2002-2003, Operation RubyThroat expanded to all 38 states in which Ruby-throated Hummingbirds (RTHUs) regularly occur, and is going international in 2003-2004 with the inclusion of Canada, plus Mexico and the seven countries of Central America where RTHUs overwinter.

Operation RubyThroat's essential goals are to: 1) enhance K-12 science learning; 2) enlighten students about hummingbirds and environmental factors that affect them; 3) excite students about field research and environmental careers; 4) emphasize integration of natural science learning into all disciplines, including math, arts, and humanities; 5) establish Schoolyard Hummingbird Habitats; 6) expand student use of technology and the Internet, especially in the natural sciences; 7) encourage international understanding by building student and teacher networks in the Western Hemisphere; and, 8) establish an exemplary program that serves as a model for other cross-disciplinary projects that focus on topics other than hummingbirds.

Operation RubyThroat affiliated with The GLOBE Program (www.globe.gov) in March 2002, when the protocols were posted to the GLOBE Web site. This alliance greatly expanded Operation RubyThroat by enabling student observers in the GLOBE network to collect and submit data about RTHUs and to correlate hummingbird observations with data on phenomena that may influence RTHU behavior. Historically, GLOBE students have compiled data about atmosphere/climate, hydrology, soils, land cover, and plant phenology; Operation RubyThroat was the first protocol to involve vertebrate observations.

This collaborative effort between Operation RubyThroat and GLOBE presents an unusual opportunity for students to make real contributions to our understanding of a single hummingbird species. RTHUs nest across the eastern two-thirds of the U.S. and southern Canada—the largest breeding range for any of the 338 species of hummingbirds. Nonetheless, surprisingly little is known about some aspects of RTHU behaviors—especially variations across the species' range, migration details, and impact of abiotic factors (such as those studied through GLOBE). Hummingbird protocols are designed so that new data of significant scientific value can be contributed by students from kindergarten through high school, and so that teams of project scientists, teachers, students, and citizen scientists can collaborate to publish RTHU research results in peer-reviewed literature.

In March 2003, Hilton Pond Center received the initial disbursement of a 42-month award from the National Science Foundation. Funds are being used to help meet Operation RubyThroat's general goals (above) and allow the Center to work more closely with GLOBE students and/or teachers to: 1) collect scientific data using hummingbird protocols; 2) correlate hummingbird observations with other GLOBE data; 3) fine-tune GLOBE's existing hummingbird protocols and design new ones to answer new questions; 4) align GLOBE protocols with national and state science education standards; 5) develop standards-based curricula that use hummingbird protocols; 6) expand the project audience; 7) hold training workshops for GLOBE teachers and citizen scientists; 8) interact on-line with students; 9) challenge students to engage in independent and advanced field investigations; and, 10) mentor students with the goal of publishing in refereed journals any significant research results derived from Operation RubyThroat and GLOBE data.

Operation RubyThroat is collaborating with other GLOBE-related projects as part of the GLOBE ONE field campaign being conducted in Black Hawk County, Iowa in 2004-2005.

"Operation RubyThroat: The Hummingbird Project"
A GLOBE-related initiative through which students and scientists explore relationships between birds and the environment

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ORGANIZATIONAL BACKGROUND

Hilton Pond Center for Piedmont Natural History in York, South Carolina, is a 501(c)(3) organization whose Mission is "to conserve animals, plants, habitats, and other natural components of the Piedmont Region of the eastern United States through observation, scientific study, and education for students of all ages."

Since its founding in 1982, Hilton Pond Center has been the most active bird banding station in the Carolinas and one of the most active in the southeastern U.S., with 45,000 birds of 123 species banded locally—including almost 3,000 Ruby-throated Hummingbirds (*Archilochus colubris*). Because of its long-term research projects, the site has been designated an Important Bird Area by the National Audubon Society and BirdLife International. Although the facility was operated until 2001 on a part-time basis by unpaid staff and volunteers, up to a thousand people still benefited each year from Guided Field Trips on the property. Visitors continue to include K-12 students, education interns, teachers, college classes, senior citizens, conservation groups, garden clubs, and civic organizations from across the region and as far away as Canada and Europe. The Center involves both public and private K-16 institutions in its education and research activities, and makes a special effort to work with inner-city and rural schools, young women in science, and other traditionally under-served populations.

As part of its outreach program, the Center maintains an extensive Web site (www.hiltonpond.org) that is regarded nationally by educators and scientists as a valuable source of up-to-date natural history information. It is complemented by the award-winning Web site for "Operation RubyThroat: The Hummingbird Project" at www.rubythroat.org. In 1999, the Center was incorporated by a national Board of Trustees that received federal non-profit status to allow the Center to accept tax-deductible contributions and apply for grants from foundations and corporations.

PROJECT BACKGROUND: Overview

"*Everybody loves hummingbirds, and they are wonderful tools to excite students about learning in science, math, and other subjects!*" This enthusiastic quote from a classroom teacher is the basis for "Operation RubyThroat: The Hummingbird Project," an innovative Web-based cross-disciplinary initiative through which students, teachers, and others collaborate to study behavior and distribution of Ruby-throated Hummingbirds (RTHUs).

Teachers involved in Operation RubyThroat use hummingbirds as a "hook" to grab students' attention and to interest young people in science and other disciplines. Project participants learn about natural history; reinforce skills in science, math, writing, geography, art, language, and other academic areas; AND gain deeper understanding of the need for environmental cooperation among people of the Americas. Student participants

observe RTHU behavior in their home countries and use technology to share hummingbird observations with peers in other schools.

Because RTHUs tolerate humans and are drawn to feeders and flower gardens, these tiny birds are ideal subjects for observation and research. In addition, the general mystique of hummingbirds makes them a stimulating topic for study and discussion among children and adults of all ages. Operation RubyThroat capitalizes on such interest to raise in its participants awareness of natural history and of the interconnectedness—and mutual conservation needs—of countries in the Western Hemisphere.

Year One (2001-2002) participants in Operation RubyThroat lived in the United States, primarily in the Carolinas and New York. In Year Two (2002-2003), the project expanded to include students and teachers in 38 states and Washington DC, and in Year Three (2003-2004) to Canada, Mexico, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama—everywhere Ruby-throated Hummingbirds regularly occur.

The main goals of Operation RubyThroat are the "Eight E's":

- Enhance K-12 learning in science, particularly natural history and conservation
- Enlighten students about hummingbirds and environmental factors that affect them
- Excite students about field research and potential careers in ecology and related areas
- Emphasize integration of science learning into all disciplines, including math, arts, and humanities
- Establish Schoolyard Hummingbird Habitats to demonstrate the value of small-scale conservation efforts in protecting larger-scale ecosystems and the organisms they contain
- Expand student use of technology and the Internet, especially in the natural sciences
- Encourage international understanding by building student and teacher networks in the Western Hemisphere
- Establish an exemplary program that serves as a model for other technology-enabled cross-disciplinary projects that focus on new topics other than hummingbirds

In January 2002, Operation RubyThroat affiliated via letter of agreement with The GLOBE Program, a worldwide network of students, teachers, and scientists working to study and understand the global environment. The GLOBE program is highly acclaimed for its use of technology and the Internet to connect student observers around the world. As an optional Phenology Protocol, Operation RubyThroat brings to GLOBE a new dimension that relates life science and hummingbird behavioral ecology to GLOBE's traditional emphases on atmosphere/climate, hydrology, soils, and land cover. It is GLOBE's first protocol that involves extensive faunistic observations.

PROJECT BACKGROUND: Need for the Operation RubyThroat Project

A map of the Western Hemisphere shows many political boundaries, but migratory animals, weather patterns, and ocean currents pay no heed to state lines or borders between countries. Ruby-throated Hummingbirds, for example, breed in Canada and the U.S. but typically winter in Mexico and all seven Central American countries. Using RTHUs as its focus, Operation RubyThroat helps students and teachers see that these Neotropical migrants—as well as air we breathe and water we drink—are resources shared with citizens of other states and countries. This core concept is not easily taught, but through Operation RubyThroat young people come to understand that what happens to organisms, habitats, and natural resources in North America can impact greatly on Central America, and vice versa.

Few projects focus on building friendship and understanding among young people across the Western Hemisphere, and almost none encourage cooperation on conservation- or science-related endeavors. Thus, Operation RubyThroat is a much-needed mechanism for creating and nurturing a network of K-12 students (and potential future scientists) whose international collaborative efforts may become increasingly important in preventing or solving environmental problems—whether those problems involve hummingbirds or some other

aspect of ecology. As the Operation RubyThroat network grows, student participants are also stimulated to learn more about science and to apply their new knowledge to everyday life.

Numerous studies by the National Research Council and other organizations have shown that U.S. students lag behind other countries in science and mathematics. Through its on-line lesson plans and collaborative data collection, Operation RubyThroat emphasizes solid science learning and integrates it into other disciplines such as math, geography, humanities, and the arts. Overall goals of Operation RubyThroat dovetail nicely with National Science Foundation and GLOBE interests in science and math education, conservation, the environment, and related issues.

PROJECT BACKGROUND: Web Site & Field Test

As a trial project, Operation RubyThroat first appeared in October 1999 as centerpiece of its own Web site. The site attracted immediate attention from educators, scientists, students, nature centers, scout leaders, and the lay public, and has been recognized with awards for content and design from National Academy Press and the Eisenhower National Clearinghouse for Math and Science. *Scientific American* acknowledged its technical and educational validity by naming it "Pick of the Web," and its popular appeal is indicated by its selection as a "Hot Site" by *USA Today*. The Operation RubyThroat Web site has become a frequently visited Internet source for information about Ruby-throated Hummingbirds, general hummingbird ecology, and hummingbird research. Students, teachers, and the public consistently post Guestbook messages that the Operation RubyThroat site is an extremely helpful source for hummingbird facts and educational ideas. An alternate Spanish-language home page reaches Latino educators and students in Mexico, Central America, and the U.S. at www.rubythroat.org/spdefault.html; as the project expands, all key sections of the Web site will be available in English, Spanish, and French.

Six U.S. teachers and nature center educators field-tested Operation RubyThroat during the 2000-2001 school year (see www.hiltonpond.org/FieldTest2000Main.html). They reported that project principles excite students about science and math, and yield demonstrable improvement in science and math learning. A South Carolina teacher found that the project "aligns perfectly with state and local curriculum standards." Field testers reported that another compelling aspect of Operation RubyThroat principles is that they can be used with students at any grade level. For example, kindergarten students can learn to make simple observations about hummingbirds at feeders, while high school advanced biology classes can conduct hummingbird research projects worthy of publication in refereed journals.

Operation RubyThroat is, by design, a cross-curricular project that encourages teachers to incorporate science into other disciplines, and vice versa. When a science class studies hummingbird migration, students learn about geography; or, when those students generate graphs showing how many times a hummingbird visits a feeder in a day, they also master math skills. Likewise, when an art teacher has students observe a hummingbird and make sketches, her students will learn about hummingbird morphology, as will those of a drama teacher who has his students write and perform a play based on hummingbird behavior. And, when any of these students enter and analyze data, use digital cameras, or access the Internet to share information with peers in distant schools, they improve their command of technology.

PROJECT BACKGROUND: Operation RubyThroat's Year One (2001-2002)

In 2001-2002, project staff for Operation RubyThroat actively recruited educators and students in North Carolina, South Carolina, and New York—three states in which Hilton Pond Center has extensive school contacts. Potential teacher collaborators were recruited through listservs and other Internet resources, local school districts and state departments of education (with help from science curriculum coordinators), National Science Teachers Association state affiliates, and presentations at professional education meetings; some student participants were contacted through Junior Academies of Science and science clubs. By the end of Year One, more than 400 teachers and 5,000 students were enrolled in Operation RubyThroat.

Although the original Field Test in 2000-2001 received no extramural funding and was conducted completely out-of-pocket, Year One (2001-2002) was supported in large part by grants from The Christensen Fund ($35,000), National Fish and Wildlife Foundation ($17,500), Phillips Petroleum Company Migratory Bird Fund ($17,500), Foundation for the Carolinas Impact Fund ($6,000), Perky-Pet Corporation ($2,000), and individual donors ($8,000). These funds allowed for instructional site visits to schools in the Carolinas and New York, establishment of Schoolyard Hummingbird Habitats at seven schools in the Charlotte NC area, and expansion and maintenance of the Operation RubyThroat Web site.

In May 2001, staff from Hilton Pond Center for Piedmont Natural History also began working with GLOBE on an initial set of protocols based on the behavioral ecology of Ruby-throated Hummingbirds. Final letters of agreement were signed by GLOBE and the Center in January 2002. Protocol descriptions, reference photos, and on-line forms for Operation RubyThroat were completed in early March 2002, and all hummingbird protocols became accessible to student observers by the beginning of RTHU migration on 15 March 2002. (A major revision of the hummingbird protocols was completed in 2003 and now appears on the GLOBE Web site.)

PROJECT BACKGROUND: Scientific Rationale

The Ruby-throated Hummingbird (*Archilochus colubris*) is an ideal species for a cross-disciplinary science study involving students from Canada, Mexico, the United States, and all seven Central American countries. Known in Spanish as *mansoncito garganta de fuego* or *chupaflor rubi*, ruby-throats are Neotropical migrant insect- and nectar-eaters that come readily to artificial feeders and are tolerant of human observers (Hilton, pers. obs.). Ruby-throated Hummingbirds (RTHUs) are fascinating creatures that immediately capture a student's imagination and lead him or her into scientific investigation and discovery. Extensive information and photos about RTHU biology, behavior, ecology, and banding research can be found on the Web site for Operation RubyThroat: The Hummingbird Project at www.rubythroat.org.

RTHUs nest throughout the eastern two-thirds of the U.S. and parts of southern Canada, the largest breeding range of all 338 species of hummingbirds (Johnsgard, 1997). Nonetheless, surprisingly little is known about aspects of RTHU behavior—and especially how behaviors may vary across the species' range. It is generally assumed, for example, that changes in day length are the strongest influence on RTHU autumn migration from the U.S. and Canada (Robinson *et al.*, 1996), but no one has looked thoroughly at impact of ambient temperature, barometric pressure, wind speed, wind direction, or other weather factors already being reported by GLOBE participants. Likewise, in some spring migrations, RTHUs appear to move northward at about the same rate as the 1.7 degree C isotherm (Austin, 1975); this may correlate with availability of small insects and flowering times of several temperate plant species that provide energy-rich nectar, but no one has specifically investigated many of the potential environmental influences on RTHU spring migration across eastern and central North America. Correlation of hummingbird observations with data from GLOBE's traditional protocols—and relatively new ones in categories such as Phenology (bud burst, etc.)—may allow students and cooperating scientists to discover additional environmental factors that affect migration.

Some Operation RubyThroat participants are likely to find active RTHU nests. If this happens, students may conduct in-depth observations of nesting behavior, taking care not to disturb the nest, chicks, or adults. Except for a single report (Welter, 1935), RTHU males are not known to build nests, incubate eggs, or care for nestlings (Bent, 1940), so any observation of adult male activity near the nest is potentially important. Female RTHUs may lay a second or third clutch of eggs in one breeding season (Nickell, 1948), but it is not clear whether this behavior occurs regularly or because an earlier nest fails from predation or other interference. Little is known about the relationship between re-nesting, weather, and geographic latitude.

It is anticipated that thousands of Operation RubyThroat student observers in 38 states and Canada—plus Mexico and Central America where RTHUs overwinter—will produce a large database from which to interpret

RTHU behavior in migration and on breeding and wintering grounds. Hilton Pond Center is strongly committed to working with teachers and students to publish in refereed journals any new knowledge about RTHUs that is revealed from correlating hummingbird observations with data collected through other GLOBE protocols.

Students participating in Operation RubyThroat also will be instructed to be alert for "unusual" hummingbirds that are color-marked or that are overwintering out of normal range. Because Hilton Pond Center color marks all banded RTHUs with a necklace of green dye, and since less than a dozen banded RTHUs have been encountered more than 15km away from their banding sites (U.S. Bird Banding Laboratory, Laurel, Maryland, pers. comm.), any student sightings of color marked birds will contribute significantly to our understanding of RTHU migratory movements in both spring and fall. As an example, a color-marked bird from the Center that was seen 370km away in Atlanta in 1991 was the first RTHU ever recaptured more than 15km from its banding site (Hilton, 1994); it and two other of the Center's color-marked birds were encountered in Louisiana (1996) and Alabama (2000). These birds provide strong evidence that at least some eastern RTHUs fly overland across the southeastern U.S.—which contradicts the popular belief that all East Coast RTHUs go to Florida before crossing the Gulf of Mexico.

Lastly, in the past quarter century there has been apparent increase in hummingbirds from the western U.S. and Mexico appearing in the central and eastern U.S. in fall and winter (Conway & Drennan, 1979; Hilton, 2004b), and even in late summer (Hilton, 2004a). In January 2002, for example, staff from Hilton Pond Center banded the first Buff-bellied Hummingbird (*Amazilia yucatanensis*) ever seen in South Carolina (Hilton, 2004c). No one knows whether this increase in numbers and species of vagrants is due to greater public interest in hummingbirds, improved Internet-based communications about winter sightings, or some environmental change such as global warming or habitat destruction in the bird's typical wintering areas (see www.hiltonpond.org/ResearchHummerVagrantMain.html). Although these vagrant species are not RTHUs, a network of Operation RubyThroat student observers spread over the central and eastern U.S. may help clarify trends and discover environmental influences on hummingbirds, especially when sightings of winter vagrants are correlated with GLOBE data on ground cover and climate.

To this end, participating students will be asked to report all sightings of hummingbirds in the central and eastern U.S. or southern Canada from 15 October through 15 March. When color marked RTHUs or winter vagrant hummingbirds are reported to GLOBE by student participants, staff at Hilton Pond Center will validate the sighting or alert a hummingbird expert who is closer to the observation site. A bander may attempt to capture the hummingbird(s) to look for bands or to make a positive identification on the species. In any case, each sighting by GLOBE's student network has the potential to make a significant contribution to our understanding of movements by vagrant hummingbirds that historically have overwintered primarily in the western U.S., Mexico, or Central America.

All investigations described above (and in the following section) have potential for producing new data with real scientific value. These data will allow teams of project personnel, teachers, and students to collaborate on publishing RTHU research results in peer-reviewed publications.

HUMMINGBIRD PROTOCOLS & RESEARCH QUESTIONS

As part of the general GLOBE protocols, all participating schools determine their exact latitude and longitude by using GPS instruments. Schools that do not own a handheld GPS locator are encouraged to borrow—not buy—a device for this one-time measurement. It is anticipated that most participants in Operation RubyThroat will begin with simple observations at a hummingbird feeder hanging in an appropriate location on the school campus. Feeders are inexpensive ($5 and up) and are easily obtained from discount department stores, pet shops, and other retail outlets; the feeder is the only "required" equipment for project participation, but even feeders are not needed if teachers and students decide to make observations of RTHUs only at nectar flowers. Some schools may elect to enhance or create Schoolyard Hummingbird Habitats as outdoor observation sites on

their campuses; small grants for this purpose often are available from local garden clubs and other sources, and Hilton Pond Center will provide guidance for schools that wish to install habitats. Classroom field guides to help with identification of hummingbirds and nectar plants are desirable but not required because photos and descriptions are available on-line on many natural history Web sites, including those for Operation RubyThroat and Hilton Pond Center. (Forestry Suppliers has developed a phenology kit that includes basic equipment for the hummingbird protocols; similar items may be available from other vendors.)

All hummingbird data are reported through the GLOBE Web site on electronic forms that include name of school and participating students, and date and time of observations. A duplicate copy of each submitted form is also transmitted to Hilton Pond Center for validation; questionable data may be flagged and/or removed from the database after a staff member consults via e-mail with the observer's teacher. It should be noted that Excel-based data forms are now available to expedite bulk reporting of hummingbird data to GLOBE, thus eliminating slow and repetitive use of on-line forms.

Through GLOBE and Operation RubyThroat, students in the U.S. and Canada collect data for one or more of the following protocols for Ruby-throated Hummingbirds:

1. Observe the first spring sighting of RTHUs
2. Make daily observations and record RTHU sightings during the hummingbird season (spring through autumn)
3. Observe final departure date of RTHUs in autumn
4. Count the number of RTHU visits to birdfeeders or to flowers over time, or compare birdfeeder versus flower visits over time (45-minute blocks)
5. Count the number of RTHU visits to different flower species in a garden, flower box, or natural area over time (45-minute blocks)
6. Observe RTHU nesting behavior
7. Report "unusual" hummingbirds that are color-marked or that are overwintering out of normal range

Students in Mexico and Central America make similar observations, except that they report the last RTHU sighting in spring and the first sighting in autumn; they do not have opportunities to observe nesting behavior on the wintering grounds.

Students submitting hummingbird data through GLOBE are expected to be able to identify RTHUs, and for most protocols, to sex and age the birds visually. Operation RubyThroat's introductory section on the GLOBE Web site contains detailed descriptions and photographs of RTHU age and sex classes; additional information is at www.rubythroat.org. Age determination from March through mid-May in the U.S. and Canada is absolute, since all free-flying RTHUs in spring are adults; sexing is also easy in that time frame because only adult males have the bright red gorget that gives Ruby-throated Hummingbirds their name. Sexing and ageing become more complicated when the earliest RTHUs begin to fledge in May, since first-year males have not acquired their full red gorget and resemble females (Leberman, 1972; Baltosser, 1987; Pyle, 1997). Knowing the age and sex of RTHUs allows students to draw conclusions about differential behaviors. Students are cautioned NOT to guess about the age and sex of hummingbirds they observe; any RTHUs not positively aged and sexed are reported as "undetermined" in those categories.

Operation RubyThroat's seven initial protocols were designed to answer general and specific research questions about RTHUs. Some questions may be answered simply by making hummingbird observations, while others require correlation of hummingbird data with data collected as part of other GLOBE protocols. Hilton Pond Center, collaborating with teacher-student teams, will investigate several environmental- and hummingbird-related questions and their associated protocols (enumerated above). These include, but are not limited to, the following:

- Most observers state that adult male RTHUs arrive before adult females during spring migration (Robinson *et al.*, 1996). Is this true at all latitudes? (Protocol #1)

- In 1975, Austin reported that RTHUs appear to move northward in spring at about the same rate as the 1.7 degree C isotherm. Has this behavior changed in the last 30 years? (#1, correlated with GLOBE's minimum-maximum temperature data.)
- Can the number of feeder or flower visits by RTHUs in a 45-minute observation period provide an accurate estimate of the number of individual RTHUs in the vicinity? (#4.)
- Are plant species with a long blooming season attractive to RTHUs during the plant's entire blooming season? (#5.)
- RTHUs apparently have coevolved with tubular flowers such as those of Trumpet Creeper (*Campsis radicans*), a native vine that occurs almost everywhere RTHUs breed. Do RTHUs prefer tube-flowers when other shapes are available? (#5.)
- Some observers report a gradual increase in RTHU numbers in early spring, followed by a lull and then another peak—perhaps indicating two different migration waves (see www.rubythroat.org/Chart01RTHUDates.html). Is this a valid interpretation of early and late spring activity? (#1, #2, #4.)
- It seems likely that RTHU nesting success is based, at least in part, on external factors. In a given year, is nest loss greater at certain latitudes? Do climatic factors seem to have an effect? Are early nesters more or less likely to succeed than later nesters? (#6, correlated with various GLOBE weather datasets.)
- Is double- or triple-brooding in RTHUs more likely to occur in coastal areas? Is there a latitudinal gradient? A weather effect? (#6, correlated with various GLOBE weather datasets.)
- Banded and color-marked RTHUs from Hilton Pond Center have been seen or recaptured in Georgia, Alabama, and Louisiana during fall migration. Will autumn sightings of additional color-marked birds continue to support current speculation that East Coast RTHUs are likely to migrate through the Gulf Coast states rather than flying to Florida for a trans-Gulf trip? (#7, color-marked RTHUs.)
- There has never been a RTHU color-marked or banded in the U.S. and Canada and then encountered in Mexico or Central America. Can sightings south of the Rio Grande River provide information about whether RTHUs from specific areas of North America go to specific wintering areas? (#7, color-marked RTHUs.)
- Through December 2003, twelve different hummingbird species had been reported from the Carolinas, even though the RTHU is still the only species that breeds there (see www.hiltonpond.org/ResearchHummerVagrantMain.html). Will additional species show up in the Carolinas or in other states during fall and winter? Do there appear to be any environmental factors affecting the "displacement" of winter vagrants from their traditional wintering grounds? (#7, winter vagrants, correlated with various GLOBE data sets on weather, land cover, phenology, etc.)

Questions such as those outlined above have real potential to lead to analyses that reflect the interaction between RTHUs and their environment, and that, in turn, will result in publications having scientific merit.

GLOBE-RELATED ACTIVITIES: "Citizen Scientists"

After almost a decade of limiting its data collection scheme to K-12 students, GLOBE is beginning to expand into the realm of "citizen science." Because hummingbirds are so popular among the public-at-large, Operation RubyThroat stands to benefit greatly by training observers who are not classroom educators. Thus, Hilton Pond Center has been offering one-day training sessions to which educators AND non-educators are invited. These "outside" participants include birders, master gardeners, retirement home residents, conservation organization members, scout leaders, and other hummingbird enthusiasts who are certified only in the hummingbird protocols and who may submit only hummingbird data to GLOBE. These "citizen scientists" have potential to add significant hummingbird data, especially during summer when schools are not in session.

GLOBE-RELATED ACTIVITIES: Years Two, Three & Four (2002-2005)

In June 2002, Hilton Pond Center for Piedmont Natural History received preliminary notification it had been awarded National Science Foundation funding under Area 1 of Program Solicitation NSF 02-013, "Global Learning and Observations to Benefit the Environment (GLOBE)." After considerable delay, reduced funding

of $180,000 was finalized for the period March 2003 through December 2005. Partial disbursements received on a month-to-month basis are being used to implement, expand, refine, evaluate, and disseminate Operation RubyThroat's GLOBE-based protocols for Ruby-throated Hummingbirds, with an end goal of publishing significant scientific results. NSF funds—in conjunction with expected monies from non-governmental sources—are being used for activities such as those described below.

The primary GLOBE-related goals of Operation RubyThroat through 2005 (and beyond) are to work closely with students and/or teachers to implement the general goals of Operation RubyThroat (p. 2) and to:

- Collect scientific data about Ruby-throated Hummingbirds using GLOBE hummingbird protocols
- Correlate hummingbird observations with other GLOBE protocols in atmosphere/climate, hydrology, soils, land cover, and phenology
- Fine-tune current hummingbird protocols and design new ones to answer new questions
- Align all hummingbird protocols with national and state science education standards
- Help educators develop standards-based curricula that use the hummingbird protocols
- Expand the project audience to include participants in all states and countries where RTHUs breed, migrate, and/or overwinter
- Hold local, state, regional, and national training workshops for teachers to empower them to use Operation RubyThroat and GLOBE in their classrooms
- Hold additional training workshops for "citizen scientists"
- Make classroom visits to a limited number of U.S. schools submitting hummingbird data
- Facilitate on-line interactions between hummingbird scientists and students
- Challenge students to engage in independent and advanced field investigations into behavioral ecology of RTHUs
- Mentor—in cooperation with their classroom teachers—a select group of advanced students in grades 6-12, with the ultimate goal of publishing in refereed journals any significant research results derived from GLOBE/Operation RubyThroat data

Through June 2004, more than 250 educators and "citizen scientists" had been trained in the GLOBE/Operation RubyThroat hummingbird protocols; workshops have been held for as few as two and as many as 60 people in Florida, Iowa, North Carolina, Ohio, South Carolina, and West Virginia. In December 2004 and January 2005, up to three eight-day excursions to Costa Rica will involve teachers and others in the study of RTHUs on their wintering grounds; each trip will provide full scholarships to two Costa Rican teachers so they can participate fully in GLOBE/Operation RubyThroat training. (Trip sign-up information is on the Hilton Pond Center Web site at www.hiltonpond.org/CostaRicaAnnounceMain04.html .)

GLOBE-RELATED ACTIVITIES: GLOBE ONE

Operation RubyThroat is part of the GLOBE ONE field campaign being implemented in Black Hawk County, Iowa in 2004-2005. In February and March 2004, hummingbird protocol training workshops were held for more than 100 community members that included classroom teachers and citizen scientists from diverse venues. Presentations were also made for K-12 students at several area public and private schools and for a Waterloo IA television station. Operation RubyThroat anticipates collaborating fully with all GLOBE ONE principal investigators in evaluating relationships between the environment and till or no-till agricultural techniques at the Iowa study sites, and in publishing a summary paper at the campaign's end.

GLOBE-RELATED ACTIVITIES: Future Protocols & Exportability

The seven main hummingbird protocols are expected to result in extensive data about RTHUs being submitted by students and others to GLOBE and Operation RubyThroat. These data, in turn, may provide answers to questions listed in previous sections—and to other hypotheses likely to grow in the fertile minds of student participants. Any student who observes hummingbirds has the potential to generate new questions; the most intriguing of these will be considered as additional GLOBE hummingbird protocols in future years.

Several of GLOBE's Operation RubyThroat protocols also might be exportable for use with migratory animals other than RTHUs. For example, students in the western U.S. where RTHUs do not occur might observe behavior and migration in the Black-chinned Hummingbird (*Archilochus alexandri*), a RTHU congener. Another avian group that may lend itself to study through GLOBE is *Sialia*, the genus that includes Eastern Bluebirds (*S. sialis*), Mountain Bluebirds (*S. currucoides*), and Western Bluebirds (*S. mexicana*). All three species are cavity nesters that frequently use artificial nest boxes; these could be manufactured, erected, and examined during the breeding season by students, and data on egg-laying and nesting success might be correlated against GLOBE weather data. At least one of these three bluebird species is found regularly in every state except Hawaii, as well as in the southern and western Canadian provinces, in Mexico, and even as far south as Nicaragua. This wide distribution would allow for development of GLOBE protocols for bluebirds that are modeled on those developed for Operation RubyThroat.

GLOBE-RELATED ACTIVITIES: Caveat on Hummingbird Phenology & the Academic Year

Ruby-throated Hummingbird activity in much of North America begins with the arrival of the first spring migrants about 15 March (somewhat earlier in Gulf Coast states, much later in Canada), and ends in early October when virtually all RTHUs have departed for Mexico or Central America. Since many U.S. schools are out of session from June through August, teachers must be prepared to maximize observation opportunities in April, May, and September. Advance planning will allow students to implement nearly all the hummingbird protocols in those three months. However, since the prime observation time for RTHU nesting activity is midsummer, provisions may been made for students to continue observations at a private home or public facility and to report their data through GLOBE. Operation RubyThroat suggests in its on-line instructions that teachers encourage students to conduct at-home observations of RTHUs on weekends during the school year, and during summer months. Each student may set up a backyard observation locale as a "satellite site" and report observations through the school's site ID. Home-schooled students and schools with summer courses and special programs also may submit RTHU data, as may nature centers and summer camps at which a collaborating teacher or staff member is designated. Any observations made separate from classroom activities will still follow GLOBE's precise guidelines for standardized data collection and will enhance the data set. (NOTE: Citizen scientists also may designate their backyards as observation sites; however, each adult who attends a GLOBE/Operation RubyThroat hummingbird training workshop receives a personal GLOBE ID that allows data submission via GLOBE's Web site.)

GLOBE-RELATED ACTIVITIES: Other Impediments to Success

Although Hilton Pond Center is very grateful for NSF funding, a 60% cut in the original budget request eliminated a key personnel position and reduced the amount of money available for travel to conduct training workshops. Together these factors: 1) make it impossible to provide training at the desired level; 2) greatly reduce reinforcement and follow-up for trainees; and, 3) severely limit the amount of personal contact with student participants in GLOBE/Operation RubyThroat. (NOTE: A supplemental request for $5,500 was approved in June 2004 to provide some additional travel and to replace a laptop computer used in training presentations. Funding from non-NSF sources helps with overhead costs but does not provide enough to allow Hilton Pond Center to hire an additional staff person whose principal responsibility would be to implement GLOBE/Operation RubyThroat activities and provide much-needed synergy within the organization.)

Success of Operation RubyThroat through GLOBE is also limited because the hummingbird protocols are considered "optional" and are not part of typical GLOBE training workshops. (The hummingbird protocols are not included in the printed Teacher Guide, but are available on-line through the GLOBE Web site.) Through June 2004, there had been no formal hummingbird protocol training for GLOBE Master Trainers, so ALL training up to that date had been conducted solely by Operation RubyThroat's principal investigator.

To facilitate entry of hummingbird data, an Excel-based bulk reporting Operation RubyThroat spreadsheet was made available in Spring 2004. By using the spreadsheet, participants can avoid having to enter observations one at a time on the GLOBE Web site. It is hoped this will help overcome the on-going difficulty GLOBE has with getting teachers to input data for any given protocol.

SUMMARY

Despite existing impediments to success, it is anticipated that better exposure and increased training in the GLOBE/Operation RubyThroat protocols will result in greater participation by teachers, students, and citizen scientists during 2004-2005. Hilton Pond Center will work diligently with participants in making observations, submitting data, and interpreting results with the ultimate goal of publishing significant new knowledge about relationships between Ruby-throated Hummingbirds and their environment.

KEY PROJECT PERSONNEL

Bill Hilton Jr. serves as executive director of Hilton Pond Center for Piedmont Natural History and as Principal Investigator for Operation RubyThroat. He is responsible for ALL day-to-day activities of the Center and of the GLOBE/Operation RubyThroat initiative. Hilton has nearly 30 years of teaching experience in the public schools and at the college level, and in informal and outdoor education settings. Hilton was twice named South Carolina Science Teacher of the Year and was also the state's Outstanding Biology Teacher. He has a Master of Arts in Teaching Biology and an M.S. in Ecology & Behavioral Biology, providing him with a broad background in pedagogy and natural history. Dr. James C. Shuman is chair of the Education Department of St. Lawrence University in Canton NY, where he has coordinated the teacher education program for the past 12 years. He serves as chairman of the Board of Trustees of Hilton Pond Center and is Co-Principal Investigator for Operation RubyThroat, An educator with 30 years of experience, Dr. Shuman has taught science and mathematics in public schools in Maryland, California, and Vermont and has been a science and education faculty member at colleges and universities in West Virginia, Vermont, California, and New York. Dr. Mark W. Miller is an independent consultant in biostatistics. He coauthored (with Hilton) a paper on survival and population recruitment in Ruby-throated Hummingbirds and is evaluating RTHU data for other papers now under consideration. Dr. Miller worked as Data Manager at Hawk Mountain Sanctuary, analyzing that organization's massive database that includes more that includes 65 years of raptor migration sightings. Drs. Shuman and Miller serve primarily in advisory capacities.

REFERENCES CITED

Austin, D.V. 1975. Bird flowers in the eastern United States. Florida Sci. 38:1-12.

Baltosser, W.H. 1987. Age, species, and sex determination of four North American hummingbirds. N. Am. Bird Bander 12:161-166.

Bent, A.C. 1940. Life Histories of North American Cuckoos, Goatsuckers, Hummingbirds and Their Allies. U.S. Natl. Mus. Bull. 176:332-352.

Conway, A.E. and S.R. Drennan. 1979. Rufous Hummingbirds in eastern North America. Am. Birds 33:130-132.

Hilton Jr., B. 1994. Migration of Ruby-throated Hummingbirds. WildBird 8(5)42-45.

Hilton Jr., B. (2004a). First summer occurrence of an adult male Rufous Hummingbird in South Carolina. Chat. (submitted for possible publication in 2004)

Hilton Jr., B. (2004b). Winter vagrant hummingbird species banded in the Carolinas. Chat. (submitted for possible publication in 2004)

Hilton Jr., B. (2004c). First Carolinas record of Buff-bellied Hummingbird, *Amazilia yucatanensis*. Chat. (submitted for possible publication in 2004)

Hilton Jr., B., and M. W. Miller. (2002). Annual survival and recruitment of Ruby-throated Hummingbirds, controlling for transients. Condor. (submitted for second review and possible publication in 2002)

Johnsgard, P.A. 1997. The Hummingbirds of North America (2nd ed.). Smithsonian Institution Press, Washington DC, USA.

Leberman, R.C. 1972. Identify, sex, and age it. Key to age and sex determination of Ruby-throated Hummingbirds in autumn. Inland Bird-banding News 44:197-202.
Nickell, W.P. 1948. Alternate care of two nests by a Ruby-throated Hummingbird. Wilson Bull. 60:242-243.
Norris, E.A., C.E. Connell, and D.W. Johnston. 1957. Notes on fall plumages, weights and fat condition in the Ruby-throated Hummingbird. Wilson Bull. 69:155-163.
Pyle, P. 1997. Identification Guide to North American Birds (Part I). Slate Creek Press, Bolinas, California, pp. 121-152.
Robinson, T.R., R.R. Sargent, and M.B. Sargent. 1996. Ruby-throated Hummingbird. No. 204 in Poole, A. and F. Gill (eds.). The Birds of North America. Academy of Natural Sciences, Philadelphia, Pennsylvania, and American Ornithogists' Union, Washington, DC.
Welter, W.A. 1935. Nesting habits of Ruby-throated Hummingbird. Auk 52:88-89.