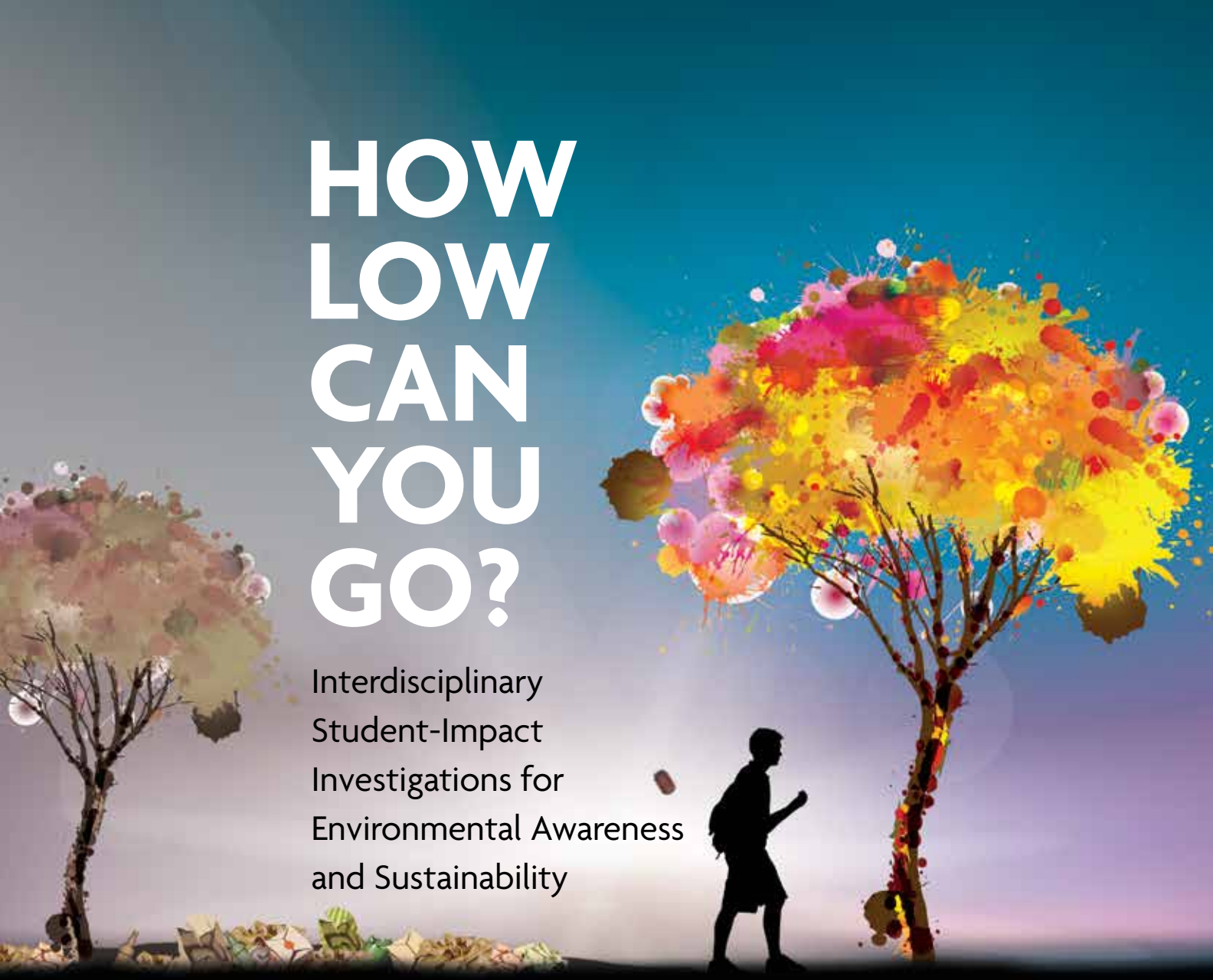

HOW LOW CAN YOU GO?

Interdisciplinary Student-Impact Investigations for Environmental Awareness and Sustainability

by Renee Clary and James Wandersee

Many students have difficulty comprehending the large scale and scope of global sustainability issues, such as the number of years remaining before fossil fuel resources run out or what sea levels are predicted to be in 50 years. However, when classroom investigations focus on individuals and their communities, students are able to more easily understand the variables involved in the issues and how they personally affect, and are affected by, them.

To that end, we have developed hands-on inquiry activities that focus on consumption and waste generation. Through data collection, analysis, and evaluation, students assess their routines and investigate human impact on the planet and its sustainability. Using the most basic definition, *sustainability* refers to the Earth's ability to endure, including maintenance of diverse, healthy biological ecosystems and natural resource extraction practices that won't result in complete depletion. Through these activities, we can educate students not only for science content understanding but also for consumer awareness of sustainability issues.

These activities may be used individually, as part of a larger data-gathering unit, or as timely investigations for Earth Day. We also provide suggestions for extending impact investigations beyond consumption and waste-generation practices.

FIGURE 1 The ecological footprints of countries reveal that the United States and the United Kingdom have the most impact on the planet

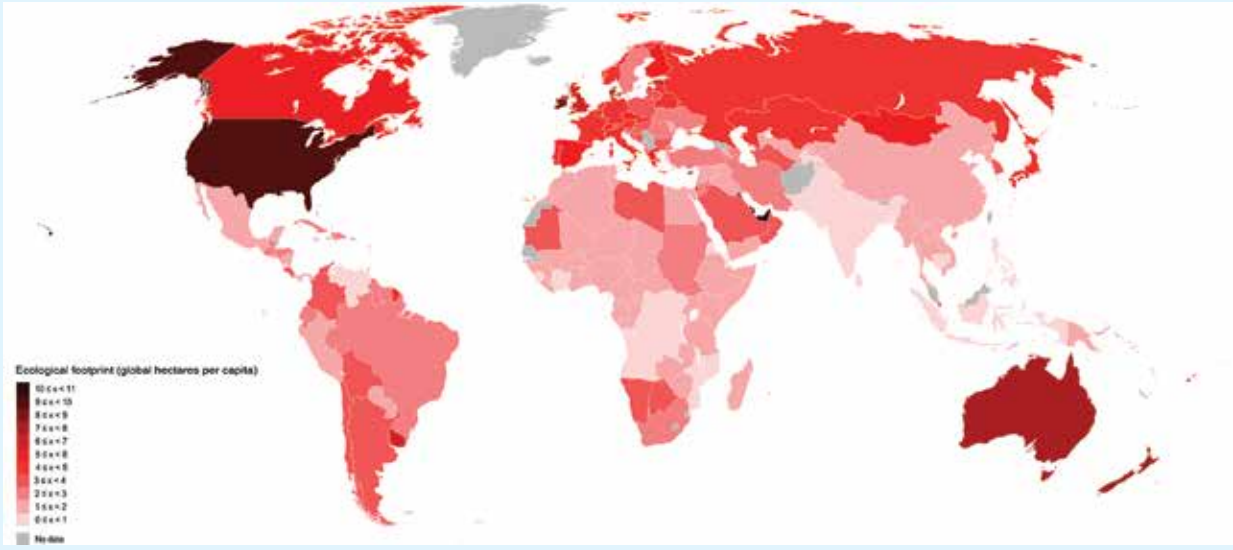

DIAGRAM COURTESY OF JOLLY JANNER

Sustainability and individual effort: Does it matter?

Why should we educate our students to analyze their role in the consumption of Earth's resources? Although our planet is currently home to more than seven billion people, the habits of people living in the United Kingdom and United States lead to more than double (UK) and triple (U.S.) the world's average ecological footprint (Facing the Future 2013) (Figure 1). If all seven billion people consumed like Americans, we would need more than five planets to support the population. Therefore, U.S. and UK students who examine their impact can make changes in their daily habits that will accrue over years and potentially yield great benefits toward sustainability. It's also important to note that a change in just one aspect of a person's life can have ripple effects toward helping our planet. For example, a student who makes a concerted effort to eat unpackaged, locally grown foods reduces waste in the form of packaging materials and reduces the fossil fuels needed for transportation of agricultural products grown elsewhere. Fossil fuels are implicated in human-induced climate change, and packaging materials are long-term waste products in landfills. Whereas the majority of our solid waste materials now consists of plastics, decomposable organic material made up the bulk of our refuse 50 years ago (Sheavly 2010).

Consumption and waste generation go hand in hand, and the amount of waste we generate as individuals can add up quickly. Yet many people who place their trash at curbside on pickup days do not consider where the trash actually ends up. Solid waste landfills receive the items that are thrown away, but their capacity is limited (Figure 2).

FIGURE 2 This modern landfill at Waimanalo Gulch serves as the municipal landfill for Honolulu, Hawaii

PHOTOGRAPH COURTESY OF ERIC CUINTHER

FIGURE 3 A Saturday morning farmers market in New Orleans offers fresh, locally grown produce to the city's residents

PHOTOGRAPH COURTESY OF INFROGMATION

Classroom investigations and consumption analysis

Through the years, we've found that students show more interest in science concepts if those concepts are linked to students' local environment (Clary and Wandersee 2006; Clary, Wandersee, and Sumrall 2013). Therefore, our classroom sustainability investigations provide students with opportunities to gather their own local data and assess the impact of their daily habits, particularly with respect to consumption and waste generation.

Consumption activity

Most students have strong opinions about which foods taste the best and what they prefer to eat. However, most people do not give much thought to the waste items that are generated by their consumption habits. Ask your students to estimate how many food-related waste items—such as packaging materials, aluminum cans, and plastic bottles—they generate in one day. Discuss these predictions, and then ask students to suggest *how* they can verify their estimations. Students, working in groups of three to five, next design a data table that should include the types of foods they consumed, the packaging materials, the ingredients within the food items, and the origin or packaging location for each food. Groups share their data tables with their classmates, and the class can vote on which one to adopt. Alternatively, if all tables are adequate, and have spaces to record all the requested data, each group can use its own organizer. For homework, students should record every item they consume for the next 24 hours, list the ingredients in each item, note where each item was packaged or manufactured, and record the packaging materials that resulted.

When students have completed their tables, ask them to examine the data related to the packaging materials of the foods they recorded, whether a breakfast muffin box, potato chip bag, or Styrofoam cup. Students then quickly tally the number of waste items they generated in one day and compare the actual number

FIGURE 4 **Rubric for persuasive essay assessment**

In addition to addressing the *Next Generations Science Standards* MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations (NGSS Lead States 2013), the persuasive essay also addresses *Common Core State Standards, ELA*, WHST.6-8.1: Write arguments to support claims with clear reasons and relevant evidence, and, if teachers require additional research, WHST.6-8.9: Draw evidence from literary or informational texts to support analysis, reflection, and research (NGAC and CCSSO 2010).

Category	4 Above standards	3 Meets standards	2 Approaches standards	1 Below standards	Score
Focus or thesis statement	The thesis statement identifies the topic and outlines the student's position.	The thesis statement identifies the topic of the essay.	The thesis statement outlines the student's position but does not identify the topic.	The thesis statement does not name the topic nor outline main points.	
Argument: Evidence and examples	All evidence and examples are specific and relevant, and explanations are given that show how each piece of evidence supports the student's argument.	Most evidence and examples are specific and relevant, and explanations are given that show how each piece of evidence supports the student's argument.	At least one piece of evidence or an example is relevant and has an explanation that shows how that piece of evidence supports the student's argument.	Evidence and examples are not relevant and/or not explained.	
Research: Support for position	The essay includes 3 or more pieces of textual evidence (facts, statistics, examples, real-life experiences) that support the position. The writer anticipates the reader's concerns.	The essay includes 3 or more pieces of evidence (facts, statistics, examples, real-life experiences) that support the position statement.	The essay includes 2 pieces of evidence (facts, statistics, examples, real-life experiences) that support the position statement.	The essay includes 1 or fewer pieces of evidence (facts, statistics, examples, real-life experiences).	
Accuracy	All supportive data and statistics are reported accurately and cited.	Almost all supportive data and statistics are reported accurately and cited.	Most supportive data and statistics are reported accurately, but few are cited.	Most supportive data and statistics are reported inaccurately.	
Sentence structure	All sentences are well constructed with varied structure. Spelling and grammar are exemplary.	Most sentences are well constructed, with only 1–2 spelling or grammar errors.	Most sentences are well constructed, with 3–4 spelling or grammar errors.	Most sentences are not well constructed, and there are multiple spelling or grammar errors.	
Sources	All sources used for quotes, data, and statistics are credible and cited correctly.	All sources used for quotes, data, and statistics are credible, and most are cited correctly.	Most sources used for quotes, data, and statistics are credible and cited correctly.	Many sources are suspect (not credible) and/or are not cited correctly.	

with their first prediction. Discuss how the initial predictions varied from the actual numbers and the variations among students within the class.

Next students investigate the ingredients in the foods they consumed and where the final products and the ingredients originated. Students may be surprised to learn that many of the processed and packaged foods they eat include a lot of corn products. Ask students to return to the ingredient list for their food items and circle corn, high fructose corn syrup (or HFCS, also called *isoglucose*), starch (modified or unmodified), lecithin, monoglycerides, diglycerides, caramel color, citric acid, fructose, glucose, maltodextrin, ascorbic acid, dextrose, lactic acid, lysine, maltose, monosodium glutamate (MSG), and xanthan gum—all of which originate from corn (Sherman 2013). This reliance on corn promotes monoculture and lack of biodiversity within agriculture (Clary and Wandersee 2013).

Next ask students to investigate the paths that their favorite foods followed by returning to their foods' source locations on their data tables. If the location is local, it may be possible to investigate the sources of select ingredients (e.g., where the potatoes in potato chips come from). Once the sources are determined, students use mapping software (such as the free Mapquest or Google Maps websites) to determine the *minimum* number of miles the food traveled from the manufacturer to their mouths. A simple investigation would involve the number of miles from the place of packaging to the local store. (Teachers have an option to add a level of complexity to this investigation by asking students to determine whether distribution centers are used and to consider these in mileage investigations.) When Smith and MacKinnon (2007) tried to eat foods within a 100-mile radius of their home, they learned that the *average* distance that foods travel in North America is 1,500 miles.

In a class discussion, ask students to identify the possible benefits of locally grown foods. For example, students may mention that the foods are fresh (and do not need preservatives), and transportation costs are less. As a final assignment, students return to their completed tables and identify at least three foods that can be substituted with locally grown and locally made foods (Figure 3). If local, fresh food is too expensive to be considered a feasible alternative for some families, students should try to identify local brands of processed foods that can reduce impact through minimizing transportation.

Each student writes a final report that summarizes (1) the amount of waste items generated by each student in one day; (2) the minimum number of miles food items traveled; (3) three food items from the data table that could be purchased or made locally (with recipes included for home-prepared items); and (4) the number of miles saved in a day, then extrapolated to a month and a year, if the student made a concerted effort to replace those three food items. Projects can be assessed through a teacher-designed rubric, based on the components required of students.

These activities may be extended into informal environments by arranging a field trip to a local farm or food packaging facility. If class trips are problematic, ask a local farmer to visit the classroom and explain his or her community connections. When students investigate the sources and ingredients of their food, and find local alternatives, they focus on how interconnected agriculture, economics, and ecology are (Clary and Wandersee 2010).

Waste activity: Generation and landfills

Resources such as the No Impact Project are available to illustrate and document how individuals can reduce waste and make a difference. In 2006, a family in Manhattan embarked on a one-year journey to live in the city with as little impact as possible. Colin Beavan, along with his wife, Michelle Conlin, and their two-year-old daughter, Isabella, disconnected their electricity, used the stairs to access their ninth-floor apartment, purchased fresh food items, and generated very little waste. They assembled their own cleaning products and hygiene items and even discontinued the use of toilet paper. Their yearlong journey was documented in the movie *No Impact Man*, which is available for free viewing online (see Resources; teachers should preview the movie before watching it with students, as some language and content are inappropriate for the middle school setting). The No Impact Project website (see Resources) has free lesson plans available for the middle school classroom.

One of our favorite vignettes of the film shows Colin Beavan holding up the family's wastebasket, which contains only a few items from the *entire week*. Beavan stated that the average American family generates 1,600 pounds of trash per year (Gabbert and Schein 2010). Ask students if they predict this claim is valid and have them compare their own habits and extrapolate for one year.

For the waste-generation investigation, give individual students an empty bag, preferably a paper one that is decomposable or a plastic one that can be recycled. Tell students to write their name on their bag and place in it any waste items they generate for the next 24 hours. There are some rules, however: (1) No food or biological waste is allowed, and (2) all waste

FIGURE 5 Items students made from used plastic bottles (top), bottle caps (middle), and telephone books (bottom)

ALL PHOTOGRAPHS COURTESY OF EARTHSCHOLARS RESEARCH GROUP

containers must be rinsed. In class, combine students' bags (without emptying them) in a large trash bag (or bags, depending on the amount of waste and number of students), and weigh the bag with a spring-loaded scale. Record this number on the board. Have students calculate the average weight of trash generated per student. Next extrapolate family waste per day by using the 2010 U.S. Census average U.S. family size of 3.14, and then extrapolate the waste generated by a family in one year. How does the class number compare with the 1,600 pounds per year noted in the video? (If it is not feasible to have all students collect waste, classroom representatives can be elected to collect waste items.)

Return bags to students and have them investigate whether any items in their bags could have been recycled. If so, remove the recyclable material and reweigh the accumulated class waste. (Safety note: Dispose of all waste materials properly in the school recycling bins or school Dumpster, wear gloves and goggles, and wash hands after handling trash or recycling.)

Challenge the class to minimize waste generation by becoming aware of unnecessary packaging materials, buying fresh foods more often, and reusing grocery bags at local stores. At the end of the unit (or the year), repeat the waste experiment and determine whether students (or the class representatives) made any changes in the amount of waste they generated.

Students summarize their waste habits—before and after the experiment—and argue for waste reduction in a persuasive essay that details human impact on our planet. By using their own evidence in the essay, students address *Common Core State Standards, ELA*, WHST.6-8.1: Write arguments to support claims with clear reasons and relevant evidence (NGAC and CCSSO 2010). Teachers can also require that students find additional text resources to support their analysis (WHST.6-8.9). The persuasive essay also directly addresses *Next Generation Science Standards* performance expectation MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations (NGSS Lead States 2013). A rubric is provided for assessing the project in Figure 4.

We have also challenged students to design alternative uses for items that typically end up in landfills (e.g., plastic bottles, bottle caps, telephone books). (Not all of these items are recyclable; bottle caps are not recycled along with plastic bottles since the plastic hardness differs, and bottle caps are the most littered item behind cigarette butts.) Students designed and attempted to "market" alternative products that could be made from these items (Figure 5).

You could also show your students a CBS *60 Min-*

FIGURE 6 Students are asked to identify daily habits that can be restructured to conserve fossil fuel resources and promote sustainable lifestyles, including drying clothes naturally on a line

PHOTOGRAPH COURTESY OF MICHAEL GÄBLER

utes video that features an unusual example of reusing waste items: A landfill in Paraguay supplies the materials for musical instruments for a student "orchestra." The video (see Resources) offers a powerful reminder that much of our discarded refuse in landfills can be reused and has value to others. Teachers can also connect this video, and the concepts of refuse, landfills, and environmental justice, with the *National Curriculum Standards for Social Studies* (NCSS 2010). Ask students where landfills exist in their community and state and what happens to discarded electronic items, such as computers and large television sets. Once students locate landfills within their community and state, they can determine whether any correlation exists between areas of high poverty and landfill sites (see Mapping Poverty in America in Resources). The research and student investigations can extend into production, distribution, and consumption (National Curriculum Standards for Social Studies theme 7); science, technology, and society (theme 8); and global connections (theme 9) (NCSS 2010).

Extension activities: Consumer habits

Although we focused on consumption and waste generation, teachers can extend critical examination of planet resources to transportation (renewable energy, fossil fuels) and students' lifestyle choices (laundry, air conditioning). For example, students can log the total number of miles/kilometers they travel each day walking or cycling or by car, bus, or subway. How does the distance they travel that depends on nonrenewable resources compare with the distance they travel sustainably, such as travel by foot or bicycle? Using public transportation, such as the bus or subway system, is a much more sustainable option than travel by personal automobile. Students can also journal their daily habits and propose ways in which they can cut fossil fuel consumption. Some examples may include lowering the thermostat in winter (or raising it in summer) or using clotheslines instead of gas- or electric-powered dryers (Figure 6). Students can also calculate their carbon footprints at online websites and identify where changes can be implemented (see Resources).

Can we make an impact?

What is the value in introducing critical analysis of and reflection on students' daily habits and lifestyles within

the science classroom? Foremost, students enjoy directly participating in data collection, and inclusion of their own consumption habits makes the projects relevant to their own lives. The activities also illustrate how students can break down the sustainability issue into smaller components that are easier to understand, especially since the component measured here is their own environmental impact and subsequent efforts to reduce it. Although the investigations center on smaller parts of the big issues within sustainability, these activities underscore how small changes can yield larger impacts when considered as a composite classroom effort, or when extrapolated over time. Similar classroom activities have demonstrated that small decisions can reduce students' carbon footprints (Heddings and Frazier 2009). Other case studies have illustrated that "ecotipping points" exist that can restore the environment and move a population toward sustainability (Marten and Matthews 2009).

Interdisciplinary in scope, the consumption and waste-generation activities can be implemented within various science content units. The investigations address *Next Generation Science Standards* disciplinary core ideas in life science (MS-LS2C: Ecosystems Dynamics, Functioning, and Resilience) and Earth and space science (MS-ESS3C: Human Impacts on Earth Systems) (NGSS Lead States 2013).

By relating the large sustainability issues to our students' lives, we promote an awareness of individual impact on larger issues. Does promotion of environmental awareness result in accrued changes in students' behaviors? Perhaps our classroom activities affect our students' reflections on their sustainable and nonsustainable practices, and eventually result in positive measures toward their reduced impact on our planet. ■

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Resources

Mapping poverty in America—*www.nytimes.com/newsgraphics/2014/01/05/poverty-map/?nl=todaysheadlines&emc=edit_th_20140106*

No Impact Man—www.filmsforaction.org/watch/no_impact_man

No Impact Project (click "For Educators")—*http://noimpactproject.org*

Paraguayan Youth Orchestra: Land philharmonic (*60 Minutes* segment)—*www.youtube.com/watch?v=WJ19EQbqCEk*

What's my footprint? (free carbon footprint calculator)—*www.nature.org/greenliving/carboncalculator*

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