A UMD UNDERGRADUATE RESEARCH JOURNAL

Scientific Terrapin

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Engineers Without Borders Reflects on Burkina-Faso Project

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SCIENTIFIC TERRAPIN

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MISSION STATEMENT

The University of Maryland, College Park has long been established as a top national research university. It is consistently named as one of the top fifty research universities and one of the top twenty-five public research universities in the nation. The university garnered $471 million dollars in research money in 2011, funding faculty and graduate investigation of our world from the myriad perspectives of scientists, sociologists, businesspeople, historians, and artists.

However, for the University to fully reach its potential as a top research institution, we believe that undergraduate students should play a more central role in the discussion, exchange, and visibility of research on campus. Currently many undergraduate students complete Honors Theses, Gemstone Theses and conduct research in labs on campus. Before now, though, there have been few outlets for students to share their work with the rest of the community and engage in the academic discussion and debate across specialties that sharing of research confers. It is this very "culture of research" that we wish to promote. Scientific Terrapin salutes student researchers for their initiative, their dedication, and their pursuit of knowledge and, thus, will fill this void by offering an outlet for student researchers to publish their work across all disciplines, including:

• The Life Sciences - biology, chemistry, biochemistry, and ecology
• The Applied Sciences - engineering, mathematics, computer science, physics, and geology
• The Social Sciences - economics, government and politics, psychology, business, and sociology

Scientific Terrapin provides a stepping stone for scientists across disciplines at the beginning of their research careers. We seek to provide undergraduate researchers a forum to present their work and receive peer and faculty review, as well as readership and recognition. We seek to connect student researchers with one another, so they might form intellectual partnerships and friendships, and so will sponsor workshops and presentations to not only encourage interdisciplinary discussion and debate, but to share research opportunities and practical advice for advancement in their fields. We herald the work of promising young minds and extraordinary mentors, allowing the community to learn about exciting research produced at the University of Maryland. And last, we hope to inspire students as they enter the university or continue with their education, to take the next step and join their fellow classmates in contributing to this culture of research and to claim their integral role in the vibrant and dynamic research at the University of Maryland.

CALL FOR SUBMISSIONS

We are now accepting submissions on a rolling basis. Manuscripts are reviewed as they received, and finalized articles are printed in the upcoming or following edition of the journal depending on when they have prepared. We encourage you to submit your work with a faculty mentor on campus, your findings from an internship, or an abridged Honors thesis or Gemstone paper in a scientific research article. The journal is accepting articles in the fields of life sciences, physical sciences, social sciences, and applied sciences. Submission details and guidelines can be found at our website, scientificterrapin.umd.edu.

Scientific Terrapin models our review process after professional research journals. It is designed in a manner to provide authors rigorous and valuable criticism to help them learn about the scientific writing process and to improve the quality of their analysis. Upon submission of a manuscript, a qualified student editorial staff conducts an initial peer review. Components such as quality of analysis, scope of work, and quality of writing are evaluated. The manuscript is then return to the author with a request for revisions. Revised manuscripts are ten shared with the University of Maryland faculty members in the field of the work in review. Faculty members evaluate the quality of the work and its contribution to the field. The recommendations of the faculty members deem whether the work is published. Any required revisions are returned to the author make changes. A final version of the manuscript is then prepared to publish in the journal.

ACKNOWLEDGEMENTS

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Staying safe on campus

M-Urgency app adds live video to 911 calls

By: Nicholas Hung

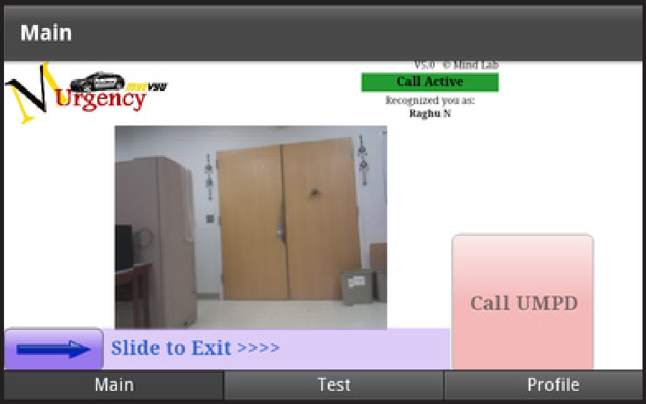
As you're walking around campus at a reasonably late time, you notice a fire blazing away inside a building. Unfortunately, most people are asleep and there aren't any emergency telephones nearby. However, you happen to have an Android phone and downloaded the M-Urgency application. Never fear, for M-Urgency is here!

Developed by Computer Science Professor Ashok Agrawala and his group, the M-Urgency application, which was first released for free download on January 25, 2012, provides a new level of safety and ingenuity for the University of Maryland community.

"For the last many years, my focus has been to come up with the ways in which technology can be used for improving the quality of life on campus," Agrawala said. "M-Urgency is an effort in that kind of direction."

M-Urgency is an application for cell phones which, in an emergency that typically requires a 911 call, can connect the caller to a police dispatcher, not just through audio but through real-time video via the caller's phone as well. The police will be able to see what is occurring at the caller's location and know the caller's number and exact location, which will appear on a map on the police dispatcher's computer screen. As a result, emergencies can be more effectively handled than a traditional 911 call.

M-Urgency was conceived by Agrawala and his group after they examined the amount of crime on campus and students' perception of their safety on campus. Because of this project, one student's Ph.D. has been completed and three more are expected to be completed as well. M-Urgency is the first phone application of its kind that has the potential to increase safety to such a high degree. "We are implementing all the cutting state-of-the-art status [technology]… and inventing new techniques, new ways [to develop applications]," he said.



A simple user interface allows users to give emergency dispatchers a first-person perspective. Image courtesy of MIND Lab.

The conception of M-Urgency has also spawned the creation of other useful applications. One example involves the police escort service, in which the user can contact the police for monitoring through real-time video via phone. The caller's location is continuously tracked and, if anything suspicious is detected, the police can easily dispatch officers to intervene. Another application will reveal important details of buildings on campus, such as the presence of hazardous materials, layout and occupancy, so that the emergency scene can be taken care of appropriately.

There are more improvements to the M-Urgency application yet to come. The next version is planned to include the ability of the police dispatcher receiving the call to see where police near the caller are, assign them to the caller's location and transmit the real-time information from the caller to the nearby police. An iPhone version is expected to be released sometime in the near future.

"This [application] serves as a major detriment," Agrawala added. "If a criminal know[s] that any student could be carrying this device...they'll think twice before coming to the campus."

Positively Buoyant Research

Kate McBryan and the Space Systems Laboratory

By: Abby Ahlert

You don't have to be an astronaut to get a taste of outer space exploration. In fact, if you're looking to design, build and test spacecraft, look no further than the Space Systems Laboratory (SSL) on the University of Maryland's College Park campus. Graduate and undergraduate students in this lab use robotics and aeronautics to develop new satellites using world-renowned facilities.

Kate McBryan is a graduate student at the SSL and is working on a project called the Dynamic Manipulator Flight Experience (DYMAFLEX). McBryan and the other members of her team are in the process of designing, constructing and testing a satellite that will compete with ten other schools in the University Nanosatellite Program. Once it is completed, their work will be judged and the winner of the competition will have their satellite launched into space for free thanks to funding by the American Institute of Aeronautics and Astronautics and the United States Air Force.

The satellite will be used as a test subject to study the effects of a large, fast-moving robotic arm on the satellite's movement. "Our plan is to send this up, fly it, move the arm around and see how the spacecraft base is going to move," McBryan said. If perfected, the arm would be used to repair other satellites in space. Most robotic-arm-to-satellite-body ratios are on the order of 1:100, but DYMAFLEX will have a ratio of about 1:5. According to McBryan, the arm will also move at up to ten times the speed of average robotic arms. Both variables are expected to produce non-linear movements of the satellite body.

With two years to complete the project, McBryan and the team are now in the machining phase of the satellite development. The SSL is committed to conducting as much work in-house as possible, so that most parts will be built in the lab, and any others will be

Above is the Neutral Buoyancy Research Facility, where researchers at the Space Systems Laboratory test satellite missions. Robotic satellites are lowered by a crane into the tank, which is almost three stories deep. Researchers then have the opportunity to scuba dive with their projects as they are being tested.

The Neutral Buoyancy Research Facility

Though DYMAFLEX is one of many robotics constructions taking place at the SSL, it will not be tested in the on-campus Neutral Buoyancy Research Facility (NBRF). The NBRF is a 50-foot wide, 25-foot deep tank that holds almost 367,000 gallons of water. It is one of only two such tanks in the U.S., and is the only one located on a college campus. The tank was finished in 1992 and has been used to simulate the effects of weightlessness in space. Underwater versions of spacecraft, robots, and spacesuits are constructed such that the buoyancy that pulls them towards the surface is equal to the gravity that pulls them towards the bottom of the pool, thus the net force on the hardware is zero.

Other methods of mimicking zero gravity include NASA's "Vomit Comet": the KC-135. On this plane, researchers experience intervals of significantly less gravity, but these time frames are mere seconds long. "With each parabola [of flight] you get eight to twenty seconds of zero g_0, and it's not always zero g_0," McBryan says. To test full missions, researchers need much more time, and this can be achieved in a tank. "One of the benefits of being able to test robots in neutral buoyancy is that you can do really long tests. You can simulate a mission from beginning to end," she said.

In order to make mission testing a realistic possibility, the large spacecraft are lowered into the tank via crane. Then, immediately after the submersion, members of the SSL don scuba equipment to dive with their machines. The NBRF faculty keeps the tank temperature around 85 degrees Fahrenheit to ensure the warmth and comfort of the divers, since missions can last up to eight hours. "Water will suck away your body heat four times fast than air...even at 90 degrees, I've been shivering at the end," she said.

While underwater, the divers are responsible for monitoring the joints of the spacecraft, and though it may seem that air bubbles coming out of the joints would be bad, it's actually a good sign. Students at the NBRF know that air coming out means water isn't getting in. Satellites do not need to be airtight when traveling in space, but it is an absolute necessity when testing in water. In fact, that's one of the reasons that DYMAFLEX won't be in the NBRF. The shell of the spacecraft will have an isogrid structure, which will make it lighter, but definitely not watertight.

sent to aerospace machinists due to lab machine size constraints.

After the satellite is fully constructed, it will be tested for durability and control. One trial is on an air-bearing table, which, like an air hockey table, is a nearly frictionless surface. "It's kind of like being weightless but on a flat surface," she explained. McBryan will then review the effects of the robotic arm movement on the satellite body motion in this two-dimensional study. Her team will also place the subject in the SSL's thermal chamber, where it will experience extreme temperatures for up to a few months to test the satellite's endurance in harsh, space-like conditions.

The DYMAFLEX team is made up of both graduate and undergraduate students, all with aerospace engineering interests. McBryan sees the benefits of having undergraduates in the lab, and has her own method of identifying good workers. She gives prospective undergrads a tour of the SSL, and tells them to email her about coming back. "Eighty percent of them won't come back," she said. "If they come back, we say, 'Great, join a project!'"

McBryan mentioned that the lab even prefers freshman and sophomores, so they can be trained appropriately and their skills utilized. "Once an undergrad proves themselves, we basically treat them like graduate students," she explains. "Enthusiasm is the only requirement for undergrads."

Building a difference

Engineering Without Borders in Burkina Faso

By: Emily Jones

What would you do if you couldn't simply turn on the faucet for a clear disease-free glass of water? While most Terrapins were relaxing in a post-finals slump this January, a team of six engineering students, a professional engineer and a faculty mentor from the University of Maryland's Engineers Without Borders (EWB) chapter traveled halfway around the world to Burkina Faso to help a village that faces that problem.

Burkina Faso is one of the poorest countries on Earth, with most of the population living in small, rural villages and surviving mainly on subsistence agriculture. Ailments such as malnutrition, malaria, dysentery, and respiratory infections are all too common; as a result, many people rely heavily on local medical centers, which do not have access to the national electrical grid and depend on villagers to carry water from nearby wells.

In the small town of Dissin in the southwest of the country lives the family of Thierry Some, an alumnus from the A. James Clark School of Engineering, who proposed that EWB help the village in 2007. Since then, EWB has provided lighting for schools and health centers and constructed automated water pumps in Dissin. This year, for their fifth project, they sought to help the Done health clinic, which serves a community of 8,000 residents without electricity or running water. The clinic's water supply was limited to a shallow water well, which had high fecal coliform levels, and a deep water well 300 meters away, according to team member sophomore electrical engineering major George Kinchen. EWB's goal was to provide a sustainable solution to the clinic's water and energy needs by building a solar-powered water pump and filtration system. The group, led by senior chemical engineering major Matt Conway, spent two years designing the system. The project was broken down into electrical, pumps and piping, tanks, and sanitation subsystems. Their aim was to minimize the number of com-

Photo Gallery

Despite the lack of local infrastructure, EWB sourced their materials in-country rather than importing supplies from foreign nations. This supports the local economy and ensures that broken parts can be easily replaced by the community. Still, some supplies were difficult to obtain and had to be purchased from the capital city.

> “ EWB’s goal was to provide a sustainable solution... by building a solar-powered water pump and filter. ”

ponents in each subsystem to simplify use and maintenance.

Once in Dissin, the team worked with local experts – two local electricians, a plumber, a hardware store owner, the nuns and priests of a Catholic parish that housed them and the three nurses that staff the health center – to install the health center’s water filtration system. The final system consists of two pumps that transport water from the clinic’s well through a slow-sand filter to a distribution tank on the roof of the clinic. The pumps are powered by batteries charged by solar panels, which also provide power for lighting at night. During construction, they focused on ensuring system longevity by training the community members to maintain the machinery and by purchasing their materials from a local hardware store so that broken parts could easily be fixed or replaced.

The team faced several unexpected challenges unique to working abroad. “Supplies you could easily find at your local hardware store here could take days to obtain there,” Kinchen said. Near the end of the project, “We had the wonderful experience of wiring everything together, flicking the switch, and the pump definitively not roaring to life,” Conway said. The team eventually identified the DC to AC inverters as the source of the problem, and ordered three models of new inverters, which had to be bussed in from the capital. Luckily, the team had contingency time that allowed them to complete the project before departing despite these setbacks.

From this project, they made invaluable partners in construction who can help on later projects. They learned that they should seek local expertise earlier, as their PVC welding had to be patched multiple times by the local plumber since the team did not know that Burkina Faso glue was much more potent than pipe glue in the US. They also learned to have flexible schedules, as “it’s not necessarily having everything step-by-step; it’s having a plan to base off when you get there,” said Kinchen. In later years, EWB plans to return to Dissin to examine and repair old projects. There is still much left to accomplish in Burkina Faso, but for a clinic in the small town of Dissin, babies can be delivered at night under lamplight, and doctors performing surgery can wash their hands with clean running water.

The team worked with community members, training them on use and maintenance of the pump and filtration system as they built it so that local experts could repair the system if it were to break. In the process, they learned about the country’s culture. Above, the team enjoys a dish native to Ethiopia consisting of several wats (stews) served on an injera (flatbread).

Planning the Perfect Exposition

Maryland Day presents a mix of old and new

By: Warren Zhang

For the past fourteen years, the last Saturday in April has meant one thing for the normally drowsy University of Maryland campus – Maryland Day, a campus-wide festival showing off the various programs, majors and people at the University of Maryland.

According to Gene Ferrick, director of the College of Computer, Math and Natural Sciences, Maryland Day started out as an extension of the long running Agriculture Day. Part of this year's theme, Ferrick noted, revolves around this year being the 150th anniversary of the Morrill Act, which established land grant universities like the University of Maryland.

The theme, however, is tricky to integrate into science and technology exhibitions. Instead, Maryland Day's scientific events will proceed as usual, despite the Science & Engineering Festival planned for the same day on the National Mall in Washington, D.C. "We looked at it and said, 'Well, what are we going to do? Are we going to send people down there?'" Ferrick said. "And the administration said, 'No. we're doing Maryland Day.'"

The events slated for the day include a mix of new and old displays. Ferrick said that the events repeated from year to year are the most popular events. "Like the insect petting zoo or the Physics is Phun crowd, where they make ice cream using liquid nitrogen," he said. "They're just things that draw families."

However, Ferrick doesn't feel the need to repeat every popular Maryland Day event. "We have enough events that I don't need to push anyone," he said. Conversely, less popular Maryland Day activities are usually not repeated. "One of our faculty members back in the early days of Maryland Days was giving a talk about the science behind X-Files," he said. "It was a great talk but not a lot of people showed up."

One of the secrets to success for Maryland Day, as noted by Ferrick, is to have the

Photo Gallery

The various departments of CMNS set up hands-on stations on the mall and outside academic buildings that teach advanced science topics in a simple, kid-friendly manner. This year, Joelle Presson will be running an evolution exhibit with hominid skull models and a DNA bracelet craft for the Biology Department. Above, volunteers explain aphasia, or loss of language ability, and centripetal force.

event take place outside. "People like being outside unless there's a really big draw inside," he said. "So if you're going to have an intellectual seminar type talk, it may not draw people."

Ideas for new events, according to Ferrick, often come from within departments. "Some departments like to look at what they're doing and say, 'Well let's do something different,'" Ferrick said. "With the insect petting zoo, that's pretty much the same every year. They bring out the bugs and many of the faculty from that department show up, because they just love the kids."

One of the more recent additions is a series of biology-related events organized by the Biological Sciences Undergraduate Program, according to Associate Dean Joelle Presson. "So, the way we did it, in biology, was we got a lot of the faculty who teach lower level biology together," she said. "Everybody kind of offered their interesting ideas. I took those ideas and distilled them and chose the ones I thought would be most effective."

Since creating these events three years ago, Presson said that these activities have not significantly changed. "Once we got it running, I just implement what we've been doing," she said. The challenge, then, is to find volunteers to manage these activities on Maryland Day. Fortunately, Presson has not had problems finding suitable undergraduate volunteers. "The really interesting thing is how readily and easily the undergraduates just go with it," she said. "They immediately get what the point is, they come on the day and they take care of it."

Students are also given the opportunity to create and run Maryland Day events, according to Ferrick. Indeed, groups such as Alpha Chi Sigma and the American Chemical Society have organized activities in the past. "I read them the riot act because there are little children around and they like to blow things up, but they do it on their own," Ferrick said.

These children and their families are, according to Ferrick, the target audience for Maryland Day. "I'd say most of this is geared to get families to come here," he said. "That doesn't mean we're excluding students on campus, because a lot of this stuff can be flat out fun."

There are a few students every year who miss out entirely. "Sometimes students actually don't go to Maryland Day," he said. "It's hard to miss, considering what's going on, but sometimes they don't roam around, which I think is sad."

Other departments also host exhibits, including a performance on the lawn outside the Clarice Smith Performing Arts Center, lower left, and a basketball meet-and-greet with the team and coaches, below with President Loh.

A New Algorithm for the Cake-Cutting Problem of Unequal Shares for Rational Ratios: The Divisor Reduction Method

Edward Carney

Abstract

The cake-cutting problem is a long-researched question of resource allocation. The problem asks the following: How can a group of players fairly divide a continuous resource (the cake) in an efficient manner if each player has a personal valuation of portions of the resource? The definitions of "fair" and "efficient" can easily complicate the problem. A concept of fairness must be defined at a given problem's outset. Efficiency often refers to using the least amount of divisions (cuts of the cake) possible while still maintaining fairness. The sub-problem of unequal shares asks how the participants can best divide the cake unequally, according to some predetermined ratio. In the case that this ratio is rational, the accepted method for division by unequal shares is the Cut Near-Halves algorithm [1]. Number theory is applied to this problem in a new way, with the express purpose of besting the efficiency of the Cut-Near Halves algorithm. The result is a novel method for division that is both more efficient and optimal more often than Cut Near-Halves. The new algorithm is described and its effectiveness is empirically analyzed.

I. Introduction

Since the problem was first posed in the 1940's, the literature on cake-cutting has grown significantly. Books detailing algorithms for cake-cutting include Brams and Taylor [2] and Roberston and Webb [1], and more recent publications include Barnabel and Brams [3] and Brams, Jones, and Klamler [4]. Robertson and Webb describe several methods for division by unequal shares, and demonstrate that for rational ratios, the Cut-Near Halves algorithm is the best of those presented [1]. They conclude their discussion of unequal shares by suggesting that a better algorithm than Cut Near-Halves may exist, and provide one example for which an alternate sequence of cuts proves more efficient [1]. The goal of this paper is to explicitly define such an algorithm; this has not been done yet in the literature. The rest of this paper is organized as follows: The necessary assumptions are stated in Section II, and since it is a prerequisite for the new algorithm, Cut Near-Halves is described in Section III. In Section IV an algorithm designed explicitly to beat Cut Near-Halves is explored, and an empirical analysis of this new algorithm is presented in Section V. The paper concludes in Section VI.

II. Problem Statement & Assumptions

Consider the case where two players, Alice and Bob, are tasked with splitting the cake in accordance with a given ratio of integers, a:b, such that Alice receives a/(a+b) of the cake, and Bob receives b/(a+b) of the cake. (Henceforth, all variables will refer to integers, unless otherwise noted). Perhaps a judge has ruled that Alice and Bob are to receive these portions of a prize, or that Alice and Bob are inheriting these portions of some property, or some similar circumstance. To use an example, the required split may be 9:4, meaning that Alice is to receive 9/13 of the cake, and Bob 4/13. It is assumed that each person views the cake differently, so that a piece that Alice views as x/(a+b) of the cake is not necessarily worth the same amount to Bob, and vice versa (for $0 < x < (a+b)$). In the previous example, some portion of the cake that Alice values at 7/13 may only be worth 3/13 to Bob, etc. It is assumed that any player may cut off any portion of any piece of the cake, as they see it. From the example, Alice may be asked to cut a portion of 1/7 off of a piece which she values at 7/13; this portion would then be worth 1/13 of the original cake to Alice. It is also assumed that no individual has any knowledge of any other individual's valuation of the cake. Lastly, and for simplicity, take $a > b$, or that Alice is to receive a greater portion than Bob.

III. The Cut Near-Halves Algorithm

A. Description and an Example

Cut-Near Halves (henceforth referred to as CNH) is a simple procedure wherein the cake is repeatedly cut in (approximately) half until its entirety has been divvied out. The player who is owed the lesser portion of the cake cuts the cake into two "near-halves," and the player who is owed the greater portion takes the piece which is acceptable. The term near-half is used because the problem is dealing only with integers, and therefore a portion representing an odd integer value of the cake is cut into two near-halves, or as close to halves as integrally possible. For example, if the split ratio is 9:4 (implicitly meaning 9/13: 4/13, and so the denominator is often omitted), the near-halves would be 7 and 6 (as in 7/13 and 6/13). After the chooser selects a near-half, the process is repeated on the remaining portion until either both players have their required portions, or the required split is 1:1. In the latter case, the players perform the Divide-and-Choose algorithm, meaning one player cuts the cake in half, and the other player selects which half they prefer [2]. The required ratio should always be written in lowest terms (cutting 9:3 is the same as cutting 3:1). The algorithm is easily modeled by a cut-tree diagram, wherein each node is labeled with the remaining portions of the cake owed to both players, and each branch represents one cut of the cake. Each branch therefore represents a subtraction of (near) half of the ratio sum from the total of the player who is owed more cake. Two branches emerging from the same point indicate that the player had a choice of two near-half valued pieces, allowing for more than one possible sequence of cuts. The worst-case scenario number of cuts is represented by the longest path through the tree. The following cut-tree diagram illustrates every possible sequence of cuts for two players carrying out CNH for the ratio of 9:4:

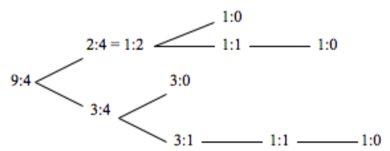


Figure 1: Cut-Tree Diagram demonstrating the Cut Near-Halves algorithm for a 9:4 ratio. Alice is to receive 9/13 of the cake, and Bob 4/13. Bob first cuts the cake into two pieces, worth 7/13 and 6/13. (We omit the denominators for simplicity.) Alice chooses one of these, and so she requires either 2/13 or 3/13 more, depending on her choice. This process continues until one of the players has received their due portion, at which point the other player takes the remaining cake.

B. Remarks

The figure shows that for a split ratio of 9:4, CNH may take up to 4 cuts. Moreover, it can be shown that the number of cuts necessary for a division of a:b approaches ceiling(log2(a+b)) [5]. This is because the cake is being cut approximately in half at each step. Indeed, less cuts than ceiling(log2(a+b)) will often suffice, however, if interested in the worst case scenario for which ceiling(log2(a+b)) cuts is a good working estimate. It is noted that the mechanism behind the success of CNH as opposed to other methods: when the cutter proposes two (near-) halves to the chooser, the chooser is guaranteed to agree that one of them is worth at least (near-) half of the cake, thereby reducing the subsequent ratio sum by (nearly) a factor of 2. Suppose the cutter offers portions other than halves to the chooser as is the case when dividing by Ramsey Partitions [1]. Then if the chooser disagrees with the larger portion and instead selects the smaller portion, the subsequent ratio sum has not been reduced by a factor of 2. CNH seems to reduce the resultant ratio sum by the greatest amount, independent of the chooser's selection. The only way to improve upon the algorithm would be to somehow guarantee that after each cut; the resultant ratio sum reduces by greater than a factor of 2.

IV. A New Algorithm

A. Initial Strategy and an Example

It has been recognized that in order to improve upon CNH, some factorization of resultant ratio sums must be achieved. An additional fact will accompany this idea. If the player who is owed less of the cake cuts a certain portion which is less than the amount the player is owed, then either player may take that portion and the integrity of the problem is still upheld. To demonstrate this through an example, consider again the ratio of 9:4. Suppose Bob cuts 1/13 and proposes that Alice take it. Whether or not Alice takes it, Bob believes the rest of the cake to be worth 12/13, so he is satisfied. Perhaps Alice disagrees, and Bob takes the 1/13. By virtue of rejecting the 1/13, Alice believes the remaining cake is at least 12/13. Since Bob cut the 1/13, he believes the rest is exactly 12/13. Alternatively, if Alice takes the piece, she must believe it is worth x/13, with x > 1. The problem remains linear, and so after the division of the remaining cake, Alice will likely have more than her 9/13 requirement.

Can a portion that would guarantee a factorization of the subsequent ratio be found? More formally, for a given ratio of a:b, seeking a portion x, with x < b, such that if the chooser takes the x portion, then the fraction (a–x)/b reduces by some factor, and likewise if the cutter takes it, the fraction a/(b–x) reduces by some (other) factor. Here, the worst case is the scenario where the subsequent ratio sum reduces the least. Suppose such a cut can be devised, and both subsequent ratio sums reduce by more than a factor of 2. Then if CNH is performed for the remaining division, it is very likely that this method will require fewer cuts than standard CNH. This is because the standard algorithm requires approximately ceiling(log2(a+b)) cuts, and factoring by an integer greater than 2 will reduce this logarithm. The following cut-trees demonstrate how this procedure can lead to fewer cuts than CNH. The desired ratio is 25:12, and the non-standard cut is 7:30.

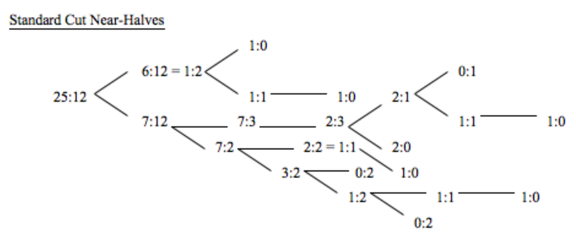


Figure 2: Cut Near-Halves for a 25:12 ratio. $Ceiling(log_2(25+12)) = 6$, and as we see in the diagram, the worst case requires 6 cuts.

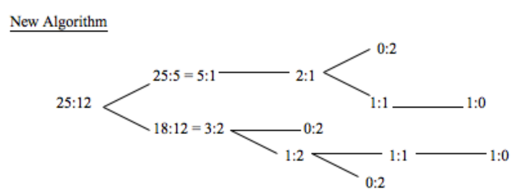


Figure 3: An initial, non-standard cut of 7:30, followed by Cut Near-Halves. This cut reduces the ratio sum by a factor of either 5 or 6, and the worst case requires 4 cuts.

The diagram makes it clear; if the first cut of 7:30 is made, then no matter which player takes the 7/37, the resultant ratio sum reduces substantially. And now the obvious question, how is it known that 7:30 is the optimal cut to make? One could exhaustively check each integer from 1 to (b–1) and determine which of these portions would yield the best reduction. This brute-force approach is certainly inefficient, especially if none of the options yields any reduction at all. Is there some way of determining whether or not a reduction is achievable, and if so, is there a technique for finding the exact cut that will do the job? These are all questions that Robertson and Webb ask in their text [1]. It turns out there is such a method to explicitly solve for more efficient cuts.

B. A Useful Result

Recall that a portion of the cake x is sought, with x < b, such that (a–x)/b = n, for some integer n, and a/(b–x) = m, for some integer m. For a given ratio of a:b, such portions x are given by the formula:

$$x \equiv a+b \ (mod\ m*n), \text{ where } m|a \text{ and } n|b$$

The term x will be named a "simplifier" for a:b, as it simplifies ratio sums. The above result can then be derived. First, the properties of a simplifier are translated into the language of number theory. The result is a system of linear congruences, and the system can be solved accordingly. The derivation is shown below.

Given:

(1)	$a \equiv x \ (mod\ n)$	Since $(a-x)$ reduces by a factor of n
(2)	$b \equiv 0 \ (mod\ n)$	Since b reduces by a factor of n
(3)	$b \equiv x \ (mod\ m)$	Since $(b-x)$ reduces by a factor of m
(4)	$a \equiv 0 \ (mod\ m)$	Since a reduces by a factor of m

From (1), (3), and the symmetry of congruence as an equivalence relation:

$$x \equiv a \ (mod\ n)$$
$$x \equiv b \ (mod\ m)$$

By the Chinese Remainder Theorem, if gcd(m,n)=1, then a solution to the above system does exist, where x (mod m*n) is unique [2]. In this case, it is guaranteed that gcd(m,n)=1, since otherwise the ratio a:b would not be in its most simplified form. Thus the system will always have a unique solution. Solving the system:

Given:

(1)	$a \equiv x \pmod{n}$	Since $(a–x)$ reduces by a factor of n
(2)	$b \equiv 0 \pmod{n}$	Since b reduces by a factor of n
(3)	$b \equiv x \pmod{m}$	Since $(b–x)$ reduces by a factor of m
(4)	$a \equiv 0 \pmod{m}$	Since a reduces by a factor of m

C. Choosing a Simplifier

In order to obtain a non-trivial simplifier, neither m nor n may be equal to 1, since reduction by a factor of 1 is not a true reduction. Implicit here is the strength of this method; the divisors which determine the simplifier are the same as the factors by which the ratio sum will reduce, and the player is free to choose these divisors. Can any divisors of a and b be chosen with the assurance that if the appropriate cut is made, the ratio sum will be reduced by a factor equal to one of these divisors?

There are a limited number of divisors that may be chosen, as a few more requirements must be met. It is necessary that x < b, since Bob cannot accept more of the cake than he is owed. This is easy to check; simply reduce a+b (mod m*n); if the resulting simplifier is less than b, the cut is valid. Furthermore, having a > b means that a must not be prime, since (b–x) cannot be reduced by a factor greater than itself (namely, a). In fact, the same argument demonstrates that a must have a divisor that is no more than (b–1)/2. So far it seems that there are many criteria for finding simplifiers.

Actually, if a is composite and b is not "small," then the existence of simplifiers is quite likely, especially if b is also composite. Indeed, there are often many simplifiers for a given ratio which can make it complicated to select one. It is known that the ratio sum will reduce by a factor equal to exactly one of the divisors. Therefore, if a player is interested in improving upon the worst-case scenario, the player should choose the pair of divisors such that the minimum divisor has the largest possible value. If multiple such pairs exist, the pair with the greatest maximum divisor should be chosen.

D. Relationship to Cut Near-Halves

What about beating the Cut Near-Halves algorithm? It has been seen that an algorithm that reduces the ratio sum by more than a factor of 2 will very likely require fewer cuts than CNH. It follows that if a valid simplifier is found by using divisors greater than 2, it can be expected to beat CNH. Suppose a search for simplifiers is conducted for each required ratio, and CNH is performed. The only way that the standard CNH algorithm could be more efficient than this method is if a given ratio is particularly favorable for CNH, i.e. CNH inadvertently results in a reduction by more than a factor of 2. Such ratios do exist, but they are very rare. Moreover, it can easily be checked whether standard CNH would result in a greater reduction than a given simplifier by looking one step ahead, which can be incorporated this into the new algorithm. Indeed, it can be expected that an algorithm that uses simplifiers should be highly favorable when compared to CNH.

E. The Divisor Reduction Method

It is now feasible to codify a new algorithm for division by unequal shares that are explicitly designed to perform better than CNH. Predictably, the algorithm will be recursively defined. This procedure will be called the Divisor Reduction Method (DRM). For a given integer ratio of a:b, with a > b, the algorithm proceeds as follows:

- Reduce the ratio a:b to its lowest terms.
- If a = 1 and b = 1, perform the Divide-and-Choose algorithm.
- If a is composite:
    - o Search for a simplifier x, x ≡ a+b (mod m*n), where m|a and n|b, such that the minimum of {m,n} is maximized while the following properties hold:
        - x ≡ a+b (mod m*n) < b
        - The minimum of {m,n} is greater than 2
        - The minimum of {m,n} is greater than twice the minimum of {gcd(a–ceiling((a+b)/2), b), gcd(a–floor((a+b)/2), b)}
        - If more than one such pair {m,n} exists, select the pair with the greatest maximum
    - o If such an x is exists
        - The player owed the lesser portion cuts a portion off the cake equal to x and of fers it to the player owed the greater.
        - If the player owed the greater portion accepts, give them the portion, and per form DRM on the remain ing cake according to the ra tio (a–x):b.
        - If the player owed the greater portion declines, give the portion to the player who cut it, and perform DRM on the remaining cake according to the ratio a:(b–x).
    - o If no such x exists:
        - Perform one step of CNH on a:b.
        - Perform DRM on the re sultant ratio.
- If a is prime:
    - o Perform one step of CNH a:b.
    - o Perform DRM on the resultant ratio.

V. Empirical Analysis

A. Data Collection

Both CNH and DRM lend well to computer simulations, and can be effectively implemented by dynamic programming. A dynamic program that stores the result of every sub-problem is very advantageous for several reasons. First, it provides a computationally feasible method for the ratio-by-ratio comparison of each algorithm on an entire range of integer pairs. Second, the DRM can be amended so as to account for when CNH is inadvertently more efficient. Finally, and perhaps most importantly, a dynamic program can find the optimal number of cuts for any integer pair, by searching every possible cut at every step and choosing the best one by looking at the previously computed sub-problems. It should be noted that finding the optimal algorithm is totally infeasible without a computer. In this way, CNH can be compared to DRM and the optimal algorithm, and also the amended DRM to the optimal algorithm. It is now possible to present statistics obtained from examining each algorithm's performance on every "unique" pair of integers across two ranges: [1, 100] and [1, 1,000]. It will be stated that the pair of integers a:b is "unique" if a > b and gcd(a,b)=1. This is because for data collection purposes, the ratio 2:1 is the same as 4:8, etc. The following data is obtained from analyzing MATLAB implementations of the exact DRM and CNH algorithms described previously with the noted amendment to DRM when being compared to the optimal algorithm.

B. Statistics and Discussion

As expected, DRM compares favorably to CNH, achieving optimality more than four times as often on [1, 100]. Perhaps disappointing at first glance is the fact that the amended DRM is only optimal for about 26% of integer pairs on [1, 100], and just over 6% on [1, 1000]. The more telling statistic though, is the percentage of optimal first cuts, over 32% and 17% on [1, 100] and [1, 1,000], respectively. This statistic carries more weight because DRM offers no systematic approach for improving upon some pairs (for which the greater integer is prime, for instance), while the brute-force search for optimality will almost always find some efficient cut for any given pair. It is also intuitive that DRM performs better than CNH more often on the interval [1, 1,000] (≈72.00%) than on the interval [1, 100] (≈38.93%). This is because as numbers become larger; their chances of being prime become smaller, thereby increasing the chances of susceptibility to DRM. Indeed, it may even be possible to prove that DRM improves upon CNH with increasing probability as upper interval bounds increase. Another noteworthy statistic is "average percentage of cuts less," which does not increase significantly with the interval bound. This is predictable, since beating a logarithmic algorithm such as CNH is not

Statistical Category	Interval	
	[1, 100]	[1, 1000]
Unique integer pairs	3,044	304,192
Number of unique pairs for which CNH and DRM require the same number of cuts	1,847 (≈60.68%)	82,348 (≈27.07%)
Number of unique pairs for which DRM require strictly *less* cuts than CNH	1,185 (≈38.93%)	219,017 (≈72.00%)
Number of unique pairs for which DRM require strictly *more* cuts than CNH	12 (≈0.39%)	2,827 (≈0.39%)
Average percent of cuts less than CNH that DRM requires	≈21.40%	≈22.69%
Number of unique pairs for which CNH is exactly optimal	267 (≈8.77%)	1,369 (≈0.45%)
Number of unique pairs for which amended DRM is exactly optimal	785 (≈25.78%)	18,606 (≈6.12%)
Percentage of unique pairs for which DRM produces the exact optimal first cut (assuming a simplifier exists)	≈32.28%	≈17.39%

Table 1: Statistics for CNH and DRM on the intervals [1, 100] and [1,1000]

typically a linear task.

VI. Conclusion

The cake-cutting problem of unequal shares for rational ratios can be modeled as a number-theoretic problem. It is not surprising then, that an algorithm for determining efficient sequences of cut ratios would be dependent on the divisors of the given ratio members. The known Cut Near-Halves algorithm can be altered so that at each step, portions that will reduce subsequent ratios are sought out. This new method of finding and using simplifiers, dubbed the Divisor Reduction Method, has the potential and tendency to perform better than standard Cut Near-Halves. The simplifiers used in the Divisor Reduction Method are given by the formula $x \equiv a+b \pmod{m*n}$, where $m|a$, $n|b$, and the minimum of m and n is maximized. Though not always optimal, the new algorithm is optimal significantly more often than Cut Near-Halves, especially on smaller intervals. Future work on this topic might include specific guidelines for the (efficient) generalization of the Divisor Reduction Method to more than two people, further application of analytic number theory to the problem, a probabilistic analysis of the Divisor Reduction Method's effectiveness, and perhaps a study of how various additional requirements for simplifiers affect results.

Acknowledgments

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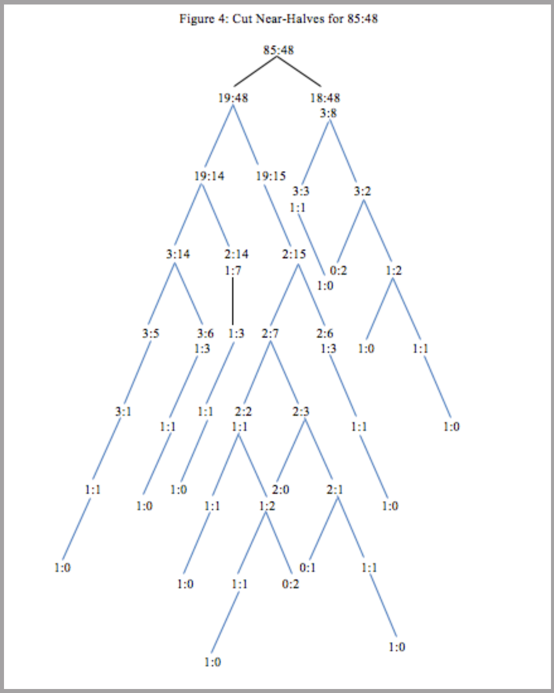


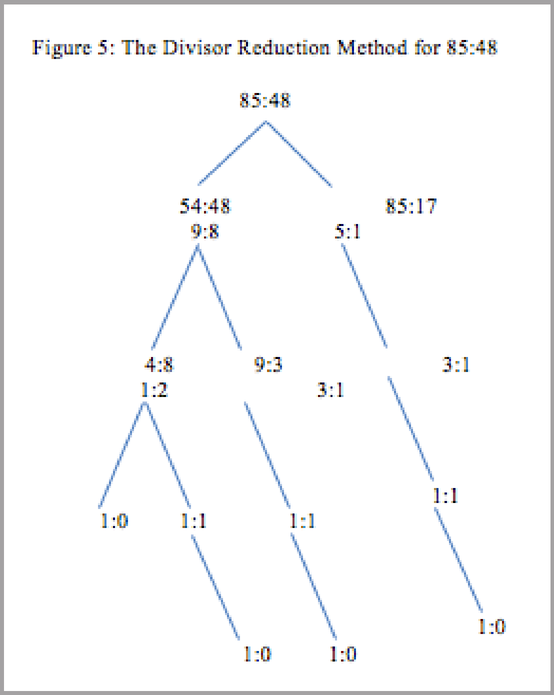
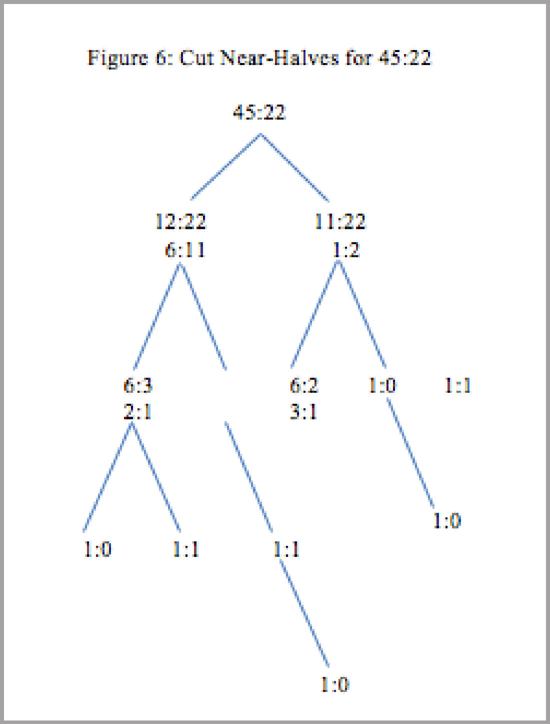


Figure 4: A cut-tree displaying Cut Near-Halves for the ratio 85:48. The maximum number of cuts required is 8, as predicted by ceiling(log2(85+48)) = 8. This ratio is a good example of the advantages of using the Divisor Reduction Method as opposed to Cut Near-Halves (see Figure 5).

Figure 5: The cut-tree displays the Divisor Reduction Method for the ratio 85:48. The optimally chosen simplifier is 31; it offers a reduction by a factor of either 17 or 6. The maximum number of cuts is 4, significantly less than that of Cut Near-Halves (see Figure 4 above). (Note that at the 54:48 node, a second simplifier of 5 is used, yielding an additional reduction by a factor of either 4 or 3).



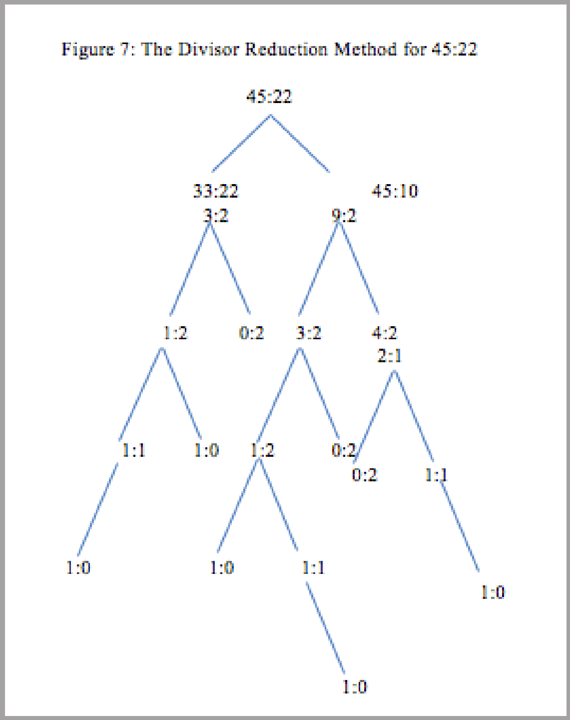


Figure 6: A cut-tree displaying Cut Near-Halves for the ratio 45:22. This ratio is one of twelve unique ratios on the interval [1,100] for which Cut Near-Halves performs better than the divisor reduction method. The maximum number of cuts is 4, noticeably less than the typical estimate, ceiling(log2(45+22)) = 7. The disparity is due to the significant reductions in each portion of the tree.

Figure 7: The cut-tree displays the Divisor Reduction Method for the ratio 45:22. The optimally chosen simplifier is 12; it offers a reduction by a factor of either 11 or 5. The maximum number of cuts is 5, unfortunately greater than that of Cut Near-Halves (see Figure 6).

Translocation as a Conservation Strategy: The Birds of Mainlands and Islands

Felicia Kulp, Zach Knudson, Katherine Mersinger, David Sayre, and Anna Sharova

Abstract

Previous literature contends that a larger founder group size is correlated with an increase in the probability of a successful translocation. To test this theory, translocation data was collected from journal articles on various bird species living on islands (New Zealand) and on mainlands (North America and Germany), including both indigenous and introduced species. Data on the success of the translocations and data on the population size several years after the translocation date were used. Upon analysis, the founder group size was found to be a determining factor for successful translocation of introduced birds only; translocations of native birds showed no statistical difference between founder group sizes of successful and failed translocations. Other factors need to be taken into account when translocating indigenous species such as those studied here. Sampling bias and the lack of recent monitoring data are limitations of this study. Translocations involving birds should be evaluated on an individual basis and not solely on trends presented in the literature.

Introduction

Translocation is a radical conservation strategy that involves the release of animals or plants into a habitat to establish or reestablish a population. The populations that are released, called founder groups, come from a source population or have been raised in captivity. The ecologists and breeders who release these organisms often take some necessary steps to help the population survive and successfully establish itself [1]. These actions often include captive rearing, supplemental feeding, multiple releases, and man-made nests. They are intended to give captivity-bred animals a chance for survival in the competitive environment. In current conservation biology, translocation is only used in extreme circumstances because it is usually expensive and success is not guarunteed [1]. Although translocation can be a good conservation strategy, biologists try to avoid situations that demand such drastic action.

The success of a translocation is often variable and can be determined by factors such as founder group size, characteristics of species, and habitat quality [2]. Case studies, such as Griffith *et al.* and Wolf *et al.*, have used a large amount of data on translocations to study the effects of each factor [1-2]. The effect of founder group size is the most contested. It has been established that a larger founder group improves the success of translocation, but Griffith *et al.* argues that at a certain size threshold, a larger founder group size has little effect on translocation success [1]. In the more recent study by Wolf *et al.*, the conclusion was that a larger founder group is always better [2].

To assess the effect of founder group size on the success of a translocation, indigenous birds from New Zealand, North America, and Germany were examined. In studying the island translocations, data were collected from the translocations of the kakapo [3], takahe [4], saddleback [5], stitchbird [6], and robin [7-8] from the islands of New Zealand. The species used to examine mainland translocations were the trumpeter swan [9], brown-headed nuthatch [10], eastern bluebird [10], peregrine falcon [11], capercaillie [12], ruffed grouse [13], and California condor [14]. In addition to these indigenous species, 37 other species were examined to analyze translocations of birds introduced into the New Zealand habitat [15]. All of these introduced species are passerines and come from a variety of different genera.

The data compiled on these birds were used to examine the factors that correlate with a successful translocation. In particular, this study examines whether a larger founder group size is always beneficial to the success of a translocation.

Methodolody

We examined 13 journal articles, a total of 152 individual translocation events for native New Zealand and mainland species as well as species introduced to New Zealand. We used 48 translocations for five species of indigenous New Zealand avifauna [3-8], 89 for 37 introduced New Zealand species [15], and 15 for seven mainland North American and northern European species [9-14].

For the purpose of this study, a successful translocation was defined as a translocation in which the population size at a later date, which varied from 1 to 47 years later, was larger than the founder group size. Any translocation that had a later population size that was zero or that was less than the founder group size was considered a failed translocation. This is consistent with the definition of success used by Griffith *et al.* [1]. Tallies of the successful and failed translocations were used to construct box plots that relate the founder group size to the success of the translocations. Statistical comparisons of data were performed using two-sample t-tests and a p-value less than 0.05 was considered significant.

Results

Box plots were constructed to illustrate possible differences in the significance of the founder group size in the native and the introduced species. Figure 1 shows the box plot that displays the relationship between the size of the founder group and the success of the translocations for native New Zealand avian populations. The plots show little difference between the founder group sizes of successful and failed translocations. The median founder group size for both plots was 25 individuals.

The relationship between the founder group size and the success of the mainland indigenous avian populations is

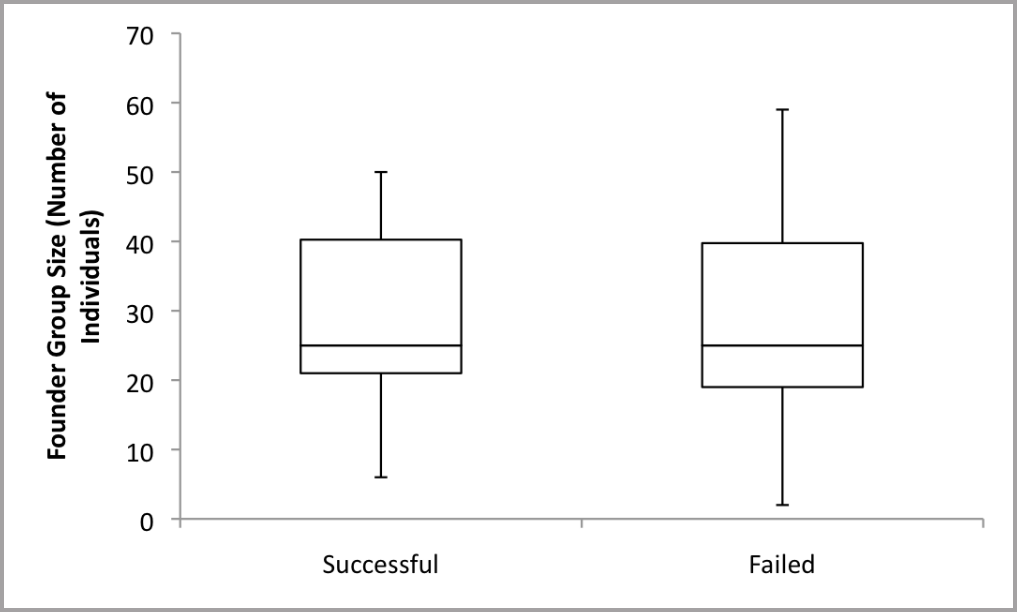


Figure 1: Founder group size relative to the success of the translocation for birds native to New Zealand. Data were collected from published literature [3-8]. There are no outliers.

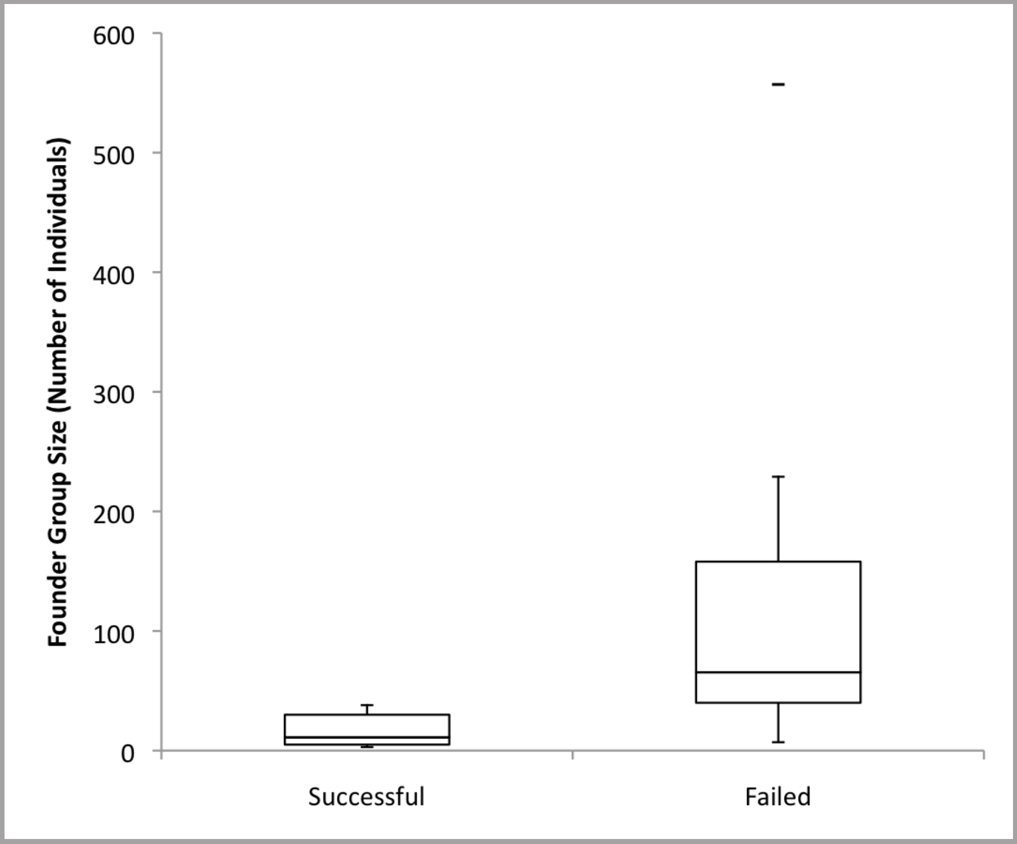


Figure 2: Founder group size relative to the success of the translocation for birds native to North America and Europe. Data were collected from published literature [9-14]. In the box plot for the founder group sizes of the failed translocations, the dash indicates the only outlier.

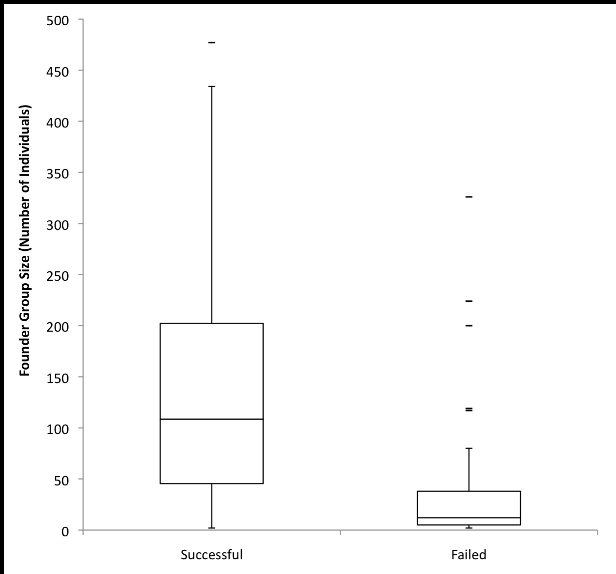


Figure 3: Founder group size relative to the success of the translocation for birds introduced to New Zealand. Data were collected from Duncan [15]. In both box plots, the dashes indicate outliers.

shown in Figure 2. The median for translocations that were unsuccessful is 65.5 individuals; for successful translocations, the median is 11 individuals.

The relationship between the size of the founder group and the success of translocations of passerines introduced to New Zealand was examined (Figure 3). The median founder group size was 12 individuals for failed translocations and 108.5 individuals for successful translocations. Of the successfully translocated passerine species, 57% were generalists. For the failed translocations, 44% of the species were generalists.

Finally, all translocation data were combined in order to evaluate the relationship of founder group size and translocation success regardless of the land type and the origin of the bird species. As presented in Figure 4, the median founder group size for the successful translocations was 47 individuals. For the failed translocations, the median was 22 individuals.

Two-sample t-tests were performed on the data. The results of these t-tests are given in Table 1. Tests were used to compare the average founder group size of successful translocations and failed translocations within the native New Zealand translocations, the native North American and European translocations, and the translocations that introduced passerines to New Zealand. Two further tests were used on the combined data from the native New Zealand and native North American and European translocations together and the founder group size of the translocations of introduced birds. The last analysis combined all of the data to assess success or failure of translocations in general.

Using the p-value results from the statistical tests, it was determined that successful translocations overall and of native

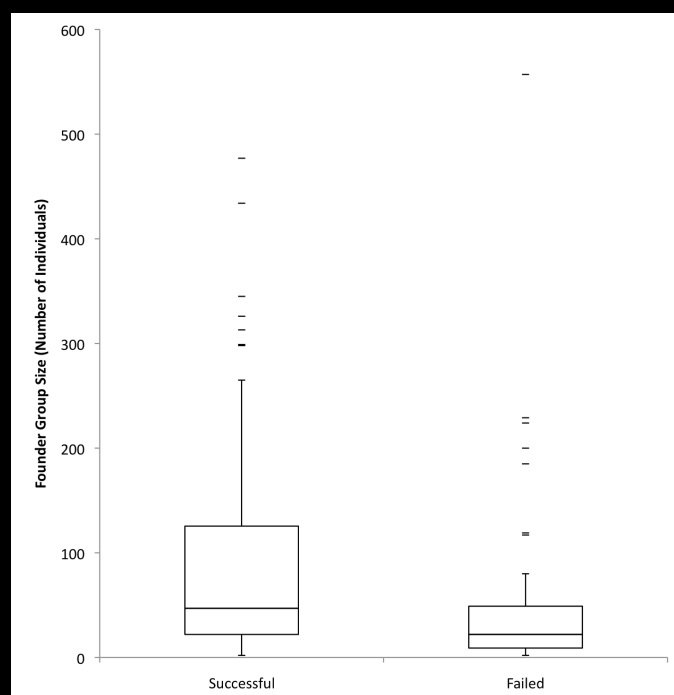


Figure 4: Founder group size relative to the success of the translocation without regard to land type and origin of the bird species. Data were collected from published literature [3-15]. In both box plots, the dashes indicate outliers.

Statistical Comparison	p-value
Native New Zealand: S vs. F	0.988
Native N. American and Europe: S vs. F	0.0645
Introduced to New Zealand : S vs. F	7.96×10^{-7}
Native: S vs. F	0.076
Successful: Native vs. Introduced	8.87×10^{-8}
Failed: Native vs. Introduced	0.183
Native and Introduced: S vs. F	7.76×10^{-4}

Table 1: Statistical test results for six comparisons as stated. An alpha of 0.05 was used. (S: successful translocations; F: failed translocations)

birds specifically had significantly larger founder group sizes than failed translocations. Introduced birds also had significantly larger founder group sizes of successful translocations than those of native species. Also, when all translocations were combined and successful translocations were compared to failed translocations, it was determined that successful translocations overall had significantly larger founder group sizes than failed translocations. All other comparisons performed did not result in statistically significant differences.

Discussion

Statistically, there was no difference between the mean founder group size for successful and failed native translocations, indicating that factors other than founder group size are critical to the success of a translocation. Several factors could have produced the observed results. Griffith *et al.* and Wolf *et al.* both agree that habitat quality is an important factor for the success of a translocation [1, 2]. For the kakapo of New Zealand, none of the translocated populations were moved to ideal habitats. Several locations were degraded by farming activities before restoration programs were started [3]. Further, some translocation areas were invaded by predatory mammals after the birds were relocated [3].

Another factor that may have greater importance in the success of a translocation than founder group size in New Zealand is the use of supplementary feeding. For instance, the kakapo will not breed unless there is an abundant supply of protein-rich food [4]. Conservationists began providing foods such as nuts, apples, and sweet potatoes in the hope that the kakapo would begin to breed more. The supplementary feeding appeared to be a success on several islands. It is also possible that the birds were able to spend less time searching for food and could redirect the energy that would have been used to forage for food into breeding.

When all of the translocation data were combined, successful translocations had a significantly larger mean founder group size than that of failed translocations. The data, however, showed that individual species may or not follow this particular trend. For instance, the mean founder group sizes of the successful and failed translocations for native birds to New Zealand and the mainland were not significantly different, while those of the introduced passerines were. The analysis shows that founder group size is a significant factor of success only for the introduced passerines and not for native birds.

Based on the statistical analysis, a larger founder group size does appear to be beneficial, but it is likely not the only factor that influenced the success of the translocations of the introduced passerines. The introduced passerines that were successfully translocated and established tended to be habitat and diet generalists [15], making it easier for them to adapt to different environments. The generalist nature of the species of successful translocations made them more likely to be able to establish populations in new habitats. In contrast to generalist species, specialists may have trouble adapting to a new environment. However, birds that are specialists, but have all of their required resources present on New Zealand, may also establish themselves once translocated, assuming they can occupy open niches or outcompete animals that occupy those niches.

It should be noted that this study has several limitations. First and foremost, the sample size of the native mainland translocations is small. A larger sample size would strengthen the statistical tests and provide more accurate results. Another limitation is that most of the translocation data end around the year 2000. No data were found for the native New Zealand and native mainland translocations that extend after 2004 with the exception of two mainland translocations that go to 2007. Furthermore, all of the translocations involving the introduced passerines were from the late 1800s with only seven extending into the early 1900s. Additional monitoring years for all of these translocated populations would make this analysis stronger.

In accordance with the above conclusions, we recommend that any future translocations involving birds, especially those on islands such as New Zealand, be evaluated individually. Trends in data, like those presented in Griffith *et al.* and Wolf *et al.* [1-2], should not be the sole criteria used to determine parameters of the translocation, such as the optimal founder group size. These trends may be used to get a rough estimate of the numbers needed. However, the data in this analysis illustrates that founder group size is not a significant factor in the success of translocations of native birds. Therefore, other factors should be evaluated for their importance to the success of the translocation.

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