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Mass Latex Balloon Releases and the Potential Effects on Wildlife

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MASS LATEX BALLOONS RELEASES AND THE POTENTIAL EFFECTS ON WILDLIFE

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ABSTRACT

Many environmentally conscious organizations and well-meaning private citizens have expressed a real concern on what effect mass latex balloon releases might have both as litter and as a threat to wildlife through ingestion. A report by the National Association of Balloon Artists (NABA) professes that when conducted properly, and with the right materials, latex balloon releases are harmless to wildlife and the environment. Concerned citizens and environmental groups are speculative of the assertions and have approached numerous state legislations in an effort to ban mass release balloons in general, viewing all balloons as a threat to wildlife. Little to no evidence exists in the scientific literature to validate any of the claims—from what happens after a balloon is released and how long it persists when it lands, to what effect it might have on wildlife that ingests it. Another issue is precisely what the public opinion is; both from the average person's point of view, and those who might be prone to encounter both the latex balloon fragments and the effects on wildlife as they occur in the environment. This study sought to encompass all aspects of latex balloons releases, starting with the release, to distance traveled from the point of release and the physical condition and duration of degradation upon landing, then the attractiveness of the materials for wildlife and finally the effects of ingestion. Additionally, the opinion of the patrons of sporting events as well as natural resources officials and non-governmental organization members (NGOs; consisting of wildlife rehabilitation and rescue, nature education centers, and environmental groups) were sought both to understand public opinion and to document any real harm observed upon wildlife from these releases.

The first component of the study examined the fate of balloons after release to determine aspects of where, in what state, and how long they persist in the environment to assess potential risk of exposure to wildlife. Tagged balloons from sporting events gave estimates of mean distances traveled from releases. Effects on the structural integrity of the latex balloon as it reaches the upper atmosphere were also tested to determine the physical state when fragments landed. Degradation studies were conducted to determine the length of time latex can persist in the environment after exposure to various environmental conditions (sun, shade, lentic and lotic water). Motion activated cameras were used to determine which species are attracted to balloons where they occur in the environment. Few tagged balloons released (40 of 5600) were recovered. It was found that balloons traveled a median distance of 33.8 km (μ = 70 km) from point of origin. From atmospheric trials, approximately 12% burst into small pieces as previously described, and 81% were recovered with half the balloon mass intact. Degradation studies indicate latex breaks down to a brittle stage within 8-10 weeks when exposed to air. Balloons submerged in water degrade more slowly, retaining elasticity beyond five months. Frequency of camera activation by wildlife showed no significant difference between visitation of balloon plots and controls.

The second phase of the study examined the potential threat that latex balloon fragments may represent to wildlife through ingestion. Trial species of Japanese Quail (*Coturnix coturnix japonica*), Red-eared Sliders (*Trachemys scripta elegans*) and Channel Catfish (*Ictalurus punctatus*) were model species representing wildlife taxa potentially impacted by latex balloons. Latex fragments were offered twice weekly for

four weeks, and blood samples were taken pre and post trial to discern any change in heterophil to lymphocyte (H/L) or neutrophil to lymphocyte (N/L) ratios as an indicator of physiological stress from ingestion. Latex fragments were offered for consumption for four weeks. Blood samples were taken pre- and post-trial to discern any change in heterophil to lymphocyte (H/L) or neutrophil to lymphocyte (N/L) ratios as an indicator of physiological stress from ingestion. Weight was recorded weekly. Test organisms were euthanized at four weeks and necropsies were performed to examine for digestive tract anomalies. In summary, no significant difference was detected in H/L ratios pre- and post-trial for *C. Japonica* or for *T. scripta elegans.* There was a significant decrease in N/L ratios from pre- to post-trial for *I. punctatus*. Weight increased significantly for sub-adult quail and catfish fingerlings during the study, however no significant change of weight was observed in adult turtles. Necropsies did not reveal any digestive anomalies in quail or catfish; although turtles did show substantial accumulation of latex fragments in three of 14 specimens (21%). Results of this study suggest that consumption of latex balloon fragments may not pose a threat to many wildlife species.

The third aspect of the study sought to evaluate public opinion concerning mass latex balloon releases and document any observed effects that natural latex balloons have on wildlife or the environment. Surveys were conducted on sporting event patrons, natural resources officials, and NGOs. Patrons attending Clemson University home football games participated in a survey that focused on relevance of releases as a pregame activity and perceived harm they might pose to the environment. Natural resources officials and NGO members were surveyed to ascertain opinions of possible effects of

balloon releases on wildlife, and to provide documentation of harm caused to wildlife as a result of interaction with latex balloons. Balloon releases during pre-game were of less value to sports patrons than other aspects of the game day event. Forty-two percent believed latex balloon releases are dangerous for the environment with the main reason cited as a danger to wildlife (37%). Approximately 50% ranked protection of the environment as “important” as opposed to “very important” or “not important”. The majority of natural resources officials and NGO members responded as not having encountered animals injured by latex balloons (73%), and 90% had not observed any animal mortality due solely to latex balloons. Strings were responsible for 67% of the injuries reported by both groups; however 87% consider balloons dangerous for the environment. Sea turtles were the most cited species affected by latex balloons (53%), followed by shore birds (40%).

Results from the different aspects of this research enhances our understanding of how far latex balloons can travel after release, the physical state when they land, how long they persist, and which species are attracted to them and in what frequency. This study also suggests that consumption of latex materials may not pose a threat to many species, while further long-term studies on turtles may be necessary. Public opinion is varied, although those that work in a field related to natural resources management or NGOs tended to believe that release of latex balloons warranted concern for the safety of wildlife, without any direct observations of harm.

DEDICATION

First and foremost I dedicate this dissertation to God, without which there would have been no inspiration or faith to see it through to completion. Secondly I dedicate this work to my wife, Heather, and my daughters Zoe and Asia, for their unfaltering support through five years of graduate school, technical support, dishes, and weekends of cage cleaning.

ACKNOWLEDGMENTS

I would like to thank the Clemson University Creative Inquiry Department and Barbara Speziale for funding this project. Additional thanks go to Dr. Stephen Creager, Dr. Melanie Cooper, and Dr. Webb Smathers for sponsoring the project. None of this could have happened without the eager participation of an army of Creative Inquiry students; notably Andy Jenkins, Lydia Stiffler, Tim O'Neil, Beau Bauer, Eric Holberton, Cyrus Baird, Callen Bethea, Elaine Donithan, and many others. Special thanks go to my wife, Heather, for her creativity, technical support, and assistance in all phases of the study, and to a list of collaborators too numerous to name from a multitude of departments and backgrounds. Special thanks for assistance with Heterophil/ lymphocyte ratios go to Hiroko Taira, and for identification of helminths, Dr. Kimberly Paul. Additional thanks go to Dr. Mary Beck for input on physiological aspects of the study.

I would also like to thank my committee members, Dr. William Bridges, and Dr. J. Drew Lanham for being on-board the project. My sincerest gratitude goes to Dr. Jeffrey Foltz, who never stopped being an advisor and mentor well after serving as the chair on my Master's committee, and my current committee chair, Dr. William Bowerman, who dared to give me a chance to pursue this accomplishment.

PREFACE

Each of the three chapters in this dissertation represents an independent journal article, and each is intended for publication. Repetition in the introduction material and/or other sections occurs as necessary for each chapter to stand alone.

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INTRODUCTION

Balloon releases at sporting events and other celebratory functions are often used as a way to bring a spirit of levity and crowd enthusiasm to the atmosphere. Many enjoy the balloon releases as part of the festivities. However, the releases of the balloons have also gained the attention of both individuals and non-government organizations (NGOs) concerned about the potential impact on the environment and the wildlife that encounter the remnants of the balloons (Marine Conservation Society, 2006; Ferris, 2009, Clean Virginia Waterways, 2010).

Natural latex balloons are often categorized with plastic waste due to the outward physical characteristics of the material. Plastics have recurrently presented a hazard through consumption or entanglement to many species of wildlife, and especially in respect to aquatic life (Laist, 1987; Bjorndal et al., 1994; Thompson *et al*., 2009). Plastic occurs in a variety of forms that may appear as a food item, and through ingestion may result in respiratory or intestinal blockages, causing reduced fitness or death (Mee *et al*., 2007; Stamper *et al*., 2009). In other forms plastics can serve to ensnare or entangle the animal, reducing mobility, and subjecting it to decreased ability to escape predation, find shelter, or swim well enough to avoid drowning (Plotkin and Amos, 1989; Walde *et al*., 2007; Gregory, 2009). Some highly visible species, such as sea turtles or water birds, are especially susceptible to consumption of plastics as their diet may often be composed largely of invertebrates or prey items recovered from the water surface (Fry *et al*., 1987; Moser and Lee, 1992; Bugoni *et al*., 2001). Necropsies of sea turtles have recurrently revealed large amounts of plastic in the digestive tract, resulting in nutritive impairment

and increased potential for death (Bugoni *et al*., 2001; Tomas *et al*., 2002). As many as 50 species of seabirds have been observed to ingest plastic debris, and chicks of Laysan (*Phoebastria immutabilis*), Black-footed (*P. nigripes*), and Wandering (*Diomedea exulans*) albatrosses have been discovered with plastics in their stomachs (Fry et al., 1987; Laist, 1987). Nearly all albatrosses examined from Midway Island have plastic in their digestive tracts (Sileo *et al*., 1990). Effects of ingestion of plastics on other less visible species may go unnoticed.

While plastic waste has a confirmed impact on wildlife, no published scientific data exists on the effects of natural latex balloon fragment ingestion. Latex balloon releases from sporting events can top 15,000 per game (Central Spirit, pers. comm.). Considering the typical 28 cm latex balloon released at an event weighs approximately 3.3g, the cumulative quantity equals roughly 50kg of material released per game from one participating university. If latex balloons are a hazard to wildlife, this would represent a significant risk. Because of this, the need for an objective scientific study to determine what, if any risk, natural latex balloons pose to wildlife is warranted. Limited information is available on the range of dispersal after a latex balloon release, the physical characteristics upon arrival, and persistence in the environment.

The balloon industry has for the past twenty years relied on information from one report released by the National Association of Balloon Artists. The report focuses on the duration of the balloons after release and the rate of degradation under three specified conditions of soil contact, water contact, and sunlight exposure (Burchette, 1989). It also states that as balloons ascend and reach an altitude of approximately 8.5 km, a

combination of ultra-violet light exposure and resultant oxidation of the latex membrane, a drop in temperature to approximately -40 ^{0}C, and a reduced atmospheric pressure cause a cumulative effect on the integrity of the balloon membrane. This theoretically forces the balloon to brittle fracture (i.e. it freezes and bursts into small, thin ribbons) before descending and dispersing over a large area. The report suggests that only 5-10% of the latex balloons remain intact and return to Earth partially inflated, with the assertion that the amount is negligible. However, claims of the resulting physical size and shape of the latex fragments due to brittle fracture were not referenced, and subsequent literature reviews revealed no published scientific evidence to support this. Range traveled by the intact balloons in the report was mathematically estimated to approach a distance of 109 km (Burchette, 1989). The degradation studies consisted of exposure to sunlight and inflation, and based some of the conclusions on the degradation of the latex as compared to approximately 1.27 cm cubes of oak wood and oak leaves. Treatments were examined in 2 week intervals for a period of 6 weeks, and materials were weighed to determine change in total mass (g) as an indicator of decomposition. Because mass in each treatment did not change significantly over the 6 week period, the method of analysis shifted to a subjective interpretation of breakdown of the material. The latex in each trial was reported to become brittle, develop into a "tissue paper" like consistency, or revert back to a gum-like form by the end of the study (Burchette, 1989). Final analysis based all observations on the persistence of the oak leaves against visual comparison of the latex material, with no given time-frame of the degradation rate of an oak leaf. Another issue relating to the study was that circumstances of decomposition in aquatic

experimental trials did not consider factors of naturally occurring conditions, or in sea water or shoreline environments. Submerged conditions were conducted in a shallow pan in which nearby river water was added on a daily basis, without the natural effects from action of invertebrates on the latex material, forces of turbulence caused by the flow of the river, or the lower temperature kept constant by the volume of water. The report does emphasize that an ecologically sound release would depend on using natural latex balloons, as opposed to Mylar or other alternatives for balloon releases, as the only environmentally responsible option (Burchette, 1989). As the only known study comprehensively performed on the subject, information from this report has become widely circulated as a scientifically validated source of information, and thus appears in literature and on websites both for and against latex balloon releases.

Review of the literature offered little scientifically substantiated information on either effect of the upper atmosphere on balloons or dispersal from release. Independent efforts by Farris (2009) indicated that inflated balloons remained pliable at -50 ^{0}C and did not experience brittle fracture. No studies were found with temperature in combination with low atmospheric pressure, and no evidence was found to support the notion that balloons would climb to an altitude where they would rupture at a specific height. Numerous reports exist as to the collection of balloons after rupture in the upper atmosphere, but these are typically recoveries after the fact, with speculation as to the origins of the balloon. As far as estimating the dispersal of balloons from a release, the typical party-sized latex balloons can travel great distances, as evidenced by Walde et al. (2007), who recovered balloons in the Mojave desert that may have traveled more than

200km. Distance traveled by balloons has been shown to depend on wind speed at varying altitudes and are subjected to currents in the jet stream, with a theoretical maximum range of 965 km (Roberts, 1995).

Numerous studies have addressed the hazards to wildlife through consumption of plastics, but very little has been published on latex balloon ingestion. One investigation concerning sea turtle necropsies in the North West Gulf of Mexico did reveal the presence of latex rubber and balloons collected from the intestinal tract of sea turtles found stranded on the Southern Texas coast over a period of time from 1986-1988, although the study did not specify if the balloons were latex or another material (Plotkin and Amos, 1989). Another study concerning Desert tortoise (*Gopherus agassizii)* at the Ironwood National Monument, AZ noted a large prevalence of balloons on the site, with an estimated 11,207 balloons occurring across the expanse of the monument. While the authors do not suggest that the balloons are causing population level impacts on the desert tortoise, they suggested the balloons could be a threat to individuals consuming the material (Averill-Murray and Averill-Murray, 2002). As to a physiological study on the effect of ingestion of natural latex balloons on wildlife, only one study was found. Research on the effects of balloon fragments on two species of juvenile sea turtles was conducted by Lutz (1989) and resulted in nutritive uptake impairment, taking an average of 8 weeks to up to 4 months for complete elimination. In some instances turtles passed multiple pieces that were bound together, although pieces were fed individually at different times. Other aspects of health demonstrated no measureable changes in the

physiological parameters examined, with a conclusion by the author that more research needed to be conducted (Lutz, 1989).

Environmental organizations such as The Marine Conservation Society and Clean Virginia Waterways are active in legislation to impose regulations or bans on balloon releases. Because of the lack of formal publications submitted by various grass root efforts and conservation organizations, to adequately express the position of these entities, examining their stances depends largely on evaluating their arguments against balloon releases from newsletters and websites. Much of the available literature on the subject is contained in reports of necropsies or surgeries to remove digestive blockages in the form of non-degradable plastics accompanied by occasional latex balloon fragments (Farris, 2009; Sohn, 2009), and some of the concern implicating latex balloons has arisen from confirmed incidences of health problems or fatalities due to digestive tract blockages from ingestion of Mylar® (BoPET) balloons by sea turtles or aquatic mammals (Marine Conservation Society, 2006). One publicized account involved the rescue of a pygmy sperm whale (*Kogia breviceps*) beached on the New Jersey coast. The whale was examined and found to have numerous internal blockages; the crucial debilitating element was identified as an inflated Mylar® balloon. Another account of an imperiled infant sperm whale (*Physeter macrocephalus*) resulted in the death of the whale, again due to an inflated Mylar® balloon (Marine Conservation Society, 2006). There are also frequent accounts of harmed animals that have become entangled in attached ribbon once having ingested a balloon (Walde et al., 2007). While there is a real risk of this, and ribbon does propose a definite hazard, the current International Balloon

Association (IBA) recommendation is no strings, ribbons, or other attachments should be used in balloon releases (IBA, 2009). Of other concern is the large amount of balloon fragments recovered on the shores of some beaches, and the effects it may have on shore birds and juvenile sea turtles. Hatchling sea turtles may be particularly at risk, as they spend their first few years in a pelagic state depending on drift lines (areas of high concentrations of debris) for sustenance and are thus subject to any small object drifting in the current that can be viewed as a potential food item (Plotkin and Amos, 1989). Already at risk from strong predation, and as most are listed as endangered, any potential hazard might create an additional impact on the populations by affecting juveniles. From the efforts of concerned organizations and individuals, several states, including Connecticut, Tennessee, Florida, and Virginia have either banned or passed legislation regulating the mass release of balloons (Conn. Code Ch 490, §26-25c, 2005; Tenn. Code Ch 101, § 68-101-108, 2010; Florida Code Ch 372, §372.995, 2003; Virginia Code Ch 5, §29.1-556.1, 2010).

Currently little scientific information exists to validate either the innocuous effects of stringless natural latex balloon releases or the danger they impose on wildlife. From one facet, people enjoy celebrating with balloons, and an entire industry employs thousands of people to supply them for special events. The other perspective might be equally valid. If latex balloon releases constitute a real threat to wildlife, then an investigation into the matter bears merit. This study sought to address the discrepancies concerning the fate of latex in the environment and to evaluate the risk that latex balloon fragments might pose to wildlife through ingestion. The study also intended to assess

public opinion of patrons from sporting events on both the ceremonial importance of the latex balloon releases and the perceived impact they may have in the environment, and to evaluate the observations and opinions of natural resources officials and non-governmental environmental organizations.

LITERATURE CITED

Andrady, A.L. 1989. Environmental degradation of plastics under land and marine exposure conditions. *In* R. S. Shomura and M. L. Godfrey (editors). Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989. Honolulu, Hawaii.

Averill-Murray R.C., and A. Averill-Murray. 2002. Distribution and density of tortoises at Ironwood Forest National Monument. Sonoran Herpetologist 15:7 78-79

Bjorndal, K. A., A. B. Bolten, and C. J. Lagueux. 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. Marine pollution Bulletin 28(3) 154-158

Bugoni, L., L. Krause, and M. V. Petry. 2001. Marine debris and human impacts on sea turtles in southern Brazil. Marine Pollution Bulletin 42 (12) 1330-1334

Burchette D.K. 1989. A study of the Effect of Balloon Releases on the Environment. Final Report presented to National Association of Balloon Artists.

Clean Virginia Waterways. 2010. Balloons as litter--a problem we can solve. Clean Virginia Waterways, Longwood University, 201 High Street, Farmville, VA 23909. Retrieved January 16, 2010 from http://www.longwood.edu/cleanva/balloons.htm

Connecticut Code 2005. Title 26 Fisheries and Game, Ch 490, § 26-25c. Release of lighter-than-air balloons restricted.

Farris L. 2009.What goes up must come down. Fourth Crossing Wildlife Australian Seabird Rescue. www.fourthcrossingwildlife.com/WhatGoesUp-LanceFerris.htm. (Accessed March 18, 2011)

Florida Code 2003. Title XXVIII Natural Resources; Conservation, Reclamation, and Use; Ch 372 Wildlife, § 372.995. Release of balloons.

Fry, M., S. I. Fefer, and L. Sileo. 1987. Ingestion of plastic debris by Laysan Albatrosses and Wedge-tailed Shearwaters in the Hawaiian Islands. Marine Pollution Bulletin (18, 6b) 339-343

Gregory, M.R. 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. . Philosophical Transactions of the Royal Society B 2009 (364) 2013-2025

Laist, D. W. 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. Marine Pollution Bulletin 18 (6B) 319-326

Lutz P.L. 1989. Studies on the ingestion of plastic and latex by sea turtles. *In* R. S. Shomura and M. L. Godfrey (editors). Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989. Honolulu, Hawaii.

Marine Conservation Society. 2006. Balloon releases: pollution factsheet. 9 Gloucester Road Ross-on-Wye Herefordshire HR9 6BU Tel. 01989 566017 Fax. 01989 567815 http://www.mcsuk.org Registered Charity 1004005

Mee, A., B. A. Rideout, J. A. Hamber, J. N. Todd, G. Austin, M. Clark, and M. P. Wallace. 2007. Junk ingestion and nestling mortality in a reintroduced population of California Condors (*Gymnogyps californianus*). Bird Conservation International 2007 (17) 119-130

Moser, L. M. and D. S. Lee. 1992. A fourteen-year survey of plastic ingestion by western North Atlantic seabirds. Colonial Waterbirds 15 (1) 83-94

Plotkin P. and A.F. Amos. 1989. Effects of anthropogenic debris on sea turtles in the northwestern Gulf of Mexico. *In* R. S. Shomura and M. L. Godfrey (editors) Proceedings on the Second International Conference on Marine Debris, 2-7 April 1989. Honolulu, Hawaii.

Roberts, A. M. 1995. Dynamics of free-floating gas-filled rubber balloons. Physics Education (30) 109-113.

Sileo L., P.R. Sievert, AND M.D. Samuel. 1990. Causes of mortality of albatross chicks at Midway Atoll. Journal of Wildlife Diseases 26 (3) 329-338

Sohn, E. 2009. Study finds plastic 'diet' in leatherback turtles: Necropsy reports show a third of specimens had it in their digestive system. Retrieved January 16, 2010 from http://www.msnbc.msn.com/id/30144026/.

Stamper, M. A., C. W. Spicer, D. L. Neiffer, K. S. Mathews, and G. J. Fleming. 2009. Morbidity in a juvenile Green Sea Turtle (*Chelonia mydas*) due to ocean-borne plastic. Journal of Zoo and Wildlife Medicine 40 (1) 196-198

Stocker, R.A., R.A. Pielke, A.J. Verdon, and J.T. Snow. 1990. Characteristics of Plume Releases as Depicted by Balloon Launching and Model Simulations. Journal of Meteorology 29:53-62.

Tennessee Code 2010. Title 68 Health, Safety and Environmental Protection, Chapter 101 Miscellaneous Safety and Environmental Regulations, § 68-101-108. Limitations on release of balloons into the atmosphere exemptions

Thompson, R.C., C.J. Moore, F. S. vom Saal, and S. H. Swann. 2009. Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B 2009 (364) 2153-2166

Tomas, J., R. Guitart, R. Mateo, and J. A. Raga. 2002. Marine debris ingestion in Loggerhead Sea Turtles, *Caretta caretta*, from the Western Mediterranean. Marine Pollution Bulletin 44 (2002) 211-216

Virginia 2010. Title 29.1 Game, Inland Fisheries and Boating, Ch 5 Wildlife and Fish Laws, § 29.1-556.1 Release of certain balloons prohibited; civil penalty.

Walde, A.D., M.L. Harless, D.K. Delaney, and L.L. Pater. 2007. Anthropogenic threat to the desert tortoise (Gopherus agassizii): litter in the Mojave desert. Western North American Naturalist 67 (1) 147-149

CHAPTER 1

Mass Latex Balloon Releases and Their Fate in the Environment

INTRODUCTION

Mass latex balloon releases are often used in public events and celebrations, such as parades, memorials, and football games. The releases of balloons have gained the attention of both individuals and non-governmental environmental organizations concerned about the potential impact on the environment and the wildlife that encounter the remnants of the balloons (Marine Conservation Society, 2006; Ferris, 2009; Clean Virginia Waterways, 2010).

Natural latex balloons are often categorized with plastic waste due to the outward physical characteristics of the material. Plastics have recurrently presented a hazard through consumption or entanglement to many species of wildlife, and especially in respect to aquatic life (Laist, 1987; Bjorndal *et al*., 1994; Thompson *et al*., 2009). Plastic occurs in a variety of forms that may appear as a food item, and through ingestion may result in respiratory or intestinal blockages, causing reduced fitness or death (Mee *et al*., 2007; Stamper *et al*., 2009). In other forms, plastics can serve to ensnare or entangle an animal, reducing mobility, and subjecting it to decreased ability to escape predation, find shelter, or swim well enough to avoid drowning (Plotkin and Amos, 1989; Walde *et al*., 2007; Gregory,2009). Some highly visible species, such as sea turtles or water birds, are especially susceptible to consumption of plastics as their diet may often be composed largely of invertebrates or prey items recovered from the water surface (Fry *et al*., 1987; Moser and Lee, 1992; Bugoni *et al*., 2001). Necropsies of sea turtles have consistently

revealed large amounts of plastic in the digestive tract, resulting in nutritive impairment and increased potential for death (Bugoni *et al*., 2001; Tomas *et al*., 2002). As many as 50 species of seabirds have been observed to ingest plastic debris, and chicks of Laysan (*Phoebastria immutabilis*), Black-footed (*Phoebastria nigripes*), and Wandering (*Diomedea exulans*) albatrosses have been discovered with plastics in their stomachs (Laist, 1987; Fry *et al*., 1987).

With plastic waste having a documented impact, there is very little available scientific literature on hazards of natural latex balloons to wildlife. Research on the effects of ingestion of balloon fragments on two species of juvenile sea turtles was conducted by Lutz (1989) and resulted in the potential for nutrient dilution and delayed elimination of fragments, with a conclusion by the author that more research needed to be conducted. Animals have been recovered with evidence of latex balloon ingestion (Plotkin and Amos, 1989; Walde *et al*., 2007), but no incidences were found in the literature of harm caused directly by the latex balloon material. The past twenty years has provided evidence of harm to various forms of wildlife from other materials related to balloon releases, such as ingestion of Mylar® (BoPET) balloons by sea turtles and marine animals, or through entanglement by attached string or ribbon (Averill-Murray and Averill-Murray, 2002; Marine Conservation Society, 2006; Walde *et al*., 2007). Latex balloon releases from sporting events can exceed 15,000 per game (Central Spirit, pers. comm.). Considering the typical 28 cm latex balloon released at an event weighs approximately 3.3g, the cumulative quantity equals roughly 50kg of material released per

game from one participating university. If latex balloons do represent a hazard to wildlife, this would present a significant risk.

Limited information is available on the range of dispersal after a latex balloon release, the physical characteristics upon arrival, and persistence in the environment. In 1989, the reaction to latex balloon releases prompted the National Association of Balloon Artists (NABA) to issue a bulletin concerning the fate of latex balloons after release (Burchette, 1989). The report speculated the distance traveled by the balloons after release, the effects the upper atmosphere had on the physical state of the latex materials, and rate of degradation once landed. According to the report, balloons ascend to an altitude of roughly 8 km and undergo a process of brittle fracture (i.e. it freezes and bursts into tiny pieces) before falling back to earth and rapidly biodegrading (Burchette, 1989). However, claims of the resulting physical size and shape of the latex fragments due to brittle fracture were not referenced, and subsequent literature reviews revealed no published scientific evidence to support the claims. Range traveled by the intact balloons was mathematically estimated to approach a distance of 109 km (Burchette, 1989). Degradation trials were conducted on a small sample of latex balloons placed in trays exposed to sunlight, with final analyses consisting of a comparison of degradation of latex over time against that of an oak leaf. The report concludes that the fast degradation rate, coupled with dispersal and brittle fracture, would not propose a threat to sea turtles or dolphins (Burchette, 1989). Andrady (1989) examined persistence of latex and several thermoplastics in sea water, showing a reduction in degradation over time for latex balloons and retention in elasticity for up to 12 months, 6 times longer than trials exposed

only to air in marine environments. In addition, the typical party-sized latex balloons can travel great distances, as evidenced by Walde *et al*. (2007), after recovery of balloons in the Mojave desert that had traveled more than 200 km. Distance traveled by balloons has been shown to depend on wind speed at varying altitudes and are subjected to currents in the jet stream, with a theoretical maximum range of 965 km (Roberts, 1995).

The first objective of this study was to determine the distances traveled by the balloons after release, and to ascertain the physical characteristics of the latex material after the balloon ruptures in the upper atmosphere. The results of these trials will provide information as to the distances the balloons travel from releases, and the size and morphology of latex balloon material after a release for ingestion by wildlife. The second objective was to monitor change in elasticity over prolonged environmental exposure as a measure of the rate of degradation. Lastly, field observations were performed to determine if wildlife are most attracted to balloon fragments, and how frequently balloon fragments were ingested by them.

METHODS

Dispersal of latex balloons — All trials involving balloon dispersal were released from the Clemson University (CU) football stadium, Clemson, South Carolina. To determine the movement and mean distance traveled by the balloons, dispersal information was collected with the assistance of Central Spirit; the organization responsible for the balloon releases from the events at CU. Labels weighed approximately 0.3g, and provided contact information and date of release. Central Spirit currently releases approximately 15,000 Tuf-tex® balloons per football game, and attached the labels to

1400 of the balloons during each of four home games throughout the football season (11 September, 2 October, 23 October, and 6 November 2010) for a total of 5600 labeled balloons. The interval approximates 20 days between releases to accommodate for the varying seasonal weather conditions (i.e., temperature, cloud cover, wind speed, precipitation, etc.). Temperature and weather conditions were recorded for each date. Location of retrieved balloons and their condition was collected through voluntary e-mail and telephone correspondence.

***Atmospheric effects on Latex Balloons* —**Twenty-eight 28cm Tuf-tex® balloons were inflated with helium to an approximately 28 cm diameter and placed in a 1.5 x 1.8 m, 2mm mesh sack and tied shut with a length of nylon rope. A Motorola i290 pre-paid phone and back-up battery (Motorola Mobility Inc., Libertyville, Illinois) was used for GPS tracking. The back-up battery was attached to the phone and activated to prolong the duration of the signal. The phone and battery were wrapped with newspaper and two chemical hand warmers to protect the electronic devices from sub-zero temperatures in the upper atmosphere. The bundle was secured in a 6L, 22cm x 27cm Styrofoam container (a standard minnow bucket), sealed with duct tape, and labeled with contact information. Two- 28 cm toy rocket parachutes were attached to the container to slow descent. A 300g sounding balloon was filled to an approximately 1.5 m diameter, and the Styrofoam container was tethered to the balloon with nylon rope and duct tape. A 300g sounding balloon rises to a height of approximately 27 km before bursting- much higher than the 8 km altitude necessary to burst the 28 cm latex balloons. The mesh sack was tethered to the opposite end of the Styrofoam container in a similar fashion. All necessary

officials, including local law enforcement and the air traffic control of the Greenville-Spartanburg Airport, were contacted for approval of release of the sounding balloon and payload prior to the scheduled launch from Bowman Field on the CU campus. After release of the sounding balloon and payload, the retrieval location was determined using Instamapper.com (http://www.instamapper.com), a free, online cell phone GPS tracking service.

Degradation of latex balloons — A device was constructed to measure the maximum diameter of Tuf-tex® balloons during inflation to observe loss of elasticity as a measure of material degradation over time. Inflation was chosen to test material fatigue as latex has a radial molecular formation and inflation would subject the material to uniform biaxial strain (Lickfield, pers. comm.; Stevenson and Thomas, 1979). Two 46 cm vertical panels were attached to separate sleds resting on two polished metal pipes. A mounting device fitted with flexible PVC tubing was positioned above and between the two panels for balloon inflation. As the balloon pressed against the panels, the sleds were moved apart with manual assistance until rupture of the latex balloon. Distance between the two panels was measured at a fixed point for maximum diameter of the balloon. A control for maximum mean diameter in cm before exposure was established by inflation of 30 balloons, ten of each of white, orange and purple, until rupture using a compressed air-line at a constant air pressure of 10 kg/cm^2. The three colors were chosen by collaborating undergraduate researchers and represent the colors of balloons released from CU events. One thousand twenty balloons were inflated with hand pumps, clamped shut with binder clips, and suspended from nylon line in order to best duplicate the

weathering effects of stretching and oxidation that occur during a balloon release. Balloons were subjected to a minimum of six hours of sunlight, similar to conditions performed by Burchette (1989). After exposure balloons were deflated and subjected to four experimental trials of terrestrial sun and shade, and still and running fresh water environments. Trials took place during the months of October through November, with a mean daily temperature of 12.11^{0}C. The number of balloons allowed for a sample of ten balloons of each of the three test colors to be taken from each of four environmental conditions every two weeks for ten weeks. Measurements of balloons exposed to aquatic conditions were planned to continue for an additional 12 weeks due to the decrease in oxidative and photodegradation properties presented by submersion in water. Terrestrial trials took place at the CU Aquaculture Facility and consisted of placing 50 balloons of each of the three colors in 61 x 91 x 45.7 cm wire insect collection cages. The cage floors were lined with felt to avoid abrasion of the latex by the cage wire during the trials. Pond and river trials were conducted using wire cages at the CU Aquaculture farm and at Six Mile Creek in the CU Experimental Forest (CUEF), respectively, and consisted of 80 individual balloons of each of the three colors in each box. Balloons were then collected and maximum mean diameter was measured as before. Maximum mean diameter was recorded at two week intervals for ten weeks for all conditions, and after ten weeks, aquatic trials were sampled at four week intervals for an additional 12 weeks.

Field plots —Field trials were conducted on two sites in the CUEF and another two on private land in Antreville, South Carolina. The first CUEF plot was conducted in the north forest in an open field adjacent to Wildcat Creek within 91m of the forest road

crossing; the second was in a cove on Lake Hartwell at the shoreline near Fants Grove. Two trials were conducted at the Wildcat Creek location and a third at Fants Grove. The two sites in Antreville occurred on a privately owned plot of 75.67 hectares, and consisted of an open field and an edge of a wetlands habitat. Of these, two trials were conducted at the field and five at the wetlands site. Treatment plots consisted of two 3m x 3m areas separated by a 3m expanse. Areas were marked with survey flags. One area functioned as a control, the second served as the experimental area. Each area was monitored by a Moultrie Game Spy I-45s (Birmingham, AL) motion activated camera set approximately 3m away from the outside corner of the plot. Cameras were placed at a 45^0 angle to allow for overlap of field of view for each camera to allow for greater camera capture of approach of wildlife to either area. Camera activation was set on a three picture burst, and recorded date, time and temperature upon image capture. Twenty-five Tuf-tex® balloons, in a variety of colors, were cut into the shapes and sizes observed from the atmospheric trials, and then added to the experimental area of the plot to determine if there was a significant attraction due to the latex fragments. The placement of latex balloon fragments was approved by the CU Institutional Animal Care and Use Committee (IACUC) and the South Carolina Department of Natural Resources (SCDNR). Neither treatment area was supplemented with additional attractant and latex gloves were used to place survey flags and latex fragments so contact with skin would not affect attraction. Plots remained in place to collect data for 48 to 72 hours.

Statistical analysis — The data analysis consisted of three steps for the three objectives. The first step involved description of the distances traveled by the balloons. A box plot

was used to display several descriptors of the distribution traveled, such as maximum, minimum, median, and mean. The second step was to compare mean degradation across exposure treatments and time. A model was developed in which degradation was a function of treatment and time. ANOVA was used to determine overall significance of treatments and time effects on mean degradation; and Tukey's difference test was used to compare means of specific treatments and times. The third step was to compare frequencies of specific wildlife occurrences between areas with balloons present and not present within a plot. A generalized linear model was developed that related frequency to plot and area using Poisson distribution to determine overall significant differences among frequencies of visitation between plots and visitation of species between plots. All calculations were performed using SAS version 9.2 (SAS Institute, Inc., Cary, NC; http://www.jmp.com).

RESULTS

Dispersal of balloons — Forty responses with location information (0.7%) were received from the 5600 labeled balloons released. The mean distance traveled was 70.16 km (median 33.8 km, SD = 92 km; Fig. 1, 2). Outliers were recovered from Clarendon County, South Carolina, and Reidsville and Goldsboro, North Carolina with distance traveled of 270, 341 and 451 km, respectively (Fig. 1). Recovered balloons were reported to be shredded or tattered.

Atmospheric effects — The payload was retrieved 111 km northeast of release in Rutherfordton, North Carolina. All 28 cm balloons were ruptured. Mean weight of individual balloons before release was 3.38g, and combined weight of latex balloons was

94.65g. The largest percentage (81.85%) came down partially intact with a mean weight of 1.69g per piece (~77.5g total weight), and typically were observed to have a radial fraying around a central circular mass (Fig. 3). Approximately six percent came down intermediate sized (~5.50g total weight; fig. 4), were ~ 2.5-5cm^2 in total area, and occurred in various shapes. The remaining fragments were the smallest in size and represented 12.35 percent (11.69g), with the recovered pieces comprising 9.1 percent (8.61g) of the total weight. Fragments were shredded into thin, 0.50 to 2.50 cm long ribbons (Fig.5). Lost material (3.08g) was assumed to have a similar structure to the smallest fragments and most likely passed through the 2mm mesh of the net.

Degradation of latex balloons — Latex rapidly lost elasticity in air-exposed treatments, but remained elastic when submerged. The ANOVA for the two week treatments (n=30 per condition) showed no significant difference in maximum mean diameter between the control (34.85cm), and pond (30.10cm). The river (25.97cm), shade (14.56cm) and sun (12.79cm) trials did differ significantly from the control and pond (ANOVA; df = 4, 145, F = 31.94, $P < 0.0001$; Fig. 6). At four weeks, the control (34.85cm) differed significantly from pond (26.32cm), pond from river (16.53cm), and river from shade and sun (9.15 and 5.66cm, respectively; ANOVA; df = 4, 147, F= 71.65, $P < 0.0001$). The six week sample showed a similar significance between control and pond (28.93cm), however 95% of the remaining river sample was lost due to heavy rains. What remained (5%) showed no significant difference between pond and river (n=10, 24.73cm), but river was significantly different than shade (6.90cm) and sun (5.53cm; ANOVA; df = 4, 126, F = 157.17, $P < 0.0001$). At eight weeks, control was still significantly different than pond

(26.61cm), as pond was with shade and sun (5.65 and 3.89cm, respectively; ANOVA; df = 3, 116, F = 295.36, $P < 0.0001$). At ten weeks, control and pond (28.99cm) were still significantly different, as was pond with shade and sun (6.01 and 4.69cm, respectively; ANOVA; df = 3, 115, F = 227.68, $P < 0.0001$). Tukey's difference to compare specific treatments and times demonstrated pond trials did not change significantly throughout the 22 week duration of the trial (ANOVA; df =7, 235, F = 0.34, $P = 0.9360$; Fig. 6).

Field plots — Motion cameras predominately caught images of raccoon (*Procyon lotor*) and white-tailed deer (*Odocoileus virginianus*) with little variation. Frequency of camera activation by wildlife showed no significant difference between treatment plots (GLMM; df = 1, 87, F = 0, $P = 0.9998$) or difference in treatment by species (GLMM; df = 5, 87, F = 2.23, $P = 0.0587$) with Poisson distribution. Wildlife activating the cameras for the control plots were raccoon, deer, great blue heron (*Ardea herodias*), grey squirrel (*Sciurus carolinensis*) and coyote (*Canis latrans*) with frequencies of $n = 35, 25, 1, 1$, and 1, respectively. Species photographed at the latex plots were raccoon, deer, coyote, heron and gray fox (*Urocyon cinereoargenteus*) with frequencies of $n = 5, 16, 1, 1$, and 1, respectively. Latex was undisturbed in each trial. Due to camera malfunction, no data was recorded for two trials at Antreville.

DISCUSSION

Dispersal of balloons — Balloon return was lower than expected, Stocker *et al*. (1990) recorded a return rate of ~ 4.5% for balloons in studies of atmospheric transport of pollutants; in our study, the return rate was 0.7%. This may be related to the land cover in South Carolina; 5.2 million ha (63%) of land in the state is forested, 3.1 million ha

(15.5%) is agriculture/pastureland, and 0.79 million ha (9.5%) is wetlands or water (Conner *et al*., 2009). The remaining 1 million ha (12%) is urban or developed (Fig. 6). Every reported balloon was recovered in a developed area, either a residence or a place of work, indicating that all balloons found landed in 12% of the state's total land cover and within a median distance of 34 km from point of release. Therefore, there is a low probability of humans encountering the balloons released.

Another factor influencing the return rate may be due to the delay in time of release after pre-game inflation. Balloon gas is a mixture of helium and air. Once inflated, latex balloons immediately begin to lose helium; this results in irregularities in rate of ascent, and affects the dispersal of the balloons. Stocker *et al*. (1990) found that 30cm balloons released 20 min after inflation maintained a relatively tight clustering after traveling 100 km, while three balloons that were allowed to diffuse helium for two h before release were recovered at 75, 75, and 250 km along the same flight path. Balloons that have diffused helium may not have the necessary lift to quickly reach an altitude of rupture and may be carried greater distances by the jet stream (Walde *et al*., 2007). Central Spirit begins filling balloons from one to four hours before a game day release. The three outliers of 270, 341 and 451 km demonstrate that the latex balloons do have the potential to travel substantial distances, and in the case of CU football releases, can reach the coastline and the Atlantic Ocean.

Atmospheric effects — Recovery of the balloon fragments confirmed the size and morphology of latex balloons as they would be encountered in the environment, with 12% of the total material shredded into small pieces as previously proposed (Burchette,

1989). Over 85% of the recovered latex fragments may still be large enough to potentially cause a complication in an animal that ingests the material, and due to morphological characteristics may readily be consumed by seabirds or sea turtles (Fig. 3). Research conducted on juvenile green sea (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles demonstrated that the turtles would actively approach and consume the latex material (Lutz, 1989). Similar results were observed in trials conducted simultaneously with this study (Irwin, 2012).

Degradation of latex balloons — After two weeks, signs of degradation were evident in the pliability of the latex material in the air-exposed sun and shade trials, as was demonstrated by difference in maximum diameter versus the control. These groups were subjected to the greatest stress from oxidation (photodegradation) and ozonolysis; the primary factors responsible for the breakdown of latex (Andrady *et al*., 1998; Somers *et al*., 2000). Material failure occurred nearly instantly at eight weeks in the majority of balloons upon the introduction of enough pressure to cause any test of elasticity. By week ten, the outer surface of the material appeared scored, cracks of complete material failure occurred in areas folded by the balloon's own weight, and any effort in manual stretching would result in ripping of the material. The river trial showed a slower rate of degradation, but was terminated by a period of heavy rainfall that washed away the remaining sample at week six. The pond trial occurred in a highly eutrophic catfish pond; therefore balloons in this sample were exposed to the lowest levels of oxidation and photodegradation. Latex balloons in this trial demonstrated an initial decline in mean maximum diameter from the control at two weeks, but afterwards displayed little if any

change in elasticity throughout the twenty-two week period tested. The rates of degradation indicate that balloon materials landing on a terrestrial environment will lose much of their elasticity the first month and become brittle by eight to ten weeks of exposure. Submersion in water retarded the degradation rate, and when the latex was submerged in a low oxygen environment with little light penetration, elasticity was retained for a markedly longer time span. Latex that retains elasticity without breakage and does not pass through the digestive tract would pose the greatest risk of creating a blockage.

Field plots — Examination of the images captured by the motion-activated cameras revealed little visitation to either the control or latex plots. The Antreville plots revealed a greater visitation and diversity of species bordering the marsh habitat, while the CUEF plots captured almost exclusively deer with the exception of one fox examining the latex plot at the Fants Grove location. Observations were made of wildlife examining the latex; deer inspected the latex in five images, raccoons twice, and a fox once. No evidence was observed of any disturbance or removal of any of the latex fragments during the trials, and no observations were made of avian or other species approaching or examining the latex; photos of the heron in each instance captured the heron at the periphery of the latex plot standing in an adjacent creek.

Conclusions — From this study, definitive answers were obtained as to the fate of latex balloons after release, and how and in what form balloons may come into contact with wildlife. While the total number of recovered balloons was small, the possible distance traveled established that balloon releases from the CU football games can reach the

Atlantic Ocean. Degradation trials demonstrated latex balloons rapidly become brittle in terrestrial conditions, but submerged pieces remained elastic for the six month trial period. Pieces recovered from rupture were large enough to present a gastrointestinal blockage if the material is conducive to such actions in the GI tract of a given species, although camera trials as conducted did not indicate the balloons attracted wildlife. In addition, the field plots examined terrestrial conditions and areas adjacent to lakes and wetlands in the upstate of South Carolina. Future studies performing trials in environments along the coastline would provide additional information of the potential for seabirds and wetland species to be attracted by or consume latex fragments.

LITERATURE CITED

Andrady, A.L. 1989. Environmental degradation of plastics under land and marine exposure conditions. *In* R. S. Shomura and M. L. Godfrey (editors). Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989. Honolulu, Hawaii.

Andrady, A. L., S. H. Hamid, and A. Torukai. 1998. Effects of increased solar ultraviolet radiation on materials. Journal of Photochemistry and photobiology B: Biology 46 (1998) 96-103

Averill-Murray R.C., and A. Averill-Murray. 2002. Distribution and density of tortoises at Ironwood Forest National Monument. Sonoran Herpetologist 15:7 78-79

Bjorndal, K. A., A. B. Bolten, and C. J. Lagueux. 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. Marine pollution Bulletin 28(3) 154-158

Bugoni, L., L. Krause, and M. V. Petry. 2001. Marine debris and human impacts on sea turtles in southern Brazil. Marine Pollution Bulletin 42 (12) 1330-1334

Burchette, D.K. 1989. A study of the Effect of Balloon Releases on the Environment. Final Report presented to National Association of Balloon Artists.

Clean Virginia Waterways: Balloons as litter--a problem we can solve. 2010. Clean Virginia Waterways, Longwood University, 201 High Street, Farmville, VA 23909. Retrieved January 16, 2010 from http://www.longwood.edu/cleanva/balloons.htm

Conner, R. C., T. O. Adams, T. G. Johnson, and S. N. Oswalt. 2009. South Carolina's forests, 2006. Research Bulletin SRS-158. Asheville, NC: USDA Forest Service, Southern Research Station. 57p.

Ferris L. 2009.What goes up must come down. Fourth Crossing Wildlife Australian Seabird Rescue. www.fourthcrossingwildlife.com/WhatGoesUp-LanceFerris.htm. (Accessed March 18, 2011)

Fry, M., S. I. Fefer, and L. Sileo. 1987. Ingestion of plastic debris by Laysan Albatrosses and Wedge-tailed Shearwaters in the Hawaiian Islands. Marine Pollution Bulletin (18, 6b) 339-343

Gregory, M.R. 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. . Philosophical Transactions of the Royal Society B 2009 (364) 2013-2025

Irwin. S. 2012. Mass Latex Balloons Releases and The Potential Effects on Wildlife. Dissertation. Clemson University, Clemson, South Carolina

Laist, D. W. 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. Marine Pollution Bulletin 18 (6B) 319-326

Lutz, P. L. 1989. Studies on the Ingestion of Plastic and Latex by Sea Turtles. *In* R. S. Shomura and M. L. Godfrey (editors) Proceedings of the Second International Conference on Marine Debris. Honolulu, Hawaii. U.S. Department of Commerce, NOAA Technical Memo.

Marine Conservation Society, 2006. Balloon releases: pollution factsheet. 9 Gloucester Road Ross-on-Wye Herefordshire HR9 6BU Tel. 01989 566017 Fax. 01989 567815 http://www.mcsuk.org Registered Charity 1004005

Mee, A., B. A. Rideout, J. A. Hamber, J. N. Todd, G. Austin, M. Clark, and M. P. Wallace. 2007. Junk ingestion and nestling mortality in a reintroduced population of California Condors (*Gymnogyps californianus*). Bird Conservation International 2007 (17) 119-130

Moser, L. M. and D. S. Lee. 1992. A fourteen-year survey of plastic ingestion by western North Atlantic seabirds. Colonial Waterbirds 15 (1) 83-94

Plotkin, P. and A. F. Amos. 1989. Effects of Anthropogenic Debris on Sea Turtles in the northwestern Gulf of Mexico *In* R. S. Shomura and M. L. Godfrey (editors) Proceedings of the Second International Conference on Marine Debris. Honolulu, Hawaii. U.S. Department of Commerce, NOAA Technical Memo.

Roberts, A. M. 1995. Dynamics of free-floating gas-filled rubber balloons. Physics Education Vol 30:109-113.

Somers, A. E., T. J. Bastow, M. I. Burgar, M. Forsythe, and A. J. Hill. 2000. Quantifying rubber degradation using NMR. Polymer Degradation and Stability 70 (2000) 31-37

Stamper, M. A., C. W. Spicer, D. L. Neiffer, K. S. Mathews, and G. J. Fleming. 2009. Morbidity in a juvenile Green Sea Turtle (*Chelonia mydas*) due to ocean-borne plastic. Journal of Zoo and Wildlife Medicine 40 (1) 196-198

Stevenson, A. and A. G. Thomas. 1979. On the bursting of a balloon. Journal of Physics D: Applied Physics 1979 (12) 2101-2109

Stocker, R.A., Pielke, R.A., Verdon, A.J., and Snow, J.T. 1990. Characteristicis of Plume Releases as Depicted by Balloon Launching and Model Simulations. Journal of Meteorology 29:53-62.

Thompson, R.C., C.J. Moore, F. S. vom Saal, and S. H. Swann. 2009. Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B 2009 (364) 2153-2166

Tomas, J., R. Guitart, R. Mateo, and J. A. Raga. 2002. Marine debris ingestion in Loggerhead Sea Turtles, *Caretta caretta*, from the Western Mediterranean. Marine Pollution Bulletin 44 (2002) 211-216

Walde AD, Harless ML, Delaney DK, Pater LL. 2007. Anthropogenic threat to the desert tortoise (Gopherus agassizii): litter in the Mojave desert. Western North American Naturalist 67:1 147-149

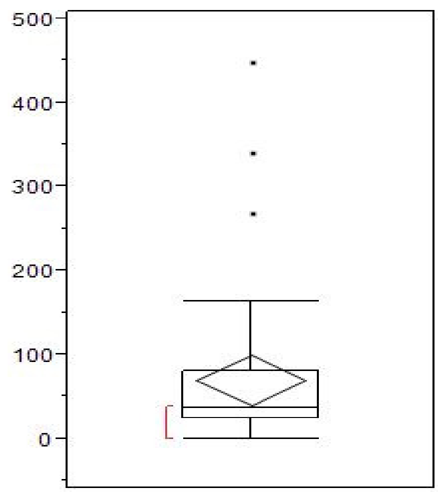


Fig 1. Distance traveled (km) by latex balloons from Clemson University football games with outliers.

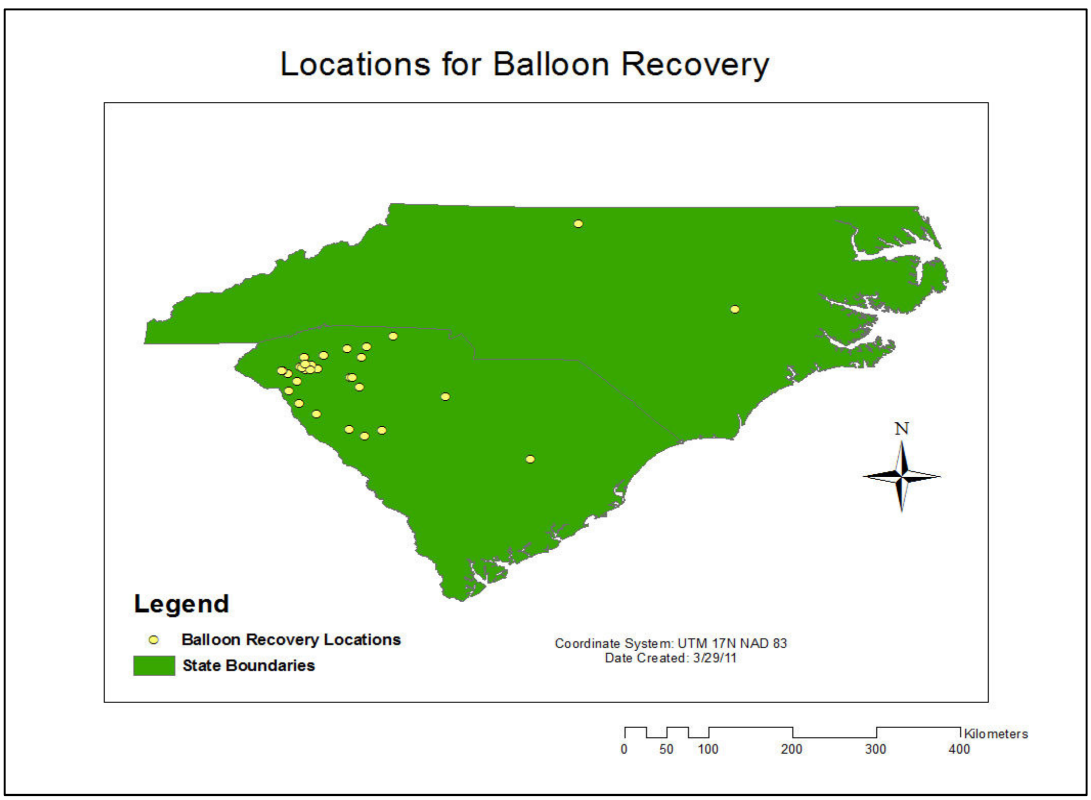
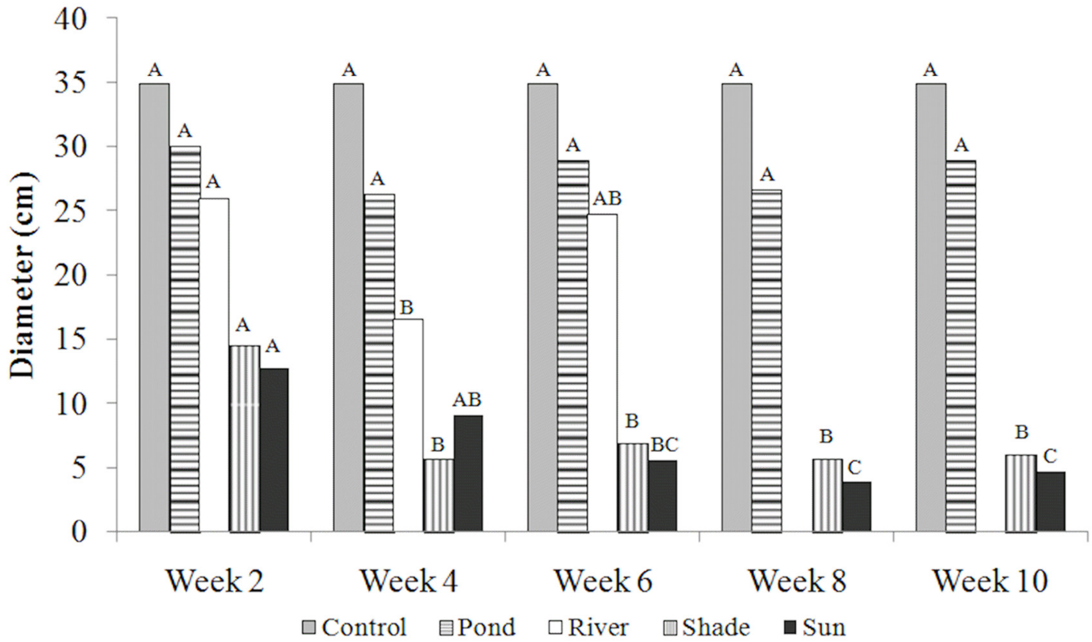


Fig. 2. Location of balloon recoveries after release from Clemson University football games in North and South Carolina.

Fig. 3. Large balloon fragments (81.85% total weight released) recovered after rupture in upper atmosphere

Fig. 4. Medium balloon fragments (5.8% total weight released) recovered after rupture in upper atmosphere

Fig. 5. Small balloon fragments (9.1% total weight released) recovered after rupture in upper atmosphere



Means with the same letter are not significantly different for each treatment over time

Fig. 6. Mean maximum diameter (cm) for latex balloons for each treatment (n= 30) in two week intervals. Means sharing the same letter are not significantly different.

CHAPTER 2

Physiological Effects of Ingestion of Latex Balloon Fragments in Three Species

INTRODUCTION

For many years mass latex balloon releases have been used to celebrate a variety of public events from holidays to sporting events. Concern has risen over these releases as to what risk the balloons pose to wildlife (Marine Conservation Society, 2006). This concern is based on the detrimental effects on the environment and wildlife from plastic waste and litter (Thompson *et al*., 2009), although natural latex balloons are not plastic. Various forms of plastics and litter are readily consumed by a number of different wildlife species. Studies have shown that seabirds, such as Laysan albatrosses (*Phoebastria immutabilis*) and Wedge-tailed Shearwaters (*Puffinus pacificus*), are prone to ingesting plastics they pick up in the surf while scavenging for food, and as a result they have been found to carry a large gut-load of the indigestible material (Fry *et al*., 1987). Unfortunately for nesting chicks, a large part of their diet may be composed of this non-nutritive and potentially obstructive material, causing a decline in growth, general health, or impaction leading to death (Sileo *et al*., 1990). Terrestrial birds and waders are affected as well; Henry *et al*. (2011) observed gut occlusion and death solely from rubber band consumption in White Storks (*Ciconia ciconia*) scavenging dumps, and Mee *et al*. (2007) found significant accumulations of plastics and other indigestible material in the gut contents of deceased California Condor (*Gymnogyps californianus*) nestlings. Sea turtles have proven to be particularly susceptible to ingestion of plastic debris, from sheets of polyurethane to bits of loose netting and plastic bottles – as well as Mylar

(BoPET) and latex balloons (Tourinhno *et al*. 2010; Stamper *et al*. 2009; Tomas *et al*., 2002). Desert tortoises (*Gopherus agassizii*) have been observed to consume latex balloon materials and become entangled in attached ribbon or string (Averill-Murray and Averill-Murray, 2002; Walde *et al*. 2007). And although less visible, numerous fish species have shown to readily consume plastics and may also be at risk to any detrimental effects presented by balloon consumption (Hoss and Settle, 1990; Boerger *et al*., 2010, Possatto *et al*., 2011).

Studies concerning the effects of latex balloons on wildlife are limited. In 1989, the National Association of Balloon Artists (NABA) released a report on mass latex balloon releases as they occur in the environment. Amidst the assertions that latex balloons were harmless, the report maintained that a safe latex balloon release should follow certain guidelines; such as only using 100% natural latex balloons, hand-tied and without plastic clasps, and with any string or ribbon attached being no less degradable than latex (Burchette, 1989). Currently the International Balloon Association (IBA) recommends no strings or attachments either, as string has proven to present a hazard through entanglement (IBA, 2009; Averill-Murray and Averill-Murray, 2002; Walde *et al*. 2007). Preliminary research on the effects of latex balloon fragments on two species of juvenile sea turtles has been conducted, and resulted in potential nutritive uptake impairment (Lutz, 1989). Other aspects of health demonstrated no measureable changes in the physiological parameters examined, with a conclusion by the author that more research needed to be conducted. For the purposes of this study, only natural latex was used.

In order to properly assess the health effects that ingestion of latex materials may have upon the digestive physiology in different groups of vertebrate wildlife, three representative species underwent closely monitored feeding trials of latex balloon material. This study examined the pre- and post-trial H/L and N/L ratios, body mass over the duration of the trials, and health of the digestive tracts of these species after ingestion of latex balloon materials over a one month period. Stress as a result of environmental or internal factors upon species has been successfully measured through observation of heterophil to lymphocyte (H/L) ratios. The H/L ratio has been conclusively determined to be an indicator of physiological stress in birds and reptiles (Gross and Siegal, 1983; Davis *et al*., 2008). Comparatively, the neutrophil to lymphocyte (N/L) ratio is a reliable indicator of physiological stress in fish (Davis *et al*., 2008). The trial species were Japanese quail (*Coturnix japonica)*, Red-eared sliders (*Trachemys. scripta elegans*), and channel catfish (*Ictalurus punctatus*), to represent the birds, reptiles and fish that may be impacted by latex balloons in aquatic environments and wetlands.

METHODS

Study sites — All studies of feeding trials occurred in laboratory facilities on or near the Clemson University (CU) campus, Clemson, South Carolina. Quail were housed at the Morgan Poultry center, turtles at the Biosystems Research Complex, and catfish at the CU Aquatic Research laboratory.

Feeding trials — All specimens were separated individually throughout the trials and maintained for a minimum one week acclimation period for adjustment to conditions and to ascertain health. Temperature range was recorded daily for each facility. After the

acclimation period, two trials per week were performed for four weeks during routine feeding by offering latex fragments to each specimen. A variety of shapes and colors were offered until a preference was determined. Fecal material was collected when present and examined for presence of latex. To monitor health, body weight (g) was measured once weekly to examine for loss, and animals were monitored daily throughout the experiment for abnormal behavior. All specimens were euthanized upon conclusion of feeding trials, and necropsies were performed to examine the digestive tract for anomalies and retention of latex fragments. Before the feeding trials, and again upon completion of the study, one to two drop venous blood samples were obtained to examine H/L ratios. Blood was immediately plated to two microscope slides per specimen, smeared, and allowed to dry. Slides were stained using Camco Quik Stain II (Fort Lauderdale, Florida). H/L ratios were determined by counting the number of heterophils and lymphocytes per slide to total 100, and then averaging the sums of the two slides per specimen to find the proportion of each (Campbell and Ellis, 2007; Taira, pers. comm.).

Quail — Japanese quail consisted of twenty adult quail hens provided by Manchester Farms, Columbia, South Carolina. Hens alone were used to avoid intrasexual stress in males due to housing conditions, and were housed in individual cages in a vertical unit with *ad libitum* access to food and water. Feeding trials began by offering approximately 3cm X 3mm elongate latex strands to mimic a worm-like appearance in a variety of colors until color preference of pink was established. Approximately ten pieces per trial (≈0.25 g) were offered during the first week, but as material was rapidly consumed, the amount was increased to 20 fragments (≈0.50). Fragments that were not consumed

during observation were placed in feeding bowls overnight, with the intent of quantifying remaining fragments from droppings to provide an estimate of latex consumed. Blood samples were obtained via the alar vein. Specimens were euthanized with CO^2 gas followed by cervical dislocation (AVMA, 2007).

Turtles — Red-eared sliders were obtained from Turtle Shack, Port Richey, Florida. Fifteen adult sliders of approximately 15 to 20 cm carapace length were housed individually in eight, 568 liter Rubbermaid® tubs divided into two partitions by an acrylic barrier. Turtles were provided with eight inches of water and a basking platform, and were fed Repto-min® *ad-libitum* once daily. Latex pieces approximated 1.5 cm^2, and were cut into a different shape for each feeding trial (approximately 0.5g per trial) to determine time of passage through the digestive tract. A range of colors were offered the first week, and green and yellow were chosen to mimic the color of naturally consumed vegetation in an attempt to stimulate ingestion. Initially ten of the fifteen sliders seemed unresponsive to the latex, so fragments were left up to 48 hours to promote consumption. Blood samples were obtained via the dorsal coccygeal vein. At the end of the trials turtles were anesthetized with 200mg/kg IM Ketamine, followed by euthanasia with 120mg/kg intraperitoneal sodium pentobarbital and subsequent pithing of the brain (AVMA, 2007).

Catfish — Channel Catfish were obtained from a stock grown at the Clemson Aquaculture Facility. Twenty fish, approximately 10 to 15 cm total length, were maintained individually in 19 liter substrate-free aquaria as part of a flow-through system supplied with fresh water from Lake Hartwell. Fish were fed Li'l Strike® pelleted food ad libitum once daily. Catfish were initially unresponsive in preliminary tests using 4mm cut

circles of various colors; the pieces floated and were odorless, and the fish showed no interest. To counter the latex buoyancy, roughly 3 cm x 4mm strips of latex (0.04g mean weight per piece) were threaded through a small puncture in 0.5-0.8 g slices of raw chicken liver. The liver also acted to attract the catfish, and all specimens readily consumed the latex. Uneaten latex materials were left for 24 hours. At week three, the quantities of latex and liver were doubled, and still completely consumed. Blood samples were taken from the ventral caudal vein to examine neutrophil to lymphocyte (N/L) ratios. Fish were sacrificed by submersal in buffered 1000 mg/L MS-222 (tricaine methanesulfanate) followed by decapitation (AVMA, 2007).

Statistical Analysis — Pre- and post-trial H/L or N/L ratios for each of the three species feeding trials were analyzed using a paired t-test. A model was written in which weight was a function of specimen and week. ANOVA was used to determine overall significance of week effects on mean weight; and Fisher's LSD test was used to compare the weights between weeks. All calculations were performed using JMP version 9.0 (SAS Institute, Inc., Cary, NC; http://www.jmp.com).

RESULTS

Quail trials —Latex balloon consumption had no measured effect on quail in this study. Examination of mean H/L ratios in *C. japonica* (n=20) revealed no significant difference after four weeks of latex consumption (Paired t-test, df = 1, t = 2.09, $P = 0.11$). Mean pre-trial H/L ratio for quail was 0.45 ± 0.17 with a range of 0.17 to 0.79, post-trial ratio was 0.39 ± 0.14 , ranging from 0.09 to 0.74. Weight increased significantly over the five week period of acclimation through trials (ANOVA, df = 4, 76, F = 10.40, P < 0.0001), and

differed significantly between weekly means (Fisher's LSD test, df = 4, 76, t = 1.99, $P < 0.0001$,Table 1). Necropsies of the crop, proventriculus, gizzard, and intestinal tract (including cecae) revealed no signs of blockage or irritation in any specimen examined. Two quail had latex fragments exiting through the gizzard-duodenal junction, one had a ground piece in the gizzard (Fig. 1), and a fourth contained latex broken down into several $2mm^2$ fragments just above the junction with the pyloric cecae.

Turtle trials — Sliders showed no change in H/L ratios or weight, but did accumulate latex in different degrees. Examination of mean H/L ratios in *T. scripta elegans* (n=14) revealed no significant difference between pre-trial ($\mu = 0.39 \pm 0.16$) and post-trial ($\mu = 0.45 \pm 0.21$) ratios (Paired t-test, df = 1, t = 2.16, $P = 0.24$). One specimen was omitted from the statistical analysis with an elevated pre-trial H/L ratio of 2.5, although that specimen's H/L ratio dropped to 0.55 post-trial; possibly due to an increase in the quality of living conditions. Pre-trial H/L range for RES was 0.16 to 0.72; post-trial was 0.17 to 0.66, with an outlier of 1.01. RES weight showed no significant difference over the five week period (ANOVA, df = 4, 48, F = 1.23, P = 0.31), but did fluctuate slightly between weekly means (Table 1). Necropsies revealed different quantities of latex, with four sliders having cumulative latex in the digestive tract of 1.74, 2.78, 2.98, and 4.04g. Three specimens had substantial accumulations in the stomach of 21, 22, and 24 pieces (1.24g, 1.36g, and 1.31g, respectively, Fig.2). These individuals showed a change in H/L ratio of +0.28, -0.09, and +0.14. One specimen had latex masses occurring in upper, mid, and lower colon, while two others had masses only in the upper colon and another only the lower colon. Intestinal masses ranged from 1.08 to1.52 g (Fig. 3). Recovered fragments

from necropsies revealed the rate of time latex materials remained in digestive tract ranged from one to 23 days, with 48% of all items fed within the past seven days, 75% within 14 days, and 90% within 21 days.

Catfish trials — Latex consumption had no measured effect on catfish health. Feeding trials demonstrated a significant decrease in H/L Ratios (Paired t-test, df = 1, t = 2.10, $P <$ 0.02), with mean pre-trial and post-trial ratios of 0.044 ± 0.03 and 0.028 ± 0.02, respectively. Pre-trial H/L ratio range for *I. punctatus* was 0.01 to 0.12; post-trial was 0.02 to 0.06. Time of passage for latex pieces ranged from one to seven days, with percentages of total time for latex passed per day as roughly 33%, 18%, 15%, 21%, 10%, 2%, and less than 1%, respectively. Analysis of weight over the duration of the study resulted in a significant increase over time (ANOVA, df = 3, 54, F = 18.10, P < 0.0001), and between weekly means (Fisher's LSD test, df = 3, 54, t = 2.00, P < 0.0001, Table 1). Necropsies revealed healthy digestive tract tissues without any anomalies or blockages.

DISCUSSION

Quail trials — The analyses of passage times and weight did not reveal significant latex accumulation or wasting from latex consumption in quail. Actions from digestion prevented a reasonable summation of latex fragments occurring in droppings, as strands were broken down into small particles with little remaining pigmentation, and were largely indiscernible from regular excreta. A modest estimate of latex consumed per hen over the four week trials was a mean of 0.85g, with a range from 0 to 2.5g. Gut passage rates in White Leghorn hens (*Gallus Gallus domesticus*) have been determined from 2.5 to 12 hours for near complete elimination, with a peak of roughly four hours (Dunkley *et*

al., 2008). Similarly, Harlander-Matauschel *et al*. (2005) estimated 50% elimination of all passage markers in Rhode Island Red hens within five hours. The last feeding trial occurred two days prior to euthanasia, and four quail contained amounts of latex in the stomach or intestinal tract of less than 0.05g. This suggests latex fragments do have the potential to remain in the digestive tract longer than the grain diet; however, nearly all of the latex consumed was broken down by digestive action and passed within 48 hours. Ingestion of latex did not detectably impair nutrient uptake for growth, and an increase in weight was expected as hens used were approximately seven weeks old when obtained and not fully mature. Some daily fluctuation in weight was anticipated as well; each hen typically laid one egg per day (≈14.0 g).

Comparison of H/L ratios pre- and post-trial did not indicate that the quail suffered any prolonged physiological stress as a result of consumption of latex. H/L ratios in Japanese quail exhibit some variation in the literature; Nazar and Marin (2011) found non-stressed *C. coturnix japonica* hens in enriched environments to have H/L ratios of roughly 0.5 to 0.6 with stressed hens over 1.0, and Coban *et al.* (2009) observed non-stressed hens in photoperiod trials to have an H/L ratio of 0.60 ± 11. In contrast, Janes *et al.* (1994) observed control groups with a mean H/L ratio around 0.30, while virus-inoculated quail approached 1.0. The mean H/L ratios of 0.45 ± 0.17 and 0.39 ± 0.14 in this study do not suggest the quail were experiencing any physiological stress as measured by that parameter.

Turtle trials — Latex passage rates in sliders fell within normal parameters and weight remained relatively constant, although accumulation of latex in a few digestive tracts was

observed. First signs of latex gut passage occurred as individual pieces recovered in holding tanks, and by week four, masses were recovered consisting of nine to twelve latex fragments adhering together. Pieces from the masses had a mean transit time after ingestion of 7.49 ± 3.02 days. Transit times in turtles varies with temperature, diet, and species; Florida Red-Bellied Turtles (*Pseudemys nelsoni*) have been observed to have a mean transit time of 68 ± 2 hrs, Leopard Tortoises (*Stigmochelys pardalis*) with transit times of 6 to 6.95 days, and Loggerhead Turtles (*Caretta caretta*) up to 13.25 ± 4.86 days (Bjorndal and Bolten, 1993; Valente *et al*., 2008). Bjorndal and Bolten (1993) determined a transit time in *T. scripta elegans* of 72 ± 26 hours and 164 ± 46 hours as dependant on digestibility of two differing plant diets. Turtles in the present study had relatively similar transit times to previous studies with *T. scripta elegans*, despite the accumulation of latex in the stomachs and intestinal tracts of some specimens. Turtles with blockages have demonstrated gastrointestinal disease signs including anorexia and weight loss; Stamper *et al.* (2009) observed cachexia in a juvenile Green Sea turtle with gastrointestinal obstruction from plastic refuse (it should be noted, latex balloon material was present), and Reidarson *et al.* (1994) diagnosed similar conditions in a captive Hawksbill turtle (*Eretmochelys imbricate*). Additionally, food-deprivation studies performed on Eastern Painted Turtles (*Chrysemys picta picta*) conducted over 50 and 65 day trials resulted in immediate and significant weight loss as compared to controls (Morlock *et al.*, 1972). No Red-eared Sliders, including those with large accumulations of latex, significantly lost weight over the course of these trials or exhibited other signs of

gastrointestinal disease seen in reptiles, such as lethargy, anorexia, or prolapse (Benson, 1999).

Pre- and post-trial H/L ratios did not indicate physiological stress from consumption of latex for *T. scripta elegans*. Ratios of 0.39 and 0.45 correspond with the values of 0.3 to 0.45 for non-stressed Western Pond Turtles (*Emys marmorata*) as observed in studies on the effects of water treatment plants (Polo-Cavia *et al*. (2009). Additionally, Keller *et al*. (2004) documented correlations between organochlorine concentrations and H/L ratios ranging from 0.3 in slightly contaminated to over 1.0 in highly contaminated Loggerheads, and Yu *et al*. (2011) found Red-eared sliders with H/L ratios from 0.02 to 1.63 correlating with degree of metal accumulation in tissues. In both of these studies, the degree of physiological stressor resulted in markedly higher H/L ratios approaching or exceeding 1.0. Sliders in this study maintained comparatively low ratios both before and after the trials.

While no anomalies attributable to latex were observed, all specimens exhibited some degree of stomach and intestinal parasitization from Spirurid nematodes (*Serpinema spp*), regularly found in the upper digestive tract of North American freshwater turtles (Mader, 2006). Thickening of duodenal tissue occurred in a few parasitized individuals with twenty plus worms. The turtle with an outlying post-trial H/L ratio demonstrated an increase in ratio of 0.29, ate only two, 1 cm^2 pieces of latex throughout the trial, and passed three, 7 cm Acanthocephalan worms (*Neoechinorhyncus emyditoides*) the second week (Barger and Nickol, 2004). The necropsy revealed three additional equally sized worms. One other necropsy revealed six helminths of the same

description, with a similar increase in H/L ratio of 0.28, suggesting that the parasites may have some role in the increase of H/L ratios in the two specimens.

Catfish trials —Transit time of latex through the gut was slower than passage rates found in previous research for Channel Catfish, but had no observable effect on weight gain. Latex materials were easily recovered after passage through the gut, with a third of all latex consumed eliminated in one day and over half within two days at a mean temperature throughout the trials of 23.9^0 C. At that temperature, Shrable *et al*. (1969) observed evacuation of 88% of all materials fed from the stomach and intestine of *I. punctatus* within 24 hours. Necropsies revealed undamaged, healthy tissue with no apparent signs of ulceration, irritation, or thickening of the intestinal and stomach tissues. Only one fish still contained any fragment of latex, as specimens were offered fragments three days prior to euthanasia. The remaining fragment was discovered in close proximity to the anus. No signs of erratic behavior or other signs of distress were noted, and fingerlings continued to grow at a steady rate until completion of the trials.

The drop in N/L ratios observed in *I. punctatus* may be due to an increase in the quality of living conditions provided by the flow through system, as specimens were individually housed, fed, and supplied with a constant influx of fresh water. Ellsaesser *et al*. (1985) observed channel catfish acclimated at 22^0C to have lymphocyte and neutrophil percentages of total leukocyte counts of 48 ± 8.7 and 2.7 ± 2.2, respectively, similar to the N/L ratios in this study. Additionally, *I. punctatus* subjected to transport stress or infection had lymphocyte and neutrophil percentages of roughly 30-35 and 18-22, respectively, demonstrating a substantial increase in N/L ratio for catfish subjected to

physiological stress (Ellsaesser *et al.*, 1985). The decline in N/L ratios for catfish in this study support that consumption of latex balloon fragments do not cause physiological stress.

Future considerations — The results of this study demonstrated ingestion of natural latex materials had little impact on physiological stress as measured by H/L and N/L ratios, had no negative effect on body weight from blockages or wasting, and showed no signs of internal retention in *C. coturnix japonica* or *I. punctatus*. It may likewise be implied to have the same result on species with similar morphologies and digestive traits. However, considering the diverse digestive physiologies among avian species, a study of a species with more digestive action from the proventriculus and less action from the gizzard may offer insight into the effects that latex consumption may have on a number of waterfowl. Trials on *T. scripta elegans* did not exhibit any differences from the other species in effects from latex apart from the transit time of the latex materials, although in extreme circumstances, it may be possible for a turtle to ingest enough material to impede nutrient uptake. Additionally, the turtles in this study possessed unknown parasite loads that may have contributed to physiological stress. As sea turtles are often cited as at risk for balloon consumption, a species with a more analogous digestive tract, such as the common Snapping Turtle (*Chelydra serpentine*), may better represent sea turtles in the potential for blockages and transit times for latex material (Wyneken, pers. comm.). This study only examined the short term effects of latex ingestion, therefore, a long term study using captive reared juvenile *C. serpentine* would allow for control of parasitism and

other health factors, and any impact on growth from nutrient dilution or other unforeseen effects could be observed.

LITERATURE CITED

American Veterinary Medical Association. 2007. AVMA Guidelines on Euthanasia (Formerly Report of the AVMA Panel on Euthanasia)

Anderson, R. C., A. G. Chabaud, and S. Wilmott (eds) 1974-1983. CIH Keys to the Nematode Parasites of Vertebrates. Nos 1-10. Commonwealth Agricultural Bureau, Farnham Royal, UK

Averill-Murray, R. C., and A. Averill-Murray. 2002. Distribution and density of tortoises at Ironwood Forest National Monument. Sonoran Herpetologist 15 (7) 78-79

Barger, M. A. and B. B. Nickol. 2004. A key to the species of *Neoechinorhynchus* (Acanthocephala: Neoechinorhynchidae) from Turtles. Comparitive Parasitology 71 (1) 4-8

Benson, K. G. 1999. Reptilian Gastrointestinal Diseases. Seminars in Avian and Exotic Pet Medicine 8 (2) 90-97

Bjorndal, K. A., and A. B. Bolten. 1993. Digestive efficiencies in herbivorous and omnivorous freshwater turtles on plant diets: do herbivores have a nutritional advantage? Physiological Zoology 66 (3) 384-395

Boerger, C. M., G. L. Lattin, S. L. Moore, and C. J. Moore. 2010. Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Marine Pollution Bulletin 60 (2010) 2275-2278

Burchette, DK. 1989. A Study of the Effect of Balloon Releases on the Environment. Final Report presented to National Association of Balloon Artists.

Coman, O., E. Lacin, N. Sabuncuoglu and Z. Ozudogru. 2009. Effect of self-photoperiod on live weight, carcass, and growth traits in quails (*Coturnix coturnix japonica*). Asian-Australian Journal of Animal Sciences 22 (3) 410-415

Campbell, T.W. and C. K. Ellis. 2007**.** Avian and Exotic Animal Hematology and Cytology, Third Edition. Blackwell Publishing, Ames, Iowa

Davis, A. K., D. L. Maney, and J. C. Maerz. 2008. The use of leukocyte profiles to measure stress in vertebrates: a review for ecologists. Functional Ecology (22) 760-772

Dunkley, C. S. W. K. Kim, W. D. James, W. C. Ellis, J. L. McReynolds, L. F. Kubena, D. J. Nisbet, and S. C. Ricke. 2008. Passage rates in poultry digestion using stable isotope markers and INAA. Journal of radioanalytical and nuclear chemistry 276 (1) 35-39

Ellsaesser, C. F., N. W. Miller, M. A. Cuchens, C. J. Lobb, and L. W. Clem. 1985. Analysis of Channel Catfish peripheral blood leucocytes by bright-field microscopy and flow cytometry. Transactions of the American Fisheries Society (114) 279-285

Fry, M., S. I. Fefer, and L. Sileo. 1987. Ingestion of plastic debris by Laysan Albatrosses and Wedge-tailed Shearwaters in the Hawaiian Islands. Marine Pollution Bulletin (18, 6b) 339-343

Gross, W. B., and H. S. Siegal. 1983. Evaluation of the heterophil/ lymphocyte ratio as a measure of stress in chickens. Avian Diseases 27 (4) 972-979

Harlander-Matauschek, A., H. P. Piepho, and W. Bessei. 2005. The effect of feather eating on feed passage in laying hens. Poultry Science 2006 (85) 21-25

Henry, P, G. Wey, and G. Balanca. 2011. Rubber band ingestion by a rubbish dump dweller, the White Stork (*Ciconia ciconia*). Waterbirds 34 (4) 504-508

Hoss, D. E. and L. R. Settle. 1990. Ingestion of Plastics by Teleost Fishes. *In* R. S. Shomura and M. L. Godfrey (editors) Proceedings of the Second International Conference on Marine Debris. Honolulu, Hawaii. U.S. Department of Commerce, NOAA Technical Memo.

International Balloon Association. 2009. Talking Points to Combat Negative Legislation http://www.ibaonline.net/TheBalloonCouncil/SpeakingPointstoOpposeBansonBalloons/tabid/102/Default.aspx (Accessed March 17, 2012)

Jacobson, E. 2007. Infectious Diseases and Pathology of Reptiles: Color Atlas and Text. CRC/Taylor & Francis, Boca Raton, Florida

Janes, M. E., R. K. Bower, and N. B. Anthony. 1994. The leukocyte response of Japanese Quail to Rous sarcoma virus-induced tumors. Avian Diseases 38 (3) 610-615

Keller, J. M., J. R. Kucklick, M. A. Stamper, C. A. Harms, and P. D. McClellan-Green. 2004. Associations between organochlorine contaminant concentrations and clinical health parameters in Loggerhead Sea Turtles from North Carolina, USA. Environmental Health Perspectives 112 (10) 1074-1079

Lutz, P. L. 1989. Studies on the Ingestion of Plastic and Latex by Sea Turtles. *In* R. S. Shomura and M. L. Godfrey (editors) Proceedings of the Second International Conference on Marine Debris. Honolulu, Hawaii. U.S. Department of Commerce, NOAA Technical Memo.

Mader, D. R. 2006. Reptile Medicine and Surgery, 2nd Edition. Saunders Elsevier, St Louis, Missouri

Marine Conservation Society, 2006. Balloon releases: pollution factsheet. 9 Gloucester Road Ross-on-Wye Herefordshire HR9 6BU Tel. 01989 566017 Fax. 01989 567815 http://www.mcsuk.org Registered Charity 1004005

Mee, A., B. A. Rideout, J. A. Hamber, J. N. Todd, G. Austin, M. Clark, and M. P. Wallace. 2007. Junk ingestion and nestling mortality in a reintroduced population of California Condors (*Gymnogyps californianus*). Bird Conservation International 2007 (17) 119-130

Morlock, H., S. Herrington, and M. Oldham. 1972. Weight loss during food deprivation in the Eastern Painted Turtle (*Chrysemys picta picta*). Copeia 1972 (2) 392-394

Nazar, F. N. and R. H. Marin. 2011. Chronic stress and environmental enrichment as opposite factors affecting the immune response in Japanese Quail (*Coturnix coturnix japonica*). Stress 14 (2) 166-173

Polo-Cavia, N., T. Engstrom, P. Lopez, and J. Martin. 2009. Body condition does not predict immunocompetence of Western Pond Turtles in altered versus natural habitats. Animal Conservation 2010 (13) 256-264

Possatto, F. E., M. Barletta, M. F. Costa, J. A. Ivar do Sul, D. V. Dantas. 2011. Plastic debris ingestion by marine catfish: An unexpected fisheries impact. Marine Pollution Bulletin 62 (2011) 1098-1102

Reidarson, T. H., C. A. Jantsch, S. N. Gendron.1994. Medical treatment for multiple foreign objects in a Hawksbill Turtle (*Eretmochelys imbricata*). Journal of zoo and wildlife medicine 25 (1) 158-160

Shrable, J. B., O. W. Timeier, and C. W. Deyoe. 1969. Effects of Temperature on Rate of Digestion by Channel Catfish. The Progressive Fish-Culturist 31 (3) 131-138

Sileo, L., P. R. Sievert, and M. D. Samuel. 1990. Causes of mortality of albatross chicks at Midway Atoll. Journal of Wildlife Diseases 26 (3) 329-338

Stamper, M. A., C. W. Spicer, D. L. Neiffer, K. S. Mathews, and G. J. Fleming. 2009. Morbidity in a juvenile Green Sea Turtle (*Chelonia mydas*) due to ocean-borne plastic. Journal of Zoo and Wildlife Medicine 40 (1) 196-198

Thompson, R.C., C.J. Moore, F. S. vom Saal, and S. H. Swann. 2009. Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B 2009 (364) 2153-2166

Tomas, J., R. Guitart, R. Mateo, and J. A. Raga. 2002. Marine debris ingestion in Loggerhead Sea Turtles, *Caretta caretta*, from the Western Mediterranean. Marine Pollution Bulletin 44 (2002) 211-216

Tourinho, P.S., J.A. Ivar do Sul, and G. Fillmann. 2010. Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil? Marine Pollution Bulletin 60 (3) 396-401

Valente, A.L., I. Marco, M. L. Parga, S. Lavin, F. Alegre, and R. Cuenca. 2008. Ingesta passage and gastric emptying times in Loggerhead Sea Turtles (*Caretta caretta*). Research in Veterinary Science 84 (2008) 132-139

Walde A.D., M. L. Harless, D. K. Delaney, and L.L. Pater. 2007. Anthropogenic threat to the desert tortoise (*Gopherus agassizii*): litter in the Mojave Desert. Western North American Naturalist 67(1) 147-149

Yu, S., R. S. Halbrook, D. W. Sparling, and R. Colombo. 2011. Metal accumulation and evaluation of effects in a freshwater turtle. Ecotoxicology 2011 (20) 1801-1812

Table 1. Records of mean weekly weight for Japanese1 Quail (Coturnix coturnix japonica), Red-eared Sliders (Trachemys scripta elegans), and Channel Catfish (Ictalurus punctatus). Means with the same letter are not significantly different.

	Weekly weight per gram				
Species	Week 1	Week 2	Week 3	Week 4	Week 5
Japanese Quail	299.30 C	311.50 AB	312.25 AB	314.65 A	307.10 B
Red-eared Slider	701.54 AB	710.00 A	706.15 AB	693.08 B	699.23 AB
Channel Catfish	*	23.48 C	24.31 BC	25.27 B	27.87 A

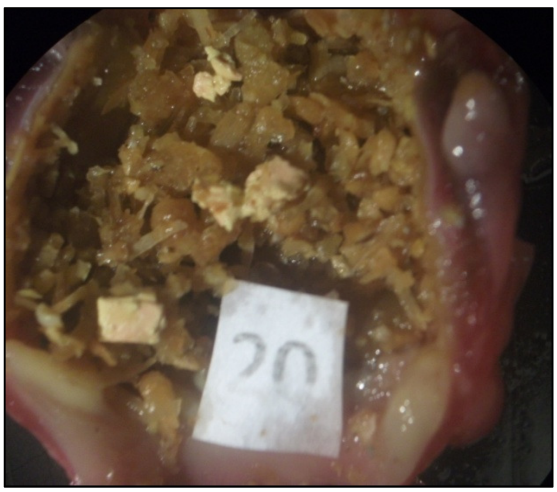


Fig. 1. Broken latex fragments occurring in gizzard of Japanese Quail (*Coturnix coturnix japonica*)

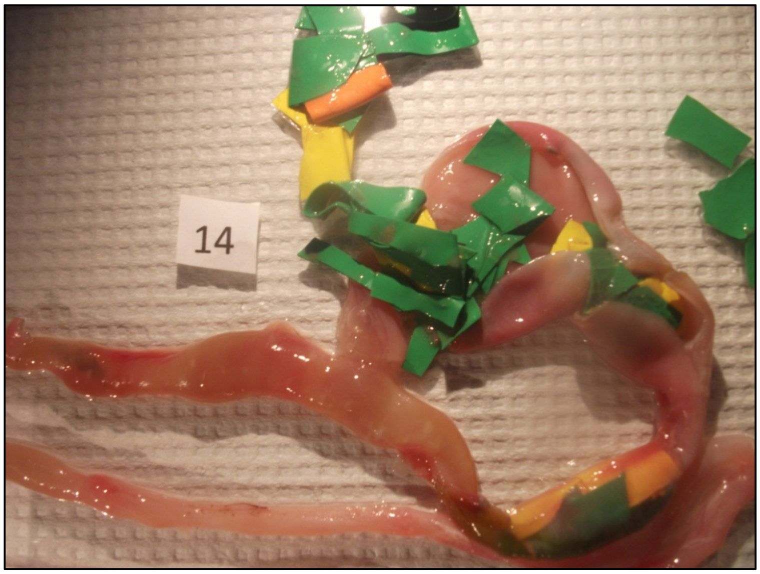


Fig. 2. Stomach and intestinal accumulation of latex fragments in Red-eared slider (*Trachemys scripta elegans*)

Fig 3. Latex bundle collected from intestinal tract of Red-eared Slider (*Trachemys scripta elegans*)

CHAPTER 3

Professional Observations and Public Opinion on Impact of Mass Latex Balloon Releases on Wildlife

INTRODUCTION

Mass releases of latex balloons are a common feature used in celebrations such as graduations, memorials, and sporting events. Private individuals and environmental advocacy groups have expressed concern about the potential hazard the balloons may present to wildlife and how they may contribute to litter (Marine Conservation Society, 2006; Ferris, 2009; Clean Virginia Waterways, 2010). Although 99% of the natural latex on the world market is derived from the coagulated sap of the rubber plant (*Hevea brasiliensis*) and is made up of 50-70% water (Rose and Steinbüchel, 2005), the outward physical characteristics and appearance of natural latex have resulted in balloons being grouped with plastic waste. Plastic refuse occurs as the bulk of marine litter on a global scale and is well documented as a hazard to wildlife through consumption and entanglement, particularly in sea turtles and marine birds (Laist, 1987, Azzarello and Van Vleet, 1987; Bugoni et al., 2001; Derraik, 2002; Votier et al., 2011). While no scientific literature is available on the threat of latex balloons specifically, some of the concern implicating latex balloon releases has arisen from confirmed incidences of health problems or fatalities due to digestive tract blockages from ingestion of Mylar® (BoPET) balloons by sea turtles or aquatic mammals (Marine Conservation Society, 2006). In other cases, birds, turtles, and other wildlife have become entangled in the ribbon or string attached to the balloons, and have become incapacitated or lost limbs (Walde et al., 2007, Ferris, 2009). This has led environmental organizations and concerned individuals

to lobby for legislation banning mass latex balloon releases, and as a result several states, including Connecticut, Tennessee, Florida, and Virginia have either banned or passed legislation regulating the mass release of balloons (Conn. Code Ch 490, §26-25c, 2005; Tenn. Code Ch 101, § 68-101-108, 2010; Florida Code Ch 372, §372.995, 2003; Virginia Code Ch 5, §29.1-556.1, 2010).

For the past 20 years the balloon industry has relied on information from one report released by the National Association of Balloon Artists (Burchette, 1989). The report speculated the probable distribution and degradation rate of the balloons in the environment, that wildlife should be unaffected, and suggested that a responsible balloon release should consist of using 100% natural latex balloons, hand-tied and without clasps, and with string or ribbon attached being no less degradable than the latex (Burchette, 1989). Currently the International Balloon Association (IBA) recommends no strings or attachments as well (IBA, 2009). Following these guidelines, the only material released into the environment consists of the latex balloon and the lighter than air gas used for lift.

Clemson University (CU) is one college that opens the home football games with a mass latex balloon release as part of the pre-game festivities, and has done so for decades. In 1983, CU was listed in the Guinness Book of World Records for a pregame release of over 315,000 balloons, in addition to 250 miles of string (Sheppard, 1983). Since those times, Central Spirit, the organization behind the balloon releases, has changed the methods of the releases to reflect a responsible approach to sustainability, and presently follows the balloon industry's safe release guidelines (Central Spirit, pers. comm.).

The objective of this study was to ascertain the public opinion concerning mass latex balloon releases and to look for any observed evidence supporting that natural latex balloons have detrimental effects on wildlife or the environment. Surveys of patrons attending CU home football games were conducted to determine the general opinion of sports fans on both the popularity of the releases as a pregame activity and the perceived environmental risk the balloon releases might pose. In addition, surveys of natural resources officials and non-governmental organization members (NGO; consisting of wildlife rehabilitation and rescue, nature education centers, and environmental groups) were taken to explore their opinions about the potential effects of latex balloon releases on wildlife and provide documentation of harm ensued by wildlife as a result of interaction with latex balloon materials.

METHODS

Sports patron survey — A survey was created and administered using the appropriate human protocol (IRB Protocol #2010-253). The survey included 19 closed-ended questions and two potentially open-ended responses (Table 1). Closed-ended questions consisted of demographics, yes or no answers, multiple choice options, or rankings of a topic. The two, open-ended questions were conditionally based on a "yes" response to two of the close-ended questions. Surveys were performed by five undergraduate students on game-day patrons during tailgating before three CU home football games (16 October, 23 October, and 6 November 2010). Participants were chosen at random and asked to complete the survey. A letter of consent was read to participants prior to administration of the survey, and copies were distributed to participants if requested.

Natural resource officials and NGO survey —An internet survey using Survey Monkey (SurveyMonkey.com; IRB2011-109) was conducted to assess both natural resources officials and NGO members observations and opinions on latex balloon/wildlife interaction. NGOs consisted of wildlife rehabilitation and rescue, nature education centers, and environmental groups. The survey was composed of nine close-ended questions and ten open-ended questions (Table 2). Four undergraduate researchers created a database of approximately 350 e-mail and phone contacts for North Carolina, South Carolina, Georgia and Florida, and each contact was sent a brief e-mail discussing the project and requesting participation. A link to the survey and a letter of consent was attached to each correspondence. Follow up e-mails were conducted to facilitate responses and to answer any questions proposed by participants.

Statistical analysis — The analysis was divided into three primary parts. Part one was concerned with determining if a majority (percent > 50) of responding sports patrons considered latex balloon a danger to the environment. To accomplish this binomial test was performed. Part two was to determine if level of education, knowledge of legislation, or importance of environmental protection were related to frequency of responses that considered balloons dangerous. This was analyzed using Fisher's Exact test. The third part of the analysis examined distributions of response proportions from natural resource officials and NGO members to questions relating to string attachment in recovered balloons, observed injuries from latex balloons, observed mortality, and the danger of latex balloons to the environment. Fisher's Exact test was used to determine if these questions distributions were related to groups (natural resources officials and NGO

members). All statistical analyses were performed using JMP version 9.0 (SAS Institute, Inc., Cary, NC; http://www.jmp.com).

RESULTS

Sports patron survey — Game day surveys resulted in a marginal interest in balloon releases, and mixed opinions concerning the environmental impact of balloons. With 190 people surveyed, four people (2%) held the pre-game balloon release as the best aspect of the Clemson football game (Figure 1); most people ranked the pre-game balloon release as their fourth most enjoyable aspect of the day out of five options. Patrons still placed value in the pre-game balloon release even though it was not ranked as the best aspect of the day by most participants; 81% (n=155) of fans agreed that Clemson had "the most exciting 25 seconds in college football" during the pregame ritual (Figure 2). The mean cost of the balloon release to the school was typically overestimated at $3,643.67 per game, whereas actual cost approximates $1,400 to $2,800 (Central Spirit, pers. comm.). Respondents also overestimated the average distance the balloons travel (301.36 km); mean distance was found to approximate 70.16 km (Irwin, 2012). Proportion of patrons that did not think balloons were dangerous was significantly higher than those that did (Binomial test, $P = 0.0387$), and level of education was not associated with this response (Fisher's Exact Test; df = 2, $\chi^2 = 1.666$, $P < 0.4346$). Knowledge of other states' legislation of latex balloon releases and perceived dangers of balloons showed a significant positive relation (Fisher's Exact Test, df = 1, $P < 0.0341$). Of the 80 respondents (42%) that believe balloons are dangerous (Figure 2), the number one reason given was danger to wildlife. About 51% (n=96) ranked the protection of the

environment as “important” compared to “very important (32%)” or “not important (17%)”, and 83% (n=128) ranked it as “very important” or “important”. There was a significant positive relationship in responses between importance of environmental protection and dangers of latex balloons (Fisher's Exact Test; df = 3, $\chi^2 = 14.051$, $P < 0.0028$). The majority of all responses (42%) believed CU does a “good” job at remaining environmentally friendly, followed by “very good” (27%), in contrast to neutral (22.6%), or “bad “(13%).

Natural resource officials and NGO survey —There were 117 governmental employee and NGO member respondents of which two listed multiple states they represented. Florida was the most represented state (47%), and represents the largest area of shoreline habitat. North Carolina came in second at 20% and Virginia third with 6%. Sixty-three percent of the respondents were less than 80 km from the coast; those that reported being 80 to160 km from the coast held 17% of the total and the remaining 20% reported being over 160 km from the coast. Seventy-nine percent of the 117 respondents have worked or volunteered for six-plus years in their field. The top two organizations represented in this survey were NGOs (45%) and state governments (39%), followed by federal government (16%). The majority that answered (114 respondents; 41%, n=47) were responsible for over 4,047 ha, from which 61% (n=70) found balloons in less than 30% of their responsible hectarage and 37% reported rarely finding balloons. Of the 61% (n=70) that found balloons, 82% (n=98; or 98 out of 119) of the respondents found them either torn (46%; n=45) or mostly whole (51%; n=50) with only 31% (n=31) completely tattered. Reports of balloons found with strings attached were significantly higher among NGO

members (97%; n=35) than natural resources officials (82%; Fisher's Exact Test, df = 1, $P < 0.028$). Seventy-five percent (n=78) of all respondents have not encountered animals that have sustained injury as a result from contact with latex balloons; however NGO members reported significantly more encounters of injuries (44%; n=60) than government officials (14%; Fisher's Exact Test, df = 1, $P < 0.0009$). Sea turtles were the most cited species negatively affected by contact with latex balloons (53%; n=16), with shore birds at 40% (n=12). The remaining 7% (n=2) were categorized as “other” and included raptors and small mammals. The most frequent type of injury reported was entanglement (61%) from 26 responses. When asked to provide details of injury not specified on the survey (entangled, minor, serious, fatal, and other), the remaining respondents did not provide accounts for any cases involving only latex balloons or fragments. Strings or ribbons were responsible for 67% of the injuries reported by survey participants. There was no significant difference between natural resources officials (14%; n=44) and NGO members’ responses (21%; n=29) in observed animal mortality due to latex balloons (Fisher’s Exact Test, df = 1, $P < 0.3146$), and 84% of the responses (n=73) had not observed any animal mortality due to latex balloons. However, 87% consider them dangerous for the environment, with a significantly higher number from NGO responses (98%; n=42) than officials (80%; n=61; Fisher’s Exact Test, df = 1, $P < 0.0074$) When asked to specify how balloons were dangerous to the environment, the number one answer was detrimental to wildlife (50%; n=47), followed by entanglement with attached strings (29%; n=27), litter (13%; n=13), non-degradable (6%; n=5), and other (2%; n=2). Thirty-two percent of the open-ended questions attributing observed

injury or death due to latex balloons resulted in answers of Mylar® (BoPET) balloons, strings or ribbons, or second-hand knowledge.

DISCUSSION

The public opinion from the football games demonstrated that while people enjoyed the pre-game activities, they placed less value in the balloon releases than other aspects of the game day event, and although the majority thought latex balloons were harmless, there was still a consensus among 42% of respondents that balloon releases were in some way detrimental to wildlife or the environment. Even though there was no indication of a significant relationship between education and opinions on balloons, the degree of education among the respondents was disproportionately high compared to the American populace (U.S. Census, 2011); number of years of education has been found to be positively associated to pro-environmental attitudes (Jones and Dunlap, 1992). This was evidenced in the responses on the importance of protecting the environment. The adoption of some states to ban balloon releases may also have influenced public opinion on the hazards of latex balloons; Dwyer *et al*. (2008) found that legislation enacted to place limitations on smoking had an effect on what was considered as an acceptable public practice, and Erikson (1976) suggested that individuals uncertain on opinions may tend to support the existing policies of the times. Among the responses, knowledge of legislation concerning balloon releases did show a positive relationship in the opinion that latex balloons were dangerous to wildlife.

Natural resources officials and NGOs were evenly represented, and the years of experience reported should offer a reliable estimate of latex balloons in the environment.

Florida was the most represented state, with a coastline serving as nesting habitat for loggerhead (*Caretta caretta*), green sea (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) turtles (Witherington *et al.*, 2011). NGO members reporting a greater frequency of encounters with balloons was expected as many are often involved in shoreline litter removal; Clean Virginia Waterways (CVW) has organized yearly clean-ups since 1995 and reported 17,035 latex and Mylar balloons collected from Virginia beaches and rivers over 15 years, making up 1.5% of all items found (Clean Virginia Waterways, pers. comm.). The majority of professional opinions held that the released latex balloons were dangerous, although few respondents claimed to have observed injury or mortality strictly from latex balloons. In most cases actual observed harm was a result of attached strings. Ultimately there were no direct observations of injury or harm from latex balloons alone, and harm to wildlife was either a result of another factor other than latex or passed on as word of mouth.

Based on extensive review of the literature, this is one component of the first actual study on the effects of latex balloon releases on wildlife. It is apparent that both the public and natural resources officials' opinions have formed through limited observation and exposure to assertions provided by efforts of environmental groups and concerned individuals. Such efforts are important in mobilizing public support, influencing judgments and attitudes, and enacting legislation for environmental causes (Stern *et al.*, 1986). The internet plays a large role in the dispersal of such information, and numerous environmental advocacy websites exist that are designed to affect opinions and provide information to a strong following of sympathetic advocates (Stein, 2011). In addition,

environmental groups have successfully used charismatic flagship species such as sea turtles to help foster a broader public concern for the environment and elicit a protective stance when the species is viewed as in jeopardy (Konteleon and Swanson, 2003; Stern *et al*., 1986). However, after conducting the surveys on both officials and private interests, there is no available evidence to indicate latex balloons are the problem.

Latex balloons are a vehicle for a confirmed threat to wildlife in the form of strings and ribbons. The frequency of strings found attached to balloons by non-profit/private respondents suggest most balloons did not come from mass releases, or are not released following IBA guidelines (IBA, 2009). This would also account for the number of injuries due to entanglement, and strings or ribbons were the factor involved in most observed injuries. String, ribbon and monofilament fishing line represent a serious threat to wildlife through entanglement or gastrointestinal obstruction; linear foreign bodies are well documented in veterinary science with domestic animals and have been observed to cause intestinal perforation and death (MacPhail, 2002; Hoffman, 2003). Hoffman (2003) diagnosed intestinal perforation in a pet Maltese resulting in peritonitis and death after ingestion of a party-balloon string, and monofilament fishing line has shown to cause linear intestinal perforation in snapping (*Chelydra serpentina)* and loggerhead turtles (Borkowski, 1997, DiBello *et al*., 2006). Strings and ribbons from balloons should have the same effect on any animal that ingests the material. The problem is that balloons that are recovered most likely did not originate from a mass balloon release, but were released individually at a frequency high enough to cause an accumulation. With this observation, protective efforts should be towards regulating

harmful attachments on individually sold latex balloons. Developing a material for balloon tethers should also be explored for a product that is rapidly biodegradable and digestible. Efforts to develop and produce such a material would provide an important solution to both conservation efforts and the balloon industry.

LITERATURE CITED

Azzarello, M. Y., and E. S. Van Vleet. 1987. Marine birds and plastic pollution. Marine Ecology 1987 (37) 295-303

Borkowski, B. 1997. Lead poisoning and intestinal perforations in a snapping turtle (Chelydra serpentine) due to fishing gear ingestion. Journal of Zoo and Wildlife Medicine 28 (1) 109-113

Bugoni, L., L. Krause, and M. V. Petry. 2001. Marine debris and human impacts on sea turtles in southern Brazil. Marine Pollution Bulletin 42 (12) 1330-1334

Burchette, D.K. 1989. A Study of the Effect of Balloon Releases on the Environment. Final Report presented to National Association of Balloon Artists.

Clean Virginia Waterways: Balloons as litter--a problem we can solve. 2010. Clean Virginia Waterways, Longwood University, 201 High Street, Farmville, VA 23909. Retrieved January 16, 2010 from http://www.longwood.edu/cleanva/balloons.htm

Connecticut Code 2005. Title 26 Fisheries and Game, Ch 490, § 26-25c. Release of lighter-than-air balloons restricted.

Derraik, J. G. B. 2002. The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin 2002 (44) 842-852

DiBello, A., C. Valastro, and F. Staffieri. 2006. Surgical approach to the coelomic cavity through the axillary and inguinal regions in sea turtles. Journal of the American Veterinary Association 228 (6) 922-925

Dwyer, T., J. Bradshaw, W. K. Mummery, K. R. Searl, D. Rossi, and M. Broadbent. Public support for anti-smoking legislation varies with smoking status. Australian journal of Rural Health 16 (2008) 231-236

Erikson, R. S. 2012. The relationship between public opinion and state policy: A new look based on some forgotten data. American Journal of Political Science 20 (1) 25-36.

Ferris L. 2009.What goes up must come down. Fourth Crossing Wildlife Australian Seabird Rescue. www.fourthcrossingwildlife.com/WhatGoesUp-LanceFerris.htm. (Accessed March 18, 2011)

Florida Code 2003. Title XXVIII Natural Resources; Conservation, Reclamation, and Use; Ch 372 Wildlife, § 372.995. Release of balloons.

Hoffman, K. L. 2003. Sonographic signs of gastroduodenal linear foreign body in 3 dogs. Veterinary Radiology & Ultrasound 44 (4) 466-469

International Balloon Association. 2009. Talking Points to Combat Negative Legislation http://www.ibaonline.net/TheBalloonCouncil/SpeakingPointstoOpposeBansonBalloons/tabid/102/Default.aspx (Accessed March 17, 2012)

Irwin. S. 2012. Mass Latex Balloons Releases and The Potential Effects on Wildlife. Dissertation. Clemson University, Clemson, South Carolina

Jones, R. E. and R. E. Dunlap. 1992. The social bases of environmental concern: Have they changed over time? Rural Sociology 57 (1) 28-47

Kontoleon, A. and T. Swanson. 2003. The willingness to pay for property rights for the Giant Panda: can a charismatic species be an instrument for nature conservation? Land Economics 79 (4) 483-499

Laist, D. W. 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. Marine Pollution Bulletin 18 (6B) 319-326

MacPhail,C. 2002. Gastrointestinal obstruction. Clinical Techniques in Small Animal Practice 17 (4) 178-183

Marine Conservation Society, 2006. Balloon releases: pollution factsheet. 9 Gloucester Road Ross-on-Wye Herefordshire HR9 6BU Tel. 01989 566017 Fax. 01989 567815 http://www.mcsuk.org (Accessed March 12, 2010)

Rose, K., and A. Steinbüchel. 2005. Biodegradation of natural rubber and related compounds: Recent insights into a hardly understood catabolic capability of microorganisms. Applied and Environmental Microbiology. 71 (6) 2803-2812

Stein, L. 2011. Environmental website production: a structuration approach. Media, Culture & Society 33 (3) 363-384

Stern, P. C., T. Dietz, and J. S. Black. 1986. Support for environmental protection: The role of moral norms. Population and Environment 8 (3-4) 204-222

Tennessee Code 2010. Title 68 Health, Safety and Environmental Protection, Chapter 101 Miscellaneous Safety and Environmental Regulations, § 68-101-108. Limitations on release of balloons into the atmosphere exemptions

Sheppard, P. 1983, November 17. Balloons color sky, break a world record. The Tiger 77 (12)

United States Census. 2011. Educational Attainment of the Population 25 Years and Over, by Selected Characteristics: 2011

Virginia 2010. Title 29.1 Game, Inland Fisheries and Boating, Ch 5 Wildlife and Fish Laws, § 29.1-556.1 Release of certain balloons prohibited; civil penalty.

Votier, S. C., K. Archibald, G. Morgan, and L. Morgan. 2011. The us of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Marine Pollution Bulletin 62 (2011) 168-172

Walde AD, Harless ML, Delaney DK, Pater LL. 2007. Anthropogenic threat to the desert tortoise (Gopherus agassizii): litter in the Mojave desert. Western North American Naturalist 67:1 147-149

Witherington, B., S. Hirama, and A. Mosier. 2011.Barriers to sea turtle nesting on Florida (United States) beaches: Linear extent and changes following storms. Journal of Coastal Research 27 (3) 450-45

Table 1. Summary of Public Opinion Survey Questions

1. Number of males/females in group
2. Age of males/females in group
3. Number in household under 18
4. Number in household over 18
5. Level of education
6. Number of people in group
7. Number of times you attend games
8. Are you a student, alumnus or neither?
9. Rank the top 5 things you enjoy most about games
   Tailgating
   Pregame rituals
   Watching the game
   Halftime show
   Bonding with friends and family
10. How far do you think a latex balloon filled with helium will travel after released
11. Have you ever found or seen any balloons from a Clemson's game-day balloon release outside the stadium, if yes where?
12. Estimate the cost of a typical balloon release
13. Clemson does a very bad, bad, neither bad nor good, good, very good job remaining green or environmentally friendly
14. Protecting the environment is very unimportant, unimportant, neither important nor unimportant, important, very important to me
15. Clemson's pregame ritual is the most exciting 25 seconds in college football Yes or No
16. Do you think Balloon from balloon releases are litter Yes or No
17. Are you aware that some states have legislation about public balloon releases Yes or No
18. Do you know if balloon releases are outlawed in some states Yes or No
19. Are balloons dangerous for the environment Yes or No if yes how are they dangerous

Table 2. Professional and Volunteer Survey for observations and opinions of latex balloons in the environment (n=117).

1. What state(s) do you represent
2. What is your proximity to the coast
   <50 miles 50-100 miles >100 miles
3. How long have you worked/volunteered in your field
   0-2 years 3-5 years 6+years
4. What is the name of the organization with which you work/volunteer

5a. How many acres are you responsible for managing
   <5,000 5,000-10,000 >10,000 NA
5b. Of those acres, in what percentage have you ever found latex balloons
   <30% 30%-60% 60%-90% >90% NA
5c How often do you find balloons
   Very often Often Sometimes Rarely Never
5d. What month and/or year did you first start finding balloons
5e. What condition are they in when found
   Torn Completely Tattered Mostly Whole
5f. Are strings or ribbons attached
   Yes No
5g. If yes, what percentage of the time
6a. Have you or someone in your organization encountered animals that have sustained injury as a result from contact with latex balloons
6b. If yes, what species
6c. What was the extent of the injury
   Entangle Minor Serious Fatal Other
6d If other please specify
6e Where strings or ribbons responsible for the injury

7. Have you observed any animal mortality due to latex balloons

8a. Do you consider balloons dangerous for the environment
   Yes No
8b. If yes, how are they dangerous

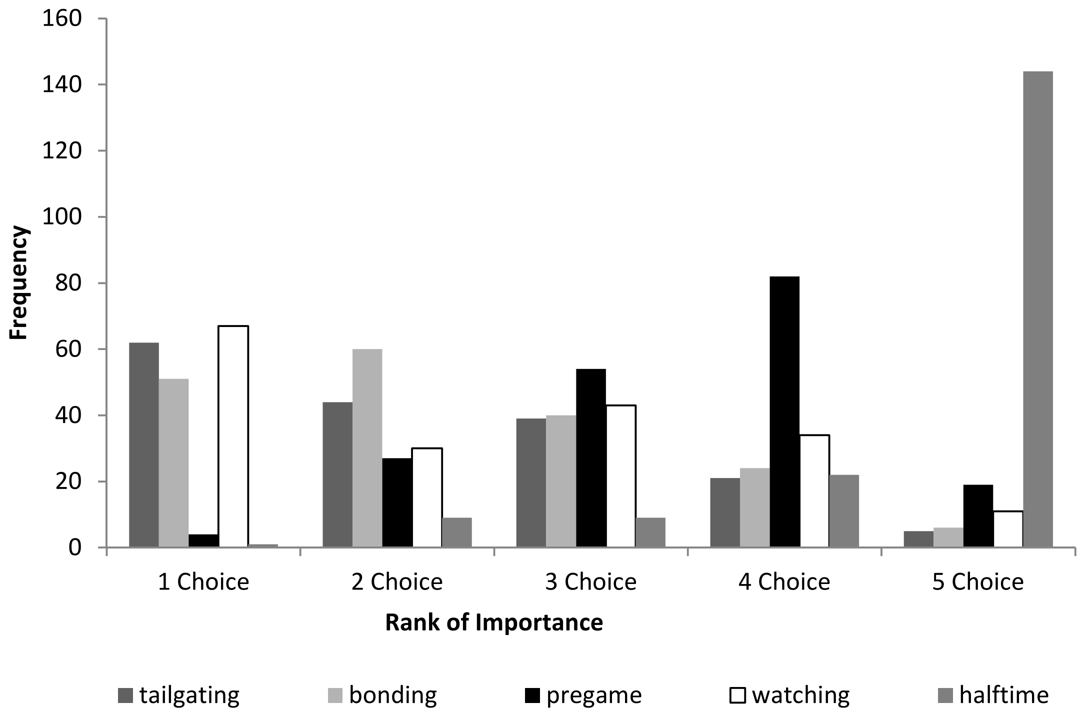
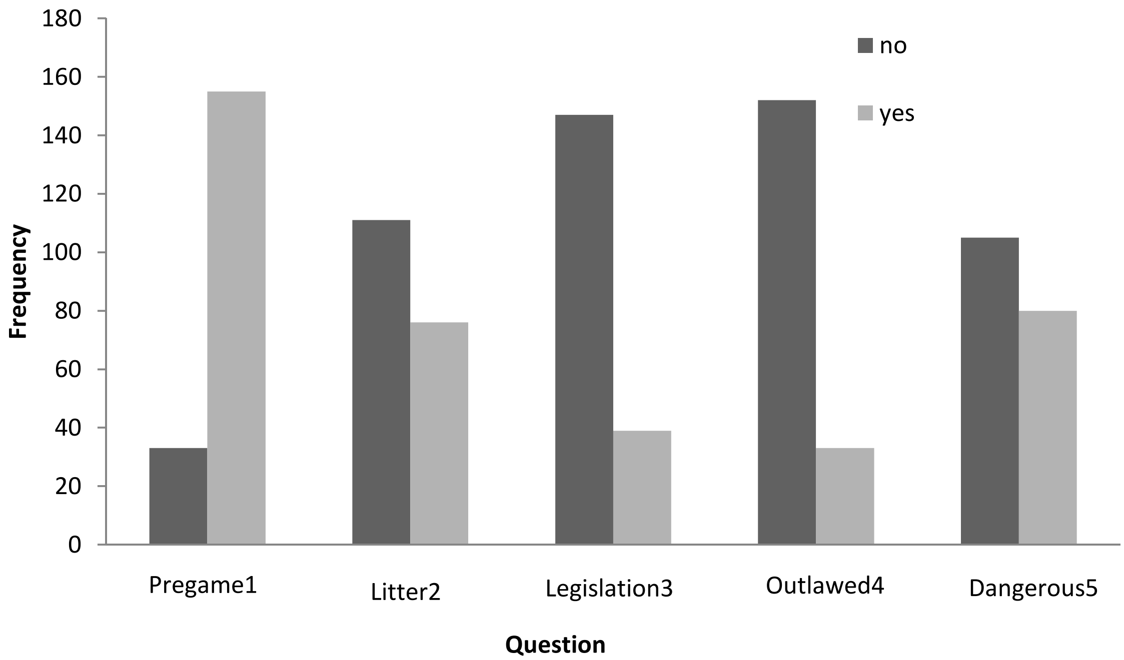


Fig 1. Top 5 rankings of most enjoyed aspects of Clemson Football Games by attending football game patrons (n = 190)



Pregame[1] = Clemson's pregame ritual is the most exciting 25 seconds in college football.
Litter[2] = Do you think Balloons from balloon releases are litter?
Legislation[3] = Are you aware that some states have legislation about public balloon releases?
Outlawed[4] = Do you know if balloon releases are outlawed in some states?
Dangerous[5] = Are Balloons dangerous for the environment?

Fig 2. General opinion and knowledge of environmental awareness from surveys on Clemson University football game patrons (n = 190)

CONCLUSIONS

This is the first comprehensive study to examine latex balloon releases and the potential effects they might have on wildlife. The study sought to encompass every aspect that may have a role in the detriment to wildlife: the distance latex balloons traveled from release and the physical state upon arrival; persistence time as a possible hazard in the environment and attractiveness as a novel food item; physiological effects from ingestion by wildlife; and natural resources officials' and non-governmental organization members' observations of harm to wildlife and opinions concerning balloons. Additionally, public opinion of the value of the releases during sporting events and concern of potential environmental impacts were also assessed.

Aspects of the fate of the balloons from release provided definitive results as to where balloons might go, in what form they arrive, and how long they can persist for potential ingestion by wildlife. Distance traveled by the latex balloons demonstrated that most balloons recovered did not travel very far (median = 33.8 km), but were capable of traveling great distances. The bursting of balloons in the upper atmosphere resulted in over half of the material from each balloon landing in one piece; still large enough to present a physiological obstruction in many species if the material is conducive to such actions in the GI tract. However, camera trials conducted in forested areas and adjacent to wetlands and lakes in the upstate of South Carolina did not indicate the balloons attracted wildlife. Future trials in environments along the coastline would provide additional information of the potential for seabirds, waterfowl, and wetland species to be attracted by or consume latex fragments.

Examination of the physiological effects of latex consumption on three trial species did not reveal latex to represent a hazard through ingestion, with one consideration. None of the species tested demonstrated latex ingestion as harmful using H/L or N/L ratios as a measure of physiological stress. No unanticipated changes occurred in weight in all three species. Transit time through the GI tract for latex pieces was delayed compared to typical diet, although still occurred within acceptable parameters for each species. Red-eared sliders did exhibit the potential to retain pieces for a longer period of time, as some individual pieces remained in the digestive tract for up to 23 days. However, no apparent blockages occurred, and turtle gut transit times of latex were still within previously observed ranges. The turtles retaining the pieces did not show any signs of GI disease as a result, possibly due to the duration of the study. It should be noted that all trial species were fed latex balloon fragments at quantities and at a frequency that is unlikely to occur in natural conditions. Nonetheless, long-term feeding trials on turtles may be warranted to examine for the potential of gastrointestinal disease or nutrient dilution.

Observations and opinions of natural resources officials and members of non-governmental organizations indicated that little to no actual confirmed harm from latex balloons has been observed, although the consensus from both groups was that latex balloons represent a hazard to wildlife. Nearly all cases of observed harm by balloons involved Mylar balloons or attached string, and remaining observations were derived from second-hand information. Ninety percent of respondents still considered latex

balloons a threat to wildlife, although strings or ribbons accounted for 67% of all reported injuries.

The public opinion concerning the danger of balloons releases to the environment was divided among sports patrons, with the majority (58%) concluding that releases were not a hazard. A similar response was given when asked if balloons were perceived as litter, however most respondents did value protecting the environment. Rankings of most enjoyed aspects during the game day event did not provide much support for the releases, as importance of pre-game rituals was ranked fourth after tailgating, the game itself, and spending time with family and friends. Nonetheless, most of the respondents agreed that Clemson had “the most exciting 25 seconds in college football” during the entrance of the football team; which is accompanied by the balloon release.

This study did not indicate an observable impact on wildlife or the environment from latex balloon releases following IBA guidelines, although new questions were raised. Further examination through additional feeding and camera trials could lend support to the evidence of the innocuous nature of latex to wildlife, or may reveal unforeseen hazards to other species. On a separate note, a poll performed on sports patrons concerning the importance of the balloon releases as part of the game day experience should be conducted. The results would indicate a preference or indifference toward the releases, and assist in the decision to continue this tradition.