Experimental degradation of latex and foil balloons in semi-tropical, coastal environments

Abstract

Marine debris is an ever-increasing global issue that is affecting all the world's oceans. Marine debris impacts marine wildlife through entanglement and ingestion. Ingestion of marine debris can lead to life-threatening complications such as gut perforation or impaction. A recent study has shown that sea turtles show a preference for ingesting balloons from the marine environment, yet there is a lack of scientific studies on the degradation rates of balloons in this habitat. This is important to our understanding, as a recent study has shown that sea turtles selectively target and ingest balloons from their tropical environments. The aim of this study was to test the degradation rate of different coloured rubber and silver foil balloons across a range of different treatments (sand, soil, salt- and freshwater) that replicated tropical coastal conditions. The degradation rate was recorded qualitatively as visual change and quantified as mass loss. Observations were taken every seven days for a total of 91 days. Further tests were conducted to investigate the unexpected results generated from the fresh water treatments. Results indicated that the colour of the balloons did not affect degradation rates, however treatment did. It was calculated that a balloon in coastal soil and sand environments would take between 23 and 36 years to degrade, respectively. Salt water slowed down the degradation rate of balloons, with no change recorded in neither visual characteristics nor the mass of the balloons over the length of the study. However, balloons in the fresh water treatment showed both visible signs of degradation and interestingly a significant increase in mass over the length of the study. A theoretical model of the different stages of the degradation of rubber balloons in fresh- and salt water has been created. Samples in saltwater treatments were acting different than other treatments, further study to the reaction of salt water on manmade debris is necessary. Furthermore further study is recommended to investigate the degradation process over a longer amount of time.

Introduction

Marine debris has become an increasing problem, affecting all the world's oceans. Marine debris are defined as 'any manufactured or processed solid waste material that enters the marine environment from any source' (Coe J.M., 1997) The United Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) estimated that land-based sources of litter are responsible for up to 80% of marine debris while the remainder is due to sea-based activities (Sheavly, 2005). It is estimated is that up to seven billion tons of marine debris are entering the sea annually (Faris J., 1995). The amount of general source debris items found on beaches has increased over the last few years. For example, on beaches in the United States, an annual increase of marine debris of 5.4% over a five-year period (2001-2006) was found (Sheavly, 2007).

Marine debris has a range of hazardous effects on marine life. Marine debris affects at least 267 species worldwide; including 86% of all sea turtles, up to 36% of seabirds and up to 28% of all marine mammals (Laist, 1997). Marine animals mistake the debris for natural prey items causing them to ingest the debris (Bjorndal et al., 1994). Ingested marine debris can perforate the gut wall of the marine animal, which could lead to septicemia and death (Wallace, 1985). Pieces of debris can also cause impaction or blockage of the gastrointestinal tract, which could result in abrasion of the gut wall (Wallace, 1985). Research shows that it can take from several days up to four months for a sea turtle to expel rubber and plastic pieces (Lutz, 1990). During this time, these animals can suffer from a shortage of nutrients because the debris material takes up room in the gastrointestinal system without adding nutritional content which could lead to a decline in the overall fitness of the sea turtle, including: decreased growth rates, longer developmental periods at sizes most vulnerable to predation, lower energy reserves, reduced reproductive output and decreased survivorship, all of which could lead to long term population level impacts (McCauley and Bjorndal, 1999).

Entanglement in debris is also impacting marine wildlife (Beck and Barros, 1991; Sadove, 1990). Entanglement has two impacts; firstly it could lead to a rapid death if it inhibits the animal's ability to reach the surface to breathe and they drown, secondly entanglement can makes it difficult for the animal to reach the surface and inhibits movements of animal which could lead to exhaustion, malnutrition, and ultimately death from starvation or predation (Laist, 1987).

Marine debris consists mainly of polymer-based items, rubbers (which includes balloons), fishing gear and other manmade items (Coe J.M., 1997). It is estimated that between 60 and 80% of all marine debris existing in the world is plastic polymer-based (Derraik, 2002). The dominance of plastic fragments was also noted in studies all over the world, for example in South Africa (Madzena and Lasiak, 1997), Israel (Golik and Gertner, 1992), Brazil (Santos et al., 2009) and Australia (Whiting, 1998).

Although polymers are more commonly found as marine debris, recent studies have shown that sea turtles are targeting balloons above and beyond what is available in the marine environment (Schulyer et al 2012). There are currently limited peer reviewed studies on balloons and their degradation rates in the environment. This is of some concern as rubber balloons are counted as one of the dominating land-based indicator items, with a percentage up to 7,8% of all the debris found during Sheavly's study (Sheavly, 2007). While research in Arnhemland, Australia reported that rubber made up to 21% of the debris found, which includes rubber balloons (Kiessling and Hamilton, 2003).

Types of balloons

Most commonly found balloons are rubber balloons made from natural rubber. Natural rubber is an elastomer called polyisoprene that was originally derived from latex, a milky colloid produced by plants (Burchette, 1989). During balloon releases, an estimated 90-95% of released balloons rise to an altitude of 5 miles where the temperature and pressure is such that they burst into small fragments. The remaining 5-10% that do not reach this altitude could remain inflated and can float many miles before it comes back to the land or the sea in a semi-inflated state(CleanOceanAction, 2003). Also string and ribbons attached to balloons are seen during many balloon releases. Balloons tied together can be even more threatening to marine life through ingestion and entanglement (CleanOceanAction, 2003).

According to a study done by Burchette on the effect of balloon releases on the environment, it was concluded that rubber balloons degrade at the same rate as oak tree leaves, which is about six months, under a wide range of exposure conditions in the environment including sunlight, weathering, soil and water exposures (Burchette, 1989).

Foil or mylar balloons are foil-like, usually silver and cost significantly more than latex balloons. Mylar is a synthetic, metalized plastic/nylon material, which is recyclable, but not biodegradable (Burchette, 1989). Foil balloons are usually not used for balloon releases but are accidentally released due to a breaking string or a consumer who has released the balloon. Foil balloons as marine debris are not found as commonly as rubber balloons (CleanOceanAction, 2003).

Many estimates on degradation rates of marine debris can be found on the internet, however most of these estimates are not from controlled experiments. Also some of the estimates made on the internet are sponsored by the industry. An example for this is the paper of Burchette about the degradation rate of balloons; at the time that the paper was made Burchette was working as the Technical Advisor of the National Association of Balloon Artist. Although estimates of degradation rates of marine debris are common in the internet stimates of degradation rates of balloons are hard to find, the paper of Burchette as described as above is the only scientific paper found on the degradation rate of balloons, which also makes the paper often cited.

Although there are not many papers about balloons still papers about the degradation rate of balloons are particularly important as recent research has shown that 8.7% of the investigated sea turtles have ingested rubber balloons (Schuyler et al., 2012). Research done by Schuyler shows that there is a color preference per type and size class of the sea turtle (Schuyler et al., 2012). This is the motivation as to why in this research the rubber balloons have been tested across a range of colors. The foil balloon is not tested across a range of colors because this type of debris usually comes in a single color, silver. Also Burchette investigated the degradation rate of balloons in a range of colors, therefore we chose to redo some parts of Burchette's research with comparable methodology, concentrating in a semi-tropical environment (Burchette, 1989).

The aim of this study was to investigate the degradation rate of different types of balloons across a range of colors in common Australian semi-tropical, coastal environmental circumstances.

Materials and methods

This study was conducted at the Moreton Bay Research Station on North Stradbroke Island, Queensland, Australia (27°30'2.46"S, 153°23'59.28"E). Two types of debris were investigated; rubber balloons and foil balloon. All materials used as samples for this research were derived from different stores in a local shopping centre, which is open for the general public. The size of the samples of both rubber balloons and foil balloon was 40x10mm per sample. Four types of treatment have been used for this research: sand, soil, fresh water and salt water. The sand and soil were derived from around the Moreton Bay Research Station, the freshwater from the tap and the salt water from the Bay in front of the Moreton Bay Research Station. All samples were held in plastic trays measuring 100x170x50mm.
During the study all of the samples were kept in an open air caged shed with a clear corrugated roof, which exposed the samples to UV rays, ambient temperature changes and wind to mimic the environmental conditions as much as possible, while preventing disturbance from large animals and people.

The study consists of two sections; the first experiment controlled for the potential effect of color, therefore only balloons of a single color were tested: clear rubber balloons and silver colored foil balloons. Every type of balloon and treatment (sand, soil, fresh water and salt water) had three replicates, for a total of 24 trays being monitored.

The second part consisted of rubber balloons across a range of colors. Rubber balloon samples were used in the colors white, yellow and blue. Each tray was filled with one of the four treatments (sand, soil, fresh water and salt water) and one sample of the rubber balloons from one of the three test colors were added. Every type of colored rubber balloon and treatment had three replicates for a total of 36 trays being monitored.

The plastic trays were marked with a control and replicate number and approximately half filled with the different treatments, then the pre-weighed samples of the different types of debris were added (t=0). After the set-up the samples were weighed every seven days. For each measurement the samples were retrieved from the plastic trays with their treatment, blotted dry, dried carefully and spun around in a salad spinner-if it was a retrieved from a liquid treatment-, and weighed on the Shimadzu AX 200 scale; tolerance of ± 1 mg. After each measurement, the samples were placed back into the correct tray after the loss of the treatment-media had been replaced, this action was repeated every seven days for a total of 91 days.

Extra experiment
During the experiment, rubber balloons (in every color) in the freshwater treatment substantially increased in mass. For some rubber balloons it even lead up to more than 200% of their t=0 mass. The occurrence of gaining this much mass did not happen with any other sample in any other treatment which lead to set up an extra experiment:
Four types of treatment were prepared ranging from freshwater, salt water with a salinity of 35.0 $^{0}/_{00}$ (this salinity has been chosen because this is the average salinity of seawater around Australia, see figure 1), salt water with a salinity of 150.0$^{0}/_{00}$, and dry salt. The salt water solution were made by mixing up Sea salt and fresh water. For example for 400 ml of salt water with a salinity of 35.0$^{0}/_{00}$: 0.4(amount of liters)*35(grams of salt per liter)=14 grams of salt and 400(amount of milliliters)-14=386 grams of water(one gram of water has a mass of 1 ml).

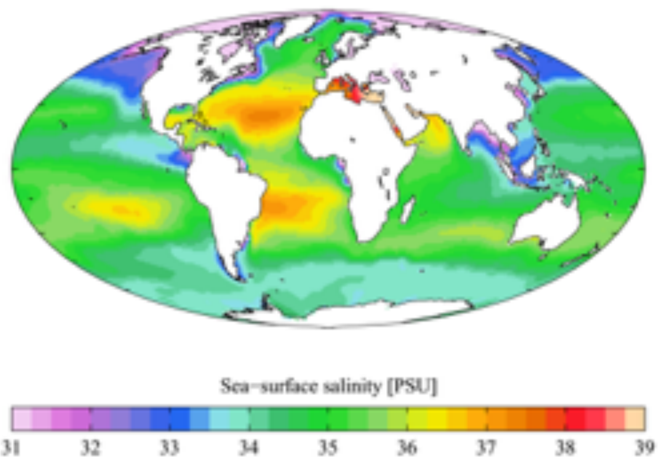

Fig. 1: Sea-surface salinity (source: World Ocean Atlas 2005)

Four clear rubber balloons were cut up in five pieces each. The rubber balloons samples were put in 20 glass vials with caps and the vials were labeled to make sure that the samples wouldn't be mixed up and to make sure that every balloon had one piece in every type of treatment.
Every type of treatment has been researched in quintuple, which means that for every treatment there were always five vials filled with the same treatment. After the balloons were weighed, which is t=0, and put in the right vials the treatment have been poured in the vials. After seven days the balloons were retrieved from the glass vials, blotted dry, dried carefully and spun around in a salad spinner and weighed on the Shimadzu AX 200 scale; tolerance of ± 1 mg. After this measurement the samples were placed back in the right vial and the loss of treatment-liquid had been replaced. This action was repeated for two times every seven days, which equates to a total of fourteen days.
In addition to this extra experiment there has been chosen to switch the rubber balloons (in all colors) in the freshwater treatment after the 91 days of the first experiment and put them for an extra seven days in a saltwater treatment to see if there would be any decrease in mass.

Statistics
The mean change in mass of different colored rubber balloons and the foil balloons over the 91 days was compared via a repeated measures ANOVA test using the statistical program SPSS 17.0.
Calculating the degradation rate of the different types has been done through ratio calculation with an assumption of linear relationship. For example the samples of the yellow rubber balloon in soil treatment had an average of 1.07% mass loss in 91 days. 100% is the total mass of the sample/1.07% the mass los during this study=93.46*91(days needed per mass loss of 1.07%)=8504 days which is equal to (8504/365)≈23.3 years.

Results

Statistical analysis

Because the response was not normally distributed there has been chosen to analyse the masses in milligrams with an ln transformation, this helped to distribute the response more normally. The repeated measures ANOVA test showed a significant difference in the Mauchy test of Spericity table. Spericity is an assumption of the model, which corresponds to equal variances and no correlation between the columns t=0 and t=91. Spericity couldn't be assumed because a significant difference was found (df=90, Sig.=0.000). This means that the Greenhouse-Geisser correction had to be used which showed significant differences between weeks, weeks*treatments, weeks*different types of manmade debris and weeks*treatments*different types of manmade debris (table 1).

Table 1: Values of the Greenhouse-Geisser correction for the different sources. All sources are significant, Sig.<0.05.

Source	Sum of squares	df	Mean square	F	Sig.
Weeks	438.624	1.655	265.069	1089.441	<0.0001
Weeks*treatments	12.706	4.964	2.559	10.520	<0.0001
Weeks*different types of manmade debris	368.864	6.619	55.728	229.043	<0.0001
Weeks*treatments*different types of manmade debris	9.315	19.857	0.469	1.928	0.028

Visual inspection

Visual inspection of balloons kept in fresh water all showed signs of degradation(fig. 2) this in contrast with the balloon samples in salt water which showed no visual difference(fig.3) from the new balloon samples. As did the balloon samples in the treatments soil and sand, which did not show any difference from the new balloon samples.

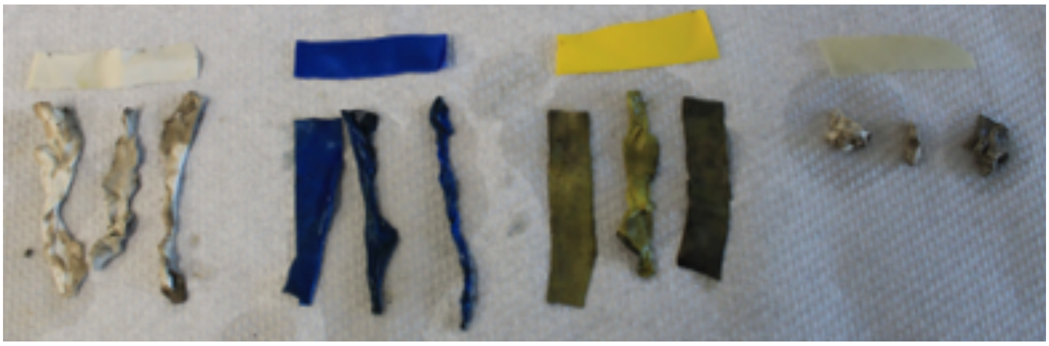

Fig. 2: Horizontal: new samples. Vertical: balloons after 91 days in freshwater treatment

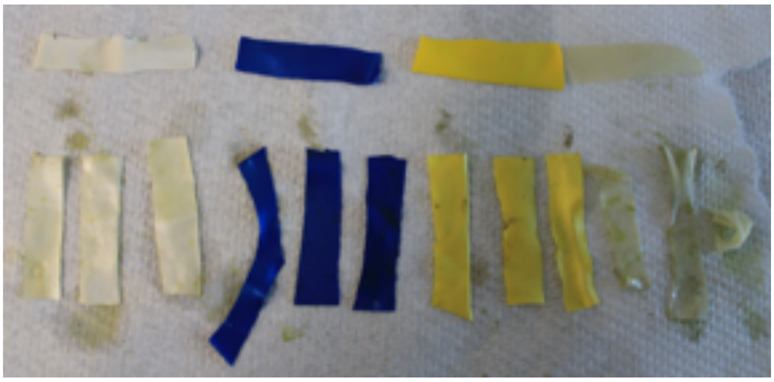

Fig. 3: Horizontal: new samples. Vertical: balloons after 91 days in salt water treatment

Also for the Foil balloon samples hardly no difference between used and new samples can be seen in all treatments. The only thing that can be seen is a minor discoloration of the foil balloon samples in the salt- and freshwater treatment. Figure 4 shows new foil balloon samples versus used foil balloon samples in the salt- and freshwater treatment.

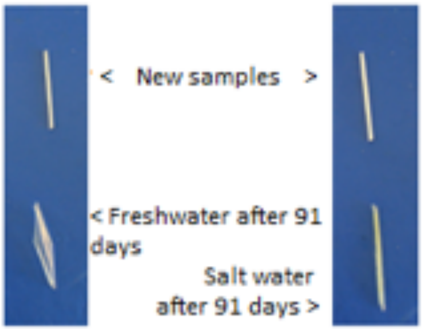

Fig. 4: New foil balloon samples versus foil balloon samples from the salt- and freshwater treatment.

Mean change in mass

Rubber balloons

Notable about the rubber balloons is that the balloons in the freshwater treatment(see figure 5) gain a tremendous amount of weight, way higher than the weight gained by rubber balloons in other treatments. The rubber balloons in the freshwater treatment all gained between 60 – 120% of their initial mass. As well as the freshwater treatment also rubber balloons in the salt water treatment gained mass(figure 6) but not as much as the rubber balloons in the freshwater treatment. The rubber balloons in the sand(figure 7) and soil(figure 8) treatment generally lost little of their mass with exception of the clear rubber balloon samples in the sand treatment, who gained little of their initial mass.

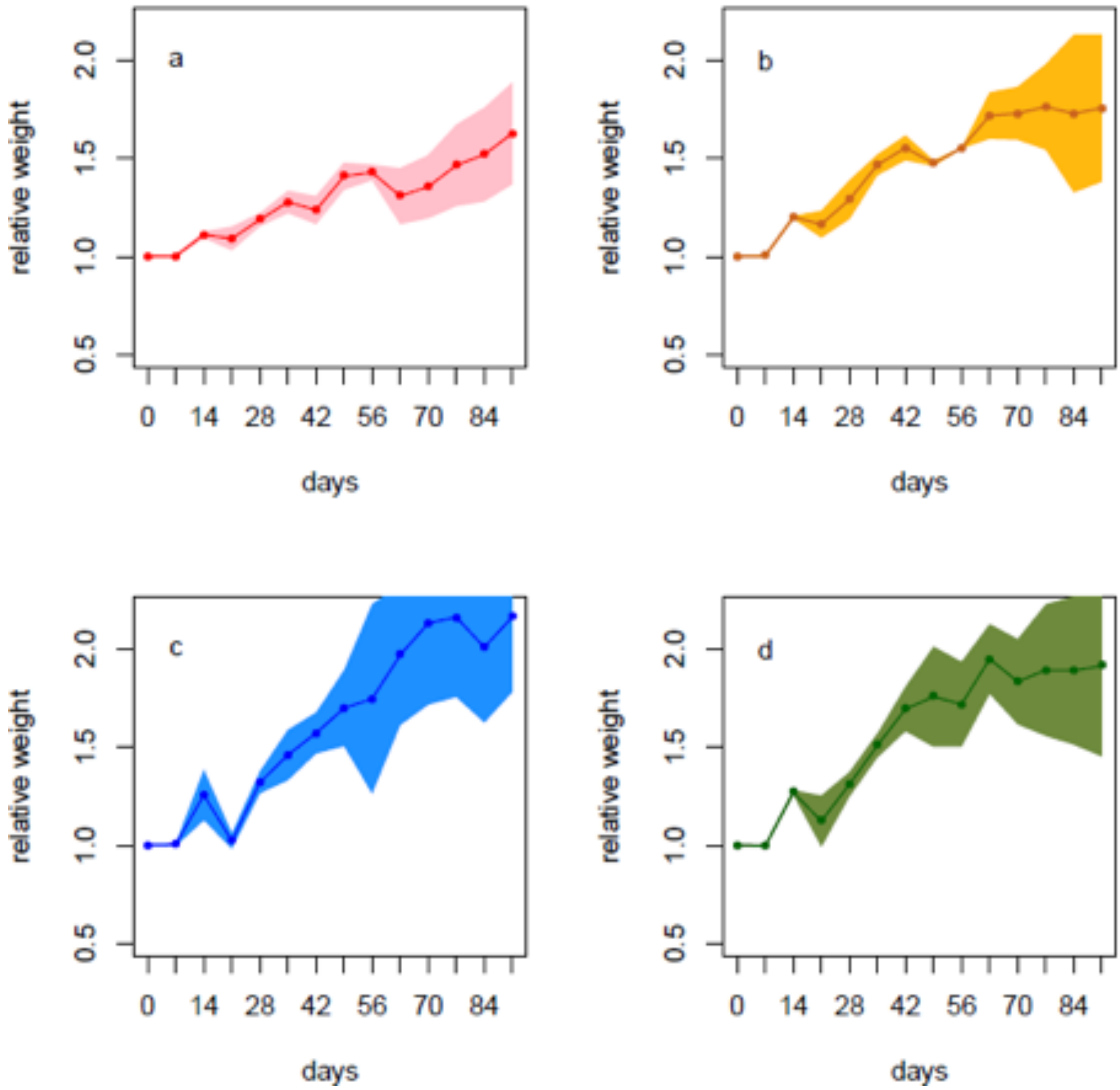

Fig. 5: Mean change in mass after every seven days for in total 91 days for every sample type in the freshwater treatment. (+/- std error)

A: Mean change clear balloon

B: Mean change yellow balloon

C: Mean change blue balloon

D: Mean change white balloon

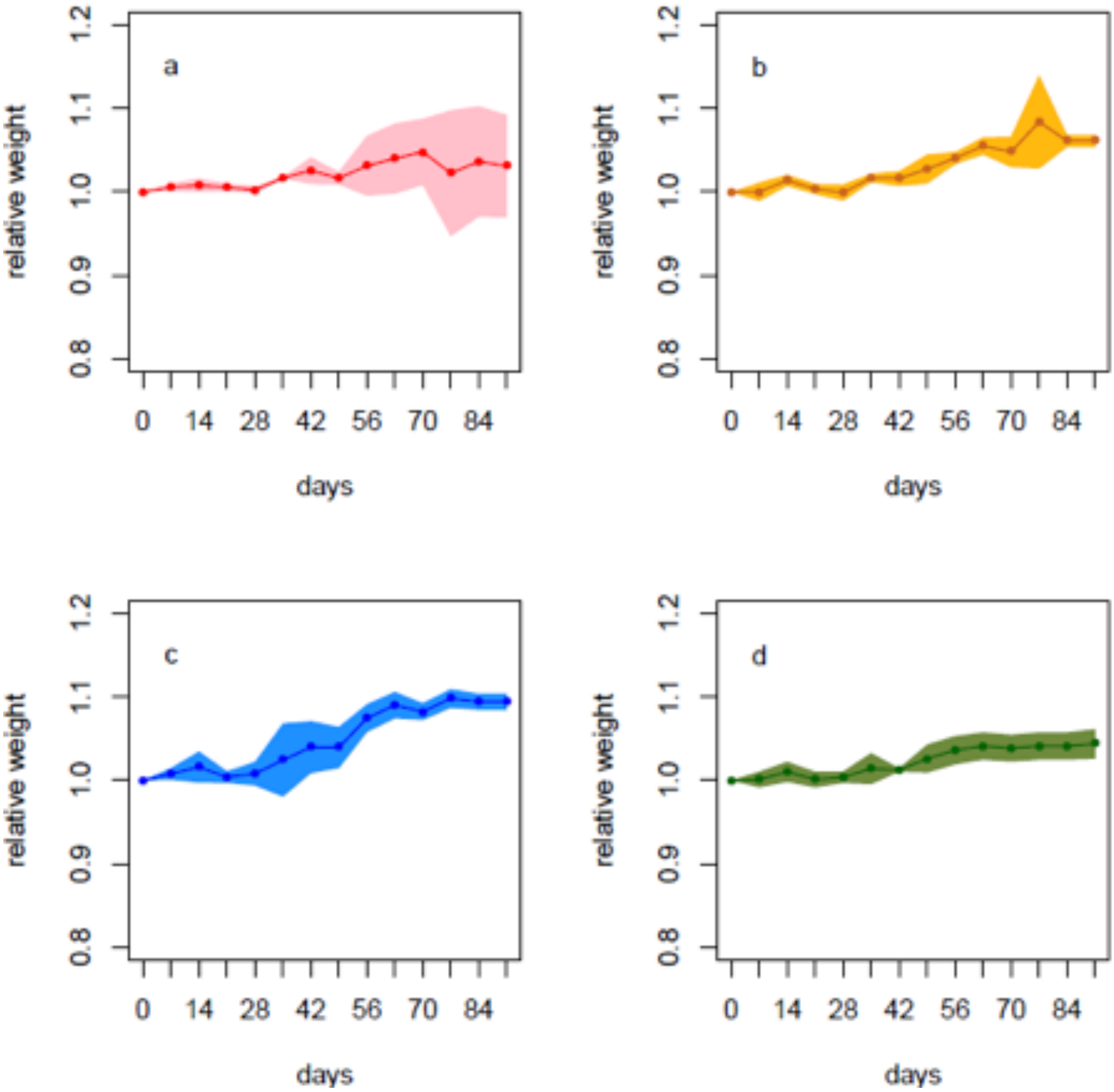

Fig. 6: Mean change in mass after every seven days for in total 91 days for every sample type in the salt water treatment. (+/- std error)
A: Mean change clear balloon
B: Mean change yellow balloon
C: Mean change blue balloon
D: Mean change white balloon

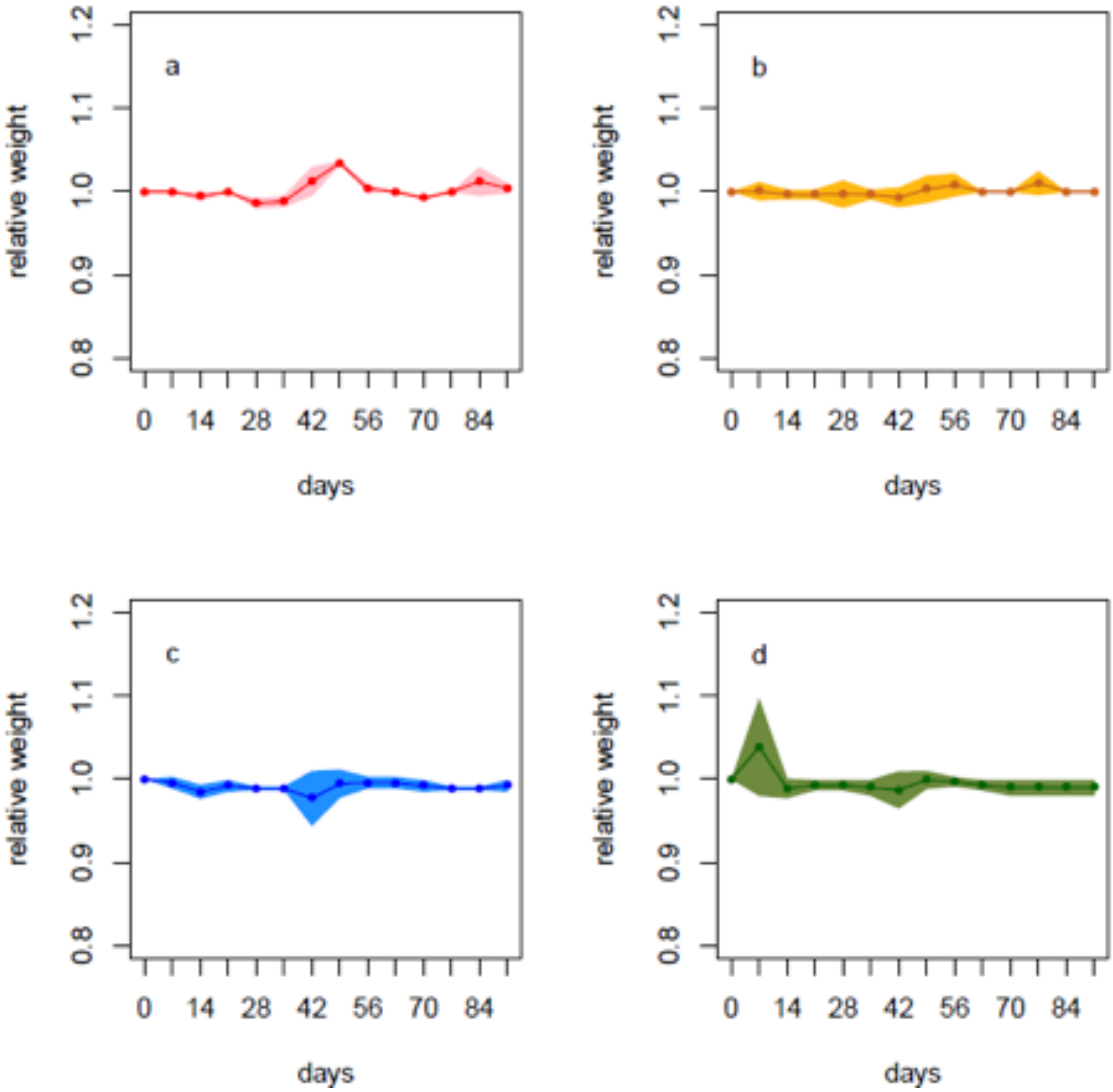

Fig. 7: Mean change in mass after every seven days for in total 91 days for every sample type in the sand treatment. (+/- std error)

A: Mean change clear balloon

B: Mean change yellow balloon

C: Mean change blue balloon

D: Mean change white balloon

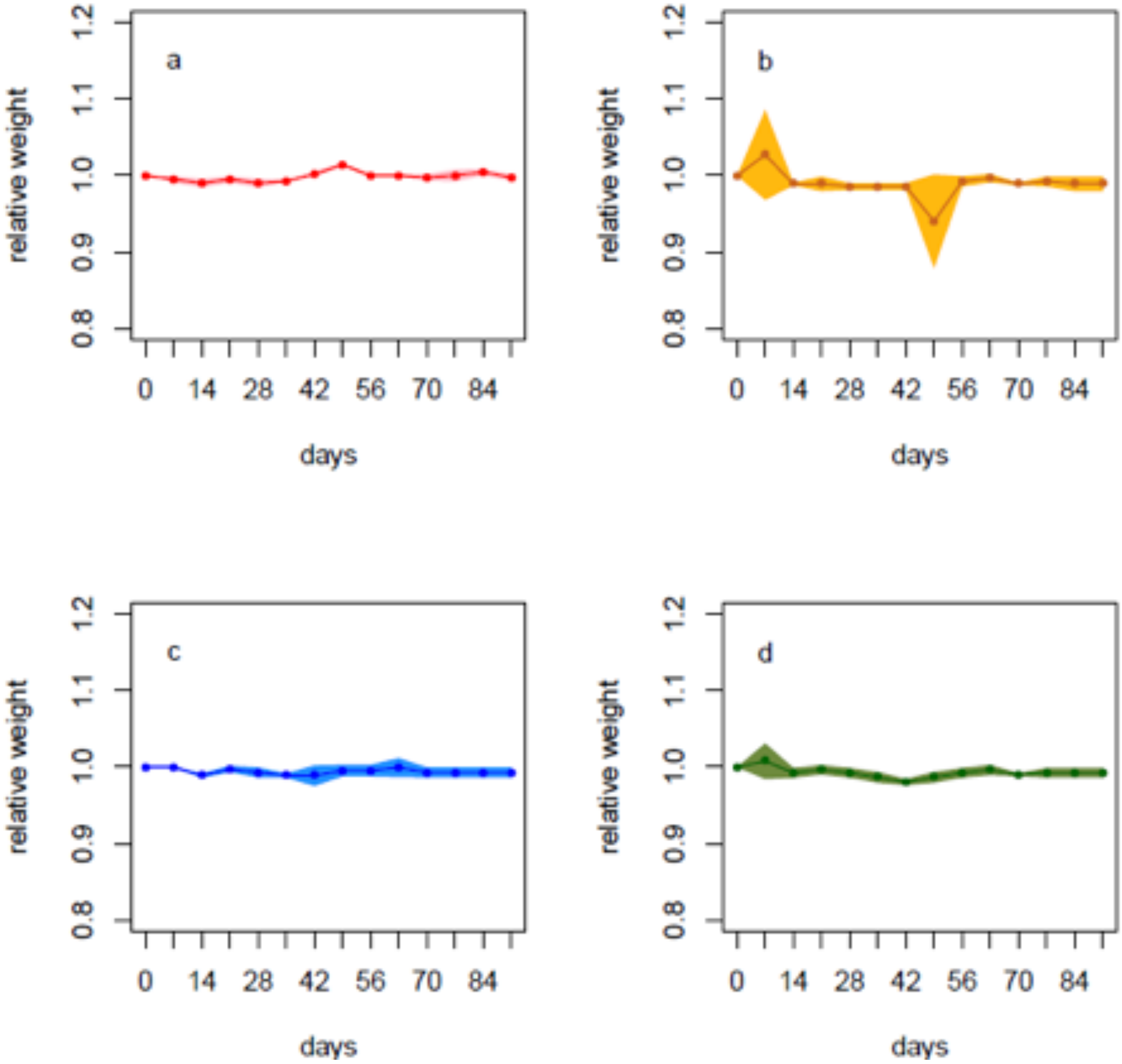

Fig. 8: Mean change in mass after every seven days for in total 91 days for every sample type in the soil treatment. (+/- std error)
A: Mean change clear balloon
B: Mean change yellow balloon
C: Mean change blue balloon
D: Mean change white balloon

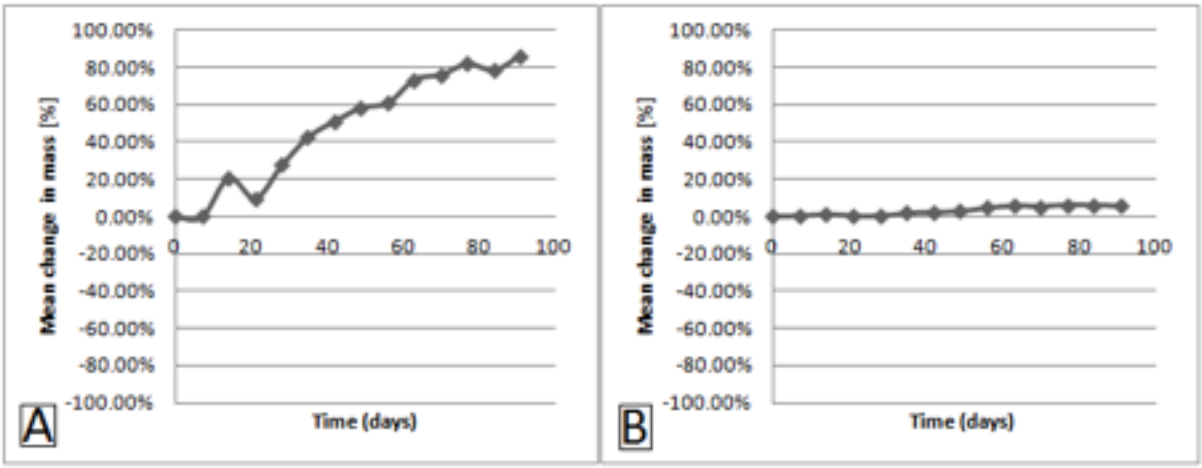

Fig.9: A: Mean change in mass of rubber balloons in freshwater over time(days)
B: mean change in mass of rubber balloons in salt water over time(days)

Figure 9 shows the mean change in mass of rubber balloons in all colors used in this study in the freshwater treatment (See A) and the salt water treatment (see B). It can be seen that the mean change in mass becomes for as well as the freshwater as well as the salt water treatment becomes more positive during the 91 days of this study, which means that the samples gained mass. Striking about the figures above is that the mass gained in the freshwater treatment is way higher than the mass gained in the salt water treatment.

Foil balloon

Figure 10 shows that the mean change in mass after 91 days for foil balloons in most of the treatments is 0%, exception is the salt water treatment which caused the foil balloon to have a minimal increase in weight after 91 days.

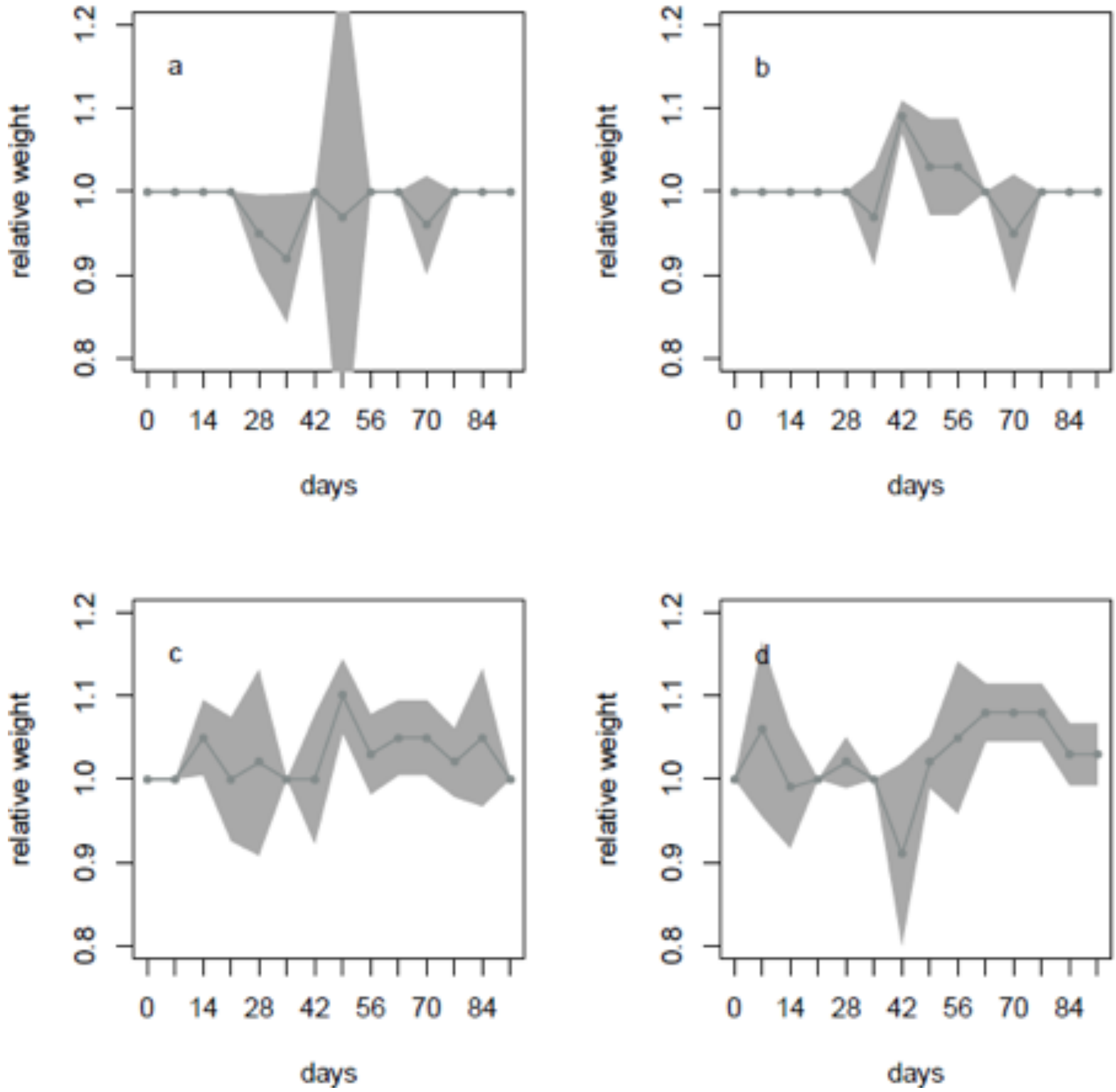

Fig.10: Mean change in mass after every seven days for in total 91 days for foil balloons in different treatments. (+/- std error)
A: Mean change sand treatment
B: Mean change soil treatment
C: Mean change freshwater treatment
D: Mean change salt water treatment

Extra experiment
The extra experiment consists of two parts;
Part 1: Rubber balloons from a 91-days freshwater treatment in a salt water treatment

Figure 11 shows the mean change in mass of rubber balloons that were used in a 91-days freshwater treatment and were put in a salt water treatment for seven days. The begin mass is similar to the end mass of the rubber balloons in the 91-days freshwater treatment. The end mass is the mass of the rubber balloons after seven days in a salt water treatment. In only seven days all rubber balloons decreased their weight up to 20 – 40%.

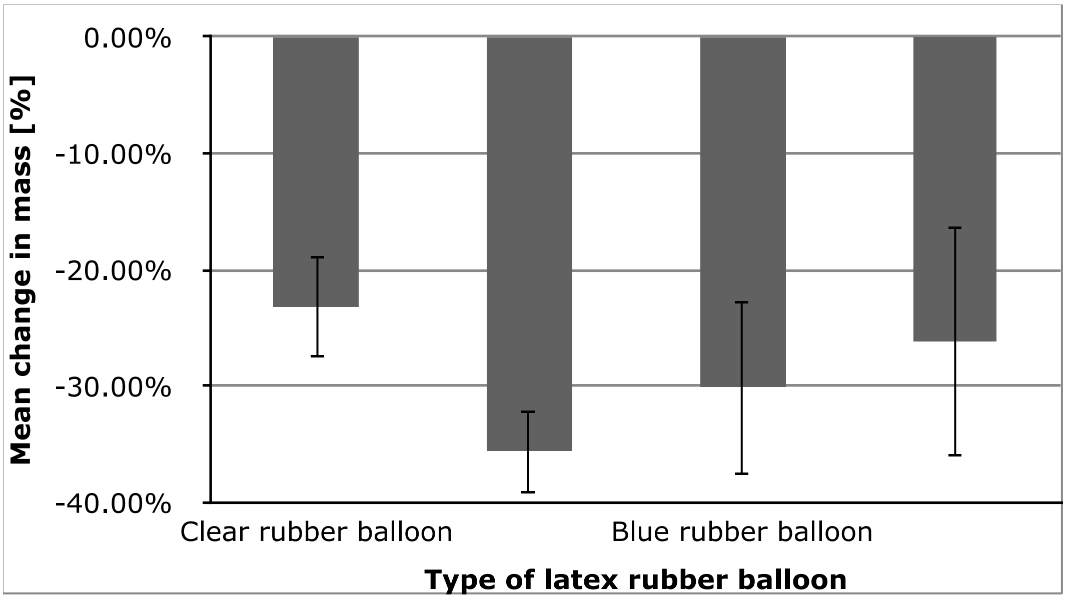

Fig. 11: Mean change in mass of rubber balloons that came from a 91-days freshwater treatment and were put in a salt water treatment for seven days. Note: negative values indicate a decrease in mass.
(+/- std error bars)

Part 2: Treatment with different concentrations of salt
After fourteen days the mean change in mass of clear rubber balloon in different treatments with ascending salt concentration was found. Striking about figure 12 is that the fresher the water, in terms of lack of salt, the bigger the increase of mass. The 150.0 $^{0}/_{00}$ salt treatment showed no change in mass and the rubber balloons in the dry salt treatment showed a slight decrease of mass.

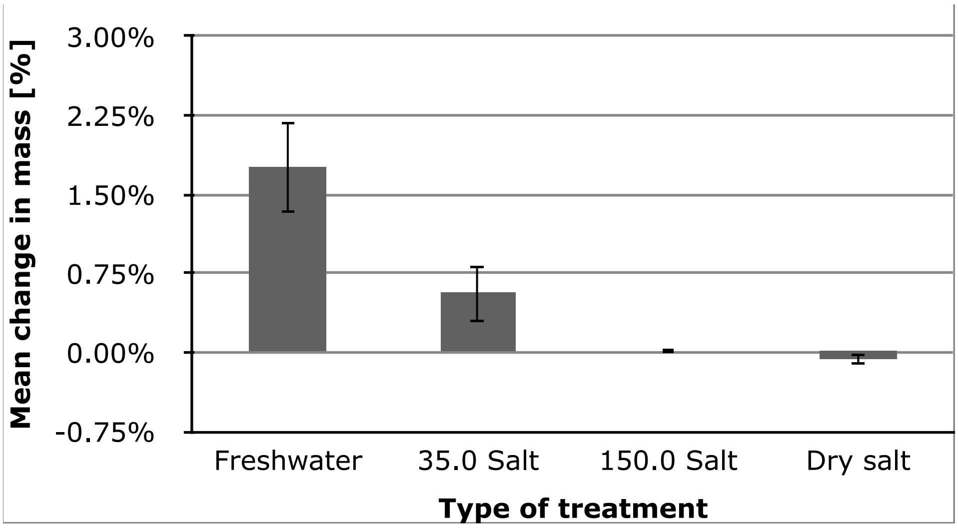

Fig. 12: Mean change in mass of clear rubber balloon after fourteen days in different treatment with ascending salt concentrations. (+/- std error bars)

Ratio calculation
After the experiment of 91 days, ratio calculation could be carried out to find out the expected time before full degradation using the mean change in mass per balloon in the different treatments (Table 2). Types of balloons and treatments that are not present in

Table 2 either had an standard error that was too big, had a mass change after 91 days of 0% or the mass has been increased which makes it impossible to calculate the expected time before full degradation.

Table 2: Expected time of different types of debris in different treatment before full degradation.

Type of debris	Treatment	Mean change in mass	Expected time before full degradation (years)
Clear rubber balloon	Soil	-0.25%	99.73
Yellow rubber balloon	Soil	-1.07%	23.30
Blue rubber balloon	Sand	-0.81%	30.78
Blue rubber balloon	Soil	-0.68%	36.66
White rubber balloon	Sand	-1.03%	24.21
White rubber balloon	Soil	-0.73%	34.15

Discussion

Rubber balloons

Albertsson and Karlsson described the three different stages of degradation of LDPE polymers in environmental circumstances (Albertsson and Karlsson, 1988). Although this model was not created for the degradation of rubber balloons it shows similarities to the results found for the degradation of rubber balloons in salt- and freshwater. Figure 13 shows the theoretical model made of the degradation stages of rubber balloons in water, which consists of three stages what can potentially can occur over time. This theoretical model has been based on results found by Albertsson and Karlsson but also on results found in this study(Albertsson and Karlsson, 1988) . In figure 5 and 6 mean change of rubber balloons in fresh- and saltwater throughout the time can be seen as it degrades.

In stage one the rubber balloons absorbs water whereas the change in mass becomes positive, in other words, the rubber balloons get heavier. The majority of rubber balloons in the freshwater treatment that can be seen in figure 5 seem to be in stage 1, an upward trend can be observed which corresponds with an increase in mass. After reaching the saturation point starts stage two, in this stage the mass of the rubber balloon stays unchanged, an equilibrium with the environment has been reached. the majority of the balloon samples in the salt water treatment showed a mass that hasn’t been changed in multiple weeks, which corresponds with stage two in this theoretical model (see figure 6). In stage three the mass of the rubber balloons rapidly declines which eventually results in a change of mass of -100%, in other words, a full degradation of the balloon.

It’s important to notice that the balloon samples in salt water do not gain the same amount of mass as the balloon samples in freshwater, which means that the stage two equilibrium will be reached at a different percentage. Most of the balloon samples, especially the clear and blue samples, in the fresh water treatment showed a constant increase in mass, which corresponds with stage one (Figure 5). Furthermore two balloon samples in the freshwater treatment showed an unchanged mass for a while which corresponds with stage two and even two balloon samples showed the beginning of stage three, which means that they started to lose mass. How long every stage of the balloon degradation in water takes is unknown. The slope and width of the theoretical model can change according to different treatments, the thickness of the balloon and the environmental conditions.

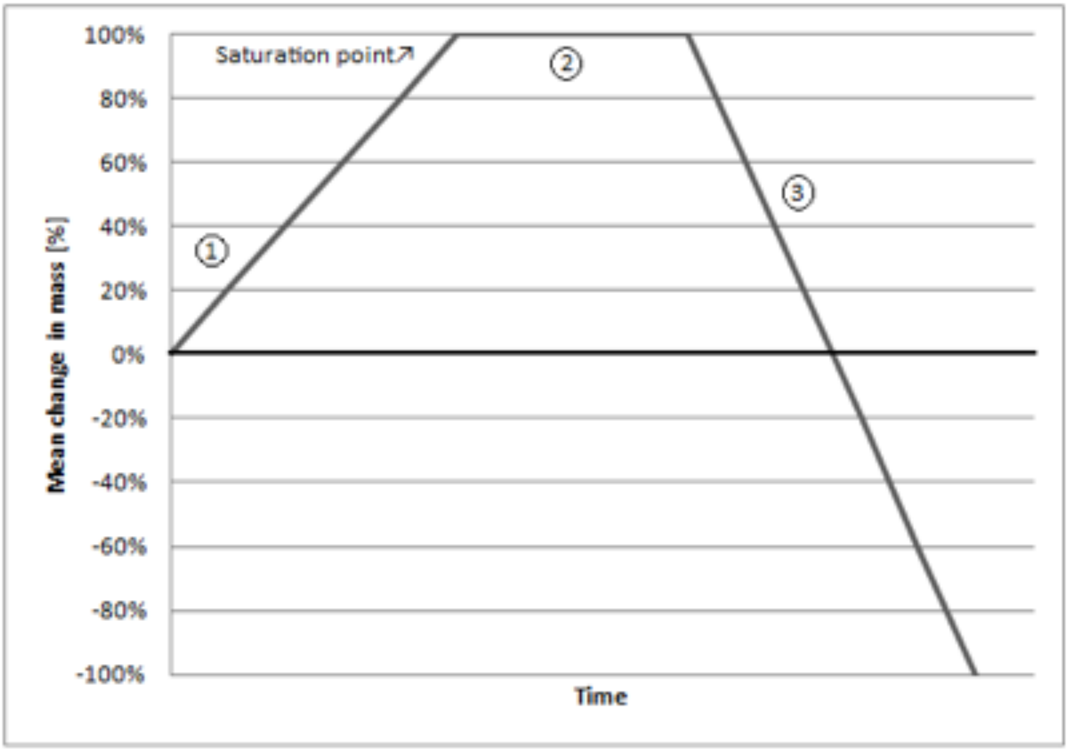

Fig. 13: Theoretical model of the different stages of the degradation rate of rubber balloons in salt- and freshwater based on Albertsson and Karlsson (Albertsson and Karlsson, 1988)
1: In stage 1 the balloons have a positive change in mass which corresponds with an increase in mass through possible osmosis which eventually leads to an saturation point: the point where the rubber balloon no longer can absorb any fluids.
2: After the saturation point comes stage 2, in this stage the rubber balloons is in equilibrium with the environment leading to a stabilization of the mass of the balloon.
3: In stage 3 the rubber balloon starts to decrease in mass, which rapidly leads to full degradation.

A research done by Burchette shows that rubber balloons degrade about as fast as oak tree leaves under a wide range of exposure conditions in the environment including sunlight, weathering, soil, and water exposures(Burchette, 1989). Burchette states that clear rubber balloons exposed to soil have a degradation rate of 3.57% in six weeks, clear rubber balloons exposed to water have a degradation rate of 8.81% in four weeks and that clear rubber balloons that have been exposed to the weather reverted to sap in one week (Burchette, 1989). This is contrary to the results of this research, which showed that there was no significant difference in change of mass for the rubber balloons in the soil and sand treatments.
An explanation for the big increase in mass of rubber balloons in fresh water and the little increase in mass in saltwater could be because of osmosis. The water is first absorbed in the surface layer of the rubber balloon, then it slowly diffuses into the mass, followed by a more or less complete dispersion of the rubber. Natural rubber has a much higher rate of adsorption than synthetic rubber (Boggs and Blake, 1926)

This happens mostly in the freshwater treatment because the salt in the saltwater treatment works as a force that works against the osmosis process. The salt in the water draws the water that has been piled up in the pores of the rubber balloon back into the solution to keep the solution constant. Research has shown that a sample of masticated

rubber increased mass 87% in fresh water within nine months in comparison to 5.6% in salt water (Miller, 1865).
An explanation for the different outcome of the study of Burchette and this research might be because of multiple factors. Burchette describes in his paper that before his experiment started he blew up the balloons and hung these on a clothing line for approximately 6 hours on a sunny day which could have had an influence on the degradation process of the balloons. Also Burchette dried the balloon samples in a desiccators for at least one week before every weighing. In this research the samples were blotted dry and dried in a salad spinner but not placed in a desiccators since this method is not similar to the environment. Also this research took place for 91 days, a significantly longer time than the 42 days research of (Burchette, 1989). As Burchette describes mass loss is not a good criterion for judging degradation of rubber balloons due to the difficulty of cleaning partly degraded samples (Burchette, 1989). Moreover in this research that only counts for the rubber balloon samples in the fresh water treatment: after 42 days the rubber balloon samples became sticky and difficult to clean (indicating degradation). After 91 days the rubber balloon samples in the other treatments were still solid enough and easy to clean for weighing.

Different coloured samples
The rubber balloon samples were researched in four different colours: clear, white, blue and yellow. According to Burchette yellow rubber balloons have a percentage loss of 1.36% within two weeks of water exposure and percentage loss of 6.13% within six weeks of weather exposure (Burchette, 1989). Whereas all the rubber balloons in this study in both the freshwater as well as the salt water increased in mass. Furthermore no significant difference of the mass loss between the different colours was found. Burchette did not use white and blue rubber balloons.

Salt water treatment vs freshwater treatment
The salt water treatments correspond to seawater found in the environment where the manmade debris causes the biggest threat to wildlife. All of the samples gained mass in the saltwater treatment which is similar to the freshwater treatment with the exception of the foil balloon. The foil balloon did not have any change in mass in most of the treatments except for an increase in mass in the salt water treatment. It could be said that salt water is not reacting in the same way as the other treatments. The salt water could slow down of even stop the degradation process. It is striking that the rubber balloons in the freshwater treatment have a much bigger increase in mass than the increase in mass of the balloons in the salt water treatment.

Future study
Future studies about the degradation rate of different types of manmade debris should have a longer study-period where there is more time for the samples to degrade and possibly samples who increased in mass during this study then go to the next phase of decreasing in mass. Albertsson and Karlsson stated that the degradation of LDPE consist of three phases, increase in study time could help by finding the time that it takes for one phase to finish, which could help by making a model to calculate the degradation rate for different polymers (Albertsson and Karlsson, 1988). Also the different phases of degradation for other types of debris could be studied by conducting a longer study. As told before, the saltwater treatment reacts differently than the other treatments. Salt water though is one of the most important treatments as it represents the environment where most threat to marine animals can occur. Further study on the impact of salt water on manmade debris needs to be done.

Conclusion

The rubber balloons in the salt- and freshwater treatments all gained weight. The rubber balloons in the freshwater treatment showed a way higher increase in weight than the rubber balloons in the salt water treatment. The rubber balloons in the soil and sand treatments showed a little decrease in weight. Most of the foil balloons stayed on the same weight or gained a little bit of weight. The most striking result about this experiment is the massive increase in mass of the latex rubber balloons in the freshwater treatment, which could lead to an increase of the degradation time of latex rubber balloons in freshwater. The extra experiment showed that balloons who showed a massive increase in weight in the fresh water treatment already showed an 20-40% decrease of weight after being in a salt water treatment for seven days. This means that the increase in weight is reversible and largely dependent upon absorption which disturbs the measurement of the degradation. The theoretical model made in this research could help by finding out the degradation process of rubber balloons in fresh- and salt water but further study to determine the time span is needed. While the latex rubber balloons in freshwater started showing some visual degradation, this contrasted with the latex rubber balloons in salt water, which didn't show any visual signs of degradation. It can be said that salt water is not reacting in the same way as the other treatments. The way balloons react in salt water is important for the marine wildlife, the fact that the reaction of salt water is hard to find out makes it even worse for the marine wildlife. Further study to the reaction of salt water on manmade debris is necessary.
Differences between the colored latex rubber balloons can be seen but these differences are not striking. The weight gained by the latex rubber balloons all seem to be in the same range.
Eventually every type of manmade debris can degrade but most of the materials used in this experiment seem to have a degradation rate that is too slow to be of environmental relevance most marine life.

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