1. CRITICAL DISCUSSION

Optimum images were used to test the entire data base of 35 giraffe; out of 140 images to choose from, and a second test was run testing the sex appropriate database of 10 males with 40 images to choose from, and 25 females with 100 images to choose from. I^3S was able to recognise the correct image in the top place 37% of the time, and 42% of the time in the top five results. This falls short of the required 75% in order to be useful for accurate in-situ monitoring of *G.camelopardalis*. When chi squared tests were conducted, it showed this was not statistically significant, however, had I^3S matched just one or two more images correctly, that would have been quite significant. This leads to the conclusion that although this test was unsuccessful against the original hypothesis, that with more images and more tests, there could be a significant improvement. With these current results, this method of monitoring giraffe, *G. camelopardalis* is not consistent enough for conservation efforts, and gps, although more invasive, results in large quantities of useful data (Schofield *et al*, 2007) that is not possible with photo identification.

Using sub-optimum images to test both databases again, I^3S was able to recognise the correct image in the top place 14% of the time, and 17% - 20% of the time in the top five results. This also falls short of the expected 50% success rate for sub-optimum images. There was however, statistical data to suggest that sub-optimum images could be useful to a study, and had their place. This is good news, as it is more than likely that images obtained from a placed camera trap as seen in figure 1, or submitted from tourists would be of sub-optimum conditions (Schofield *et al* 2008). Once again the results suggest that a larger data set and more testing would enhance positive results.

I^3S was able to pick the correct image in the top place the same number of times when testing optimum images, whether testing the entire database or the sex appropriate database, however, there was a difference in the top three and top five, with the sex appropriate database choosing the correct image more often than the entire database. There was a difference of 9% in the top three, and 3% in the top 5. In practice there would be no need to test the entire database if you were certain of the gender of the giraffe in the test image. By testing the sex appropriate database, I^3S is immediately

able to reduce the chances of an incorrect result by 50% in an evenly distributed data set, and by nearly a third in this test case.

When testing sub-optimum images, I^3S was able to pick the correct image in the top place 14% of the time, whether testing in the entire database or in the sex appropriate database. There was also no difference in the number of correct matches in the top 3, with I^3S recognising 17% of sub-optimum images in both databases. There was a difference of 3% in the top five with the sex appropriate database recognising one more image than the entire database. This shows the accuracy and objective nature of the program; it also shows that, as already thought, there are no gender specific differences between the male and female coat pattern (Uhlenbroek, 2008; Cooke et al, 2008; Dagg & Foster, 1976). This is a positive result, as mentioned in the case of whale shark images (ECOCEAN, 2013), that often untrained people will be submitting the images, and information on gender may not always be available.

The first statistical test, testing the use of optimum and sub-optimum using first the entire database, and then the sex appropriate database returned a result of being very nearly statistically significant (see table 8), but is not statistically significant. With a larger data set this result could have been very statistically significant. Having more images of each angle saved in each giraffe's folder likely would have improved the chances of returning a correct match.

Table 11 Chi-square test for testing entire and sex appropriate database using optimum and sub-optimum images

Chi-square	3.66453
p=	0.05
chisq critical value (df=1)	3.84

Working with such a small sample size may have hindered the accuracy of testing the sex appropriate database, as with fewer images to test against, the program may list images which are completely inaccurate, just for the sake of listing fifty. This is one reason why the top five were the only matches recorded.

It would also be advantageous to be able to search the database in other ways, for example, not just the entire database and the sex known and unknown database, but

also to search only the left images within the database if you have a left image of a giraffe to test. With the tests conducted in this study, a third of the database was not relevant. However, it is still worth collecting images from all angles of an animal, as drawbacks from only gathering, for example, the left side of an animal can lose you data opportunities if the animal can only be seen from the back, right or front.

There were a range of ages among the data set, ranging from Woburn Safari Park's 'New Calf' at few weeks old, to 16 year old Matilda at Marwell Wildlife. Though there wasn't room in the parameters of this study, if the program had a higher success rate, the next step would be to see how the program manages when testing images of the same individual at different life stages as this is where it is needed to succeed for in-situ monitoring. Issues such as males growing darker with age may present issues for the software, and calves tend to have loose skin when they are born, and take a few weeks to grow into it; these wrinkles can obscure the pattern, which again, may present issues for the software. This emphasises the importance of choosing an appropriate reference space, as mentioned by Tienhoven *et al,* (2007) and The Manta Trust, (2013).

Behansen, a large male hybrid form Yorkshire Wildlife Park, returned the correct match in the top one, testing both the entire database and sex appropriate database, using an optimum image of his left side. This perhaps could have been due to the unusually dark pattern (typical of the Masai breed), which isn't seen in any of the other giraffe in the sample. When testing Behansen's right side however, he was not ranked at all in the top 50 matches of either the entire database or the sex appropriate database. Behansen also happens to be quite overweight, with extra roles of fat, which can make it difficult to determine the pattern edges, which may have hindered identification. In an in-situ situation, an overweight giraffe would be highly unlikely, and so this would not be expected to be an issue, and if it did occur, it would be so unusual that, the researcher could most likely identify the correct match without the use of the I^3S software.

Being able to keep a constant record of a giraffe throughout its lifespan would be an invaluable insight into the behaviour, range, interactions and general ecology of the giraffe which photo identification could observe in a non-invasive manor. Bercovitch *et al* (2012) noticed that male Thornicrofts giraffe patches grow progressively darker with age, which may hinder the observer's natural ability to recognise a giraffe throughout different life stages. This is where the algorithm of photo identification software could help by providing consistent technical support.

Due to time restraints of the project, the data collection portion of the project was time budgeted to happen between October and February; UK winter. This is a time of year when collections are working with fewer staff, so are unable to accommodate data collection very easily. The study would have benefitted from a larger sample size, which would have been possible during the summer.

Out of the 60 zoological collections originally contacted only 6% chose to participate, with 1 replying to say the no longer kept giraffe, 1 UK park with a large herd said yes but on the day arranged for data collection, the keepers were unaware of the project and its needs and the giraffe were shut in winter pens out of decent camera view, 2 collections requested gross amounts of paperwork to be filed, which due fully were, then no reply was to be had. Four parks were kind enough to grant full access to their giraffe, were deeply interested in the project and its application for conservation and were happy to be contributing. The remaining 50 collections never gave any response – 5 of these UK collections were visited as a member of the paying public to gather images, to discover at all parks the giraffe were shut away on winter grounds and unable to be photographed.

This startlingly low uptake of participants in a project which has such low impacts upon keeping staff and the animals involved was a surprise. The Zoo Licensing Act 1981, Section 1A specifies that all zoos are obligated to undertake certain conservation measures, two of which would have been met by participating in this study; "(i) research from which conservation benefits accrue to species of wild animals", and "(iii) the exchange of information relating to the conservation of species of wild animals" (DEFRA, 2003).

A common welfare issue also became apparent throughout this project; with many collections keeping their giraffe indoors and on small hard standing yards for 4 - 5

months every winter due to cold and wet weather creating unstable, muddy, slippery, icy or flooded paddocks. Apart from this creating many issues with usable data collection, this greatly reduced the exercise opportunities for hundreds of giraffe across the country. The issue of non native animals whose natural climate is not represented in the UK is becoming more prevalent when discussing captive welfare implications, One collection which had a calf with pneumonia, who was shut in the giraffe house, with its mother for several months, also meant that 3 other herd members were also shut in the house, due to the poor design on the old listed building preventing the outdoor access to some, while keeping a portion of the house warm for the sick individual. There appears to be an issue of zoological collections taking on giraffe, *G.camelopardalis* as an attraction, knowing they do not have the capitol to back up that decision by providing the animals with suitable indoor and outdoor housing, browsing and roaming opportunities all year round. The lack of keepers wishing to be involved in the project was also surprising; having expected that most keepers would already be in possession of images of all the giraffe, *G.camelopardalis* in their care and there would be no need for a visit.

Although this program does not appear to be as accurate for obtaining good information as other methods of monitoring, this method is very worth persevering with due to its non-invasive nature. This method of monitoring, although not 100% accurate yet, is one of the cheapest ways to collect data; and in some cases it is actually a project funding opportunity, as whale shark, Rhincodon typus and Rothschild, G.c.rothschildi projects charge volunteers to take images for them as a conservation holiday (MCSS, 2013; Rothschild Giraffe Project, 2013).

The main limitation of I^3S is in the use of software which works in 2D, when working with 3D animals. This explains the camera angles at which the program is effective and accurate to; working best at 90 degree angles, thereby providing the most 2D angle possible. This is an issue for which the program will need to be configured to each species the program would be used for (Jurgen & Reijns, 2007).

2. CONCLUSION AND FUTURE WORK

While this investigation has not proved I^{3}S to have as high a success rate when testing with *G. camelopardalis* as it has with other species; this was a small investigation, with limited data set, and it seems very worthwhile to continue data collection to keep testing the program with.

There are still approximately another 80 giraffe on ISIS records in the UK alone (2011) that could be entered onto the I^{3}S database from around the UK; and as mentioned the task of data collection will be considerably easier in the summer months. This would mean a complete data set of over 100 individual giraffe, which would be more persuasive in future tests.

Photo identification software is still a new technology and is continuing to improve as different models are created with specific species in mind. Until the technology catches up with the conservation need, data collection can continue, and with giraffe, G.camelopardalis having a lifespan of approximately 20-25 years (Dagg & Foster, 1976), those images will still be useful for many years.

When considering the costs of other applications such as GPS, a free software such as I^{3}S, which produces very nearly significant data, which can be gathered through free volunteering, as the sub-optimum testing showed, this form of monitoring is worth investigating further.

Future work will include the continuation of data gathering, both from in situ and ex situ *G. camelopardalis* of all ages, (sub) species and genders as not only will this build a data base of giraffe images, which can be used with any software program in the future, but will also increase the chances of returning statistically accurate results.

Since the release of I^{3}S, Jurgen and Reijns (2007) have developed I3S Contour; for use with tail flukes of whales and is currently working on I3S Pattern; for use with light and dark patterns, as with the great white shark, *Carcharodon carcharias* (Jurgen & Reijns, 2007).I^{3}S Pattern may have much greater success for use with giraffe when photographed in optimum conditions. This data set can be used to test that program, possibly with a more successful outcome.

By altering the I^{3}S software to use a selection tool as seen in Photoshop software, it is feasible to make a fingerprint in I3S by selecting this tool, and clicking on the patches of the giraffe, so the tool can cling to the outline of the patch, as it distinguishes the light background from the darker patch. This could be a very successful identification tool, and minimise the limitations of working in 2D.