

Administrative Information

Institution: Lincoln Park Zoo
Project Title: Creating a Web-Based, User-Friendly Data Repository for Zoo and Wildlife Endocrinology
Project Number: LG-45-14-0013-14
Award amount: \$24,464
Project dates: August 1, 2014 to July 31, 2016
Project Director: Dr. Rachel Santymire, Director of Lincoln Park Zoo's Davee Center for Epidemiology and Endocrinology
IMLS Approved Changes: 1. Change in project dates, approved on 8/3/2015
2. Change in key personnel, approved on 6/22/2016

Project Summary

As biodiversity declines around the world, zoos and aquariums are taking a more active role in protecting threatened species. These institutions are working together around the world to build sustainable, healthy zoo-housed populations – an effort that requires intense collaboration and the creation of robust science-based methods to study and define what individual and population health means for a variety of species, with a particular focus on reproduction and stress. Within this context, an exciting field of study has emerged as a critical tool, wildlife endocrinology.

Although it is not a new scientific discipline, endocrinology (the study of hormones) has only recently broadened its scope from human health to include wildlife health and conservation. Hormones are the chemical messengers that regulate bodily functions, and hormone analysis can offer scientists a unique window into an individual animal's overall health, including reproductive status and stress levels. Already, non-invasive endocrine monitoring techniques have transformed the way leading zoological institutions assess reproductive status, confirm and monitor pregnancy, and evaluate stress responses to environmental stimuli in individual animals. Developing and applying these methods broadly and systematically has the potential to help solve a variety of management problems for many zoo-held wildlife species¹. As endocrine data are standardized and sample collection methods are adapted for use in the field, these tools can also be used to monitor and manage the health and well-being of free-ranging wildlife populations.

Unfortunately, wildlife endocrinologists lack a tool for sharing methods, resources, and knowledge about their research, which has so far made it impossible to apply these methods on a comprehensive scale. Currently, endocrinology research has only been conducted on 2% of mammals, and conducted even less on other animal classes, like birds or reptiles^{2,3}. Further, the majority of wildlife endocrinology projects never appear in publication because many endocrinologists from zoos, aquariums, and universities are analyzing samples for clinical reasons (i.e., health and reproduction of one or two animals located at their facility). These types of studies do not warrant publication due to their limited scope; however these data gathered are extremely important to others in the field.

Wildlife biologists use non-invasive sampling (i.e., feces, urine, hair and feathers) rather than blood to study animal physiology. Non-invasive sampling minimizes the disturbance to the

animal, samples can be found in large quantities, and hormonal values represent the hormones the animal produced over the past twelve to forty-eight hours – giving a better picture of the true physiology of the animal than blood sampling, which represents hormone levels only at the moment the sample was taken, and can reflect the “manufactured” stress caused by the procedure⁴. However, because wildlife endocrinologists are not using blood samples for hormonal analysis, laboratory techniques such as sample handling, sample processing, and hormonal analysis have to be modified and then properly validated for each species. Every species metabolizes hormones differently, meaning that baseline hormone levels – and the variations in hormone levels caused by events like pregnancy and stress – are drastically different for each species. Therefore, before endocrine sampling can be used as an effective indicator of an animal’s physiological state, expected ranges for its species’ hormone levels must be determined and validated. Validation requires comparing hormone analysis with previously established biochemical, biological and physiological analyses⁴⁻⁶. These checks ensure the reliability of the hormonal analysis, but the process is costly and time-consuming, and must be completed for each new species studied. Without a mechanism to share data across institutions, these validation procedures are needlessly duplicated with every study, impeding researchers’ ability to expand analyses or study new species within their collections.

In response to this community’s needs, Lincoln Park Zoo was awarded an IMLS Sparks! Ignition Grant to create a web-based venue for sharing techniques and data related to the growing field of wildlife endocrinology. This critical repository, the Wildlife Endocrinology Information Network (“WEIN”), will allow researchers around the world to access standardized animal endocrinological data in a central, searchable database for the first time. The goals of this project were to: 1) provide a repository for important data that would otherwise never be available; 2) establish a searchable database to extract data on a specific species and/or techniques; 3) provide a gateway to communication and cooperation among zoo and wildlife endocrinologists; 4) establish normal values for physiological states (i.e. pregnancy, cyclicity, and stress) for zoo-housed animals and integrating these data with animal recordkeeping software used by zoos and other animal facilities; and 5) provide a global resource to improve animal care, population management, and wildlife conservation.

Process

WEIN is a comprehensive repository to collect, store and share data. With the support of IMLS, this project tested, refined, and launched WEIN on a secure website, making the information globally accessible. As the only venue available to wildlife endocrinology researchers and practitioners for obtaining and sharing valuable, peer-reviewed data not otherwise suitable for publication, WEIN serves a growing need. The primary purpose of WEIN is to centralize information regarding endocrine monitoring in various species from both zoo and field projects, creating a critical repository and resource for endocrine laboratories at zoos and universities. Data will consist of detailed endocrine methods and analyses including sample type, sample processing, hormone assays (EIA and RIA), validation, and analysis. To address data-sensitive issues, WEIN is restricted to use by International Society of Wildlife Endocrinology (ISWE) members only. Members can log in via the ISWE website (www.iswe-endo.org) and have unlimited access to all data. ISWE’s membership fees are a nominal \$60 per year for professionals and \$30 for students, because it seeks to promote collaboration within the broader wildlife and conservation science

community. ISWE hopes to increase wildlife endocrinology's impact on this community through WEIN⁷.

WEIN was developed with an easy and user-friendly data entry process organized in hierarchical fashion incorporating five levels. The top level is the PROJECT which captures information about the location, time, duration and demographic information about the animals participating in the study. The second level is the PROCESS which details how samples were taken. Under that level is the HORMONE area which contains data about the various hormones analyzed as part of the study. The ANALYSIS and VALIDATION levels house details about any procedures undertaken to ensure the reliability of the data relating to any hormones which were extracted. The webpage user interface mirrors the database structure. The development of WEIN occurred in several steps listed below.

Alpha Testing: The Lincoln Park Zoo project team conducted its internal alpha testing of WEIN 1.0. The testing group included a committee of four Lincoln Park Zoo employees and one graduate student. Committee members tested WEIN's functionality by entering data from actual projects and searching for and reviewing others' entries. The committee met weekly throughout the alpha testing phase to address any issues encountered. Alpha testing resulted in de-bugging and additional minor changes to the application. A new version incorporating these changes, WEIN 1.1, was ready for beta testing in October 2014.

Beta Testing: Originally, the project team planned to make WEIN 1.1 available to members of the International Society of Wildlife Endocrinology (ISWE) for beta testing by launching the database on ISWE's website. Unfortunately, system errors made this impossible. Instead, the Lincoln Park Zoo team worked with ISWE leadership to recruit individual members to beta test WEIN 1.1 while it remained housed on Lincoln Park Zoo's local server. Meanwhile, the team continued to de-bug WEIN 1.1 and developed a survey form for beta testers to use while assessing WEIN. It included questions about WEIN's appearance, search and viewing functions, data entry, and the review process for submitted projects. All questions included a 5-point Likert scale response (with 5 being "highly effective") and a free-form comment box.

Through ISWE, the project team engaged four external beta testers for WEIN 1.1: researchers from the University of Chicago (Chicago, IL), Cleveland MetroParks Zoo (Cleveland, OH), Disney's Animal Kingdom (Orlando, FL), and St. Louis Zoo (St. Louis, MO). This first round of beta testing occurred between October 2014 and January 2015. To assess all aspects of the database, the beta testers entered real data from their own projects and reviewed previously-entered projects. The beta testers found WEIN's data entry process straightforward and very user-friendly, rating it a 4.6 out of 5. They also liked how WEIN allowed them to view projects already entered in the database, scoring those functions between 4.3 and 5 out of 5.

The beta testers did identify some significant issues, however. They found the database's appearance confusing, rating it just a 3.8. These issues stemmed from the fact that WEIN's user interface, as originally conceived, did not reflect the database's hierarchical structure. WEIN 1.1 had a block-style interface, showing the data structured in sliding panels. As the user clicked on each of the panel headings, additional details and related data entry fields appeared. The limitation

of this approach is that the user never sees the entire project, with all of its parts, in one view (Figure 1).

Implementing Feedback on WEIN 1.1: As a result of the beta testers' feedback, the Lincoln Park Zoo project team decided to completely overhaul the WEIN user interface. They first designed a "data tree," which resembles an organizational chart, as a way to reimagine the application's overall appearance. The team shared the new design concept with the ISWE board members, who enthusiastically approved the change.

Edward Wilkerson redesigned the WEIN 2.0 interface to reflect this hierarchical structure for project data entry. The user now sees the "data tree" structure first, which encompasses the entire project. Then, s/he is able to click on the individual boxes within the entire project's "tree" to access the associated data entry fields (Figure 2).

Server Modifications and Alpha Testing WEIN 2.0: The project team completed and began Alpha testing WEIN 2.0 in December 2015. At the same time, Lincoln Park Zoo began to move all of its internal web-based projects to a cloud-based system called Amazon Web Services (AWS). This move is in line with industry trends. AWS maintains a huge array of servers which may be configured to suit almost any project. It also offers automatic software updates and daily data backups. Finally, AWS environments are scalable, meaning that as each project grows its server resources are automatically marshaled to accommodate that growth.

The downside of this migration was that AWS environments work differently than a standalone server and required changes to the newly-developed WEIN software. It also required that the ISWE website, where WEIN would ultimately be hosted, needed to be moved to AWS as well. Because the website was active and in daily use, multiple testing environments had to be maintained to ensure that the website was always up and running even if WEIN was not. Therefore, the entire project had to be moved to AWS in stages, which slowed the testing process.

Further complicating things, Lincoln Park Zoo's SQL server license was not transferrable to AWS. The SQL Server database is the backbone of both the ISWE website and WEIN, and is essential if either is to run. The move to AWS required configuring a new SQL Server instance using the free version of SQL Server called SQL Server Express. This resulted in additional testing delays.

While testing and modifications continued, the Lincoln Park Zoo team updated all WEIN website content to reflect the new interface. These documents, including a full "Frequently Asked Questions" guide, incorporate more feedback from the application's beta testers. The website now also features graphics depicting current WEIN statistics, including the number of projects uploaded organized by genetic families, hormone, institution, and sample type (Figures 3-6). Finally, the team updated all of the text for the WEIN main page on the ISWE website (<http://www.iswe-endo.org/WEIN>). This page describes WEIN's goals, benefits, and overall functionality – including descriptions of each of the data management sections (Project, Process, Hormone, Validation and Analysis), the unique review process that ensures all data submitted are verified, and plans for future development of WEIN to maintain its applicability to this scientific community. This information will ensure that WEIN users understand the purpose of the database.

It serves the added function of educating visitors to the ISWE website about the benefits of becoming an ISWE member.

Finally, because WEIN is only available to ISWE members, ISWE needed to update its website and membership system to host the database. As a relatively new organization, ISWE had been collecting dues checks via mail and recording membership status manually. Mr. Wilkerson worked with ISWE leadership to set up an automated, online membership system which allows members to log in and access password-protected areas of the ISWE website, including WEIN, as well as pay dues and check membership status online. Not only will the new system allow ISWE to host the database, but it has also streamlined the society's membership process – a necessary change to facilitate ISWE's continued growth.

WEIN 2.1 Launch to ISWE Membership: WEIN 2.1 launched to all ISWE members via the ISWE website on April 6, 2016. ISWE leadership and the Lincoln Park Zoo project team e-mailed ISWE members to let them know that WEIN had launched, and to encourage members to upload their projects. In fact, the ISWE Board offered members an incentive to begin using the new database right away – a free, two-year society membership (worth \$120) for the member who inputs the most projects this year. Each Board member has committed to uploading five projects by the end of 2016, and collectively put out a call for ISWE members to volunteer as WEIN reviewers for new projects. Each project uploaded to WEIN is currently reviewed by Dr. Rachel Santymire and one other wildlife endocrinology expert. The Board has also featured WEIN in a blog post and on ISWE's Facebook page. The project team is pleased with the amount of support it has received from ISWE leadership so far, and is optimistic that it will help keep WEIN's momentum going.

Since WEIN launched in April, ISWE members from 8 institutions have entered 16 new projects, bringing the total number of projects entered in WEIN to 38, from 12 institutions total. In June, Lincoln Park Zoo hosted a WEIN working session to introduce more local ISWE members to WEIN. Researchers were able to come to the zoo and enter their project data into the database with live support from team members Dr. Santymire, Mr. Wilkerson, and Ms. Fowler. Santymire and Wilkerson attended the annual ISWE Board meeting in late September, where they strategized about hosting similar working sessions at the next ISWE conference, in August 2017. Santymire and Wilkerson also provided general updates to the Board about WEIN usage, including database activities, such as the number of new projects, searches, and improvements, as well as WEIN's impact on ISWE website traffic and membership (please see PROJECT RESULTS).

WEIN was built to suit the needs of the field and will continue to evolve with the needs of this community. After an ISWE member has a project submitted, reviewed and entered into WEIN, the team sends him/her a survey with questions about WEIN's appearance, search and viewing functions, data entry, and the review process for submitted projects. All questions included a 5-point Likert scale response (with 5 being "highly effective") and a free-form comment box. So far, survey results have demonstrated a marked improvement in WEIN 2.1's appearance, functionality and usability from the previous version. Average responses to these questions are listed in the table below.

WEIN users have used the free-form comment section to provide additional suggestions to improve WEIN’s functionality. For example, one user suggested adding FAQs as a side-bar to help to answer questions as data is being entered. Another helpful suggestion was to increase the size of the search results box so that more projects could be shown at one time. These modifications will be implemented in a future version of WEIN. As more ISWE members use WEIN, the team will continue to obtain feedback using this survey. Moving forward, small changes like adding new hormones or chemical suppliers to drop-down lists will be implemented on an ongoing basis, and more major changes to the site will be implemented annually.

WEIN User Survey Average Responses	<i>WEIN 1.1 (ISWE Beta testers)</i>	<i>WEIN 2.1 (ISWE general members)</i>
<i>WEIN Appearance</i>	<i>3.8</i>	<i>4.9</i>
<i>WEIN Searchability</i>	<i>3.3</i>	<i>4.5</i>
<i>Viewing WEIN Content</i>	<i>4.3</i>	<i>5.0</i>
<i>WEIN Data Entry</i>	<i>4.6</i>	<i>4.9</i>

Project Results

By completing the activities described above, the zoo’s project team hoped to achieve these goals, as set forth in the original proposal to IMLS:

1. Provide a repository for important data that would otherwise never be available;
2. Establish a searchable database to extract data on a specific species and/or techniques;
3. Provide a gateway to communication and cooperation among zoo and wildlife endocrinologists;
4. Establish normal values for physiological states (i.e. pregnancy, cyclicity, and stress) for zoo-housed animals and integrating these data with animal recordkeeping software used by zoos and other animal facilities; and
5. Provide a global resource to improve animal care, population management, and wildlife conservation.

During this grant period, the project team accomplished the first three of these goals, and laid the critical groundwork for the final two goals to be achieved as researchers continue to upload and share data to WEIN.

Goals 1 and 2: The creation, refinement, and launch of WEIN to ISWE’s general membership created a vital repository for wildlife endocrinology data which might not be eligible for

publication otherwise. It also established a database for this information which is easily searchable based on specific species, hormones, and testing techniques.

So far, more than 38 authentic projects (16 since WEIN's launch) have been entered into the database by the Lincoln Park Zoo team and 11 other collaborators. These projects include studies of species from 21 different genetic families and five different hormones, and used seven different sample types to collect data (Figures 3-6). All of these metrics have approximately doubled since WEIN launched in April. This increase in number and diversity of data entries demonstrates WEIN's inherent flexibility, and reinforces the team's confidence that WEIN will successfully fulfill the need for a comprehensive wildlife endocrinology data repository.

The majority of projects initially entered into WEIN come from published literature. However, even these projects contain information that was not originally published with the studies, or is organized differently in the new database. These data provide another perspective on the results and methodologies, which will support future projects with specific species or techniques. Importantly, WEIN captures both effective and less effective methods so that researchers can share methods that were not successful and learn from others' efforts. Further, compiling these data in a searchable format allows researchers to access them with much greater ease. Previously, a person would have needed to search the literature for relevant studies, obtain the manuscripts, and manually extract these data. Now, all of this information can be quickly found in one location, and WEIN can export the data into Microsoft Excel[®] instantaneously.

Goal 3: When WEIN launched, a number of people e-mailed Mr. Wilkerson because they could not access the database. In nearly every case, it was because the individual had allowed his or her ISWE membership to lapse. As such, WEIN's launch prompted more than 60 people to renew their memberships or to join ISWE for the first time. Particularly for a non-conference year, this was a major uptick in membership for the society, indicating that access to WEIN can serve as a significant draw for ISWE. As a collaborative organization, ISWE and its members benefit from a wide and diverse membership base. By promoting active membership in the society among wildlife endocrinology researchers around the world, WEIN is already serving as a gateway to communication and cooperation among zoo and wildlife endocrinologists.

To ensure that WEIN continues to fulfil this role, the project team will use Google Analytics[®] to track demographics and engagement levels of visitors to the ISWE website and WEIN. Initial data on visits to the ISWE website have already shown an increase in the number of webpages viewed and pages visited per session after WEIN's launch. Compared to 2015 (a conference year), visitors spent 83% more time on ISWE's website after WEIN went live.

Goals 4 and 5: As scientists continue to enter projects into the database, and pull data from others' projects, WEIN will grow as a resource, facilitating cooperation and informing new research. Ultimately, this powerful tool will allow researchers to integrate enough data to establish normal values for physiological states (i.e. pregnancy, cyclicity, and stress) for zoo-housed animals, thus providing a global resource to improve animal care, population management, and wildlife conservation.

Successes and Failures

The team learned a number of things over the course of WEIN's development. First, when developing a scientific database to be used at a global scale, the software and interface needs to be robust and adaptable. One of the first protocol types of this database was created in Microsoft Access®. However, many colleagues who needed to view and evaluate the database did not have Access software. Instead, the team needed to adjust WEIN to use Microsoft SQL Server as its database engine, along with Microsoft ASP.Net and DotNetNuke to manage the web front end.

Second, opinions will vary from how much information should be captured and how data fields are organized and presented. Based on these important factors, the team set out to create a database that collected enough relevant information that users could repeat others' methods – or, at the very least, give the user enough of an overview that s/he could get started and have a person to contact (the project creator) if there were any questions. It was also important to capture techniques that may have failed with a particular species, so that scientists would know not to use time and resources pursuing those methods.

WEIN's data entry process was designed to be easy-to-use, with a webpage user interface mirrors the database structure. However, a lesson learned during the Beta testing of WEIN was that the user needed to have a different interface than the database structure itself. These issues stemmed from the fact that WEIN's user interface, as originally conceived, did not reflect the database's hierarchical nature. As noted above, WEIN 1.1 had a block-style interface, showing the data structured in sliding panels. As the user clicked on each of the panel headings, additional details and related data entry fields appeared. The limitation of this approach is that the user never sees the entire project, with all of its parts, in one view. The project team decided to completely overhaul the WEIN user interface. We designed a more user-friendly "data tree" interface which resembles an organizational chart, as a way to simplify the application's overall appearance.

Finally, one of the most important elements of a successful database is ensuring that it is capturing valid and error-free data. To address this, the Lincoln Park Zoo team added a review process function in WEIN. It begins once the user has completed his or her data entry. The submitted project is tasked to the WEIN Manager (Dr. Rachel Santymire) who will briefly review the entry and then forward it to a WEIN Reviewer. The WEIN Reviewer is a specialist chosen for his or her expertise in wildlife endocrinology. The WEIN Reviewer, who is an ISWE member and expert in their field, will carefully go through the record and determine if these data are accurately entered based on his or her experience with that species or another similar species. This review process ensures that these data are biologically valid for that species. The reviewer can accept the project in its current state or ask for revisions. To ensure the anonymity of the WEIN Reviewer, the project is then sent back to the WEIN Manager and is either returned to the submitter for editing or, if there are no errors, is released into WEIN for general viewing by ISWE members.

What's next?

Short-term

The Lincoln Park Zoo team will continue to manage WEIN. They will facilitate reviews of submitted projects and make ongoing, minor modifications to the database as needed. They will

Administrative Information

Institution: Lincoln Park Zoo
Project Title: Creating a Web-Based, User-Friendly Data Repository for Zoo and Wildlife Endocrinology
Project Number: LG-45-14-0013-14
Award amount: \$24,464
Project dates: August 1, 2014 to July 31, 2016
Project Director: Dr. Rachel Santymire, Director of Lincoln Park Zoo's Davee Center for Epidemiology and Endocrinology
IMLS Approved Changes: 1. Change in project dates, approved on 8/3/2015
2. Change in key personnel, approved on 6/22/2016

Project Summary

As biodiversity declines around the world, zoos and aquariums are taking a more active role in protecting threatened species. These institutions are working together around the world to build sustainable, healthy zoo-housed populations – an effort that requires intense collaboration and the creation of robust science-based methods to study and define what individual and population health means for a variety of species, with a particular focus on reproduction and stress. Within this context, an exciting field of study has emerged as a critical tool, wildlife endocrinology.

Although it is not a new scientific discipline, endocrinology (the study of hormones) has only recently broadened its scope from human health to include wildlife health and conservation. Hormones are the chemical messengers that regulate bodily functions, and hormone analysis can offer scientists a unique window into an individual animal's overall health, including reproductive status and stress levels. Already, non-invasive endocrine monitoring techniques have transformed the way leading zoological institutions assess reproductive status, confirm and monitor pregnancy, and evaluate stress responses to environmental stimuli in individual animals. Developing and applying these methods broadly and systematically has the potential to help solve a variety of management problems for many zoo-held wildlife species¹. As endocrine data are standardized and sample collection methods are adapted for use in the field, these tools can also be used to monitor and manage the health and well-being of free-ranging wildlife populations.

Unfortunately, wildlife endocrinologists lack a tool for sharing methods, resources, and knowledge about their research, which has so far made it impossible to apply these methods on a comprehensive scale. Currently, endocrinology research has only been conducted on 2% of mammals, and conducted even less on other animal classes, like birds or reptiles^{2,3}. Further, the majority of wildlife endocrinology projects never appear in publication because many endocrinologists from zoos, aquariums, and universities are analyzing samples for clinical reasons (i.e., health and reproduction of one or two animals located at their facility). These types of studies do not warrant publication due to their limited scope; however these data gathered are extremely important to others in the field.

Wildlife biologists use non-invasive sampling (i.e., feces, urine, hair and feathers) rather than blood to study animal physiology. Non-invasive sampling minimizes the disturbance to the

animal, samples can be found in large quantities, and hormonal values represent the hormones the animal produced over the past twelve to forty-eight hours – giving a better picture of the true physiology of the animal than blood sampling, which represents hormone levels only at the moment the sample was taken, and can reflect the “manufactured” stress caused by the procedure⁴. However, because wildlife endocrinologists are not using blood samples for hormonal analysis, laboratory techniques such as sample handling, sample processing, and hormonal analysis have to be modified and then properly validated for each species. Every species metabolizes hormones differently, meaning that baseline hormone levels – and the variations in hormone levels caused by events like pregnancy and stress – are drastically different for each species. Therefore, before endocrine sampling can be used as an effective indicator of an animal’s physiological state, expected ranges for its species’ hormone levels must be determined and validated. Validation requires comparing hormone analysis with previously established biochemical, biological and physiological analyses⁴⁻⁶. These checks ensure the reliability of the hormonal analysis, but the process is costly and time-consuming, and must be completed for each new species studied. Without a mechanism to share data across institutions, these validation procedures are needlessly duplicated with every study, impeding researchers’ ability to expand analyses or study new species within their collections.

In response to this community’s needs, Lincoln Park Zoo was awarded an IMLS Sparks! Ignition Grant to create a web-based venue for sharing techniques and data related to the growing field of wildlife endocrinology. This critical repository, the Wildlife Endocrinology Information Network (“WEIN”), will allow researchers around the world to access standardized animal endocrinological data in a central, searchable database for the first time. The goals of this project were to: 1) provide a repository for important data that would otherwise never be available; 2) establish a searchable database to extract data on a specific species and/or techniques; 3) provide a gateway to communication and cooperation among zoo and wildlife endocrinologists; 4) establish normal values for physiological states (i.e. pregnancy, cyclicity, and stress) for zoo-housed animals and integrating these data with animal recordkeeping software used by zoos and other animal facilities; and 5) provide a global resource to improve animal care, population management, and wildlife conservation.

Process

WEIN is a comprehensive repository to collect, store and share data. With the support of IMLS, this project tested, refined, and launched WEIN on a secure website, making the information globally accessible. As the only venue available to wildlife endocrinology researchers and practitioners for obtaining and sharing valuable, peer-reviewed data not otherwise suitable for publication, WEIN serves a growing need. The primary purpose of WEIN is to centralize information regarding endocrine monitoring in various species from both zoo and field projects, creating a critical repository and resource for endocrine laboratories at zoos and universities. Data will consist of detailed endocrine methods and analyses including sample type, sample processing, hormone assays (EIA and RIA), validation, and analysis. To address data-sensitive issues, WEIN is restricted to use by International Society of Wildlife Endocrinology (ISWE) members only. Members can log in via the ISWE website (www.iswe-endo.org) and have unlimited access to all data. ISWE’s membership fees are a nominal \$60 per year for professionals and \$30 for students, because it seeks to promote collaboration within the broader wildlife and conservation science

community. ISWE hopes to increase wildlife endocrinology's impact on this community through WEIN ⁷.

WEIN was developed with an easy and user-friendly data entry process organized in hierarchical fashion incorporating five levels. The top level is the PROJECT which captures information about the location, time, duration and demographic information about the animals participating in the study. The second level is the PROCESS which details how samples were taken. Under that level is the HORMONE area which contains data about the various hormones analyzed as part of the study. The ANALYSIS and VALIDATION levels house details about any procedures undertaken to ensure the reliability of the data relating to any hormones which were extracted. The webpage user interface mirrors the database structure. The development of WEIN occurred in several steps listed below.

Alpha Testing: The Lincoln Park Zoo project team conducted its internal alpha testing of WEIN 1.0. The testing group included a committee of four Lincoln Park Zoo employees and one graduate student. Committee members tested WEIN's functionality by entering data from actual projects and searching for and reviewing others' entries. The committee met weekly throughout the alpha testing phase to address any issues encountered. Alpha testing resulted in de-bugging and additional minor changes to the application. A new version incorporating these changes, WEIN 1.1, was ready for beta testing in October 2014.

Beta Testing: Originally, the project team planned to make WEIN 1.1 available to members of the International Society of Wildlife Endocrinology (ISWE) for beta testing by launching the database on ISWE's website. Unfortunately, system errors made this impossible. Instead, the Lincoln Park Zoo team worked with ISWE leadership to recruit individual members to beta test WEIN 1.1 while it remained housed on Lincoln Park Zoo's local server. Meanwhile, the team continued to de-bug WEIN 1.1 and developed a survey form for beta testers to use while assessing WEIN. It included questions about WEIN's appearance, search and viewing functions, data entry, and the review process for submitted projects. All questions included a 5-point Likert scale response (with 5 being "highly effective") and a free-form comment box.

Through ISWE, the project team engaged four external beta testers for WEIN 1.1: researchers from the University of Chicago (Chicago, IL), Cleveland MetroParks Zoo (Cleveland, OH), Disney's Animal Kingdom (Orlando, FL), and St. Louis Zoo (St. Louis, MO). This first round of beta testing occurred between October 2014 and January 2015. To assess all aspects of the database, the beta testers entered real data from their own projects and reviewed previously-entered projects. The beta testers found WEIN's data entry process straightforward and very user-friendly, rating it a 4.6 out of 5. They also liked how WEIN allowed them to view projects already entered in the database, scoring those functions between 4.3 and 5 out of 5.

The beta testers did identify some significant issues, however. They found the database's appearance confusing, rating it just a 3.8. These issues stemmed from the fact that WEIN's user interface, as originally conceived, did not reflect the database's hierarchical structure. WEIN 1.1 had a block-style interface, showing the data structured in sliding panels. As the user clicked on each of the panel headings, additional details and related data entry fields appeared. The limitation

of this approach is that the user never sees the entire project, with all of its parts, in one view (Figure 1).

Implementing Feedback on WEIN 1.1: As a result of the beta testers' feedback, the Lincoln Park Zoo project team decided to completely overhaul the WEIN user interface. They first designed a "data tree," which resembles an organizational chart, as a way to reimagine the application's overall appearance. The team shared the new design concept with the ISWE board members, who enthusiastically approved the change.

Edward Wilkerson redesigned the WEIN 2.0 interface to reflect this hierarchical structure for project data entry. The user now sees the "data tree" structure first, which encompasses the entire project. Then, s/he is able to click on the individual boxes within the entire project's "tree" to access the associated data entry fields (Figure 2).

Server Modifications and Alpha Testing WEIN 2.0: The project team completed and began Alpha testing WEIN 2.0 in December 2015. At the same time, Lincoln Park Zoo began to move all of its internal web-based projects to a cloud-based system called Amazon Web Services (AWS). This move is in line with industry trends. AWS maintains a huge array of servers which may be configured to suit almost any project. It also offers automatic software updates and daily data backups. Finally, AWS environments are scalable, meaning that as each project grows its server resources are automatically marshaled to accommodate that growth.

The downside of this migration was that AWS environments work differently than a standalone server and required changes to the newly-developed WEIN software. It also required that the ISWE website, where WEIN would ultimately be hosted, needed to be moved to AWS as well. Because the website was active and in daily use, multiple testing environments had to be maintained to ensure that the website was always up and running even if WEIN was not. Therefore, the entire project had to be moved to AWS in stages, which slowed the testing process.

Further complicating things, Lincoln Park Zoo's SQL server license was not transferrable to AWS. The SQL Server database is the backbone of both the ISWE website and WEIN, and is essential if either is to run. The move to AWS required configuring a new SQL Server instance using the free version of SQL Server called SQL Server Express. This resulted in additional testing delays.

While testing and modifications continued, the Lincoln Park Zoo team updated all WEIN website content to reflect the new interface. These documents, including a full "Frequently Asked Questions" guide, incorporate more feedback from the application's beta testers. The website now also features graphics depicting current WEIN statistics, including the number of projects uploaded organized by genetic families, hormone, institution, and sample type (Figures 3-6). Finally, the team updated all of the text for the WEIN main page on the ISWE website (<http://www.iswe-endo.org/WEIN>). This page describes WEIN's goals, benefits, and overall functionality – including descriptions of each of the data management sections (Project, Process, Hormone, Validation and Analysis), the unique review process that ensures all data submitted are verified, and plans for future development of WEIN to maintain its applicability to this scientific community. This information will ensure that WEIN users understand the purpose of the database.

It serves the added function of educating visitors to the ISWE website about the benefits of becoming an ISWE member.

Finally, because WEIN is only available to ISWE members, ISWE needed to update its website and membership system to host the database. As a relatively new organization, ISWE had been collecting dues checks via mail and recording membership status manually. Mr. Wilkerson worked with ISWE leadership to set up an automated, online membership system which allows members to log in and access password-protected areas of the ISWE website, including WEIN, as well as pay dues and check membership status online. Not only will the new system allow ISWE to host the database, but it has also streamlined the society's membership process – a necessary change to facilitate ISWE's continued growth.

WEIN 2.1 Launch to ISWE Membership: WEIN 2.1 launched to all ISWE members via the ISWE website on April 6, 2016. ISWE leadership and the Lincoln Park Zoo project team e-mailed ISWE members to let them know that WEIN had launched, and to encourage members to upload their projects. In fact, the ISWE Board offered members an incentive to begin using the new database right away – a free, two-year society membership (worth \$120) for the member who inputs the most projects this year. Each Board member has committed to uploading five projects by the end of 2016, and collectively put out a call for ISWE members to volunteer as WEIN reviewers for new projects. Each project uploaded to WEIN is currently reviewed by Dr. Rachel Santymire and one other wildlife endocrinology expert. The Board has also featured WEIN in a blog post and on ISWE's Facebook page. The project team is pleased with the amount of support it has received from ISWE leadership so far, and is optimistic that it will help keep WEIN's momentum going.

Since WEIN launched in April, ISWE members from 8 institutions have entered 16 new projects, bringing the total number of projects entered in WEIN to 38, from 12 institutions total. In June, Lincoln Park Zoo hosted a WEIN working session to introduce more local ISWE members to WEIN. Researchers were able to come to the zoo and enter their project data into the database with live support from team members Dr. Santymire, Mr. Wilkerson, and Ms. Fowler. Santymire and Wilkerson attended the annual ISWE Board meeting in late September, where they strategized about hosting similar working sessions at the next ISWE conference, in August 2017. Santymire and Wilkerson also provided general updates to the Board about WEIN usage, including database activities, such as the number of new projects, searches, and improvements, as well as WEIN's impact on ISWE website traffic and membership (please see PROJECT RESULTS).

WEIN was built to suit the needs of the field and will continue to evolve with the needs of this community. After an ISWE member has a project submitted, reviewed and entered into WEIN, the team sends him/her a survey with questions about WEIN's appearance, search and viewing functions, data entry, and the review process for submitted projects. All questions included a 5-point Likert scale response (with 5 being "highly effective") and a free-form comment box. So far, survey results have demonstrated a marked improvement in WEIN 2.1's appearance, functionality and usability from the previous version. Average responses to these questions are listed in the table below.

WEIN users have used the free-form comment section to provide additional suggestions to improve WEIN's functionality. For example, one user suggested adding FAQs as a side-bar to help to answer questions as data is being entered. Another helpful suggestion was to increase the size of the search results box so that more projects could be shown at one time. These modifications will be implemented in a future version of WEIN. As more ISWE members use WEIN, the team will continue to obtain feedback using this survey. Moving forward, small changes like adding new hormones or chemical suppliers to drop-down lists will be implemented on an ongoing basis, and more major changes to the site will be implemented annually.

WEIN User Survey Average Responses	<i>WEIN 1.1 (ISWE Beta testers)</i>	<i>WEIN 2.1 (ISWE general members)</i>
<i>WEIN Appearance</i>	3.8	4.9
<i>WEIN Searchability</i>	3.3	4.5
<i>Viewing WEIN Content</i>	4.3	5.0
<i>WEIN Data Entry</i>	4.6	4.9

Project Results

By completing the activities described above, the zoo's project team hoped to achieve these goals, as set forth in the original proposal to IMLS:

1. Provide a repository for important data that would otherwise never be available;
2. Establish a searchable database to extract data on a specific species and/or techniques;
3. Provide a gateway to communication and cooperation among zoo and wildlife endocrinologists;
4. Establish normal values for physiological states (i.e. pregnancy, cyclicity, and stress) for zoo-housed animals and integrating these data with animal recordkeeping software used by zoos and other animal facilities; and
5. Provide a global resource to improve animal care, population management, and wildlife conservation.

During this grant period, the project team accomplished the first three of these goals, and laid the critical groundwork for the final two goals to be achieved as researchers continue to upload and share data to WEIN.

Goals 1 and 2: The creation, refinement, and launch of WEIN to ISWE's general membership created a vital repository for wildlife endocrinology data which might not be eligible for

publication otherwise. It also established a database for this information which is easily searchable based on specific species, hormones, and testing techniques.

So far, more than 38 authentic projects (16 since WEIN's launch) have been entered into the database by the Lincoln Park Zoo team and 11 other collaborators. These projects include studies of species from 21 different genetic families and five different hormones, and used seven different sample types to collect data (Figures 3-6). All of these metrics have approximately doubled since WEIN launched in April. This increase in number and diversity of data entries demonstrates WEIN's inherent flexibility, and reinforces the team's confidence that WEIN will successfully fulfill the need for a comprehensive wildlife endocrinology data repository.

The majority of projects initially entered into WEIN come from published literature. However, even these projects contain information that was not originally published with the studies, or is organized differently in the new database. These data provide another perspective on the results and methodologies, which will support future projects with specific species or techniques. Importantly, WEIN captures both effective and less effective methods so that researchers can share methods that were not successful and learn from others' efforts. Further, compiling these data in a searchable format allows researchers to access them with much greater ease. Previously, a person would have needed to search the literature for relevant studies, obtain the manuscripts, and manually extract these data. Now, all of this information can be quickly found in one location, and WEIN can export the data into Microsoft Excel[®] instantaneously.

Goal 3: When WEIN launched, a number of people e-mailed Mr. Wilkerson because they could not access the database. In nearly every case, it was because the individual had allowed his or her ISWE membership to lapse. As such, WEIN's launch prompted more than 60 people to renew their memberships or to join ISWE for the first time. Particularly for a non-conference year, this was a major uptick in membership for the society, indicating that access to WEIN can serve as a significant draw for ISWE. As a collaborative organization, ISWE and its members benefit from a wide and diverse membership base. By promoting active membership in the society among wildlife endocrinology researchers around the world, WEIN is already serving as a gateway to communication and cooperation among zoo and wildlife endocrinologists.

To ensure that WEIN continues to fulfil this role, the project team will use Google Analytics[®] to track demographics and engagement levels of visitors to the ISWE website and WEIN. Initial data on visits to the ISWE website have already shown an increase in the number of webpages viewed and pages visited per session after WEIN's launch. Compared to 2015 (a conference year), visitors spent 83% more time on ISWE's website after WEIN went live.

Goals 4 and 5: As scientists continue to enter projects into the database, and pull data from others' projects, WEIN will grow as a resource, facilitating cooperation and informing new research. Ultimately, this powerful tool will allow researchers to integrate enough data to establish normal values for physiological states (i.e. pregnancy, cyclicity, and stress) for zoo-housed animals, thus providing a global resource to improve animal care, population management, and wildlife conservation.

Successes and Failures

The team learned a number of things over the course of WEIN's development. First, when developing a scientific database to be used at a global scale, the software and interface needs to be robust and adaptable. One of the first protocol types of this database was created in Microsoft Access®. However, many colleagues who needed to view and evaluate the database did not have Access software. Instead, the team needed to adjust WEIN to use Microsoft SQL Server as its database engine, along with Microsoft ASP.Net and DotNetNuke to manage the web front end.

Second, opinions will vary from how much information should be captured and how data fields are organized and presented. Based on these important factors, the team set out to create a database that collected enough relevant information that users could repeat others' methods – or, at the very least, give the user enough of an overview that s/he could get started and have a person to contact (the project creator) if there were any questions. It was also important to capture techniques that may have failed with a particular species, so that scientists would know not to use time and resources pursuing those methods.

WEIN's data entry process was designed to be easy-to-use, with a webpage user interface mirrors the database structure. However, a lesson learned during the Beta testing of WEIN was that the user needed to have a different interface than the database structure itself. These issues stemmed from the fact that WEIN's user interface, as originally conceived, did not reflect the database's hierarchical nature. As noted above, WEIN 1.1 had a block-style interface, showing the data structured in sliding panels. As the user clicked on each of the panel headings, additional details and related data entry fields appeared. The limitation of this approach is that the user never sees the entire project, with all of its parts, in one view. The project team decided to completely overhaul the WEIN user interface. We designed a more user-friendly "data tree" interface which resembles an organizational chart, as a way to simplify the application's overall appearance.

Finally, one of the most important elements of a successful database is ensuring that it is capturing valid and error-free data. To address this, the Lincoln Park Zoo team added a review process function in WEIN. It begins once the user has completed his or her data entry. The submitted project is tasked to the WEIN Manager (Dr. Rachel Santymire) who will briefly review the entry and then forward it to a WEIN Reviewer. The WEIN Reviewer is a specialist chosen for his or her expertise in wildlife endocrinology. The WEIN Reviewer, who is an ISWE member and expert in their field, will carefully go through the record and determine if these data are accurately entered based on his or her experience with that species or another similar species. This review process ensures that these data are biologically valid for that species. The reviewer can accept the project in its current state or ask for revisions. To ensure the anonymity of the WEIN Reviewer, the project is then sent back to the WEIN Manager and is either returned to the submitter for editing or, if there are no errors, is released into WEIN for general viewing by ISWE members.

What's next?

Short-term

The Lincoln Park Zoo team will continue to manage WEIN. They will facilitate reviews of submitted projects and make ongoing, minor modifications to the database as needed. They will

Literature Cited

1. International Society of Wildlife Endocrinology (ISWE). 2013. About ISWE: Wildlife Endocrinology. Available at: <http://www.iswe-endo.org/AboutISWE.aspx>.
2. Monfort, S.L. 2003. Non-invasive endocrine measures of reproduction and stress in wild populations. In: Holt WV, Pickard AR, Rodger JC, Wildt DE (eds) Conservation biology: Reproductive science and integrated conservation. Cambridge University Press, Cambridge pp. 147-165.
3. Wildt, D.E., S. Ellis, D. Janssen and J. Buff. 2003. Toward more effective reproductive science for conservation. In Reproductive science and integrated conservation (eds W.V. Holt, A.R. Pickard, J.C. Rodger and D.E. Wildt), pp. 2–20. Cambridge, UK: Cambridge University Press.
4. Santymire, R., E.W. Freeman, E. Lonsdorf, M. Heintz and D. Armstrong. 2012. Assessment of adrenocortical activity after ACTH challenge in diverse African wildlife species. *International Journal of Animal and Veterinary Advances* 4(2): 99-108.
5. Santymire, R.M., and D. Armstrong. 2010. Development of a field-friendly technique for fecal steroid extraction and storage using the African wild dog (*Lycaon pictus*). *Zoo Biology* 29:289-302.
6. Wielebnowski, N. and J. Watters. 2007. Applying fecal endocrine monitoring to conservation and behaviour studies of wild mammals: Important considerations and preliminary tests. *Israel Journal of Ecology and Evolution* 53:439-460.
7. International Society of Wildlife Endocrinology (ISWE). 2013. Membership. Available at: <http://www.iswe-endo.org/Membership.aspx>.

also continue to survey WEIN users to determine how WEIN can be improved to suit the changing needs of the wildlife endocrinology field, and implement large-scale database updates on an annual basis. An example would be improving WEIN's data export function in Microsoft Excel® to allow for better analysis. Santymire and Wilkerson will demonstrate this proposed change at the next ISWE bi-annual conference which will be held at Disney's Animal Kingdom in August 2017. At the conference, Santymire and Wilkerson are also planning to host a second working session to demonstrate WEIN's functionality and answer questions. Attendees will be encouraged to bring their own scientific research and/or manuscripts to enter projects into WEIN during this session.

Long-term

Another large-scale update for WEIN will allow data exported from WEIN to be easily transferrable to other software packages used by animal managers, like behavioral, management, husbandry and health monitoring tools. WEIN's XML schema allows for data export and import in a variety of ways, which facilitates the use of animal endocrinological data by scientists from all over the world. The XML schema is structured to allow for data integration in a manner similar to that currently used in human endocrinology data which employs the UML (Universal Medical Language). The WEIN XML is based upon an expandable WEIN XSD (XML Schema Definition) which delineates the structure to which the XML must adhere. The WEIN XSD is applied to the current WEIN data, which allows downloads from the WEIN database. Ultimately, Mr. Wilkerson will develop software tools which use the new WEIN XSD to integrate WEIN data with existing animal recordkeeping software used by zoos and other animal facilities, like TRACKS or ZIMS. Additionally, the WEIN XSD will allow us to develop software tools to export WEIN data into external software for reporting and statistical analysis such as R.

Wildlife endocrinology has the potential to transform animal care at zoos and aquariums around the world. Creating a forum where scientists have the opportunity to connect and share resources is vital to promote innovation in this growing field. As WEIN 2.1 builds information gathering, sharing, and analysis capacity within the wildlife endocrinology community, it will act as a catalyst to further the standardization process of endocrinological data – facilitating consumption and utilization of these studies on a systemic level. Zoo and wildlife endocrinologists will use WEIN 2.1 to determine which methodologies to use to analyze samples from different animals.

As WEIN becomes more robust and widely used, its data will be used to establish means and ranges for species' physiological traits, such as pregnancy or stress hormone values, allowing researchers to better predict and manage animal health and behavior. These established physiological values will play a key role for zoological institutions building science-based foundations for animal welfare and reproductive success; both to ensure that zoo animal populations are healthy and sustainable, and to support wildlife conservation in the field. Finally, as this data becomes more easily integrated with existing animal management and welfare tools, WEIN can begin to reach its full potential as a resource to improve animal management and care around the world – both at zoological institutions and in the wild.

Thanks to the IMLS Sparks! Ignition Grant, Lincoln Park Zoo researchers were able to develop and launch WEIN. With the enthusiastic support of ISWE, WEIN will become not only a repository for published results but also unpublishable data. WEIN is novel because it provides an opportunity to capture and share unpublished data, has a review process to maintain its

integrity into the future, and is robust and malleable so that it can evolve with the needs of the scientific discipline of wildlife endocrinology. Overall, the scientific community is becoming more open with data to improve the trust of the public. WEIN will provide repository critical venue where researchers can join this trend within the burgeoning field of wildlife endocrinology.

Figure 1: "Project" data entry page in WEIN 1.0

Project

Select... Search... New Project...

Species: [Select an Institution...]
 Institution: [Select a Sample Type...]
 Sample Type: [Select a Hormone...]
 Hormone: [Submit]

Search: zoo [All] Search

Species: [sichuan takin](#) Institution: [Lincoln Park Zoo](#) Sample: [Feces](#) Hormone: [Feces](#) Bio: [Feces](#) Phys: [Feces](#)

Project sichuan takin/Lincoln Park Zoo

WEIN Project Number	LPZ0015BOV	Project Contact	Rachel Santymire
Institution Name	Lincoln Park Zoo	Taxon	Bovid
Project Contact Email	rsantymire@lpzoo.org	Taxonomic Name	Budorcas taxicolor tibetana
Common Name	sichuan takin	Reason For Sampling	Basic Reproduction
Reason For Analysis	Research	End Date	01/31/2008
Start Date	11/04/2006		

Project Animals

Project Size	Male 2 Female 3	Project Mean Age (yrs)	5.0
Project Male Repro Status	Breeding	Project Age Range Min. (yrs)	1.0
Project Female Repro Status	Breeding	Project Age Range Max. (yrs)	10.0
Project Age Class	Adult		

[View Publications](#)

[Edit](#) [Delete](#)

Figure 2: "Project" data entry page in WEIN 2.0

PROJECT
LPZ0040CAL

- PROCESS**
 - Feces
 - HORMONE**
 - Progesterone
 - VALIDATION**
 - Pregnancy
 - ANALYSIS**
 - Seasonality
 - Urine
 - Serum
 - HORMONE**
 - Androgens
 - VALIDATION**
 - Reproduction
 - ANALYSIS**
 - Male contracept..

Project Pied tamarin/Lincoln Park Zoo

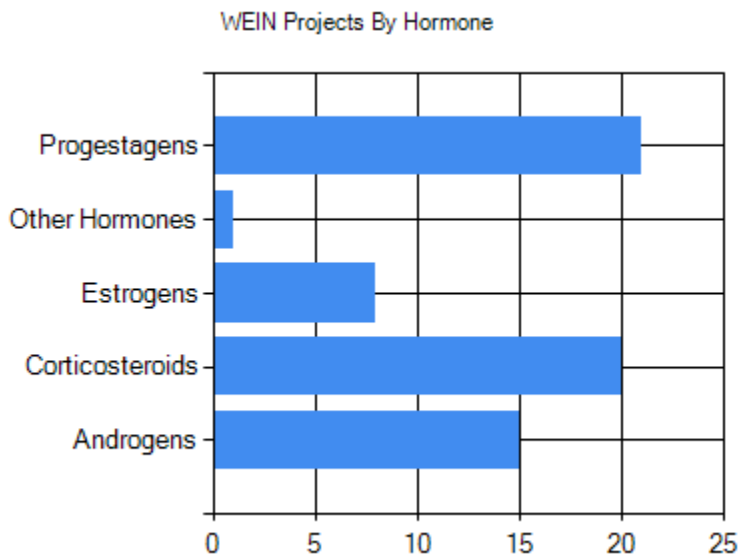
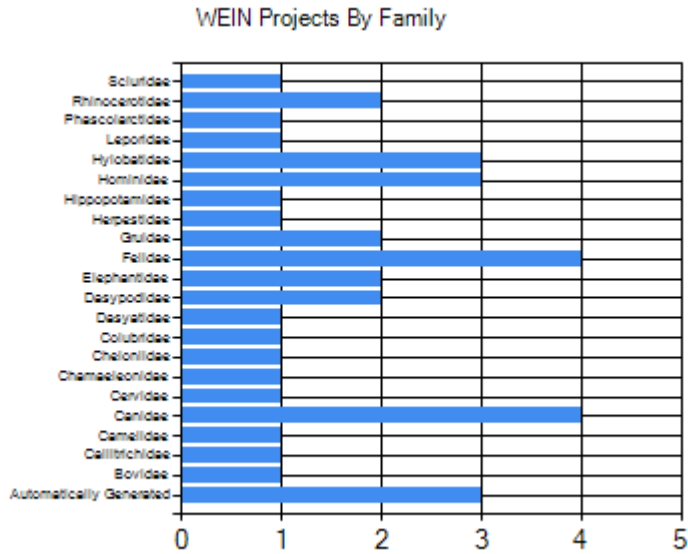
WEIN Project Number	LPZ0040CAL	Project Contact	Rachel Santymire
Project Contact Email	rsantymire@lpzoo.org	Contact Institution	Lincoln Park Zoo
Study Site	Zoo	Family	Callitrichidae
Common Name	Pied tamarin	Taxonomic Name	Saguinas bicolor
Reason For Analysis	Research		
Project Start Date	12/01/2007	Project End Date	08/01/2008

Project Animals

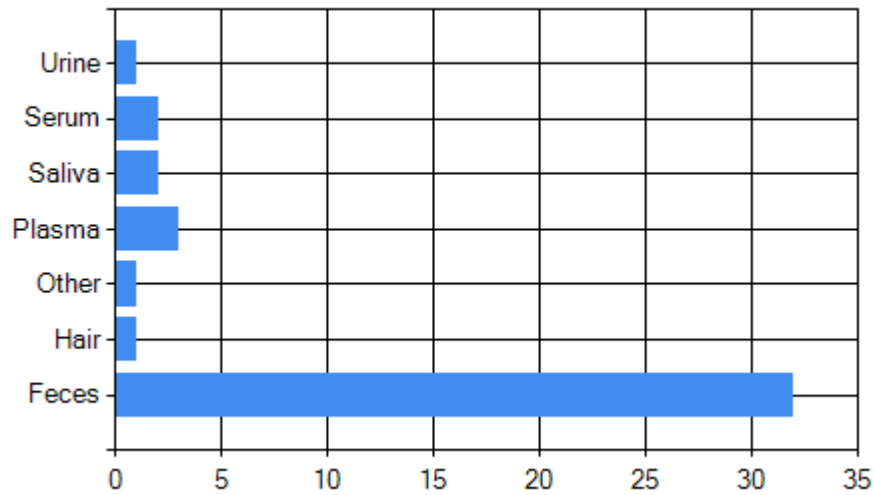
Project Size	Male 2 Female 2	Project Age Class	Adult
Project Mean Age (yrs)	6.5	Project Age Range Min. (yrs)	3.9
Project Age Range Max. (yrs)	9.2	Project Male Repro Status	Mixed
Project Female Repro Status	Mixed		

[View Publication Citations](#)

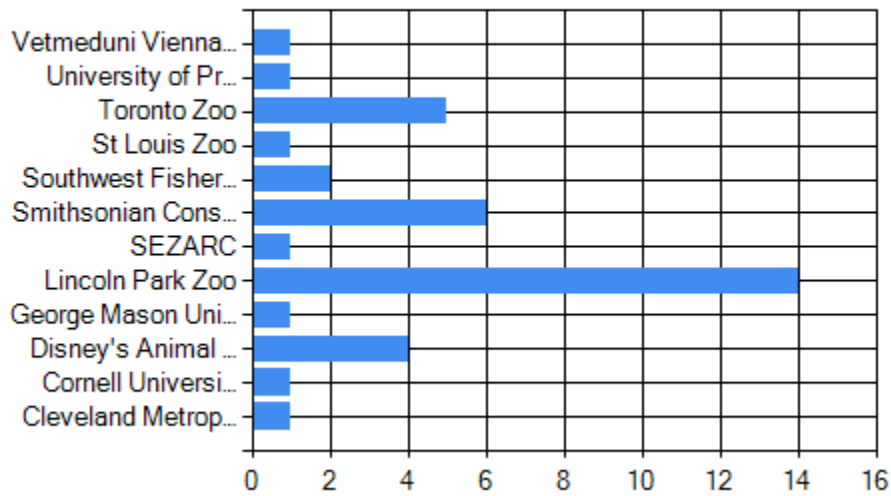
Figures 3 – 6: Current WEIN statistics – Projects currently entered in the database by family, hormone focus, project institution, and sample type, respectively.



WEIN Projects By Sample



WEIN Projects By Institution



Literature Cited

1. International Society of Wildlife Endocrinology (ISWE). 2013. About ISWE: Wildlife Endocrinology. Available at: <http://www.iswe-endo.org/AboutISWE.aspx>.
2. Monfort, S.L. 2003. Non-invasive endocrine measures of reproduction and stress in wild populations. In: Holt WV, Pickard AR, Rodger JC, Wildt DE (eds) Conservation biology: Reproductive science and integrated conservation. Cambridge University Press, Cambridge pp. 147-165.
3. Wildt, D.E., S. Ellis, D. Janssen and J. Buff. 2003. Toward more effective reproductive science for conservation. In Reproductive science and integrated conservation (eds W.V. Holt, A.R. Pickard, J.C. Rodger and D.E. Wildt), pp. 2–20. Cambridge, UK: Cambridge University Press.
4. Santymire, R., E.W. Freeman, E. Lonsdorf, M. Heintz and D. Armstrong. 2012. Assessment of adrenocortical activity after ACTH challenge in diverse African wildlife species. *International Journal of Animal and Veterinary Advances* 4(2): 99-108.
5. Santymire, R.M., and D. Armstrong. 2010. Development of a field-friendly technique for fecal steroid extraction and storage using the African wild dog (*Lycaon pictus*). *Zoo Biology* 29:289-302.
6. Wielebnowski, N. and J. Watters. 2007. Applying fecal endocrine monitoring to conservation and behaviour studies of wild mammals: Important considerations and preliminary tests. *Israel Journal of Ecology and Evolution* 53:439-460.
7. International Society of Wildlife Endocrinology (ISWE). 2013. Membership. Available at: <http://www.iswe-endo.org/Membership.aspx>.