UPPSALA UNIVERSITET
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The skeletal remains of the naval ship Mars

An osteological pre-study for analysing digitally documented skeletal remains in a marine context.

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Bachelor's thesis, 15 ECT's, spring 2015
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Cover photo of the naval ship Mars by Tomaz Stachura.

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ABSTRACT

Matilda Fredriksson, 2015

The skeletal remains of the naval ship Mars: An osteological pre-study for analysing digitally documented skeletal remains in a marine context.

De skeletala kvarlevorna från skeppet Mars: En osteologisk förstudie för analys av digitalt dokumenterade skeletala kvarlevor i en marinkontext.

Bachelor's thesis in Archaeology with a focus in Osteology (15 ECT's), Uppsala University Campus Gotland.

Denna kandidatuppsats är ämnad att ligga som grund för framtida osteologisk dokumentation och analys av de skeletala kvarlevorna från skeppet *Mars*, och är utförd i samarbete med projektet *Skeppet Mars (1564).*Syftet med denna uppsats är att undersöka och problematisera möjligheterna att analysera digitalt dokumenterade skeletala kvarlevor i en marin miljö. För att utvärdera möjligheterna och begränsningarna med att utföra en digital osteologisk analys utfördes en mindre studie av det digitalt dokumenterade material som hittills insamlats från skeppet *Mars*. Analysen visade att en osteologisk analys kan utföras på digitalt dokumenterade skeletala kvarlevor men att det finns begränsningar med att utföra en analys av ett två dimensionellt källmaterial. Syftet med denna uppsats är även att diskutera och lyfta fram hur skeletala kvarlevor påverkas under längre tid i marina sediment* samt bräckt/salt vatten. Syftet med denna uppsats är även att diskutera hur en hypotetisk inhämtning och konservering av de skeletala kvarlevorna från skeppet *Mars* bör utföras.

This bachelor's thesis is intended to lay the ground for future osteological documentation and analysis of the skeletal remains from the naval ship *Mars*, and is conducted with the project *Skeppet Mars (1564)*. The main purpose of this thesis is to examine and problematise the possibility to analyse digitally documented skeletal remains in a marine context. In order to evaluate the possibilities and limitations of performing an osteological analysis, a small analysis was conducted on the digitally documented skeletal remains collected from the naval ship *Mars* so far. The analysis showed that an osteological analysis can be performed on digitally documented skeletal remains, there are, however, limitations of performing an analysis on a two dimensional documentation. The secondary purpose of this thesis is to discuss and highlight how skeletal remains are affected by marine sediment* and brackish/saltwater over a long period of time. An additional goal for this thesis is to discuss how a hypothetical retrieval and conservation of the skeletal remains of the naval ship *Mars* should preferably be performed.

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KEYWORDS: *Osteology, Marine osteology, Human osteology, Animal osteology, Taphonomy, Naval ship Mars, Digital methods, Saltwater, Brackish water, Marine sediment, Conservation methods*

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CONTENTS

1. INTRODUCTION

This bachelor's thesis represents an osteological pre-study in a research project called *Skeppet Mars (1564)* and will lay the ground for future osteological analysis of the skeletal remains of the naval ship *Mars*. The project is a cooperation between MARIS (marinarkeologiska forskningsinstitutet) at Södertörns University, researchers at Försvarshögskolan, Southampton University, Uppsala University Campus Gotland, Maritima museet and the companies Ocean Discovery, Deep sea production and Maritim mätteknik AB, and is funded by Östersjöstiftelsen and National Geographic.

The skeletal remains of the naval ship *Mars* are located sixty-five to seventy-five meters below surface, east of the island of Öland. Since no recovery of the skeletal remains has been made, an interesting question arose among the members of the research project *Skeppet Mars (1564)*: *Can the skeletal remains be analysed through using digital documentation?* This question was forwarded to my supervisor professor Sabine Sten who suggested that I, due to my previous experience working with computers, should use this question as a basis for my bachelor's thesis. I found both the project and the prospect of using modern techniques to analyse skeletal remains in a marine context very intriguing and, therefore, decided to join the project.

The ship *Mars* can be studied as a frozen moment in time, where the archaeological artefacts and skeletal remains can work as clues. These clues may, if treated right, allow us to understand both the downfall of the ship and its crew, as well as the life and naval warfare of the sixteenth century.

An osteological analysis of the skeletal remains of the ship *Mars,* therefore, sheds light on the lives and death of the crew through the documentation of trauma, diseases and signs of famine*, as well as highlight the represented provision compared to the historical documentation. An osteological analysis may also be used to assess different attributes to specific individuals and perhaps even place them into different social strata of the sixteenth century. An osteological analysis may, therefore, be used to either underline or discard the accuracy of information retrieved from historical sources.

The author has been invited to participate on the research vessel during the planned field study taking place in the summer of 2015, in order to influence the osteological documentation process. This pre-study and the newly assembled material will then be used as the basis for a future master's thesis and further analysis of the skeletal remains.

Words marked with * are listed and defined in the *Wordlist* found in the appendix. These definitions are included in order to ease the reading process for non-native speakers and those who have no previous knowledge of osteology.

1.1 Purpose

The purpose of this bachelor's thesis is firstly to lay the ground for the future documentation of the skeletal remains of the naval ship *Mars*. This thesis is, therefore, foremost an osteological pre-study where the possibilities and limitations of performing an osteological analysis on digitally documented skeletal remains is the main focus.

The second purpose of this thesis is to lay the ground for future method development and discuss the possibilities and limitations of performing an osteological analysis of digitally documented skeletal remains.

An additional goal for this thesis is to discuss the effects of salt/brackish water and marine sediment* on skeletal remains, and how a hypothetical retrieval and conservation should preferably be carried out. This will be done in order to discuss the preservation and conservation conditions of the skeletal remains in the marine environment and how they should preferably be handled in the case of an attempted recovery from the ship *Mars*.

The future osteological analysis results will be integrated as a part of the existing exhibition about the naval ship *Mars*, as decided during a meeting with Palm and Norman at Västerviks museum.

1.2 Research questions

The following research questions have been formulated with the researchers at Södertörns University, in order for this pre-study to be relevant for future documentation and the analysis of the skeletal remains of the naval ship *Mars*.

- **What information is it possible to retrieve through performing an osteological analysis of the digitally documented skeletal remains of the naval ship Mars?**
- **How are skeletal remains affected by brackish/saltwater over time?**
- **How are skeletal remains affected by marine sediment?**
- **How would a possible retrieval and conservation of the skeletal remains preferably be carried out in the case of an attempted recovery of the naval ship Mars?**

2. SOURCE CRITICISM AND DELIMITATION

2.1 The digitally documented skeletal remains

The image material gathered during the previous field studies is limited to six images and eighteen hours of ROV (Remotely Operated vehicle) film, which limits the possibility to perform a complete osteological analysis of the archaeological site. This study will, therefore, primarily focus on the possibilities and limitations of performing an osteological analysis on digitally documented skeletal remains.

The image material limits the osteological analysis to a two dimensional analysis of the skeletal remains. This means that the osteologist lacks the ability to measure, weigh and rotate the documented bone elements, and to some extent even see the entire bone due to sediment* cover.

Three presumed bone elements have been observed in the ROV film, but since neither bone type or species could be determined for two of these, only one of the observed bone elements has been included in this thesis. An osteological analysis has, therefore, been performed when the following two criteria's has been fulfilled:

1. Enough osteological characters must be represented on the documented bone element in order for a proper analysis to be performed.
2. The image quality must be at such a level that the documented osteological characters can be observed and compared with the osteological reference collection at Uppsala University Campus Gotland.

2.2 Positioning

The image material has not yet been positioned on a geographical grid and can, therefore, not be used to create a distribution pattern as originally intended.

2.3 Literature limitations

Marine osteology is a fairly new concept and has foremost been applied in the retrieval of ship wreckages and in developed coastal areas such as harbours, where human remains have been encountered. The amount of literature describing methods of retrieval, conservation, taphonomical* changes, the impacts of marine sediment*, and the analysis of skeletal remains in marine contexts is, therefore, rather limited and not included in most osteological literature. The limited amount of information available about the decomposition of human remains in a marine context is also underlined by Dumser and Türkay (2008) in their investigation of post-mortem* changes of human bodies on the bathyal sea floor (Dumser & Türkay, 2008:1048f).

The amount of literature dealing with the osteological conservation methods of the skeletal remains from the Swedish ships *Kronan* and *Vasa* has also been limited. Why no documentation concerning the desalting process has been made is unclear at this time.

3. BACKGROUND

3.1 The research project Skeppet Mars 1564

The naval ship *Mars* was located east of the island Öland by Ocean Discovery in the summer 2011 and was examined in October the same year to determine the identity of the wreckage (Rönnby, et *al.*, 2013:5). The ship's identity was confirmed by an assessment of markings found on one of the larger cannons located at the site (Eriksson, et *al.*, 2012:5). A second archaeological survey was conducted during the summer of 2012, where sonar, ROV and divers with handheld cameras were used to document the wreckage and possible archaeological artefacts. During the investigation three silver coins were located, and were after careful consideration retrieved by the participating divers (Rönnby, et *al.*, 2013:5). A third archaeological survey was conducted during the summer of 2013, where ROV and divers with handheld cameras were used to document the ship and possible archaeological artefacts. It was also determined during this time that two cannons and several wooden structures of the ship would be retrieved in order to evaluate possible future preservation methods. These objects are presently kept at Västerviks museum as a part of the exhibition and for evaluation of the presently used conservation methods (Eriksson, 2015:5). A fourth archaeological survey was conducted during the summer of 2014, though the report of this investigation has not yet been published.

The project group consists of Ocean Discovery, MARIS (Marin Arkeologiska forskningsinstitutet) at Södertörns University, Försvarshögskolan, Southampton University, Uppsala University Campus Gotland, Maritima museet, Marin mätteknik AB and is financed by Östersjöstiftelsen and National Geographic.

3.2 The naval ship Mars

The Swedish naval ship *Mars* was completed in 1563 at Björkenäs shipyard north of Kalmar. The ship was probably an impressive sight as she is reported to have been over 60 meters long and estimated to a tonnage of 1800 (Rönnby, 2014:61). The ship is reported to lack any kind of decor (Rönnby, et *al.*, 2013:15), except from a gilded figurehead of the war god *Mars* (Sjöblom, 2011).

The Swedish fleet was ordered by King Erik XIV to place a group of men on the Danish islands to extort contributions from the population before heading on to Öresund to claim customs from all Danish ships. The Swedish fleet intended to sail to the island of Gotland before heading to Öresund. Unfortunately, they dispersed during a storm during their procession and by the time the naval ship *Mars* encountered the Danish-Lübeck fleet on May 30,1564, only two other ships were under its command (Smirnov, 2009:100-101).

The battle between the Swedish and Danish-Lübeck fleet began at midday on May 30, by the firing of three rounds from the Danish flagship Fortuna (Smirnov, 2009:101). Fortuna, however, was shortly taken out of the battle for repairs after having its main mast shot down by *Mars*. More Swedish ships eventually joined the battle and two Danish ships were reported sunken during the day, one by its own artillery and one by the naval ship *Mars* (Smirnov, 2009:102). At the end of the day, nightly repairs were performed by both sides of the battle. In the morning of May 31, *Mars* was surrounded by enemy ships and fired upon with both small hail storm cannons, hand thrown fire bombs and lances. (Smirnov 2009:105).

Historical sources also describe how one of the great cannons (apostles) exploded and thereby lifted the entire cow bridge up in the air while fire broke out on the ship (Smirnov, 2009:105). This lead to Admiral Bagges surrender, resulting in the future confinement of both himself, the mayor Mats Person and dozens of the members of the crew, who were transferred to the Lübeck ship Der Engel. After the surrender several hundred Lübeck men entered the ship in hope of finding riches onboard. Shortly after their arrival the ship exploded and split in two, taking the bodies of both Swedes and Lübecks down to the bottom of the sea (Smirnov, 2009:106).

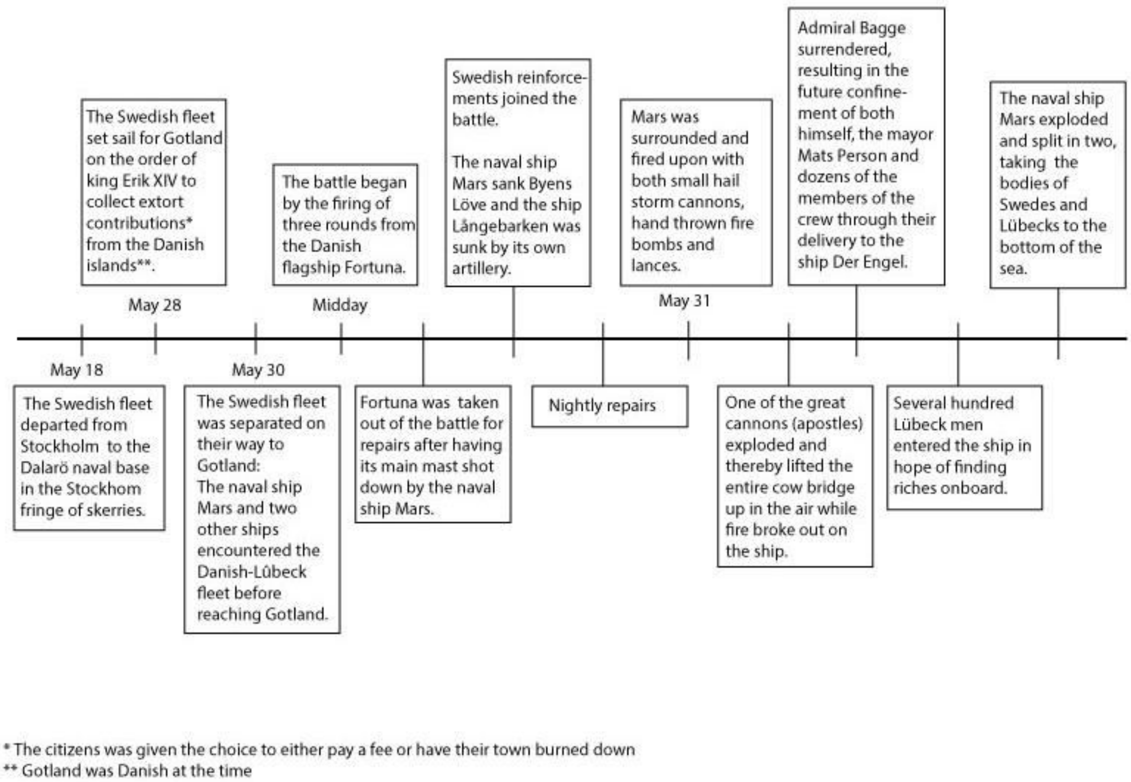


Figure 1 The series of events leading to the end of the naval ship *Mars*.

4. MATERIAL

4.1 The skeletal remains of the naval ship Mars

The naval ship *Mars* is located east of the island of Öland at a depth of sixty-five to seventy-five meters. The skeletal remains were documented in 2014, using ROV and divers with handheld cameras. No osteological analysis has been performed up until this point. The reports do, however, describe observations of both human and animal remains (Eriksson, et *al.*, 2011:5). The presence of both human and animal remains is also underlined by historical documentation, describing how approximately 14,5 tons of meat and pork, and 5 tons of dried fish were loaded onboard the naval ship *Mars* before setting sail for the island of Gotland (Sjöblom, in prep:6).

4.2 Retrieval, conservation and analysis of ships in similar contexts

The Swedish ships *Vasa* (see 4.2.1) and *Kronan* (see 4.2.2), and the British ship *Mary Rose* (4.2.3) - are used as reference material since they all represent different aspects found in the naval ship *Mars*. They are used as the basis for the discussion on the retrieval and conservation methods suitable for a hypothetical retrieval of the naval ship *Mars*, as well as a reference to the amount of information retrievable through analysing physical skeletal remains from a marine context.

The *Mary Rose* sank in the salty strait of Solent, in the Atlantic sea, in 1545 (Stirland, 2013:66-67) and is, therefore, more contemporary with *Mars* that sank in 1564 (Rönnby, et *al*. 2013:5;Smirnov, 2009:105) than *Kronan* that sank in 1676 (Kronanprojektet, 2013:1; Einarsson, 1990:41) and *Vasa* that sank in 1628 (During, 1994:10). The two ships *Vasa* and *Kronan*, on the other hand, are placed in a similar environment as the ship *Mars*; this since all three of them are placed in different parts of the brackish water of the Baltic Sea. *Kronan* was located south east of the island of Öland (Kronanprojektet, 2013:1; Einarsson, 1990:41) and *Vasa* was located in the Stockholm fringe of skerries (During 1994:10).

4.2.1 Vasa

The ship *Vasa* was salvaged and placed in a dry dock before the excavation. The ship was treated as an archaeological excavation site where each bone element and artefact was collected and given a specific number connecting them to a specific position in correlation to the nearest deck beam. After the ship was salvaged, additional skeletal remains were located and retrieved by divers from the sea bed (During, 1994:23).

The skeletal remains went through a short preliminary osteological analysis in 1969 before being temporarily buried in consecrated ground. The skeletal remains were placed in plastic bags marked with metal tags before being placed in cement caskets (During, 1994: 24, 30). The skeletal remains were then retrieved in 1989 for further analysis. Unfortunately, several of the bone elements were water damaged and infected by mold (During, 1994: 29). The skeletal remains were, therefore, rinsed in freshwater and the mold infested bones were washed in ninety-five percent ethanol before being placed in a cool and well ventilated room to air dry (During, 1994: 31).

All skeletal remains were sent to the osteological laboratory for further osteological analysis, (During, 1994:31) where bone elements from different parts of the ship were grouped to form individuals based on bone element size, shape, age and sex (During, 1994:40).

The MNI (minimal number of individuals) estimation was based on the bone representation of sides of paired bones, age groups, sex, bone element size and shape (During, 1994:38). The age estimation was based on tooth eruption, dental wear, cranial suture closure, symphysis closure of the pelvis and discriminant function analysis, where the long bones were sawed into halves and analysed according to the density of the spongious bone tissue (During, 1994: 45). The sex assessment was based on morphological characters of the pelvis, cranium and jaw, and measurements of the proximal end of humerus* and the proximal and distal* end of femur* (During, 1994:43-45). The stature estimation was based on the length of the long bones, and foremost the femur* (During, 1994:52-53). The estimated appearance of each individual was based on the length and width of the cranium (During, 1994:55).

The dietary analysis was based on isotopic- and chemical analysis on the bone tissue to determine if the individuals on the ship had lived on a diet composed of primarily of either terrestrial or marine content (During, 1994:59). This method was also used to determine which individuals had been exposed to famine* recently or during their childhood (During, 1994:64). The general pathology and injuries were assessed by analysing fractures and abnormalities of the skeletal remains. Common pathologies among the crew were enamel hypoplasia* and lesions in the thoracic vertebrae (During, 1994:68).

4.2.2 Kronan

The recovery of the skeletal remains of *Kronan* began in 1981 and is still an ongoing process (Einarsson, 1990:41; Kronanprojektet, 2013:25). The remains were collected by divers on an individual basis where the bones were collected and placed in netting bags placed on the sea bed before being brought to the surface for labelling and analysis. Each netting bag were numbered according to were the skeletal remains were found (Kronanprojektet, 2013:25).

Reports mention that information such as age, sex and stature has been assessed through osteological analysis. No exact results or methods are, however, listed in the literature. The main focus has been on describing the trauma and pathology of the crew. Some of the most common pathologies were osteoarthritis* and pathological changes in the orbital roof (cribra orbitalia) (Kronanprojektet, 2013:25).

The documentation also mentions that several of the retrieved skeletal remains were stained during their time in the water (Kjellström & Hamilton, 2014:37).

4.2.3 Mary Rose

The skeletal remains of the *Mary Rose* were collected as mass-material because the sweeping tides of the Atlantic sea had dragged the bones back and forth within the ship. The bones were, therefore, connected to different regions of the ship instead of being given specific positions (Stirland, 2013:67). The divers placed the bones in numbered netting bags, where they were sorted by bone element and tagged according to the section where they were found. The skeletal remains were then brought to the surface for conservation and osteological analysis (Stirland, 2013:67).

The bones were immediately sent to undergo a desalting process where they were placed in four different tubs with decreasing salinity* levels before being placed in a temperature-controlled environment to dry. Each bone element was marked with the number of the netting bag (Stirland, 2013:67).

Each bone element was then grouped to form individuals through pairing each bone element and then comparing the proximal* and distal* ends of the bones in order to find its match. Through this process, almost all bones could be connected to specific individuals. Unfortunately, no fitting of the arms to the correct individual could be performed due to the open shape of the scapula* sockets. This since scapula sockets are too widely open to only fit one specific humerus* (Stirland, 2013:72).

The sex assessment was performed based on morphological characters, the size of the collarbones and the measurement of the head of the femur* and humerus* (Stirland, 2013:79). The stature estimation was based on the measurement of the GL (greatest length) of the left femur*.The tibia* was used in those cases when no femur* could be connected to the individual (Stirland, 2013:82).

General pathologies and trauma were assessed through analysing fractures and abnormalities on the skeletal remains. Some of the most common pathologies among the crew were tuberculosis (TBC), scurvy* and rickets* (Stirland, 2013:89-101). Irregular characters of the bones were also used in order to determine which irregularities could be connected to specific activities (Stirland, 2013:118).

5. TAPHONOMICAL CHANGES

The disintegration of bone is affected by its size, placement, environment, saturation and density (Lyman, 1994: 354, 361). Skeletal remains that are placed above ground disintegrate faster than skeletal remains placed in the soil. This because weather and wind, and the different temperatures in the air help dissolve bone tissue (Lyman.1994: 360). The soil may, therefore, work as a shield against both oxygen and extreme temperature changes, similar to a thermos, keeping the skeletal remains fresh for a longer period of time (Lyman 1994: 354).

The soil may, on the other hand, have negative effects on skeletal remains since bone tissue consists of hydroxyapatite, water and collagen (Christensson, 1999:65) that is easily affected by different substances and ph-values in the surrounding environment (Christensson, 1999:172).

5.1 Skeletal remains in saltwater

Bones placed in a salt environment for a long period of time absorb sodium (Na+) and chloride (Cl-), soluble salt, which leads to increased porosity in the organic collagen (Pokines & Symes, 2013: 152; Grant, 2007; Brothwell, 1981:8; Christensson, 1999:172). If bones found in saltwater are dried immediately after the retrieval in a salted state they will crack and flake due to the salt crystallisation occurring during the drying process (Pokines & Symes, 2013: 152; Grant, 2007; Brothwell, 1981:8). If the skeletal remains are not properly desalted the process will be repeated further by variated humidity levels in the place of storage (Christensson, 1999:174).

5.2 Conservation of skeletal remains from a saltwater context

Hamilton (1999) recommends three different conservation methods for skeletal remains from a saltwater context where the skeletal remains have absorbed soluble salt. See listed below.

5.2.1 Desalting

The desalting process is recommended for structurally sound skeletal remains sustainable enough to go through a rinsing process without breaking (Baxter, 2004:43; Brothwell, 1981:8, Hamilton, 1999; Stirland, 2013:67-71). The skeletal remains go through a six step process whereby the bones are placed in five different tubs (Hamilton, 1999; Stirland, 2013:67-71) for approximately seven days per tub (Stirland, 2013:71). Four of the tubs contain a hundred, seventy-five, fifty and twenty-five percent saltwater diluted with freshwater, whereas the fifth tub contains only freshwater (Hamilton, 1999;

Stirland, 2013:67-71). When the skeletal remains are fully rinsed they are placed in temperature-controlled environment dry (Hamilton, 1999; Stirland, 2013:67-71).

5.2.2 Consolidating and rinsing

The consolidating and rinsing method is foremost recommended for structurally unsound bone where the skeletal remains are at risk of being disintegrated during the desalting process (Hamilton, 1999; Brothwell, 1981:8-10; Baxter, 2004:43). This method is used when the morphological characters are of bigger value than the possibility to chemically analyse the skeletal remains in the future, this since the consolidating process injures and capsules bone tissue. The skeletal remains are placed in a five percent acroyloid B-72 fluid before undergoing the desalting process previously described (see 5.2.1) (Hamilton, 1999). It is important to note that the steps in this conservation method are recommended to be performed for a longer period of time than during the desalting process, though the amount of time is not specified by Hamilton (1999) for either of these methods.

5.2.3. Alcohol baths

Alcohol baths are foremost recommended for structurally sound bone and can be performed in two variations depending on the skeletal remains. The remains go through a four step process in which they are placed in three different tubs containing a mixture of ethanol and water with a varying alcohol degree from zero, fifty to ninety percent alcohol. Ivory and teeth, on the other hand, need to undergo a slower process of desalting with a varying alcohol degree from five, ten, fifteen, twenty etc. percent until the ivory/teeth eventually are placed in a tub containing a hundred percent alcohol. The skeletal remains or ivory/teeth are then left in a temperature-controlled environment to air dry (Hamilton, 1999).

5.3 Skeletal remains and marine sediments

Marine sediment* is a complex compound of porewater*, inorganic material and organic material settling on the sea bed. Inorganic material such as rock, gravel, sand and clay particles are transported through rivers and other water sources from land to sea. Bigger particles such as rock, gravel and sand are generally not transported further out than the coast, whereas small clay particles are transported far into the sea through undercurrents. The organic material consists of bacteria, animal remains and plants, where the most common material consist of floating algae (plankton) (Jansson, 1978:47).

There are two types of generic sediment* variations called oxidizing sediments* and reducing sediments*. Both of these sediment* types are created when organic material settles on a seabed with high oxygen concentrations, where aerobic* bacteria use free oxygen to extract energy from the organic material. High concentrations of organic material allow the aerobic* bacteria to thrive, leading to a high oxygen consumption and an increased sedimentation* process (Jansson, 1978:45). In low oxidized sediment*, sulphate-reducing bacteria thrive and consume sulphur from sulphate producing hydrogen sulphide. These bacterias are introduced when the aerobic* bacteria have consumed most of the present oxygen (Jansson, 1978:47). Depending on the present water circulation two different scenarios may occur, resulting in either an oxidizing or a reducing sediment* (Jansson, 1978:45).

The oxidizing sediment* consists of lower anaerobic* layers with an oxidized top layer. This due to a constant water circulation generating an influx of new oxygen, allowing the oxidizing top layer to slowly raise as the aerobic* bacteria eat their way through the newly added organic material (Jansson, 1978:45). The reducing sediment* only consists of anaerobic* layers; this due to the limited amount of water circulation and low oxygen levels. This leads to an increased conservation ratio since oxygen is one of the main keys in the decomposition process (Jansson, 1987:45; Christensson, 1999:172; Boddington, et *al*., 1987:47).

The positive effects of marine sediment* have been underlined by a group of scientists who performed a study on a whale carcass placed in the bottom of the bathyal Sainta Catalina sea basin (Allison, et *al.*, 1991:80). They reported observations where both covered and uncovered bone elements were represented. The covered skeletal remains were documented to be heavily stained by iron sulphide but in a more intact condition than the uncovered parts of the skeleton (Allison, et *al.*, 1991:80). It is also stated that the small bones are easier to cover and have a higher survival rate than the larger and more sensitive cancellous* bone (Allison, et *al.*, 1991:84).

The positive effects of marine sediments* were also underlined during the osteological analysis of the skeletal remains from the *Mary Rose* "*The anaerobic conditions of the seabed silts, in which there was no free oxygen, had slowed down the processes of decomposition, so that the preservation of the majority of organic material from the ship, including the human bone, was superb*" (Stirland, 2013:71).

6. METHOD

The theoretical part of this thesis is based on literature including previous research and historic documentation of other ships in similar context, such as the *Mary Rose*, *Kronan* and *Vasa*. Their work process, conservation process and osteological analysis results are here used as here an example of how retrieval, preservation and analysis of the skeletal remains has been made in the past and how the usage of non-destructive digital methods may produce similar results. The theoretical parts of this thesis also discusses the taphonomical* effects of salt/brackish water and marine sediment* on skeletal remains based on previous studies of skeletal remains and organic material in a marine context.

The practical part of this thesis is based on the observations made on the digitally documented skeletal remains. The osteological analysis have been performed according to the methods listed under 6.1 and are foremost considered suitable due to their focus on morphological characters.

The digitally documented skeletal remains was provided by the project group and collected by the author during a meeting with Eriksson and Sjöblom at Södertörns University. The digitally documented skeletal remains where compared with the Uppsala University Campus Gotland's reference collection. Each bone element was then documented in digital form on a copy of the original image through adding informative text and osteological character clarification. The text contained the information retrieved through the osteological analysis and represented species, bone element, side and epiphyseal* closure. The work images were then controlled assessed by professor Sabine Sten.

6.1 Osteological analysis

The osteological analysis has been performed based on morphological characters on digitally documented skeletal remains. This was due to the lack of availability to measure the different bone elements. The osteological reference collection at Uppsala University Campus Gotland was used for bone element assessment and species identification.

6.1.1 Identification of species

Identification of species was performed through using the Uppsala University Campus Gotland osteological reference collection.

6.1.2 Bone element assessment

Identification of bone element was performed through using the Uppsala university Campus Gotland reference collection.

6.1.3 Age assessment

Human

Age assessment for humans are based on epiphyseal* closure according to White & Folkens (2005).

Animal

Age assessment for domestic animals are based on epiphyseal* closure according to Silver (1969).

Epiphyseal* closure occur at different stages in an individual's life and can therefore be used to estimate an approximate age.

The epiphyseal* closure is graded with the proximal* value followed by the distal* value, listed as followed:

o = open
c = closing
f = fully closed
x = missing
? = undocumented
- = bone element not included in bone coding
< = older than

6.1.4 Bone coding

Bone coding is used to document the representation of a specific bone element. The bone coding used in this bachelor's thesis is a modified version of Lepiksaar (1988) by the author. Each bone element is divided into 10 parts in order to provide a higher detail of the specific fragmentation. The documented part of the bone element will be marked with black and placed next to the digitally documented skeletal remains in this report (see 7.1).

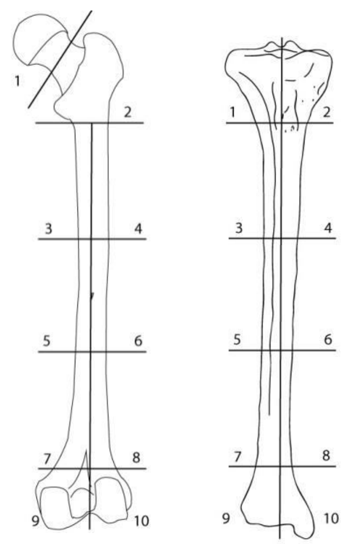


Figure 2 Bone coding grid. Femur* on the left and Tibia* on the right. Dorsal view.

The bone is divided into 10 parts on a grid:

1-2 Proximal* epiphysis*
3-8 Corpus*
9-10 Distal* epiphysis*

6.1.5 MNI assessment

For this bachelor's thesis the simple MNI (Minimal Number of Individuals) count based on Gautier (1984) is used to estimate the minimum number of individuals documented on the site. This through sorting bone elements into species, estimated age and bone type, and then comparing the results to the amount of singular or plural bone element representation for a singular individual.

6.2 Literature review

In an attempt to answer the theoretical work questions of this thesis a thematic literature review has been performed. This means that information have been retrieved and compiled (see 4, 5) through the use of the literature concerning; the recovery, conservation and analysis results of skeletal remains in a marine context (During, 1994; Stirland, 2013; Kronanprojektet, 2013; Kjellström & Hamilton, 2014; Einarsson, 1990), the general recommendations for conservation of skeletal remains in a saltwater context (Christensen, 1999; Pokines & Symes, 2013; Grant, 2002; Baxter, 2004; Stirland, 2013), and the taphonomical* effects of marine sediment* and saltwater on skeletal remains (Hamilton, 1990; Jansson, 1978; Boddington, et *al*., 1987; During, 1994; Stirland, 2013; Alison, et al, 1991)

7. RESULTS

7.1 What information is it possible to retrieve through performing an osteological analysis of the digitally documented skeletal remains of the naval ship Mars?

Due to the limited amount of digitally documented skeletal remains from the ship *Mars*, only four individual bone elements have been analysed. The represented bone elements are estimated to a femur* from a pig (figure 3), a tibia* from a pig (figure 4), a hip joint from a pig (figure 5) and a femur* from a human (figure 6).

Through analysing the epiphyseal* closure of the human femur* (see figure 6) according to White & Folkens (2005) a minimum age of twenty-two years has been estimated. This since both ends of the femur* have been interpreted as being fully closed. The bone element is estimated to be relatively intact according to the modified version of Lepiksaars (1988) method and is estimated to be from the right side of the body (see table 1). The distal* end of the femur* show probable signs of peri*- or postmortem* trauma (see black arrow, fig.6).

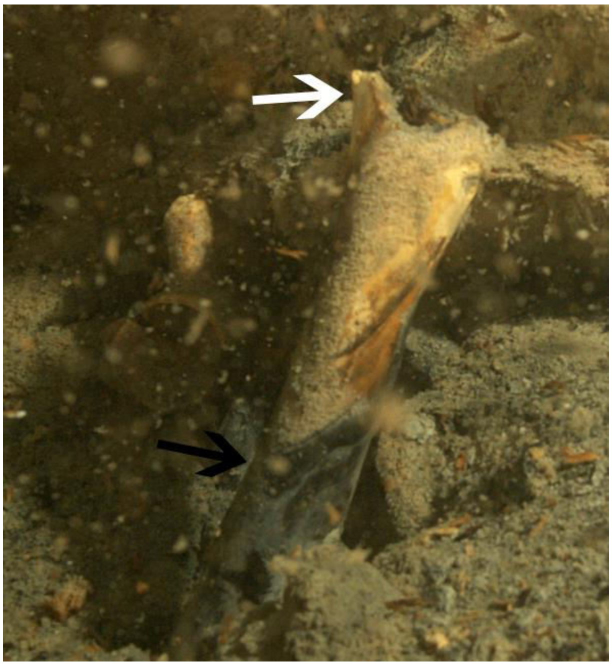
Through analysis of the epiphyseal* closure of the pig tibia* (see figure 4) according to Silver (1969) a minimum age of two years has been estimated. The estimation is based on the fact that only the distal* end of the tibia* has been documented and appears to be fully closed. Due to the documentation angle only parts of the bone element has been documented, this limiting the amount of retrievable information for an osteological analysis. The bone element is estimated to be from the right side of the body (see table 1).

Through analysing the pig femur* (see figure 3) according to the modified version of Lepiksaars (1988) method only part 3-8 of the bone element is represented. The distal* end of the femur* lay covered under marine sediment* and the proximal* end of the femur* shows probable signs of postmortem fracture (see white arrow, fig.3). An age assessment has not been able to be performed. This due to the documentation angle and sediment* cover. The bone element is estimated to be from the right side of the body (see table 1). A blackish discolouration has been noted on the proximal* end of the corpus* (see black arrow, fig.3). The discolouration has been interpreted as either an absorption of substances from the marine sediment*, or as a result of close encounter with fire.

Through analysing the pig hip bone (figure 5) the bone element is estimated to be from the right side of the body (see table 1).

The minimum number of individuals (MNI) documented on the site so far is estimated to one human and one pig. This estimation has been made on the singular bone element representation, as well as the limited amount of information retrieved from each bone element (see table 1).

Image 1: DSC_4879



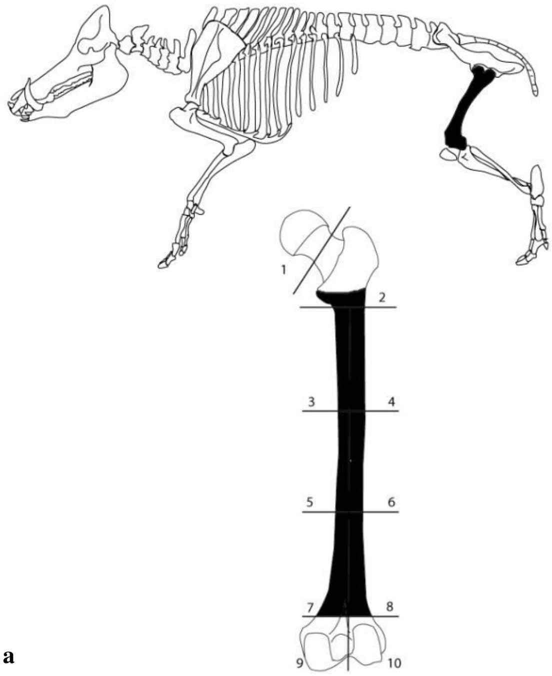


Figure 3 Pig. Right femur with blackish discolouration and a possible fracture. Photo: Tomaz Stachura
Femur illustration from a dorsal view.

Image 2: DSC_4879

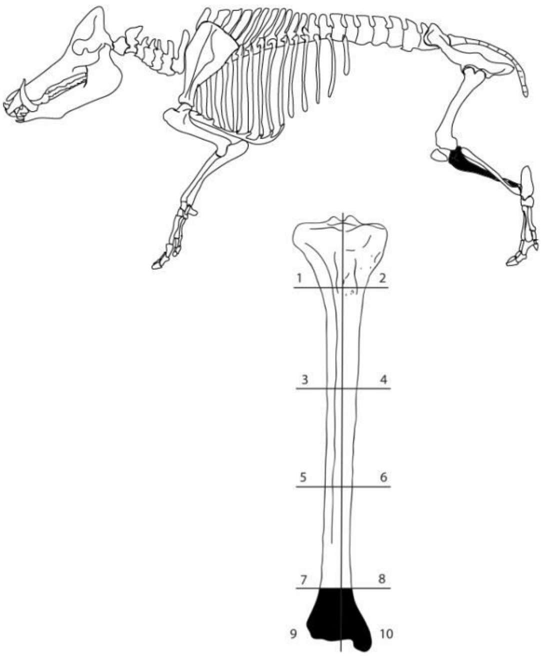
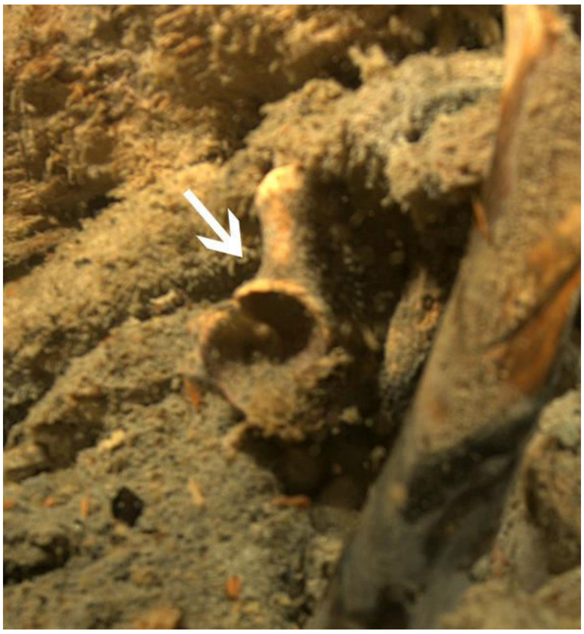


Figure 4 Pig. Right tibia. Fusioned. Photo: Tomaz Stachura. Tibia illustration from a dorsal view.

Image 3: DSC_4881



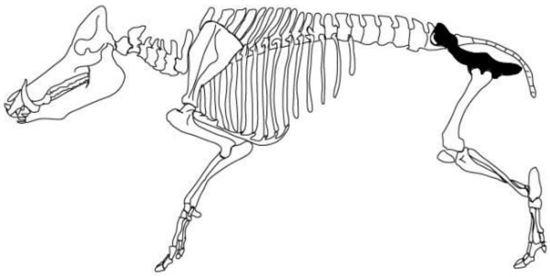


Figure 5 Pig. Right hip joint. Photo: Tomaz Stachura

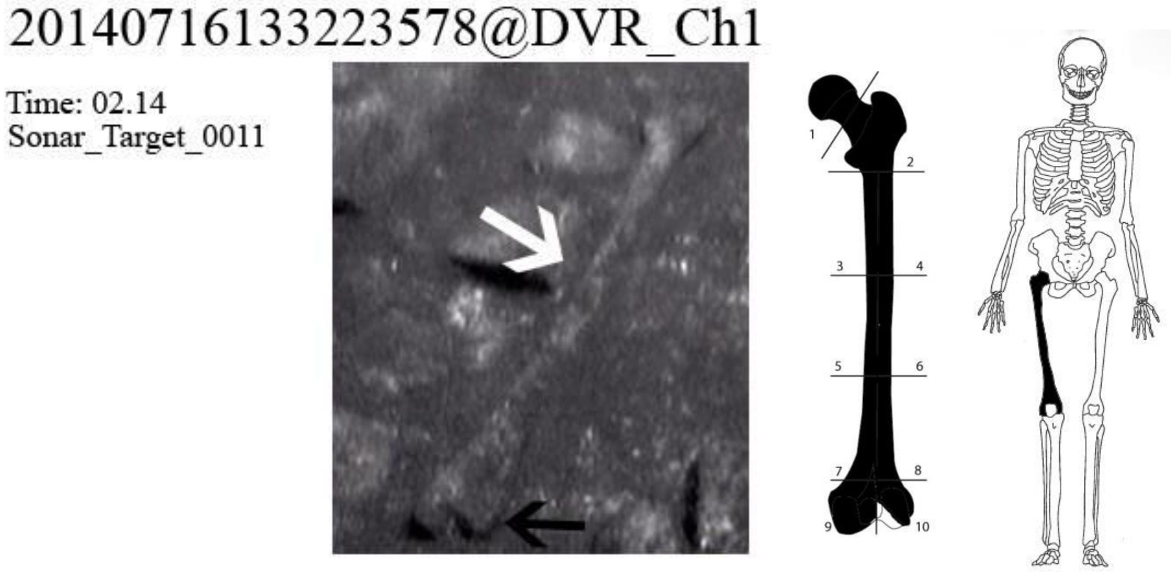


Figure 6 Human. Right Femur*. Documented with ROV film camera.

Human skeleton illustration from Aftandilian, et *al.* (1994)

Femur* illustration from a dorsal view.

Table 1: Compilation of osteological results

Image number	Species	Bone element	Side	Bode code	Epiphyseal closure	Age
DSC_4879	Pig	Femur*	Right	3-8	x.x	-
DSC_4879	Pig	Tibia*	Right	?-9-10	x.f	2y<
DSC_4881	Pig	Coxae: hip joint	Right	-	-	-
20140716133223578@DVR_Ch1	Human	Femur*	Right	1-10	f.f	22<

The epiphyseal* fusion is graded with the proximal* value followed by the distal* value, listed as followed:

o = open
c = closing
f = fully closed
x= missing
? = undocumented
- = bone element not included in bone coding
< = older than

7.2 How are skeletal remains affected by brackish/saltwater over time?

The general answer to this question is that skeletal remains placed in saltwater for a long period of time will absorb soluble salt in the organic collagen (Grant, 2007; Pokines & Symes, 2013: 152) and that skeletal remains will start to crack and flake during the drying process due to the expansion of salt crystals captured within the bone tissue. The expansion of salt crystals is referred to as the crystallisation process (Pokines & Symes, 2013:152; Grant, 2007; Brothwell, 1981:8) and that it can be avoided through letting the skeletal remains undergo a desalting process (Hamilton, 1999). This is, however, a very general answer and it is, therefore, most likely not applicable in every case. The affects of skeletal remains placed at different salinity* levels are, therefore, not clear at this time since the literature only discusses general effects of bones in saltwater. What happens with skeletal remains in brackish water is neither discussed nor mentioned. It may, therefore, be preferable to perform further studies of skeletal remains placed in different salinity* levels and study their degeneration during the drying process in order to fully answer this question.

7.3 How are skeletal remains affected by marine sediment?

The decomposition process of skeletal remains is slowed down when they are covered with marine sediment*. The marine sediment* do to a large extent consist of anaerobic* sediment* layers where aerobic* bacteria lack the free flowing oxygen needed in order to break down organic material. This means that the aerobic* bacteria are unable to extract energy from the bone tissue placed in the lower parts of the marine sediment*. The decomposition process is, therefore, not completely haltered but to a large extent slowed down. This means that skeletal remains placed in marine sediment* will remain intact for a longer period of time than skeletal remains placed out in the open water (Jansson, 1978:45f). It is also important to note that the skeletal remains may absorb foreign substances from the marine sediment* leading to a discolouration of the bone tissue (Allison, et *al.*, 1991; Jansson, 1978:45-47).

7.4 How should a possible retrieval and conservation of the skeletal remains preferably be carried out in the case of an attempted recovery of the naval ship Mars?

A future retrieval of the skeletal remains of the naval ship *Mars* should preferably be based on the proliferation of bone on the site. The procedure of bone collection should, therefore, according to the author preferably be carried out in either one or the two following ways.

1. If the proliferation of skeletal remains is in such a way that each bone element cannot be connected to specific individuals, the retrieval of the skeletal remains should be collected as mass material and related to specific position through the use of a grid. The skeletal remains should be placed in separate netting bags for each square in the grid and each bag should be marked with the number of the square of which they were found.
2. If the proliferation of skeletal remains is in such a way that each bone element can be connected to specific individuals, the retrieval of skeletal remains should be collected on an individual basis. Each individual should be collected in separate numbered netting bags connected to the position on the ship or sea bed through the use of a grid.

The conservation of the skeletal remains of the ship *Mars* should preferably be based on the exact salinity* levels of the site. It is, however, unclear how high the salinity* level need to be in order to negatively affect skeletal remains during the drying process. However, if the salinity* levels at the site imply that a desalting process is needed in order to ensure the future conditions of the skeletal remains it would be preferable to use Hamilton's (1999) regular desalting process. This since both the regular desalting process and alcohol baths appear to produce similar results at different costs. Since the regular desalting process only require access to salt- and freshwater, it should be less expensive to perform than the alcohol baths since they require big amounts of ethanol. The skeletal remains should, therefore, preferably be placed in six different tubs with a decreasing salinity* level from a hundred percent of the original water to a hundred percent of freshwater. The salinity* level should decrease with twenty-five percent per tub and the bone element should remain in the tub for approximately one week per tub. The skeletal remains should then be placed in a temperature-controlled room to air dry in order to ensure that all water has been removed from the bone before being placed in storage.

8. DISCUSSION

8.1 What information is it possible to retrieve through performing an osteological analysis of the digitally documented skeletal remains of the naval ship Mars?

The analysis results presented in this thesis underline the possibility of performing an osteological analysis on digitally documented skeletal remains. The analysis resulted in an age assessment, identification of species, identification of bone element, bone element side, MNI assessment and a noted discolouration and possible trauma (see 7.1).

The age assessment of the analysed human remains indicates that the human was at least twenty-two years old at the time of death. This estimation is based on the epiphyseal* closure of both the proximal* and distal* end of the femur* (see 7.1). Since only one bone element has been used to estimate the age of this individual it is, however, difficult to place the individual into a specific age group. What is, on the other hand, clear is that this individual has passed puberty and entered adulthood. Unfortunately, no digital measurement of the femur* could be collected at this time and no stature estimation could, therefore, be performed.

A possible trauma has been noted (see 7.1) on the distal end of the femur*, it is, however, unclear if the trauma occurred during or after death. One possible explanation may be a possible sharp force towards the outside of the right knee. The angle may imply that the force came from underneath. It is also important to underline that what has been assessed as a sign of trauma actually may be an effect of taphonomical* changes, scavenging or a distortion of the lens during the documentation process.

The age assessment of the analysed pig remains indicates that the pig was at least two years old at the time of death. This estimation is based on epiphyseal* closure of the distal* end of the tibia*. However, since only the distal* end was documented it is slightly problematic to estimate an exact minimum age. As an unfused and fused proximal* end of the tibia* would place the individual in two different age groups. An open epiphysis* would imply that the pig was between two and three and a half years old whereas a fully closed epiphysis* would imply that the pig was three years or older at the time of death.

The MNI estimation indicates that one pig and one human were documented at the site. The estimation is, however, not representative for the entire site since there are only three types of bone elements represented at this time: one right human femur*, one right pig femur*, one right pig tibia* and one right pig hip bone. It is, however, important to underline that the three documented pig remains might not be from the same individual despite the fact that they have been documented in the same location and are from the right side of the body. Historical sources describe that meat, pork and dried fish were loaded on board *Mars* before setting sail for to island of Gotland (Sjöblom, in prep:6). The historical documents, therefore, indicate that pigs were loaded on board as provision and not as a livestock, and that they were, therefore, butchered and put in containers where several different individuals were mixed. It is, however, important to note that the three documented bone elements might belong to the same individual since the hipbone, femur* and tibia* are parts of the meatier* part of the body (During, 1986:64) and might, therefore, have been left intact during the butchering process. The femur* does, on the other hand, appear to have gone through some kind of trauma since the femoral* head, neck and part of the proximal* corpus* appear to be missing (see 7.1). It is, however, hard do determine if this occurred during the butchering process in order to separate the femur* from the pelvis, or if the trauma occurred when the ship landed on the sea bed.

The blackish discolouration noted on the pig femur* (see 7.1) may be the result of either close contact with fire or absorption of substances in its immediate environment. Since the digitally documented skeletal remains are limited to only four bone elements it is hard to draw any conclusions from just one documented discolouration. However, it is noteworthy to mention that the marine sediment* appear fairly undisturbed on the other documented bone element partly covered by sediment*. This means that it may show the same kind of discolouration if it is uncovered in the future. It does seem fairly reasonable that the pig femur* absorbed substances from its immediate environment since discolouration of skeletal remains in a marine context has been described in both the cases of the ships *Vasa* (During, 1994:18-19), *Kronan* (Kjellström & Hamilton, 2014:37) and *Mary Rose* (Stirland, 2013:71), as well as in the examination of a whale carcass placed in the Sainta Catalina sea basin (Allison, et *al.*, 1991:80). It is also stated by Christensson (1999) that skeletal remains have a tendency to absorb foreign substances from their immediate environment (Christensson, 1999:172).

However, it is also important to note that the pig femur* may have been affected by fire previous to the explosion. As historical documentation describe how meat, pork, and dried fish were loaded on board the ship before setting sail to the island of Gotland (Sjöblom, in prep:6). This means that the femur* might have been stripped of its meat and thrown in the cooking fire previous to the battle, or that an unfinished meal or barrel of pork where burned by the spreading fire prior to the explosion. Without further studies of the specific bone element and the undocumented remainder of the skeletal remains of the ship *Mars*, it is, however, problematic to determine if the blackish discolouration has occurred due to fire or absorption of substances in the marine sediment*.

Through comparing the analysis results from this thesis with the osteological documentation from the ships *Kronan* (Kronanprojektet, 2013; Kjellström & Hamilton, 2014), *Vasa* (During, 1994) and *Mary Rose* (Stirland, 2013) it is clear that this osteological analysis lack information concerning stature, sex and pathologies. There are several underlying reasons as to why this information has not been retrievable at this time. One of the biggest limitations of the examined digital material is the amount of documented skeletal remains, since only four bone elements had enough osteological characters to be suitable for an osteological analysis. Hundreds of men went down with the *Mars* (Smirnov, 2009: 106) and of these only one human bone has been documented and used in this thesis. It is, therefore, unreasonable to expect that all aspects documented in the osteological documentation concerning the ships *Vasa* (During, 1994), *Kronan* (Kronanprojektet, 2013; Kjellström & Hamilton, 2014; Einarsson, 1990) and *Mary Rose* (Stirland, 2013) should also be represented in this osteological pre-study.

It is also important to note that information such as stature needs to be calculated on actual measurements. This means that either a digital or physical measurement of the femur*, tibia*, humerus*, radius* or ulna* needs to be performed in order to retrieve the GL (Greatest Length of each bone element) in order to estimate the stature of an individual.

Unfortunately, there has been no possibility to measure the bone elements at this time. It is, on the other hand, important to note this since new methods of documentation will be used in the field study taking place in the summer of 2015, which will allow the osteologist to measure each documented bone element.

Since both humans and pigs have sexual dimorphism it should be possible to perform a sex assessment based on morphological characters of the cranium, jawbone and pelvis. Unfortunately, no skeletal remains suitable for sexing were documented at this time.

8.2 How are skeletal remains affected by brackish/saltwater over time?

The questions concerning the effect of salt on skeletal remains may appear simple enough to answer in only a couple of sentences. The answer is, however, a bit more complicated. This since the literature only discusses the general effects of salt on skeletal remains. The literature states that skeletal remains in saltwater absorb soluble salt in the organic collagen (Grant, 2007; Pokines & Symes, 2013: 152) and that they will start to crack and flake during the drying process due to the expansion of salt crystals absorbed within the bone tissue. The expansion of salt crystals is referred to as the crystallisation process (Pokines & Symes, 2013:152; Grant, 2007; Brothwell, 1981:8) and can be avoided through letting the skeletal remains undergo a desalting process (Hamilton, 1999). The literature do, however, only discuss the effects of skeletal remains in saltwater. This without further mentioning the exact salinity* levels needed in order to define the water as such. This means that the literature, as informative as it is, do lack the information needed in order to answer the question concerning the effects of brackish water on skeletal remains.

In the literature describing the retrieval of the skeletal remains of the *Mary Rose*, it is clearly stated that the bones were immediately put in rinsing baths in order to avoid cracking and flaking of the bone tissue (Stirland, 2013:67). It is important to note that the skeletal remains of the *Mary Rose* were retrieved from the salty Solent in the Atlantic sea (Stirland 2013:66-67) and that they were, therefore, exposed to higher salinity* levels than the skeletal remains of the ships *Vasa* (Stirland, 2013:67) and *Kronan* (Kjellström & Hamilton, 2014:37) retrieved from the brackish water of the Baltic Sea. Both

Swedish ships appear to lack documentation describing any decision process concerning, however, a desalting process should be performed or not. This documentation would have been of interest since no desalting process has been documented in the osteological reports and summaries.

The lack of information concerning the conservation and desalting process of the skeletal remains may imply one of several of the following aspects. One rather likely scenario is that the osteologists decided that the skeletal remains would remain intact without undergoing a desalting process, due to the low salinity* levels of the Baltic Sea. Meaning that the injuries afflicted to the bone through the crystallisation process may be of such a small magnitude that no physical changes would be visible to the naked eye. Another scenario is that the osteologists decided that the financial costs of performing a desalting process would exceed the scientific value of the skeletal remains. The third and rather unlikely scenario is that a desalting process was performed without being mentioned in the official reports. Another, rather likely, scenario is that no desalting process was performed because the taphonomical* effects of salt were not known at the time of recovery. This is rather possible since the recovery of the skeletal remains of *Vasa* began in the sixties (During, 1994:23) and *Kronan* in the eighties (Kronanprojektet, 2013:1).

It is possible that the low salinity* levels of the Baltic Sea rendered a desalting process completely unnecessary. However, since there is no documentation clearly stating that they actively decided not to perform a desalting process, it is rather difficult to determine if this question was even raised.

Since no documentation regarding the decision process concerning the desalting process can be connected to either of the two ships, no further light can be shed on how skeletal remains are affected in brackish water. This, therefore, imply that the general effects of saltwater can be described but that the effects of brackish water on skeletal remains will remain unanswered at this time.

It may, therefore, be preferable to, in the future, aim to assemble some sort of grading system over the different salinity* levels and their affect on skeletal remains in order to create a general recommendation for when a desalting process should be performed.

8.3 How are skeletal remains affected by marine sediment?

Skeletal remains are positively affected by marine sediment* since the sediment* consist at least one anaerobic* layer without free oxygen (see 5.3). Since oxygen is one of the key components needed in order for aerobic* bacteria to extract energy from organic material, and thereby break them down, it means that the decomposition process is slowed down.

It is stated in the reports from the ships *Kronan* (Kjellström & Hamilton, 2014:37, Einarsson, 1990:45), *Vasa* (During, 1994: 17) and *Mary Rose* (Stirland, 2013: 71) that the skeletal remains collected at the sites where positively affected by low levels of free oxygen. It is, however, only stated in the literature concerning the *Mary Rose* that this was due to silt*.

Marine sediment* in the Baltic Sea is described by Jansson (1978) to have a positive preservation effect on organic material in the anaerobic* layers of the marine sediment* (Jansson, 1978:45). It is also described in a study of a whale carcass in the bathyal of the Sainta Catalina sea basin that skeletal remains placed under the marine sediment* are better preserved than parts of bone or bone elements placed outside of the marine sediment* (Allison, et *al.*, 1991). It is also stated that staining of the skeletal remains may occur due to the absorption of substances such as sulphur in the marine sediment* (Allison, et *al.*, 1991).

The effect of marine sediment* on skeletal remains are, therefore, estimated to be generally positive even if there is a risk of staining from absorption of sulphur etc. this since the risk of discolouration and absorption of foreign substances is always present regardless if the bones are placed in soil or water. It is also important to underline that the marine sediment* will only slow down the disintegration process and not stop it completely, and that the cover of marine sediment*, therefore, is no guarantee for perfect conservation conditions. It may, however, be preferable to leave the marine sediment* undisturbed unless a clear purpose of uncovering the skeletal remains exists. This since the marine sediment* work as a shield against free flowing oxygen, allowing the skeletal remains to remain intact for a longer period of time.

8.4 How should a possible retrieval and conservation of the skeletal remains preferably be carried out in the case of an attempted recovery of the naval ship Mars?

The retrieval methods of the skeletal remains of the ships *Kronan*, *Vasa* and *Mary Rose* was performed in two different ways. The ship *Vasa* capsized and sank due to flooding of the hull (During, 1994: 10-15, leaving the ship fairly intact on the bottom of the sea. Because the ship was found intact it means that the whole ship could be lifted out of the water with most of the skeletal remains still in the ship (During, 1994:18). This allowed the archaeologist to excavate the ship as an archaeological site where each bone element could be retrieved in a fairly dry environment and numbered according to their distance to the nearest deck beam (During, 1994:23).

The *Mary Rose* met a similar end to *Vasa* but had due to the sweeping tides of the Atlantic sea been broken down (Stirland, 1994:66-67) and to a large extent covered with silt* (Stirland, 1994:71). This means that the *Mary Rose* could not be retrieved in the same way as the ship *Vasa* and that the skeletal remains, therefore, needed to be recovered through a different procedure. The skeletal remains of the *Mary Rose* were, therefore, retrieved by divers who collected the skeletal remains in netting bags as mass material. This since the skeletal remains had been swept back and forth within the hull, making it problematic to decide at the site which bone element belonged to each individual. The skeletal remains where, therefore, collected and numbered by section and sorted by bone element before being brought to the surface (Stirland, 1994:67).

The *Kronan*, on the other hand, sank due to an explosion splitting the ship in two (Kronanprojektet, 2013:1) This means that the *Kronan* could not be retrieved in the same manner as the ship *Vasa*, but due to the limited tidal changes of the Baltic Sea the remainder of the ship on the sea bed remained fairly intact. The skeletal remains of *Kronan* was, therefore, retrieved by divers who collected the skeletal remains in netting bags on an individual basis (Kronan projektet, 2013:25). This meaning that the distribution of the skeletal remains where in such a way that most bone elements could easily be connected to specific individuals, allowing the divers to collect most skeletal remains on this basis and connecting them to a specific find number at the surface. In the case where two individuals were hard to distinguish from one another they were both collected in the same bag in order to keep the context as clear as possible (Kronan projektet, 2013:25).

Based on the recovery methods used for the skeletal remains of the ships *Kronan*, *Vasa* and *Mary Rose* it is quite clear that the way of recovery is foremost based on the condition of the ship. Since the ship *Mars* just like the ships *Kronan* and *Mary Rose* is in a fractured state it is, therefore, likely that the most suitable retrieval method for the skeletal remains of the *Mars* is one similar to theirs.

The recovery process should preferably be based on the distribution pattern of the skeletal remains. In the case where the skeletal remains cannot be connected to a specific individual the bones should be collected as mass material and connected to a specific position through the use of a grid. The skeletal remains should preferably be placed in netting bags marked with the number of the square they were collected. If the skeletal remains, on the other hand, can be connected to specific individuals on the site it would be preferable to collect them on an individual basis. Each individual should in this case be collected in separate numbered netting bags connected to the position on the ship or sea bed where they were located before recovery.

The ships *Vasa* (During, 1994:10; Stirland, 1994:67) and *Kronan* (Kronanprojektet, 2013:1) were both located in the brackish water of the Baltic Sea whereas the *Mary Rose* were placed in the salt Atlantic sea (Stirland, 1994: 66-67). No desalting process has been listed in the literature used in this thesis concerning *Vasa* and *Kronan*. The reasons for this are not clearly stated. The most likely reason for this is that no desalting process has been performed due to the low salinity* levels of the Baltic Sea, but since the effects of saltwater on skeletal remains is something that is not generally discussed it may imply that the question never even arose (see 7.1.1).

Since the retrieval of the skeletal remains of *Vasa* and *Kronan* started in the sixties (During, 1994:23) and eighties (Kronanprojektet, 2013:1) it is important to note that the methodology for retrieval of skeletal remains in a marine context may have been slightly altered. This means that the retrieval and conservation methods used on the *Mary Rose* may, even though she was placed in the Atlantic sea, be more suitable as an example of how to treat skeletal remains from a marine context. This even though the salinity* levels of the Atlantic sea is higher than the salinity* level of the Baltic Sea. It is, however, probably preferable to measure the exact salinity* levels of the immediate environment of the naval ship *Mars* in order to determine if and how a desalting process should be performed in the case of an attempted recovery of the skeletal remains.

However, if a desalting process should be performed it would be most preferable to use the regular desalting process described by Hamilton's (1999) in *Methods for conserving Archaeological material* *from underwater sites.* The regular desalting process is performed on structurally sound bone and uses freshwater in order to slowly extract the salt from the bone tissue. The bones are placed in rinsing baths for approximately seven days per tub before being moved to a new tub with a lower salinity* level until the bone has been completely desalted. The bones are then placed in a temperature-controlled environment to air dry in order to ensure that the bones are completely dry before being placed in storage. This method is preferable to the other two listed methods by Hamilton (1999) due its careful and non-destructive ways, as well as from an economical point of view. One should aim to avoid using the consolidation and rinsing process as much as possible since it uses acroyloid B-72 to strengthen the bone tissue before undergoing the regular desalting process. The acroyloid B-72 unfortunately, destroy any chance of performing any scientific methods like DNA and isotopic analysis in the future. The method is recommended by Hamilton for structurally unsound bone, and should preferably only be used in those cases where the skeletal remains are so sensitive that the bones are too fragile to undergo a regular desalting process. The alcohol baths are performed in a similar way as the regular desalting process besides from using ethanol instead of freshwater as an extractor during the desalting process. Even the alcohol baths seem to result in the same result as the regular desalting process, it is, however, important to note that the regular desalting process only require a mixture of saltwater and freshwater whereas the alcohol baths require both saltwater and ethanol (Hamilton, 1999). This means that the regular desalting process is likely to be less expensive to perform than the alcohol baths, and that this process, therefore, should be preferable since the both methods produce similar results.

9. CONCLUSIONS

The conclusion one may draw from the osteological results presented in this bachelor's thesis is that it is possible to perform an osteological analysis on digitally documented skeletal remains. Through examination of the bones it has been possible to assess both species, age, bone element, side, possible trauma and a discolouration. Neither sex nor stature has been estimated at this time. In order to be able to estimate stature the osteologist needs to be able to measure the bones, alternative methods are, therefore, needed in order to estimate stature based on digital documentation. It should be possible to perform a sex assessment based on digital when a bone with sexual dimorphism is documented. This means that it is possible to document and analyse the skeletal remains from the naval ship *Mars* through the use of digital methods.

The general effect of saltwater on skeletal remains is described to be negative since the bone absorbs soluble salts in the organic collagen. The salt crystals expand during the drying process, leading to cracking and flaking of the bone tissue. It is, however, unclear at what salinity* levels the bone absorbs an amount of salt that will result in this process. It is, therefore, not possible to describe the exact taphonomical* effects of bones placed in brackish water.

Marine sediment* do, however, appear to have a generally positive effect on skeletal remains in a marine context, this since the low levels of free oxygen in the marine sediment* slows down the degeneration process. There is, however, of staining of the skeletal remains because they may absorb foreign substances from the sediment*. A discolouration of the bones is, however, a small price to pay for increased preservation conditions. It may, therefore, be advisable to leave the skeletal remains untouched under the marine sediment* unless a clearly stated reason for uncovering them exists.

A hypothetical recovery of the skeletal remains from the naval ship *Mars* should preferably be carried out by divers, placing the skeletal remains in numbered nettings bags. In those cases where the remains can be connected to specific individuals they should be collected on an individual basis and in those cases where this is not possible the remains should be collected as mass material. It is also important that the position of the bones are registered before retrieval. This in order to analys the distribution pattern in the future. The exact salinity* levels should be measured at the site before it is determined if a desalting process should be performed or not. If it is decided that a desalting process should be performed, it should preferably be based on Hamilton's regular desalting process for structurally sound bones.

10. SUMMARY

This bachelor's thesis represents a pre-study in a research project called *Skeppet Mars (1564)* and aim to lay the ground for the osteological documentation process taking place during the planned field study in the summer of 2015 where the author has been invited to participate. The project is a cooperation between MARIS at Södertörns University, researchers at Försvarshögskolan, Southampton University, Uppsala University Campus Gotland, Maritima museet and the companies Ocean Discovery, Deep sea production and Maritim mätteknik AB, and is funded by Östersjöstiftelsen and National Geographic.

The pre-study focuses on what information it is possible to collect through the analysis of digitally documented skeletal remains and the effects of marine sediment* and brackish/salt water on skeletal remains. As well as how a preferable retrieval and conservation of the skeletal remains should preferably be performed in the case of a future recovery. A small osteological analysis has been performed on the skeletal remains documented by ROV and handheld cameras and has resulted in information concerning species, bone element, bone element side, age, a discolouration and possible trauma. Identification of species, bone element and side has been estimated through comparisons with the reference collection at Uppsala University Campus Gotland.

A thematic literature review has been performed and compiled into a reference material used in the discussion in an attempt of answering the theoretical work questions. The result of the discussion concerning the marine sediment* imply that the decomposition process of skeletal remains is slowed down by the presence of marine sediment* and that the effects are, therefore, generally positive. The theoretical discussion concerning the effect of saltwater on skeletal remains implies that skeletal remains are negatively affected. The skeletal remains have a tendency to absorb soluble salt in the organic collagen which will lead to cracking and flaking when the bone is placed in a dry environment. The result of the discussion concerning the different retrieval methods recommended for the naval ship *Mars* imply that the skeletal remains should be collected in numbered netting bags by divers. Skeletal remains should be collected on an individual basis when possible and in other cases as mass-material. The result of the discussion concerning the recommended conservation methods for the skeletal remains of the naval ship *Mars* imply that a measurement of the exact salinity* level should be performed before deciding if the skeletal remains should go through a desalting process. Hamilton's regular desalting method should preferably be used as a basis for a hypothetical conservation of the skeletal remains.

11. FUTURE RESEARCH

Since the skeletal remains of the naval ship *Mars* will most likely be the most represented find type it is important to work with the project group and their questions in order to create a complete image of the naval ship *Mars*. The following aspects are, therefore, foremost suggestions for how the future focus of further documentation and analysis may be performed.

This pre-study shows that it is possible to identify bone and bone elements, and use osteological methods to analyse digitally documented skeletal remains. It would, therefore, be of interest to continue the osteological analysis of the skeletal remains of the naval ship *Mars* in the future through the use of digital documentation. Since some of the original work questions previously intended to work as a basis for this bachelor's thesis could not be used at this time, it would be of interest for both the author and the project *Skeppet Mars (1564)* to use these as a basis for the authors future master thesis (see listed below). This in order to shed light on the lives of the men who went down with the naval ship *Mars* and the events that led to their downfall.

- How many minimum number of individuals (MNI) it is possible to determine on the site?
- Which bone elements are present on the site?
- How is the proliferation of bones?
- Are there any clear evidence on the skeletal remains that is has been subjected to pressure from the explosion?
- How is the representation of trauma on the skeletal remains, and can any of these injuries be connected to the explosion of the ship?

New documentation methods will be used during the field study in the summer of 2015 where images will be used in order to create a three dimensional documentation of the site. This will allow the osteologist to both rotate and measure bone elements, and thereby perform a more thorough examination of the skeletal remains. The issue of not being able to document the whole bone element will, however, still remain, unless marine sediment* is temporarily removed during the documentation process.

With the new documentation methods information such as stature, trauma and sex will be easier to assess through analysis of the digitally documented skeletal remains. The results from the digital analysis should preferably be compared with the results from previously analysed skeletal remains from a marine context, such as *Kronan*, *Vasa* and *Mary Rose*. It would also be of interest to highlight any presence of females on the ship and the role they might have played on board.

The image material used in this thesis has not been positioned on a geographical grid, this will, however, be performed during the documentation process in the summer of 2015. A positioning of the skeletal remains will allow the osteologist to create distribution patterns of both singular bone elements and individuals on the site. Through analysing the proliferation of bones and connecting the different species, trauma etc. to specific positions it may be possible to recreate parts of the battle or connect different parts of the ship to specific purposes and social groups onboard the ship.

Other aspects relevant to discuss in the future is the ethics of documenting, analysing and perhaps even displaying human remains in a museum in physical or digital form.

It is also important to describe both the drowning process, the decomposition of bodies, body buoyancy due to produce of intestinal gases, and perhaps other taphonomical* changes that occur on skeletal remains in a marine context. This in order to shed light on why the skeletal remains appear in a certain way, and why some individuals may not be located on the site even though they went down with the ship.

It may also be of interest to discuss the possible pros and cons considering the retrieval of skeletal remains based on different preservation methods and osteological analysis results.

If the skeletal remains are recovered in the future it will be possible to perform scientific methods such as DNA- and isotopic analysis to shed further light on the lives of the men that went down with the ship.

Since the question concerning the effects of skeletal remains in brackish water could not be answered at this time it may also be of interest to perform further studies of how different salinity* levels affect bone tissue. Through performing further studies of bones placed in different salinity* levels for a long period of time before leaving them to dry it may be possible to form general recommendations for when skeletal remains from a marine context are in need of conservation.

Very few marine osteological projects have been performed in Sweden. The osteological analysis of the skeletal remains of the naval ship *Mars* will, therefore, contribute to the marine osteological research. The osteological research will also contribute to an increased knowledge about aspects that cannot be accessed through historical documentation, such as health and trauma.

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Sjöblom, I. in prep. *Tusen tunnor öl och maten på Mars*

APPENDIX

Wordlist

Aerobic: "Relating to, involving, or requiring free oxygen"
(http://www.oxforddictionaries.com/definition/english/aerobic) 2015-04-01

Anaerobic: "Relating to or requiring an absence of free oxygen"
(http://www.oxforddictionaries.com/definition/english/anaerobic) 2015-04-01

Cancellous: "Denoting bone tissue with a mesh-like structure containing many pores, typical of the interior of mature bones."
(http://www.oxforddictionaries.com/ definition/english/cancellous) 2015-04-01

Corpus: "The main body or mass of a structure"
(http://www.oxforddictionaries.com/definition/english/corpus) 2015-05-09

Distal: "Situated away from the centre of the body or from the point of attachment"
(http://www.oxforddictionaries.com/definition/english/distal) 2015-05-08

Epiphyseal / Epiphysis: "The end part of a long bone, initially growing separately from the shaft"
(http://www.oxforddictionaries.com/definition/english/epiphysis) 2015-05-08

Famine: "Extreme scarcity of food"
(http://www.oxforddictionaries.com/definition/english/famine) 2015-05-08

Femur/Femoral: "The bone of the thigh or upper hindlimb, articulating at the hip and the knee"
(http://www.oxforddictionaries.com/definition/english/femur) 2015-05-08

Humerus: "The bone of the upper arm or forelimb, forming joints at the shoulder and the elbow"
(http://www.oxforddictionaries.com/definition/english/humerus) 2015-05-08

Enamel hypoplasia: " incomplete or defective development of the enamel of the teeth; it may be here ditary or acquired"
(http://medical-dictionary.thefreedictionary.com/hypoplasia) 2015-05-29

Marine sediment: "Marine sediment, any deposit of insoluble material, primarily rock and soil particles, transported from land areas to the ocean by wind, ice, and rivers, as well as the remains of marine organisms, products of submarine volcanism, chemical precipitates from seawater, and materials from outer space (e.g., meteorites) that accumulate on the seafloor."
(http://global.britannica.com/EBchecked/topic/365317/marine-sediment) 2015-05-04

Meaty/Meatier: "containing a lot of meat"
(http://www.oxforddictionaries.com/definition/learner/meaty) 2015-05-09

Osteoarthritis: "Degeneration of joint cartilage and the underlying bone, most common from middle age onward. It causes pain and stiffness, especially in the hip, knee, and thumb joints"
(http://www.oxforddictionaries.com/definition/english/osteoarthritis) 2015-05-18

Peri-mortem: "at or near the time of death; in perimortem injuries, bone damage occurring at or near the time of death, without any evidence of healing."
(http://anthropology.si.edu/writteninbone/comic/activity/pdf/Perimortem.pdf) 2015-05-08

Porewater: "Water contained in pores in soil or rock."
(http://www.oxforddictionaries.com/definition/english/porewater?q=pore+water) 2015-04-01

Post-mortem: "after death; in postmortem injuries, bone damage occurring at or near the time of death, without any evidence of healing"
(http://anthropology.si.edu/writteninbone/comic/activity/pdf/Perimortem.pdf) 2015-05-08

Proximal: "Situated nearer to the centre of the body or the point of attachment"
(http://www.oxforddictionaries.com/definition/english/proximal) 2015-05-08

Radius: "The thicker and shorter of the two bones in the human forearm." "The bone in a vertebrate's foreleg or a bird's wing that corresponds to the radius in a human being"
(http://www.oxforddictionaries.com/definition/english/radius) 2015-05-08

Rickets: "A disease of children caused by vitamin D deficiency, characterized by imperfect calcification, softening, and distortion of the bones typically resulting in bow legs" 2015-05-18

Salinity: "A solution of salt in water" (http://www.oxforddictionaries.com/definition/english/saline?q=salinity#saline__10) 2015-05-08

Scapula: "Technical term for shoulder blade" (http://www.oxforddictionaries.com/definition/english/scapula) 2015-05-18

Scurvy: "A disease caused by a deficiency of vitamin C, characterized by swollen bleeding gums and the opening of previously healed wounds, which particularly affected poorly nourished sailors until the end of the 18th century" 2015-08-18

Sediment: "Matter that settles to the bottom of a liquid." (http://www.oxforddictionaries.com/definition/english/sediment) 2015-04-01

Silt: "Fine sand, clay, or other material carried by running water and deposited as a sediment, especially in a channel or harbour." (http://www.oxforddictionaries.com/definition/english/silt) 2015-04-01

Taphonomy/Taphonomical: "the study of the environmental conditions affecting the preservation of animal or plant remains" (http://dictionary.reference.com/browse/taphonomy) 2015-05-20

Tibia: "The inner and typically larger of the two bones between the knee and the ankle (or the equivalent joints in other terrestrial vertebrates), parallel with the fibula" (http://www.oxforddictionaries.com/definition/english/tibia) 2015-05-08

Ulna: "The thinner and longer of the two bones in the human forearm, on the side opposite to the thumb" "The bone in a quadruped's foreleg or a bird's wing that corresponds to the ulna in a human being" (http://www.oxforddictionaries.com/definition/english/ulna) 2015-05-08