Guide to Bald Eagle Egg Incubation and Chick-Rearing

Prepared by
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Institute for Wildlife Studies
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Guide to Bald Eagle Egg Incubation and Chick-Rearing

INTRODUCTION

The Institute for Wildlife Studies (IWS) began restoring bald eagles on Santa Catalina Island in 1980. This population was extirpated by the mid-1960s as a result of DDE contamination in the food chain that caused them to lay thin-shelled eggs. The DDE contamination still plagues the restored population and the fragile eggs must be removed from the nests soon after they are laid for artificial incubation. Historically, the eggs were taken to either the Santa Cruz Predatory Bird Research Group (1989-1991) or the Avian Conservation Center (ACC) at the San Francisco Zoo (1992-2004) for incubation. Starting in 2005, IWS was asked to begin incubating the bald eagle eggs on Santa Catalina Island.

This manual provides IWS employees with an overview of the methods used to incubate bald eagle eggs and raise chicks in our facility on Santa Catalina Island. The formation and development of the egg/embryo is covered as basic background information, as well as the specific techniques used to control water loss in the eggs, monitor embryo development, care for hatched chicks, and maintain the facilities. This information has been pulled from a variety of sources, but primarily from materials provided during an egg incubation workshop conducted by Susan Kasielse of the Los Angeles Zoo and from information provided by the ACC. In addition to reviewing this manual, employees should read “The New Incubation Book” by A. F. Anderson Brown and G. E. S. Robbins for more details on egg and embryo development and incubation theory before working with the eagle eggs. Additional pertinent books/papers will be available in the facility library.

EGG FORMATION

Birds have a single, active left oviduct and a rudimentary right oviduct (Fig. 1). There is an average of 25 hours between ovulation and oviposition (laying) in chickens and the egg rotates slowly as it progresses. The yolk is deposited in rings while in the ovary (Figs. 1 and 2). Once the egg is released, fertilization occurs in the infundibulum (takes about 15 minutes to pass through; Fig. 1). The egg next moves through the magnum over a 2-3 hour period (Fig. 1). Here, the albumen is secreted in four layers: inner thick (chalaziferous), inner liquid, outer dense (albuminous sac), and outer liquid (Fig. 2). The albumen is a water and protein source for the embryo and also cushions the embryo and deters infectious agents. During the next hour the egg moves through the isthmus (Fig. 1), where two non-living shell membranes are laid down to act as a matrix supporting shell formation (Fig. 2). The shell membranes are composed of keratin-like fibers and pigment and act as a mechanical barrier to infection.

Figure 1. Reproductive organs of a female bird.
The longest part of egg formation takes place when the egg moves through the shell gland or uterus (Fig. 1), which takes about 20-23 hours. Here is where the shell, pigment, and cuticle are laid down (Fig. 2). The shell acts as physical protection for the embryo and is the primary source of calcium for the developing embryo. The shell also acts as the first barrier to infection. This is a mechanical barrier which is based upon pore size and length. The cuticle acts as a further mechanical barrier to infection by partially occluding the pores in the shell. Lastly, the egg passes through the vagina and cloaca (Fig. 1) before it is finally oviposited.

![Diagram of egg structure](image)

**Figure 2. Structure of the egg along the long axis.**

### Egg Composition

**Yolk Characteristics**
- makes up 20-70% of egg weight (less in altricial birds, more in precocial)
- composed of 49% water, 33% lipid, 17% protein, 1% carbohydrate, fat & water soluble vitamins, calcium & trace minerals

**Albumen Characteristics**
- 88% water (primarily from shell gland), 11% protein, 1% carbohydrate water-soluble vitamins, and trace minerals

**Shell Characteristics**
- composed of CaCO₃ in a protein matrix, Mg and other trace minerals
Pigment Characteristics
- shell pigments are hemoglobin-derived and are produced via the liver (ground color, which is bluish in bald eagles) and lymphocytes (superficial)

Cuticle Characteristics
- mucopolysaccharide
- can be a dull to very glossy coating or a bloom (dusty coating)

**EMBRYO DEVELOPMENT**

As the embryo develops there are several extraembryonic membranes that form: the yolk sac, amnion, and chorioallantois (Fig. 3). The yolk sac is highly vascularized and completes formation near the middle of incubation. It serves to transport nutrients and in early respiration. The amnion is minimally vascularized and completes about 1/3rd of the way through incubation. It acts as a protective fluid environment and has muscle fibers that contract rhythmically to prevent adhesions early in development before the embryo is motile. The amnion also acts as a nutrient medium. Albumen mixes with amniotic fluid soon after the middle of incubation and the embryo begins drinking this fluid, utilizing protein for rapid growth. The chorioallantois completes its formation after the middle of incubation. This is composed of the chorion, an ‘extension’ of the amnion that advances along the inner shell membrane, and the allantois, a highly vascularized membrane that emerges from the hind gut and expands to fuse with the chorion. This membrane aids in respiration, providing O₂/CO₂ exchange sufficient to support development. There is also passive transpiration from the chorioallantois, resulting in the evaporative loss of water that is generally about 15% of the egg’s initial weight (a linear loss). Urinary waste is also collected in the chorioallantois, where uric acid precipitates just before hatching. Table 1 and Appendix I describe the timing of developmental landmarks in embryo development.

![Diagram of Extraembryonic Structures in a Developing Egg](image-url)

*Figure 3. Extraembryonic structures in a developing egg.*
Table 1. Stages of bald eagle embryonic development during a 35-day incubation period as adapted from Hamburger and Hamilton (1951).

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<th>Hr/Day</th>
<th>Developmental Landmarks</th>
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<tr>
<td>1</td>
<td>0 hours</td>
<td>Embryonic shield</td>
</tr>
<tr>
<td>2</td>
<td>10-12 h</td>
<td>Initial primitive streak</td>
</tr>
<tr>
<td>3</td>
<td>20-22 h</td>
<td>Intermediate primitive streak</td>
</tr>
<tr>
<td>4</td>
<td>30-32 h</td>
<td>Definitive primitive streak</td>
</tr>
<tr>
<td>5</td>
<td>32-37 h</td>
<td>Head process, notochord</td>
</tr>
<tr>
<td>6</td>
<td>38-42 h</td>
<td>Head fold</td>
</tr>
<tr>
<td>7</td>
<td>38-43 h</td>
<td>1 somite + neural folds</td>
</tr>
<tr>
<td>8</td>
<td>43-48 h</td>
<td>4 somites + blood islands</td>
</tr>
<tr>
<td>9</td>
<td>48-55 h</td>
<td>7 somites + optic vesicles</td>
</tr>
<tr>
<td>10</td>
<td>55-63 h</td>
<td>10 somites + cranial flexure (head starting to ball up and rise off yolk)</td>
</tr>
<tr>
<td>11</td>
<td>67-75 h</td>
<td>13 somites + 5 distinct neuromeres</td>
</tr>
<tr>
<td>12</td>
<td>3-3.5 days</td>
<td>16 somites + head rotated onto left side</td>
</tr>
<tr>
<td>13</td>
<td>3.5</td>
<td>19 somites + head fold of amnion over brain</td>
</tr>
<tr>
<td>14</td>
<td>3.5</td>
<td>22 somites + visceral arches</td>
</tr>
<tr>
<td>15</td>
<td>3.5-4</td>
<td>24-27 somites, but becoming hidden</td>
</tr>
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<td>16</td>
<td>3.5-4</td>
<td>Tail and wing buds forming</td>
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<td>17</td>
<td>4</td>
<td>Leg buds forming, amnion closing</td>
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<td>18</td>
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<td>Allantois forming</td>
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<td>19</td>
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<td>20</td>
<td>5-6</td>
<td>Leg buds larger than wing buds</td>
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<td>21</td>
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<td>Faint eye pigment</td>
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<td>22</td>
<td>5-7</td>
<td>Distinct eye pigment, limbs elongating</td>
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<td>23</td>
<td>7</td>
<td></td>
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<td>24</td>
<td>7.5</td>
<td></td>
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<tr>
<td>25</td>
<td>7.5-8</td>
<td>Elbow and knee joints distinct</td>
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<td>26</td>
<td>8</td>
<td></td>
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<tr>
<td>27</td>
<td>8-9</td>
<td>Digital grooves distinct</td>
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<td>28</td>
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<td>29</td>
<td>10-11</td>
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<td>Egg tooth, two scleral papillae, limbs bent</td>
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<td>Dorsal feather germs</td>
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<td>32</td>
<td>12.5</td>
<td>6 scleral papillae</td>
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<td>33</td>
<td>12.5-13</td>
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<td>34</td>
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<td>Ventral feather germs, eyelids begin closing</td>
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<td>38</td>
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<td>39</td>
<td>22</td>
<td>Eyelids nearly closed</td>
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<td>40</td>
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<td>Nails cornified, plantar papillae (rough pads of feet)</td>
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<td>44</td>
<td>30</td>
<td>Yolk sac external</td>
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<tr>
<td>45</td>
<td>32-33</td>
<td>Yolk sac halfway internal</td>
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**HATCHABILITY OF EGGS**

There are a variety of things that can affect the hatchability of the eggs. These can occur at various times during the development of the egg and are briefly described below.
Factors Affecting Hatchability Prior to Oviposition

Genetic
• Inbreeding can result in reduced size, vigor; increased susceptibility to other factors
• Specific lethal and sublethal malformations

Nutritional
• Macronutrients
  o Deficiencies reduce egg size & quality
  o Laying ceases if severe
  o Energy
  o Protein/amino acid balance
• Micronutrients: with deficiencies, egg production continues, but embryos show defects. Examples include:
  o Vitamins:
    • A - early circulatory failure, skeletal abnormalities
    • D3 - eggshell thinning, cessation of lay
    • E - circulatory failure, retarded development, eye defects
    • Thiamine - 'stargazing' in neonate - Amprolium (coccidiostat) has anti-thiamine activity
    • Riboflavin - clubbed down, reduced size, liver/kidney abnormalities, dwarfing
    • B 12 - curled toes (unable to extend), edema, hemmorhage, malposition
    • Biotin - perosis, skeletal abnormalities, hemmorhage
    • Folic acid - growth inhibition, skeletal abnormalities
  o Minerals:
    • Iodine - retarded growth, delayed hatch
    • Mg - tremor, gasping, convulsions at hatch
    • Zn - tufted down, trunk & limb abnormalities, weak chicks
• Toxins/teratogens - examples include:
  o Pesticides - chlorinated hydrocarbons, organophosphates, organochlorines – skeletal abnormalities
  o **DDT? DDE?** eggshell thinning

Physiological
• Age of hen – eggs abnormal size/shape from very young & very old hens reduce hatchability- eggshell thinning at reproductive senescence
• Infectious disease
  o Viral infections of the hen (Newcastle, influenza) permanently damage shell gland
  o Vertical transmission (= egg borne) of bacteria (*Salmonella* spp. especially) & some viruses

Behavioral
• Stress may cause abnormal shell formation (flaws, ridges, odd shapes)
• Trauma may cause body checks - 'healed' cracks
Factors Affecting Hatchability Between Oviposition and Incubation

Infection (Shell-borne)
- Contamination from feces, nest material, human hands
- Bacteria: *Pseudomonas*, *Staphylococcus*, *Streptococcus*, *Klebsiella* spp.
- Fungi: *Aspergillus* spp. and other molds
- Cracks and flaws that increase penetrability

Physical Trauma
- Rolling egg in same direction can cause the chalazae to wind up like rubber bands and break, causing embryo to stick to inner shell membrane
- Jarring, shaking, vibration can cause the loosely adhered cells of the blastoderm to become disrupted

Environmental Conditions
- Temperature
  - 70° F is physiological zero. Above this temperature development initiates and tissues develop at abnormal rates
  - 55-60° F is the ideal storage temperature
- Humidity
  - Excessive water loss at most ambient humidities
  - 70-80% RH is ideal storage humidity

Factors Affecting Hatchability During Incubation

Temperature
- Natural conditions create a temperature gradient from the top to bottom of the egg
- Artificial incubation
  - Still-air incubators create a temperature gradient, but difficult to control temperature
  - Forced-air incubators create uniform temperature throughout
  - Contact incubation more closely mimics natural conditions
- Too high a temperature causes accelerated development (different rates in different tissues), reduced size, rough umbilical seals, and thin, noisy chicks
  - 1-2°F above optimum is often fatal within a few hours
- Too low a temperature causes retarded development (different rates in different tissues if extreme or prolonged)
  - Large, sluggish, sticky chicks
  - Incomplete yolk sac retraction and partially open seal
  - Usually not lethal unless extreme or prolonged
- Optimum temperature is based on the expected length of incubation and the quality of hatching chicks
  - 99.5°F for domestic poultry, waterfowl, and many exotic species
  - 98.0°F for condors, 99.0-99.2°F for psittacines
  - Higher temperatures for smaller eggs/shorter incubation periods (100.0-100.5°F for small passerines)
Humidity
- All avian eggs lose weight by evaporation (15% ± 3%) in a linear fashion
- Humidity too high causes insufficient weight loss
  - Can have edema, malposition, residual albumen/liquids that can cause drowning, unretreaded yolk sac, open seal, and lethargy
  - Drastic measures can be taken, such as put eggs in dry incubator, dehumidify room, sanding shell over air cell only
- Humidity too low causes excessive weight loss
  - Poor bone mineralization due to impaired Ca transport, weak, dehydrated (red) chicks, rough/bloody seals
  - Drastic measures can be taken such as saturation humidy, sealing areas of shell with white glue, nail polish, paraffin, Tegaderm

O₂/CO₂
- Need adequate ventilation
- Power failure induces CO₂ buildup if large numbers of eggs are incubated (~45 min in commercial incubators)
- Ventilation becomes more important than conserving heat

Turning & Position
- Need to turn opposite directions to prevent rupture of the chalazae
  - Turn = 90°
  - Frequency
    - Chickens turn eggs about every 35 minutes on average
    - Mechanical turners generally turn 12-24 times per day
    - By hand, turn minimum of 5 times per day (odd number of times if not turned throughout night)
- Eggs are placed on their sides and rotated around the long axis

Light
- Limited information suggests normal photoperiod improves hatchability

Microbes
- Thrive in warm, moist incubators
- Maintain high level of sanitation
- Avoid mixing species

Physical trauma
- Egg breakage due to improper setting, faulty equipment
- Mechanical vibration
- Rough handling
THE HATCHING PROCESS

As the embryo approaches maximum size, the gas exchange capacity of the chorioallantois becomes insufficient, resulting in the onset of hypoxia (decrease in blood oxygen) and hypercapnia (increase in blood CO₂). These changes in the blood trigger hatching contractions. While positioning itself for hatching, the embryo consumes the remaining fluids. The embryo’s spine aligns with the long axis of the egg and its dorsal side corresponding to the “highest” edge of the air cell (Fig. 4). The head is normally between the thighs in the small end of the egg initially, and then moves up along the side of the body to under the right wing. In this position the egg tooth is under the air cell. Next, the hatching muscle engorges with lymph (musculos hyplexus), often causing the entire head to become edematous (pulmonary respiration will dissipate the edema). Correct positioning is correlated with incubation position (on side versus air cell up) and adequate ventilation (increased CO₂ can cause the embryo to orient upside down). The air cell begins “draw down” (seen during candling) as the inner and outer shell membranes separate. Instead of being taut, the inner membrane now drapes over the embryo and the air cell may have irregular margins. Internal pipping (breaking into the air cell) occurs as contractions of the hatching muscle cause the egg tooth to pierce the inner membrane. Once into the air cell, pulmonary respiration begins and you may hear vocalizations, including response to external stimuli. Muscle contractions subside as gas exchange improves and the embryo rests. The chorioallantoic vasculature begins to recede, starting around the air cell and finally at the umbilical seal just prior to hatching. External pipping occurs as the hatching contractions resume in response to decreasing O₂ and increasing CO₂ and cause the egg tooth to pierce the shell (Fig. 4). Contractions subside again as gas exchange improves and the embryo rests again. During embryonic movement the yolk sac is gradually drawn into the abdomen. By hatching the yolk sac has been fully internalized behind a tight umbilical seal with residual chorioallantoic vessels protruding, which quickly dry. The site of external pip is broken up as hatching contractions resume in response to decreasing O₂ and increasing CO₂. Again, the embryo rests. Rotation occurs with

Figure 4. Normal and abnormal hatching positions.
sustained hatching contractions combined with pushing by the legs. Rotation occurs in a
counterclockwise direction (as viewed from air cell end) and can encompass ½ to 1+ times the
circumference of the egg. Hatching occurs as the embryo pushes out of the shell and the chick
rests and dries off.

**INCUBATION FACILITY**

Our incubation facility contains all the equipment needed to hatch bald eagle eggs under
controlled conditions. We use two types of incubators: a Grumbach forced-air incubator and a
Brinsea Contaq X8 (Fig. 5). The Brinsea is our preferred incubator in that it more closely mimics
natural incubation conditions. Eggs for which we are able to control water loss with or without
Tegaderm (see below) will be placed in the Brinsea incubator. We are able to control humidity at
higher levels in the Grumbach incubator, so eggs that are losing too much water will be placed in
this incubator until water loss trends are controlled to 15% or lower.

Power failures affecting air conditioning may cause overheating in incubators despite
power loss to incubators. Power failures causing extended cooling prolong development and
detrimental effects are usually not seen until the hatching process is initiated (late mortality
occurs). Therefore, the incubators are connected to a backup power source consisting of two
marine deep-cycle batteries and an inverter that can run the incubators for a couple of hours
during a power outage. For longer power outages, we have a gas-powered generator that can be
used to run the incubators and air conditioner.

![Image of incubation facility]

Figure 5. Incubation room with a Brinsea Contaq X8 incubator (left), a Brinsea hatching unit (center), and a
Grumbach forced air incubator (right).
Room Maintenance

The Incubation/Hatching room needs to be routinely cleaned and the environmental conditions kept relatively constant to minimize potential problems. Prior to collecting the first eggs each year, the entire room will be disinfected, including the walls and ceiling. We maintain the room temperature at about 70°F using a portable air conditioner. Relative humidity is kept at about 40-45% using a dehumidifier to minimize microbial growth. The windows have blackout shades so that it is dark enough to candle the eggs. We maintain a day/night light cycle using a lamp connected to a timer. This will need to be adjusted as the days get longer.

Routine room maintenance is conducted daily or weekly, as described below. Once the incubators are in operation, no shoes are allowed in the room. When entering the room, open the door, remove your shoes, step onto the mat inside the room (leaving shoes outside), and put on a pair of surgical booties. This will minimize the transfer of contaminants into the incubation room. Trash will be kept outside of the incubation room. While working with the eggs, it is fine to bring the trash can into the room so that paper towels, gloves, Tegaderm, etc. can be thrown away, but the can must be removed when you leave the room.

The two incubators work in different ways. You will be given instructions on how they operate, but please read the manuals for each incubator to familiarize yourself with their operation. The manuals and miscellaneous supplies for each incubator are supplied in a drawer under the incubator. There is also a funnel for refilling the incubator water reservoir in the drawer.

Each day, the water reservoir of the dehumidifier should be emptied and the date, time, and your initials entered on the Dehumidifier Record found on top of the dehumidifier. Each incubator should also be checked at least once per day, but preferably 2-4 times per day. Check/fill the water reservoirs with distilled water and record the date, time, incubator temperature, relative humidity, and your initials on the Incubator form (Appendix II) in the Incubator Records binder. Low humidity in the incubators can quickly dry out the eggs and incorrect incubation temperatures can kill the developing embryo. If temperatures are more than 1°C above or below the target temperatures posted on the incubators, notify your supervisor immediately.

At least once a week, all countertops, incubators, and floors will be cleaned with either a 100:1 solution of Brinsea disinfectant or a dilute Hexasol solution. Record the date and time of the cleaning on the Cleaning Record form by the incubation room door.

Egg Care

Upon arrival at the incubation facility, each egg will be weighed, measured, and examined by candling for abnormalities, cracks, and signs of fertility. Exam gloves and clean lab coats should be worn whenever working with the eggs. Eggs may be cleaned with a dry paper towel, but never allow the eggs to get wet, as even a drop of water can help microbes pass into the egg. Too much rubbing with a paper towel can remove part of the cuticle, increasing water loss and potential for microbe invasion, so cleaning will only be done when the egg is extremely dirty. Any cracks can be sealed and strengthened using Elmer’s glue. A piece of paper towel can be used as a patch (cover over with glue) in the case of dents or large cracks. When handling the eggs, minimize jarring, vibrations, and rolling of the eggs. There are foam forms to hold the eggs during weighing. A clean paper towel should be placed in the form so that the egg does not come in direct contact with the foam.
Equations have been developed to calculate the fresh wet weight of an egg at the time it was laid that are based upon mean length and breadth of the egg (Appendix III). Eggs should lose about 15% of their weight during the 35 day incubation period. If eggs appear to be losing too much weight, portions of the egg below the air cell will be covered with Tegaderm, which allows gas exchange, but minimizes water loss. The Tegaderm should be cut into strips about 1-2 cm wide and applied from the small end of the egg towards the air cell (do not cover air cell). All measurements, information, and comments about the egg will be entered on an Egg Intake Record form (Appendix III) and placed in the Egg Record binder.

Each egg is weighed and candled daily to monitor weight loss and development. We will mark the edges of the air cell using a pencil every 2-3 days. An Excel spreadsheet has been created to automatically calculate weight loss trends so that we can attempt to maintain a weight loss trend of ≤ 15% during incubation. Data for each egg will be entered into the Excel spreadsheet and on the Egg Incubation Record form (Appendix IV), which will also be placed in the Egg Record binder. Decisions regarding movement between incubators and addition/removal of Tegaderm will be made based upon weight loss trends and embryo development.

Eggs for which the embryo dies will be opened and the embryo aged to stage of development. All tools and glassware used during this process should be cleaned with 95% alcohol. The embryo will be separated from the rest of the egg contents (for necropsy) and placed in sterile jars. The egg shell will be rinsed, weighed, air dried, and reweighed.

**Bald Eagle Hatching Protocol**

As the embryo nears the time of hatching, the air cell will begin to grow more quickly than during the rest of incubation. At this time, we will begin keeping records on the Bald Eagle Hatching Record form (Appendix V). This form is used to keep track of the embryo’s activity and vocalizations, heart rate (using the Egg Buddy; Fig. 6), progress in pipping, and any other relevant comments.

Eggs are moved into the Brinsea hatcher unit about a day prior to expected hatch date. The hatcher is set approximately 1°C cooler than the incubators and does not roll the eggs. Hatching eggs should be monitored several times per day. If the chick does not make any progress in opening the egg or the heart rate appears to be falling or speeding up too much, then we may need to assist the chick in hatching. We have a microscope that allows us to remove small sections of shell and membrane with a minimal chance of injuring the chick. The membranes must not be ruptured while there is still blood flowing through the vessels, as this could cause the chick to bleed to death.

The following materials will be needed for hatching: Sterile culturette, red-topped blood tube (sterile glass container with rubber top); sterile scissors, forceps, syringes, needles, surgical towel, and cotton swabs; Nolvasan solution, Nolvasan ointment, and Tegaderm. Use the following procedures for natural and assisted hatchings.

**Natural Hatch**

Immediately after the chick hatches on its own, do the following:

1. Using sterile scissors, cut the end of the umbilicus that is closest to the chick. Use your best judgment, if there is no remaining umbilicus dangling from the chick - don't snip. Lay the umbilical sample on the sterile towel. With the same scissors, cut a small piece of eggshell membrane and lay it on the same sterile towel.
2. Moisten culturette with sterile saline before swabbing the umbilical area of the chick and the interior eggshell lining. With the tip of the culturette, gently collect the cut umbilical sample and the eggshell membrane lying on the sterile towel.
3. Place the used culturette with the sample into the red-topped blood tube (RTT) and snip off the excess culturette handle so that it fits into the container. Reseal the RTT with the rubber plug.
4. Using a sterile syringe, withdraw all of the air from the RTT by inserting the needle through the rubber top.
5. Using a sterile swab moistened with a 10% Nolvasan solution, swab the chick’s umbilical area.
6. Label the RTT with the Egg Number as well as what sample was taken (umbilical and shell lining).

![Figure 6. Monitoring a bald eagle embryo's heart rate using the Egg Buddy.](image)

**Manual Hatch**

If it is necessary to assist the chick in hatching, use the following protocol:

1. At the start of a manual hatch, collect a small piece of eggshell membrane and swab the interior lining of the eggshell for a bacterial culture using the protocol described above.
2. At the end of the manual hatch, collect the umbilical sample and the umbilical swab from the chick for culture using the same protocol as described above. NOTE: do not place the umbilical sample swab in with the eggshell membrane swab sample, since it may be contaminated.
Chick Hand-Rearing Protocol (developed by ACC at San Francisco Zoo)

1. Immediately Post-Hatching - Day 0 to Day 4

   A. Initial Care, Physical Examination, and Housing

   After the chick hatches, collect tissue and culture samples as described in the hatching protocols described above. Label the samples with the egg identification number and date.

   After hatching, the chick is usually left in the hatcher until it is dry. After the chick is dry, it should be weighed and examined. At this time, an individual chick record should be set up to record the results of the initial examination and weight. After hatching, the chick’s umbilicus should be 1) swabbed with a 10% solution of Nolvasan (chlorhexadine), 2) swabbed with Nolvasan ointment, and 3) covered with a small piece of Tegaderm (Fig. 7). The Tegaderm can usually be removed within 12 hours. Its purpose is to ensure that the umbilicus is kept clean while it seals more tightly. Then the chick should be moved to the brooder unit in our hand-rearing room.

   ![Figure 7. Treated umbilicus of young bald eagle chick.](image)

   The dry chick should be placed in a brooder or isocette with an interior temperature of 95°F. This will be a comfortable temperature for most newly hatched chicks. However, it may be too hot or too cold for some individual chicks. Remember to adjust the temperature according to the behavior of the chick. A comfortable chick will lie quietly in the brooder and sleep with its
wings held loosely at its sides and its legs tucked under its body. If the chick is too hot, it will pant and lie with its wings outstretched, with one or both legs stretched out to one side or to the rear. If the chick is too cold, it will huddle down, shiver, and vocalize frequently rather than just when it is begging for food.

As a general rule, the temperature in the brooder should be decreased 1° F each day until it reaches the ambient temperature in the room. The chick's behavior, not the absolute temperature, should be used as a guideline to determine whether the temperature in the brooder is appropriate for the chick. If the temperature is not appropriate for the chick, gradually raise or lower the temperature until the chick's behavior indicates that it is comfortable. A cold chick will generally be vocal and have its feathers fluffed out; while a hot chick will be panting or lying with its wings extended. A chick that is thermally comfortable will either be sleeping or moving around and will vocalize only to solicit food. Monitor the brooder temperature carefully for at least two hours to be sure that it is stable. The room containing the brooder should be kept at 68-75° F.

It is extremely important to provide humidity when chick(s) are kept in a brooder that is over 80°F. These units have water troughs that must be kept filled with distilled water to provide adequate humidity in the brooder. Additional humidity can be added by placing moist towels over the hand access portals at the ends of the isoslette. The substrate that the chick is placed on should provide the chick with traction so that its legs do not splay out. Typically the bottom of the unit is covered with a large terry cloth towel and topped with crumpled surgical towels, and a towel encircling the chick like a small nest (Fig. 8). The towels are changed as soon as they become soiled.

Chicks at or near one week of age may be aggressive and peck each other's head, so it may be necessary to separate them with towels to prevent more aggressive chicks from injuring other chicks (Fig. 8).
B. Diet Preparation

The diet for bald eagle chicks from hatch day through Day 4 should be specially prepared coturnix quail. Either the quail are maintained alive and killed one at a time each day and processed immediately; or the quail are received alive in February or March and processed in small batches and frozen immediately. Preparation of the frozen ground quail should be done as follows: Ten or twelve quail are euthanized with carbon dioxide gas, and then they are processed in less than 20 minutes. The processing includes removing the head, crop, feet, feathers, wings, and guts. A few pieces of quail breast are removed and frozen in small bags. The rest of the quail are ground to the consistency of hamburger, and then checked for chunks of bone, which need to be ground again, or pounded to break up the larger chunks. Then the ground quail is weighed into 100-gram portions and each portion is mixed with 10 cc of lactated ringer's solution and placed in a Ziploc freezer bag. The contents are flattened out and then laid out in the freezer. Then another group of quail is processed. The packets of quail are spread out in the freezer to make sure that they freeze quickly. The next day, these sandwich bags of quail are bundled together into quart sized freezer bags to help keep them fresher longer.

Guidelines for handling and using frozen quail for feeding eaglets:

- Move quail from the freezer to the refrigerator to defrost it.
- It is not necessary to defrost an entire package of quail or quail breast. Because the breast portions are laid out in a single layer and the ground quail are frozen in a flat layer, it is possible to break off a small portion of the meat rather than defrost the entire package.
- Do not refreeze the meat.
- Prior to feeding the quail to a chick, weigh out the amount needed for that feeding. Place the dish with the chick's diet inside another dish that is slightly larger and filled with warm water. Prior to feeding each bite of quail to a chick, dip the meat in a warmed electrolyte solution and then in a small amount of vitamin powder (a mixture of equal parts Vionate, Vita Hawk and Osteoform).
- Any uneaten, but warmed meat, must be discarded.
- Any defrosted quail that is not eaten in 12 or at most 24 hours should be discarded.
- All dishes and feeding equipment should be cleaned with dishwashing detergent and then soaked in disinfectant for 15 minutes and then allowed to dry between feedings. Each chick should have its own food dish and utensils.

C. First Three Feedings

A chick should not be fed until it has defecated. The chick may rest for 2-12 hours before soliciting food. Note any feces or urates on the chick's record. Check the umbilicus to be certain that it has sealed completely and that no urates are leaking out of it. If urates are leaking out of the umbilicus or the chick does not defecate within six hours after hatching, notify the veterinarian.

The chick's first three feedings should consist of a few pieces of finely minced quail breast that has been dipped in pedialyte or another electrolyte solution. No more than 1 gram of quail breast should be fed at the first feeding. Check the chick in one hour, if its crop is empty, offer it another 1-1.5 grams of quail breast. At the third feeding, the chick can be offered up to 2 grams of quail breast, if its crop is empty and it has defecated.
D. Subsequent Feedings

The chick should never be overfed. After the first three feedings, the chick should be fed ground quail, dipped in electrolyte solution such as Pedialyte. The first feeding of ground quail, for example, would typically be approximately 2 grams of quail. Each piece would be dipped into the electrolyte solution. The next scheduled feeding should be approximately 1 1/2 hours later. A scheduled feeding should be delayed if the chick's crop has not completely emptied, or the feeding should occur sooner than scheduled if the chick begs for food and has an empty crop earlier than the planned feeding time. After one feeding of ground quail, if there are no problems, begin sprinkling the quail with the vitamin mixture (Vionate, VitaHawk, Osteoform).

All diets should be weighed prior to feeding the chick and any leftovers are weighed immediately after the feeding to monitor the daily food consumption of each hand-reared bird. As the chick grows, the amount of food eaten each day should increase, while the amount of time between each feeding increases and the amount of food fed per feeding increases.

Record on the chick's Neonatal Bird Record (Appendix VI) what the chick's food response was and if a feeding was delayed because the chick's crop was not yet empty or any other problems or observations. The chick should be fed from 5 am to 8 pm or from 7 am to 10 pm for the first four days.

E. Hydration

During the first five days post-hatching, the chick should be monitored closely for signs of dehydration. The physical signs include dry mouth, wrinkled abdomen, sunken eyes, and tented skin on the tarsi. If the chick shows any signs of dehydration, the humidity in the brooder unit should be increased and the chick should receive supplemental fluid therapy as directed by the veterinarian.

F. Staffing

When caring for newly hatched chicks, we will schedule round-the-clock coverage for the chicks until they are 3-4 days old, and 14-16 hours/day until they are fostered into nests.

II. Chick Rearing from Day 4 to Day 35

A. Rearing

When possible, the chick(s) will be fostered to wild nests by one week of age. If the chick(s) are hand-reared, then contact with humans is kept to a minimum to prevent imprinting or habituating to humans. Each time that a chick is weighed, fed, or otherwise handled, it should be examined for signs of dehydration and treated, if necessary.

B. Puppet Rearing

Beginning on Day 5, all feedings are to be given by a hand puppet. There is a bald eagle puppet and a black sleeve to cover your arm (so that it looks more like an eagle's body than a human arm.) After putting, the sleeve over your arm, slip your hand into the puppet's head. Ideally, place the chick with its back to you and so that it is facing the puppet. Feed the chick is this position so that it faces the puppet. Use the puppet to pick up pieces of food and offer them
to the chick. After each feeding, clean the puppet's beak and all food utensils with soap and water, and then wipe it with a 10% Nolvasan solution.

C. Diet Preparation and Feeding

Days 5-8: The chick should be fed ground quail dipped in water and the vitamin mixture every 2 1/2 to 3 hours from 7 am to 10 pm, or 5am to 8pm.

Days 9-35: Feed the chick fresh or frozen quail with all of the bones, skin, and some body feathers. At Day 9, leave all of the body feathers in the diet. Remove all appendages and intestinal organs. Pound and chop the quail into bite-sized chunks. Add the vitamin mixture to the prepared amount of quail at first and last feedings of the day. At 15 days of age, add rodent to the chicks' diet. Remove most of the rodent fur and the guts. Chop up the rest of the rodent into bite-sized pieces and pound the bones to break them up.

Feed the chick(s) at 7 am, noon, and 5 pm until 21 days of age. At 22 days of age, feed the chick(s) at 8 am and 5 pm. The chick(s) can be encouraged to begin self-feeding. To do so, the caretaker begins the feeding using the puppet and then removes the puppet for extended periods of time to allow the chick to peck at the food.

III. Other Aspects of Hand-Rearing

A. Veterinary Care

The veterinarian should receive daily reports on the status of the chicks during the first week post-hatching, including daily weights if the chicks are being hand-reared. The veterinarian should be contacted immediately in case of emergency.

B. Sanitation

The newly hatched chick(s) (less than 5 days post-hatch) should never be left on soiled towels. The brooder should be thoroughly cleaned and disinfected once a day. The brooder substrate should be cleaned as needed, usually after each feeding, and 3 times a day for newly hatched chicks, twice daily for chicks over one week of age, and daily for chicks three weeks of age or more. Any wet bedding must be changed immediately to prevent fungal growth.

All food utensils and dishes should be cleaned and then soaked in a disinfectant solution (i.e. bleach or Nolvasan) for 15 minutes and then rinsed thoroughly. The brooder unit should also be cleaned and disinfected daily. It should also be rinsed thoroughly and dried. Towels and other reusable items should also be washed in warm water and detergent and bleach.

The staff should always wash their hands before handling the chick(s) and wash their hands between handling different chicks. Lab coats will be available in the rearing area to be used by the staff to cover-up prior to handling or feeding the chick(s).

C. Record Keeping

Each chick will have an individual file with a set of forms on which all data related to the chick are recorded. The file shall include a sheet with the date of hatch, hatch weight, the identification number of the egg that the chick hatched from, parents’ identification information,
daily feed sheets for the chick and any applicable notes regarding foster parents for the chick, daily weights, any medical exams or treatments, and the chick’s disposition and date. The Neonatal Bird Record form is used to record all feedings of the chick, its response, and the type and amount of food offered.

**VETERINARY ASPECTS OF BALD EAGLE HAND-REARING**

Occasionally, there will be a need to provide veterinary care for young chicks. Below are some guidelines for dealing with some of the more common problems.

**Open Umbilicus**

- Clean umbilicus with dilute Nolvasan solution. (avoid Betadine solution due to potential thyroid problems with iodine exposure)
- Trim umbilical vessels with sterile scissors
- Cover site with Nolvasan ointment and Tegaderm patch cut to fit chick's abdomen. Tegaderm/Nolvasan ointment patch is changed daily until umbilicus is closed/dry.
- Consider surgery to reduce open umbilicus if not closed within 48-72 hours

Every chick with an open umbilicus is started on prophylactic antibiotics and antifungal treatment, including:

- Claforan (Cefotaxime) @ 50-100 mg/kg IM/SQ three times per day (TID) (230 mg/ml solution) for 7 days
- Fluconazole @ 15-20 mg/kg PO once per day (SID) (10 mg/ml solution) for 10 days
- Warmed 0.9% NaCl/ 2.5% Dextrose/ B Vitamins:@ 75-100 mls/kg/day SQ divided TID
- Amikacin @ 10 mg/kg twice per day (BID) can be used with Claforan if chick is not responding well to the treatment with Claforan alone.

For the first few days, recommend dosing antibiotics and fluids at the higher dose range to fill the chick's extra cellular space. Then begin weaning the chick down to the low-mid dose range for maintenance if clinically responding to treatment. **Doses are updated daily on the Bald Eagle Chick Treatment Sheet; Appendix VII to account for the chick’s body weight changes.**

**Yolk Sac Removal Surgery**

Some chicks need to have the yolk sac removed from their abdomen if they appear unhealthy. Candidates for surgery are those chicks with abdominal distention, dyspnea, exercise intolerance, weight loss, anorexia, failure to grow, or inability to stand. Distended abdomen in a depressed chick is a characteristic finding of retained yolk sac. Surgery is performed on chicks from 1-3 days old by a qualified veterinarian, using the following procedures:

- Isoflurane/O₂ gas anesthesia - Doppler flow monitoring of heart rate.
- Perform positive pressure ventilation throughout the procedure.
- Place chick onto a warm heat source in addition to heat lamp directed over abdomen - monitor environmental temperature throughout procedure.
- Dorsal recumbancy with legs pulled caudally.
• Feathers on abdomen plucked between flanks and from keel to cloaca.
• Skin prepped for surgery
• Skin incised circumferentially around the umbilicus and incision is extended transversely at 3 and 9 o’clock positions to a lateral distance that will allow easy removal of the intact yolk sac.
• Body wall incised in a corresponding pattern.
• Be careful not to damage the underlying yolk sac.
• Yolk sac exteriorized by placing gentle traction on the umbilical stump.
• Vascular and yolk sac connections to the small intestine are clamped or ligated just distal to the intestine to allow the stalk to be transected and yolk sac to be removed.
• Body wall is closed with 4-0 or 6-0 monofilament absorbable suture.
• Placement of Tegaderm patch over incision helps to strengthen the site if the chick strains post-op.
• Some chicks require tube feeding for several days post-op.
• Warmed 0.9% NaCl/ 2.5% Dextrose/ B Vitamins (compensate for blood loss if needed).
• Broad spectrum antibiotics post-op pending yolk sac culture.

Ritchie, Harrison and Harrison’s *Avian Medicine: Principles and Application* gives a concise write up of the procedure and has some good pictures of the surgery.

**Blood Transfusions**

Transfusions may be needed following surgery. Decide at 24 hours post-op if transfusion is needed to boost the chick’s energy level to improve survivability.

• Collect blood from donor eagle (likely our education eagle) at a ratio of 0.15 mls ACD to 1 ml whole blood.
• 1.5 mls whole blood is a typical transfusion volume for a 2 day old eagle chick.
• Filtered blood is given slowly via jugular vein. Recommend using a Doppler probe on the heart to monitor for tachycardia if transfusion is given too fast.

**Feeding Sick Neonate Bald Eagles**

Start each day by weighing each chick before feeding it. Every chick should be gaining weight each day. Female chicks tend to gain up to twice as much weight per day initially when compared to the males. So it is not appropriate to compare the daily weight gain of one chick to another. Calculate the amount of weight gained per day and the percent increase in weight per day for each individual alone. Each chick should also consume more grams of solid food each day than it did the day before.

If the chick is ill, weak, has no feeding response or a less than enthusiastic response, it may need to be fed a special diet or even fed by gavage to get additional calories into the chick. First, assess the hydration status of the chick and treat appropriately before feeding. Second, calculate the number of calories that a chick of that weight needs to consume per day. One formula for calculating the calories needed for non-passerine birds is:

\[
78.3 \times \text{body weight (in Kg)}^{0.75} \times 4 = \text{kcal/24 hours} \quad \text{For Healthy Chick} \quad (\text{Eq. 1})
\]

\[
78.3 \times \text{body weight (in Kg)}^{0.75} \times 5 = \text{kcal/24 hours} \quad \text{For Sick Chick} \quad (\text{Eq. 2})
\]
(See Table 2 for calculations for chicks up to 0.5 kg)

Table 2. Calculated energy requirements of young healthy and sick bald eagle chicks based upon Equations 1 and 2.

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<th>Body Wt. (g)</th>
<th>Body Wt. (Kg)</th>
<th>Kcals/day for Healthy Chick</th>
<th>Kcals/day for Sick Chick</th>
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Some of the products that can be used include:

- Aminoplex
- Clinicare Feline Liquid Diet (Abbott Animal Health)
- Hill's Science Diet Feline dry and canned
- Quail
- Mice

The following vitamin supplements can also be used:

- Vita Hawk
- Vionate
- Calcium Carbonate (Ca without P)
- Osteoform (Ca/P)
- Brewer's yeast

It is not always possible to get enough calories into a very small weak chick. A diet with a higher density of calories in a small volume helps, but a weak chick cannot process food that is
too complex, too fatty or that requires a lot of energy to digest. Give fluids subcutaneously rather than orally. If you have to feed the chick by feeding tube, start with small frequent feedings and gradually increase the volume.

References

APPENDIX I: Stages of Chick Development

The description which follows should be used in conjunction with the illustrations (Plates 1-14) which are numbered according to stages. The approximate times at which the stages occur are based on a temperature of incubation of 38°C. Measurements are for a chicken embryo.

NORMAL STAGES IN THE DEVELOPMENT OF THE CHICK

I. Before Laying:

1. **Maturation and fertilization**: found in the oviduct above the isthmus.
2. **Early cleavage**: up to about the thirty-two-celled stage found in the isthmus of the oviduct during the formation of the shell membrane (Patterson).
3. **Later cleavage**: formation of periblast and entoderm, etc., found in the uterus up to time of laying.

II. After Laying:

**Stage 1. Pre-streak**: Prior to the appearance of the primitive streak. An "embryonic shield" may be visible, due to the accumulation of cells toward the posterior half of the blastoderm.

**Stage 2. Initial streak**: ("Short-broad beginning-streak" of Spratt, '42.) A rather transitory stage in which the primitive streak first appears as a short, conical thickening, almost as broad as long (0.3-0.5 mm. in length), at the posterior border of the pellucid area. Usually obtained after 10-12 hours of incubation.

**Stage 3. Intermediate streak**: (20-22 hrs.) The primitive streak extends from the posterior margin to approximately the center of the pellucid area. The streak is relatively broad throughout its length, and is flared out where it touches the opaque area. No primitive groove. (See Plate 1.)

**Stage 4. Definitive streak**: (30-32 hrs.) The primitive streak has reached its maximal length (average length = 1.88 mm., Spratt, '46). The primitive groove, primitive pit, and Hensen's node are present. The area pellucida has become pear-shaped and the streak extends over two thirds to three fourths of its length.

**Stage 5. Head-process**: (32-37 hrs.) The notochord or head-process is visible as a rod of condensed mesoderm extending forward from the anterior edge of Hensen's node. The head fold has not yet appeared. Since the length of the notochord increases during this stage, it is suggested that the length of the notochord in millimeters be appended to the number of the stage for further precision (e.g., "Stage 5-0.2" would designate a notochordal blastoderm with notochord 0.2 cm. in length).

**Stage 6. Head fold**: (38-42 hrs.) A definite fold of the blastoderm anterior to the notochord now marks the anterior end of the embryo proper. No somites have yet appeared in the mesoderm lateral to the notochord. This is a transitory stage, since the head fold and the first pair of somites develop rather closely in time.
Stages 7 to 14 are based primarily on the numbers of pairs of somites which are clearly visible. The number of somites appears to be the simplest criterion for staging this phase of development, and it is sufficiently accurate for practical purposes. A stage is assigned to every third pair of somites which is added; embryos with in-between numbers of somites are designated by adding a + or - sign to the appropriate stage. Thus, stage 7 designates an embryo with one pair of somites; stage 7+ = two pairs; stage 8- = three pairs; stage 8 = four pairs; etc. (See Plates 2 and 3.)

**Stage 7. One somite:** (38-43 hrs.) This is actually the second somite of the series; number one is not yet clearly defined. Neural folds are visible in the region of the head.

**Stage 8. Four somites:** (43-48 hrs.) Neural folds meet at level of mid-brain. Blood islands are present in posterior half of blastoderm.

**Stage 9. Seven somites:** (48-55 hrs.) Primary optic vesicles are present. Paired primordia of heart begin to fuse.

**Stage 10. Ten somites:** (55-63 hrs.) The first somite is becoming dispersed; it is not included in the counts for subsequent stages. First indication of cranial flexure. Three primary brain vesicles are clearly visible. Optic vesicles not constricted at bases. Heart bent slightly to right.

**Stage 11. Thirteen somites:** (67-75 hrs.) Slight cranial flexure. Five neuromeres of hind-brain are distinct. Anterior neuropore is closing. Optic vesicles are constricted at bases. Heart bent to right.
Stage 12. Sixteen somites: (3-3.5 days) Head is turning onto left side. Anterior neuropore closed. Telencephalon indicated. Primary optic vesicles and optic stalk well established. Auditory pit is deep, but wide open. Heart is slightly S-shaped. Head fold of amnion covers entire region of fore-brain.


Stage 14. Twenty-two somites: (3.5 days)

Flexures and rotation. Cranial flexure: axes of forebrain and hind-brain form about a right angle. Cervical flexure a broad curve. Rotation of body back as far as somites 7-9. Behind this level, a slight flexure makes its appearance which will be referred to as “trunk flexure.”

Visceral arches 1 and 2, and clefts 1 and 2 are distinct. Posterior arches not distinct. Primary optic vesicle begins to invaginate; lens placode is formed. Opening of auditory pit constricted. Rathke’s pouch can be recognized. Ventricular loop of heart now ventral to atrio-ventricular canal. Amnion extends to somites 7-10.

Plate 3

2 It is suggested that embryos which have gained one somite beyond stage 10, but have lost s. 1 in the meantime, be designated as stage 10±; stage 10+ would then have 11 s., not counting the rudimentary one; stage 11− = 12 s., not counting the rudimentary one, etc.
Beyond stage 14 the number of somites becomes increasingly difficult to determine with accuracy. This is due in part to the dispersal of the mesoderm of the anteriormost somites, and, in later stages, to the curvature of the tail. Total somite counts given for the following stages are typical, but sufficiently variable so as not to be diagnostic. For these reasons, the limb buds, visceral arches, and other externally visible structures are used as identifying criteria from stage 15 onward.

**Stage 15. (ca. 3.5-4 days)**

1. **Lateral body folds** exterior to anterior end of wing level (somites 15-17).
2. **Limb primordia**: prospective limbs are flat, not yet demarcated. Inconspicuous condensation of mesoderm in wing level.
3. **Somites**: 24-27.
4. **Amnion** extends to somites 7-14.
5. **Flexures and rotation**. Cranial flexure: axes of fore-brain and hind-brain form an acute angle. The ventral contours of fore-brain and hind-brain are nearly parallel. Cervical flexure a broad curve. The trunk is distinct. Rotation extends to somites 11 to 13.
6. **Visceral arches**: Visceral arch 3 and cleft 3 are distinct. The latter is shorter than cleft 2 and usually oval in shape.
7. **Eye**: Optic cup is completely formed; double contour distinct in region of iris.

**Stage 16. (ca. 3.5-4 days)**

1. **Lateral body folds** extend to somites 17-20, between levels of wings and legs.
2. **Limbs**: Wing is lifted off blastoderm by infolding of lateral body fold. It is represented by a thickened ridge. Primordium of leg is still flat; represented by a condensation of mesoderm.
4. **Amnion** extends to somites 10-18.
5. **Flexures and rotation**: All flexures are more accentuated than in stage 15. Rotation extends to somites 14-15.
6. **Tail bud** a short, straight cone; delimited from blastoderm.
7. **Visceral arches**: Third cleft still oval in shape.
8. **Fore-brain** lengthened; constrictions between brain parts are deepened. **Epiphysis** indistinct or not yet formed.

**Stage 17. (ca. 4 days)**

1. **Lateral body folds** extend around the entire circumference of the body.
2. **Limb buds**: Both wing and leg buds lifted off blastoderm by infolding of the body folds. Both are distinct swellings of approximately equal size. (See Plates 4 and 5.)
3. **Somites**: 29-32.
4. **Amnion**: Considerable variability, ranging from a condition in which posterior trunk and tail, from approximately somite 26, are uncovered, to complete closure except for an oval hole over somites 28-36. Intermediate stages with an anterior fold covering as far back as somite 25 and a posterior fold covering part of the tail are common.
5. **Flexures and rotation**: Cranial flexure is unchanged. Cervical flexure is more sharply bent than in preceding stages, but its angle is still larger than 90°. Trunk flexure is distinct in brachial level. Rotation extends to somites 17-18.
6. **Tail bud** bent ventrad. Its mesoderm unsegmented.
7. **Epiphysis**: A distinct knob. Indication of **nasal pits**.
8. **Allantois**: Not yet formed.
Plate 4

Stage 18. (ca. 5 days.)
1. **Limb buds** enlarged; leg buds slightly larger than wing buds (see plates 4 and 5). L/W of wing = 6 or < 6 (L = length = anterior-posterior dimension as measured along the body wall; W = width = distance from body wall to apex; see stage 20, plate 5).
2. **Somites**: 30-36; extend beyond level of leg bud.
3. Amnion: Usually closed; occasionally an oval hole in lumbar region.
4. **Flexures and rotation**: At the cervical flexure, the axis of the medulla forms approximately a right angle to the axis of the posterior trunk. The trunk flexure has shifted to the lumbar region. The rotation extends now to the posterior part of the body; hence, the leg buds are no longer in the horizontal plane.
5. The **tail bud** is turned to the right, at about an angle of 90° to the axis of the posterior trunk.
6. **Visceral arches**: Maxillary process absent or inconspicuous. Fourth visceral cleft indistinct or absent.
7. **Allantois**: A short, thick-walled pocket; not yet vesicular.

Stage 19. (ca. 5-6 days)
1. **Limb buds**: Enlarged, symmetrical. Leg buds slightly larger and bulkier than wing buds. (See Plates 5 and 6) L/W of wing buds = 4-6.
2. **Somites**: 37-40; extend into tail; but the end of the tail which is directed forward is unsegmented.
3. **Flexures and rotation**: In the cervical flexure the axis of the medulla forms an acute angle with the axis of the trunk. The trunk flexure has nearly or entirely disappeared due to the
rotation of the entire body. The contour of the posterior part of the trunk is straight to the base of the tail.

Plate 5. Drawings of the contours of the right limbs of stages 17-20. In stage 20 the dotted lines indicate the levels at which the length (L) and width (W) are measured.
4. **Tail bud** curved, its tip pointing forward.
5. **Visceral arches:** The maxillary process is a distinct swelling of approximately the same length as the mandibular process. The first visceral cleft is an open narrow slit at its dorsal part. It continues into a shallow furrow. The second arch projects slightly over the surface. The fourth cleft is a fairly distinct slit at its dorsal part and continues ventrally as a shallow groove. It does not perforate into the pharynx as a true (open) cleft, but is, nevertheless, homologous to the other three clefts.
6. **Allantois:** "A small pocket of variable size; not yet vesicular.
7. **Eyes** unpigmented.

**Stage 20. (ca. 5-6 days)**
1. **Limb buds** enlarged; leg buds are distinctly larger from now on than wing buds. The wing buds are still approximately symmetrical; the leg buds are slightly asymmetrical. (See Plates 5 and 6.) L/W of wing = 3-3.9; L/W of leg = 3-2.3.
2. **Somites:** 40-43; tip or tail still unsegmented.
3. **Flexures and rotation:** Cervical flexure more accentuated than in stage 19. The bend in the tail region begins to extend forward into the lumbo-sacral region. Contour of mid-trunk a straight line. Rotation completed.
4. **Visceral arches:** Maxillary process distinct, equals or exceeds the mandibular process in length. Second arch projects over surface. Fourth arch less prominent and smaller than third arch. Fourth cleft shorter than third cleft; a narrow slit at its dorsal part, continuing into a shallow groove.
5. **Allantois:** Vesicular, variable in size; on the average of the size of the mid-brain.
6. **Eye pigmentation:** A faint grayish hue.

**Stage 21. (ca. 6 days)**
1. **Lims:** Enlarged; both wing and leg buds are slightly asymmetrical; their proximo-distal axes are directed caudad, and the apex of the bud lies posterior to the mid-line bisecting the base of the bud. The posterior contours of wing and leg buds are steeper than the anterior contours; they meet the base-line at an angle of approximately 90°. L/W of wing = 2.3-2.7; L/W of leg = 2.0-2.5.
2. **Somites:** 43-44; extreme tip of tail unsegmented.
3. **Flexures:** The posterior curvature includes the lumbo-sacral region. The dorsal contour of the trunk is straight or slightly bent.
4. **Visceral arches:** Maxillary process is definitely longer than mandibular process, extending approximately to the middle of the eye. The second arch extends distinctly over the surface and overlaps the third arch ventrally. Fourth arch distinct; fourth cleft visible as a slit.
5. **Allantois:** Variable, usually larger than in stage 20; may extend to head.
6. **Eye pigmentation:** Faint.

**Stage 22. (ca. 5-7 days.)**
1. **Lims:** Elongated buds, pointing caudad. The anterior and posterior contours are nearly parallel at their bases. (See Plate 7.) L/W of wing = 1.5-2; L/W of leg = 1.3-1.8.
2. **Somites:** Extend to tip of tail.
3. **Flexures:** Little change. The dorsal contour of the trunk is a straight line or curved.
4. **Visceral arches:** Little change compared with stage 21. Maxillary process enlarged; 4th cleft distinct as a slit.
5. **Allantois:** Variable in size; extends head and may overlap fore-brain.
6. **Eye pigmentation:** Distinct.
Stage 23 (ca. 7 days)
1. **Limbs**: Longer than in stage 22; particularly the proximal parts in which anterior and posterior contours run parallel are lengthened; otherwise, little change in shape. Both wing and leg buds approximately as long as they are wide.
2. **Visceral arches** (see Plates 7 and 8): Maxillary process is lengthened further. The first visceral cleft is represented by a broken line. Its dorsal part is a distinct slit. A slight protuberance ("a") is noticeable anterior to the dorsal slit. The caudal part of the second arch is distinctly elevated over the surface. Arches 3 and 4 are still completely exposed. Visceral cleft 3 is a distinct groove, and cleft 4 is reduced to a narrow oval pit at its dorsal end.
3. **Flexures**: The dorsal contour from hind-brain to tail is a curved line.

Stage 24. (ca. 7.5 days)
1. **Limbs**: Wing and leg buds distinctly longer than wide. Digital plate in wing not yet demarcated. Toe plate in leg bud distinct. Toes not yet demarcated.
2. **Visceral arches** (see Plates 7 and 8): First visceral cleft a distinct curved line. Slight indication of two protuberances ("a," "b") on mandibular process and of three protuberances ("d," "e," "f") on second arch. Part "c" of mandibular process is receding. Second arch longer ventrally (at "f") and much wider than mandibular process. Third arch reduced and partly overgrown by second arch; 4th arch flattened. Both are sunk beneath the surface. Third visceral cleft is an elongated groove. Fourth visceral cleft reduced to a small pit.

Stage 25. (ca. 7.5-8 days)
1. **Limbs**: Elbow and knee joints distinct (in dorsal or ventral view). Digital plate in wing distinct, but no demarcation of digits. Indication of faint grooves demarcating the third toe on leg.
2. **Visceral arches** (see Plates 7 and 8): Maxillary process lengthened; it meets the wall of the nasal groove (notice the notch at point of fusion). Three protuberances on each side of first visceral cleft ("a" to "f"). In dorsal view, "a," "b," and "d" appear as round knobs, and "c" as a flat ridge. Part "f" is conspicuous and projects distinctly over the surface. It will be referred to as the "collar." Dorsal part of third arch still visible. Third and fourth visceral clefts reduced to small circular pits.

Stage 26. (ca. 8 days.)
2. **Visceral arches** (see Plates 8 and 9): Contour of maxillary process a broken line. Mandibular process lengthened ventrally. Protuberances "a" and "b" project over the surface. The middle protuberance ("b") is subdivided by a shallow groove. A small knob is distinct at the dorsal edge of "c;" On the second arch, protuberances "d" and "e" are only slightly elevated over the surface. The "collar" ("f") has broadened and overgrown visceral arches III and, IV. A deep groove separates "f" from "c." The two pits representing the third and fourth visceral clefts are no longer visible.
Plate 7

Stage 27. (ca. 8-9 days)

1. **Limbs**: Contour of digital plate angular in region of first digit. Grooves between first, second, and third digits indicated. Grooves between toes are distinct on outer and inner surfaces of toe plate. First toe projects over the tibial part at an obtuse angle. Tip of third toe not yet pointed.

2. **Visceral arches** (see Plates 8 and 9): Contour of maxillary process is a curved, broken line. Mandibular process has broadened ventrally (at "c") and grown forward. Protuberances "a" and "b" project over the surface. Parts "d" and "e" are flat. Protuberances "b" and "e" are close to fusion, but a separating line is still distinct. The "collar" ("f") has broadened and continued its growth backward. It rises conspicuously above the surface. The groove between "c" and "f" has widened.

3. **Beak**: barely recognizable.

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**Plate 9**

Stage 28. (ca. 9-10 days.)

1. **Limbs**: Second digit and third toe longer than others, which gives the digital and toe plates a pointed, contour. Three digits and four toes distinct. No indication of fifth toe.

2. **Visceral arches** (see Plates 8 and 9): Protuberance "a" still projects over the surface. Mandibular process has lengthened and grown forward. Parts "b" and "e" have fused; a fine suture line is occasionally still visible. Parts "b," "d," and "e" no longer project above the surface. External auditory opening is now very distinct between “a,” “b,” and “d.” “Collar”
("f") projects distinctly over surface when viewed in profile. "Collar" ("f") projects distinctly over the surface. The neck between "collar" and mandible has lengthened.

3. **Beak**: A distinct outgrowth is visible in profile.

**Stage 29. (ca. 10-11 days)**

1. **Limbs**: Wing bent in elbow. Second digit distinctly longer than the others. Shallow grooves between first, second, and third digits. Second to fourth toes stand out as ridges separated by distinct grooves, and with indications of webs between them. Distal contours of webs are straight lines, occasionally with indication of convexity. Rudiment of fifth toe visible.

2. **Visceral arches**: Mandibular process lengthened (compare with stage 28). Mandibular process and second arch are broadly fused. Auditory meatus distinct at dorsal end of fusion. All protuberances have flattened. Neck between "collar" and mandibular process has lengthened. "Collar" stands out conspicuously (Plate 10).

3. **Beak**: More prominent than in stage 28. No egg tooth visible as yet.

**Stage 30. (ca. 11-12 days)**

1. **Limbs**: The three major segments of wing and leg are clearly demarcated. Wing bent in elbow joint. Leg bent in knee joint. Distinct grooves between first and second digits. Contours of webs between first two digits and between all toes are slightly curved, concave lines.

2. **Visceral arches**: The mandibular process approaches the beak, but the gap between the two is still conspicuous. Lengthening of neck between "collar" and mandible is very conspicuous. "Collar" begins to flatten (Plate 10).

3. **Feather germs**: Two dorsal rows to either side of the spinal cord at the brachial level. Three rows at the level of the legs; they are rather indistinct at thoracic level. None on thigh.

4. **Scleral papillae**: One on either side of choroid fissure; sometimes indistinct but never more than two.

5. **Egg tooth**: Distinct, slightly protruding. Beak more pronounced than in previous stage.

**Stage 31. (ca. 12 days)**

1. **Limbs**: Indication of a web between first and second digits. Rudiment of fifth toe still distinct.

2. **Visceral arches**: The gap between mandible and beak has narrowed to a small notch. "Collar" inconspicuous or absent.

3. **Feather germs**: On dorsal surface, continuous from brachial to lumbo-sacral level. Approximately seven rows at lumbo-sacral level. Distinct feather papillae on thigh. One indistinct row on each lateral edge of the tail.

4. **Scleral papillae**: Usually 6; 4 on the dorsal side near the choroid fissure, and 2 on the opposite side (Plate 10).

**Stage 32. (ca. 12.5 days)**

1. **Limbs**: All digits and four toes have lengthened conspicuously. Rudiment of fifth toe has disappeared. Webs between digits and toes are thin and their contours are concave. Differences in size of individual digits and toes become conspicuous.

2. **Visceral arches**: Anterior tip of mandible has reached the beak. "Collar" has disappeared or is faintly recognizable.
3. **Feather germs**: Eleven rows or more on dorsal surface at level of the legs. One row on tail distinct, second row indistinct. Scapular and flight feather germs barely perceptible at optimal illumination or absent.

4. **Scleral papillae**: Six to 8, in two groups; one group on dorsal and one on ventral side. Circle not yet closed (Plate 10).

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**Plate 10**

**Stage 33.** (ca. 12.5-13 days)

1. **Limbs**: Web on radial margin of arm and first digit becomes discernible. All digits and toes lengthened.

2. **Visceral arches**: Mandible and neck have lengthened conspicuously. (Compare the ventral contour of body, from heart region, along neck to tip of mandible, in this and the preceding stages.)

3. **Feather germs**: Scapular and flight feather germs not much advanced over stage 32. Tail: three rows distinct, the middle row considerably larger than the others.

4. **Scleral papillae**: Thirteen, forming an almost complete circle, with gap for one missing papilla at a ventral point near the middle of the jaw (Plate 11).

**Stage 34.** (ca. 13 days)

1. **Limbs**: Differential growth of second digit and third toe conspicuous. Contours of webs between digits and toes are concave and arched (Plate 11).

2. **Visceral arches**: Lengthening of mandible and of neck continues (see previous stage).

3. **Feather germs**: On scapula, on ventral side of neck, on procoracoid, and posterior (flight) edge of wing, feather germs are visible under good illumination. Feather germs next to dorsal mid-line, particularly at lumbo-sacral level, extend slightly over surface when
viewed in profile. Feather germs on thigh protrude conspicuously. One row on inner side of each eye. None around umbilical cord.

4. **Scleral papillae:** Thirteen or 14.

5. **Nictitating membrane** extends halfway between outer rim of eye (eyelid) and scleral papillae.

**Stage 35. (ca. 14-15 days)**

1. **Limbs:** Webs between digits and toes become inconspicuous. A transitory protuberance on the ulnar side of the second digit is probably a remnant of the web. Phalanges in toes are distinct (Plate 11).

2. **Visceral arches:** Lengthening of beak continues. Compare the distance between the eye and the tip of the beak, in this and the preceding stages.

3. **Feather germs:** All are more conspicuous. Mid-dorsal line stands out distinctly in profile view. At least four rows on inner side of each eye. New appearance of feather germs near mid-ventral line, close to sternum, and extending to both sides of umbilical cord.

4. **Nictitating membrane** has grown conspicuously and approaches the outer scleral papillae. Eyelids (external to nictitating membrane) have extended towards the beak and have begun to overgrow the eyeball. The circumference of the eyelids has become ellipsoidal.

![Image](image_url)

**Plate 11**

**Stage 36. (ca. 17 days)**

1. **Limbs:** Distal segments of both wing and leg are proportionately much longer. Length of third toe, from its tip to the middle of its metatarsal joint = 5.4 ± 0.3 mm. Tapering primordia of claws are just visible on termini of the toes and on digit 1 of the wing. Protuberance on posterior side of digit 2 of wing is missing (Plate 12).
2. **Visceral arches:** Primordium of the comb appears as a prominent ridge with slightly serrated edge along the dorsal mid-line of the beak. A horizontal groove (the "labial groove") is clearly visible at the tip of the upper jaw, but is barely indicated on the tip of the mandible. Nostril has narrowed to a slit. Length of beak from anterior angle of nostril to tip of bill = 2.5 mm.

3. **Feather germs:** Flight feathers are conspicuous; coverts are just visible in web of wing. Feather germs now cover the tibio-fibular portion of the leg. At least 9-10 rows of feather germs between each upper eyelid and the dorsal mid-line. Sternal tracts prominent, with 3-4 rows on each side of ventral mid-line when counted in anterior part of sternum, merging into many rows around the umbilicus.

4. **Eyelids:** Nictitating membrane covers anteriormost scleral papillae and approaches cornea. Lower lid has grown upward to level of cornea. Circumference of lids is a narrowing ellipse with its ventral edge flattened.

**Stage 37. (ca. 18 days)**

1. **Lims:** Claws of toes are flattened laterally and curved ventrally; dorsal tips are opaque, indicating onset of cornification. Tip of claw on wing is also opaque. Pads on plantar surface of foot are conspicuous and smooth. Transverse ridges along the superior surfaces of the plletatarsus and phalanges are first indication of scales. Length of third toe = 7.4 ± 0.3 mm.

2. **Visceral arches:** Labial groove on mandible is now clearly marked off. The comb is more prominent and clearly serrated. Length of beak from anterior angle of nostril to tip of bill = 3.0 mm (Plate 12).

3. **Feather germs:** Much more numerous, and in most-advanced tracts (e.g., along back and on tail) elongated into long, much-tapered cones. External auditory meatus is nearly surrounded by feather germs. Circumference of eyelids is bordered by a single row of just-visible primordial; none on remainder of lids. Sternal tracts contain 5-6 prominent rows when counted at anterior end of sternum.

4. **Eyelids:** Nictitating membrane has reached anterior edge of cornea. Upper lid has reached dorsal edge of cornea, Lower lids covered one third to one half of cornea. Circumference of lids now bounds a much narrowed and ventrally flattened biconvex area.

**Stage 38. (ca. 20 days)**

1. **Lims:** Primordia of scales are marked off over entire surface of leg; ridges have not yet grown out to overlap surface. Tips of toes show a ventral center of cornification as well as the more extensive dorsal one. Main plantar pad is ridged when seen in profile. Length of third toe = 8.4 ± 0.3 mm (Plate 12).

2. **Visceral arches:** Labial groove marked off by a deep furrow at the end of each jaw. Length of beak from anterior angle of nostril to tip of bill = 3.1 mm.

3. **Feather germs:** Coverts of web of wing are becoming conical. External auditory meatus is surrounded by feather germs. Sternum is covered with feather germs except along mid-line. Upper eyelid is covered with newly formed feather germs; lower lid is naked except for 2-3 rows at its edge.

4. **Eyelids:** Lower lid covers two thirds to three fourths of cornea. Opening between lids is much reduced.

**Stage 39. (ca. 22 days)**

1. **Lims:** Scales overlapping on superior surface of leg. Major pads of phalanges covered with papillae; minor pads are smooth. Length of third toe = 9.8 ± 0.3 mm (Plate 12).

2. **Visceral arches:** Mandible and maxilla cornified (opaque) back as far as level of proximal edge of "egg tooth," The channel of the auditory meatus can be seen only at the posterior
edge of its shallow external opening. Length of beak from anterior angle of nostril to tip of bill = 3.5 mm.

3. **Feather germs:** Coverts of web of wing are very long tapering cones. Note great increase in length of feather germs in major tracts. Four to five rows of feather germs at edge of lower eyelid.

4. **Eyelids:** Opening between lids reduced to a thin crescent.

Plate 12
Stages 40 to 44 are based mainly on the length of the beak and on the length of the third (longest) toe, since other external features have lost their diagnostic value. Of these two criteria, the length of the beak is the better, because it is more easily and accurately measured (with calipers) and shows less variability (Plates 13-14).

Stage 40. (ca. 23 days)
1. **Visceral arches**: Length of beak from anterior edge of the nostril to tip of bill = 4.0 mm. The main channel of the auditory meatus is not visible in strictly lateral view of its external chamber. 2.
2. **Lims**: Length of third toe = 12.7 ± 0.5 mm. Scales overlapping on inferior as well as superior surfaces of leg. Dorsal and ventral loci of cornification extend to base of exposed portion of claw. Entire plantar surface of phalanges is covered with well-developed papillae.

Stage 41. (ca. 25 days)
1. **Beak**: Length from anterior angle of nostril to tip of upper bill = 4.5 mm.
2. **Third toe**: Length = 14.9 ± 0.8 mm.

Stage 42. (ca. 27 days)
1. **Beak**: Length from anterior angle of nostril to tip of upper bill = 4.8 mm.
2. **Third toe**: Length = 16.7 ± 0.8 mm.

Stage 43. (ca. 28 days)
1. **Beak**: Length from anterior angle of nostril to tip of upper bill = 5.0 mm. “Labial grooves” are reduced to a white granular crust at the edge of each jaw; that of the lower jaw may be partially or completely sloughed off.
2. **Third toe**: Length = 18.6 ± 0.8 mm

Stage 44. (ca. 30 days)
1. **Beak**: Length from anterior angle of nostril to tip of upper bill = 5.7 mm. The translucent peridermal covering of the beak is starting to peel off proximally.
2. **Third toe**: Length = 20.4 ± 0.8 mm.

Stage 45. (ca. 32-33 days)
1. **Beak**: Length is no longer diagnostic; in fact, the beak is usually shorter than in stage 44, due to a loss (by sloughing off) of its entire peridermal covering. As a consequence, the beak is now shiny all over and more blunt at its tip. Both labial grooves have disappeared with the periderm.
2. **Third toe**: Average length is essentially unchanged from that of stage 44, except in those breeds with a longer period of incubation (21 days) and a heavier build of body. For these latter, length of third toe = ca. 21.4 ± 0.8 mm.
3. **Extraembryonic membranes**: Yolk sac is half enclosed in body cavity. Chorio-allantoic membrane contains less blood and is "sticky" in the living embryo.

Stage 46. Newly hatched chick (35 days).
# APPENDIX II: Incubator Record Form

Incubator: ________________  Year: __________
Page: ______

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<th>Time</th>
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Appendix III: Egg Intake Record Form

Institute for Wildlife Studies - Egg Intake Record

Egg Number ____________________
Species ________________________ Territory _____________________________
Estimated Lay Date _____________ Date Collected ______________ Date Set __________
Clutch Number ________________ Eggs in Clutch ___________
Predicted Hatch Date ___________

Measurements

Length 1 ________ Length 2 ________ Length 3 ________ Mean Length ________
Breadth 1 ________ Breadth 2 ________ Breadth 3 ________ Mean Breadth ________

Calculated Fresh Weight = Mean Length*Mean Breadth²*KW

KW1: 0.000549 Calculated Fresh Weight __________
KW2: 0.000562267 Calculated Fresh Weight __________
KW3: 0.0005541 Calculated Fresh Weight __________
Egg Weight at Intake: __________ g
Added Weight in Tegaderm, glue, etc. at Intake: __________ g

Summary

FW Used in Calculations __________ DWL = ______ g for ______ % Loss
Target Pip Weight __________ g
Total Incubation
Natural: ________ days
Artificial: ________ days

Hatched? __________ Disposition ____________________________________________
Days Incubation to Pip ____________
Hours Pip to Hatch ______________

Notes: ____________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

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# Appendix IV: Egg Incubation Record Form

<table>
<thead>
<tr>
<th>Species</th>
<th>Institute for Wildlife Studies - Egg Incubation Record</th>
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<td>Egg Number</td>
<td>Date Set In Incubator</td>
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<td>Day of Incubator</td>
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<td>Time Incubator</td>
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<td>Temp/ Hum Incubator</td>
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<td>Total +/- Egg Incubator</td>
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<td>Expected Incubator</td>
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<td>Predicted Povy</td>
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<td>Estimation Log Date</td>
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<td>Target DWL</td>
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<td>Comments</td>
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<td>Initials</td>
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Page 43
# APPENDIX V: Bald Eagle Hatching Record Form

Institute for Wildlife Studies’ Bald Eagle Hatching Record

<table>
<thead>
<tr>
<th>Egg Number: __________</th>
<th>Territory: __________________</th>
<th>Year: __________</th>
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<tbody>
<tr>
<td>Date</td>
<td>Time</td>
<td>Hole Size</td>
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</tbody>
</table>
APPENDIX VII: Bald Eagle Chick Treatment Sheet

Bald Eagle Chick Treatment Sheet

Date: ____________________     Egg Number: ____________________
Territory: ____________________     Weight: ____________________

**Cefotaxime (Claforan)**

__________ mls given under the skin every eight hours. The treatments should be given at the time designated underneath each check box.

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Treatment Times: ______   ______   ______

**Fluconazole**

__________ mls given **orally** every 24 hours. The treatment should be given at the time designated underneath the check box.

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Treatment Time: ______

**Fluids**

__________ mls given under the skin every eight hours. The treatments should be given at the time designated underneath each box.

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Treatment Times: ______   ______   ______