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## SPECIAL CONFERENCE ON CAPTIVITY BREEDING OF RAPTORS–A REPORT

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Part B. Incubation, Natural and Artificial (Panel 8)

edited by
Richard R. Olendorff
3317 Olympus Drive
Bremerton, Washington 98310

*Panel Members:* Richard R. Olendorff, Chairman; Robert Berry; James Enderson; John Snelling; Stanley Temple.

### *INTRODUCTION*

OLENDORFF. One critical aspect of the wholly artificial method of rearing birds of prey is artificial incubation. Really, it should not be a problem at all considering the state of the art in the poultry business. I would venture a guess that if we gave some fertile eggs to an avian scientist specializing in incubation, he would chuckle at our floundering and hatch out a high percentage of the birds. Berry and Temple will talk about using conditions suitable for chickens or hawks. For this discussion I have considered what literature was available on the various aspects of incubation by falconiforms only, and will review this briefly as we go. I will invite discussion by the panel and the audience of each point separately. Some of the things we will be talking about include temperature, humidity, egg-laying, attentiveness to the first egg of the clutch, candling, and turning. Some other considerations we might want to talk about are egg weight loss, length of the incubation period, the roles of the sexes in incubation, the mechanics of hatching, the analysis of failure to hatch and incubation of hawk eggs by chickens.

### *TEMPERATURE CONSIDERATIONS*

OLENDORFF. Beginning with temperature, all we have to go on is what has been tried and what small successes have resulted. First we should dispense with the notion that there is a single incubation temperature for a species. We should probably speak of ranges of incubation temperatures and optimum incubation temperatures. Huggins (1941) studied incubation temperatures of wild Marsh Hawks and found that *during attentive periods* the eggs were incubated at an average temperature of 90.1 F. The temperatures varied from 82.9 to 95.7 F over an extended period of observation. In the laboratory Stanley and Witschi (1940) used a temperature of 96.0 F to incubate Red-tailed and Cooper's Hawk eggs when older developmental stages were required for their embryological studies. I incubated two Swainson's Hawk eggs full term at 96.0 F while conducting my dissertation research, but the embryos died in the very late stages of incubation several days beyond the expected hatching date. I understand that this is one result of too low an incubation temperature, but it is difficult to attribute failure to any one cause. Moving up the temperature scale, Hunter (1970) attempted to get incubation temperature readings from captive Goshawks. The average of ten readings was 95.4 F, with a maximum of 97.2 F. Hunter thought that this was quite low. Enderson (1971) used a temperature of 97 to 98 F to artificially incubate Prairie Falcon eggs with some success. He also placed a dummy egg with a thermister in it under some Prairie Falcons. At no time did the temperature exceed 95 F in the center of the egg. I will let him expand on this when I finish. Lawson and Kittle (1970) incubated American Kestrel eggs at 99.0 F and got large embryos, but none hatched. Kish and Clark (1971) used 99.5 to 99.8 F to incubate 5 Golden Eagle eggs, but all were apparently infertile. Dr. H. Mendelsohn of Tel Aviv, Israel, hatched a clutch of Long-legged Buzzard eggs at 100.4 F. Enderson (1971), again with Prairie Falcons, used 101 to 102 F in a still air incubator and 99.2 F in a forced air incubator to achieve success. Again, I will leave the details to him. Hancock (1971) used temperatures of 102 to 103 F top of the egg and 99 F bottom of the egg to incubate Peale's Falcon eggs, but the eggs were infertile. Finally, for comparison, the optimum for chicken eggs according to Bellairs (1960) is 101.3 F which corresponds to the body temperature of the hen. Along these lines, I have seen the body temperature of Marsh Hawks, Peregrines, Red-tails and Swainson's Hawks published as roughly 105 F. Kestrels were somewhat higher at 107 F. Some unpublished data I have indicate that body temperatures of Red-tails and Swainson's Hawks are actually lower than that, about 99 to 101 F depending on the time of day. Perhaps someone can recall other representative body temperatures. Those I took were over a twenty-four hour period ½ to ¾ inch deep in the cloaca. The figures of 105 F may have been deep core temperatures, but the point should be made that incubation temperatures probably do not exceed peripheral body temperature. Another temperature consideration is the matter of allowing eggs to cool once or twice a day. Certainly the eggs of wild birds are cooled periodically during inattentive periods. Eric Stauber reported that Fesner (see Stauber (1971)) cooled eggs to room temperature twice a day and I have seen other references to it. It is difficult for me to see any advantage in doing so. Perhaps there is a greater exchange of oxygen and $CO_2$ during the cooling and reheating period. If anyone can shed any light on this, please do so.

So much for my discourse on temperature. I'd like to turn it over to Jim Enderson now.

ENDERSON. In the packet that you have received I have spelled out some of the temperatures I have used. These are as follows: In 1970 four Prairie Falcon eggs incubated at 99.7 F, forced air temperature, 75 percent humidity and tilted through 150 degrees at three-hour intervals, while resting on the small end of the egg, died at ages varying from one to three weeks. In 1971 another captive-produced egg hatched after full-term incubation at 99.3 F still air temperature at the upper surface of the shell, 70 percent humidity and about five turnings per day using freshly washed hands. About 80 percent humidity was reached in the last three days of incubation with an air-pump driven power atomizer. Two other embryos died at about 7 days of incubation when the incubator rose to about 101 F because of a faulty thermometer. Hatching in Prairie Falcons requires 50-60 hours; eggs were not rotated at this time. Hatching was aided successfully in one case when it was clear that the chorionic vessels were dry. The eggs were candled daily; embryos appear most active around 21 days, the air space enlarges rapidly after 30 days and hatching of four captive Prairie Falcon eggs required about 35 days. Chicks hatched from the pipped condition in less than 30 minutes. There are a couple of other things I would like to mention. Thermisterized whole eggs appear to give readings 1 to 2 F below the air temperature immediately surrounding the egg. I believe that John Snelling experienced that as well with thermisterized American Sparrow Hawk eggs. Another thing you have to watch is the distinction between still air and forced air temperatures. Forced air temperatures are usually below those used in still air incubators. Another problem is where do you measure the temperature surrounding the egg? In a still air incubator my technique has been to measure the temperature at the upper surface of the egg. In a still air incubator the temperature there is much different than at the lower surface of the egg, the egg being progressively cooler as one goes down through the thermal stratification in a still air incubator. You get into all sorts of complexities because the embryo, at least in early stages, is within a quarter inch, perhaps, in an egg the size of a Peregrine (maybe a little more), of the upper surface of the egg. The forced air incubator is quite a different matter. I strongly suspect that temperatures exceeding 99.5 F are too high for incubation of the eggs of most large raptorial birds.

HINCKLEY. Is that temperature a still air or a forced air temperature?

ENDERSON. I would not raise the temperature over 99.5 F in any case, even at the upper surface of the egg in a still air incubator. The standard temperature used by Cornell in a forced air incubator for chicken eggs is 99.7 F.

HUNTER. That is equivalent to 101.6 still air, right?

ENDERSON. I don't know. Where do you measure the still air temperature?

Actually, I think if the temperatures are of the order of 99.2 to 99.4 in a forced air incubator, the eggs can stand some latitude temperature wise. Probably even temperatures like 98.8 will work. The only difference there would be the time for development.

HUNTER. I think it is important to define exactly where we are measuring the still air temperature. We don't need to worry about forced air. Don't you think some kind of a standardization is necessary? Where do you measure still air temperatures? I measure it 3/8 of an inch below the top of the egg. And then it depends on whether your heating element is above or below, because in a still air incubator the hottest air rises because of the thermal qualities. There are a lot of variables here which I really think need to be defined.

OLENDORFF. The incubator I used had two vents in the top which I left open assuming that that was for circulation of air so that there should be a certain amount of circulation even in a still air incubator.

LAWSON. I think the poultry people measure their temperature one third of the way from the top of the egg.

SWARTZ. Jim, do you find the disparity between air temperature and thermister temperature to be the same in forced air and still air?

ENDERSON. I don't have experience with still air thermisterized eggs.

WALKER. How does this disparity come to be? Do you calibrate these to air temperature? If you did so, you would get a direct read out of air temperature.

ENDERSON. A possibility is that the lower temperature of the thermisterized egg is due to evaporative cooling, although this is a little hard to explain. It would seem to me to take considerable loss of moisture to cool an egg 1-2 degrees at that temperature.

OLENDORFF. Let's get a little more input on temperature.

BERRY. The incubator I used to incubate Northern Goshawk eggs was a forced air, Sears and Roebuck type incubator. The temperature ranged from 99.0 to 99.5 F throughout the hatching period. Relative humidity was kept between 86 and 90 percent. I would say the average was between 86 and 88 percent. Since the relative humidity outside was so high, it was difficult to get the relative humidity down below 90 percent in the incubator. I also hatched some Peregrine Falcon eggs which were taken from the Canadian arctic. I hatched them at the same temperature, 99.0 to 99.5 F. I took some temperature readings of both the Northern Goshawk and the Bantam hen. This involved taking the temperature about 2 dozen times throughout the nest to get a median temperature within the nest area. The Goshawk temperature ranged from 96 to 99 F with a median of 98.5 F. The chicken ranged from 97 to 101 F with a median of 99.5. The chicken was a full degree warmer than the Goshawk which, according to A. van Tienhoven from Cornell and John Skinner from the University of Wisconsin, may have contributed to the death of several Goshawk embryos during the 1970 year—that one degree temperature difference. The maximum skin temperatures of the brood spots were also measured for the Goshawk and the chicken. The Goshawk had a temperature of 101 F and the chicken 103 F. These are not necessarily very accurate temperatures, but it does indicate that the chicken is somewhat higher in incubation temperature than the Goshawk, and apparently some of these other hawks do have a lower incubation temperature than we might expect in domestic fowl.

UNKNOWN. Did you cool the eggs which were successful?

BERRY. Yes. All eggs were cooled twice per day every day including the days immediately preceding hatching for 15 to 20 minutes in a room temperature of approximately 70 F. Werner Fesner suggests that this cooling is very important to allow the reabsorption of oxygen.

HUNTER. The Goshawk under which I took the temperatures would not tolerate a remote sensing device in the nest (Hunter, 1970). I put a temperature thermometer in the nest and she would throw that out except when I went in at night and worked it up through the nest to the desired height. In this way I got the unexpectedly low temperatures. I put a chicken egg under her and it took her 28 days to hatch it. This indicates that the Goshawk is probably incubating at a lower temperature than the chicken.

SWARTZ. The poultry people abandoned this cooling business some years ago, finding that it is not only dispensible, but that the implications are that it may very slightly lower hatchability. The last is in doubt.

BERRY. I think just the reverse of that. John Skinner at the University of Wisconsin also corroborated Werner Fesner and said he thought that cooling would definitely increase hatchability of the eggs.

FYFE. Relative to some of our observations on the prairies, the impression we have is that the birds very seldom remained off of the eggs for any more than a short time. There was a definite attempt for the male to get immediately back to the nest as soon as the female came for food.

## *TURNING*

OLENDORFF. It is generally agreed that eggs should be turned several times daily to prevent adhesion of membranes and, according to the Lanyons, to provide exercise for the developing embryo.

NELSON. Bob Berry, were you turning the Goshawk and Peregrine eggs a certain number of times per day?

BERRY. All eggs were turned every three to four hours every day, with a reduction in frequency 3 to 4 days prior to hatching. They were turned throughout the day and night, 180 degrees at a turn.

FYFE. We didn't actually observe any turning as such with our Prairie Falcons, but the birds did shuffle on the nest to readjust their position. This would probably roll the eggs. This often happened several times in an hour. Other times the bird would sleep for an hour or so at a time.

NELSON. I have written to a few people here about the studies of gulls which were done I believe in Europe by Dr. Rudy Drent of the University of British Columbia at Vancouver, and there have been a couple of other studies as well of wild birds. They marked the eggs with lines at varying degrees around the egg so that they could determine what part of the egg is uppermost. All of the shuffling we are seeing in the nest, the various shifting of the feet which appears to be threatening the egg, seem to be to keep the egg in exactly the same position so that the embryo is uppermost. If you take a reasonably well-incubated egg and mark a line on it and you put it in a bowl of water, the egg will take up a particular position because a certain part of the egg is heavier. It happens that the embryo part of the egg is lighter and it always floats uppermost. This is the whole purpose apparently of why birds of a variety of species shuffle the eggs. It is shuffling to keep the embryo uppermost and closest to the brood patch of the adult. Artificial incubation in incubators has been done with uncountable numbers of chicken eggs. It is very likely that in chickens we have selected for those birds that lay eggs for which it doesn't matter whether they are upside down or not. Jim Enderson said awhile ago that there is a very great difference between the temperature at the top of the egg and the temperature at the bottom. With the gulls and with the godwits in Europe it has been proven quite conclusively that all of the movement of the eggs in the nest are to keep the embryo uppermost against the brood patch.

TEMPLE. Did that fellow ever candle an egg? You can follow an embryo all the way around an egg as you turn it. The embryo floats in the egg.

NELSON. They have opened a variety of eggs at various stages and it is quite so. It is in the latest issue of the supplement for *Behaviour.*

HAMERSTROM. This all begins to make some sense to me. I marked my Golden Eagle eggs on the bottom as they were laying so I could tell which egg was which. As I went to the nest day after day I never could find those markings. I thought that they had worn off. When I took the eggs away, the marks were still there. This suggests, although my eyes are not very good without glasses, that those markings were usually at the bottom.

WOLHUTER. Do you have any theories as to why the markings were down? Could it have been the bird's reaction in wanting to put the markings down, or do you think that this was just the position the eggs happened to be in.

HAMERSTROM. I don't think it was the bird's reaction.

HUNTER. This brings up a good point that somebody really ought to check out. Does the position of the shell have anything to do with where the embryo is? I think that no matter where you turn the shell the embryo will stay on top, because it is floating in fluid inside. It is not attached to the eggshell in any way. I have often questioned in my own mind why an egg needs to be turned, but everybody does.

TEMPLE. That is exactly why you turn it. That embryo remains free. If you don't turn it, the membranes will adhere to the shell. Then, later on, if the membranes adhere to the shell and you turn it, you get rupturing of blood vessels.

ENDERSON. The embryo won't float if you don't turn it. I think in this case one picture or 3600 pictures is worth a thousand words. In the summer of 1970 Gerald Swartz, Stan Temple and I took some time-lapse motion pictures of Peregrine Falcons incubating eggs along the Yukon River. I want to run a section of that film for you now. This is just the part where the bird is incubating eggs. This is, of course, greatly speeded up. The frames were taken about 2½ minutes apart. You get a feel for the activity over the eggs. The change in position of the bird on the nest averages out to about once every 30 minutes. I presume that changes such as these involve some movement of the eggs. We did see active turning as well. The manuscript dealing with these films is being submitted to the *Living Bird.* Only less than one percent of the time are the eggs exposed.

## *TEMPERATURE AND TURNING*

TEMPLE. This is a summary of our data from seven Peregrine eyries at which we had time-lapse cameras. A couple of interesting things showed up including the one that Jim Enderson just mentioned. If we assume that Peregrine Falcons in the wild do it the right way, we can probably get some pretty good insight into some of these questions. One very important point is this thing on periodic cooling of the eggs. I think the thing that was surprising to us is that inattentive periods—times when the eggs were uncovered and not actively incubated—were less than one percent of the time. The average time that these eggs were exposed was less than three minutes. In other words, Peregrine Falcons do not periodically cool their eggs. Less than three minutes of exposure does not allow the eggs to cool down hardly at all. The other thing you will notice here is that the inattentive periods drop off in the last five days before hatch, during which the embryo breaks into the air sac. You will then hear the embryo peeping and scratching around in the egg. With regard to the role of the sexes in incubation for those of you who are going to allow your birds to incubate, quite surprising again to us, the male incubated approximately one-third of the time. The times they were on the eggs per shift were about two hours for the male and 3½ hours for the female. The male definitely (in wild pairs) contributes substantially to the incubation of the eggs. This is quite contrary to impressions of quite a few people who have published on this for Peregrine Falcons. The important thing to note is that the inattentive periods are very insignificant.

HAMERSTROM. How many eyries were involved in your study?

TEMPLE. Seven. Not all of them were involved in each of the periods into which we broke the incubation period.

SMYLIE. Did the inattentive periods correspond to the times when they were changing?

TEMPLE. The information would suggest that it is usually when the male brings food in and the falcon leaves the eggs to go meet him. The eggs are left alone while the food exchange takes place away from the eyrie.

SMYLIE. When he comes in to incubate, how long does it take to make the change from male to female? Even if it is 30 seconds, if it happens enough times during the day, you are going to get up to a 20 to 30 minute total that the eggs might be exposed.

TEMPLE. Here we have the percentage of the total time those eggs were exposed and it is less than one percent.

FYFE. The exchange is a short thing.

TEMPLE. It is very short. The eggs are not allowed to cool. Anyone who has worked with eggs knows that in three minutes that egg is not going to cool very much.

UNKNOWN. Have you every seen the male incubate through the night?

TEMPLE. Yes. The male incubated during the night in approximately the same proportion as he incubated—about a third of the nights.

WOLHUTER. Perhaps Dr. Porter can agree or disagree with me, but it seems that male kestrels do more of their incubating at night.

PORTER. We didn't record data on what happened at night, although the literature has one or two references to it. I believe that Tom Cade published on this.

TEMPLE. Ours seemed to be completely random. In other words, about one-third of the nights—about what you would expect—the male incubated.

UNKNOWN. What was air temperature at these nests?

TEMPLE. This was on the Yukon River so the air temperature was down to 60 to 70 F.

PORTER. Is there any indication of abnormality which might be expected from the pesticide situation?

TEMPLE. We didn't observe anything we could directly relate to pesticides. We did find that at the two eyries out of the seven that failed to produce young, eggs were broken. Thin eggshells did accompany failure. In one nest where eggs were broken and young did not hatch, the tiercel did not fulfill his responsibility during incubation. We only had a camera at this eyrie for a short period because we had a malfunction, but during that time when the female would get off apparently to feed, the male would not incubate his whole attentive period.

ENDERSON. Dr. Porter, that is true. At the two nests that failed, we found the thinnest shelled eggs. Egg breakage occurred at other eyries as well. Small sample size, I'm sorry.

NELSON. When you are talking about one percent or so of the time, this amounts to about 15 minutes per day.

TEMPLE. Right. The inattentive periods averaged about three per day. There were three intervals when the eggs were left uncovered each day. The eggs were left uncovered for an average of less than three minutes each time.

NELSON. How often did you expose a frame?

TEMPLE. About every 2½ minutes. This gives us a less than three minute interval. The bird is incubating in one frame, he is gone the next and he is back the next. This gives you a maximum time of five to six minutes off per exchange, but we are averaging.

GRIER. You have thousands of pictures there and they are using a sampling procedure.

NELSON. In any case, someone made the point that cooling of the eggs was required for oxygen reabsorption. Fifteen minutes per day may be very important.

TEMPLE. But it is not 15 continuous minutes.

NELSON. But for oxygen reabsorption it doesn't matter.

TEMPLE. Who brought up this oxygen reabsorption business?

BERRY. Werner Fesner is the source of that little bit.

TEMPLE. Fesner is not an expert in avian biology, and I would question that he had done anything to indicate this.

OLENDORFF. From the laws of physics, most of the cooling will occur during the first three to five minutes that the eggs are uncovered. In other words, when the difference between ambient temperature and egg temperature is the greatest, the rate of cooling will be the greatest, and the rate will decrease as cooling continues. I cannot tell you if it is significant or not, but the cooling is faster at first.

TEMPLE. The studies they have done on the cooling of eggs indicate that the albumen is a tremendous insulator. Uncovered eggs retain their temperature for quite a while.

HUNTER. It looks like we are just conjecturing on this. No one really knows. Maybe someone ought to get some data on this.

GOBEN. I watched this fairly closely with my Ferruginous Hawks just to see this cooling period. On the exchange they were very careful not even to let cool air get to the egg. If the female was on, the male would stand right beside her, slip a wing half underneath her and she would lift off. He would then slip a wing over the egg and move over on to the eggs. The opposite exchange would occur the same way. You never get to see the eggs.

FYFE. Our field observations would very closely parallel what you have here for the Peregrines. Most of the movement of eggs was just with the foot movements. The time off the eggs was usually just the time it took for the female to go and get food and the male to come back and go on to the eggs. It would certainly be less than three minutes. We spent a lot of hours observing, but we could have missed periods. I don't think, however, that we would have missed a long inattentive period. With our captive birds we found the same thing. They made very sure that the eggs were incubated virtually all of the time.

SWARTZ. On the general point of cooling, I think we have a relatively foolish situation. The point doesn't deserve too much discussion. As for movement, I wonder if we are not, in the incubator, substituting with infrequent large movements for very frequent small movements. It is probably not necessary for a bird to roll an egg clear over.

TEMPLE. I might add that most poultry people now have automatic turners in their incubators. This is the way I handled the red-tail egg we got from artificial insemination. It was moved through a 90 degree arc every hour. The egg was never completely rolled over. It was rocked back and forth through a 90 degree arc. It was lying on its side in a normal incubating position.

ENDERSON. Someone might experiment with a clock drive turner using rollers.

TEMPLE. That would save getting up in the middle of the night to turn eggs.

SNELLING. In 1970 I addressed myself to the problem of artificial incubation in the American Kestrel, specifically to all of the questions we are asking today. For logistical reasons I only decided to look at temperature relations and cooling. I had at my disposal a sample of wild laid American Kestrel eggs, 36 fertile ones to be exact. I used a still air incubator, a very simple unit which can be constructed by hand for less than $15.00. I divided my eggs into three temperature treatments. All eggs were in the same incubator. The middle level was at 101 F (38.5 C). The low level was at 97 F (36.0 C). The upper level was at 104 F (40.0 C). These eggs were divided another way. It was a three by two experimental design actually. Half of the eggs were cooled twice a day to about 21 C (morning and evening). The results are shown in Tables 1 and 2. These are the hatching successes for the various temperature treatments. At 38.5 C (101 F), 11 out of 11 eggs hatched normally and they were all raised to fledging. At 36.0 C, five eggs hatched, while eight did not hatch. At 40.0 C, three eggs hatched; nine did not hatch. If you perform a Chi Square test on these data, the conclusion is that 38.5 C (101 F) was the optimum incubation temperature. Bear in mind that there is a distinct difference between still air and forced air temperatures. This was a still air unit in which normally you would have a higher incubation temperature. This would correspond to about 99.7 F which is the proper forced air incubation temperature. Apparently American Kestrel eggs, with respect to temperature, react like chicken eggs. The sensor was simply a dry bulb thermometer at the top of the eggs. The heating element was throughout the entire incubator on the sides.

OLENDORFF. You got better hatching at the lower temperature than you did at the higher. Was that statistically significant?

SNELLING. No. Table 3 shows you what we have with respect to cooling. The eggs were cooled for 30 minutes twice a day down to room temperature around 21 C. Of the eggs which were cooled, 11 hatched and seven didn't hatch. Eggs not cooled, eight hatched; ten did not hatch. The Chi Square test perform-

**Table 1. Effects of Incubation Temperature and Periodic Cooling on Artificially Incubated American Kestrel Eggs (Snelling)**

| Temperature Treatment | Cooling Treatment: 30 Minutes Twice Daily | Not Cooled |
|---|---|---|
| 36 C | | |
| no. fertile eggs | 6 | 7 |
| no. eggs hatch | 3 | 2 |
| mean age[1] when taken | 10.3 | 11.6 |
| mean hatch time[2] | 49.3 | 78.8 |
| condition unhatched eggs | | |
| no. pipped, fully formed | 1 | 3 |
| no. fully formed, yolk sac external | 1 | - |
| no. ¾ developed | - | 1 |
| no. ½ developed | 1 | 1 |
| 38.5 C | | |
| no. fertile eggs | 6 | 5 |
| no. eggs hatch | 6 | 5 |
| mean age when taken | 13.3 | 12.2 |
| mean hatch time | 50.7 | 44.2 |
| 40 C | | |
| no. fertile eggs | 6 | 6 |
| no. eggs hatch | 2 | 1 |
| mean age when taken | 9.8 | 13.0 |
| mean hatch time | 47.0 | 62.2 |
| condition unhatched eggs | | |
| no. pipped, yolk sac external | 4 | - |
| no. pipped, fully formed | - | 1 |
| no. fully formed | - | 1 |
| no. ¾ developed | - | 2 |
| no. ½ developed | - | 1 |

[1]days
[2]hours from pip to hatch

**Table 2. Hatching Success of Artificially Incubated American Kestrel Eggs as a Function of Incubation Temperature.**

| | Incubation Temperature: 36 C | 38.5 C | 40 C |
|---|---|---|---|
| no. hatch | 5 | 11 | 3 |
| no. unhatched | 8 | 0 | 9 |

$Chi^2$ (2 d.f.) = 14.63, $p < .001$

**Table 3. Hatching Success of Artificially Incubated American Kestrel Eggs as a Function of Periodic Cooling.**

| | Eggs Cooled for 30 Minutes Twice Daily | Eggs Not Cooled |
|---|---|---|
| no. hatch | 11 | 8 |
| no. unhatched | 7 | 10 |

$Chi^2$ (1 d.f.) = 1.02, p ≫ .05 n.s.

ed on these data shows no significant difference. My conclusion is that cooling American Kestrel eggs has no effect on the hatch whatsoever. Cooling is not detrimental or helpful.

HUNTER. Is there a difference in the time of incubation at the different temperatures?

SNELLING. I cannot say for sure, because I was not sure how old the eggs were when I got them. Table 4 summarizes data I got from thermisterized eggs. Once again, the general pattern of a two to three degree (C) drop with thermisterized eggs is seen. First of all, concern yourself only with the right-hand column. An experimental pair of birds which was fed on pesticides incubated at 34 to 36 C. The control pair which was not fed pesticides incubated their eggs at 34 C. This is a two to three C drop from what we would expect from incubator temperature. In the next three figures down—temperatures with respect to still air incubator—eggs thermisterized in the incubator at the 36 C, 33 C was

**Table 4. Temperatures of Eggs Incubated by Captive American Kestrels and in a Still-air Incubator.**

| | Thermister Coil under Eggs | Thermisterized Egg |
|---|---|---|
| Captive Kestrels | | |
| experimental[1] | 31 C | 34-36 C |
| control | – | 34 C |
| Still-air Incubator | | |
| 36 C level | – | 33 C |
| 38.5 C level | – | 36 C |
| 40 C level | – | 38.5 C |

[1]Fed on day-old cockerels injected with 5 ppm Arochlor 1254 and 15 ppm DDE.

obtained from the middle of the egg by thermister. At the 38.5 C level, 36 C was obtained by thermister. At the 40 C level, 38.5 C was obtained. Consistently lower temperatures at the center of the egg than in the air surrounding the egg were obtained. I would like to reiterate the point that people should be very cautious attempting to "naturally" incubate eggs from what they read from the center of the egg by thermister. If you will recall, the temperature data showed that a low incubation temperature can be just as bad as a high incubation temperature. There are some data from poultry studies that this is not the case with fowl, but I think that at this point in time we had better conclude that a low incubation temperature could be detrimental.

ENDERSON. In 1970 I placed a thermisterized egg under a captive Prairie Falcon which was incubating eggs. The highest temperature I could read was 35 C, which agrees fairly well with Snelling's data. That would mean that the other eggs in the clutch may have been reaching on the order of 36.5 to 37.0 C.

OLENDORFF. Has anyone ever placed thermisters on the surface of the egg?

ENDERSON. No. This is the kind of detail we are going to have to do on it.

SNELLING. Figure 1 just shows the incubator I used. This unit was designed by a poultry scientist at Cornell University. It can be built for under $15.00 and has many uses. It could also be used as a brooder for young raptors. You can see that the resistor wires are strung out along the entire length of the sides. It is made out of a styrofoam ice chest. It is a simple unit to use. It can also be adapted for battery powered use. While I still have the floor, let me complete the results of this particular study. The mean time of hatching from the time which the eggs pipped until they actually emerged was 55.4 hours. This agrees well with what the Snyders found with their Cooper's Hawk eggs. Everybody here who has watched an egg hatch will bear me out in this–one is strongly tempted to hatch them artificially, to start picking away at eggshells. This is the worst thing you possibly could do. The natural situation is perhaps two days. I think you should just be patient and wait. As Jim Enderson has aptly pointed out, assistance to the young birds at hatching can be disastrous. The embryonic circulatory system may not be reabsorbed, resulting in massive bleeding, and unbilical infections.

LAWSON. What is an estimate of the age of the youngest egg you started with?

SNELLING. The eggs ranged from about two to about 22 days of age when they were taken from the wild. The grand mean would run around 12 days, so they were about one third incubated when I got them. Statistical tests on the age of the egg with respect to the temperature treatments showed no significance. They were randomly placed in the different treatments.

GRIER. You might point out that Jeff Lincer has incubated a lot of eggs in captivity using the same technique.

SNELLING. Jeff Lincer is a graduate student at Cornell who has done his research on Kestrel-pesticide relationships. He had a very bad hatch this year. Less than 50 percent of his eggs hatched. He was using 97 F for his incubation temperature.

ENDERSON. Eggs can be easily turned without actually handling them by placing them on a sheet of paper toweling and sliding the paper toweling, the eggs being held in the rack by wires on either side.

GRAHAM. Talking with poultry people, they indicate to me that the largest mortality is at about nine to 11 days. Eggs obtained later on might be expected to have a higher hatch rate than natural.

SNELLING. That is very true. However, 11 of 17 eggs which did not hatch reached either completely developed embryos in the egg or pipping. I think that the most critical time was at hatching.

GRAHAM. The poultry people indicate two times of high mortality at nine to 11 and then at 18 days in a chicken egg.

HUNTER. With Prairie Falcons, two clutches with which I cooperated were hatched at 101 F. One hatched within two days after they were removed from the nest in the wild. The other hatched seven days after removal from the nest. This was still air incubation.

OLENDORFF. From my own experience, I found in two cases, young which had difficulty hatching were also difficult to raise during the first five days. They simply died.

SMYLIE. Snelling, did you have a fan in your unit?

SNELLING. No, it was completely a still air unit.

SMYLIE. Could you put one in? Have you had any plans for that?

SNELLING. No, it could be done I suppose.

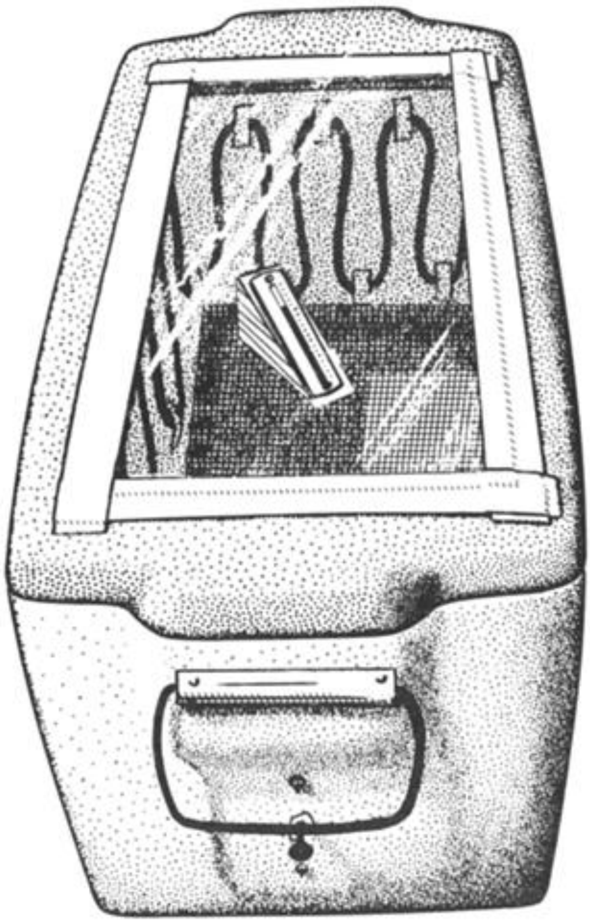
NELSON. How humid was the environment in your incubator?

SNELLING. I didn't mention humidity or turning. I did turn the eggs four times per day at least 180 degrees. The humidity I figured I couldn't control very well. In a situation where I had cloth wicks projecting out of the pans of water in the bottom of the incubator I have a rough humidity measurement of

**Figure 1.** The still-air incubator employed to incubate American Kestrel eggs. The size of the unit depends on the type of styrofoam ice chest from which the body is constructed (Snelling, from Schano, 1969).

Abstract of "How to make a still-air incubator" by E. A. Schano.
(4-H Poultry Science Incubator Project, pamphlet 1-8-1a, 6 pp., rev. 1969. N.Y. State Coll. of Agric., Cornell Univ., Ithaca, N.Y.)

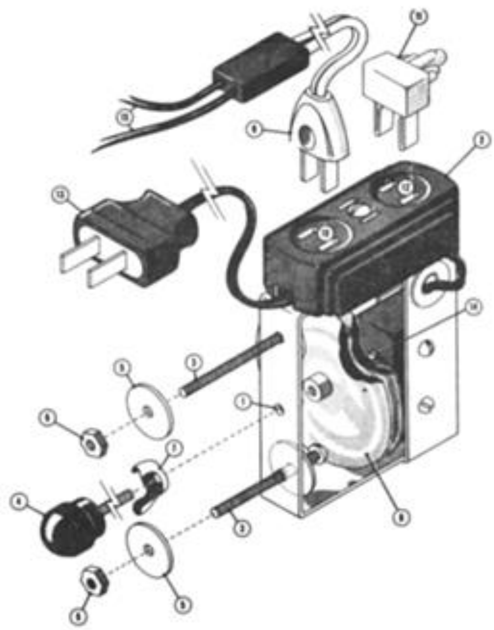
1. Use styrofoam plastic ice chest (12-16"x20-24"x12-15").
2. Cut ¼" welded wire 6" wider and 6" longer than inside bottom; cut 3" squares from corners, fold the sides down, test for loose fit, tape edges to prevent punctures.
3. Place three rings of masking tape inside—2½" from top, 1" above screen, and half way in between.



4. Install microswitch assembly (see illustration): *a.* place assembly so center hole (1) is ca. 5½" down from the top on one end with outlet box (2) on top; *b.* with pencil make three holes for two bolts (3) and control bolt (4), insert bolts from inside, add washers (5), tighten nuts (6) until firm; *c.* insert control bolt (4) with locking wing nut (7), screw into either wafer (8); *d.* insert heating cable plug (9) into outlet (10) and pilot light (11) into other outlet; *e.* to check, plug cord (13) to 110V source, pilot light glows when wafer (8) in contact with micro-switch (14), cable warms, turn control bolt clockwise until click heard and pilot out, turn control bolt counterclockwise until click heard and pilot goes on and cable warms; *f.* disconnect. (Heating cable, thermostat, and thermometer available from Lyon Rural Electric Company Box 30, San Diego, CA 92012; ask for New York Kit and No. 66 Incubator Thermometer; as of July 1971 price including postage and handling was $11.55.)

**MICRO-SWITCH ASSEMBLY**

1. Centerhole
2. Convenience Outlet Box
3. Bolts
4. Temperature Control Bolt
5. Washers
6. Nuts
7. Self-locking Nut
8. Ether Wafer
9. Plug
10. Convenience Outlet
11. Pilot Light
12. Convenience Outlet
13. Lead Cord Plug
14. Micro-Switch
15. Heating Cable



6. Make observation window on top of chest: cut around glass on cover ¼" into styrofoam, cut hole in cover ¾" inside this cut, and cut out strip ¼" thick and ¾" wide, insert glass, fasten with tape.

7. Make ventilation holes: on long sides make four holes with a pencil 2" from top and 4" apart and four holes 3" from bottom and 4" apart.

8. Test: put cake tin (9x14x1½") under screen with ½" of warm water, put thermometer 1" above screen, plug in, turn control bolt until pilot on, adjust to desired temperature. (Abstract—B.E.H.)

70 percent.

WOLHUTER. You mentioned that the birds which had the most difficulty hatching were the hardest to raise after hatching. Could this be a natural selection against weak birds?

OLENDORFF. I think that those which had a difficult time hatching were simply too exhausted to even accept food and swallow it.

MENG. I noticed with my Peregrine when she laid, in fact she had three eggs at the time, that the eggs were not in the center. They were around her body. She was sitting on the sand and her wings were just covering the eggs to keep the eggs from freezing. It was cold outside. After she had a full clutch, I found the eggs under her. I was wondering if in the wild the bird could be setting on the eggs and the eggs could be at the bird's side under her wings and they could be cooled that way.

ENDERSON. We have time-lapse photos of Prairie Falcons at the time of egg-laying in Colorado in 1971 and it is clear that at this one eyrie the degree of incubation, i.e. the time spent incubating per day, increases from about ten percent or so after the laying of egg 1, until about 90 percent after the laying of egg 5. We saw that at dawn and at dusk the frequency of which the bird was on the nest increased rapidly. Apparently, the birds do sit on the eggs at night even after the laying of the first egg.

MENG. Could the eggs be under the wings so the temperature would not be up?

ENDERSON. I don't know.

PORTER. In our kestrels we found that although the females were sitting on the eggs, they were not warming the eggs until late in egg-laying. They would probably keep them from freezing, however.

WHITE. It is important to remember that the genus *Falco* has brood patches on the sides, rather than in the middle.

MENG. The eggs were quite far apart, and later when she was really actively incubating they were together.

HALLIWELL. It would seem to me, just thinking of it from the practical standpoint that the eggs would be less vulnerable to gross temperature changes immediately after the laying of the egg, at the moment you have a blastoderm with one or two cell layers. Just a chilling of an embryo in the early stages will not cause death. Later on you probably will.

TEMPLE. This is well known to poultry people. In fact, right after laying, they put them in a refrigerator and hold them until they have a large batch that they can start incubating at the same time. They store these eggs for up to six days without a decrease in hatchability.

ENDERSON. I think 40 F is the preferred temperature.

HALLIWELL. The other thing probably is that the falcon gets more maternal the more eggs she has.

RICHARDS. At the end of March, one of my kestrels laid two eggs. About this time the temperature went down to -12 C. I was worried about the eggs freezing so I stayed up a whole night and a day to watch to see what happened. The female would go into the nest box and stay there for a while and then leave. Every time she left I put a thermometer underneath the eggs. She would take the egg up to about 16 C, but it wouldn't get higher than that. I never recorded a temperature lower than about 0 C. As soon as several more eggs were laid the temperature went up to 25 C and higher.

*HUMIDITY*

OLENDORFF. Humidity is another problem. Most people who have tried artificial incubation thus far have not bothered measuring it. I simply kept a shallow pan the size of the bottom of my incubator filled with water at all times. Enderson and Mendelsohn in separate experiments used humidity as high as possible. Kish and Clark (1970) measured it at 86 percent. Stauber (1971) stated that Fesner actually sprayed a fine mist of water on the eggs he incubated and had nearly total success when he did so. Although there are some data that submerging eggs quickly in water decreases hatchability, a fine spray may indeed increase hatchability. If we talk about the microclimate of the egg during incubation, it is certain, according to Wesley Lanyon who knows a great deal about hand-rearing passerines, that considerable moisture is supplied to the eggs from the skin of the brood patch. Furthermore, incubating birds have been observed to bathe and almost immediately return to the eggs. During my recent stay at the American Museum of Natural History I spoke with Jean Delacour who has artificially raised countless birds of scores of species in France, and to Wesley Lanyon. Both Delacour and Lanyon spoke of using the highest humidity possible and spraying or painting the eggs periodically with water. In the Lanyons' article on hand rearing young passerines, they state that "When the eggs begin to pip, the moisture should be increased. The glass on the chamber door should show some moisture condensation during the hatch. If necessary, one can place sponges in the water pans at this time to increase evaporation. . . . Too little moisture restricts movement within the shell and may make the membranes too dry and tough for the chicks to penetrate." I note along this line that incubation attentiveness in Enderson, Temple and Swartz's study increased in the five days preceding hatching. In the still air incubator I used for the Swainson's Hawk eggs there were vents for circulation of air and the eggs were simply laid on ¼ inch mesh hardware cloth. The eggs were, for all practical purposes suspended in air. I would suggest that this may have had a considerable drying effect on the eggs in spite of my attempts to keep the humidity high. Never did water vapor condense on the glass portions of the incubator. It is possible that the embryos met with the fate that the Lanyons suggest. This is pure speculation on my part.

TEMPLE. With the red-tail eggs we incubated absolutely as though they were chicken eggs, we, of course, had a very close measure of the humidity in the incubator. During the major portion of the incubation period, from laying up to five days before hatch, the humidity was maintained between 75 and 80 percent. During the five days just prior to hatch, after the young had broken into the air sac, the humidity was raised and held as high as possible, which usually meant slightly over 90 percent relative humidity. This is standard procedure with the poultry industry. They have a separate chamber that they call a hatcher where it is possible by the use of cloths suspended and soaked in water to increase the humidity. As Olendorff said, this is very important to prevent drying of the membranes.

OLENDORFF. We have had a lot of failure of incubation in the very late stages. Remember Frank Beebe and his work with Peale's Falcons. Everyone was questioning humidity at that time several years ago. I feel that that was a fair analysis of the situation.

HUNTER. Is there any danger of too high a humidity at any stage?

TEMPLE. Actually, I think the poultry people would say no. You cannot overdo relative humidity in the air. There have been a number of experiments performed on this dipping of eggs and spraying them.

HUNTER. With goose eggs this is apparently necessary.

TEMPLE. That goose egg experiment was done again, and what they found was that they increased infection of the embryo by moistening the surface of the egg. Getting the surface of the egg moist allowed bacteria to enter the pores of the egg and cause infection in the developing embryo. So, probably it is not a good idea to get the surface of the egg moist. There is a different situation with waterfowl where, as with a goose, every time the bird gets on the egg she brings water.

HUNTER. Ducks hatch so easily that if you keep them moist and put them under the register behind the stove they'll hatch.

NELSON. There is some good information for Ospreys as well. They actually bring water. Welty cites some literature example concerning this. Has anyone actually seen with raptor incubations that wetting eggs will cause infection?

TEMPLE. This was a general sort of thing with many poultry eggs. I might add that with the Ospreys there was some artificial incubation done this last summer. I think the sample size was somewhere around one dozen eggs. The hatchability was as good as you would expect from the wild. The incubation was done once again precisely as with chickens. I think seven out of the 12 hatched.

RICHARDS. I would like to comment on something that impressed me in reading about Lanner Falcons in the Sahara. It said that for 100,000 square miles or something like that in any direction there was hardly any vegetation let alone a water hole. Still they are nesting out there. It would be impossible for them to get a drink, let alone bring back water on their feathers.

TEMPLE. Just an observation on those nesting Peregrines, there weren't very many times during incubation when the falcon came back to the eggs appearing to be wet like she had been in the water. This was not true during the brooding period. During brooding the falcon would often come in obviously just returning from a bath.

ENDERSON. I wouldn't say it was very often even during brooding.

WHITE. One point that is fairly clear with nearly all types of birds, for anyone who has done anything with passerines, that under the brood patches birds have a very jelly-like area. The brood patch is a highly vascular area with a lot of moisture and lipid there. This does provide moisture through the skin to the egg.

PORTER. I noticed in the American Kestrel just after the eggs were laid, they had a rather rough surface. As incubation started, the eggs developed a glossy, almost waxy-like, texture on the surface. This was probably involved with this brood patch.

WHITE. The brood patches are a very important physiological phenomenon where the blood vessels engorge just below the skin.

OLENDORFF. I wonder if it wouldn't be a good index for high humidity to use the technique of Lanyon of observing water condensing on a piece of glass on the door of the incubator.

TEMPLE. That's of course, just a function of the gradient between the incubation temperature and the outside temperature.

OLENDORFF. Yes, but if the incubators are in rooms near room temperature and the incubation temperatures are roughly 99 F, condensation would occur at nearly the same relative humidity each time.

GOBEN. In 1965 I raised two prairies. For what it is worth, twice a day for an hour, I would take a wet cloth and wrap the two eggs. I always had a pan of water in the incubator. I also had problems of the chick sticking to the membrane at hatching and I took a dropper with water and moistened them.

GRAHAM. In Germany a very successful hatcher has a heating element in his water. Five days prior to hatching he turns it on. By heating the water you get more evaporation and a higher relative humidity.

ENDERSON. I used a pump driven atomizer to obtain 80 percent relative humidity in an incubator in Colorado Springs. In our climate 70 percent humidity is no small chore, since the humidity of the outside air is about 15 percent. Another possibility which occurred to me was to use an aquarium pump and air stone submerged in the water pan at the bottom. You will have trouble getting too much humidity.

SWARTZ. There are available very convenient electronic hygrometers.

ENDERSON. We had one hooked into the circuit for the atomizer so when the humidity fell below 80 percent, the pump came on.

*INDETERMINATE EGG-LAYING*

OLENDORFF. Egg-laying has not presented major difficulties except where females have become egg bound. We have spoken to this point earlier. Just to point out a few facts about egg-laying–it is a fairly widespread characteristic that falconiforms lay their eggs every 48 to 60 hours on the average. Variation does exist and it is not uncommon for 72 hours to pass between eggs. In the wild, birds of prey desert most easily at egg-laying, a point to remember when disturbing your birds. One interesting aspect of egg-laying is whether falcons and hawks are determinate or indeterminate layers. Determinate layers produce a fairly constant number of eggs (say four in the case of most shore birds) and then stop laying–period. Indeterminate layers will continue to lay eggs as their clutches are removed one by one at the time of laying. Ratcliffe (1963) states that Peregrines do not usually continue to lay if an incomplete set of eggs is taken. Davenport (1900) was able to collect as many as 16 European Sparrowhawk eggs from a single nest by removing each one soon after it was laid every other day for a month. Dr. Porter has some evidence that this is also the case with American Kestrels and I would like to give him the opportunity to expand the comments he made yesterday about indeterminate laying.

PORTER. I think that Green, who studied the Peregrines in the Aleutians early in the century removed eggs and got renesting in very short periods of time. I would suspect that the Peregrine follows the same pattern as the kestrel. I ran an experiment using four single female kestrels from which I removed each egg as it was laid. I used four other females, but I left one egg in the nest at all times. Three other females I let incubate normally. The latter females laid the usual five-egg clutch and incubated them consistently even beyond the normal incubation period. Those from which I removed eggs, but left one egg in the nest, one female laid eight eggs at the normal two-day interval and then had a gap of 12 days before laying five more eggs. After a gap of 11 days, five more eggs followed; then, after 14 more days without laying she laid four more eggs. She laid 22 eggs in all. Another female which was always left one egg laid 23 eggs with the greatest interval of only four days between eggs. A third one laid 18 eggs with the greatest interval being six days. A fourth female laid eight eggs with the greatest interval of four days. This suggests that if they are indeterminate, they are just now evolving the capability. There is some variation within the species. Those from which I removed all eggs as they were laid, one female laid only three eggs and laid them very late. Another laid 13 eggs with the largest interval between eggs being five days. Another laid 26 eggs with the largest interval being four days. The fourth female laid 17 eggs with the largest interval being five days. A five- or six-day interval is probably not a recycling interval. The latter ranges from nine to 17 days in the kestrel. The following year I placed four eggs in a kestrel nest after the female had laid her first egg. She continued laying until she had laid a total of four eggs. This was a second nesting for the female for the season. Very frequently, on the second nesting, one fewer (four) eggs are laid. I feel that the four-egg clutch was complete. Thus, she laid a full clutch despite the fact that additional eggs were added to her nest. This supports the hypothesis that the American Kestrel is an indeterminate layer.

OLENDORFF. It makes us wonder if there really is much difference between the concept of indeterminate laying and recycling. In the case of your kestrels there is represented some middle ground between the two concepts.

THOMAS. What happened with regard to fertility in these cases?

OLENDORFF. Davenport (1900) did not mention fertility. The point is that with artificial insemination one could fertilize the excess eggs.

PORTER. All of the birds I used were single females.

GRIER. The ones at Cornell last summer were almost all fertile. This involved 23 and 26 eggs from different pairs of kestrels.

HUNTER. Did you have any problems with calcium, Dr. Porter? Was there any dietary supplementation? Was there any thinning of the eggshells?

PORTER. We didn't get any appreciable differences in texture on eggshells until we reached about the 19th egg in 1967. The thickness of the shells remained fairly constant, while the texture began showing signs of deterioration. In 1970, even the 26th egg appeared to be in relatively good condition.

OLENDORFF. We don't have to be that greedy. If we just got two or three more Peregrine eggs—.

HUNTER. Did you do anything to the diet?

PORTER. No. We just gave them our normal kestrel diet.

OLENDORFF. It seems that if you did want to get more eggs by these methods, you would supplement the diet with calcium.

HALLIWELL. The calcium which goes into the eggshell indirectly comes from the diet, but the bird must take it in in the correct ratio. It must be absorbed and then stored in the bone. It is withdrawn from the bone back into the serum and then goes to the shell-forming portions of the body. Feeding more calcium during the laying period is not sufficient. You must have a build-up of calcium previous to egg-laying.

ENDERSON. In 1971 my nine year old Peregrine laid a clutch of four eggs. I removed them and she then started on a clutch which eventually yielded 13 eggs. I left a single egg in the nest at all times. This went on until the 11th egg at which time I took the bird out of the room and blocked her down. Two more eggs were laid while she was on the block. Both of these had ultra-thin, soft shells; the last one was unpigmented.

OLENDORFF. The Peregrines, then, seem to be indeterminate layers.

GOBEN. With my Ferruginous Hawks this year, the seventh egg was obviously lacking. The color was completely abnormal. It was odd-shaped and broke the second day.

BERRY. It would appear that at least one female Goshawk is not an indeterminate layer. For five separate years she was allowed to retain only one egg in every clutch which she incubated. In several of these years all eggs were taken and she failed to recycle or lay additional eggs.

OLENDORFF. We are all sorry to hear that.

BERRY. There was also appreciable shell thinning in the three eggs she laid in 1971 from the first to the last shell. The last shell seems to be only about half as thick as the first shell. She was vitamin supplemented for at least two months prior to egg-laying with calcium glutonate about three times a week.

*RECYCLING*

OLENDORFF. It is well known from egg collecting days that many raptors have the capability of completing a successful nesting even if their first clutch of eggs is taken. Bond (1946) mentions two observers taking 12 fertile Peregrine eggs from the same eyrie in the same year (three clutches of four) and a fourth clutch of undetermined number was laid. The potential for recycling seems to be related to the time invested in any given set of eggs. If young are destroyed, birds will rarely, if ever, renest. An interesting question for study would be to figure out how long you can let the parents incubate before recycling is curtailed. The reasoning here is that we have had trouble with full-termed incubation, but relatively less with short-termed incubation. The Lanyons and aviculturists in general have little or no luck incubating passerine eggs full term. The possibility remains, however, that we could allow captives to incubate for two weeks, then recycle and increase our chance of successful artificial incubation by taking advantage of natural incubation of the parents at first. Perhaps we will be able to leave them under the parents until candling is feasible and then to recycle the parents.

ANDERSEN. We have been working with Swainson's Hawks for about three years now. In any case, if the nest is destroyed during the first week of incubation, there will invariably be a renesting. We have yet to find any case where a successful renest has been made after two weeks of incubation. We see nests relined, but never relaying. If we use this approach, probably no more than one week of incubation by the parents will be possible with the buteos.

NELSON. In the wild Peregrines this year we had two nests which lost young and one of the pairs lost their youngster within the first week after it hatched. They slipped right back into courtship behaviors we would expect prior to egg-laying. They did not lay eggs, however. I mention the point because we may think that if we get the early courtship activities, we will get eggs. If this happens during a recycling procedure after one clutch of eggs hatches, there is not much hope for a second clutch.

HUNTER. I did not take the eggs away from my Peregrine until the 13th day. They went through all of the courtship again, but no eggs were laid.

GOBEN. Lester Boyd had three clutches of Prairie Falcon eggs from a single pair and he removed eggs on the 14th day each time.

PORTER. We have some instances with the kestrels in which the female laid the first egg of her second clutch before the young of the first clutch had fledged or left the nest box. Apparently, the recycling was initiated at some earlier time even when the nestlings were younger, probably 14 days prior to fledging.

WOLHUTER. I question the fact that birds that tend to nest early in the season or late in the season have smaller clutches. I wonder if the time of year we are trying to get the birds to recycle is important. If it gets to be too late in the summer when you try to recycle, are you missing your whole chance? Should you start the whole process early so you have more time later in the year for a second clutch?

PORTER. Our data on removing eggs suggest that the later the birds start laying, the fewer eggs will be laid in a sequence.

GRIER. Part of this might be tied in to photoperiod considerations. Later on, day length is starting to drop off. It might be possible to keep things going by maintaining a long photoperiod.

GALICZ. I have one pair of Peregrines that laid in late March and incubated for 39 days. Fourteen days later she began laying a clutch of three eggs. Again, after a second full incubation period on August 18 she began a clutch of three eggs. I did not use artificial light.

PORTER. As you found with Peregrines, we also found with kestrels that about 12 to 13 days was the average period for recycling, from the time the first clutch was removed until the first egg of the second clutch was laid. We found also that the period from the time that they were paired and placed into pens with a nest hole to the time it took to stimulate reproduction was about 12 to 13 days. This is in press in *The Condor* at this time.

HUNTER. How many of the kestrels which successfully raised young recycled after they raised young?

PORTER. I don't have those data. The percentage was rather low.

HUNTER. Does anyone know if that is common in the wild?

ANDERSEN. We did some work on clutch size of Swainson's Hawks two years ago and looked at replacement clutches. The replacement clutches were the same size as the original clutch in every case. As far as raising them, we get a much lower success ratio of second clutches.

WOLHUTER. I think it is your southern birds that would have a higher incidence of recycling at least with kestrels. I think it would be interesting to take eyass birds from very far south and put them in a breeding project and see if there is a higher tendency for them to recycle.

WHITE. There is one literature citation in the publication of the London Academy of Sciences where it said that Peregrines in Africa near the equator do lay twice a year. We need to substantiate this statement.

TEMPLE. In arctic Peregrines, this year on the Colville River we discovered for the first time an arctic Peregrine with a replacement clutch. The bird broke her first set of eggs, and laid a second clutch.

PORTER. How far along were those birds in incubation?

TEMPLE. We could not tell because the eggs were broken when we got there.

UNKNOWN. What happened to the second clutch?

TEMPLE. The second clutch hatched and the young were dead when we made our second float.

BERRY. In the Ungava region of northern Quebec I took four Peregrine eggs this year and artificially incubated them. They were taken at the mid-point of incubation. Two of the four eggs hatched. I went back a month later to see if those birds had recycled, and while both adult birds were on the actual eyrie ledge there was no indication of a recycling. At least a recycling attempt did not result in eggs being laid.

*CANDLING*

OLENDORFF. I realize that candling is a very simple procedure. I've never done it and I'm sure many of you haven't. Perhaps Jim Enderson would tell us a little about it.

ENDERSON. My experience with candling is limited to the eggs of Prairie Falcons and Peregrines. Only the Prairie Falcon eggs contained embryos. The presence of an embryo can be determined using a standard commercial candler, or a two-lb coffee can with a 40-watt bulb inside and with a small hole about the size of a quarter in the lid. By rotating the egg after four days of incubation, that is four days after the completion of the clutch, and waiting for the yolk to come up, you can see behind the pigment layer a distinct shadow cast on the inside surface of the shell. You must be careful not to overheat the egg, because with the coffee can device a great deal of heat is generated. I turn the light off between candlings. Bob Berry has mentioned that the problems of candling Goshawk eggs are not the same as with falcons. As the embryo gets bigger, after about the 24th or 25th day, it is nearly opaque and very difficult to see motion. The easiest thing in that case is to turn the egg so the air sac end is down. As the light comes up along the side of the air sac, you may see motion where the embryo pushes against the air sac and casts a shadow on the side of the egg. By about 32 days the air sac enlarges rapidly and you must avoid the impression that the embryo is dead and that the egg is suddenly drying out. On about the 34th day the embryo will break the air sac and motion is again easy to see. Pipping in Prairie Falcons usually takes place around the 34th or 35th day. At least two more days are required before hatching occurs.

EBERLY. How large is the embryo at 10 to 15 days?

ENDERSON. By about the 10th day it is still under one cm long.

BERRY. At six to seven days in Goshawk eggs you can see a pea-sized dark spot. You can see the blood vessels around that spot. The circumference of the area of blood vessels might be the size of a quarter.

ENDERSON. Especially with the pale Prairie Falcon eggs, the vessel system is obvious by two weeks.

TEMPLE. People have been worried about the possible deleterious effects of candling. The poultry literature suggests that as long as candling is done quickly and you don't expose the egg to the heat of the candler, candling has no adverse effect. I candled the red-tail egg I hatched sometimes twice a day every day.

PORTER. At times when I would open the nest boxes of the kestrels the bright sunlight would hit the eggs directly. I've had the same thing occur with Prairie Falcons in the wild. Does anyone know if this has deleterious effects on them?

FYFE. One time we set a blind up and the eggs were exposed to direct sun for quite a while. The outside temperature was between 50 and 60 F. The bird was off the nest for an hour and 20 minutes. All eggs hatched.

HUNTER. I use a slide projector for candling. You just use your hand. In seven days you see blood vessels all over the inside of the egg. In my limited experience, if you can see anything inside the egg at seven days, it is probably fertile.

NELSON. In the wild Peregrine on the coast where the air temperature almost never gets over 68 to 70 F, it is very obvious, possibly without exception, that the female incubates during the heat of the day. She just will not let the male come on until the eyrie gets into the shadow. Are there changeovers in the taiga Peregrines that will allow the sun to hit the eggs?

TEMPLE. At one eyrie which had a very sunny exposure, there frequently occurred over-heating of the young and an adult was often present to shade the young. I do not recall about changeovers during incubation, but they changed about every three hours, so there must have been changeovers during the sunny part of the day.

NELSON. One thing that alarmed me one day when I went to an eyrie the day that one of the eggs hatched (the adult female was off the ledge for less than a minute by the time I got to the scrape) the young bird was on its side thrashing and squirming. As soon as I shaded it, it was perfectly all right. You would think it would lie motionless. I think some of the reaction was to sun light.

TEMPLE. We will show exactly that in some of our films for the next panel.

OLENDORFF. Let's use that as a lead in for the next panel.

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