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Part I. Photoperiod Problems and Management (Panel 4)

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TEMPLE. Photoperiod is one type of external stimulus that we are definitely able to manipulate, something that we have under our control when we put the bird in a captive situation. This subject is going to be particularly critical with the falcons, since different populations nest at different latitudes. I might start out by telling you how birds evolved a photoperiodic or light induced control or timing mechanism for their reproductive cycle. There are several requirements that they would probably want in terms of what function they would use. One, it must be something that is easily perceived by the animal. Another thing, it must be something fairly constant from year to year, it shouldn't be changing drastically. Probably another thing is that it should be something that would vary geographically, so that the birds can adapt themselves to a specific geographic region; I think it doesn't take much to see that the varying daylight length throughout the year fits all these requirements admirably. It doesn't vary from year to year. March first is the same period of daylight from one year to the next. Light is something that is very easily perceived by a bird—birds are primarily visually oriented animals. Also it is something that varies quite a bit geographically, particularly with latitude. You all know that if you go north, you are going to have longer days proportionately during the summer breeding season of most birds. So, as Peregrine Falcons—we might as well address ourselves to Peregrine Falcons right off—as Peregrine Falcons evolved in the tundra ecosystem they had to adapt their endocrine system specifically so they

were using the light regime, the photoperiod, that is present in the tundra. They are specifically adapting themselves for that condition.

I think, very simply, you don't have to get anything very complicated, on what kind of light regime to put a bird on in terms of light and dark. You can pretty much point blank say that. You should try to duplicate as closely as possible the light conditions of the latitude of the region from which the bird came. For tundra birds this means that during the breeding season you should have them on long periods of light, probably 20 hours of light a day is going to be necessary. For birds such as Peale's Falcon or an *anatum* type of Peregrine, if you keep them at the latitude where they were normally taken or fairly close to it, there is no need to supplement with artificial light. I think that it is abundantly clear from the success with Peale's Falcons and Jim Enderson's *anatums.* Natural light is perfectly adequate unless you have a closed breeding chamber. For tundra birds, and I suppose this is where most of our potential breeders are probably going to come from since that is the only viable continental race of Peregrines left, you are going to have to go to supplemental light in your breeding chamber.

What do we know about the type of light that should be given artificially? There are a couple of things that are definitely known about a bird's receptiveness to different types of light. This has been shown conclusively in studies of photoperiodicity on many species of passerine birds; not much has been done with birds of prey. But all of the other kinds of birds that have been looked at once again show this uniformity—they are all pretty much the same in their adaptation to photoperiod. One thing that comes up right away is the intensity of the light. Every experiment that has been done to measure the intensity of light that is necessary to trigger a photoperiodic response in a bird shows that there is a threshold level above which more intensity does nothing to increase the photoperiodic response. In other words, if you get the light to a certain level, more light is **not** going to strengthen the photoperiodic response. The threshold level that has been discovered in such birds as House Sparrows, finches, Starlings, is quite low, below what I've seen at most breeding facilities. Just take a regular camera light meter; you can approximate the light that you would get from daylight with your photofloods. Take a light meter reading off the floor; if you can duplicate the intensity with photofloods, you are in fine shape as far as intensity of light goes. There is no evidence to suggest that brighter intensity is going to help you out. The other thing that is probably critical is the color or the colorimetric spectrum or character of the light. The spectral quality of artificial light will vary from light source to light source. They have done quite a few experiments once again on different species of birds to find out which wave lengths are most stimulating to the gonads. And I don't know whether you want to call it a night club effect or something—red light is the most stimulatory. If you submit a bird to light that is rich or has a high red wave length to it you are more likely to get a stimulatory response from the bird. Blue light, light that tends toward the ultraviolet, is the worst that you can use. Infrared light is not effective, it's invisible and the things that are stimulatory are in the visible spectrum.

birds, should be putting their birds onto two summers a year. And they may well get in one of these summers production, as it is. Now they're not even getting eggs with just one exception over here.

TEMPLE. Well, if you're going to assume a transequatorial migrant, then you are going to put the bird on essentially two summers. And if you suspect that, then what I mentioned earlier about this photorefractory period is protecting the bird from the second cycle. I would be very surprised if you could recycle that tundra Peregrine. Not until a year later. I'm almost certain.

GRIER. Dr. Porter, have your American Kestrel populations from different areas shown the same thing? You've got different times under the same regime with the breeding.

PORTER. Right, we, in our colony, have Kestrels that were obtained as nestlings from Massachusetts, New York, Ohio, Pennsylvania, and Maryland. We also had a group of Kestrels, female Kestrels from Florida, that were obtained in the winter. The weights of the Florida Kestrels from Florida were not significantly different from those from the northeast which suggests that they're probably not of the small Florida race, the resident race. In any event the Florida Kestrels nested a month later than did the birds from the northeast. They maintained this despite the fact that they were right in the middle—even the Florida Kestrels that were placed right in the middle of the colony with the birds from the northeast, still maintained this month's difference in nesting data, a month later. However, as we looked over our records, there was a tendency for this gap to decrease slowly each year. We really need some experiments with the Kestrels to determine what they're actually behind in.

TEMPLE. I think it's a little bit too much to hope that all tundra birds will quickly adapt, you know, in a matter of several years.

HUNTER. Would you think then that maybe just a total increase in light suddenly would be as good as a gradient?

WHITE. That probably may not be the answer.

HUNTER. What I'm getting to is, is a sudden increase in the total light equally as good as a gradient increase?

TEMPLE. Once again if we're safe in extrapolating from other species there doesn't seem to be any advantage to giving the birds graded increase in light. For most species the sudden jump up to a stimulatory photoperiod is sufficient, unless raptors are very different from the other birds who have been examined; there's no reason to think that. If you're going to bring this on your tundra birds at the appropriate time, sometimes perhaps during May, up into 20 hours, I would think that would be perfectly adequate to do it in one increase.

HUNTER. Some chicken people do this though. They bring the light up slowly, graded, to increase productivity.

WOLHUTER. I'm wondering if there's a difference between just all of a sudden throwing a long photoperiod, versus gradual, when you talk about the threshold, the bird reaching a threshold, is there any difference in that? Also would that differ with some birds, like our transequatorial migrants?

TEMPLE. I can't say that we know for sure with birds of prey, but with other birds that are easier to breed in captivity, the sudden increase in duration is sufficient.

WOLHUTER. There's no need to build up—you can start them long?

TEMPLE. No, so it is with other birds. I'm not saying it's the same as raptors, but seemingly we can apply information from other birds to raptors, just as well.

GRIER. We can't say that poultry takes a 14-hour day and all you have to do is put them at that and hold them at that and they'll keep producing.

MOLT PROBLEMS

HUNTER. I have another comment I would like to make. Something on the order of seven or eight years ago, I put Dakota Belle, a tundra Peregrine, on 24-hour light on January 1; 43 days later she began to molt. The next year I did exactly the same thing but I waited one month later until February 1; 44 days later she dropped her first feathers with the full light, 24 hours. Then the next year I gave her no light; she dropped her feathers as she always had before, on the 12th of July. Now we're only assuming that there is some tie-up between molt and reproductive activity, but . . .

TEMPLE. Yes, the correlation between reproduction and molting, photoperiod molt, is probably just a sort of a spurious correlation. It's pretty clearly shown that the thyroid is probably the organ that is most directly related to inducing molt. And it is being stimulated by photoperiod, you're right, but the stimulation is going to the hypothalamus and it's releasing another hormone that has little effect on the gonads; this is the thyroid stimulating hormone which stimulates the thyroid in the same way that the gonadotropins stimulate the gonads.

HUNTER. On the questionnaires, one of the things I left out I am afraid was a question of when the first feathers dropped in molt; now I do have some of these data from various people, many of them having observed the first feathers to be dropped in the molt after the second egg was laid in the first clutch.

MARCUS. I'm a little confused about all this conversation about total exposure and total light, integrated light exposure versus light periods. I think we're getting mixed up about how many Langleys, for example, does a bird get exposed to? All this seems to be affected by weather and it seems like an unusual condition in which it would be clear short days that would stimulate, perhaps help stimulate activity. Then you'd have all kinds of false starts possibly.

TEMPLE. Remember what I said, there is a threshold level above which more intensity doesn't stimulate the bird any more strongly, you know.

MARCUS. Energy, you have to measure the light energy. The temporal light has to do something, it has to cause, let's say, a photochemical reaction and so it has to be a total energy quantum, or something that . . .

TEMPLE. No, that's exactly what these experiments disproved, that there is not a direct correlation between intensity of light and response. There is none. In other words, you don't get it below a threshold; as soon as you reach that threshold, you get that response.

MARCUS. I'm just disturbed about this business of length of period versus total exposure. I just plain cannot get the question out of my mind.

TEMPLE. In order to explain why transequatorial migrants ever leave South America, there is an hypothesis that it is the total exposure to light on the wintering ground that triggers them to leave. I don't see how this would work on stimulating the gonad in light of what we know with other birds.

GRIER. I think what you're saying is whatever it is, the total amount of radiation isn't as constant as what you were saying initially was necessary from an evolutionary sense. Let's say the day length is going to be the same thing from year to year on the 15th of May. The amount of light can depend on fog or cloud cover and all that.

MARCUS. But you have to measure the exposure in some way. It's not a timed period and how are you going to measure total exposure time? You have to integrate it in some way.

TEMPLE. In other words you're saying that two days out of two days and a foggy day is worth one day in a sunny day.

MARCUS. I'm not saying that's so. I'm saying it doesn't make sense that way.

TEMPLE. No, it doesn't. I agree.

HUNTER. What about the problem of light intensity for threshold?

TEMPLE. I don't think that is a problem, Don. I think all the breeding chambers I have seen or heard of are sufficiently bright.

HUNTER. One thing that bothers me is that it was said by someone and I got the impression that we need the approximate light outdoors inside the building; a little bit difficult.

TEMPLE. The evidence from sparrows and other species indicates no.

HUNTER. It might be helpful—I would like to suggest this—it might be helpful if we take candlepower which we can do with a regular photographic light meter. If anyone could do this and take light meter readings, it may be of some value.

TEMPLE. Certainly as bright as possible.

CAMPBELL. Don, I went into this quite extensively, not being much of a photographer. I went into this with the poultry peopld; the intensity of artificial light comparable to daylight is four watts per square foot of floor area. I also went into this in the schools and the same principle applies in the schools, your overhead lights or movable, I think, is four watts per square foot, this is what I am told.

HUNTER. At what distance from the light would this be? It seems there would have to be a distance factor.

CAMPBELL. No, I don't think so; if you put your light meter on the ground. In my own case each breeding chamber has roughly 145 square feet, 12 by 12, so I can put 600 watts, equally distributed in that pen.

SIMONYI. May I say something, since for the past four years I have had Redtails and the past two years, Peregrines. They need from 95 to 110 candle foot power, per square foot, and that's it, nothing else.

HALLIWELL. And you run yours 13½ hours a day?

SIMONYI. Well, I start off at nine and from there I work it up; you can go as high as you want, up to maybe 20 hours.

THACKER. You were talking about colored lights, reds and blues. Four years ago in Europe there was some work done by Manholds, mostly on lab mice and rats. If they were exposed to different colored lights, you could almost tell what sex the offspring would be. The various colored lights would produce various sexes, like blues would produce one sex, reds would produce another.

TEMPLE. I know that experiment; a lot of people were very skeptical about the results. It's the type of thing where your sample sizes weren't large enough,

there's a possibility those were spurious.

THACKER. Well, I think he repeated them after he did them the first time, because there were so many people that were doubtful.

STODDART. I understand that for mammals to reach puberty they have to have so many hours of infra-red.

TEMPLE. I'm not really up on the mammalian literature, but as far as I know, that is still pretty much a theory.

GEOGRAPHIC PROBLEMS

GALICZ. Just for a point of information on our birds in British Columbia that did lay late in the fall, there was no artificial light used, both last year and this year.

TEMPLE. This is a phenomenon that is sometimes seen in many species and it's very difficult to explain, especially in male birds. You often do see some type of sexual activity in the fall and the reason for this isn't clear—some species even increase their gonadal size.

GALICZ. These birds are very sexy, they produced fertile eggs.

TEMPLE. That's very interesting.

MENG. Stan, in this whole regard I have a feeling that if we have tundra birds, eyasses, that are four years old, they'll probably react like four year old Peale's. I don't think there have been any that have been kept for four years, are there any?

FYFE. I have an eyass female and the eyass male will be three next year. But the female is eight, and she was raised as an eyass.

TEMPLE. We have six year olds, Alaskan birds at Cornell. This is one thing I'd want to clarify right off the bat. A bird will probably not adapt to a different photoperiod from that of the population it is taken from. The experiments here were taken from White-crowned Sparrows which breed, as you know, from California right on up to Alaska and they were not able to stimulate White-crowned Sparrows from Alaska to the summer photoperiod in California.

WHITE. I'd like to make a couple of comments here that I would hope may be germaine at this time, because I think a lot of us think photoperiod is really not understood and we'd hope that those of you working especially with birds of tundra origin would take very good notes on what happens to your birds and the way in which they respond. As Stan mentioned, there are often double cycles. Ptarmigans are a good example of birds that in September set up terri-

tory for about a week. This may be what happened in British Columbia with these resident birds. Secondly, as Stan also mentioned, when you have trans-equatorial migrants, we don't really know what it is that triggers off the return of migration. For example, there are voluminous data to demonstrate that birds from tundra origin moving north in the spring as in April and May across breeding grounds of birds that are already breeding. Many of these birds do not have developed gonads, and when they arrive in the tundra, many of them still do not have developed gonads. And so one would suggest that rather than the hour photoperiod, say a 16-hour photoperiod, or whatever, but rather it is the total accumulation of light over a given period that causes gonadal cycling. So with these long-distance migrants I would hope that those who are working with them would take very, very good notes on what they do in terms of this because the same phenomenon has been noted in birds of the Soviet Union in birds here.

NELSON. On these arctic birds would you care to speculate as to the time ranging on them. I'm thinking particularly of Bob Berry's notes in one of the BPIE reports in which he said the birds started getting hepped up in the fall. Now as I see it, if the tundra birds are down in South America, something is getting them to move back north; this may be why the tundra Peregrine stimulated with hormones over here was exercising so much. Maybe she was trying to migrate back north as Richard Fyfe's captives apparently tried doing a few years back. The transition between South America and the Canadian Arctic, let's say, is going from an autumn to a spring and summer very rapidly. Now would you care to speculate on what type of a light regime people should be using in their captive building and how they might stimulate the birds as they would be stimulated in the wild.

TEMPLE. As I say you can do probably no better than to approximate the natural condition. I would probably put the birds onto a stimulatory photoperiod. For a tundra Peregrine, probably sometime around the first of May, the end of April. I would suggest something on the order of 20 hours of light, four hours of darkness. I would probably hold the birds on that light until probably late July or August and then drop them down to a winter photoperiod, perhaps drop them down to the normal photoperiod for the area where they were.

NELSON. That's the problem. I think that's what everybody has been trying to do. They give them one summer and then put them back into a winter which the birds never ever have seen.

TEMPLE. That's not true, because tundra birds, some of them, are transequatorial where they do go down there, but they certainly do winter on the Texas coast and Mexico.

NELSON. Yes, but we don't know where those birds are coming from necessarily. My point is that these people, at least some of them with high arctic

Now how do you stand when you start using incandescent bulbs or fluorescent light? You're actually in pretty good shape on both of these. They both tend to produce light of a wave length that will give you a good red component. And actually I can't think that you can improve very much on normal indandescent and fluorescent light. They're both very adequate. There are some that may be better. You may be familiar with light called Vita-light. It is a fluorescent bulb that has specially tinted glass and very closely approximates the natural spectral composition of daylight. If you want to do it naturally, one of these Vita-lights is probably one of the best things you can get for it. We've got a couple of other considerations . . .

CRAWFORD. Is that the same as Gro-light?

TEMPLE. Gro-light, yes, the same thing. It's a different product name. Any of these, there are several brand names, but these are ones that are filtered so they approximate a natural spectrum. You're basically pretty safe with just about any of the artificial light sources.

One other thing that you have to worry about is the phenomenon that's been called the refractory period. Let's just follow a Peregrine, she's migrating up to the tundra, increasing her photoperiod, the daylight per day stimulating her gonads, she reaches a point at the end of the breeding season where her gonads start to regress. As her gonads start to regress, she enters a photorefractory period. This photorefractory period varies from species to species in how long it is, how long it lasts. During this period further increases in the photoperiod will not stimulate gonadal growth. This is very adaptive; consider what happens to that tundra Peregrine when she leaves the arctic in late summer. There is a decrease in photoperiod; by heading south, she crosses the equator, going down to Argentina or wherever she might want to winter. Once she crosses the equator, she's in the Southern Hemisphere and she starts increasing her photoperiod again. It's obviously nonadaptive to have gonads enlarging on the winter grounds. And this photorefractory period, you can almost assuredly say, in a species like the Peregrine Falcon where they're known to be transequatorial migrants, is probably quite long, It probably takes them on through to early winter, probably mid-winter, on the order of four or five months.

Now what does this mean in terms of recycling your bird? We haven't really discussed this at all, but it's something that really bears consideration. Using the photoperiod and artificially manipulating the photoperiod, it is possible to put your bird on more than one stimulatory light cycle a year. There have been a number of people who've tried this; I think Jim Enderson has been the most successful in getting some reproductive behavior from his Prairie Falcon by giving it a stimulatory light regime in the late fall. This is fine for a Prairie Falcon. The Prairie Falcons, since they aren't highly migratory, probably have a very short photorefractory period. I would definitely say that it's not going to be possible with tundra falcons to get them to recycle, to go through more than one breeding cycle in a given calendar year because of this photorefractory period. It may be very different with Peale's Falcons and I understand the group

in British Columbia has some evidence that they are able to recycle their Peale's Falcons so they can get an extra reproductive cycle in the fall. Now the way you would accomplish this if you're going to do it by artificially manipulating the light, would be to allow your bird perhaps in the spring to follow a normal stimulatory photoperiod, once she had finished a reproductive cycle, drop the lights down to a nonstimulatory or winter photoperiod, keep the bird on that. I would probably say extend that period; without any basis for how long, you should extend it, but for most species I would imagine you should probably extend it for a good three or four months, I would say 90 days at least, before you started increasing the birds' photoperiod again, to restimulate. This way I think by careful manipulation you should be able to get more than one clutch out of a bird a year. I think it hasn't been said so far, but I think you're probably all aware that in falcons in particular you can remove a first clutch of eggs and they will replace with a second and sometimes a third clutch. Once again if you've got a Peregrine that will produce fertile eggs, you can probably get 25 Peregrine eggs out of two Peregrines by constantly causing them to recycle, as Jim Enderson has shown very clearly, even though these were infertile. I think that's probably about it for photoperiod. It's really fairly simple. There's no mystique about it.

LIGHT–QUANTITY AND QUALITY

LAWSON. I think there have been some experiments done in poultry where they actually put discs in the eyes of the birds and they claim that the light stimulus actually goes through the skull.

TEMPLE. This is serious controversial work. I might summarize that because a lot of that was done at Cornell. What they've done is to remove the eyeball and stimulate the optic nerve directly, using a quartz rod transmitting the light. You probably know that quartz will transmit the light in a straight line, and they transmit it right on to the surface of the optic nerve and they're able to stimulate gonadal development doing this. Another common theory, if it is still in a theory stage, is that the organ called the pineal body in the brain which is the vestige of an actual photosensitive structure in lower vertebrates, such as amphibians and reptiles, is still present in birds and mammals and is located in such a position in the skull that it's possible that light is transmitted through the skull. This pineal body may be a very important internal clock mechanism to the animal; they don't think that it has much to do with reproduction. All vertebrates have daily cycles of events that are very precisely controlled. We get longer cycles that have some type of internal control and it's been theorized that the pineal body may be responsible for some of these controls.

HUNTER. I read some work with Mallard ducks, in which they remove the eyeball, cover the eye up, and subjected the light directly on the skull, and they got gonadal development without even going through the optic nerve.

TEMPLE. Well, we've got some interesting observations that Jim Enderson and Jerry Swartz and I made up in Alaska using a time-lapse camera of nesting Peregrine Falcons throughout their nesting season. The photographs were good enough that we could monitor the molt of these Peregrines throughout the reproductive period. Basically what we found was that the molt was not sort of a steady molt throughout the breeding period. The female at the hatching of the eggs stopped her molt; her molt arrested right there and she did not continue her molt until much later on after the young were fairly close to fledging. This may be very adaptive for the birds because when the young are growing of course the female is at a handicap if she'd molt; she's going to have to go out and help provide food, you know. They're going along very steadily; undoubtedly it is tied in to a certain extent with the reproductive cycle. Dr. Awender, haven't you done some work on inducing molts with hormones?

AWENDER. Yes, but that was female sex hormones; it was very closely related to the progesterone, Noroleucate. There are a couple of new ones which I haven't tried yet. This is a strong pregestational and antiestrogenic effect that does it, nothing to do with thyroid.

TEMPLE. Of course, you realize that the molt in most birds seems to be associated with a decrease in the gonads or a decrease in the circulation titre of steroid hormones. This may be a spurious correlation.

GRAHAM. I have a quick question maybe someone can throw some light on. Has anyone thought of why a Gyrfalcon from the arctic brought down will molt in Alaska, whereas the tundra Peregrines brought down from an arctic regime having this different molting season . . .

HUNTER. That's not just the same.

WHITE. No, the tundra birds I brought down molted the same time the rest of the wild population do. I'm talking about eyasses. Eyass tundra birds brought down in this example kept in mid-latitude for three or four years molt at the same time that the wild tundra populations do. Now you're talking about trapped eyasses.

GRAHAM. No, I'm comparing trapped passage Gyrfalcons and trapped passage tundra Peregrines.

WHITE. Eyasses molt at the same place regardless. You take an eyass tundra bird—it'll molt the same time the tundra populations does—they'll start in April and end, you know, in August.

STODDART. I was just wondering with all this discussion, what were you talking about when you talk about tundra birds? Are you classifying the passage

Peregrines trapped on the beach?

WHITE. Of course, when you get a migrating bird, all you can say is that it is from some place further north. I don't want to comment because many tundra birds do appear on the Texas coast, and many, in fact probably some of the western birds that are raised right in Colorado occur on the coast; nobody really knows until we get banding data. What Dick asked was whether birds taken from the Colville River, for example, molt at the same time that the wild population molts along the Colville River. If you were to have a passage bird from the Colville I would wager you that it would not molt at the same time as the eyasses.

STODDART. Wouldn't you think if we are going to birds especially the passagers, that you should match molts.

TEMPLE. The molt of the male and the female are drastically difficult.

STODDART. No, compared to the wild.

HUNT. In regard to bird trapped on the Texas coast, I've never seen one that looks like an *anatum* or molts like an *anatum.*