TECHNIQUE OF RAPTOR FOOD HABITS STUDY

WITH TWO ILLUSTRATIONS

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This paper has to do with the technique of some phases of raptor food habits study worked out in connection with the Wisconsin Quail Investigation, a cooperative project supported by the Sporting Arms and Ammunition Manufacturers' Institute, the United States Biological Survey, and the University of Wisconsin. Since the investigation was begun in July, 1929, I have had experience to date (November, 1931) with 73 raptor nests, namely, 21 of Horned Owl, 9 of Barred Owl, 4 of Long-eared Owl, 2 Screech Owl, 14 Red-tailed Hawk, 10 Marsh Hawk, 6 Cooper Hawk, 3 Duck Hawk, 2 Red-shouldered Hawk, 1 Broad-winged Hawk, and 1 Sparrow Hawk. In addition to the nesting studies, much field observational work on hawks and a rather large scale examination of owl pellets have been carried on. Special emphasis has been laid on determining direct and indirect relations of each raptor species to poultry and game birds, particularly quail. The food habits data as such will be published separately.

It was soon learned that hawks and owls were not equally amenable to the same methods of study. Methods invaluable for the study of one group proved of negligible utility in the study of the other. It was likewise learned that, where possible, distinction should be made between quantitative data which give a cross-section of the food habits of a raptor species and qualitative data which show only the kinds of prey taken without reference to the proportion of each kind.

Let us turn to a discussion and tentative evaluation of the various research methods employed.

Field observation. Field observations may be either accurate or misleading, according to whether reliance is placed upon actual observation of the capture or eating of prey under typical conditions or upon the independent reading of sign. A criticism to be made of sign reading, even when done by competent field men, is that large conspicuous avian prey is almost certain to be recorded out of all proportion to small mammalian prey. The feathers of a quail, for instance, are promptly spread over so much territory that they become noticeable even to casual observers, whereas the visible sign marking the demise of a mouse or shrew may be so imperceptible that little or no trace can be found, even should one scrutinize the spot where a hawk has been witnessed to catch or eat one of the smaller mammals. Similarly the counting of skeletal remains about Wisconsin Duck Hawk feeding ledges led to an impression that Peregrines subsisted on a nearly straight diet of domestic pigeon, while a checking over of contemporaneous pellets revealed a quite surprising representation of lesser bird life. The reading of sign *alone*, therefore, I feel to be conducive to a warped perspective. Its value, supplementary only, is in ascertaining whether *any* of some species such as quail and ruffed grouse have been killed. It should never be used in working out ratios of one kind of prey to another.

On the other hand, the listing of entire or partially eaten specimens *retrieved* from hawks gives a more reliable index to day-by-day food habits, though a hawk is somewhat more likely to be surprised with larger than with smaller prey, as the former requires more time to eat. Marsh Hawks bringing food to their nestlings can be excited into relinquishing what they have by approach of human intruders to the nest. They usually drop and recatch their quarry a number of times before letting it go. The falling object may then be marked down and procured.

The field observation method has been used in Wisconsin to advantage on Red-tails and Marsh Hawks. For obvious reasons it is not so easy to apply to nocturnal predators.

Nest studies. Raptor nest studies, like field observations, are possessed of potentialities for quantitative data, but must be handled with discretion. Quantitative data of unquestionable merit as to the diets of the young are obtainable by keeping nests under constant observation, as from a blind; but this method has the weakness of being so time-consuming that too few nests can be watched in a season. Data from but one or two or three nests, regardless of how complete for those nests, may or may not be representative even of the local food habits of the species studied. Every once in a while raptors of non-typical food habits are encountered, the proper allowance for which can not be made unless data are had treating with large numbers of the species.

Nest visits, conducted at intervals of a day or two, have been most profitable the first few days after hatching out of the young, when the nestlings were unable to eat all of the food brought in. The nests yielded less and less as the nestlings became large enough and hungry enough to clean up the prey, though valuable data were still to be derived from young hawks by examination of their gullet contents. Feather material persisted for varying periods of time, while only the barest traces of unknown numbers of small mammalian prey remained evident in the majority of nests. Thus the proportion of bird to small mammal prey recorded from ordinary nest visits (both for hawks and owls) tended to exceed the proportions determined by tried quantitative methods. This has been repeatedly checked. Mice, for example, occurred commonly in the pellets of nestling Horned Owls and in the gullets of young Marsh Hawks, yet seldom was corresponding evidence of mice to be seen in the nests.

Despite the general disadvantages of the method—to which should be added the personal risk and labor of heavy routine climbing, even with accessories as ropes and climbing irons—it was found desirable to examine the nest litter of Horned Owls and Red-tails about once a week. Observations indicated that feathers of quail and ruffed grouse, especially primaries and tail feathers, working deep into the interstices of stick nests, would remain there indefinitely, unless deliberately removed by hand. In this way an investigator, assigned to a particular game bird species, may be enabled to employ another check (not claimed utterly infallible) as to whether that species is brought into a given nest. Stick nests, that may be used on successive years or perhaps in the same season by Red-tails, Horned Owls, etc. (a late nesting raptor will sometimes take over a recently vacated nest of another), should be given a careful cleaning soon after the contained eggs hatch, to eliminate possibility of avian prey from a previous occupant being diagnosed as the prey of the wrong predator. For that matter, where feasible, a careful clean-up should also be made at each visit.

Stomach examinations. Drawbacks to the exclusive use of stomach data have already received space in literature. Stomach data at best show only what individual animals in a given locality have eaten at a given time. At worst they show only part of what individual animals have eaten some place, some time, especially where differentially resistant contents are in advanced stages of digestion.

It may be stated, preliminary to discussion later on in this article, that owl stomachs furnish much more reliable data as a rule than hawk stomachs, for the reason that bony material suffers less from the digestive processes of owls than from hawks. On the other hand, feathers and fur appear to survive digestion better in hawk stomachs than in those of owls. These generalizations are based upon feeding experiments with 6 Horned Owls, 1 Barred Owl, 1 Long-eared Owl, 3 Red-tailed

Hawks, 3 Cooper Hawks, 1 Red-shouldered Hawk, and 1 Marsh Hawk, as well as upon my own 1929-31 experience with 59 miscellaneous raptor stomachs and many thousands of pellets.

I have never been able to regard stomach analyses as contributing the best quantitative data, except in the case of species having such monotonous food habits that their diets would remain about constant wherever and whenever they fed.

For one thing, the number of stomachs examined representative of a given set of conditions is usually too small to have much mathematical significance. The number of raptor stomach analyses of which American scientific institutions have record only totals up to a relatively few thousand for all species, and the specimens were collected over a long period of years, taken at all seasons and from all sorts of environments.

While they may give a good general idea as to the kinds of food and the frequency with which they are taken, country-wide examinations of individual stomachs from a versatile feeder like the Horned Owl may fall far short of reflecting the local food habits of the species—which local application, I understand, is one of the primary aims of food habits research. Wholesale stomach examinations cannot be expected to remedy this defect unless maximum consideration be given to dynamic ecological factors which profoundly modify the food habits of at least some species—ordinary fluctuations of native plant and animal populations, ascendencies and declines of exotics, drastic environmental changes brought about by man, fire, flood, drought, deep snows, etc.

It is evident that a definite local program of raptor study based upon stomach examinations would demand each year perhaps hundreds of stomachs if the data were to have high quantitative rating. It is evident furthermore that such an ambitious program might necessitate a heavy killing of birds of prey to supply the requisite number of stomachs, a certain proportion from species already depleted from human persecution or other causes. Irrespective of scientifie ends, undue pressure upon rare or waning species is hardly consistent with the principles of conservation, particularly when many of those species can satisfactorily be studied by less lethal methods.

However, while stomach examination as a major method of study may not be all a method ought to be—no method is—it still remains about the main source of pre- and post-nesting data on Buteos and Accipiters. The Buteos are among the most commonly shot hawks in many communities, notably in the West, and can often be seen strung up on wire fences, nailed to the sides of barns, etc. In cold weather or where dessication occurs without decay and the approximate date of killing can be established by inquiry or by the condition of the carcasses, considerable stomach data can be procured incidental to automobile trips throughout the country and at no further sacrifice to the species. Besides, the opening of a dozen or more Rough-legs and Swainson Hawks in the presence of the farmer who shot them may have decided educational value.

The elusive Cooper Hawks and Sharp-shinned Hawks are of the few of our raptors, which, in view of their apparent ability to hold their own against man and their ill repute—though it should be admitted that we know next to nothing of the true ecological role of these birds—might be collected on almost any reasonable scale at present, *by persons who know hawks*, without foreseeable detriment either to the species or to human interests.

All in all, the investigator should strive to let no hawk or owl stomachs go to avoidable waste, whether those birds were shot wantonly or for an intelligent motive. Why cannot use be made of the uncounted thousands of hawks annually slaughtered along the highways in the southwestern United States? Indefensible as may be the practice of shooting those fine Western Red-tails and Rough-legs for little reason than because they make conspicuous targets on telephone poles, yet the victims have nothing more to lose by having their stomach contents analyzed. And what about the shops of obliging small-town taxidermists as sources of stomach material?

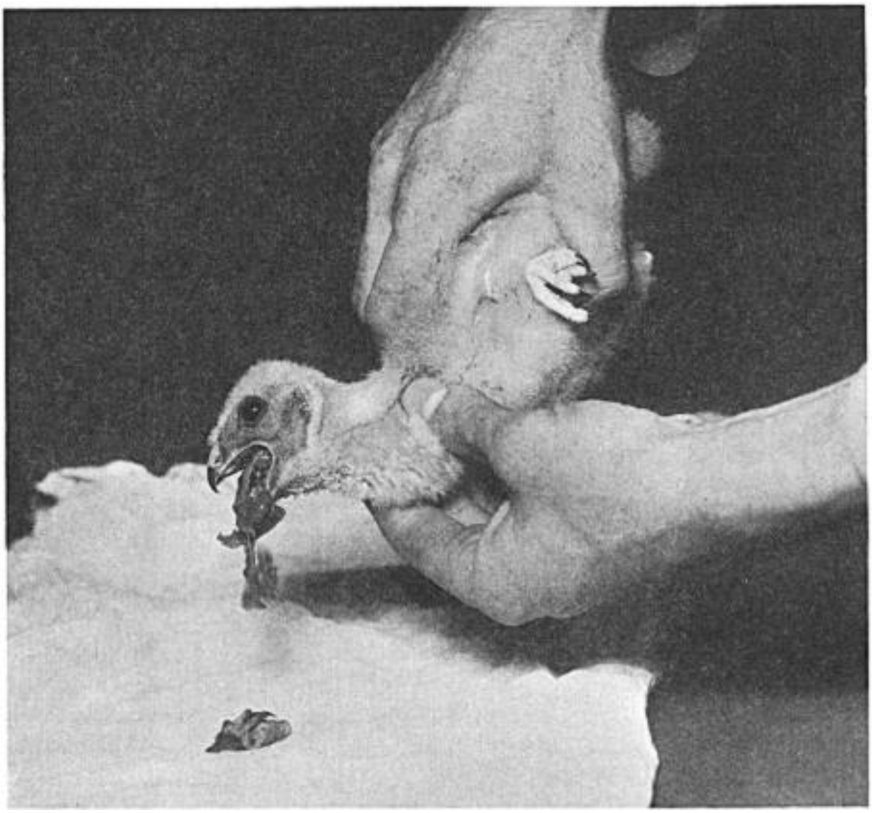

Fig. 12. JUVENILE MARSH HAWK SHOWING TECHNIQUE OF GULLET SQUEEZING.

Gullet examinations. Comparable to stomach examination, but lacking some of the disadvantages, is the gullet examination method of studying the food habits of nestling hawks. Food swallowed by all hawks studied (not owls) did not go directly to the stomach but was retained in the enlargement of the esophagus, functional as the crop, the period of retention varying according to the age and rate of development of the nestling. It was observed in experimental raising of young raptors, that Cooper Hawks one to two weeks old, when well "stuffed" at 8:00 a. m. still had a reserve of food in their crops at mid-afternoon, whereas older juveniles slipped, bit by bit, their gullet contents into their stomachs at a more rapid rate. The same seemed true of Red-tails and Marsh Hawks.

Now this gullet food material can be forced upward and out of the mouths of nestling hawks, day after day, without injury to the birds. (See figs. 12 and 13.) In the 1931 study of Marsh Hawks, the youngsters were robbed of their meals once and twice a day for the duration of the nesting season and for some time afterward.

The young were tethered near the nests when they became well feathered and ready to fly; thus they remained available for study a total of about two months, as the old birds continued feeding them up to a month or so past the date that the young normally would have left.

The quality of the food habits data obtainable by squeezing the gullets of young hawks is considered of the highest excellence. The material is fresh, with meat, bones, skin, fur, and feathers unsubjected to gastric action. The material is representative of the food that the adults regularly bring the young and is fed in sufficiently large pieces to give an analyst something to work with. If the gullet contents, taken together from all the young in a nest, be sorted out and wings, feet, tails, etc., matched up, what appear to be accurate quantitative data may be secured. In all instances where the food of both adults and their young could be checked up on (this was done with no hawks, but with Horned and Barred owls), no major discrepancies in diet were discovered, though it is suspected that the adults eat more of the smaller prey themselves.

The suggestion might be made that young hawks relieved of their meals two or more times a day be force-fed at the last visit in late afternoon or evening, so as not to deprive them completely of their nourishment. Non-diagnostic portions of prey may be fed, or the investigator may carry with him fragments of wild ground squirrels or cottontails (with plenty of bone and liver to furnish the calcium and vitamins essential to healthy growth). Where supplementary feeding is necessary to make up for systematic robbing of the youngsters, precautions should be taken not to feed within eight hours previous to the next visit, to allow ample opportunity for the gullets to become empty of items having no place among the food habits data. The most likely time to find food in the gullets of Marsh Hawks and Cooper Hawks was about an hour before dark or about eight or nine o'clock in the morning, although one could never be assured of reward for all visits after the young attained growth.

Fig. 13. JUVENILE MARSH HAWKS. BIRD ON LEFT HAS GULLET EMPTY, ONE ON RIGHT HAS GULLET FULL.

Pellet examinations. Preliminary experiments in 1930 (Errington, Paul L. The Pellet Analysis Method of Raptor Food Habits Study. Condor, XXXII, 1930, pp. 292-296), in which captive raptors were fed various kinds of prey to determine the analytical value of pellets, showed broadly that pellets reflected quite consistently the food habits of owls, while the pellets of hawks were not so satisfactory. The reason for the comparative inadequacy of hawk pellets has already been indicated: the skeletons of prey did not hold up well under hawk digestive processes. Digestion of bones was especially pronounced in the Buteos, in fast-growing young hawks having high calcium requirements, and in most cases where soft-boned juvenile prey was eaten. Marsh Hawk and Peregrine pellets, though usually inferior to those of owls so far as bones were concerned, may be regarded as the best hawk pellets worked with.

The second summer's experiments (1931) substantiated on the whole the earlier results and were productive of some additional data. Perhaps the most significant experiments were those performed with grown juvenile Horned Owls, by which it was demonstrated that characteristic bones (tarso-metatarsi) of extremely immature quail chicks—chicks as small as 13 grams or about 10 days old—withstood digestion well enough to be recognized in pellets. The tarso-metatarsi of quail chicks 15 to 20 grams in weight could be made out in the pellet debris without difficulty. Birds one-third grown (70 grams) were easily distinguishable in pellets of mixed composition by the larger long bones and mouth parts. If game as delicate as tiny quail chicks leaves recognizable trace, we can surely expect that few items in the diet of adult Horned Owls (and likely the other Wisconsin owls) are apt to escape representation in the pellets. The calcium demands of very young owls, however, were so great that bony material rarely came through, a recently hatched Horned Owlet ejecting at the start boneless pellets on practically any rough diet.

The pellet analysis method is especially suited to the study of owls on account of the ease with which first-rate pellets can often be found. Wild Horned Owls under observation the past two years displayed inclinations to roost in certain trees—usually in the vicinity of old red-tail nests which were eventually preempted—under which roost trees their pellets accumulated. The trees favored were those to which leaves clung during the winter, those the tops of which were entangled with vines, those with broken, hanging tops, or those otherwise promising sanctuary to owls not desirous of spending the daylight hours in the entertainment of crows. Horned Owls were known to alternate between perhaps a dozen trees in an area of a few acres from fall until vegetation leaved out in the spring; when the foliage became uniformly dense they revealed no partiality for any tree unless situated in some strategic relation to the nest.

Long-eared Owls exhibited roost preferences as did Horned Owls. Their roosts were to be found mainly in evergreen clumps or in the willow and alder growths along creeks. In some retreats hundreds of pellets would be in sight at once. Short-eared Owls often perched on particular fence posts, corn shocks, or hay cocks about which their pellets could be picked up. This statement refers only to their winter behavior, for no personal observations on the summer habits of these owls were made. Saw-whets preferred to headquarter (winter) in red cedar patches. Winter data were obtained on four Barn Owls, three of which habitually frequented crevices in an old rock quarry, and the fourth stationed itself in a planting of white cedars. Screech Owls likewise appreciated conifers in winter, retiring also to convenient holes in old stubs. The same seemed generally true of Barred Owls. These latter two—Screech Owl and Barred Owl—have proved the most baffling of resident southern Wisconsin owls to study, for the reason, I think, that they leave pellets in their holes. Whatever the explanation, I have simply been unable to locate their pellets in desirable quantities.

Is there danger of confusing the pellets of one owl with those of another species? A Horned Owl pellet may range in size from a ball ¾ inch in diameter, containing the remains of a single wood mouse, to a club-like mass of bone and fur 6½ inches long and 1¾ inches across. Barred Owl pellets made up of mice may be indistinguishable from Horned Owl and Barn Owl pellets made up of the same prey, and some Barred Owl pellets may resemble those of the Long-eared Owl. It is scarcely conceivable that anyone could tell the difference between Long-eared and Short-eared owl pellets merely by looking at them. Going down the scale, Long-ear pellets grade into Screech Owl, and Screech Owl into Saw-whet. Yes, there *could* be danger, but—

The Wisconsin studies have failed to bring out an instance of one species of owl inhabiting the same roosting territory with another species for any length of time. Aside from wide differences in species habitats, it appears to be the rule that when a small owl ventures into the territory of a large owl, the small owl either ventures out again or ceases functional existence as the original owl. Hence, when a Horned Owl or a Long-eared Owl or a Saw-whet Owl is seen now and then to occupy a given roost, the chances are trivial that the fresh pellets under that roost or adjacent roosts are deposited by any except the regular occupant. And granted that occasional pellets, considered singly and without accompanying data, may be mistakenly identified, pellets in *lots*, from beneath *known* roosts have run more or less typical.

Where identification of an isolated owl pellet is for some reason deemed of special interest, and where the pellet itself does not betray its identity (Horned Owls, for example, feeding on fairly large prey, break heavy bones in a way not possible for less powerful predators), a thorough familiarity with the Strigine fauna of the locality is the greatest—not absolute—safeguard against error. The weighing of probabilities, the finding of a feather or a track in the snow, the following up of some obscure lead, the "playing of hunches," altogether may help one orient what evidence he has until it begins to mean something, even if the evidence from "sign reading" in itself may be glaringly inconclusive. The thought will bear repetition that the foregoing indirect means of tracing the origin of a pellet are suggested for use only under extraordinary circumstances; ordinarily one should reject outright all questionable pellets.

Prospective investigators might be cautioned against gathering up, supposedly as one pellet, fragments of two or more, for such could be ruinous to quantitative data. Where several pellets have been broken and intermixed, as beneath a high Horned Owl roost, some pellets may be pieced together on the basis of size, age, fitting of broken ends, or distinctive coloration. Where the task of putting pellets together again with accuracy is hopeless, all of the pellet material may be gathered up in bulk, and the bones separated out to give the tally of individuals of the prey.

A yet unfathomed weakness in quantitative methods has to do with the correct allowance to be made for the representation of one medium-sized or large kill in more than one pellet. How many meals does a rabbit last a Horned Owl? If domestic chicken remains comprise three Horned Owl pellets, have three chickens been killed, or two, or only one?

Further experiments in 1931, and field work with Marsh Hawks, Cooper Hawks and Red-tails modified little the 1930 conclusions that any prey having distinctive fur, feathers, or scales would probably be represented in hawk pellets and in a condition recognizable by a skilled analyst, regardless of how badly decomposed the bones.

In general it might be recommended—with reservations—that no pellet material save bones be accepted for quantitative studies. I see no way to tell whether a given amount of meadow mouse fur in a boneless pellet represents the fur of one mouse swallowed whole or the accumulated fur of several partly skinned mice. The same principle applies to other species of prey common enough to occur twice or more in one pellet. In addition there is reason to believe that young Red-tails and Marsh Hawks pick up and swallow odd feathers detached from prey eaten at the nest or feeding place days before. A captive Marsh Hawk had exactly this habit, which, if not but the vagary of a captive, may explain the occurrence of meadowlark feathers in an extremely high percentage of juvenile Marsh Hawk pellets, while contemporaneous field observations and gullet examinations showed that no more than 3 per cent of the vertebrates brought in were meadowlarks. Determinations based solely upon bones should obviate the likelihood of such feather contaminations receiving disproportionate emphasis.

Theoretically, though the undigested bones in a given lot of hawk pellets may not represent a fifth or a tenth or a twentieth of the total of animals eaten, since the animals last eaten before the ejecting of the pellets suffer the least digestion, the bones should, according to the laws of chance, come through roughly in the proper prey-to-prey ratio. Actually, allowances must be made when the prey is exceptionally large or exceptionally small (or immature); in the former case bones are not always eaten; in the latter, the bones may be so delicate that they may not last through a rather brief period of digestion. It seems plain, then, that even bone data from pellets of some hawk species may have but meagre, if any, quantitative status.

Pellets of Buteos gave fair qualitative data but poor quantitative. They were difficult to find save in nests, and those from nestlings were the worst to do anything with. Pellets of nestling and juvenile Cooper Hawks seemed all right for qualitative data. I have had no personal experience with pellets from mature Accipiters. Pellets from nestling and juvenile Marsh Hawks are of aid in qualitative work, not so good for quantitative. Spring and fall Marsh Hawk pellets examined (no winter pellets were had) have been richer in bone remains than those of the summer and consequently of greater quantitative value. Of all hawk pellets dealt with, those of the falcons, notably the Peregrine, were adjudged (no experimental work done) the most promising from both qualitative and quantitative standpoints, the pellets at times appearing almost owl-like as to preservation of bony contents. The superiority of Peregrine pellets I am inclined to believe due to more than one ejection a day, possibly attributable in turn to the metabolic demands of an active and skillful hunter.

The technique of tethering. A long-felt weakness in the Wisconsin raptor studies up to 1931 has been the utter lack of certain species data for certain months of the year. The quantitative data pertaining to hawks have been confined largely to the nesting season; pertaining to owls, nesting season plus winter. The nesting data of necessity terminated when the young left the vicinity of the nest. It was apparent that if the young could be prevented from leaving, the period of productive study might be lengthened. This was accomplished by tethering youngsters on the ground where they could be located and fed by the adult birds. By this method a number of gaps in the seasonal food data of some species were filled in.

The tethering method was tried on Horned and Barred owls, Marsh Hawks, Red-tails, and Cooper Hawks. With Horned and Barred owls it worked splendidly, the young of these species still being faithfully cared for by the parents until released August 8. Parent Red-tails and Marsh Hawks were not as devoted as the owls but attended their offspring from a month to six weeks past the time that the latter ordinarily left the nests. Attempts to tether out Cooper Hawks were discouraging, as two out of three young broke their soft, spindly legs in the most comfortable of leather anklets, and the third was soon deserted by the mother. Accipiters are so high-strung anyway that one studying them can never seem to predict exactly what is going to happen.

The apparatus for tethering a hawk or owl consisted of a non-slipping leather anklet wired to a swivel which was in turn fastened to a 12- to 18-inch length of chain. The end of the chain was stapled to the base of a tree for woods raptors, or wired to an iron stake for use with Marsh Hawks. Where pellet studies were depended upon (owls), the youngsters were tethered on sloping ground so that the pellets rolled out of reach of the captives and were not trampled into worthlessness. A slope of around 30° was satisfactory if the site had been cleared of brush, leaves, sticks, etc. Visits to tethered owls at intervals of a week to ten days sufficed unless carrion beetles were active, in which event it became necessary to gather up the pellets two or three times a week. Tethered hawks were visited once or twice a day for gullet contents as long as the visits continued to yield worth-while data. It was also possible after gullet squeezing had ceased to be profitable to check upon hawk food habits in a crude way by examining the pellets of the tethered birds.

There are important precautions that should be taken in the tethering of young birds to insure a minimum of misfortune. All anklets should be of pliable but stout leather, one-half to one inch in width, according to the species to be held, and should be sufficiently loose-fitting that no injury be done to the captive's foot. A little superficial chafing above the toes is nothing to cause concern, if circulation is not impaired.

For small raptor species heavy tether chains are not needed, but it should not be overlooked that chains like those on small steel traps may be unequal to the wear and strain put upon them by Horned Owls. Suitable lengths for tethers can be cut from side sections of worn-out tire chains. Medium weight copper wire has been found adequate for the binding of anklet to swivel and swivel to chain, and likewise for securing the anklet about the tarso-metatarsus of the bird.

The most opportune time to tie up juvenile arboreal raptors is shortly before they are able to launch forth in a true flight, or in other words, when they flap to the ground as an intruder climbs to the nest. Young Marsh Hawks should be caught and tied before they become difficult to locate on account of their sneaking off and hiding in the vegetation.

Although the investigator must reconcile himself to some mortality among his tethered raptors, he can take measures to keep the losses down. If the ground beneath the nest is too much in view of passers-by or over-run by dogs and stock, better places for tethering can sometimes be found 50 to 100 yards distant. Young hawks and owls are able to acquaint their parents as to their whereabouts, within limits. Biological Survey bands spared two tethered Wisconsin owls immediate disaster at the hands of human discoverers, who, while they didn't know what everything was all about, attributed purpose and authority to the bands. Possibly explanatory placards, situated to be seen only if the bird were seen, could be used. Marsh Hawks should be staked where they can draw back on hot days into whatever shade is available. Finally, unless there is good reason why they should not be, the youngsters should be released as soon as it becomes noticeable that the old birds are growing neglectful.

A warning might be interpolated here relative to dealing with powerful young raptors, for the pedal equipment of a grown juvenile Red-tail or Horned Owl can do an incredible amount of damage in an incredibly short time. One should not court injury from parent raptors displaying frenzied anxiety when the sanctity of the nest is violated. The ripping talons of mother Horned Owls are most to be guarded against, but incessantly swooping Marsh Hawks may enliven matters also. No personal difficulty was had with other species.

In all cases where the adults were unusually hostile (there is much individual variation as to temperament), actual attacks were averted by the *mere presence* of a second person. A lone investigator can ward off attacks by a wave of the hand or a flourish of a stick, but he is often in an unhandy position to do this. If one is visiting Marsh Hawk nests alone, he can lie on his back as he chokes up the gullet contents of the nestlings, keeping boot or shoe above him in the air for the parents to strike. Marsh Hawks are too weak to do much slicing anyway. But if one is alone and wants to climb up to a Horned Owl nest, and the old bird sits in the next tree, snapping bill and "talking"—the answer is *don't*! Twice under such circumstances have I been lacerated by Horned Owls.

Interpretation of kills. Of fundamental importance to those carrying on a life history study of a given species is the ability to read sign when a kill of that species is found. This ability is acquired slowly and never can begin to approach perfection, if for no reason other than the imperfection of the sign itself. Always must the investigator watch himself, *lest he find out things that aren't true.*

Perhaps it would be in order to review a specific incident. On December 24, 1930, the remains of a quail were seen in a railroad ditch south of Madison, Wisconsin. The sign was two days old. An empty shot-gun shell lay on the grade 60 feet from the quail and there were two wads on the snow between quail and shell. No shot pattern could be located. Cat tracks were noted about the quail remains, and it was obvious that the cat had partaken thereof. A search in the snow brought up a portion of a quail skull, with marks of two canine teeth where a piece had been bitten off. The tooth marks were too close together for cat.. To the side of the track-beaten space were rather indistinct prints of mink. The canines of a mink skull checked with the marks on the quail skull. But along with the quail skull a wing had been dug out of the snow—a wing showing the typical clean plucking of an accipitrine hawk. Since a wintering Cooper Hawk had been flushed on December 20 from a warm quail killed out of a neighboring covey, the evidence was now about as clear as circumstantial evidence ever is.

This kill, fairly fresh and rendered conspicuous by snow, is illustrative of how in one way or another the fleeting records of the wild fade into illegibility. Suppose that the wing had disappeared, or both wing and skull? Suppose that the kill had not been seen until days later, and the site had been inspected in the meantime by weasel, fox, Red-tailed Hawk and other flesh-eaters not averse to scavenging when that is easier than hunting? Suppose that the kill had taken place in summer, a week previous to discovery, and rains, putrefaction, maggots, ants, and what not, had had their part in the obliteration of the story?

I do not know what are the possibilities for accurate *ex post facto* kill determinations. So far as I am aware, it appears to be a nearly universal trait of raptors (except falcons) to pluck the primaries from avian prey of the sizes convenient for handling, though this doesn't always hold true for larger sizes. Occasionally the entire outlines of raptor beaks were to be seen on primaries of plucked prey, which impressions, if of characteristic size or shape, served well in identification. In the majority of instances, unfortunately—and this has been checked experimentally—there did not seem to be imprints that one would be justified in accepting as wholly diagnostic. There is, too, a dangerous liability of a person seeing amid the confusing array of marks present on almost any set of primaries, evidence of about whatever raptor species he might have in mind. Bill marks of the larger raptors have been the ones most likely to be recognized. On the whole, while I have not been blessed with any spectacular success from the scrutiny of hawk- or owl-plucked feathers, I am convinced that this or some comparable method, reduced to a technique finer than my own, may prove our "best bet" for the solving of old kills.

Of course, the various leads—site of killing and picking, probabilities based on intimate knowledge of local raptor species, habitual and adaptive behavior of the species preyed upon, and sundry minor clues—all may be of assistance, but, in the absence of anything indubitably characteristic, one cannot conclude a great deal with certainty. One should never be hasty in the interpretation of what is to be seen; it is too easy to record opinion as fact. By designating in his notes the data and the specimens that are doubtful, one can spare himself much grief.

Work from predator to game, that is, pellet analyses and other quantitative methods, in connection with the Wisconsin studies, frequently contributed the final check upon kills diagnosed in working from game to predator (sign reading, intensive and prolonged observation of quail coveys, etc.). Of six Ruffed Grouse kills by Horned Owls, pellets corresponding to four as to age and proximity were found. A number of times quail vanished from observational coveys, to be later retrieved from Horned Owl pellets or from nests. How could it be known whether a quail, the remains of which had been found in a Horned Owl pellet, had been taken from one covey or from another, assuming that the quail had not been banded? Familiarity with the current food habits of the surrounding quail population was of great aid in tracing victims to their coveys, on the basis of undigested quail food contained in the pellets.

Experimental technique. The Wisconsin studies with captive raptors, devised to check experimentally certain phases of normal food habits (pellet formation, handling of prey), were beset by trouble from three principal sources: (1) the physical and (2) the psychic condition of the raptor, and (3) the food. Apart from experimentation with very young birds, to which no allusion in this section is intended, *hungry, half-wild, experienced killers* given access to *live prey* were productive of incalculably superior results.

Half-wild birds were most likely to have an optimum balance of independence, resourcefulness, and tolerance toward confinement, and hence most likely to behave naturally. Very wild raptors, especially sensitive hawks bewildered by captivity, were not reliable, nor were always those raised as pets. A very wild Red-shoulder had to be force-fed at each feeding, the effect of which on its gastric economy made an intriguing topic for conjecture. A very tame Red-tail, acting as though obligated to gulp down food given it at any time, was known to eat before ridding itself of its customary morning pellet, thereby causing over-long retention of that pellet, once for several days.

The difference in results arising from the feeding of living and dead prey to the same raptor may be so pronounced as to render valueless some of the conclusions derived from experiments in which this point was not taken into account. A raptor's clutch on dying prey elicits on the part of the raptor a series of reflexes not confined to the killing; responses manifested by jerking out the primaries, tugging at the head, and "mouthing," all more or less bound up with the possession of something alive or very recently alive. Horned Owls and Red-tails given live rats, ground squirrels, quail, or young chickens regularly ate the heads first; if offered the same prey dead and cold they often started eating almost any place on the carcass. Cooper Hawks ate all of the heads except the mouth parts of sparrows which they killed, but discarded whole the heads of sparrows tossed to them dead. Much irregularity in the plucking of primaries of dead birds was also noted.

Why this paper? I labor under no delusions that my methods are entirely new; they most obviously do not represent the last word in raptor food habits technique. I am submitting them for the reason that they have served best of any the purposes of the Wisconsin investigation, and in the hope that they may be of utility to kindred wild life research projects elsewhere. By means of these methods it has been possible to gather large amounts of presumably sound data, despite the fact that the time spent upon birds of prey has been strictly limited by other duties. The food habits of the Horned Owl have been followed through nearly all months of the year, and the methods show equal promise for some other owls. To the study of hawks they have not been so well adapted, but have helped to patch up some of the as yet lamentably ragged seasonal data.

And these are methods which conscientious persons having no special training in analytical work but having economic or esthetic interests in wild life may perhaps find practicable. One engaged in game management, for example, could hardly aspire to the technique of those who make stomach and pellet examination their profession, nor could he be expected to build up a reference collection of bones, feathers, etc., completely adequate for all possible needs. Nevertheless, he could by earnest application familiarize himself with significant anatomical details of common small mammals, game birds, poultry, and other forms of consequence. However unpolished his findings, his specimens, if properly labeled (raptor species, date, and locality, in lead pencil or India ink) and preserved (dry pellets in glassine bags, perishable material in alcohol or 5% formaldehyde), could later be looked over by qualified analysts.

In particular, pellet and gullet examinations for owls and hawks, respectively, with the period of profitable study extended by the tethering of young birds, are productive of the quantitative data imperative to an unbiased insight into the ecology of creatures that eat and are eaten. The ecological viewpoint cannot be over-emphasized if our data are to mean the most. We should not stop with quantitative data any more than we should be satisfied with qualitative. To achieve something of an understanding of raptorial relationships, we must delve deeper.

Does a given predator species take a given type of prey because of preference, because of convenience, or because of inability to take other types? What is inherent in predator species to enhance or to delimit their ability to capture prey: intelligence, patience, persistence, special senses, strength, stamina, speed, agility, facility of movement in the environment of the prey, racial modes of hunting? What are the factors governing the ability of the prey to escape, aside from inherent endowments matching those of predacious enemies? It is not enough to record that on such a date and in such a locality some raptor ate quail. Was the quail mature and in good shape, starved, crippled, diseased, carrion? What was the role of weather, accident, human agencies? The role of food-cover combinations, comparative population densities of quail, predator, and "buffer" species?

That our present research mechanism has not answered—or cannot answer—these questions as well as we might desire, does not preclude any possibility of that mechanism being expanded to do so. If it is not feasible to expand the old mechanism, a new one might conceivably be evolved, not necessarily to displace the old one but to go on from where the old one left off. Ultimately we must look forward to going on.

Madison, Wisconsin, December 7, 1931.