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COMPARISON OF PELLETS VERSUS COLLECTED BIRDS FOR SAMPLING DIETS OF DOUBLE-CRESTED CORMORANTS[1]

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Abstract. For many fish-eating birds, two types of samples can be used to determine diets of adults during both breeding and nonbreeding periods: esophagus and gizzard contents of birds collected at feeding sites, and pellets (indigestible residue) cast up at roosts or breeding colonies. We compared these two methods for Double-crested Cormorants (*Phalacrocorax auritus*) collected on the North Platte River, Wyoming and nesting at a nearby colony both before and after fingerling trout were stocked in the river. Before stocking, there were no significant differences between pellets and collected birds in percent masses of different fish types in different length classes. After stocking, the two methods yielded similar results for different length classes, but differed in relative proportions of suckers and trout. Patterns in percent occurrence of crayfish in the diet suggest that the time of day adults are collected might affect comparability of the two methods.

Key words: diet sampling, Double-crested Cormorant, Phalacrocorax auritus, *fish-eating birds, otoliths, pellets, trout, sucker.*

Two methods can be used to sample diets of adult fish-eating birds during both breeding and nonbreeding periods. The first is analysis of esophagus or gizzard contents from birds that are collected, usually by shooting (Baltz and Morejohn 1977, Ottenbacher et al. 1994, Glahn et al. 1995). The second method is analysis of pellets (indigestible residue) cast up by adults at colonies or roosting sites (Keller 1995, Brown and Ewins 1996). A third type of sample, sometimes combined with pellets (e.g., Craven and Lev 1987), is more recently ingested material regurgitated when birds at colonies are disturbed (Blackwell et al. 1995, Findholt and Anderson 1995). However, when searching a disturbed colony for regurgitations it is often not possible to distinguish regurgitations of adults versus chicks, which might be fed different foods (Harris and Wanless 1993, Veldkamp 1995). In contrast, pellets usually are not produced by cormorant chicks < 7 weeks old (Russell et al. 1995, Trauttsmansdorff and Wassermann 1995, Zijlstra and Van Eerden 1995).

Collecting birds away from colonies or roosts, especially pelagic divers, can be difficult and time-consuming. Also, sensitive population status of the birds or proximity to people can make shooting birds biologically or politically undesirable. For these reasons, sample sizes of colonial diving birds in given months or years are usually < 25 and often < 10 (e.g., Baltz and Morejohn 1977, Kennedy and Greer 1988, Ottenbacher et al. 1994), although greater samples are sometimes possible at wintering concentrations (Glahn et al. 1995). Collecting birds also requires that all important feeding sites be located and sampled.

Gathering pellets at colonies or roosts does not require killing birds, can provide integrative samples of all feeding sites, and can result in larger sample sizes with less time and effort (Veldkamp 1995, Warke and Day 1995). However, this method cannot be used if colonies or roosts are inaccessible (e.g., on cliffs), are directly over water where pellets cannot be retrieved (on pilings, etc.), or have too few birds to yield enough pellets in a given period. Also, disruption of colonies while gathering pellets, causing increased predation on eggs and young and nest abandonment, might often have greater impacts on bird populations than shooting adults away from colonies (Bunnell et al. 1981). For cormorants, the latter problem is especially great in areas such as the Intermountain region of western North America, where colonies often contain only 20–200 cormorant nests (Findholt 1988) and many depredating gulls.

Otoliths (hard inner-ear bones of fish) found in pellets or collected birds often are used to identify fish species and estimate lengths of fish remains (Craven and Lev 1987, Martucci et al. 1993, Veldkamp 1995). However, in some studies of captive cormorants, digestive acids partly or completely dissolved some otoliths. These changes caused underestimates of size for larger fish and of total numbers of smaller fish, and distorted the apparent species composition of prey (Johnstone et al. 1990, Harris and Wanless 1993, Veldkamp 1995). Other workers have concluded that these effects are negligible (Martucci et al. 1993), do not apply to field situations (Zijlstra and Van Eerden 1995), and can be largely eliminated by excluding otoliths that are clearly eroded (Suter and Morel 1996). Regardless of these concerns, otoliths continue to be used (Suter 1995, Veldkamp 1995, Warke and Day 1995) because they greatly increase the number of food items identified.

Despite variations in desirability and possibly results of pellets versus collected birds, the two methods have not been compared at the same location and time during known changes in prey availability. We performed such an analysis for Double-crested Cormorants (*Phalacrocorax auritus*) feeding on an inland coldwater riv-

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er before and after the river was stocked with fingerling trout.

METHODS

Our study was conducted on the North Platte River near Casper, Wyoming, and on two nesting islands in Soda Lake, 2.5 km north of Casper. Nesters included both Double-crested Cormorants (maximum of 243 and 77 pairs on the two islands, respectively, in 1994) and several hundred pairs of California Gulls (*Larus californicus*). The 83-km section of river upstream of Casper to Gray Reef Dam was stocked on 27 June 1994 with 54,100 rainbow trout (*Oncorhynchus mykiss*) and 38,900 cutthroat trout (*O. clarki*), both species 11.4–12.6 cm long.

From this section of river, we shot and collected 12 cormorants from 2 to 23 June, and 11 cormorants from 30 June to 14 July. In the previous year, we found that cormorants collected while actively foraging often had empty esophagi and gizzards, whereas birds collected while drying their wings (typically on rocks in the river) usually contained food.

Fresh pellets (moist, mucus-coated capsules cast up by adult birds; Harris and Wanless 1993) were gathered from both nesting islands before trout stocking on 24 June (31 pellets) and after stocking on 1 July (15 pellets). Lack of vegetation, high densities of cormorant nests, and many breeding gulls made these colonies very sensitive to human disturbance; visits every other week caused complete abandonment of one of the islands the previous year. Thus, we restricted pellet collection to single visits before and after stocking. The colony was searched between 06:30 and 07:30 to minimize heat stress on nestlings not brooded during our presence.

We gathered pellets only in the area of cormorant nests, which were generally < 1 m apart. In over 200 hr of dawn-to-dusk observations during incubation and early brood-rearing the previous year, the dense nesting areas were seldom if ever entered by adults that were not obviously paired. In studies of Great Cormorants (*Phalacrocorax carbo*) and European Shags (*P. aristotelis*), chicks < 7 weeks old did not produce pellets, apparently digesting all calcareous materials (Russell et al. 1995, Trauttmansdorff and Wassermann 1995). These results indicate that fresh pellets we collected were mostly from nesting adults. To exclude pellets from earlier periods, we did not analyze dry pellets that were presumably over 2 days old. We also did not analyze regurgitations of recent ingesta found while searching for pellets, because both chicks and adults can regurgitate during disturbances.

From cormorants collected on the river, we removed the esophagus and gizzard as soon as birds were retrieved, and stored them in a cooler for 1–4 hr before processing. In the laboratory, food contents were removed by thorough rinsing, whole fish were identified and measured, and otoliths were retained for analysis. Otoliths were later mounted in epoxy on microscope slides, and sanded (without prior sectioning) with 600-grit sandpaper to expose growth rings. Mounted otoliths were examined at 40× magnification under a compound microscope, and the maximum distance between the center of the nucleus (Williams and Bedford 1974) and the edge of the thick end of each otolith was measured with an ocular micrometer. This method was intended to reduce error in measurements of total otolith length caused by variable erosion of the opposite, thinner end of the otolith. We also excluded from analysis otoliths that were clearly eroded (Suter and Morel 1996). Total fish length was estimated from separate regression equations relating otolith radius to total fish length for trout, suckers (*Catastomus commersoni* and *C. catastomus*), and minnows (mainly *Rhinichthys cataractae* and *Pimephales promelas*) (Derby and Lovvorn 1997). Fresh masses of fish in each length class were calculated from allometric equations of mass versus total length for samples of whole fish of the different species.

In both pellets and collected birds, we matched pairs of otoliths (two occur in each fish) whenever possible, so numbers of fish analyzed equaled the number of matched pairs plus the number of unmatched otoliths. These sucker species do not eat fish, nor do rainbow trout in all studies to date in Wyoming (e.g., Hubert et al. 1994); electroshocking on 9–10 May 1994 revealed almost no cutthroat trout of piscivorous size in the study area. Thus, otoliths in diet samples probably did not result from otoliths in the stomachs of prey eaten by cormorants. Percent masses of each fish type (trout, sucker, minnow) in each of five length classes (8-cm intervals from 0 to 40 cm) were calculated for each individual sample (pellet or collected bird) (aggregate percentage method of Swanson et al. 1974). Crayfish (Cambaridae) and tiger salamanders (*Ambystoma tigrinum*) could not be counted based on miscellaneous fragments, so for these foods we recorded only percent occurrence (percentage of individual samples containing the food item).

To test for differences between sampling methods in percent masses of fish in different length classes, we performed analyses of variance (ANOVA) with PROC GLM (SAS Institute Inc. 1987). We used arcsine square root transformations to stabilize variances. For percent occurrence of crayfish and salamanders, we used percentage tests (Sokal and Rohlf 1981).

RESULTS

In both pellets and collected birds, prey items consisted of trout, suckers, minnows, crayfish, and salamanders. We first examined overall variations between pellets and collected birds in percent masses of different fish types in different length classes (Fig. 1). Before trout stocking, a 3-way ANOVA (method × fish type × length class) showed that percent mass differed only among fish types ($P < 0.01$), with no effects of method, length class, or any interactions (all $P > 0.14$). After stocking, percent mass was again unaffected by sampling method overall ($P = 0.53$ for main effect), but results of the two methods differed depending on fish type ($P < 0.01$ for method × fish-type interaction, $P = 0.15$ for method × length interaction). Consequently, we used two-way ANOVAs (method × length) within each fish type separately after stocking. For trout and suckers separately, effects of method, length, and their interaction were all significant (all $P < 0.04$), whereas for minnows there was no main effect of method or interaction of method with length

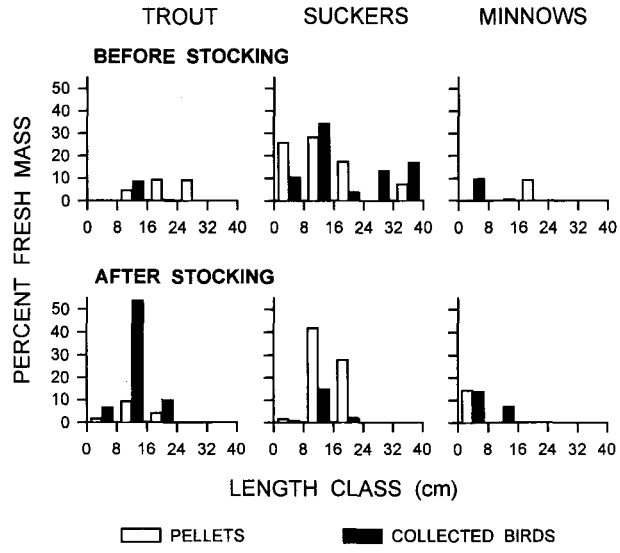

FIGURE 1. Percent fresh masses of fish in pellets gathered at nest sites, and in esophagi and gizzards of cormorants collected on the North Platte River, before and after trout stocking on 27 June 1994. Sample sizes before stocking were 31 pellets and 12 collected birds, and after stocking were 15 pellets and 11 collected birds. Total numbers of fish were 18 for pellets and 61 for collected cormorants before stocking, and 49 for pellets and 209 for collected cormorants after stocking.

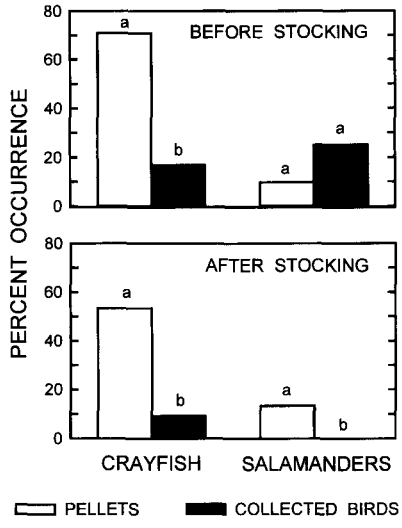

FIGURE 2. Percent occurrence (percentage of individual samples that contained a prey item) of crayfish and salamanders in pellets gathered at nest sites, and in esophagi and gizzards of adult cormorants collected on the North Platte River, before and after trout stocking on 27 June 1994. Sample sizes as in Figure 1. Within period and prey type, bars sharing the same letter are not significantly different (percentage tests, $P > 0.05$).

(both $P = 0.68$; $P < 0.01$ for main effect of length). Thus, the two methods differed mainly after stocking, owing mostly to more trout 8–16 cm long in collected birds and more suckers 8–24 cm long in pellets (Fig. 1).

Percent occurrence of crayfish was higher in pellets than in collected birds both before trout stocking (71% vs. 17%) and after stocking (53% vs. 9%) (percentage tests, $P < 0.01$, Fig. 2). Percent occurrence of salamanders did not differ between pellets (10%) and collected birds (25%) before stocking ($P = 0.09$), but was higher in pellets (13%) than in collected birds (0%) after stocking ($P = 0.02$).

DISCUSSION

Comprehensive aerial surveys (Derby and Lovvorn 1997) revealed no sites other than Soda Lake and the North Platte River with appreciable numbers of cormorants, and Soda Lake was too saline to support trout and suckers. Thus, differences between methods in fractions of trout and suckers (Fig. 1) were probably not influenced by feeding away from the river. Possible explanations include (1) sucker otoliths are less easily digested and persist longer until pellet ejection the following dawn and (2) cormorants foraged mostly on trout early in the day before the typical time of collection, but fed mainly on suckers in the afternoon.

Because of partial or total digestion, otoliths sometimes underestimate fish length and alter relative numbers of different species (Johnstone et al. 1990), but this effect is not always observed (Martucci et al. 1993). We measured otolith radius rather than total length to minimize effects of digestion of the thinner end of otoliths (see Methods), and used fairly broad

length classes to minimize incorrect placement of fish in the next lower class. Zijlstra and Van Eerden (1995) argued that much of the differential digestion of otoliths found in captive cormorants results from higher gastric secretions in birds stressed by experimental conditions, and that such findings do not apply to wild birds. Because the difference between trout and suckers between methods was not evident before stocking but was large after stocking, we feel that differential digestion was not the major explanation.

Patterns of crayfish occurrence suggest that the time of day birds are collected might be important. Presence of crayfish in diet samples was easily detected by the distinctive reddish color of such samples, even when there were few recognizable body parts. Thus, we feel that differences in crayfish occurrence between sampling methods (Fig. 2) were minimally affected by differential digestion. Adult cormorants usually eject one pellet per day in the morning before leaving colonies or roosts to feed, and all indigestible materials appear to be expelled at that time (Russell et al. 1995, Zijlstra and Van Eerden 1995). Thus, pellets integrate meals of adults over an entire day. In contrast, we collected most cormorants on the river before noon, during a feeding period after the morning pellet ejection. Greater occurrence of crayfish in pellets than in collected birds suggests that cormorants fed on crayfish later in the day than most birds were collected, fed at sites away from the river where no birds were collected, or both. Given the lack of alternative feeding sites, crayfish were probably taken in the afternoon from either the river or Soda Lake, after a morning feeding session on the river. Data on salamander occurrence (Fig. 2) also suggest that patterns of prey taken, rather than variable digestion, were the main cause of differences between methods. Several studies of gulls have shown diel schedules in prey types delivered to chicks (see Discussion in Brown and Ewins 1996), which also may reflect foraging patterns and diets of adults. No studies have addressed possible differential regurgitation of foods for chicks, which might affect the gut contents of adults before and after feeding young (collected birds versus pellets, respectively).

Regardless of why they occurred, the differences between methods are important in evaluating impacts of birds on stocked trout. Pellets alone would indicate no appreciable shift in diet after stocking, and effects of cormorants on trout would appear low (Fig. 1). If only collected birds were used, it would appear that cormorants shifted to eating stocked trout with substantial impacts.

Aggregate percentages, in which percent compositions are calculated for each individual sample (Swanson et al. 1974), have some shortcomings. Because relative sizes of individual samples are not considered in calculations, samples with very small total masses and perhaps revealing less about diets have equal weight with very large samples with more extensive contents. For example, a cormorant that has been relatively unsuccessful at foraging before being collected in the morning might contain only a few fish that do not represent the composition of larger, adequate meals. However, this sample has the same influence on aggregate percentages as another more successful bird containing a more typical, adequate meal. Pooled samples avoid this problem and can yield appreciably different results (as in our case), but provide lower power for statistical tests. This discrepancy between analytical approaches is not solved by increased sample size.

For aggregate percentages, larger sample sizes of pellets and collected birds might reduce differences between sampling methods. However, larger samples would require much greater expense to collect birds and probably substantial disruption of nesting activities because of more frequent visits to the colony. Our searches for pellets were quite thorough, and are representative of samples attainable in single visits to colonies of this size (~200 nests). Our results are based only on Double-crested Cormorants in such environments, and should not be extended uncritically to other cormorant species or habitats. However, in sampling diets to evaluate effects of cormorant predation on fish, we suggest that collected birds and pellets gathered at colonies can lead to different inferences, and that daily schedules of hunting for different prey might explain such patterns.

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