STUDY AREAS

Field work for this study was conducted in the Front Range of the Rocky Mountains near Boulder, Colorado. For general discussions and references on the topography, climate and vegetation of this area, see Gregg (1963), Paddock (1964), and Marr (1967). Dipper populations on two streams, Boulder and South Boulder Creeks, were selected for intensive study (see Fig. 1).

The two study areas are generally representative of Front Range streams; they are fast-flowing, clear, rocky-bottomed creeks. Both flow east from headwaters at 3300–4000-m elevation along the continental divide, dropping rapidly for some 40 km to emerge suddenly from narrow canyons onto the plains at approximately 1650 m. Boulder Creek flows through the town of Boulder, and South Boulder Creek through the small community of Eldorado Springs before they join and eventually enter the South Platte River (Fig. 1). Because Dippers require pristine mountain streams, they do not extend more than a few kilometers onto the plains. Humans have damaged the habitat by mild pollution and some channelization, but have also improved it by constructing bridges which serve as excellent Dipper nest sites, and, on Boulder Creek, by constructing a hydroelectric plant which keep much of that stream ice-free in winter.

The two principal study sites were divided into 400-m segments, which were numbered from downstream to the tops of the study areas (49 for Boulder and 23 for South Boulder). Throughout the rest of this paper we will use "segment" to refer to these divisions of the study sites.

South Boulder Creek Study Area

The South Boulder Creek site extended 9.3 km from the Colorado Department of Water Resources gauging station at 1920 m elevation down to an irrigation ditch at 1670 m (Fig. 2). The stream's drainage basin encloses a total of 308 km^2. The upper 0.5 km of the study area (segments 23–22) has been disturbed by construction of the Moffat Diversion Dam which backs up a small reservoir for diversion to the city of Denver. There is ample flow below the dam to maintain a natural stream environment.

The next 2.6 km (segments 22–16), from the Moffat Dam to South Draw (Fig. 2), is relatively undisturbed. The slope is 2.3%, the substrate is mostly rubble, and there are many emergent rocks. The banks are extensively lined by willow (*Salix*), alder (*Alnus*), and occasional ponderosa pine (*Pinus ponderosa*) and narrowleaf cottonwood (*Populus angustifolia*).

The section from South Draw 1.0 km downstream to Rattlesnake Gulch (segments 16–14) has been severely disturbed by flood control channelization for a small group of houses and a campground. The slope is still gentle (2.0%), but there is little vegetation along the banks, and the creek bottom is mostly small rubble with few emergent rocks.

The 0.8 km below Rattlesnake Gulch to just above the town of Eldorado Springs (segment 14–12) is steep (10.0% grade) and narrow, with little quiet water. There has been some disturbance of the south bank by road construction, but even on the undisturbed side there is only moderate vegetative cover. The creek bed probably has always been mostly boulders.

At this point South Boulder Creek emerges from its canyon and for the next

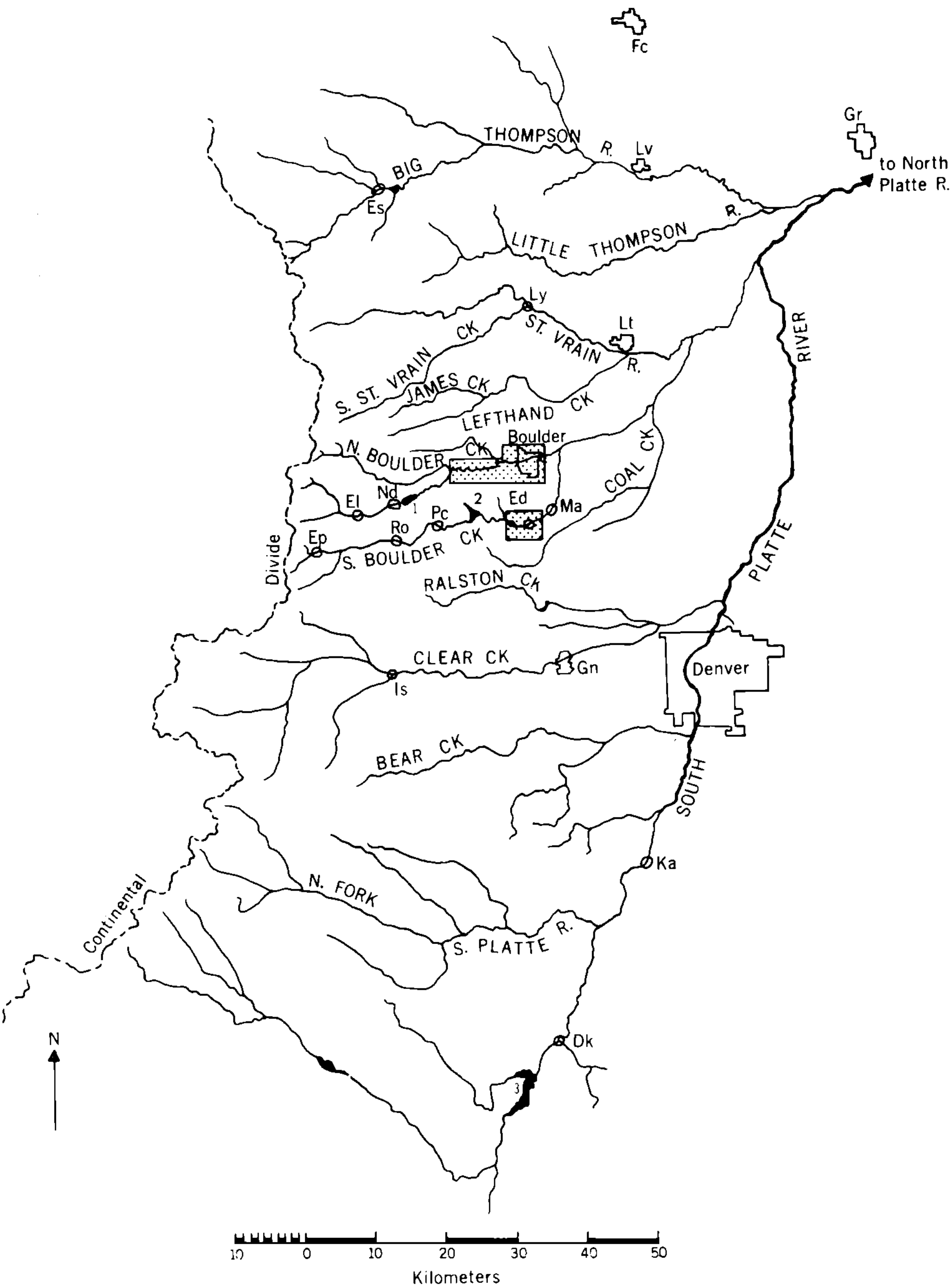

FIGURE 1. General map of study area. Shaded areas enclose intensive study areas shown in detail in Figures 2 and 3. (Abbreviations of towns from north to south: Fc, Fort Collins; Es, Estes Park; Lv, Loveland; Gr, Greeley; Ly, Lyons; Lt, Longmont; El, Eldora; Nd, Nederland; Ep, East Portal; Ro, Rollinsville; Pc, Pinecliff; Ed, Eldorado Springs; Ma, Marshall; Is, Idaho Springs; Gn, Golden; Ka, Kassler; Dk, Deckers. Reservoirs: 1, Barker Reservoir near Nederland; 2, Gross Reservoir near Eldorado Springs; 3, Cheeseman Reservoir near Deckers.)

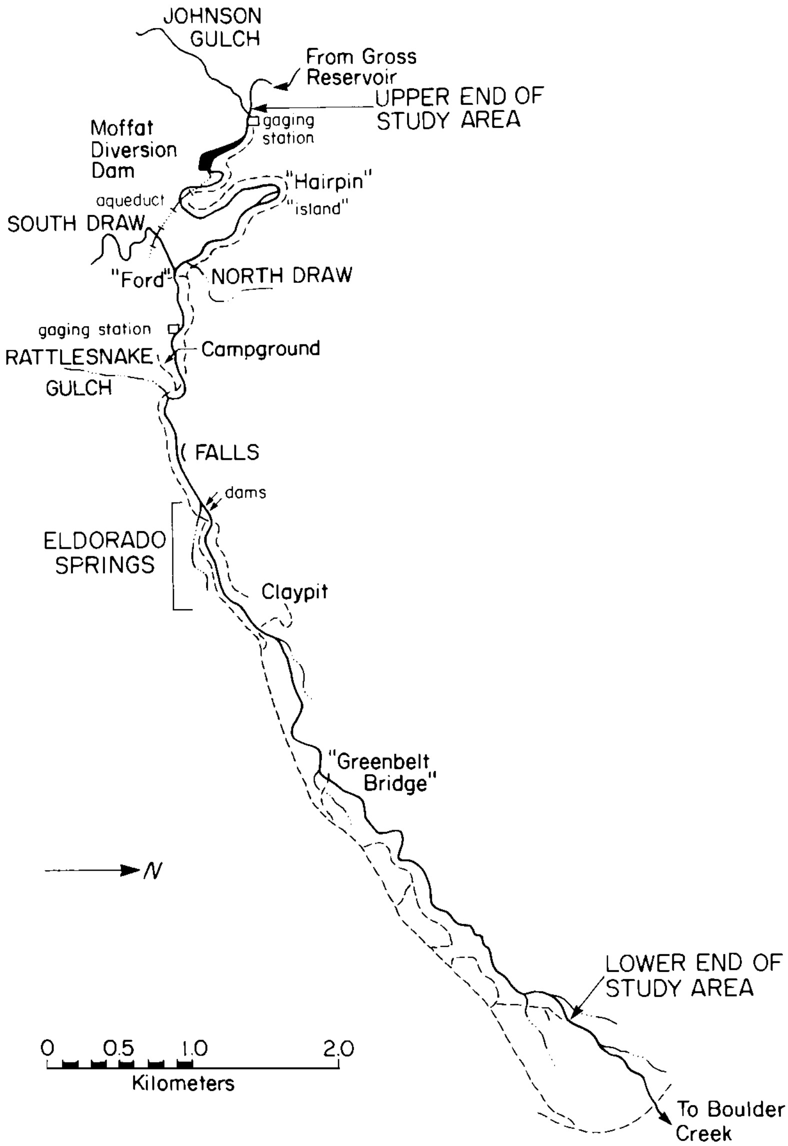

FIGURE 2. Map of South Boulder Creek study area. (The stream and major tributaries are represented by solid lines, roads by dashed lines, and intermittent streams and irrigation ditches by dashed and dotted lines.)

0.8 km (segments 11–10) flows through the community of Eldorado Springs. Despite some dumping of trash and about 200 m of channelization above the claypit bridge (Fig. 2), the town has relatively little effect on the stream. The bottom is rubble, with many emergent rocks, and the slope is 3.8%. There are small thermal springs at the western end of Eldorado Springs which keep a variable length of stream open and habitable for Dippers in winter.

In the remaining 3.7 km of the study area below the claypit (segments 10–1) the slope is 1.6%, the bottom excellent, food abundant, and banks almost completely lined by undisturbed riparian woodland of cottonwood, willow, alder, and box elder (*Acer*). There is some residential development along the south bank in the lowest 1.9 km.

Below the study site, irrigation and civic water supply ditches cause severe dewatering except during spring runoff. The remaining 9.7-km section, before South Boulder joins Boulder Creek (Fig. 1), is increasingly inhospitable for Dippers because of dewatering in early spring and late summer, channelization, and subdivision construction.

Width of the stream varies from less than 1 m in the narrow canyon to over 15 m in the bottom section. Depth varies from a few centimeters to more than 2 m. Mean daily discharge during the study ranged from 0.08 m^3/sec in late February and early March 1971 to 12.3 m^3/sec on 27 and 28 June 1971 (Colorado Department of Water Resources, pers. comm.).

Boulder Creek Study Area

The Boulder Creek study area extended 20.0 km from the junction of Middle and North Boulder Creeks at 2100 m elevation down to the Boulder sewage plant outflow at 1600 m (Fig. 3). Area of the drainage basin totals 290 km^2. The vegetation is similar to that of South Boulder Creek. Boulder Creek has no steep areas comparable to South Boulder Creek and has been more heavily modified by humans.

The upper 2.7 km from Boulder Falls to Black Tiger Gulch (segments 49–43) is the steepest, with an average grade of 7.7%. This area has been disturbed comparatively little, although in places the stream bed was narrowed during road construction.

The 7.6 km from Black Tiger Gulch to the bridge below the junction with Fourmile Creek (segments 43–26) is the least disturbed physically. It has a gentle slope (2.8%) and more rubble substrate than the section above. There is slight pollution from a septic system below Lost Gulch, but this is rapidly diluted.

The 2.4 km from the bridge below Fourmile Creek to the junction of Arapahoe Road and Canyon Boulevard (segments 25–18) is slightly steeper (2.9%) and is severely damaged. Road construction has narrowed the stream bed and filled it with large boulders, retaining walls have been built to retard bank erosion, and several large areas have been channelized and have little streamside vegetation. The first of many irrigation ditches begins dewatering the creek.

Just below the road junction the creek emerges from its canyon and flattens to a 1.4% grade. The city of Boulder occupies 5.3 km of the stream bank. In the 2.0 km above the Broadway bridge (segments 18–14) the creek is in good condition. It runs through a mixture of residential areas and parks and is relatively undisturbed. Just below the bridge, however, an irrigation ditch may almost completely dewater the stream in early spring and late summer. In the 3.2 km from Broadway to the east Arapahoe Road bridge (segments 13–5) Boulder Creek is severely disturbed by polluted drainage from a gas station just below the ditch, and by flood-control channelization. For more than half of this stretch there is no streamside vegetation, the bed is bulldozed, and, except during periods of dewatering, there are few emergent rocks.

In the 1.9 km from the easternmost Arapahoe Road bridge to the sewage outflow

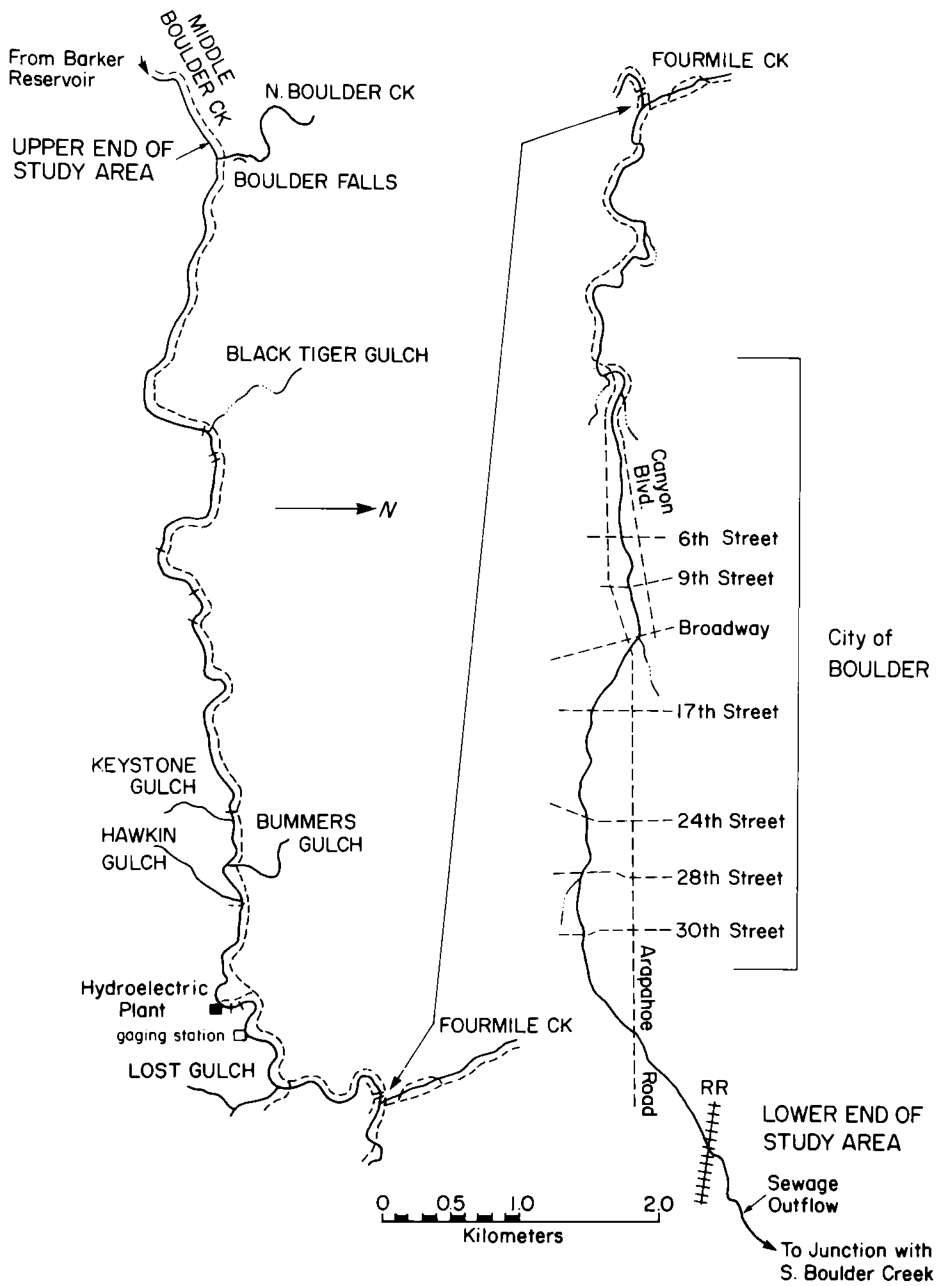

FIGURE 3. Map of Boulder Creek study area. (The stream and major tributaries are represented by solid lines, roads by dashed lines, and intermittent streams and irrigation ditches by dashed and dotted lines. Note that this map has been divided at Fourmile Creek to conserve space.)

TABLE 1
COMPARISON OF HABITAT QUALITY AND POPULATION DENSITY OF STUDY AREAS

Habitat measure	Study area: Boulder Creek	South Boulder Creek
Mean width index/segment[a]	3.39	3.42
Mean cover index/segment[a]	2.82	3.17
Mean bottom index/segment[a]	2.67	3.47
Mean food density index/segment[a]	3.01	17.22 (segments 1–23) 5.82 (segments 10–23)
No. quality 3 nest sites/km[a]	0.85	1.86
Breeding density/km		
1971	1.12	1.62
1972	1.47	1.73
1973	0.96	1.40
All years: Mean ± SD	1.18 ± 0.26	1.58 ± 0.17
CV[b]	0.22	0.11

[a] See Methods section for explanation of indices.
[b] Coefficient of variation.

(segments 5–1), Boulder Creek itself is relatively undisturbed. It flows through riparian woodland and has a canopy of cottonwoods, although there are few shrubs along the banks because of grazing by cattle. There is a good rubble bottom and enough groundwater enters the stream bed to maintain some flow even during severe dewatering. From the sewage outflow to the junction with St. Vrain Creek (Fig. 1) Boulder Creek is severely polluted, increasingly sandy, and not Dipper habitat.

Perhaps the most important human influence on Boulder Creek is the Colorado Public Service Company hydroelectric plant in about the middle of the study area (segment 30). That plant, which gets its water via a pipeline from Barker Reservoir (Fig. 1), provides power only during periods of peak demand, during which its discharge may raise the water level of Boulder Creek 0.5 m or more, with a maximum discharge 5.7 m^3/sec (Colo. Public Service Co., pers. comm.). These rapid fluctuations in water flow keep the stream ice-free below the plant and provide critical winter habitat that would otherwise be unavailable to Dippers.

The width of Boulder Creek varies from 1.2 m in the upper canyon to over 20 m in the lowest channelized portion. Depth varies from a few centimeters to over 2 m. Mean daily discharge during the study ranged from 0.104 m^3/sec on 31 December 1971 to 19.2 m^3/sec on 20 June 1971 (Colo. Dept. Water Resources, pers. comm.).

COMPARISON OF BOULDER CREEK AND SOUTH BOULDER CREEK STUDY AREAS

In general, South Boulder Creek had better habitat than Boulder Creek. Table 1 contains summaries of width, bottom, cover, and food-density indices for the two study areas, along with density of good nest sites and density of breeding birds (see section of Methods for definitions of indices). South Boulder Creek clearly was better by all of these measures. Note especially that it had densities of breeding birds that were 34% higher, but only half as variable as those on Boulder Creek.

Other Study Areas

In addition to the intensive study areas on Boulder and South Boulder Creeks, portions of both streams up to elevations of 3050 m were visited periodically, especially during the breeding season. Once we discovered that local Dipper populations were more mobile than expected, we made irregular visits to Lefthand, St. Vrain, and Clear Creeks, to the South Platte River below Deckers, and occasionally to the Big Thompson River, Coal and Ralston Creeks, and many small streams near the continental divide (Fig. 1).

METHODS

Principal objectives of this study were 1) to describe population dynamics of the Dipper, especially density, dispersion, territoriality, movements, mortality, and recruitment; and 2) to relate these to quantified resources and environmental variables. Methods used for the first objective were relatively standard: banding, censusing, mapping territories, and monitoring nests. An advantage of studying Dippers is that these methods are less time-consuming than with most species. Resulting extra field time and the nature of the species' habitat and feeding habits made it possible to quantify resources and various factors of the abiotic environment for the second objective.

Data were collected from 7 February 1971 to 27 July 1973 on a total of 472 field-days: 306 and 192 days, respectively, for the Boulder and South Boulder Creek study areas, and 68 days for other areas. Because amount of effort may affect quantity of various data, several indices of monthly effort were tabulated. In most cases amount of effort did not correlate with variation in data. Daily summary maps were prepared, listing observers, areas of stream covered, numbers and identities of birds seen, and status of nests visited. Information on identified birds was transcribed onto individual bird data sheets and maps. Data on nest construction, dates and numbers of eggs, nestlings, and fledglings were tabulated on individual nest summary sheets.

Maps and Measurements

Study area maps (used for individual records and summaries) were traced from United States Geological Survey 7.5-minute topographic maps. Some distance measurements were made to the nearest 0.1 km on the original topographic sheets with a measuring wheel. Territories were measured in the field using a 50-m steel surveyor's tape. Elevation measurements of nest sites (variable ELEV; see Table 2) were taken directly from topographic maps.

Banding

Because of the importance of identifying individuals in a study such as this, we made every effort to band as many Dippers as possible. In all, we banded 558 individuals. Of these, 341 were captured on our study areas and 217 at higher elevations on the study streams or on the nearby drainages of Lefthand Creek, St. Vrain Creek, and the Big Thompson River. Adults were captured by chasing them into a mist net stretched across the stream. Nestlings and some females were hand-captured by climbing to the nests with a ladder or rock-climbing equipment. Nestlings were banded before 14 days of age, because older nestlings