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THE DISTRIBUTION AND STATUS OF THE FLATTENED MUSK TURTLE, *STERNOTHERUS DEPRESSUS* (TESTUDINES: KINOSTERNIDAE)

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THE PREVALENCE AND INTENSITY OF *PERKINSUS MARINUS* FROM THE MID NORTHERN GULF OF MEXICO, WITH COMMENTS ON THE RELATIONSHIP OF THE OYSTER PARASITE TO TEMPERATURE AND SALINITY

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ABSTRACT

A survey of the distribution and local population densities of the flattened musk turtle, *Sternotherus depressus*, was conducted in the Black Warrior River drainage of Alabama in 1983. A total of 577 *S. depressus* was collected at 36 (53%) of the 68 sites sampled; 18 (26%) sites had moderate to high density populations, and 8 (12%) other sites supported populations regarded as between low to moderate in density. One 1.6 km stretch in the Sipsey Fork, Bankhead National Forest, Winston County, supported the highest density population yet recorded: 237 *S. depressus* were collected in 3 days. Several of the sites from which the animal previously was reported to have been extirpated or absent produced specimens during the present study. Extensive sand deposits were a major physical component of most of the high density sites, contrary to what has been considered optimal *S. depressus* habitat. Major threats to the species were determined to be agricultural influence, surface mining, forestry practices, commercial collecting, and municipal and industrial pollution. State legislation (1984) now prohibits collection other than by permit for scientific study. Because population numbers are low or appear to be declining across large portions of the species' range (including habitats formerly occupied), we conclude that the status of *S. depressus* should be monitored. However, we believe that the available evidence, including the recent discovery of several high density populations in the northern part of the range, does not support a threatened or endangered listing at the time of this writing. Additional observations on habitat, daily activity patterns, predation and health are also presented.

INTRODUCTION

The flattened musk turtle, *Sternotherus depressus*, was described by Tinkle and Webb (1955) on the basis of specimens collected "in the Mulberry Fork of the Black Warrior River, 9 miles east of Jasper, Walker County, Alabama, near the bridge crossing of U.S. highway 78—a sluggish tributary of the Black Warrior River." Since then *S. depressus* has been collected by scientists only sporadically, and its geographical range has been determined to be permanent streams of the Black Warrior River system above the Fall Line (Iverson, 1977). Thus, its entire range lies within Alabama and, more importantly, within the Warrior Coal Basin. The secretive nocturnal nature, restricted range, reported commercial exploitation in recent years, and general lack of information regarding this turtle have led some conservationists and herpetologists to question the overall population status of the turtle and its chances of continued survival (Iverson, 1977; Mount, 1975, 1981). Within the range of the flattened musk turtle extensive surface mining, forestry, and agriculture occur, and several of the major streams have been impounded. Iverson (1977) thought that elimination of fast water environments by impounding was detrimental, and Mount (1981) suggested that acid runoff from mines and siltation from mining, logging and agriculture have been harmful to the turtle. Unfortunately, little is known regarding the basic biology of *S. depressus* or the status of existing populations. Studies on the species' biology and distribution are limited to those of Tinkle and Webb (1955), Tinkle (1958), Estridge (1970), Close (1982) and Mount (1981).

The Office of Endangered Species, United States Fish and Wildlife Service, in 1981 contracted Dr. Robert H. Mount, Auburn University, to determine the status of the flattened musk turtle. In his report, Mount (1981:80-81) concluded that "(1) *depressus* has probably been extirpated from about 220 miles of its former stream habitat; (2) about 101 miles of habitat have been degraded to the extent that the probability of *depressus* occurring and/or being able to maintain viable populations within it is very low; (3) about 349 miles of habitat are marginal in supportive capacity, and that while *depressus* may now occur, its ability to survive under the current conditions ranges from questionable to doubtful; and (4) about 142 miles of free-flowing stream habitat are of sufficiently high quality to continue to support healthy, viable populations of *depressus*." According to Mount (1981:81), the single greatest threat is siltation, and he placed the major blame for this on surface coal mining. On the basis of Mount's report, a federal process to list *S. depressus* as "threatened" was begun. The present study was initiated in an attempt to provide additional data regarding the current status of the species and to gain some knowledge of the waterways in which it lives.

It should be noted that Seidel et al. (1986) have recently proposed placing the genus *Sternotherus* in the synonomy of *Kinosternon*. For purposes of general familiarity, however, this paper retains the taxon *Sternotherus*.

METHODS AND MATERIALS

Field work extended from 15 June 1983 until 9 September 1983. Initially (15 June-ca. 15 July), stream conditions were poor for collecting because of high water levels. Rainfall during the first half of the year within the Warrior Basin averaged 22.5-25.0 cm above normal. Thereafter, precipitation decreased dramatically and water levels subsequently declined. Collecting conditions had greatly improved by 15 July and generally remained conducive for trapping and/or wading for the remainder of the study period.

Several methods were utilized in collecting specimens of *S. depressus*. These are in order of decreasing effectiveness: trapping, nocturnal wading with a lantern, diurnal wading, seining, raking and seining through weed beds, and snorkeling.

Traps used were very similar to those previously utilized and described by Mount (1981; after Iverson, 1979) and differed only in that 18 mm mesh rather than 25 mm mesh chicken wire was used. Several designs of traps constructed from corrugated plastic pipe (20 cm and 30 cm diameters) were tested following discussions with several persons who recommended traps with dark interiors. These were later discarded, in favor of the lighter and more easily manipulated wire traps, when results indicated no significant differences in success between the two types.

Traps were set in a wide variety of microhabitats between 1500 hours and 1900 hours and recovered early the following morning. Depending upon logistics, between 30 and 60 traps were set per night (normally 15-20 traps per site). In most instances, traps were spread over a 300-500 m stretch of stream and left undisturbed for 12 to 18 hours. Successful settings ranged in depth from 25 cm to 450 cm and included areas of extremely fast current to pools with virtually no detectable current. Most traps, however, were set at depths ranging from 45 cm to 150 cm in areas with slow to moderate current. We observed that traps placed with one of the long sides flush to the bank, a large boulder, a crevice in the bedrock or a submerged log were, on the average, more effective.

A variety of baits were tested early in the study to determine if one bait type was more effective than others. Chicken parts, chicken livers, various types of canned cat food, canned sardines, canned herring, and native molluscs (snails and mussels ground or sliced and placed in a porous bait pouch) were compared. Canned herring and native molluscs appeared to be the least effective attractants. Because there were no observable differences in trap-capture rates between the other types of baits, canned sardines were used predominantly during the majority of the study because of convenience, cost and relative effectiveness.

Several references were used to assist in the preliminary selection of sampling sites. These included: Alabama County Highway Maps; Geological Survey of Alabama, Atlas Series 12, "Drainage Areas for the Upper Black Warrior River Basin, Alabama (1978)"; U.S.G.S. 7 1/2 minute quadrangle maps; U.S.G.S. 1:250,000 Base Maps (Birmingham and Gadsden); county surface mining maps provided by the Alabama Surface Mining Commission; and the USFWS publication on the status of *S. depressus* by Mount (1981).

Final selection of sampling sites (Fig. 1) was based on two major factors:

Location within the Warrior Basin—The need to provide the broadest possible coverage of known or potential *S. depressus* habitats was considered. Although practical considerations prevented a true random distribution of sites, the overall "scatter" of sampling sites throughout the basin yielded an approximate random distribution.

Specific site selection—Determination of the precise locality for sampling involved consideration of several factors, such as access to a stream, size of the stream, permission of landowner and time limitations. Isolated areas, such as those where access was limited or where access could be gained only by crossing private land, were preferred. Bridge sites were, of necessity, utilized in many instances. Of these, bridge access sites that received minimal disturbance from human recreational activities were normally preferred. Access to several sites could be gained only by boat.

Fifty-seven percent of the streams examined were sampled at more than one site, for one or more of the following reasons:

a) The length of the stream or size of the impoundment necessitated multiple sampling sites in order to compile as accurate an assessment as possible (e.g., Locust Fork, Mulberry Fork, Smith Lake).
b) The presence of particularly good *S. depressus* populations along selected stretches of a stream made it advisable to sample multiple sites. In this way, differences in habitat quality could be compared to population estimates at specific sites within the same stream (e.g., Blackburn Fork of the Little Warrior River, Blackwater Creek).
c) The absence of good *S. depressus* populations within some streams demanded the sampling of more

> than one site to minimize the chances of deriving a population estimate which was artificially low (e.g., Clear Creek, Lost Creek, North River, Gurley Creek).

In several instances, a particular locality was investigated more than once. Most were areas which appeared to meet the habitat requirements for flattened musk turtles, but at which trapping results were initially low, primarily due to rain-related stream conditions. At some sites, subsequent efforts revealed the presence of a larger population than would have been suspected after only one attempt (e.g., Turkey Creek, Blackburn Fork, Blackwater Creek). At others, low population density estimates or the apparent absence of the species was supported (e.g., Gurley Creek. Clear Creek, Duck Creek, Locust Fork, Mulberry Fork). Some sites yielded excellent results immediately, and subsequent efforts were made to more accurately estimate population density and population numbers (e.g., Sipsey Fork, Brushy Creek).

A general description of each site was prepared for future reference, and pertinent habitat characteristics noted. These included dominant terrestrial and aquatic vegetation present, characteristics of banks, width of stream, odors, vertebrate and invertebrate associates, water clarity estimates, bottom characteristics, column profile, stream current, dissolved oxygen content (ppm), air and water temperatures, and selected water quality parameters.

A modified Wentworth Scale was employed to determine bottom particle size as follows: boulders = 256 mm or larger; cobble = 64-256 mm; pebble (includes both pebble and granule categories) = 2-64 mm; sand = individual particles visible to the unaided eye up to 2 mm; silt and clay = fine particles individually invisible to the unaided eye. The preceding scale was used to quantify stream bottom characteristics by estimating the percentage of the total for each particle size category present.

Water depth is also an important habitat characteristic for *S. depressus*, as it fluctuates considerably within a stream, both geographically and temporally. Therefore, a column profile was constructed at each sight. The column profile is a proportional representation of various depth categories within the water column. Each of these is expressed as a percentage of the total within the area sampled. The following categories were established: a) riffles = shallow areas with fast current and possessing a roiling surface turbulence; b) <15 cm depth; c) 15-60 cm depth; d) 60-150 cm depth; e) 150-240 cm depth; and f) >240 cm depth.

The exact location, description, and above physical characteristics of each site have been compiled into an Appendix which will be made available to legitimate researchers by the authors upon request. Figure 1 depicts the approximate location of the sites sampled.

Captured flattened musk turtles were taken to the laboratory, assigned an individual identification number by notching the marginal scutes, measured, weighed (to the nearest 0.1 g), photographed and released within 24 hours at the capture site. Previous damage to or erosion of other marginal scutes was noted. Linear measurements (to the nearest 0.1 mm) made with dial calipers were: carapace length, carapace width, plastron length, anterior plastron width, and shell height. Body mass was obtained using a Sartorius top-loading electronic balance (accuracy = ± 0.003 g). Photographs of each captured individual were taken from a position directly above the animal.

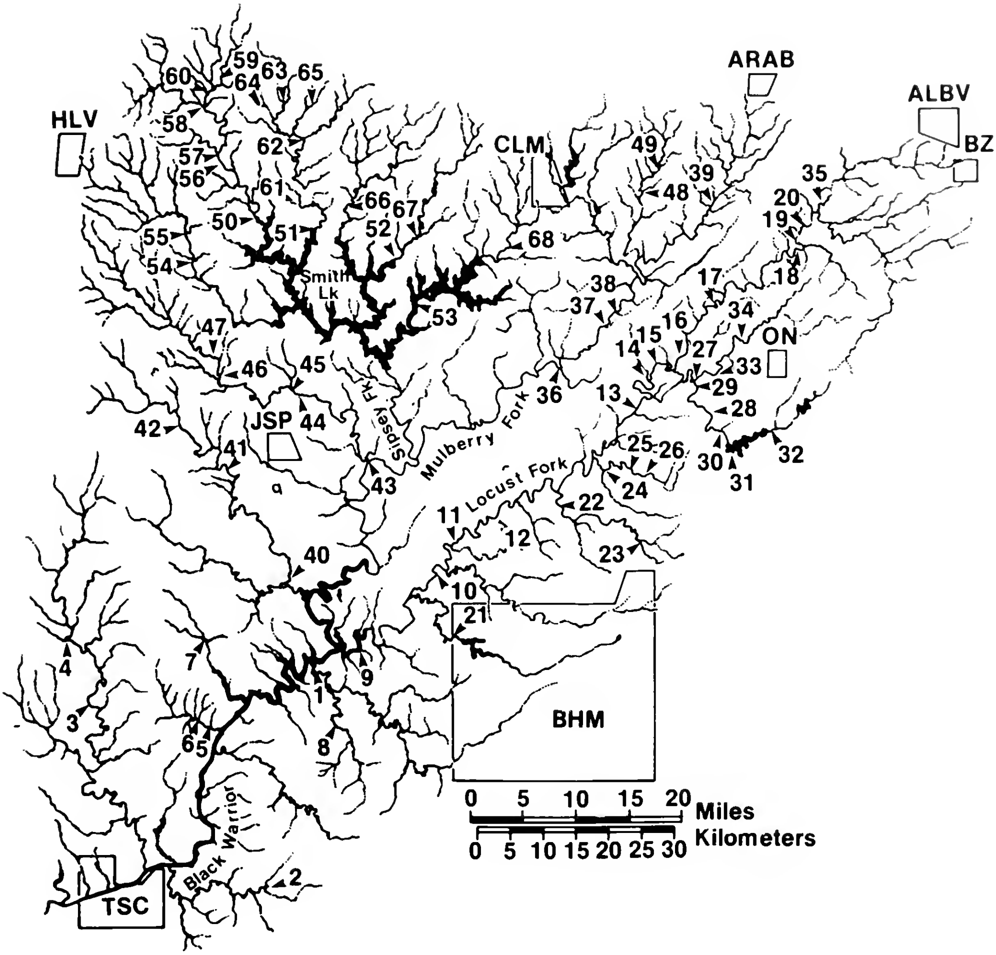

Fig. 1. Map of the Black Warrior River drainage basin showing approximate location of sites examined during 1983. Sites are identified by number. Exact locations and descriptions of sites are available from the authors upon request. Town abbreviations: ALBV = Albertville; ARAB = Arab; BHM = Birmingham; BZ = Boaz; CLM = Cullman; HLV = Haleyville; JSP = Jasper; ON = Oneonta; TSC = Tuscaloosa.

Additional data recorded for each turtle included the presence of old or recent injuries or lesions; sex; the presence of algae, leeches or other epizoics; the presence of oviductal eggs (determined by palpation); whether or not fecal samples were obtained; and the date, site and method of capture.

Interviews with landowners, local residents or others familiar with a particular area or stream often enhanced our understanding of local conditions. On five occasions, we received comments from people who possessed knowledge of important information spanning 20-30 years.

Results and Discussion

A total of 577 *Sternotherus depressus* was collected (Table 1) and approximately 20 others were sighted but escaped. Of those collected, 509 were caught in traps in 20,169.7 trap-hours

TABLE 1. Summary of 1983 collection data by site (see Fig. 1). N = number of *Sternotherus depressus* captured. A size-class distribution by carapace length is given for each site. Trapping efforts (number of nights each site trapped), trap hours and wading hours indicate degree of effort.

Site	N	X̄ Carapace Length (mm) + 1SD (Range)	Size Classes (mm) CL									Trapping Efforts	Trap Hrs.	Wade Hrs.
			30-	40-	50-	60-	70-	80-	90-	100-	110-			
1	4	94.5 ± 11.6 (80.2-108.0)						1	2	1		1	273	
2	0													21
3	5	83.6 ± 20.2 (64.1-106.4)				2		1		2		1	255	
4	13	94.3 ± 13.9 (65.7-108.3)				2		1	5	5		1	320	
5	11	73.6 ± 19.5 (36.5- 93.6)	1	1	1		3	3	2			1	469	21
6	49	89.6 ± 13.2 (57.2-116.5)			1	4	5	8	24	5	2	2	810	14
7	0											1	442	
8	0											1	171	13
9	14	89.2 ± 11.2 (66.7-105.7)				2	1	3	6	2		1	800	
10	1	70.5					1					1	180	
11	0											1	96	
12	9	90.8 ± 5.9 (82.1- 98.7)						4	5			1	280	
13	0											1	255	
14	6	89.4 ± 16.7 (57.0-105.5)			1				4	1		2	520	5.5
15	4	93.1 ± 3.4 (89.7- 97.7)						1	3			2	425	6
16	0											1	261	
17	0											1	168	
18	7	88.9 ± (84.9- 94.5)						4	3			2	413	
19	4	93.4 ± (79.5- 99.7)					1	2	1			1	324	
20	0											1	160	3
21	0											1	210	2.25
22	29	89.1 ± 8.8 (77.0-110.5)					4	11	11	2	1	3	931	38
23	3	97.0 ± 6.2 (93.1-104.2)							2	1		1	190	
24	0											2	511	
25	0											1	209	
26	0											1	187	
27	9	89.2 ± 20.9 (35.5-105.0)	1					1	5	2		2	425	7
28	2	97.0 ± 4.9 (93.5-100.4)							1	1				10
29	20	84.7 ± 8.1 (70.9- 97.4)					7	7	6			2	656	10
30	14	84.1 ± 12.1 (66.9-102.9)				2	3	4	4	1		2	215	10
31	0											1	320	
32	0											1	360	
33	0											1	283	
34	1	94.2							1			1	275	
35	0													5

36	0										1	200	
37	1	94.9							1		2	332	
38	0										1	160	1.5
39	2	101.2 ± 5.4 (97.5-105.1)							1	1	1	255	2
40	0										1	234	
41	0										1	569	
42	11	83.9 ± 8.5 (64.9- 95.4)				1	2	6	2		1	490	
43	3	62.1 ± 25.2 (36.5- 89.9)	1			1		1			1	112	6
44	20	68.9 ± 18.4 (34.5- 96.3)	3	1		6	5	4	1		4	909	19
45	16	80.8 ± 12.0 (62.1-102.3)				4	2	6	3	1	1	170	
46	0										1	144	
47	0										1	70	
48	0										1	195	4
49	0										1	208	5
50	2	84.8 ± 22.0 (62.2-100.3)				1				1	1	128	
51	13	74.2 ± 13.0 (56.1- 93.6)			1	6	2	1	3		1	160	
52	0										1	144	
53	0										1	255	
54	3	95.0 ± 14.1 (78.8-104.1)					1			2	1	247	
55	2	93.4 ± 5.0 (89.9- 96.9)						1	1		2	671	
56	151	79.2 ± 12.6 (33.6- 98.9)	2	6	3	12	43	65	20		3	441	8
57	86	79.2 ± 14.4 (39.8-106.6)	1	4	6	5	25	24	18	3	1	266	6.75
58	16	91.1 ± 6.7 (80.0-104.0)						9	5	2	1	385	3
59	0										1	251	
60	0										1	182	
61	3	72.7 ± 4.7 (67.4- 76.2)				1	2				1	176	
62	41	82.0 ± 16.8 (37.7-106.9)	1	3		3	8	9	13	4	2	806	23.25
63	0										1	221	
64	0										1	93	
65	0												35
66	1	96.4							1		1	211	
67	1	85.0						1			1	108	
68	0										1	278	

during 1250 trap-nights (mean = 16.1 trap-hours/night) for a rate of 0.41 turtles/trap-night. An additional 68 specimens were hand-captured while wading 265.75 man-hours (0.26 turtles/man-hour). Our rate of capture was not significantly different from that of Mount (1981), who had a yield of 0.4 turtles/trap-night (272 trap-nights) and 0.23 turtles/man-hour wading (44.4 hours). Of the 68 sites sampled, 36 (53%) yielded S. *depressus* (Table 1). Mount collected them at 26 (38%) of 68 sites (approximately half of these sites correspond to those sampled in the present study). Several of the 32 sites that did not yield *S. depressus* in our study had been previously listed as degraded, and the presence of the species considered unlikely by Mount. However, a number of sites where we found turtles were locations where Mount found none (see discussion of waterway status below).

Distribution and Status

Table 2 assesses the status of *S. depressus* at each site. Because no historical population density data are available for the species, the categories in Table 2 are relative estimates of population density. Placement of sites into specific categories was based on 1) collecting results, 2) effort expended, and 3) both qualitative and quantitative habitat evaluation.

The following discussion of distribution and status is presented by drainage from the southwesternmost to the northeasternmost. Refer to Fig. 1 and Table 1 for site locations and collecting results.

TABLE 2. Status of the flattened musk turtle at sites examined during 1983. Refer to Fig. 1 for approximate site locations. Exact locations and descriptions of sites are available from the authors upon request. Status determinations are relative estimates of density based on 1) collecting results, 2) effort expended, and 3) both qualitative and quantitative habitat assessment.

Population Assessment	Sites
Absent	2, 21, 60, 63, 64
Absent to Low	7, 8, 11, 13, 16, 17, 20, 25, 26, 31, 32, 33, 35, 36, 38, 40, 41, 46, 47, 48, 49, 52, 53, 65, 68
Low	10, 15, 19, 23, 24, 34, 37, 39, 55, 59, 66, 67
Low to Moderate	1, 9, 14, 18, 43, 50, 54, 61
Moderate	3, 4, 12, 27, 28
Moderate to High	22, 29, 30, 42, 44, 45, 51, 58
High	5, 6, 56, 57, 62

A. Black Warrior River (below junction of Locust and Mulberry Forks) and its tributaries.—In Bankhead Lake (Site 1), flattened musk turtles are fairly common around the scattered rocky bluffs, but are low in numbers or absent from the numerous mud flats. The overall assessment is that of a low to moderately dense population. However, access to suitable trapping sites is limited, and trapping at additional sites could reveal a larger population than we estimate. This agrees essentially with Mount's (1981) conclusions that *S. depressus* is locally common in Bankhead Lake.

Hurricane Creek (Site 2), an eastern tributary, was the most degraded waterway sampled. No *S. depressus* were collected, silt deposits were deep, coal fines were abundant, and the pH was 4.2. The only direct evidence of current pollution from surface mining runoff detected during the study was here, where nearby "abandoned mines" (according to ASMC inspectors) were still leaching into the creek. We agree with Mount's (1981) conclusion that essentially no *S. depressus* survive in this stream.

Healthy populations of moderate density were found at two sites on the

North River (Sites 3, 4). However, runoff from agricultural areas and siltation are evident.

Blue Creek is a stream in which Mount (1981) found no turtles, but he concluded that conditions there were acceptable, and thought *S. depressus* probably well-represented. The populations at Sites 5 and 6 (approximately 1.6 km apart) are healthy, reproducing, and of high density. However, the stream does not fit the criteria given by Mount (1981) for optimal habitat. The stream bed is extremely sandy, with some boulders and rock crevices present. The original substrate is largely obscured by sand, up to 60 cm deep in places. Blue Creek is of particular interest since it is apparently recovering from severe past pollution as a result of nearby surface mining. Local residents told us that the turtle and fish faunas were "completely wiped out" over 20 years ago when the contents of a sedimentation basin flooded into it. Mining operations ceased about 10 years ago. The presence of a high density population today apparently indicates that the species can naturally repopulate areas from which it has been eradicated. The turtles apparently immigrated either from areas above those affected by mining and/or the Black Warrior River, of which this stream is a direct tributary. The musk turtles taken from Blue Creek seemed intermediate in head pattern and shell depth between *S. depressus* and *S. minor peltifer*, but whether this represents hybridization or merely intergradation is not known.

Big Yellow Creek (Site 7) is a small, intermittent, silty stream that may infrequently support *S. depressus* near its mouth. Agriculture is prevalent in the area, and there are several old surface mines 5-6 km upstream. *S. odoratus* is common in Big Yellow Creek and may outcompete *S. depressus*. Mount (1981) considered *S. depressus* to be scarce or absent in this waterway, and we concur.

Mud Creek (Site 8), a heavily-sedimented tributary of Valley Creek, has historically been influenced by agriculture, surface mining and coal-related industries. High water levels at the time of sampling may have contributed to our collecting no flattened musk turtles there, but probably at best only a low density population exists at this site.

B. Locust Fork and its tributaries.—Mount (1981) considered the ecological condition of the Locust Fork to be poor, and we concur. Overall, it is degraded; the upper portions are heavily impacted by agriculture and to a lesser degree by surface mining. In our opinion, agriculture has probably had the greater impact in the upper Locust Fork. Extensive algal growths cover the rock substrate in many areas, possibly indicating excess nutrient influx. Sediments in many places are also typical of those associated with runoff from cultivated areas. Such sediments typically consist of fine particulates possessing a floccular appearance. The possibility exists that pesticide/herbicide influence in these (and other) areas has had a debilitating effect. Coal fines and other evidence of mining-related activities are less obvious. The lower portions, however, have been more severely affected by surface mining, and industrial and municipal pollution. In some areas, old surface mines abut the river's edge. Habitats in the extreme lower portion have also been modified by reservoir backup. All 12 sites sampled during the 1983 study resulted in below average collections, and all of these sites showed some evidence of degradation. The data presently available suggest that *S. depressus* populations in the Locust Fork have declined. There are still low to moderate density, reproducing populations at Sites 9, 14 and 19. Populations at other sites, however, such as 10, 11, 13, 16, 17 and 20, are very low in density or have been eradicated. Those at 12, 15 and 18 are low density and may not be successfully reproducing. Previous scientific collecting on the Locust Fork indicated moderate to high density populations at some localities (Mount, 1981; Cox, personal experience; James V. Peavy, personal communication). In addition to habitat degradation, collection for the pet trade appears to have been a major factor in the decline at certain sites. The populations at easily accessible sites, such as 16 and 18, have been especially affected by collectors. Mount (1981) provided comments on Site 18. At Site 16, Cox collected 15 *S. depressus* in 10 man-hours wading during 1977, and Peavy reports having seen numerous individuals at this site during the period 1966-1976. We caught no *S. depressus* at this location during our survey, despite ideal collecting conditions. Since gastropods and *Corbicula* (important food items in the diet of adult *S. depressus*) were usually abundant at most sites on the Locust Fork during our study and the general physical characteristics (current, rock substrate, refugia) appear acceptable, the lack of success in obtaining flattened musk turtles at these and other Locust Fork localities was startling.

Village Creek (Site 21) has been highly polluted by both industrial and municipal effluents in the past, and appears degraded and presently eutrophic. No snails or clams were observed, and it is unlikely that *S. depressus* still exists in the creek. However, our one collecting attempt was during a period of high water. The fish fauna seems abundant and varied, and perhaps the stream is recovering.

Turkey Creek (Sites 22, 23) has been heavily influenced by surface mining and, to a lesser degree, by agriculture and other human activities (e.g., road-building, construction, urbanization, etc.). Mount (1981) considered the presence of *S. depressus* unlikely. Turkey Creek at Site 23 is small and considerably degraded, with a heavy silt load and obvious coal fines; a large inactive surface mine is located upstream. Only a low density *S. depressus* population is present. Site 22, downstream from 23, is also degraded with silt and coal fines, but in all other respects appears to be favorable habitat, having large boulders, riffles and weed beds. There are extensive sand deposits on the bottom; snails are abundant and *Corbicula* are present. The *S. depressus* population at this site is one of moderate density. If this population is left undisturbed, it has the potential for naturally restocking those sections of the stream that retain suitable habitat characteristics.

We trapped but did not wade three sites on Gurley Creek (Sites 24, 25, 26) and caught no *S. depressus*. Historically, it has been affected by surface mining and municipal pollution. Some segments of the stream are still degraded, while others appear able to support these turtles. Mount (1981) arrived at essentially the same conclusions. Possibly a low density population of *S. depressus* is present, as potential food items (*Corbicula*, snails, and aquatic insect larvae) are moderately abundant and the physical habitat appears acceptable.

The Blackburn Fork (Sites 27, 28, 29, 30) contains favorable habitat for *S. depressus*, and the present overall density is moderate to high. Populations are more dense in the upper reaches. However, the population appears to have declined in recent years, especially at Site 28 (Cox and Marion, past experience), and this decline is probably attributable to commercial collecting. Site 28 has been extensively collected during the past ten years by amateurs and commercial collectors and is well known throughout the southeast by those interested in flattened musk turtles. Discussions with several people who are familiar with the pet trade (and comparing figures provided by them) yields a conservative estimate of 300-400 turtles removed from this stretch during the last ten years. If recent state legislation prohibiting commercial collecting is enforced, however, the Blackburn Fork overall should continue to support a large breeding population of *S. depressus*; the water quality is good and food is abundant.

No flattened musk turtles were collected at two sites (31, 32) on Inland Lake, despite setting 40 traps for two consecutive days. It is a large, deep, cold, rocky reservoir, with water depths dropping off sharply near the shoreline. No molluscs or gastropods and few other potential *S. depressus* food sources were observed, even while scuba diving. The species may no longer be present in the lake.

Calvert Prong (Sites 33, 34) has been heavily influenced by agricultural runoff and possibly surface mining (Mount, 1981), and appears degraded. A low density *S. depressus* population is present. The possibility of additional natural restocking exists, as there is a moderate to high density population in the Blackburn Fork upstream from the confluence with Calvert Prong. A fisherman, when shown a flattened musk turtle, said he was familiar with the animal, and that he had seen them at Site 33. We caught none there in traps, but the habitat appeared suitable.

Slab Creek (Site 35) is small, with a silt-sand bottom. Sedimentation is heavy, and fine sediments typical of nearby agricultural utilization uniformly cover all rock substrate to a depth of 1.5 cm. *Corbicula* are abundant, but no snails or aquatic insect larvae were observed. Although we collected no *S. depressus* while wading one hour (1200-1300), a low density population may occur.

C. Mulberry Fork and tributaries.—The Mulberry Fork (Sites 36, 37, 38, 39) has been considerably degraded by agricultural siltation (and possibly pesticides/herbicides) and perhaps by effluents from several municipalities. Surface mining has had little effect except in the lower reaches, where commercial collecting has also occurred. Mount (1981) thought this stream supported a low density population of *S. depressus*, and this is also our assessment. The population is probably declining; according to one source, commercial collectors found it more difficult to obtain specimens in 1982-83 than in previous years.

Lost Creek (Sites 40, 41, 42) has some areas of suitable habitat remaining in the upper stretches. A moderate density, reproducing population of *S. depressus* exists near Pocahontas (Mount, 1981), and we found a moderate to high density reproducing population near Cedrum (Site 42). We trapped 11 specimens there after heavy overnight rains made collecting conditions suboptimal. This site contains numerous shelves of eroded stratified rock; snails, *Corbicula*, and aquatic insects are abundant. The lower and middle stretches, however, have been strongly influenced by past and present surface mining, agriculture and impoundment (Sites 40, 41), and collecting efforts were unsuccessful. At best, a low density population may still exist in the lower reaches of the stream.

Mount (1981 considered the *S. depressus* population in Blackwater Creek (Sites 43, 44, 45, 46, 47) to be the most extensive and important in this portion of the species' range. This is especially true of the midreaches of the stream. We also found these areas to be favorable habitat and still supporting a moderate to high density population. However, many sites are readily accessible to human disturbance. The upper reaches are degraded with silt and some coal fines; agriculture and mining have both affected these localities. The confluence of Blackwater Creek with the Black Warrior River (Site 43) is the type locality of *S. depressus* (Tinkle and Webb, 1955), and a low to moderate density, reproducing population still occurs there (possibly reinforced by turtles entering from the Black Warrior River). This site has apparently not changed appreciably since it was described as the type locality (J. Whitfield Gibbons, personal communication following on-site inspection).

Duck Creek (Sites 48, 49) is small, but *Corbicula* are abundant and the physical characteristics are well within the limits of favorable habitat observed elsewhere. Possibly a low density population of *S. depressus* occurs there, although repeated efforts (Mount, 1981, and present study) have failed to produce specimens. The heavy concentration of agriculture along this stream (and, indeed, all of those within Cullman County) has probably adversely affected the species. Fine sedimentation is moderate to heavy in some locations and extensive algal growths indicate probable organic enrichment. Although there are no historical records indicating dense populations in this and other streams within Cullman County, the habitats appear suitable, and adequate routes for dispersal from populated drainages have historically been present. These facts strongly suggest that *S. depressus* was present in these streams in the past.

D. Smith Lake.—We sampled four sites (50, 51, 52, 53) on this large reservoir (8,550 ha). Low to moderate density S. *depressus* populations occur at the mouths of the Sipsey Fork and Brushy Creek in Winston County (Sites 50, 51), but only low density populations are present at the confluences of Crooked Creek and Ryan Creek with Smith Lake in Cullman County (Sites 52, 53). Many areas of suitable physical habitat are found in the lake, with rock shelves and boulders abundant, and probably low to moderate density populations of turtles occur at these scattered sites. However, the steep bluffs and scarcity of shallow water habitat in the lower reaches may hinder or prevent turtles from inhabiting or colonizing the main portions of the lake. Further, populations of potential food items may be low in these regions. Mount (1981) sampled four sites in Winston County and believed a healthy, but low density, population inhabited the lake. A massive effort would be required to fully assess the population density of flattened musk turtles along the extensive shoreline of Smith Lake. The average population density for Smith Lake in its entirety is probably low. It does, however, possess the potential for supporting a large total number of *S. depressus*, especially if isolated populations are considered in aggregate.

E. Streams tributary to Smith Lake and their tributaries (major tributaries arranged from west to east, and their tributaries from north to south).—Clear Creek lies west of the Bankhead National Forest and traverses an area of intensive agriculture. We sampled two sites. The lower site (54) has sufficient rock crevices for cover and a moderate supply of snails for food. Sand deposits are extensive and and the site apparently supports a low density, and probably reproducing, population of *S. depressus*. The upper site (55) is a less suitable habitat, with few rock crevices, a very sandy bottom, and little molluscan food, but an occasional flattened musk turtle can still be found. Generally, the lower reaches of the creek seem to be better habitat than those areas upstream. Agriculture appears to be the major influence along much of the stream, as there are areas of occasional brown surface "foam" and extensive algal growths on the submerged rocks, both indicative of organic enrichment. Mount (1981) felt that Clear Creek had acceptable physical habitat and that *S. depressus* was moderately common. He suggested that low food availability was the most important limiting factor at Camp McDowell.

The Sipsey Fork was sampled at four sites above Smith Lake. Site 50 (at the confluence with Smith Lake) supports a low to moderate density population of *S. depressus*. Upstream, Site 58 on the West Sipsey Fork at Cranal Road (Bankhead National Forest) was sampled by us and also by Mount (1981). The site has some deep pools and rock crevices, but also has several sandy stretches. We found both snails and *Corbicula* present, and our data indicate that a moderate to high density, reproducing population occurs there. However, this is a recreation area, and human disturbance may adversely influence the turtle population. Mount (1981) considered the habitat relatively good and *S. depressus* "moderately common", but that population levels are probably limited by low food availability. Sites 56 and 57 are separated from each other by about 1.6 km and are downstream from Site 58. Although boulders and some rock crevices are present, the bottom is extremely sandy. Snails, *Corbicula* and insects are common to abundant. The *S. depressus* population at Sites 56 and 57 is one of extremely high density and is healthy and reproducing. In fact, this portion of the Sipsey Fork supports the densest population of *S. depressus* recorded to date (Table 1).

Borden Creek, a shallow tributary of the Sipsey Fork, was trapped at one site (59). No turtles were collected, but some areas appeared to be suitable habitat. *Corbicula* were common and some snails were present. The stream widens and deepens below the bridge access, and the presence of *S. depressus* between that point and the confluence with the Sipsey Fork, approximately 1.6 km downstream, is considered probable. However, due to the short length of this stream segment and general character of the habitat, only a low density population should be expected. Braziel Creek (Site 60), a small tributary of Borden Creek, contains marginal habitat, and few if any flattened musk turtles occur there.

Brushy Creek was sampled at four sites (51, 61, 62 and 63). We found a low to moderate density, reproducing population at U.S. 278 (Site 61), but the habitat was somewhat degraded by logging operations. A high density, reproducing population of *S. depressus* is present at Site 62, which is easily accessible by a Forest Service road. *Corbicula* and snails are common, and the stream drainage is densely forested. At Brushy Creek Lake, a shallow, swampy impoundment on the upper reaches of the stream (Site 63), we caught no *S. depressus* and the physical habitat was unacceptable. There is, however, a sizeable population of *S. odoratus* in the lake. The confluence of Brushy Creek and Smith Lake at County Road 63 (Site 51) supports a moderately dense population. A wide size-class range (46.1 mm to 93.6 mm CL) was captured, and the presence of smaller animals indicates a reproducing population. Brushy Creek arm below this site probably continues to support a moderately dense population, at least in areas of suitable habitat.

Limited trapping in Beech Creek (Site 64) produced no *S. depressus*, and our data and observations of habitat characteristics suggest they are absent. It is a small tributary of Brushy Creek, with poor habitat and low food availability. Another Brushy Creek tributary, Rush Creek (Site 65), may have at best a low density population of *S. depressus* in the lower reaches. It is shallow and the habitat questionable; few large rocks or hiding places are present. This site was waded once, and collecting conditions were good. Lower water levels later in the season alter habitat conditions, and the stream probably does not retain sufficient water depth for safe permanent occupancy by musk turtles.

Rock Creek (Site 66) supports a low density population of *S. depressus*. There are heavy sand deposits and evidence of organic enrichment, probably due to agriculture. Trapping was minimally successful. *Corbicula* are fairly abundant, and several defecated piles of *Corbicula* fragments were also observed. Mount (1981) examined Rock Creek at Smith Lake where it is a narrow, deep channel, and felt that the presence of *S. depressus* was unlikely at that locality.

Crooked Creek in Cullman County (Sites 52, 67) supports only a low density population of *S. depressus*. The stream is marginal habitat at best; it is small and shallow, with little rock substrate and low food availability.

Ryan Creek (Site 68) is agriculturally silt-degraded; *Corbicula* are present, but no snails. No *S. depressus* were detected and, if the species is present, the creek supports only a low density population.

Habitat

Mount (1981:23), based on his collections, proposed the optimal habitat for *S. depressus* to be "a segment of a free-flowing large creek or small river having the following characteristics: (1) drainage area between 50 and 500 mi^2, (2) depth averaging 2 ft., with vegetated shallows alternating with pools at least 3 1/2-4 ft. deep, (3) pools with detectable current, (4) an abundance of submerged rocks with crevices, overlapping flat rocks, or accumulations of boulders, (5) abundant molluscan fauna, (6) low silt load and minimal silt deposits, (7) relatively low nutrient content and bacterial count, (8) moderate temperatures (max. 85°F), and (9) minimal pollution by synthetic chemicals and toxic inorganic materials." We generally agree with these habitat requirements and can further substantiate the importance of certain of these characteristics. Over the stream section surveyed at each site, we were able to quantify average depth, per cent bottom cover, and amount of silt coverage on the stream bottom. We also qualitatively estimated stream size, current, and molluscan population levels on a scale of 1 (smallest or lowest) to 3 (largest or highest). In order to relate turtle population size to these stream characteristics, negative scores were given to a site for any of the following (based on comparative site differences): if an average depth of two feet did not occur in at least 50% of the area surveyed; if boulders, rock substrate and cobble did not exceed or equal 40% of the stream bottom area; if fine silt covered more than 15% of the bottom; and if any of the qualitatively-judged characters scored a "1". A Spearman's rank correlation test (SAS Institute) demonstrated a significant negative relationship between population size at a site (using the seven categories in Table 2) and the total number of negative stream characteristics, using the six we were able to measure or estimate (*r*s = –0.929; P = 0.003). Indeed, of the 18 sites ranked with moderate or greater *S. depressus* levels, only one had more than one negative character, and the five high density population sites had no negative characteristics.

However, many of the sites we examined, and especially those in which we found the highest density populations, varied somewhat from these criteria. Particularly notable is that we found sand to be a much more ubiquitous characteristic of *S. depressus* habitat than has been recognized in the past. Sandy habitats, when coupled with (a) adequate exposed bedrock, boulder, or cobble substrate, and (b) a sufficient food supply (snails, *Corbicula*, and aquatic insects), often support dense populations of flattened musk turtles. In fact, the five sites judged to support the highest density populations (Sites 5, 6, 56, 57 and 62) all had extensive sand deposits (≥35% coverage of stream bottom), sometimes as deep as 60 cm and obscuring as much as 75% of the rock substrate. We have seen *S. depressus* burrow into the sand and have collected others that had already buried themselves. The specific nature of sandy sediments also plays a role. For example, the species seems to avoid areas in which the sand is firm or hard-packed, unless there are other suitable refugia nearby (i.e., boulders, bedrock crevices, holes in banks, etc.). Apparently, such areas are suitable for foraging, as we have captured specimens in traps set there. We have not, however, observed *S. depressus* burrowing into hard-packed sand. For the most part, turtles seem to burrow in loose sand or in a combination of sand-silt and sandy-clay substrate.

Whereas sandy habitats may support good populations of *S. depressus*, finer sediments (silt and clay), on the other hand, do appear to be a decisive factor in determining habitat quality for the animal, in that areas with heavy deposits of fine silt and clay sediments do not support large populations. A Spearman's rank correlation test comparing the number of sites at each population assessment category with the occurrence of a high silt load (>15% coverage of stream bottom) revealed a significant negative relationship between population size and stream silt load (*r*s = –0.929; P = 0.003).

Adequate bottom cover at a site was also significantly correlated to *S. depressus* population levels. Using a criterion of ≥40% coverage of the stream bottom by bedrock, boulders, and cobble as adequate bottom cover, we found a positive relationship between population size and bottom cover (*r*s = 0.857; P = 0.014).

Finally, though food was not quantitatively measured during our study, each site was qualitatively judged as to whether bivalves and snails, primary *S. depressus* food items, were in low, medium, or high numbers. Food abundance appeared strongly linked to turtle abundance, as only 2 of the 18 sites ranked as having moderate-sized or greater *S. depressus* populations were judged to be deficient in food. By contrast, at many sites where *S. depressus* populations were ranked as low or absent, food levels were also low.

Daily Activity Patterns

Estridge (1970) and Mount (1981) both commented that juveniles have a greater daily activity span than do adults, which are predominantly nocturnal. We agree essentially with this, and can provide additional observations made while wading. Fewer active adults than juveniles (7 versus 9) were hand-collected during the daylight (non-twilight hours), and the juveniles collected then were usually of the smaller size classes (<50 mm CL). Juveniles became more active at twilight, with most captures occurring during this period, and as darkness increased, so did activity involving all size classes. Though precise records were not kept, there seemed to be a correlation between the time of day and the size of active turtles. In early evening we observed more juveniles foraging, but as night progressed more young.adults emerged, followed by the very large adults after 2200 hours.

Predation

We found only two dead predated *S. depressus*. Both had apparently been killed by raccoons, whose tracks were found nearby. Several other live individuals were missing limbs or tails. However, flattened musk turtles are small, and many (especially juveniles) can be swallowed whole by large predators, while even adults could easily be carried off to be eaten elsewhere. Predation on juveniles is probably high, and nesting females are more vulnerable while on land.

Health

We found no evidence of diseased *S. depressus*, although they were heavily parasitized by the leech *Placobdella parasitica*, which carries the protozoan agents (*Haemogregarina* and *Haemoproteus*) of turtle malaria (Ernst and Ernst, 1979). Estridge (1970) found *Haemogregarina* in three of seven *S. depressus* he examined. Mount (1981) reported that two of five specimens captured while basking at a Jefferson County site had abscesses presumably caused by bacteria. He thought that such basking behavior was abnormal and possibly related to their diseased condition. Basking probably occurs much more frequently in this species than has been previously reported. Healthy individuals we have kept in the laboratory readily climb out of the water when provided with basking platforms and heat lamps. We have also seen basking in the wild, and J.V. Peavy (pers. comm.) reports observing extensive basking by *S. depressus* along some streams while canoeing.

CONCLUSIONS

The present study demonstrates that *S. depressus* is more prevalent within its range than previously thought. Eighteen (26%) of the 68 sites sampled had moderate to high density populations, and an additional 8 sites (12%) had population densities which we regarded as between low and moderate (Table 2). Unfortunately, some sites could be visited only once, due to the constraints of time and logistics. As we have mentioned, initial collecting efforts at some localities failed to produce specimens, but subsequent attempts revealed the presence of good populations (e.g., Turkey Creek, Blackburn Fork, Blackwater Creek). The results of a single attempt, even with adequate trap numbers, can therefore yield an underestimation of population density.

Mount (1981) inferred from his and other existing data that discreet populations of *S. depressus* may have substantially fewer juveniles today than prior to 1970. Table 3 compares the size-class distributions obtained by: (a) pooling results for all pre-1970 studies, (b) Mount (1981), and (c) the present study. The pre-1970 data are based on several collections made by different collectors (during different years and at different periods within the collecting season) using various collecting techniques. Literature records suggest that wading and collecting by hand were the primary collecting methods employed in these earlier studies. In the present study and that undertaken by Mount (1981), the major emphasis was placed on trapping. In our experience, smaller juveniles are only occasionally collected by trapping, due probably to the mesh size of the traps (1.8-2.5 cm), through which small individuals can move with ease. Differences in dietary preferences in large vs. small turtles may also influence trapping results. The percentage of smaller individuals (<60 mm Carapace Length) is much greater in samples obtained by wading and collecting by hand (under suitable habitat conditions). Therefore, the otherwise most efficient collecting technique (trapping) appears to introduce a selective bias favoring the capture of larger individuals (≥60 mm CL). Mount (1981) waded a total of 44.4 hours and collected 6 juvenile *S. depressus* <60 mm CL. In the present study, 34 juveniles were collected during almost 250 hours wading. Catch-per-unit-effort calculations are virtually identical in both studies, with each juvenile requiring about 7.5 hours effort. Table 1 indicates that juveniles <60 mm CL were captured at 9 (56%) of the 16 waded localities at which we caught turtles, while only two were caught in traps during the entire study. Published studies on turtles indicate that in some species juveniles apparently comprise a low percentage of the population (see Harless and Morlock, 1979, for summary), although to what extent sampling bias (similar to that seen in *S. depressus*) has played a role is unknown. In addition, in almost all turtle populations juveniles are more difficult to detect. The size-class distributions obtained by Mount (1981) and in the present study (Table 3) are remarkably similar to those obtained in a northern Florida spring for *S. minor* (Cox, 1978), in which snorkeling and trapping were the major collecting techniques employed under almost ideal conditions. Also, the percentage of juveniles collected by Mount (1981) and in this study are not particularly low when compared to findings in

TABLE 3. Comparison of size-class distributions (mm carapace length) of flattened musk turtles collected prior to 1970, by Mount (1981), and during the present study (1983). Specimens considered intermediate between *Sternotherus depressus* and *S. minor peltifer* are not included. Numbers collected are indicated below each size class. The percentage of the total for each size class is given in parentheses.

	Size Class (mm CL)								
	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+	Total
Combined pre-1970 Samples (adapted from Mount, 1981, and Estridge, 1970)	18 (26%)	6 (9%)	7 (10%)	7 (10%)	8 (11%)	9 (13%)	12 (17%)	3 (4%)	70
Mount, 1981	1 (1%)	1 (1%)	4 (4%)	8 (8%)	13 (13%)	29 (29%)	35 (35%)	10 (10%)	101
Present Study, 1983	9 (2%)	14 (3%)	11 (2%)	44 (9%)	107 (22%)	164 (32%)	123 (25%)	26 (5%)	498

populations of various other turtle species (Legler, 1960; Ernst, 1971, 1976; Brown, 1974; and Vogt, 1980). Although the size-class distribution in Table 3 for pre-1970 studies might reflect real population structure, it is most remarkable for its bimodal distribution, rather than for its similarity to results from other studies. This suggests that pre-1970 investigators (with emphasis on hand-collecting) inadvertently biased their samples in favor of smaller individuals. Thus, we conclude that the evidence is not compelling enough to warrant an *a priori* acceptance of Mount's (1981) hypothesis regarding a decline in the percentage of juvenile *S. depressus.*

One of the problems that has faced *S. depressus* has been commercial collection. Although we do not know just how extensive this has been, or to what extent this may have reduced specific population levels, serious overcollecting without regard for population dynamics has been reported to us by several sources who have contacts within the pet trade. Selected areas along the Mulberry, Locust and Blackburn Forks have reportedly received much attention from commercial collectors. State legislation (1984) now prohibits the taking of *S. depressus* except for valid scientific purposes and requires a special permit. Hopefully, this will serve to reduce collecting pressure on the species. However, recent unconfirmed reports during 1985 indicated that some commercial collecting may still be occurring.

We have also found the question of sedimentation to be more complex than previously realized. First, although sediments from surface mining were present at many sites, the major source of sedimentation appears to be agriculture throughout most of the Black Warrior River drainage. We found agricultural sediments in almost all of the waterways examined. They were particularly noticeable in Cullman County, and elsewhere, both the Mulberry Fork and Locust Fork have been adversely impacted. Sand sediments do not appear to be particularly harmful, and many of our highest density populations were associated with extensive (moderate to heavy) sand deposits. There is, however, an inverse correlation between the amount of silt and clay sedimentation and the population density of *S. depressus.* No cause and effect relationship, however, has yet been established.

Early in this study, observations at various localities suggested that certain trends regarding land use practices correlated with habitat degradation. Although neither formally stated nor rigorously tested, our subsequent experiences and qualitative observations have strengthened this perception. We conclude that the two greatest influences affecting habitat quality, and therefore affecting populations of flattened musk turtles, are surface mining and agriculture. There is no doubt that surface mining can have a drastic effect, especially upon local populations that are near active or abandoned mines that are still leaching into the stream. The devastating effects of a massive influx of mining residues upon the Blue Creek population (Sites 5, 6) have been well documented. However, this population has recovered remarkably well in only a 10-20 year period. Long-term problems can also occur, though, especially when abandoned mines are not reclaimed (i.e., Hurricane Creek, Site 2). The effects of mining, therefore, are often immediate and obvious, but in some cases the damage is reversible. The streams of Cullman County, and the upper Mulberry and Locust Forks, however, present an entirely different picture. In these areas of intensive agriculture, the effects of organic enrichment, siltation, and the possible presence of pesticide/herbicide residues suggest a slow, long-term and insidious degradation of habitat. Just how serious this is, or will be in the future, is not known. No study to date has addressed the potential problems presented by agricultural influence on these waterways and upon their attendant aquatic biota.

Mount (1981) concluded that *S. depressus* meets the criteria for inclusion on the federal threatened species list, and he placed the major blame for the species' decline on siltation from surface mining. There is, unfortunately, little historical data from which to make population comparisons. The present study reveals *S. depressus* to be somewhat more numerous than previously thought, with high density populations at Sites 5 and 6 (intergradient?), 56, 57 and 62, and moderate to high density populations at Sites 22, 29, 30, 42, 44, 45, 51 and 58. We conclude that *S. depressus* is a case for special concern, but that its candidacy for inclusion on the federal threatened list is inadvisable at the present time. We do feel, however, that continued monitoring of its status is justified. In addition, the present lack of knowledge regarding populations in the major impoundments (Bankhead Lake, Smith Lake, Lake Tuscaloosa) precludes a complete understanding of the species' status. Finally, four streams are crucial to our assessment regarding the present status of *S. depressus*. These are Blackwater Creek, Blackburn Fork, Sipsey Fork and Brushy Creek. Should any one of these populations decline appreciably or should illegal commercial exploitation continue in these streams, federal protection may be warranted.

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THE PREVALENCE AND INTENSITY OF *PERKINSUS MARINUS* FROM THE MID NORTHERN GULF OF MEXICO, WITH COMMENTS ON THE RELATIONSHIP OF THE OYSTER PARASITE TO TEMPERATURE AND SALINITY

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ABSTRACT

Twenty-three samples of oysters were collected from 19 sites along the mid Northern Gulf of Mexico and assayed for the prevalence and intensity of the parasite *Perkinsus marinus*. Prevalence of infection (measured as percent infection, PI) ranged from 0 to 100%, whereas intensity of infection (measured as weighted incidence, WI = sum of disease code numbers/number of oysters) ranged form 0.00 to 3.06. WI was correlated with water salinity (Kendall Tau Beta correlation coefficient = 0.331, $P < 0.05$), but not with water temperature.

INTRODUCTION

Perkinsus marinus (Mackin, Owen, and Collier) is a protistan parasite of the American oyster, *Crassostrea virginica* (Gmelin). It was first described as *Dermocystidium marinum* by Mackin, Owen, and Collier (1950) because of its close similarity to the freshwater parasitic fungus *Dermocystidium salmonis* Davis. Later observations indicated that *D. marinum* gave rise to gliding cells on "mucoid tracks" similar to those of slime molds and was reclassified as *Labyrinthomyxa marina* (Mackin and Ray 1966). Although ultrastructural studies by Perkins (1969) revealed a likeness of the parasite to the fungi, no cytoplasmic extensions or rhizoids were observed. Levine (1978) renamed the parasite *Perkinsus marinus* on the basis of electron microscopic work by Perkins (1976) which revealed the presence of an apical complex in a motile zoospore stage (Table 1).

P. marinus is a major cause of oyster mortality along the Gulf and Atlantic coasts (Mackin et al. 1950, Ray and Mackin 1955, Andrews 1965). Histological studies of oysters infected with the parasite show areas of inflamation and tissue destruction (Mackin 1951). Significant weight loss of diseased oysters has been documented (Ray et al. 1953), and disease intensity and levels of stress in oysters have been positively correlated Soniat and Koenig 1982).

Numerous studies (e.g., Mackin et al. 1950, Ray et al. 1953, Mackin 1955, Quick and Mackin 1971, Ogle and Flurry 1980, Soniat 1985) have shown that *P. marinus* is most prevalent during the warm months in high salinity areas. Oysters are more susceptible to the disease during spawning season which, along the Gulf Coast, continues throughout the summer (Mackin et al. 1950). However, high weighted incidence values (WI, a measure of disease intensity) have been shown to be directly related to high temperatures (Hewatt and Andrews 1955, Quick 1971). Although positive correlations have been made between salinity and WI, low salinity apparently imposes no physiologi-

TABLE 1. The various names and suggested taxonomic affinities of the oyster parasite.

Name	Affinities	Reference
Democystidium marinum	Protista	Mackin et al. (1950)
	Entomophthorales (Fungi)	Sparrow (in Ray, 1954a)
	Haplosporidia (Protozoa)	Sprague (1954)
	Chytridiales (Fungi)	Mackin & Boswell (1956)
	Saprolegniales (Fungi)	Perkins & Menzel (1967)
Labyrinthomyxa marina	Labyrinthulales (Slime mold)	Mackin & Ray (1966)
Perkinsus marinus	Apicomplexa (Protozoa)	Levine (1978)

cal handicap on the development of *P. marinus* (Ray 1954a); freshwater influx may simply dilute infective elements causing lower WI values (Mackin 1962). Stronger correlations have been found between WI and the product temperature and salinity (TxS) than between temperature or salinity alone (Soniat 1985).

As part of studies of oyster ecology and genetics, as well as effects of oil and gas operations upon oysters, we have had the opportunity to collect oysters and sample parasites from numerous locations in Texas, Louisiana, and Mississippi. This paper further documents a positive correlation between WI, salinity, and TxS values. It also provides current information on distribution, prevalence, and intensity of *P. marinus* along the Mid-Gulf Coast region.

MATERIAL AND METHODS

Oysters were collected from August 1985 to January 1987 at 13 sites along the mid Gulf Coast (Figure 1). Temperature (mercury thermometer) and salinity (American Optics refractometer) were recorded at each site. Small pieces of mantle tissues (~4mm^2) from 9 to 30 oysters of approximately commercial sizes (6.0-12.5 cm umbo-to-bill distance) were examined for parasitism by *P.*

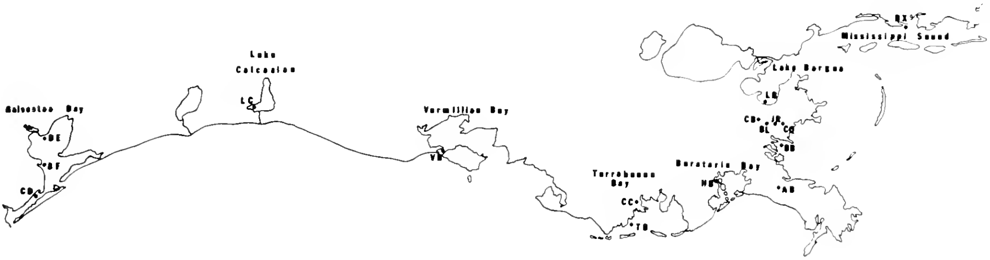

Fig. 1. A map of the mid northern Gulf of Mexico showing the sample sites. CO = Confederate Reef, AF = April Fool Reef, BE = Beasley's Reef (Galveston Bay); LC = Lake Calcasieu; VB = Vermilion Bay; TB = Terrebonne Bay; CC = Cocodrie; HB = Hackberry Bay (Barataria Bay area); AB = Adams Bay; BB = Black Bay; CB = Couchon Bay; BL = Bayou Linge; JR = Lake Jean Robin; CQ = Lake Coquille; LB = Lake Borgne; BX = Biloxi.

marinus using the Ray (1966) technique. The tissues were placed for one week in culture tubes containing a fluid thioglycollate medium and antibiotics (chloromycetin and mycostatin). Microscopic examination of the tissues revealed enlarged *P. marinus* presporangia upon treatment with iodine. The level of infection of each oyster was represented by a disease code number (Quick and Mackin 1971) which ranged as an integer from 0 (uninfected) to 6 (heavily infected). Percent infection (PI, a measure of disease prevalence) and weighted incidence were calculated for each site. Weighted incidence (Mackin 1962) was determined as follows:

$$\mathrm{WI} = \frac{\text{sum of disease code numbers}}{\text{total number of oysters}}$$

The temperature/salinity interaction term (TxS) was also calculated for each site (Soniat 1985).

Non-parametric correlations (Kendall Tau Beta correlations) between temperature, salinity, TxS, WI, and PI were determined using the Statistical Analysis System package (Helwig and Council 1979) installed on a VAX 8600 computer at the University of New Orleans.

RESULTS AND DISCUSSION

Temperatures varied from 10.5°C at Confederate Reef (CO1, Table 2) to 30.4°C at Terrebonne Bay (TB1); however, the average value was 21.1°C and most of the samples were taken when water temperatures were above 20°C. Salinity values varied more broadly. They ranged from 4 ppt at Vermilion Bay (VB1) to 32 ppt at Confederate Reef (CO2) with an overall mean of 16 ppt. The TxS was used to measure the potential of the environment to produce and sustain heavy levels of infection. The factor was developed by Soniat

TABLE 2. Data for temperature (°C), salinity (ppt), weighted incidence (WI), percent infection (PI), the product of temperature and salinity (TxS), and the number of samples (N) collected from the various sites. Site names and locations are given in Figure 1.

Site	Date	Temperature	Salinity	WI	PI	TxS	N
AB1	8/18/86	30.0	20	1.70	90	600.0	10
AF1	8/24/85	27.4	13	2.90	100	356.2	30
BB1	11/7/85	18.0	11	1.33	53	198.0	30
BE1	8/24/85	27.5	8	0.03	3	220.0	30
BL1	12/11/86	12.8	16	0.90	60	204.8	10
BX1	11/8/86	25.0	20	2.20	100	500.0	10
BX2	10/14/86	24.2	20	2.27	9	484.0	11
BX3	9/2/86	28.0	25	2.00	93	700.0	15
BX4	9/25/85	27.4	5	2.07	100	137.0	30
CB1	10/7/86	27.5	19	0.60	30	522.5	10
CC1	10/16/86	21.1	12	2.89	89	253.2	9
CO1	1/27/87	10.5	16	0.00	0	168.0	10
CO2	8/7/86	30.0	32	1.80	93	960.0	30
CO3	8/23/85	27.0	30	3.06	100	810.0	30
CQ1	12/11/86	12.8	16	1.10	70	204.8	10
CQ2	12/3/86	14.0	14	1.90	90	196.0	20
CQ3	12/11/86	13.0	16	1.90	90	208.0	10
HB1	11/19/85	25.0	9	0.00	0	225.0	30
JR1	12/11/86	12.8	16	1.60	90	204.8	10
LB1	10/8/85	10.9	10	0.17	13	209.0	30
LC1	12/17/85	11.0	11	1.20	60	121.0	30
TB1	9/12/85	30.4	16	1.27	53	486.4	30
VB1	11/30/85	22.8	4	0.00	0	91.2	30

(1985) as a simple method to account for the combined efforts of temperature and salinity since the parasite is more prevalent when high temperatures and high salinities co-occur (Mackin et al. 1950). Soniat (1985) showed a closer correlation between WI and TxS than between WI and salinity (temperature and WI were not correlated). Furthermore, salinity and temperature are sometimes inversely correlated (Soniat 1985), which confounds the interpretation of WI data in relation to these environmental variables. In the present study temperature and salinity were not correlated (Table 3). TxS values ranged from 91.2 at Vermilion Bay (VB1) to 960.0 from Confederate Reef (CO2). The highest WI value (3.06) was found at Confederate Reef (CO3), which is also where the second highest TxS value (810.0) was found. No infected oysters were found at Confederate Reef (CO1 on 1/27/87), Hackberry Bay (HB1), or Vermilion Bay (VB1). All oysters were found infected (PI = 100%) at April Fool Reef (AF1), Biloxi (BX1 on 11/8/86), and Confederate Reef (CO3 on 8/23/85). The lowest WI values (0.00-0.03) were found at sites with salinities that ranged from 4 ppt (VB1) to 9 ppt (HB1)—with two exceptions. The first exception was found at Confederate Reef (CO1) where the WI was 0.00 and the salinity was 16 ppt; however, the temperature was 10.5°C—the lowest recorded (Table 2). The low temperature could explain the low WI value; however, Ray (personal communication) found a WI of 1.62 on 1/6/87 (12°C, 14 ppt) and a WI of 0.84 on 2/17/87 (13°C, 20 ppt) from Confederate Reef oysters. The second exception was a Biloxi sample (BX4) which had a relatively high WI (2.07) and a low salinity (5 ppt). This sample was taken shortly after a freshet event and the intensity of infection probably did not have time to decrease from its typically high level.

TABLE 3. Kendall Tau Beta correlation coefficients and probability values for correlations between temperature (TEMP), salinity (SAL), weighted incidence (WI), percent infection (PI), and the product of temperature and salinity (TxS). N = 23.

	SAL	WI	PI	TxS
TEMP	0.200 0.199	0.202 0.185	0.204 0.191	0.564 <0.001
SAL	—	0.331 <0.050	0.354 <0.050	0.653 <0.001
WI	—	—	0.707 <0.001	0.321 <0.050
PI	—	—	—	0.314 <0.050

The typical WI pattern of decreasing parasitism with decreasing salinity was found at three reefs in Galveston Bay. Low (Beasley's), moderate (April Food), and high salinity (Confederate) reefs were sampled within a week of each other (the temperature difference was only 0.4°C). Beasley's Reef (BE1) had a WI of 0.03, April Fool Reef (AF1) had a WI of 2.90, and Confederate Reef (CO3) had a WI of 3.06 (Table 2). Details of the sample sites and information on *P. marinus* in Galveston Bay are provided by Hofstetter (1977). Ray (1987) finds consistently high levels of infection at Confederate Reef. The reef may serve as a refuge for the parasite in the Galveston Bay complex. Confederate Reef may also be a permanent source of infective agents (Ray, personal communication) since oysters there are not subject to freshets which would help control the parasite. Studies of oyster spat on Confederate and a nearby reef (Ray, 1987) have, in fact, caused Ray to revise earlier contentions (Mackin 1951, Ray 1954b) that young oysters (especially those less than a year old) are not susceptible to infection by *P. marinus.* Oysters may need a threshold inoculum of infective agents. The threshold is not only a function of age (or the time the oysters are exposed to infective agents), but also a function of the number of infective agents in the environment (or the proximity of oysters to the focus of infection). If oysters do become infected at earlier ages in areas near a focus of infection, then WI and PI data from oysters by size or age classes would be useful in locating disease "hot spots". Ray's work (Ray, 1987) confirms the results of Hofstetter (1971, 1977) who found *P. marinus* infections in spat from reefs in central Galveston Bay. Craig and Powell (1986) and Powell (personal communication) sampled oysters at 50 sites from Brownsville, Texas to the Florida Everglades, including 4 sites in Galveston Bay. Prevalence of the parasite was never less than 50% from sites in Texas; however, Craig and Powell did not sample any low-salinity reefs in Trinity Bay (from Beasley's Reef we found a PI of 3% and a WI of 0.03).

Mackin (1962) sampled oysters from more than 100 bays and bayous in Louisiana and found prevalences ranging from 0 to 100%. Some of his stations are near those sampled in the present study. Although *P. marinus* was discovered in Louisiana, where most of the early work was conducted, little recent information exists on the occurrence and distribution of the parasite there. Craig and Powell (1986) and Powell (personal communication) sampled nine Louisiana stations; Ray (1982) reports disease data from Lake Calcasieu; and Turner (1985) talks about *P. marinus*, but did not assay for the parasite.

The Lake Calcasieu site was in West Cove in the immediate vicinity of Ray's (1982) Station T-5 and Turner's (1985) Station W. Ray's (1982) samples from the area (taken on 11/7/82) showed higher WI values (2.1 vs. 1.2), and higher PI levels (83% vs 60%), but were taken at a higher temperature (14.4°C vs 11°C) and a higher salinity (20.1 ppt vs 11 ppt).

The Vermilion Bay location (VB1) had the lowest salinity, lowest TxS value, and a WI of 0 (Table 2). Mackin (1962) sampled the adjacent Atchafalaya Bay and likewise found no evidence of parasitism. Freshwater discharge from the Atchafalaya River maintains low salinities in both the Vermilion and Atchafalaya Bays, and *P. marinus* is not prevalent in either.

At the two sites established in the Terrebonne Bay area, WI values were 1.27 (TB1) and 2.89 (CC1). These levels of infection are similar to those found by Mackin (1962) who sampled numerous bays and bayous in the Terrebonne/Timbalier Bay area.

No infection (Table 2) was recorded in oysters from Hackberry Bay (HB1, NW section of the Barataria Bay complex). This bay is a relatively low salinity area (9 ppt on 11/19/85), where Mackin (1962) also did not detect the parasite. In contrast, the lower portions of Barataria Bay often have severe problems with *P. marinus* (Dugas, personal communication); Mackin (1962), for example, found a WI of 4.38 from gapers (dead oysters with the shells still attached and the meats intact) at Bayou Rigaud (Grand Isle).

Adams Bay was sampled numerous times by Mackin (1962); WI values ranged from 0 to 1.00. In the present study (AB1, Table 2) a WI of 1.70 was found.

The seven samples taken immediately east of the Mississippi River (BB1, BL1, CB1, CQ1-CQ3, JR1) had WI values from 0.90 to 1.90. These values were higher than those of Mackin (1962), who found a range of 0.00 to 1.77 in his samples taken east of the Mississippi River. With the present data it is not possible to definitively state that the area is experiencing increased problems with *P. marinus*; however, with an increase in salinity in this area (due to the intrusion of salt water since the construction of the Mississippi River Gulf Outlet) one could, *a priori*, expect increased problems with the parasite.

The Lake Borgne (LB1) samples were taken from an area that supports a few low salinity reefs (see Mackin and Hopkins 1962). Salinity, at the time of the sample, was 10 ppt and WI was low—0.17.

A single station in Mississippi was sampled four times (BX1-BX4). WI ranged from 2.00 to 2.27; salinity varied from 5 to 25 ppt, and temperature values were 24.2°C to 28.0°C (Table 2). Thus, temperature and WI values were relatively uniform, although salinity varied greatly. However, as mentioned previously, the BX4 sample (9/25/85) was taken immediately after a freshet, and almost certainly represents a WI typical of higher salinities. Ogle and Flurry (1980) sampled four reefs in Mississippi Sound over a 25 month period and found a low prevalance and intensity of the parasite. The greatest WI was 0.88—substantially lower than that of the present study.

Temperature was not correlated with salinity, WI, or PI (Table 3). Soniat (1985) found a significant inverse correlation between temperature and salinity from a single reef (April Fool Reef, Galveston Bay), which was also sampled for *P. marinus*. No correlation was found between temperature and WI and PI in the present study because temperatures did not vary greatly and most of the samples were taken at temperatures greater than 20°C. When temperatures are consistently high and salinity varies, salinity appears to be the controlling factor of the disease. Likewise, when salinities are relatively constant and temperatures are more variable, temperature is likely to be correlated with WI. In the present study and in Soniat (1985), salinity is correlated with WI and PI. These results are exactly opposite to those of Quick and Mackin (1971) who found no relationship between WI and salinity, and a significant relationship between WI and temperature. WI and PI are correlated with each other and both are correlated with the TxS interaction term (Table 3). In contrast to the work of Soniat (1985), temperature (in the present study) did not add to the significance of the TxS term. In fact, the TxS term is not as strongly correlated with WI as is salinity alone. Nonetheless, the TxS interaction term is a useful method of measuring the potential of the environment to sustain high levels of infection by *P. marinus*—especially when the sampling design includes seasonal sampling, and sampling of broad geographical areas, and when temperature and salinity are correlated with one another.

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SOME WEEVILS FROM WINTERACEAE AND OTHER HOSTS FROM NEW CALEDONIA

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ABSTRACT

Eleven species of Curculionidae from Winteraceae and other plant families are described from New Caledonia and the Loyalty Islands. **Palontus** new genus seems to be adelphic to *Aneuma* Pascoe from New Zealand; it is placed in the tribe Storeini of the subfamily Curculioninae. There is no evidence to suggest that these weevils occupy a position within Curculionidae comparable to that of Winteraceae in Angiospermae.

The alphabetical sequence of the new species, with the type localities and the hosts, when known, in parenthesis, is:
Palontus bellioli (Tchamba Valley, on *Belliolum*), **P. dispar** (Houailou), **P. exospermi** (Mt Panié, on *Exospermum, Belliolum, Bubbia* and *Zygogynum*), **P. fidelis** (Maré I., Loyalty Is.), **P. flebilis** (Pic d'Amoa, on *Nothofagus*), **P. iodes** (Poindimié), **P. leucopogonis** (Plum, on *Leocopogon*), **P. nothofagi** (Mt Do, on *Nothofagus*), **P. paniensis** (Mt Panié, on *Belliolum*), **P. turritus** (Table Unio) and **P. varius** (Yahoué).

INTRODUCTION

The small family Winteraceae (Magnoliales) comprises fewer than a hundred species of trees and shrubs occurring in Central and South America, eastern Australia, southeast Asia and Madagascar, New Caledonia, Pacific Islands and New Zealand. It is often regarded as the most archaic family of flowering plants or angiosperms (Cronquist, 1981; Friis, Chaloner and Crane, 1987). As most botanists seem to concur with this view the weevil species found to be associated with flowers and young growth of Winteraceae in New Caldedonia and elsewhere were studied to find out if they showed predominantly ancestral or derived features.

The earliest fossil record of Winteraceae, identified from the distinctive pollen grains characterising the family, dates from the Upper Aptian-Lower Albian of Israel, some 105 to 110 million years ago, coinciding with late Lower Cretaceous (Walker, Brenner and Walker 1983). Seed plants of early Mesozoic periods still existing today tend to hold a weevil fauna consisting of species that exhibit a conservative habitus rendering them rather uniform. This fauna possesses relatively high numbers of ancestral character-states or plesiomorphies and shows host associations of a narrow range. This pattern is not evident from the faunas thus far known on the Winteraceae of New Caledonia, New Zealand and Chile, the three areas where the species of this plant family have been searched rather intensively. It appears that the weevils now associated with Winteraceae have little to indicate that they are closer to the groundplan of Curculionidae than others occurring on plant families regarded as evolutionarily more advanced.

Pollen is presumed to have been and continues to be a rich food source for many insects, not least among Coleoptera. Pollen may have been the ancestral diet of adult Cerambycidae, Megalopodidae, Orsodacnidae, Nemonychidae, Belidae, Oxycorynidae and some families of Cucujoidea, and also the diet of the larvae of some of the earliest groups, for instance of Nitidulidae, Megalopodidae, Nemonychidae (Kuschel, 1983, and in press).

A team of floral biologists from the Department of Biology, Tulane University, New Orleans, Louisiana and the Department of Ecology and Evolution, State University of New York, Stony Brook, New York have visited New Caledonia since 1979 to observe the pollination of Winteraceae.

THE WEEVIL FAUNA OF THE WINTERACEAE OF NEW CALEDONIA, NEW ZEALAND AND CHILE

A brief survey of the rather scarce weevil fauna associated with Winteraceae in New Caledonia, New Zealand and Chile, the only areas of the world where these plants have been sufficiently explored, is offered here in response to the interest that this plant family has for systematists. Although the number of winteraceous species is rather high in New Caledonia (cf. Guillaumin, 1948) only *Exospermum stipitatum, Zygogynum baillonii, Belliolum rivulare* and *Bubbia pauciflora* have been closely examined by the biologists observing their pollination. These plants have produced three weevil species, all referable to the same genus described below as **Palontus**. Because these three species are very closely related to one or two others associated with *Nothofagus* and a further species occurring on Epacridaceae is only slightly more divergent, the host range of **Palontus** appears to be too wide for it to claim a relict pattern.

In New Zealand, the first fossil Winteraceae occur in the Upper Cretaceous (Mildenhall, 1980), but the current flora of the country has only three rather closely related species of *Pseudowintera* (Allan 1961). Vink (1988) in a recent cladistic analysis, considers this genus to be adelphic (= of sister-group relationship) to the *Zygogynum*-complex of New Caledonia.The only curculionine weevil known from *Pseudowintera* is *Peristoreus dilucidus* (Broun), a rare species whose larva develops in the fruit (May 1987). Although distinctive, the species fits easily into *Peristoreus*, a genus that has about 60 further species associated with plants of such diverse families as Polygonaceae, Elaeocarpaceae, Malvaceae, Epacridaceae, Fabaceae, Cornaceae (*Griselinia*), Oleaceae, Asteraceae and Liliaceae.

Chile has two species of Winteraceae, *Drimys winteri* on the mainland and *D. confertifolia* on the Juan Fernández Archipelago. The mainland *Drimys* has two weevil species associated with young growth, flowers and fruits, one belonging to *Berberidicola*, a genus having several species on *Berberis* (Berberidaceae) and one each on *Ribes* (Grossulariaceae) and *Nothofagus* (Fagaceae), the other belonging to a still undescribed genus somewhat related to *Berberidicola*. The two weevil species belong to the subfamily Molytinae sensu Kuschel (1987), neither exhibiting morphological features or biological characteristics that could be construed as primitive. The same *Drimys winteri* has a further weevil species, *Aegorhinus luteolus* Kuschel whose larva ring-barks live trees usually close to the base of the trunk. This particular species is more closely related to *A. nodipennis* (Hope) associated with Proteaceae, Eucryphiaceae and others than to any of the eight or so Aterpinae known to be confined strictly, as adult and larva, to the *Nothofagus* species of Chile.

The Fernandezian *Drimys confertifolia* holds one weevil species on Robinson Crusoe Island (or Masatierra) and another on Alejandro Selkirk Island (or Masafuera). They belong to the trypetidine genus *Platynanus* (Molytinae) whose species have successfully colonised almost every fern of suitable size and almost all the dicot genera and also the palm *Juania* *australis* amongst the monocots. Strangely enough *Platynanus* has no species on *Lactoris fernandeziana*, sole species of the Lactoridaceae, an endemic family to Robinson Crusoe Island that Cronquist (1981) and other botanists have tentatively assigned to Magnoliales. *Platynanus* is related to Trypetidini not from the Neotropical Region but from the southwest Pacific, to *Pogonorhinus* of ferns and *Arecophaga* of palms.

The few depositories for the specimens dealt with in the paper are indicated by their standard abbreviations as given in Arnett and Samuelson (1986). These are:

BPBM:	Bernice P. Bishop Museum, Honolulu, Hawaii.
ISNB:	Institut Royal des Sciences Naturelles de Belgique, 29 rue Vautier, Brussels, Belgium.
MNHN:	Muséum National d'Histoire Naturelle, 45 Rue de Buffon, Paris, France.
NZAC:	New Zealand Arthropod Collection, Plant Protection, DSIR, Private Bag, Auckland, New Zealand.

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Palontus new genus (Curculioninae Storeini) (palóntus: from the Greek pále = dust, pollen and ón, óntos = being, creature; gender masculine)

Eyes transverse, flat or nearly so. Funicle 7-segmented; club segments gradually increasing in length. Prothorax truncate at base, constricted at apex to form distinct collar. Scutellum visible, usually conically raised above level of elytra. Elytra parallel at basal half, considerably wider than prothorax at shoulders, with vertical or slightly proclinate base, 10-striate, striae distinctly sulcate also at declivity, 10th finely margined outward for most of length. Hind wings functional. Prosternum with canal, sidewalls of canal continuous, not interrupted or articulated at apical constriction, lacking pit on outside at constriction; fore coxae contiguous or subcontiguous. Femora with or without tooth. Tibiae uncinate or mucronate. Claws divaricate, laminate.

STRIDULATORY FILES. Present in male as long, narrow iridescent file next to suture or sutural flange on underside at apex of each elytron and 3 (rarely 2) pairs of spiculate plectral granules arranged in 2 parallel rows rather close to median line of tergite 7, Fig. 2; files absent in female.

MALE. Sternite 8 as in Fig. 3, narrowly pigmented at apical margin, pigmented area of blade divided into 2 contiguous or disjunct, strongly transverse plates having row of submarginal setae. Sternite 9 as in Fig. 3, with broad, angulate, asymmetrical arms, with robust,

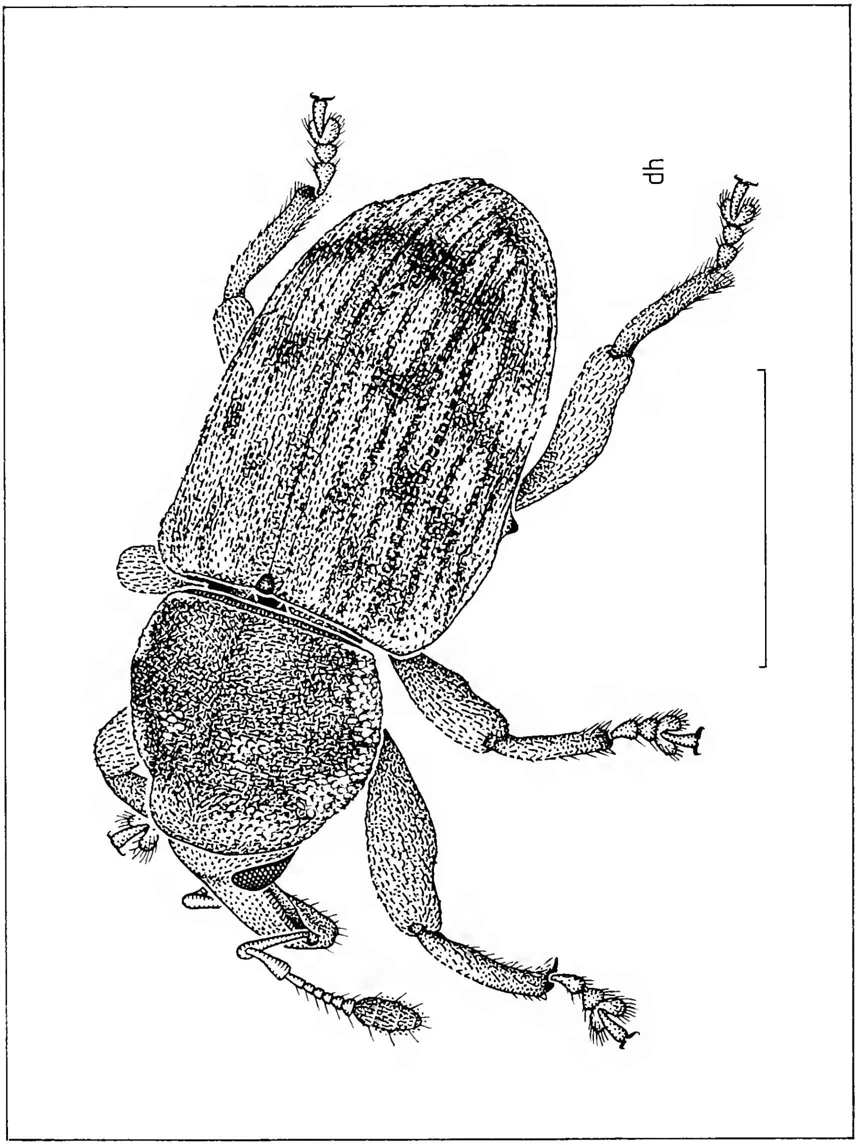


Fig. 1. *Palontus exospermi* n.sp., Mt Panié, male (Holotype) Scale = 1 mm.

towards the apex strongly curved apodeme. Tegmen with complete ring but no parameres. Aedeagus robust, long, extending into metathoracic cavity, apodemes articulated laterobasally, usually shorter than aedeagal body; internal sac contained inside aedeagal body, unless basal sclerite transformed to long flagellum.

FEMALE. Sternite 8 for all species much as in Fig. 6. Hemisternites elongate, broad at base, tapering toward apex, weakly pigmented, undivided, with pores, without distinct setae; styli well developed, rather long. Vagina and bursa short, very broad, bursa occasionally heavily pigmented to greater or lesser extent. Spermatheca variable in shape, specifically distinctive, with small gland; duct extremely variable in thickness and length, usually thicker at bursal end, insertion on bursa specifically characteristic, ventral, apical or dorsal.

TYPE SPECIES. *Palontus* **exospermi** n.sp.

HOSTPLANTS. Winteraceae, Fagaceae, Epacridaceae.

DISTRIBUTION. New Caledonia and Loyalty Islands.

REMARKS. *Palontus* agrees externally with *Aneuma* from New Zealand but the latter has rather small and coarse stridulatory files, no distinct plectral granules and the internal sac of the aedeagus is long, exposed a good deal between the apodemes although a flagellum is lacking. The larvae of *Palontus* are not known. The larvae of the probably quite closely related genus *Aneuma* are confined to *Pittosporum* (Pittosporaceae), those of *A. fulvipes* Pascoe developing in the flower buds, *A. rubricale* (Broun) living in the open flowers, and *A. fasciatum* (Broun) mining the leaves, the larvae of all three species dropping to the ground to pupate in the soil.

THE RELATIONSHIPS OF *PALONTUS*

The three species of *Palontus* from Winteraceae, the one from *Nothofagus* and a further species from an unknown host share an aedeagus that has distinctly sinuous sides and a basal sclerite that is unusually large and is contained in the aedeagal body in the sense that it does not show up between the apodemes but may be extended beyond the ostium. These features have not been observed elsewhere and consequently are taken to be derived and indicative of monophyly. A flagellum of the size and type shown for the last four species described below is a further derived attribute not seen in possible outgroups. Finally, a conically raised scutellum is a rare occurrence in Curculionidae as a whole, and yet is found in eight out of the eleven species of *Palontus* and nowhere else in Storeini and nearby tribes.

Clark, Whitehead and Warner (1977) classified a group of curculionine weevils, traditionally called Tychiinae, into four tribes. The authors discussed the interrelationships of the Palearctic, Nearctic and Neotropical genera and the tribe Endaeini, left in limbo since Burke (1976) had excluded it from Kissinger's (1964) placement in the Anthonominae. It is yet too early to be positive about the phylogenetic relationships of these and hundreds of other genera now incorporated in Curculioninae (Kuschel 1982). *Palontus* species have divaricate claws, a male sternite 9 with broad, angulate, asymmetrical arms, and elytra with stridulatory files on the underside next to the sutural flange at the tip in males only. These attributes are those of *Storeus* and most Storeini (Lacordaire 1863), a tribe well represented in the Australian Region. The genera that differ from Storeini by having stridulatory files in both sexes are grouped in Ochyromerini (Voss 1935) and Dinorhopalini (Voss 1936).

The storeine fauna of New Caledonia is rich in genera and species but few are described. *Aporotaxus* and *Gryphosternus* are endemic genera holding the largest known species of the tribe, up to 13 mm long in the case of *Aporotaxus kanalensis* Perroud whose larva develops in the fruit of *Ficus* species. The New Zealand fauna is similarly diverse and rich. A number of storeine genera have a prosternal canal, as *Palontus* has, but then the sidewalls of the canal are distinctly articulated at the apical constriction and a deep pit is showing on the outside by the articulation. *Palontus* has these sidewalls continuous all the way from the fore coxae to the apex and lacks the excavation on the outside, sharing these characters with *Aneuma* from New Zealand and *Rhinidotasia* from Queensland. Although *Palontus* and *Aneuma* resemble each other closely and are likely closely interrelated, it is not possible to be sure that there is an adelphic relationship between them without a more thorough study than the present one, not only of the Storeini, but also of the Ochyromerini, Endaeini, Derelomini and other related tribes. *Rhinidotasia* differs considerably from *Palontus* and *Aneuma* in being rather glabrous and smooth, of rhomboidal, continuous outlines, in having narrowly separated eyes, broadly separated fore and middle coxae, long, slender, almost lineal femora and distinctly striate tibiae.

Stridulatory files on the underside of the elytra seem to have appeared rather late in the superfamily considering that the fossil evidence traces weevils back to the Jurassic (Arnoldi 1977) and, according to Zherichin (1977), even to the Triassic, and that the files are absent in the families of extant Orthoceri. These are absent also in Brachycerinae, Ithycerinae, Erirhininae, Rhynchophorinae, Entiminae and a whole series of "subfamilies" more closely related to the broad-nosed weevils (Adelognatha) than to the long-nosed weevils (Phanerognatha). Files are a common occurrence in the latter group. The adults of the Curculionidae, again sensu Kuschel (1982), have the files, if present, confined to the male sex, except for Ochyromerini and Dinorhopalini; the other groups have them, again if present, almost always in both sexes.

Elytral files appear to be a derived attribute in Curculioninae. The Chilean and Australian Derelomini associated with the male strobili of Araucariaceae have, in the male, a 9th sternite with a large median plate detached from the symmetrical arms, and a tegmen with distinct parameres, and a lack of elytral files. The files are missing also from all other Curculioninae of Chile, including a dozen or so associated with *Nothofagus*, and from the dozen species occurring on *Nothofagus* in New Zealand whilst nearly all of the close to a hundred other Zelandic Curculioninae associated with flowering plants other than *Nothofagus* have them. A rather common weevil on the *Nothofagus* species of New Caledonia agrees generically well with *Neomycta* species of New Zealand, and like all other species of the genus, lacks the elytral files, too. The presence of files in *Palontus* indicates that the genus would not easily qualify as a relict within Storeini.

It is virtually certain that the Curculioninae of flowering plants of Chile are not related to the Storeini of New Zealand and New Caledonia in the sense of an adelphic relationship. New Caledonia and New Zealand are believed to have separated from Austro-Antarctica on a common continental block 78 to 56 million years ago creating the Tasman Sea (Coleman, 1980) and presumably taking with them some Storeini. Later on, "towards the end of Eocene times, about 37 million years ago, came the parting of the ways for New Caledonia and New Zealand" (Stevens 1981).

As already stated, fossil evidence shows that Winteraceae have existed at least since early Middle Cretaceous times. Although biogeographic patterns of the extant weevil fauna would suggest that representatives of the subfamily Curculioninae should have been around since late Upper Cretaceous, none of the Mesozoic fossils thus far has been recognized as belonging to a species of the long-nosed weevils and only one of the broad-nosed weevils is known (Kuschel 1959). It was described from an area north of Magellan Strait from a Maestrichtian deposit of very late Upper Cretaceous. The recently discovered fossiliferous Orapa deposits of Botswana dated as of Middle to Upper Cretaceous times (McKay & Rayner 1986) contain rather well preserved impressions of weevils but those that are identifiable with some confidence from the photographic copies made available (R. J. Rayner, pers. comm.) belong to families of the evolutionarily less advanced Orthoceri, apparently, to Attelabidae and the family-complex Brentidae/Apionidae.

From the above evidence, the species of *Palontus* now found on Winteraceae in New Caledonia and, similarly, those of *Elleschodes* of the same tribe Storeini pollinating Eupomatiaceae in Australia, show little that might suggest they are relicts within Curculioninae or its tribe Storeini.

KEY TO SPECIES OF PALONTUS

1\. Metasternum with prominent tubercle at hind angle. 1.9-2.6 mm .... 1. **exospermi**

– Metasternum lacking tubercle at hind angle. 2

2\. Metepisternum with 1 row of hairs or scales on posterior half. 3

– Metepisternum with 2 or more rows of hairs or scales on posterior half. 4

3\. Dark markings on basal quarter of elytra consisting of more or less coalescent dots or short stripes on interstriate 3, 5 and 7, one on 5 slightly farther back than others. Elytral vestiture consisting mostly of elliptic or oval scales. 2.0-2.5 mm .... 2. **bellioli**

– Dark markings on basal quarter of elytra coalescent, forming anteriorly concave arc or extending to interstriae 5. Elytral vestiture consisting mostly of hairs or lineal scales. 1.7 mm. .... 3. **paniensis**

4\. Scutellum raised conically high above level of elytra. Femora with strong tooth. 5

– Scuttelum flat or only slightly raised, if raised then middle and hind femora unarmed. . 6

5\. Sides of prothorax pubescent. Elytra variegated with pale reddish and dark brown, with large dark triangular marking in scutellar area and postmedian band across elytra. 2.0-2.5 mm .... 4. **turritus**

– Sides of prothorax white, covered in dense broad scales. Elytra rusty brown but usually with reddish brown, broad sutural stripe involving first three interstriae from basal quarter to apex, this stripe traversed by darkish band in middle. 2.20-2.45 mm. .... 5. **nothofagi**

6. All femora with distinct tooth. 7
– All or some femora lacking tooth. 8
7. Elytra squamose on reddish brown integument. Interstriae not granulose. 1.9-2.4 mm. .... 6. **flebilis**
– Elytra pubescent on rusty brown integument. Interstriae finely granulose. 2.7-3.0 mm. .... 11. **iodes**
8. Scuttelum large, flat, shiny. 1.9-2.5 mm. .... 7. **varius**
– Scuttelum small, raised, dull. 9
9. Elytra with tubercle on intrestria 3. Pronotum humped on middle in lateral view. 2.5-2.8 mm. .... 8. **dispar**
– Elytra lacking tubercle on interstria 3. Pronotum convex on middle in lateral view. 10
10. Elytra distinctly variegated with white, brown and black markings. Rostrum only faintly saddled at base. 2.3-2.6 mm. .... 9. **fidelis**
– Elytra not variegated, but with suffused bands across dorsum. Rostrum distinctly saddled at base. 2.6-2.7 mm. .... 10. **leucopogonis**

1. *Palontus* **exospermi** n.sp. Figs. 1-8

Integument pale or dark reddish brown. Vestiture forming nebulous designs (Fig. 1), consisting of dark dots across basal third of elytra, loose band across dorsum just beyond middle, usually better defined band across top of declivity, and 1 or 2 dots on each side halfway down declivity.

Head dull, shallowly punctate, usually squamose above and behind eyes. Rostrum in male rather robust, gently curved, 3 x as long as broad at apex, 0.70-0.75 length of prothorax, dull, with 3 rows of very fine puncta on each side, the rows separated by very fine carinules; prerostrum shiny, finely punctate, broader than long. Rostrum in female more slender, slightly more curved, 4 x as long as broad at apex, 0.88-0.90 length of prothorax, lacking carinules; prerostrum 1.5 x as long as broad. Prothorax broader than long, weakly convex, densely granulose-punctate. Scutellum small, dark, convex but not distinctly raised above level of elytra, finely punctate, sparsely pubescent. Elytra weakly convex across middle and from middle to apex. Fore coxae narrowly separate, pubescence on top slightly longer and ruffled in males. Metasternum with prominent tubercle at hind angle, Fig. 1; metepisternum usually with 2 rows of squamiferous puncta up to middle or beyond. Ventrite 5 in female at most with small and shallow median fovea. Femora with sharp tooth, lower margin fringed with erect hairs in male; tibiae sinuous on lower edge, fore tibiae incurved in male; fore and middle tibiae uncinate, others mucronate, distal corbels of middle tibiae obliquely ascending.

MALE. Tergite 7 as in Fig. 2. Sternites 8 and 9 as in Fig. 3, plates of sternite 8 contiguous, suffused in middle. Aedeagus as in Figs. 4, 5, constricted before apex; basal sclerite robust, with tubular extension.

FEMALE. Sternite 8 as in Fig. 6. Tip of hemisternites as in Fig. 7. Spermatheca and part of bursa as in Fig. 8; spermathecal duct short, very broad.

LENGTH: 1.9-2.6 mm; width: 0.9-1.3 mm.

DISTRIBUTION: New Caledonia. Mt Panié, 280 m, 6 Dec 1979, 29 specimens on *Exospermum stipitatum* flowers, McPherson; Mt Panié, 300 m, 2 Nov 1983, 23 specimens on *E. stipitatum* flowers, L. Thien; Mt Panié, 300 m, 27 Nov 1983, 1 specimen on *E. stipitatum* flowers, L. Thien; Mt Panié, 440 m, 27 Nov 1983, 1 specimen, Z. Mackeel; Mt Panié, 295 m, 30 Oct 1986, 3 specimens on *E. stipitatum* flowers, O. Pellmyr & R. Brown; Mt Panié, 700 m, 30 Oct 1986, 1 specimen on *Bubbia pauciflora*, O. Pellmyr & R. Brown; Mt Do, 800 m, 5 Jul 1980, 6 specimens on *Zygogynum* flowers, McPherson; Mt Mé Ori, 500 m, 21 Nov 1979, 2 specimens on *E. stipitatum* flowers, McPherson; Mt Mé Ori, 13-14 Dec 1983, 8 specimens on *E. stipitatum* flowers, L. Thien; Mt Dzumac, 800 m, 28-29 Oct 1983, 1 specimen on *Zygogynum baillonii* flower, L. Thien; Rivière Bleu, 150 m, 24 Jul 1980, 7 specimens on *Zygogynum*, McPherson. 82 specimens in all.

Holotype male, 2.5 × 1.2 mm, Mt Panié, 300 m, 2 Nov 1983, illustrated in Fig. 1, NZAC. Paratypes at BPBM, ISNB, MNHN, NZAC.

HOSTPLANTS. Adults feeding on pollen of *Exospermum stipitatum, Bubbia pauciflora* and *Zygogynum baillonii*, all Winteraceae. Vink (1988) prefers to treat the three genera as one and uses the name *Zygogynum*.

REMARKS. *Palontus exospermi* is recognizable instantly by the prominent tubercle on the hind angles of the metasternum shown in Fig. 1 just in front of the hind femora.

2. *Palontus* **bellioli** n.sp. Figs. 9-11

Integument reddish brown, sterna usually darkened. Vestiture with markings similar to those shown for *P. exospermi* in Fig. 1.

Head dull, finely punctate, pubescent or squamose in part. Rostrum in male slender, gently curved, 4.5 × longer than broad at apex, about as long as prothorax; postrostrum dull, with rows of fine puncta, the areas between the rows slightly raised to very fine carinules; prerostrum shiny, finely punctate, about as long as broad. Rostrum in female more slender, slightly more curved, 6.5 × longer than broad at apex, about 1.5 × length of prothorax; postrostrum very finely punctate, lacking carinules; prerostrum 2 or 3 × longer than broad. Pronotum densely and coarsely punctate. Scuttelum small, conically raised slightly above level of elytra, dull. Elytra moderately convex across middle, distinctly convex in lateral view between basal third and apex. Fore coxae contiguous or nearly so. Metasternum lacking tubercle on hind angles; metepisternum with single row of squamiferous puncta for most of length. Ventrite 5 with rather large and deep median fovea at apex in female. Femora armed with small tooth, occasionally very small, hardly noticeable on hind femora. Tibiae straight on lower edge; fore tibiae straight in male; fore and middle tibiae uncinate, others mucronate; distal corbels of middle tibiae not distinctly ascending.

MALE. Aedeagus as in Figs. 9, 10, apical half shaped like long, truncate spatula; basal sclerite large, robust, with dorsal tubular extension.

FEMALE. Spermatheca as in Fig. 11, duct long and fine.

LENGTH: 2.0-2.5 mm; width: 1.0-1.15 mm.

DISTRIBUTION: New Caledonia. Tchamba Valley, 40 m, 1 Nov 1983, 6 specimens on *Belliolum rivulare*, L. Thien; Thy Valley, 28 Sep 1979, 2 specimens on *Belliolum* cf. *crassifolium*, McPherson.

Holotype male, 2.1 × 1.0 mm, Tchamba Valley, NZAC. Paratypes at BPBM and NZAC.

HOSTPLANTS. *Belliolum rivulare, B.* cf. *crassifolium*.

REMARKS. A single row of scales on the metepisternum distinguishes *P. bellioli* and *P. paniensis* from all others; these two species are compared more closely in the following description.

3. *Palontus* **paniensis** n.sp. Figs. 12, 13

Hardly distinguishable from *P. bellioli* on external characters except perhaps for smaller size and for design patterns on elytra. Markings consisting of suffused darkish arc extending from basal quarter of suture forward to interstria 5, suffused band across dorsum just beyond middle and very faint darkening on each side at top of declivity. Rostrum slightly more curved, rostral carinules less distinct, elytral vestiture finer by consisting mostly of hairs or lineal scales.

MALE. Aedeagus as in Figs. 12, 13, distinctly different in shape and armature from all other species; basal sclerite lacking tubular extension.

FEMALE. Unknown

LENGTH: 1.7 mm; width: 0.8 mm

DISTRIBUTION: New Caledonia. Mt Panié, 450 m, 20 Jul 1980, 1 male on *Belliolum* sp., McPherson.

Holotype male, data as above, NZAC.

REMARKS. *P. paniensis* is defined by the aedeagal features and the characters indicated in the key to species.

HOSTPLANT. *Belliolum* sp.

4. *Palontus* **turritus** n.sp. Figs. 14, 15

Dark or reddish brown, but patterns variable, elytra variegated but rather suffused, with large triangular dark patch in scutellar area and postmedian band across dorsum. Vestiture consisting of pubescence and scaling, latter on paler areas.

Head dull, slightly asperate. Rostrum robust, gently curved, 3.5 × longer than broad at apex, 0.75 the length of prothorax, carinulate; prerostrum strongly transverse, nearly twice as broad as long. Prothorax as long as broad, weakly rounded on sides, densely and coarsely punctate, each punctum with raised margin on posterior half. Scutellum conically protruding well above level of elytra. Fore coxae subcontiguous. Metepisternum with 2 ill-defined rows of puncta. All femora with rather long sharp tooth. Fore tibiae straight but lower edge slightly sinuous, all tibiae with rather small mucro.

MALE. Sternite 8 with contiguous plates. Aedeagus as in Figs. 14, 15, shape and armature highly characteristic, the ostial margins finely and sparsely ciliate.

FEMALE. Unknown.

LENGTH: 2.0-2.5 mm; width: 1.0-1.15 mm.

DISTRIBUTION: New Caledonia. Table Unio, 550-1000 m, 16 Oct 1978, 2 males, J. C. Watt; Mt Rembai, 700 m, 18 Oct 1978, 1 male, J. C. Watt; Mt Do, 1000 m, 31 Oct 1978, 1 male, J. C. Watt; Noumea, 1 male, Coll. Fauvel.

Holotype male, 2.4 × 1.15 mm, Table Unio, NZAC. Paratypes at BPBM, ISNB, NZAC.

HOSTPLANT. Unknown.

REMARKS. *P. turritus* resembles closely *P. bellioli* but may be distinguished readily by a highly towered up (= turrítus) scutellum, strongly dentate femora and a very distinctive aedeagus.

5. *Palontus* **nothofagi** n.sp. Figs. 16-19

Integument reddish brown on rostrum, prothorax, first 3 interstriae from basal quarter of elytra, underside and legs; rusty brown on head capsule and remainder of elytra. Vestiture pubescent except for white scales on sides of head behind eyes, sides of prothorax, elytral suture at basal quarter, pleurites and sides of metasternum.

Head dull, shallowly punctate, slightly asperate. Rostrum similar in both sexes, dull, nearly straight, at least 3 × longer than broad at apex, 0.75 length of prothorax, not carinulate, rows of hairs or lineal scales slightly more distinct in male. Prothorax, about as long as broad, weakly rounded on sides, densely and coarsely punctate, puncta rimmed at posterior half. Scutellum raised well above level of elytra. Ventrite 5 with shallow median fovea near apex in female. All femora with strong, sharp tooth; tibiae slightly sinuous on lower edge, fore and middle tibiae uncinate, others mucronate, middle tibiae with obliquely ascending distal comb.

MALE. Tergite 7 with 2 pairs of distinct granules. Sternite 8 with contiguous plates. Aedeagus as in Figs. 16, 17, distinctive in dorsal and lateral views.

FEMALE. Hemisternal apex as in Fig. 18, stylus unusually long. Bursa with partly folded sclerite, Fig. 19. Spermatheca as in same Fig. 19, duct very fine at spermathecal end, very wide at bursal end.

LENGTH: 2.2-2.6 mm; width: 1.05-1.20 mm.

DISTRIBUTION: New Caledonia. Mt Do, 900-1030 m, 22 Oct 1978, 2 pairs on *Nothofagus codonandra*, G. Kuschel; Pic du Pin, 6 Oct 1978, 1 female by beating, J. C. Watt.

Holotype male, 2.2 × 1.05 mm, Mt Do, NZAC. Paratypes at BPBM and NZAC.

HOSTPLANTS. *Nothofagus codonandra* and, presumably, *N. aequilateralis*, the only southern beech growing at Pic du Pin.

REMARKS. *P. nothofagi* stands out in colour and vestiture from all others of the genus.

6. *Palontus* **flebilis** n.sp. Fig. 20

Integument reddish brown. Vestiture consisting mostly of small yellowish scales on dorsal surface, of larger white scales on underside, elytra crossed by faint band of dots on basal third, band just behind middle and one at top of declivity.

Head dull, alutaceous, very shallowly, indistinctly punctate, not asperate; pubescent or scaly. Rostrum moderately shiny, weakly curved, slightly more than 3 × longer than broad at apex, about 0.93 length of prothorax, carinulate between rows of puncta; prerostrum half as long again as broad. Prothorax slightly transverse, 1.10-1.12 × broader than long, moderately convex in lateral view, densely punctate. Scutellum small, dull, raised to low cone. Fore coxae subcontiguous. Femora with strong, sharp tooth on fore and middle pairs, with smaller tooth on hind pair; fore and middle tibiae uncinate, hind ones mucronate.

MALE. Unknown.

FEMALE. Spermatheca as in Fig. 20, with large, wrinkled extension toward very small gland; duct fine throughout, short, inserted terminally on bursa.

LENGTH: 1.9-2.4 mm; width: 0.95-1.15 mm.

DISTRIBUTION: New Caledonia. Pic d'Amoa, 450-500 m, nr Poindimié, 26 Oct 1978, 2 females on *Nothofagus aequilateralis*, G. Kuschel.

Holotype female, 2.4 × 1.15 mm and paratype at NZAC.

HOSTPLANT. *Nothofagus aequilateralis*.

REMARKS. Although the spermatheca of *P. flebilis* differs considerably from that of the other species, indications are that *P. flebilis* is related to the preceding *P. nothofagi* more closely than to the following species. All efforts and time spent to secure more specimens were in vain, hence the species name flébilis, Latin for pitiable.

7. *Palontus* **varius** n.sp. Figs. 21, 22, 27.

Integument reddish brown but elytra always, and other parts often, darkened to dark or blackish brown, especially head and sterna. Vestiture consisting of pubescence and scaling, but scales usually dominant on elytra, forming variegated patterns on elytra, white or yellowish scales mainly at base of interstria 3, on humeral area and on apical third where usually forming rather broad band across top of declivity.

Head dull, alutaceous, indistinctly, and very shallowly punctate, not asperate, pubescent except on frons. Rostrum slender, curved; in male dull, 4.5 × longer than broad at apex, at least 1.10× length of prothorax, finely carinulate between rows of puncta; prerostrum nearly twice as long as wide in male, fully twice as long as wide in female. Prothorax distinctly transverse, 1.2-1.3 × wider than long. Scutellum large, flat, shiny. Fore coxae contiguous. Femora unarmed or tooth on front ones appearing as small granule. Tibiae straight, fore and middle pair with small mucro, hind pair indistinctly mucronate.

MALE. Sternite 8 narrowly divided into 2 plates. Aedeagus as in Figs. 21, 22, of characteristic shape in dorsal and lateral views, body elongate, hardly tapering toward apex; lacking distinct basal sclerite but internal sac with rather striking longitudinal folds.

FEMALE. Bursa and spermatheca as in Fig. 27, bursa with large sclerite, spermathecal duct short, fine at both ends.

LENGTH: 1.9-2.5 mm; width: 1.0-1.3 mm.

DISTRIBUTION: New Caledonia. Yahoué, 22 Jan 1963, 1 male, G. Kuschel; Yahoué, 11 Oct 1978, 1 male by sweeping, J. S. Dugdale; between Noumea and Bourail, 2 pairs, Coll. Fauvel.

Holotype male, 2.05 × 1.05 mm, Yahoué, NZAC. Paratypes at ISNB and NZAC.

HOSTPLANT. Unknown.

REMARKS. Distinguishable from all other species of the genus by having a large, flat, shiny scutellum. The lack of a distinct basal sclerite is thus far unique in the genus.

8. *Palontus* **dispar** n.sp. Figs. 23, 24

Integument dark reddish brown. Vestiture consisting of pubescence and some pale scales, scales mainly on base of interstria 3, behind humeral callus, before middle of elytra and on underside.

Head dull, densely but very shallowly punctate, squamose. Rostrum moderately robust, dull or slightly shiny, curved, about 4 × as long as broad at apex, slightly shorter than prothorax, rather coarsely punctate, areas between rows of puncta carinulate; prerostrum as long as broad. Prothorax 1.1 × wider than long, strongly rounded on sides, so strongly convex as to appear humped on middle in lateral view, densely and coarsely punctate. Scutellum small, dull, slightly to distinctly raised anteriorly. Elytra rather broad, convex throughout in lateral view, interstria 3 on middle with elongated tubercle topped with black vestiture. Fore coxae contiguous. Fore femora with small tooth, others at most asperate. Fore and middle tibiae with small mucro, hind tibiae with very small mucro.

MALE. Sternite 8 with plates rather broadly separated. Aedeagus as in Figs. 23, 24, basal sclerite modified to flagellum as long as entire aedeagus.

FEMALE. Unknown.

LENGTH: 2.6-2.8 mm; width: 1.35-1.60 mm.

DISTRIBUTION: New Caledonia. Houailou, 30 Oct 1978, 1 male beaten at night, J. C. Watt; Baie du Prony, 1 male, Coll. Fauvel; Plaine des Lacs, 1959, 1 male, N. L. H. Krauss.

Holotype male, 2.6 × 1.35 mm,

Houailou, NZAC. Paratypes at BPBM, and ISNB.

HOSTPLANT. Unknown.

REMARKS. Readily separated from all other species of the genus by the presence of a hump on the pronotum and tubercle on the elytra giving the weevil a rather disparate facies expressed with the Latin adjective 'dispar'.

9. *Palontus* **fidelis** n.sp. Figs. 25, 26, 28

Colour and patterns much as in two preceding species.

Head dull, shallowly punctate, squamose. Rostrum slender, curved, in male slightly more than 3.5 × longer than broad at apex, 0.90 length of prothorax, carinulate, apical part (prerostrum) about as long as wide; rostrum in female slightly more than 4 × as long as wide, about 0.95 length of prothorax, also carinulate between rows of puncta, apical part about twice as long as wide. Prothorax 1.15-1.20 × broader than long, strongly rounded on sides, distinctly convex in lateral view. Scutellum small, dull, raised to low point. Fore coxae contiguous. All femora unarmed. Mucro small on fore and middle tibiae, indistinct on hind tibiae.

MALE. Aedeagus as in Figs. 25, 26, slightly asymmetrical at apex, with long flagellum.

FEMALE. Bursa and spermatheca as in Fig. 28, duct very long, thicker at bursal end, inserted on bursal apex.

LENGTH: 2.3-2.6 mm; width: 1.20-1.35 mm.

DISTRIBUTION: Loyalty Islands. Maré I., La Roche, March 1959, 1 male, 3 females, N. L. H. Krauss.

Holotype male, 2.5 × 1.3 mm, data as above, BPBM. Paratypes at BPBM and NZAC.

HOSTPLANT. Unknown.

REMARKS. Similar externally and internally to *P. dispar* but lacking the humped prothorax and tuberculate elytra of the latter. The species name 'fidélis' is Latin for loyal.

10. *Palontus* **leucopogonis** n.sp. Figs. 29, 30

Integument uniformly reddish brown. Vestiture consisting mainly of silvery grey scales with few subdued darker markings, forming 3 stripes on pronotum, median band across middle of elytra, small area at suture on top of declivity and a sutural stripe at basal third.

Head dull, densely covered in white and brown scales. Rostrum slender, 4.2-4.3 × as long as broad at apex, 0.90-0.95 length of prothorax, distinctly saddled against frons, curved, dull, carinulate between rows of puncta; prerostrum only slightly longer than broad. Prothorax as long as broad, gently rounded on sides, moderately convex in lateral view. Scutellum small, dull, raised slightly above level of elytra. All femora unarmed or fore femora alone with minute tubercle. All tibiae distinctly mucronate but mucro on hind pair smaller.

MALE. Sternite 8 with broadly separate plates. Aedeagus as in Figs. 29, 30, with flagelliform basal sclerite, the flagellum hardly longer than aedeagal body.

FEMALE. Unknown.

LENGTH: 2.6-2.7 mm; width: 1.3 mm

DISTRIBUTION: New Caledonia. Plum, 8 Oct 1978, 2 males on *Leucopogon (Cyathodes* on label), G. Kuschel.

Holotype male, 2.6 × 1.3 mm, data as above, and paratype at NZAC.

HOSTPLANT. *Leucopogon* sp., with silvery white leaves on the underside (Epacridaceae).

REMARKS. *P. leucopogonis* is characterised by its frontorostral area being distinctly depressed as a saddle seat and the silvery white scaling.

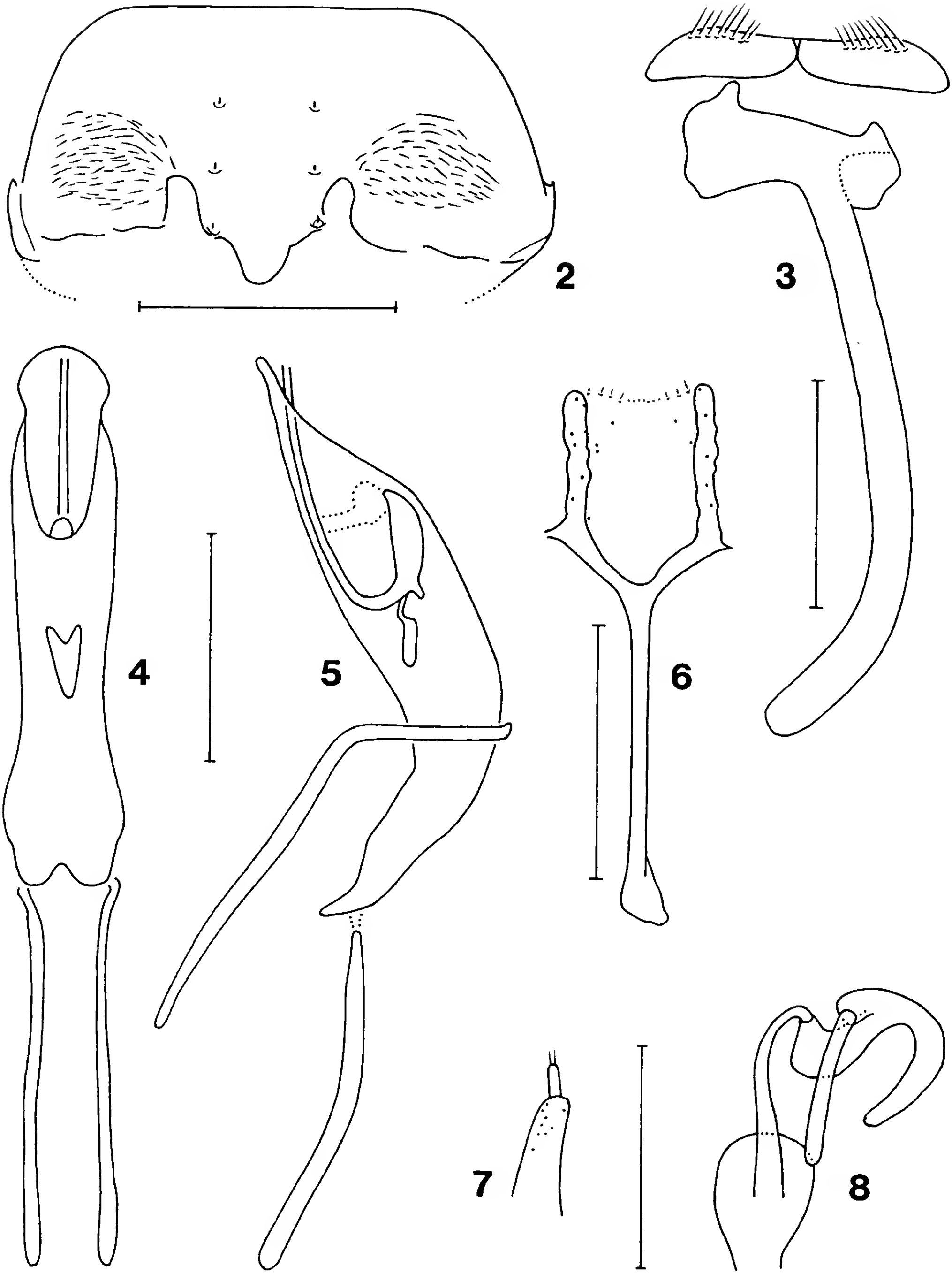
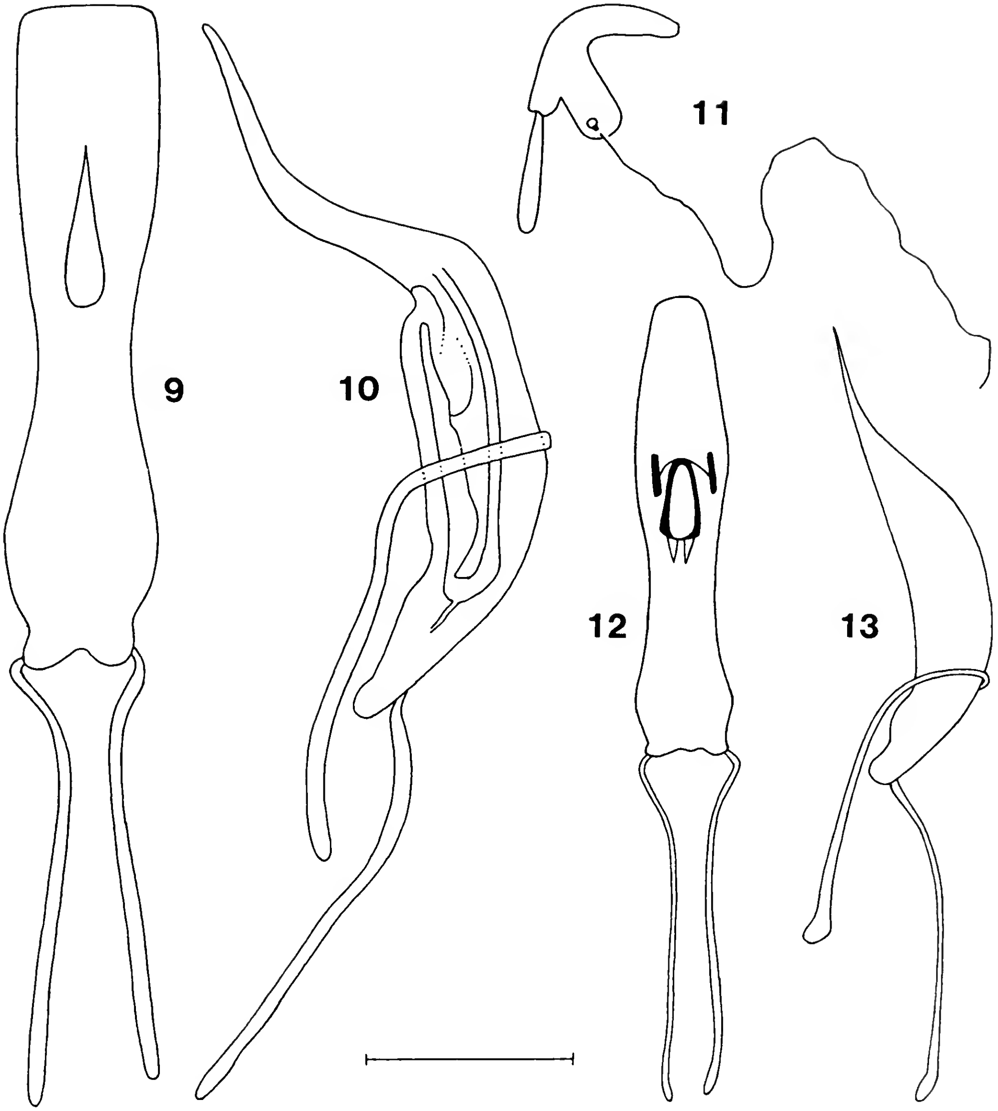


Fig. 2-8 *Palontus exospermi* n.sp., Mt Panié, 2. tergite 7 of male, dorsal; 3. sternites 8 and 9, ventral; 4. aedeagus, dorsal; 5. aedeagus, lateral; 6. sternite 8 of female, ventral; 7. hemisternal apex; 8. spermatheca and part of bursa. Scales = 0.2 mm.

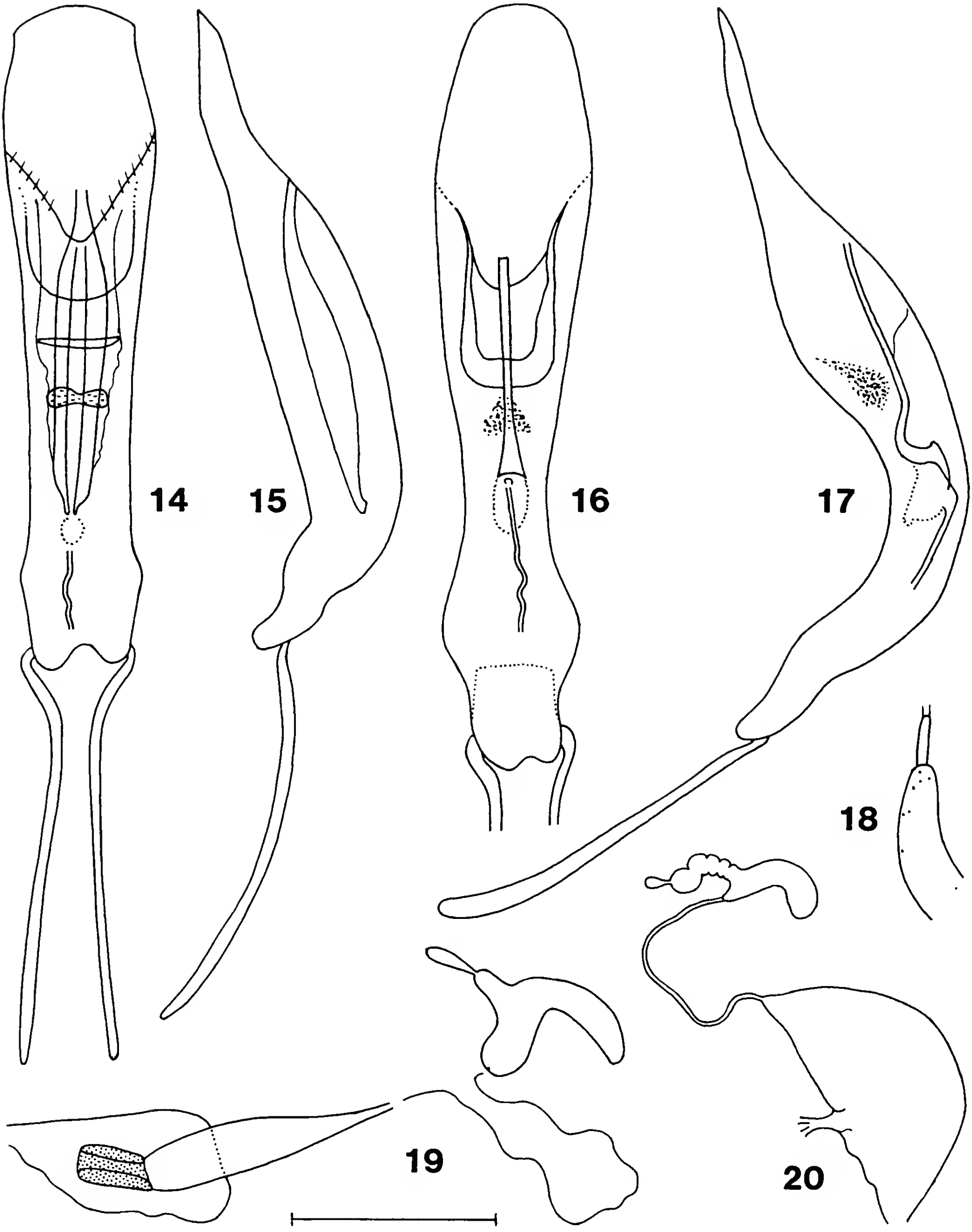


Figs. 9-13. *Palontus bellioli* n.sp., Tchamba Valley: 9. aedeagus, dorsal; 10. aedeagus, lateral; 11. spermatheca with full length of duct. *P. paniensis* n.sp., Mt Panié: 12. aedeagus, dorsal; 13. aedeagus, lateral. Scale = 0.2 mm.

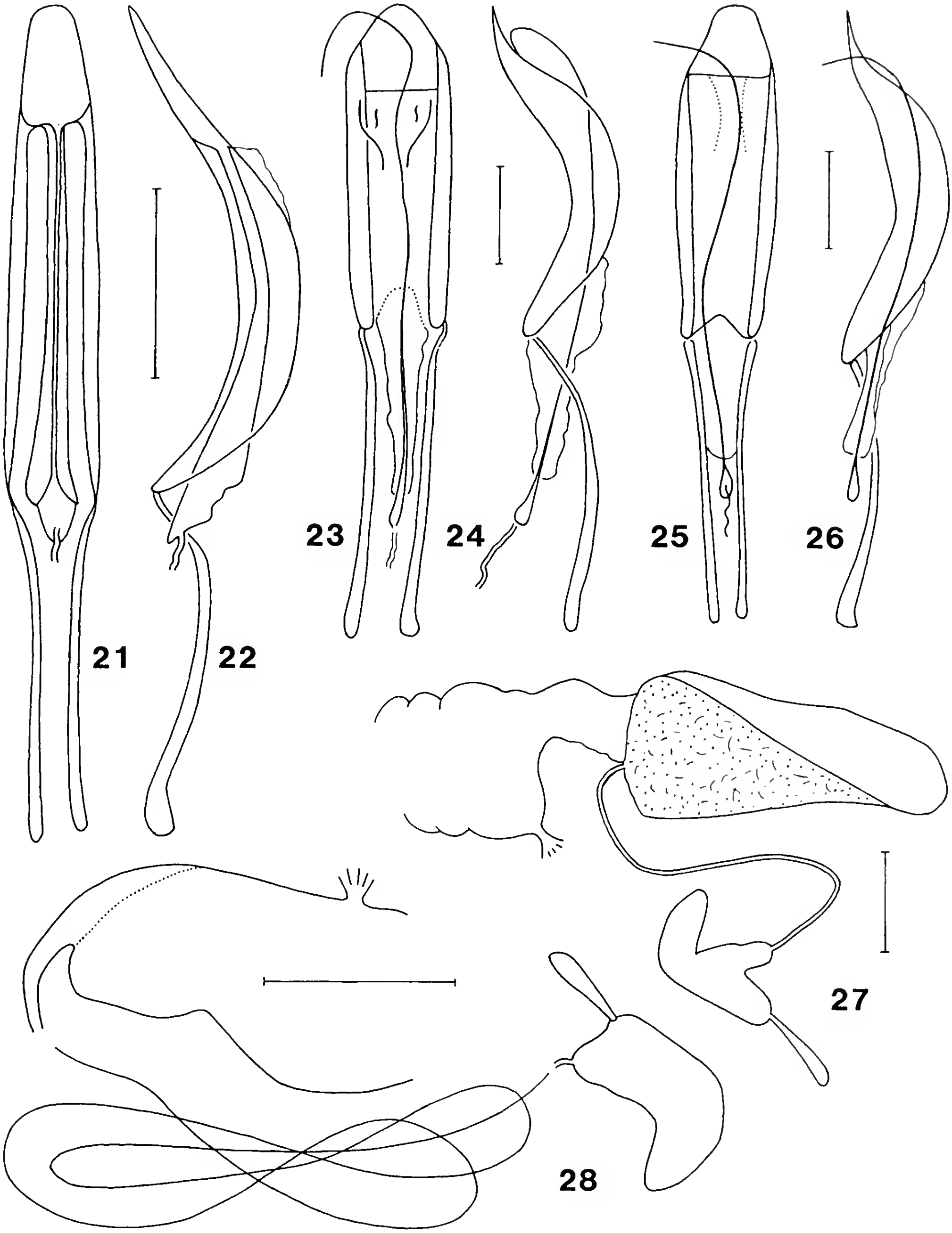
11. *Palontus* **iodes** n.sp. Figs. 31-33.

Integument reddish brown, sterna usually darker, discretely pubescent with fine, usually whitish hairs, these slightly coarser on sides of pronotum, at base of interstria 6, across top of declivity there forming narrow pale band.

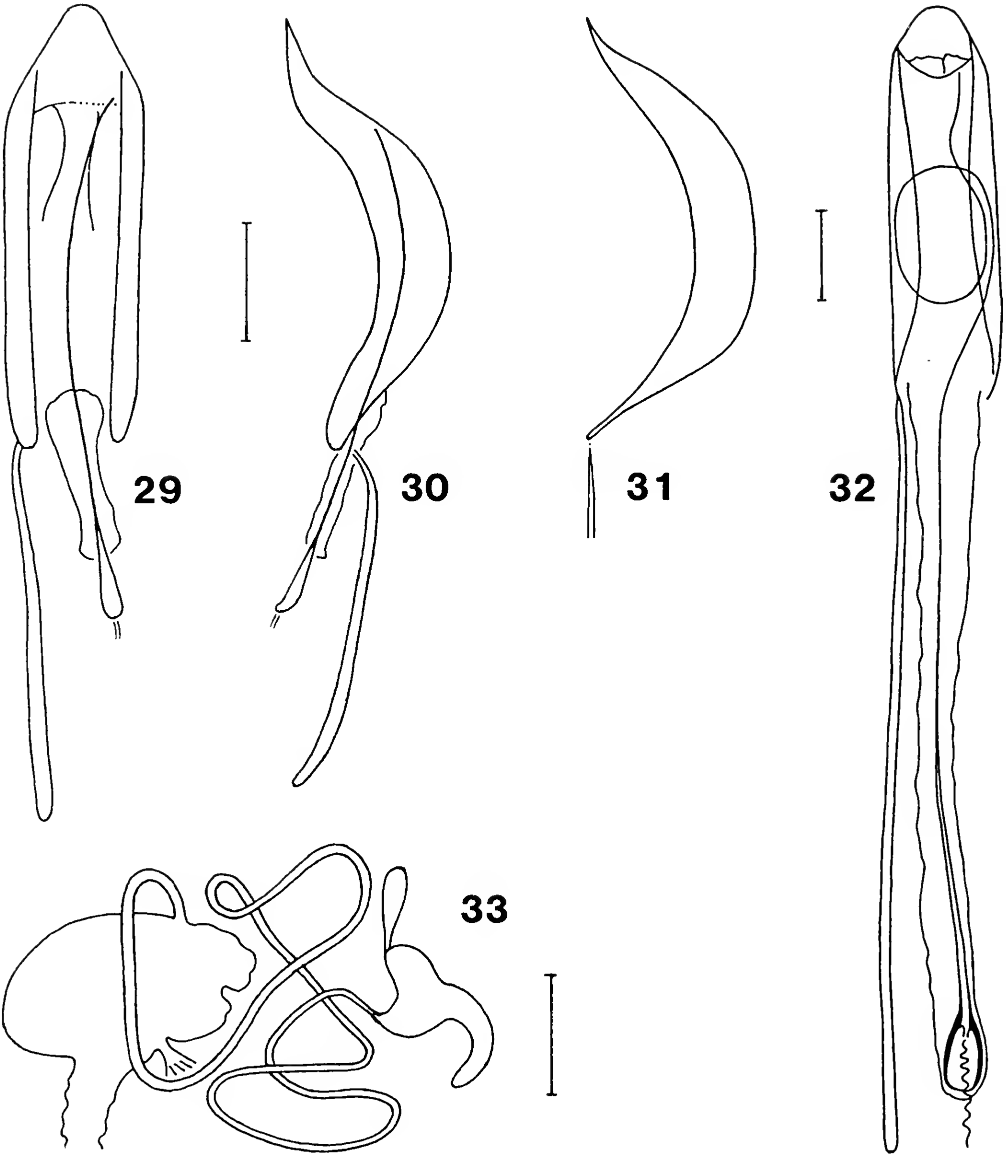
Head dull, densely, shallowly punctate. Rostrum robust, gently curved, 2.5-2.6 × as long as broad at apex, about 0.80 length of prothorax, not carinulate. Prothorax nearly 1.10 × broader than long, gently rounded on sides, almost flat dorsally in lateral view,



Figs. 14-20. *Palontus turritus* n.sp., Mt Do: 14. aedeagus, dorsal; 15. aedeagus, lateral. *P. nothofagi* n.sp., Mt Do: 16. aedeagus, dorsal; 17. aedeagus, lateral; 18. hemisternal apex; 19. spermatheca and part of bursa. *P. flebilis* n.sp., Pic d'Amoa: 20. spermatheca and bursa. Scale = 0.2 mm.



Figs. 21-28. ***Palontus varius*** n.sp., Noumea/Bourail: 21. aedeagus, dorsal; 22. aedeagus, lateral; 27. spermatheca and bursa. *P. dispar* n.sp., Houailou: 23. aedeagus, dorsal; 24. aedeagus, lateral. *P. fidelis* n.sp., I. Maré: 25. aedeagus, dorsal; 26. aedeagus, lateral; 28. spermatheca and bursa. Scales = 0.2 mm.



Figs. 29-33. *Palontus leocopogonis* n.sp., Plum: 29. aedeagus, dorsal; 30. aedeagus, lateral. *P. iodes* n.sp., Poindimié: 31. aedeagus, lateral; 32. aedeagus, dorsal; 33. spermatheca and bursa. Scales = 0.2 mm.

densely punctate with raised intervals, rendering it rugose. Scutellum small, dull, flat or nearly so. Elytra weakly convex across basal half, dorsum straight for most part in lateral view. Fore coxae contiguous or nearly so. All femora with strong, sharp tooth. Tibiae slightly sinuous on lower edge, fore and middle pairs uncinate, hind pair mucronate.

Male. Sternite 8 with contiguous plates. Aedeagus as in Figs. 31, 32; apodemes twice as long as aedeagal body; internal sac with very long flagellum, this longer than entire aedeagus.

Female. Bursa and spermatheca as in Fig. 33, spermathecal duct wider at bursal end and inserted dorsally on bursa.

Length: 2.7-3.0 mm; width: 1.30-1.45 mm.

Distribution: New Caledonia. Poindimié, 11 Feb 1963, 8 specimens, C. M. Yoshimoto and G. Kuschel.

Holotype male, 2.7 × 1.3 mm data as above, NZAC. Paratypes at BPBM and NZAC.

Hostplant. Unknown.

Remarks. *P. iodes* is distinguished by having a much more robust rostrum than any of the other species of the genus and by its distinctive colour. It differs considerably also by being the only species that has an aedeagus whose body is shorter than the apodemes. The specific epithet 'iódes' is Greek for rusty.

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NOTROPIS AMMOPHILUS, A NEW CYPRINID FISH FROM SOUTHEASTERN UNITED STATES

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ABSTRACT

Notropis **ammophilus**, a new shiner (Cyprinidae), is described from southeastern United States. It is related to *Notropis longirostris*, *N. sabinae*, and another undescribed form. The distribution of *N.* **ammophilus**, the orangefin shiner, is primarily below the Fall Line in the Mobile Bay basin in Alabama and Mississippi, in Yellow Creek, a tributary to the Tennessee River in northeastern Mississippi, in the Hatchie River system in southwestern Tennessee and northern Mississippi, and in the Skuna River drainage of the Yazoo River system in northern Mississippi.

The orangefin shiner is more similar to *N. longirostris* in nuptial coloration and tuberculation but more similar to *N. sabinae* in general body shape. These three species plus an additional undescribed form are considered to comprise a species complex by themselves.

INTRODUCTION

Existence of the orangefin shiner, herein described, has been known to ichthyologists for many years. One of the earliest references to this species appeared in Cook (1959). Most authors, including Smith-Vaniz (1968), assumed this form to be an allopatric replacement of *Notropis longirostris* in the Mobile basin. We now know that this form occurs in the headwaters of the Hatchie River system in Mississippi and Tennessee, in tributaries to the south bend of the Tennessee River system, specifically Yellow Creek in northeastern Mississippi, and in the upper Skuna River of the Yazoo River system in northern Mississippi. The primary purpose of this paper is to formally describe the species and to summarize our field observations.

Notropis longirostris (Hay 1881) was placed in the genus *Alburnops* at the time of its original description and subsequently in *Hybopsis*, as was *Notropis sabinae* Jordan and Gilbert 1886, by Jordan, Evermann and Clark (1930). The type species of *Alburnops* is *Alburnops blennius* Girard (1856: 194) by subsequent designation of Jordan and Gilbert in 1877 (Gilbert, 1978). The type species of *Hybopsis* is *Hybopsis amblops* (Rafinesque 1820: 51) by subsequent designation of Jordan and Gilbert (1877). We do not believe that *Notropis longirostris* is closely related to *N. blennius*. The senior author does not believe that *N. longirostris* is closely related to any of the typical members of the genus *Hybopsis (amblops, winchelli, amnis, lineapunctata, rubrifrons, hypsinotus)* contrary to Mayden's (1989) recent placement of these forms in his grouping of the genus *Hybopsis*. At present we place the new form, together with *Notropis longirostris*, *N. sabinae* and another undescribed species, in a species complex, *longirostris* species group, by themselves. An analysis of the *longirostris* species group will appear in a forthcoming paper. The four species of this group are characterized by: A pronounced elongate swelling of the rami of the lower jaw that bears tubercles in breeding males; distal portion of anterior rays and interradial membranes of anal fin of breeding females opaque and more or less (depending on species) flexed dorsally; subterete body shape, dorsal contour arched more than ventral; long, decurved snout; large, inferior, horizontal mouth; typically 8 dorsal fin rays, 7 anal rays, 19 caudal rays, 8—8 pelvic rays, and 12 caudal peduncle scale rows; silvery peritoneum; and psammophilous life style.

The following abbreviations are used: SL = Standard length, CU – Cornell University; GSA = Geological Survey of Alabama; MSU = Mississippi State University; TU = Tulane University, Museum of Natural History; UAIC = University of Alabama Ichthyology Collection; UF = University of Florida, Florida State Museum; UMMZ = University of Michigan, Museum of Zoology; USNM = National Museum of Natural History; and UT = University of Tennessee.

We follow Robins, et al. (1980) with regards to the gender of the genus *Lepomis* and generic groupings of the family Cyprinidae.

Notropis **ammophilus**, a new species
Orangefin Shiner
Figs. 1—4

Notropis sp. Cook, 1959 (reference to undescribed species in upper Tombigbee and eastward). Smith-Vaniz, 1968 (key, allopatric with *N. longirostris*, Mobile basin endemic). Boschung, 1973, 1984, 1987, 1989 (distribution and abundance in upper Tombigbee). Jenkins, 1976 (undescribed species, distribution). Gilbert, 1980 (distribution). Gilbert and Burgess, 1980 (distribution). Heins et al., 1980 (reproductive biology and habitat). Timmons, 1982 (impoundment of upper Tombigbee). Ramsey, 1984 (distribution and conservation status). Pierson and Schultz, 1984 (distribution and relative abundance in Bull Mountain Creek). Wiley and Mayden, 1985 (distribution). Swift et al., 1986 (distribution). Pierson et al., 1986 (distribution in Buttahatchee River). Mettee et al., 1987 (distribution and abundance in lower Tombigbee). Mettee et al., 1989 (distribution in Black Warrior River system). Pierson et al., 1989 (distribution in Cahaba River system).

Notropis ammophilus. Hubbard, 1987: (*nomen nudum*).

MATERIAL.—The type material consists of 3289 specimens measuring from 17.7 to 48.5 mm in standard length, collected from Chilatchee Creek, a tributary to the Alabama River. Other material examined consists of 41,081 specimens from 1061 collections throughout the range of the species (Fig. 1).

Holotype.—TU 151630, an adult male 48.5 mm standard length, from Chilatchee Creek, trib. Alabama River, 0.3 mi. N Alberta, State Hwy. 5 at Dallas-Wilcox county line, Alabama (T15N, R7E, Sec. 30), on 9 April 1988, collected by Royal D. Suttkus.

Paratypes.—The 124 specimens (TU 151631) collected with the holotype and 14 other series collected at the same site on the following dates: UAIC 265.04 (74), August 30, 1956; UAIC 2362.13 (116), October 11, 1966; TU 60871 (1147), December 18, 1969; UAIC 5899.04 (172), July 23, 1980; TU 121386 (129), May 15, 1981; TU 125388 (292), May 15, 1982; GSA 6865.07 (84), October 19, 1983; TU 140934, May 24, 1985 distributed as follows: TU 140934 (207), CU 71712 (20), UF 78362 (20), UMMZ 214869 (20), UT 44.4504 (20) and USNM 301164 (20);

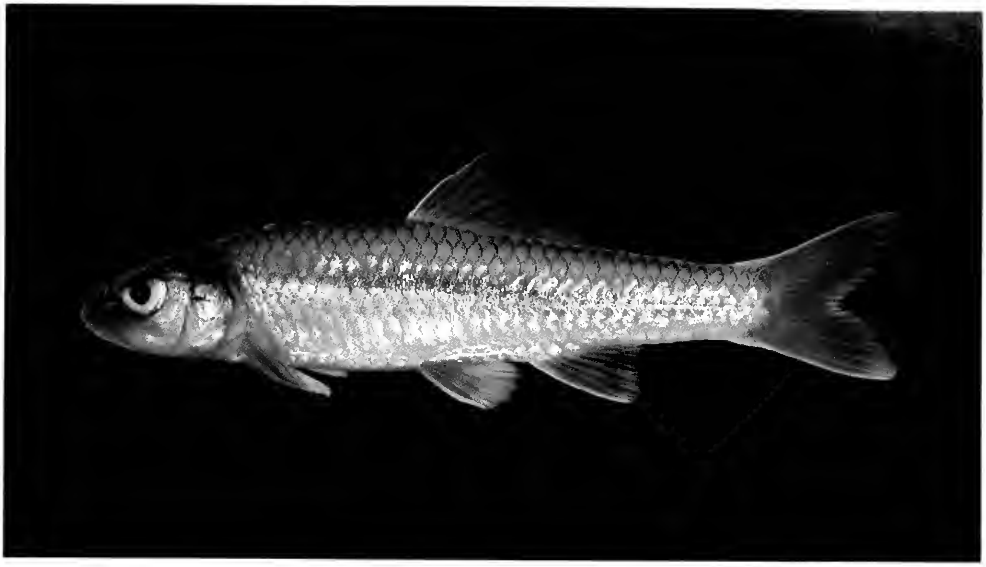

Fig. 1. *Notropis ammophilus*. Lateral view of a paratype, UAIC 5899.04, male, 44 mm in SL, collected by M. F. Mettee and P. E. O'Neil on July 23, 1980. Photo by P. E. O'Neil.

TU 145519 (117), May 20, 1986; UT 44.4341 (19), May 16, 1988; TU 153083 (98), August 2, 1988; TU 153185 (296), August 3, 1988; TU 154399 (25), February 3, 1989 and TU 154734, May 9, 1989 distributed as follows: TU 154734 (19), UMMZ 215189 (100).

Additional material examined for counts, measurements, pigmentation and/or used for distribution map, totaling 41,081 specimens, in 1,061 collections, are as follows (in parentheses, number of collections followed by number of specimens):

Lower Tombigbee River drainage. ALABAMA. Choctaw County (194 : 16,399), Clarke County (45 : 1000), Marengo County (42 : 4,837), Sumter County (31 : 1,613), Washington County (1 : 99). MISSISSIPPI. Kemper County (3 : 100), Lauderdale County (2 : 94).

Upper Tombigbee River drainage (pre-Tennessee-Tombigbee impoundment). ALABAMA. Fayette County (2 : 14), Franklin County (2 : 34), Greene County (10 : 714), Lamar County (37 : 368), Marion County, (11 : 208), Pickens County (16 : 267), Sumter County (11 : 124), Tuscaloosa County (6 : 30). MISSISSIPPI. Chickasaw County (6 : 1,079), Clay County (11 : 579), Itawamba County (32 : 186), Lee County (7 : 754), Lowndes County (81 : 518), Monroe County (39 : 557), Noxubee County (4 : 41), Oktibbeha County (8 : 224), Pontotoc County (1 : 309), Prentiss County (6 : 161), Tishomingo County (6 : 28), Union County (2 : 2), Webster County (1 : 110), Winston County (5 : 20).

Black Warrior River drainage. ALABAMA. Greene County (4 : 155), Hale County (15 : 560), Tuscaloosa County (28 : 150), Walker County (1 : 1).

Alabama River drainage. ALABAMA. Autauga County (12 : 174), Butler County, (1 : 3), Chilton County (10 : 337), Clarke County (8 : 368), Dallas County (21 : 884), Dallas-Lowndes counties (1 : 63), Elmore County (1 : 1), Lowndes County (2 : 13), Marengo

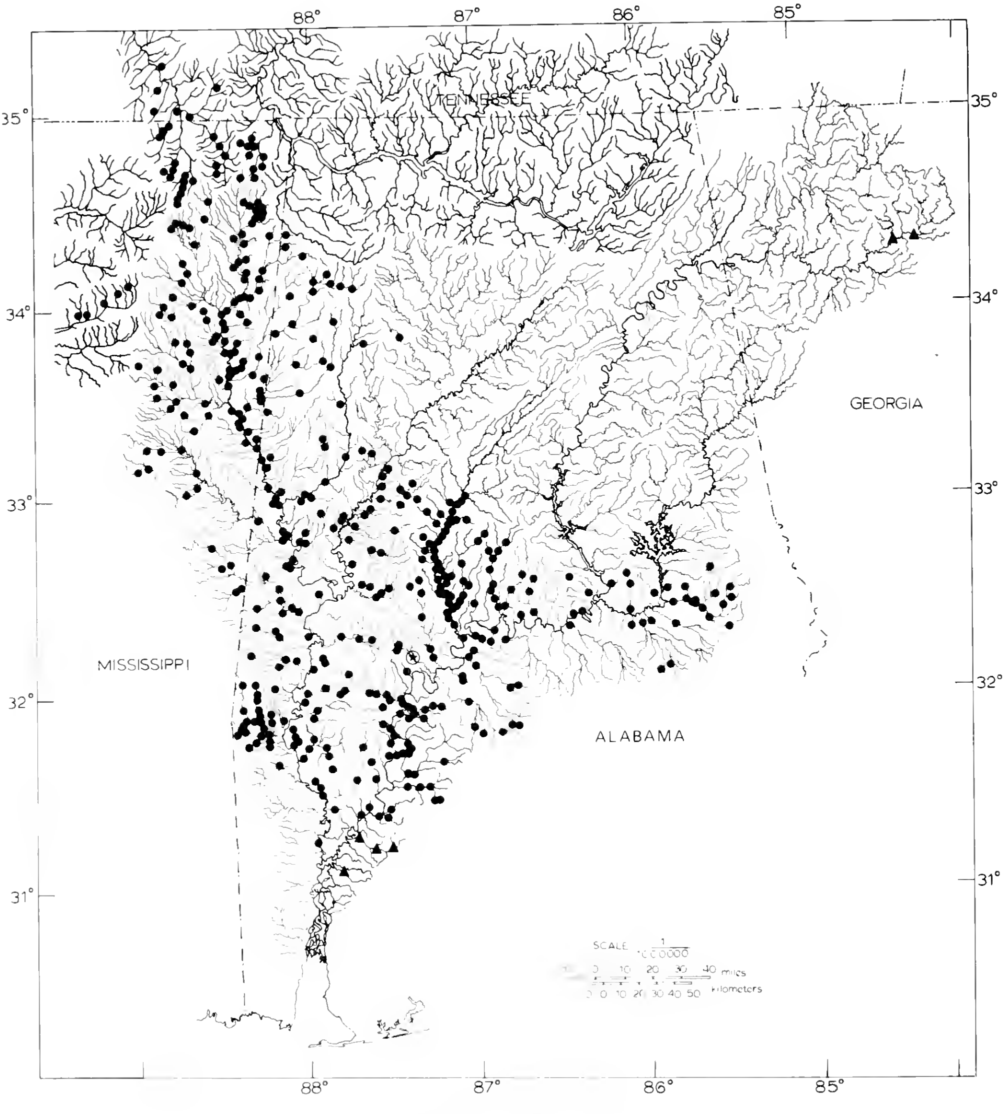

Fig. 2. Distribution by record stations of *Notropis ammophilus* (solid dots), type locality (star in circle) and *Notropis longirostris* in Mobile Bay drainage basin only (solid triangles).

County (3 : 50), Marengo-Dallas counties (1 : 147), Monroe County (33 : 348), Perry County (4 : 41), Wilcox County (137 : 2,183).

Cahaba River drainage. ALABAMA. Bibb County (21 : 476), Dallas County (15 : 302), Perry County (29 : 681).

Coosa River drainage. ALABAMA. Elmore County (4 : 64).

Tallapoosa River drainage. ALABAMA. Bullock County (2 : 65), Elmore County (5 : 43), Lee County (5 : 43), Macon County (21 : 1,662), Montgomery County (3 : 18), Tallapoosa County (1 : 3).

Tennessee River drainage. MISSISSIPPI. Alcorn County (1 : 12), Tishomingo County (15 : 157).

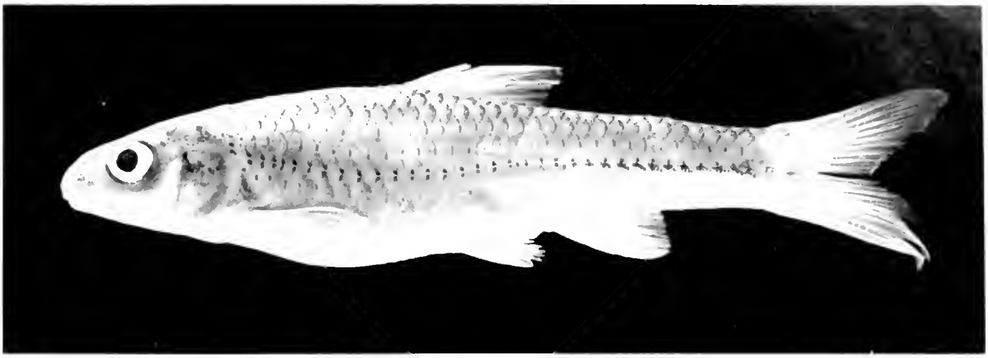

Fig. 3. *Notropis ammophilus.* Lateral view of a specimen from UMMZ 111160, 41 mm in SL. Photo by W. L. Brudon.

Hatchie River drainage. MISSISSIPPI. Alcorn County (4 : 21), Prentiss County (2 : 7), Tippah County (14 : 967), Union County (2 : 16), TENNESSEE. Hardeman County (6 : 121), McNairy County (2 : 3).

Yazoo River drainage. MISSISSIPPI. Calhoun County (2 : 109), Pontotoc County (3 : 55).

The locality data for *N. longirostris* and *N. sabinae* that were used for counts, measurements and description of pig-

Fig. 4. *Notropis ammophilus.* Anterolateral view of head of specimen in Fig. 3. Photo by W. L. Brudon.

mentation are given in the text and in Tables 2 and 3. Collection sites for eleven lots of *N. longirostris* from the Mobile basin as shown on Fig 2. There are six lots from three sites on Little River in Baldwin, Escambia and Monroe counties, Alabama: TU 32554 (1), TU 44400 (6), TU 44414 (14), TU 99939 (15), TU 153958 (7), and UAIC 6528.09 (75). There is one lot from Majors Creek, Baldwin County, Alabama: UAIC 426.02 (6). In addition to these lots from the lower part of the Mobile basin, there are four lots from two sites on the upper Etowah River in Cherokee County, Georgia: UT 44.1940 (8) and UT 44.2157 (6); UT 44.2118 (3) and UT 44.2233 (4).

Diagnosis.—A species of *Notropis* with 4—4 pharyngeal teeth and 7 anal rays. Dorsal fin origin directly over pelvic origin; both dorsal and pelvic fins equal distance between tip of snout and base of caudal fin. Anal fin length of males greater than that of *N. longirostris* and *N. sabinae*. Differs in body proportions from other members of the species complex as seen in Tables 1 and 4. Nuptial males have bright orange fins, orange along lips and on iris (Figure 1).

Description.—In addition to the characters given in the diagnosis, counts and measurements are given to compare *Notropis ammophilus* with *N. longirostris* and *N. sabinae* (Tables 1-4). The pharyneal teeth are moderately hooked, the edges of the well developed grinding surfaces are entire or weakly crenate, and, in 70 specimens examined, the formula is 4—4. The anal fin ray count is typically 7 (in 96 percent of sample), occasionally 6 (1 percent) or 8 (3 percent), where $N = 100$. The dorsal fin ray count is almost always 8 (98 percent of sample), rarely 9 (2 percent), where $N = 100$. Pelvic fin rays typically number 8—8 (92 percent of sample), occasionally 7—8 (2 percent), 8—7 (3 percent) or 8—9 (3 percent), where $N = 100$. The principal caudal rays number 19 (94 percent of sample), 18 (1 percent), and 20 (5 percent), where $N = 100$. Caudal peduncle scale rows, numbering 12 in the entire sample of 100 specimens, consist of 5 rows each above and below the lateral line. Other scale counts are given in Table 2. The Weberian apparatus, consisting of 4 vertebrae, and the single urostylar vertebra were included in the total vertebral count. *Notropis ammophilus* usually has 34 or 35 vertebrae (Table 3).

Measurements of the holotype are detailed in Table 1 and its fin ray and scale counts are as follows: D 8, A 7, P 14, V 8, C 19, lateral line scales 34, caudal peduncle scales 12, body circumferential scales 24, and predorsal diagonal scale rows 14.

The subterete body form, with a decidedly arched dorsal profile and only slightly curved venter, is well adapted to the benthic habitat. The body is moderately robust anteriorly but tapers rather abruptly posterior to the dorsal fin. The mouth is inferior and nearly horizontal to slightly angled. The dorsal fin is moderately elevated and its anterior rays are usually longer than the posterior ones of the depressed fin; the posterior margin is nearly straight, or it may describe a shallow sigmoid curve. The anal fin is less elevated than the dorsal, particularly that of the females, and its posterior margin also describes a sigmoid curve. The anterior rays of the anal fin, even the flexed rays of females, are usually longer than the posterior ones of the depressed fin. Other fins are typical in shape and size for small shiners. Usually the pectorals are more expansive in the males than in females.

Only males have well developed

TABLE 1. Proportional Measurements (Expressed in Thousandths of Standard Length) for *Notropis ammophilus*, *N. longirostris* and *N. sabinae*.

		N. ammophilus				*N. longirostris*				*N. sabinae*			
		10 Males		10 Females		10 Males		10 Females		10 Males		10 Females	
Character	Holotype	Range	x̄	Range	x̄	Range	x̄	Range	x̄	Range	x̄	Range	x̄
Standard length (mm)	48.5	42.5-45.4	43.6	43.3-47.1	45.2	48.7-55.9	52.8	51.1-57.8	54.2	41.2-48.1	44.0	44.4-47.7	46.3
Dorsal origin to snout tip	515	499-519	509	494-518	509	477-499	489	481-507	494	492-518	502	487-504	496
Dorsal origin to caudal base	519	514-539	527	511-535	519	522-545	533	524-548	535	532-554	543	527-563	548
Dorsal origin to occiput	295	276-305	296	277-296	293	283-301	294	287-311	298	269-297	283	274-292	282
Pelvic insertion to snout tip	509	498-526	509	501-527	514	462-486	478	474-495	485	474-495	482	470-503	484
Anal origin to caudal base	346	339-363	349	317-349	333	341-373	363	340-364	353	351-398	380	362-380	371
Body depth	229	209-236	220	240-266	251	180-201	188	183-215	191	225-246	237	224-243	236
Body width	155	136-148	140	163-188	177	129-140	134	127-143	136	145-163	156	148-167	161
Caudal peduncle length	235	222-240	232	229-245	237	232-258	245	235-267	251	233-255	243	228-252	242
Caudal peduncle depth	109	108-117	112	99-115	109	98-109	103	95-108	100	122-129	125	118-126	122
Head length	266	261-283	273	263-279	270	230-247	239	229-250	241	258-277	267	261-285	271
Head depth	165	162-176	167	167-182	174	137-145	142	140-150	144	165-184	176	169-182	177
Head width	152	144-159	152	155-177	164	124-133	130	124-140	131	148-166	159	149-159	154
Interorbital least fleshy	89	87-94	90	85-94	90	74-80	76	72-81	75	90-99	94	86-93	89
Snout length	97	92-99	96	88-99	94	78-87	81	78-87	82	96-104	101	96-105	99
Eye length	68	68-70	69	66-70	68	57-62	60	57-62	60	66-71	69	66-70	68
Upper jaw length	86	85-97	92	88-95	91	74-84	79	78-82	81	84-91	87	89-95	92
Dorsal fin length	206	207-233	222	202-231	215	180-200	191	181-196	188	203-233	220	200-231	218
Anal fin length	169	181-216	190	155-174	166	152-168	162	135-158	146	157-175	164	150-170	159
Caudal fin length	251	251-281	267	249-282	264	241-279	258	240-276	259	269-306	286	252-293	276
Pectoral fin length	165	164-190	180	166-189	176	154-182	172	160-186	171	161-179	170	170-183	174
Pelvic fin length	146	143-159	152	139-155	147	127-141	134	126-144	135	144-157	150	139-150	145

TABLE 2. Frequency Distributions for Pectoral Fin Rays and Scale Counts in *Notropis ammophilus*, *N. longirostris* and *N. sabinae*.

Species and system	Pectoral Fin Rays						Lateral Line Scales							
	13	14	15	16	N	$\bar{x}$	32	33	34	35	36	37	N	$\bar{x}$
N. ammophilus														
Alabama River	9	59	29	3	100	14.26	2	39	46	13			100	33.70
Tennessee River	2	22	6		30	14.13	2	9	13	5	1		30	33.80
Hatchie River		18	10	2	30	14.47		9	16	5			30	33.87
Yazoo River	5	18	7		30	14.07	2	8	16	3	1		30	33.77
	16	117	52	5	190	14.24	6	65	91	26	2		190	33.75
N. longirostris														
Biloxi River	6	31	13		50	14.14		1	5	29	13	2	50	35.20
N. sabinae														
Sabine River	8	27	14	1	50	14.16	2	26	18	4			50	33.48

Species and system	Body circumferential Scales									Predorsal Diagonal Scale Rows							
	19	20	21	22	23	24	25	N	$\bar{x}$	12	13	14	15	16	17	N	$\bar{x}$
N. ammophilus																	
Alabama River		14	15	22	28	21		100	22.27		19	63	17	1		100	14.00
Tennessee River		7	6	10	5	2		30	21.63		14	12	2	2		30	13.73
Hatchie River		1	1	8	7	13		30	23.00		9	17	4			30	13.83
Yazoo River		12	7	5	1	4	1	30	21.37	3	10	15	2			30	13.53
		34	29	45	41	40	1	190	22.14	3	52	107	25	3		190	13.86
N. longirostris																	
Biloxi River	1	20	16	10	2	1		50	20.90		1	29	13	6	1	50	14.54
N. sabinae																	
Sabine River			2	10	9	24	5	50	23.40	6	41	3				50	12.94

TABLE 3. Number of Vertebrae in *Notropis ammophilus*, *N. longirostris* and *sabinae*.

Species and system	Number of Vertebrae						
	33	34	35	36	37	N	x̄
N. ammophilus							
Alabama River	1	51	54	3		109	34.54
Tennessee River		6	15	2		23	34.83
Hatchie River	1	17	17	1		36	34.50
	2	74	86	6		168	34.57
N. longirostris							
Pascagoula River			6	47	21	74	36.20
N. sabinae							
Sabine River	5	71	40	1	2	119	34.36

nuptial tubercles. Some females have a few minute tubercles on the top of the head but the remainder of the body is devoid of tubercles. The largest tubercles are scattered over the dorsal surface of the head where they are double in size from the internarial area to the occiput. There is a single row of large tubercles, more or less evenly arranged, over the supraorbital rim. Minute tubercles cover the snout and are scattered between the larger ones on top of the head. Some males have minute tubercles extending to the lachrymal area and to the upper parts of the opercular region. The head tuberculation, as we have described it above, agrees reasonably well with the description of Heins et al. (1980) for specimens from Uphapee Creek. Multiple rows of small tubercles are present on the pectoral fin rays, and their number diminish toward the posterior rays. Nuptial males have tubercles on the first seven to nine pectoral rays. Some nuptial males taken in May have tubercles on the leading edge of the dorsal fin, the anal fin, and on the upper and lower caudal fin margins. In addition, a few males have tubercles on the predorsal and anterolateral scales. The typical intermediate tubercular pattern shows tuberculate ridges on the lower jaw, a few tubercles on the leading edge of the dorsal fin, the upper and lower margin of the caudal fin, and the lower two or three branched caudal rays.

The lateral line system is usually complete. Rarely is the last scale of the lateral line unpored. The lateral line is nearly straight, with only a slight dip anteriorly; above the pelvic fin insertion, it gradually angles dorsally and then levels at the midlateral area of the caudal peduncle.

COLORATION.—The orangefin shiner, when not in nuptial attire, is a pale, very lightly pigmented fish. The prevalent pigmentation of preserved specimens is the dark spots above and below each lateral line pore. The spots are prominent anteriorly but often blend with the lateral stripe on the caudal peduncle. The short lateral stripe begins on the lateral area above the insertion of the anal fin, and it extends posteriorly to the base of the caudal fin. The pigmentation of the stripe is somewhat imbedded and is just ventral to the lateral line pigmentation. In most specimens, the lateral line pigment spots are superimposed on the upper margin of the lateral stripe. Some specimens have an additional row of paired spots on the scale row above the lateral line, thus giving the appearance of a double lateral line on the anterior part of the body. There is a thin submarginal line of pig-

TABLE 4. Comparison of *Notropis ammophilus*, *N. longirostris* and *N. sabinae*.

(Measurements of males, expressed in Thousandths of Standard Length)

Character	*ammophilus*	*longirostris*	*sabinae*
Position of dorsal fin insertion	Nearly midway between snout and caudal base	Slightly anterior to midway	Anterior to midway
Position of pelvic fin insertion	Nearly midway between snout and caudal base	Anterior to midway	Anterior to midway
Position of anal origin in females	Nearest to caudal base	Farther from caudal base	Farthest from caudal base
Depth of caudal peduncle	Deep 108-117 (112)	Slim 98-109 (103)	Deepest 122-129 (125)
Length of head	Moderate 261-283 (273)	Shortest 230-247 (239)	Moderate 258-277 (267)
Depth of head	Moderate 162-176 (167)	Least 137-145 (142)	Moderate 165-184 (176)
Width of head	Moderate 144-159 (152)	Narrowest 124-133 (130)	Moderate 148-166 (159)
Interorbital least fleshy	Moderate 87-94 (90)	Narowest 74-80 (76)	Moderate 90-99 (94)
Length of snout	Intermediate 92-99 (96)	Shortest 78-87 (81)	Longest 96-104 (101)
Length of eye	Moderate 68-70 (69)	Smallest 57-62 (60)	Moderate 66-71 (69)
Length of upper jaw	Moderate 85-97 (92)	Shortest 74-84 (79)	Moderate 84-91 (87)
Dorsal fin length	Moderate 207-233 (222)	Shortest 180-200 (191)	Moderate 203-233 (220)
Anal fin length in males	Longest 181-216 (190)	Shortest 152-168 (162)	Intermediate 157-175 (164)
Anal fin, length of anterior rays in depressed fin	Subequal or longer than posterior rays	Subequal or longer	Shorter
Pelvic fin length	Moderate 143-159 (152)	Shortest 127-141 (134)	Moderate 144-157 (150)
Breeding colors	Usually orange	Usually yellow, sometimes orange	Plain, no bright yellow or orange
Distribution of large tubercles on head of male	Scattered over top of head	Scattered over top of head	In compact clusters on end of snout, lachrymal and preorbital areas, less compact on internarial and interobital.
Presence of large tubercles on head of female	None	None	Slightly to moderately developed on end of snout and lachrymal area.
Breast scales	None	Imperfectly scaled: a few prepectoral and between pelvic bases.	None
Mental symphyseal bib	None	None	Usually present, nuptial males and gravid females.
Pharyngeal teeth	4—4	4—4 to 1,4—4,1	4—4

ment on the scales of the lateral line and at least on two rows above the lateral line. Most of the dorsal and dorsolateral scales also have the thin submarginal line of pigment but other melanophores are clustered just anterior to the submarginal "string" and tend to obscure the fine submarginal line, particularly on the middorsal scales. Ventral to the lateral line, the melanophores of the scales' submarginal line become more disconnected and disappear completely on the belly. Most scales, except for a few in the middorsal area, have a nonpigmented anterior central area, thus emphasizing the submarginal pigmentation.

With magnification, a thin band (lateral stripe) of deeply imbedded melanophores is discernable from the central area of the scale row above the anterior part of the lateral line posteriorly in a straight line to near the base of the caudal fin. Because of the anterior dip of the lateral line, the thin band is separated from the lateral line by a distance approximately equal to the depth of a nearby scale, but it is just above the lateral line on the caudal peduncle. There is a thin middorsal stripe before and after the dorsal fin. There are some melanophores along the base of the anal fin that continue posteriorly as a faint midventral caudal peduncle stripe.

The dark pigmentation on top of the head diminishes in intensity from the occiput to the internarial area and snout. There is a moderate amount of pigmentation on the upper part of the opercle, and on the preorbital area where it forms a thin band bordering the suborbital rim. The lips, lower cheek, opercle, gular area, breast, and belly are devoid of pigmentation. The dorsal fin rays, some anal rays of some individuals, and caudal fin rays are more or less margined with melanophores. The pectoral and pelvic fins are essentially immaculate. The basal part of the caudal rays are margined with melanophores, but distally there are few or none. Melanophores at the base of the caudal rays tend to form a dusky spot which is not readily visible with the unaided eye.

Breeding coloration is the basis for the suggested common name, orangefin shiner. Males in "high" nuptial condition have bright orange fins. In some males the fins are reddish orange. The leading edges of the paired fins, the dorsal and anal fins, and the upper and lower margins of the caudal fin are milky white. The snout is pinkish orange and the upper and lower lips are bright orange. The iris is orange, particularly its dorsal part. Females, pallid compared with males, lack coloration on the fins, but have weak yellow-orange color on the snout, lips and upper part of the iris. Brightly colored male specimens were observed in early April through early August. Some male specimens collected in late May had brightly colored fins but were only slightly tuberculate, whereas, others of the same color intensity had fully developed tubercles.

ETYMOLOGY.—This fish, as stated above, has been known for many years and *ammophilus* was a manuscript name applied in 1939 by the late Carl L. Hubbs. The name is derived from the Greek *ammos*, sand, and *philo*, to love, in reference to the preferred habitat

COMPARISONS.—Characteristics common to *Notropis ammophilus, N. longirostris* and *N. sabinae* are given in the diagnosis of the species complex. The proportions in Table 4 reflect the shorter body of *N. ammophilus* and *N. sabinae* versus the elongate body of *N. longirostris.* The general body shape of *N. ammophilus* is similar to that of *N. sabinae. Notropis longirostris* is less robust anteriorly and its dorsal profile tapers less abruptly than that of the other two species. *Notropis ammophilus* and *N. longirostris* are similar in head tuberculation and breeding colors. *Notropis ammophilus* and *N. sabinae* have the same pharyngeal tooth formula of 4—4 whereas *N. longirostris* is variable in number. The tooth in the minor row of *N. longirostris*, when present, is usually very slender, fragile, and slanted toward the teeth of the major row. Undoubtedly this fragile tooth is sometimes lost during removal of arch or cleaning; however, some individuals do lack teeth in the minor. Pharyngeal arches of *N. longirostris* were removed from 20 specimens from each of five drainages from the Yellow River in Florida to the Amite River in Louisiana. The pharyngeal tooth formula was 0,4—4,0 in 35 specimens and 1,4—4,1 in 32 specimens. Thirty specimens had either 0,4—4,1 or 1,4—4,0. Of the remaining three specimens, one had the formula 0,4—3,0, one 0,4—5,0 and the other 0,5—4,0. *N. longrostris* (Biloxi River sample) has somewhat higher lateral line scale and predorsal diagonal scale row counts and a higher vertebral count (Pascagoula River sample) than the other two species (Tables 2 and 3); however, *N. longirostris* has the lowest body circumferential scale count. A more complete analysis of *N. longirostris* populations will appear in a future paper.

GEOGRAPHICAL VARIATION.—*Notropis ammophilus* does not vary significantly throughout its range. The Hatchie River and the Yazoo River specimens vary slightly from the Alabama River specimens in scale and fin ray counts (Table 2). Based on recent observations, the nuptial coloration of Hatchie and Yazoo system specimens is identical with that displayed by Tombigbee and Alabama system specimens.

HABITAT AND BIOLOGY.—*Notropis ammophilus* usually inhabits small to large streams offering the ideal habitat of clear water and a substrate of clean sand. It does occupy substrates of silt covered sand, mixtures of sand and fine gravel, or hard clay. Chilatchee Creek, the type locality, is typical habitat. The stream varies in width from 6 to 15 meters or greater, and depths from 0.1 to 0.45 meters, depending on the season. We have observed, as did Heins et al. (1980), that fairly extensive, gently sloping sand and gravel bars line the margins of preferred stream habitats. The species will occupy much smaller streams that are near the confluence of a major stream. A few specimens at various times have been collected in the main channel of the Alabama and upper Tombigbee rivers.

Notropis ammophilus is a gregarious species and, in its typical habitat, forms schools of hundreds of individuals. A school of fish will swim slowly upstream for a short distance and then more or less drift downstream while moving in and out of depressions such as troughs on the lee side of snags. Spawning was observed on numerous occasions. It occurred in the shallows and in the manner of *Notropis longirostris* as described by Hubbs and Walker (1942); however, in no instance did we attempt to follow the activities of a particular male as they reported. Based on observations spawning extended from May through August.

Chilatchee Creek, the type locality, is relatively rich in species. The following 14 species were collected with the holotype: *Campostoma oligolepis, Ericymba buccata, Notropis bellus, N. venustus, Pimephales notatus, Noturus nocturnus, Gambusia affinis, Lepomis cyanellus, L. macrochirus, L. megalotis, Etheostoma* sp., *E. nigrum, E. rupestre,* and *E. stigmaeum.* Twelve additional collections from the type locality yielded: *Carpiodes velifer, Erimyzon oblongus, Minytrema melanops,* *Moxostoma erythrurum, M. poecilurum, Hybopsis winchelli, Notemigonus crysoleucas, Notropis stilbius, N. texanus, N. volucellus, Pimephales vigilax, Sem otilus atromaculatus, Ictalurus punctatus, Noturus gyrinus, N. leptacanthus, Fundulus olivaceus, Ambloplites ariommus, Lepomis gulosus, L. microlophus, L. punctatus, Micropterus punctulatus, M. salmoides, Pomoxis nigromaculatus, Etheostoma parvipinne, E. whipplei, E. zoniferum, Percina maculata* and *P. nigrofasciata*. Thus, we have a total of 43 species from the type locality.

An analysis, of the 12,156 fish collected in 13 samples (excluding the 1989 samples) from Chilatchee Creek reveals some interesting information regarding abundance and frequency of occcurrence. *Notropis ammophilus* numbered 2976 (24.5 percent of sample), the highest in relative abundance. Next most abundant was *Pimephales notatus* (2837 specimens, 23.3 percent), another bottom dwelling fish. There were two common mid-water species: *Notropis venustus* (1952 specimens, 16.1 percent) and *N. bellus* (1667 specimens, 13.7 percent). Thus, the two mid-water species (3619 specimens) represented 29.8 percent, and the two bottom species (5818 specimens) represented 47.8 percent of all specimens collected. These four species (9437 specimens) represented 77.6 percent of the total, and the remaining 39 species represented 22.4 percent.

RANGE.—*Notropis ammophilus* is widely distributed in the Mobile basin, essentially below the Fall Line (Fig. 2). Disjunct populations occur in the Yellow Creek system, a relatively small watershed of the Tennessee drainage in northern Mississippi, in the headwaters of the Hatchie River system in northern Mississippi and southwestern Tennessee, and in the Skuna River system of the Yazoo drainage in northern Mississippi. *Notropis longirostris* is absent from nearly the entire range of *N. ammophilus*; however, there are populations of *N. longirostris* in Little River and Majors Creek which are eastern tributaries to the Alabama River in the lower part of the Mobile basin (Fig. 2). No *N. ammophilus* specimens have been taken in either of these two tributaries. Perhaps the parapatry is the result of human activities, but more likely it is the result of a natural faunal interchange between the Little River and the Escambia River system at some time in the past when the two systems were connected. There are also populations of *N. longirostris* in the upper Etowah River in northern Georgia. These populations are well above the Fall Line and far above the uppermost populations of *N. ammophilus* in the lower Coosa River (Fig. 2). We believe the Etowah River population also to be of natural occurrence and presume that lateral headwater tributaries of the Etowah and the Chattahoochee rivers were at one time connected.

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