Eye Color and Chin Pattern in the Turtle *Graptemys pseudogeographica* in the Calcasieu River Drainage of Louisiana, with Comparison to Adjacent Drainages

Eye coloration is a characteristic of freshwater turtles that is little noted in field guides and formal descriptions of taxa, probably because it cannot be assessed in preserved specimens. In the genus *Graptemys* (map turtles and sawbacks), three predominant patterns of eye coloration occur (Lindeman 2013): a) a yellow or b) white iris, bisected by a black stripe, and c) a white iris without a bisecting stripe. The striped white iris typifies *caglei, ouachitensis, sabinensis,* and *versa,* while southern populations of *pseudogeographica* (the subspecies *kohnii*) are most frequently reported to have white irises without bisecting stripes. Yellow irises with black stripes typify populations of the

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nominate northern subspecies of *pseudogeographica* as well as the remaining species, *barbouri, ernsti, flavimaculata, geographica, gibbonsi, nigrinoda, oculifera, pearlensis,* and *pulchra*.

Graptemys species all have yellow to light-orange stripes, spots, and blotches against a darker ground color on the head, neck, and limbs. Three predominant patterns of light chin markings occur and are used as reliable diagnostic characteristics of species (Carr and Marchand 1942; Cagle 1952, 1953a, b, 1954; Haynes and McKown 1974; Lovich and McCoy 1992; Vogt 1993; Ennen et al. 2010b; Lindeman 2013): a) three spots, one anterior and medial and the other two, which are often elongated, below the angles of the jaw (*ouachitensis, pseudogeographica, versa*); b) a medial longitudinal blotch or stripe and two spots under the angles of the jaw, also often elongate (*ernsti, geographica, gibbonsi, pearlensis, pulchra*); and c) a transverse chin bar, essentially a curving stripe along the lower margin of the chin (*barbouri, caglei, flavimaculata, nigrinoda, oculifera,* and *sabinensis*).

In a published conference abstract, Jackson and Shively (1983) briefly described distinctive characteristics of *Graptemys pseudogeographica* from the Calcasieu River drainage, which drains portions of seven parishes in southwestern Louisiana. In particular, the authors described two distinctive characters: 1) dark pigmentation of the entire iris, causing the irises to appear black, and 2) variation in the chin pattern, with individuals having both three-spot and barred patterns on the chin. Chin patterns were thus a mix of two of the predominant patterns used as diagnostic features of many congeners.

During wide-ranging freshwater turtle survey efforts on the Calcasieu drainage and its two adjacent drainages, the Sabine to the west and the Mermentau to the east, we encountered *G*.

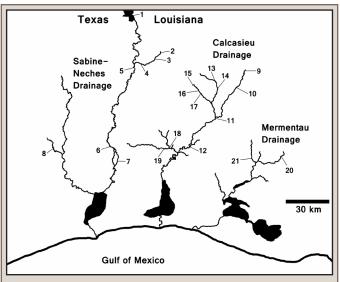


FIG. 1. Trapping and photographic localities for *Graptemys pseudogeographica* on the Sabine-Neches, Calcasieu, and Mermentau drainages of southwestern Louisiana and southeastern Texas. Numbers correspond to sites listed in Appendix I.

pseudogeographica at several sites. Here we report on patterns of iris coloration and chin patterns for specimens in these drainages to quantify the patterns noted by Jackson and Shively (1983) and make comparisons among the adjacent drainage populations.

Study Areas and Methods.—We surveyed turtles in the Calcasieu drainage in four parishes, the Sabine drainage in four parishes, and the Mermentau drainage in four parishes (Fig. 1). The Calcasieu and Sabine drainages have a mix of very low-elevation downstream reaches—less than 1 m above sea level (asl), according to Google Earth—that are uniformly deep and sluggish, contrasting with upstream reaches that have gradients that promote a riffle-run organization with currents that maintain abundant sandbars. The entire Mermentau drainage is uniformly deep and sluggish, with surface levels that are <1 m asl throughout the reaches we surveyed, according to Google Earth.

Turtles were captured in 2010-2013 using fykenets (Vogt 1980), basking traps (Lindeman 2014; Selman et al. 2012), and baited hoop nets (Legler 1960), with occasional opportunistic dipnetting or hand capture, mostly of juveniles. Eye color and chin pattern of captured Graptemys pseudogeographica were photographed with zoom or macro lenses. Turtles were marked on their marginal scutes (Cagle 1939) to avoid double-counting; however, no recaptures were registered for the species, even when trapping was conducted over several days at some sites. Additional photos of captured G. pseudogeographica were also available from previous studies (Shively and Vidrine 1984; Shively and Jackson 1985). Additional lower-resolution evidence for eve color and chin pattern was sometimes available from photographs of basking turtles taken using zoom lenses (up to 45x) on tripod-mounted cameras between 2008 and 2013. Based on geographic distances between sites, sampling dates, and details of turtles visible in photos, we feel confident that basking photos did not contain any duplicate photos of the same individual.

Fisher's exact tests were used to compare the Calcasieu drainage with its two adjacent drainages for frequency of iris and chin characters in *G. pseudogeographica*. For these analyses, darkbrown irises were compared against a combined category for



FIG. 2. Three *Graptemys pseudogeographica* exhibiting the darkbrown iris found in most specimens caught in the Calcasieu drainage. Top, juvenile, Whiskey Chitto Creek near Hwy. 26 crossing in Allen Parish, Louisiana. Middle, female, midline plastron length 209 mm, West Fork Calcasieu River at Sam Houston Jones State Park in Calcasieu Parish, Louisiana. Bottom, female, midline plastron length 187 mm, Serpent Bayou <1 km from its confluence with the mainstem Calcasieu River in Calcasieu Parish, Louisiana.

lighter colors and chin pattern was scored as complete bar, three spots or spot-line-spot, or intermediate (see below).

Results.—A total of 46 *G. pseudogeographica* were captured and photographed for iris color, with 34 of these also photographed for chin pattern. Thirty-two other individuals photographed during basking surveys had discernible iris color and 7 of these showed discernible chin patterns in their photos.



FIG. 3. Dark-brown irises evident in two basking Graptemys pseudogeographica photographed in the Calcasieu drainage. Top, female, Bundick Creek at Morrow Bridge Rd. in Allen Parish, Louisiana. Bottom, male, Calcasieu River at at Hwy. 10 crossing in Allen Parish, Louisiana.

Localities for these encounters in the three drainages are shown in Fig. 1 and listed with character data in Appendix I.

At six sites on the Calcasieu drainage, we captured 32 G. pseudogeographica, of which 30 (94%) had dark-brown irises, with a black horizontal bar bisecting each iris that was visible upon close inspection (Fig. 2). A hatchling and a juvenile female had lighter, barred irises (white in the hatchling, light yellow in the female) that were suffused with speckled gray along the outer rims in both.

Photographs of basking turtles showed evidence of darkbrown irises for 14 G. pseudogeographica at 7 sites throughout the Calcasieu drainage (Fig. 3). No other eye color pattern was evident in any basking photographs of the species from the Calcasieu drainage.

In the Sabine drainage, we captured 14 total G. pseudogeographica at 4 sites. None exhibited a dark-brown iris. The pattern observed in 8 of 9 females, including the 7 largest females (PL range 116-233 mm), was a light-yellow iris suffused with speckled gray along the outer rim, with a wide horizontal black bar bisecting the iris (Fig. 4). The second-smallest female (PL 137 mm), 3 males, and 2 juveniles likewise had gray speckling around the outer rim of the iris, but the background color of the iris was white rather than light yellow. Black bars bisected the iris in all but one of these 14 turtles; an adult male lacked iris stripes. No



FIG. 4. Two Graptemys pseudogeographica from the Sabine drainage exhibiting a light-yellow iris suffused with gray speckling along the outer margins with prominent horizontal black bars bisecting the iris, as seen in all adult females of the Sabine drainage specimens. Top, female, midline plastron length 233 mm, East Sabine River upstream of Niblett's Bluff, Calcasieu Parish, Louisiana. Bottom, female, midline plastron length 192 mm, Sabine River upstream of Palmer Lake Rd. boat ramp, Beauregard Parish, Louisiana/Newton County, Texas.

G. pseudogeographica were among 435 total turtles we captured in the Mermentau drainage (including 326 individuals of a congener, G. sabinensis).

Sixteen basking G. pseudogeographica were photographed at six total sites in the Sabine drainage. None exhibited a darkbrown iris. Eight females, all of which appeared to be of adult size, appeared to have the yellow and gray, black-barred iris type shown in Fig. 4, while the remaining female-the only clearly juvenile female-had a white, black-barred iris. In Lindeman (2013), two of the adult females appear in Plate J5 and the juvenile female appears in Plate J1. Three unsexed juveniles and three of the four males had white irises with black bars, while the remaining male had a white iris without a bar. The unbarred male appears on the back jacket cover of Lindeman (2013). Two basking G. pseudogeographica were photographed at separate sites in the Mermentau drainage. A published photograph of one individual from the Mermentau drainage shows a white iris without a horizontal black bar (Ilgen et al. 2014), although additional photographs of the same turtle suggest it may have had a very thin black horizontal bar through each iris (PVL, unpubl. photos). The other photograph from the Mermentau drainage is of poorer quality due to greater distance of the camera from

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FIG. 5. Variable chin patterns of *Graptemys pseudogeographica* in the Calcasieu drainage. Top, three-spot pattern with elongate side spots, adult female, 209 mm midline plastron length. Bottom, transverse chin bar, adult female, 195 mm midline plastron length. Both specimens from the vicinity of Sam Houston Jones State Park, near the confluence of the Houston River with the West Fork Calcasieu River.

the turtle, but shows a white iris with no evidence of a horizontal bar. Combining captured turtles and turtles photographed while basking, the difference in iris color between the Calcasieu drainage (46 dark brown vs. 2 lighter) and its two adjacent drainages (0 dark brown vs. 30 lighter) was highly significant (Fisher's exact test, p < 0.0001).

In the Calcasieu drainage, we photographed chin pattern for 22 of the 32 captured turtles (Fig. 5). Nine exhibited a round medial spot at the point of the chin and elongate spots on either side, under the angles of the jaw; 1 had two elongate spots on either side and a central spot that was merged with a neck line; 9 had transverse chin bars instead of spots; and 3 had intermediate patterns. Intermediate patterns were essentially transverse chin bars that had small gaps near the point of the chin (on both sides in 2 turtles, suggestive of 3 elongate spots that almost merged into a bar; on the left side only in the other turtle, suggestive of an incomplete bar; all patterns labeled intermediate lacked the several intervening light lines or whorls between the medial and side spots that were typical of the three-spot pattern). There was no ontogenetic component evident in the variation, as the chin bars were exhibited by 4 adult females, 1 juvenile female, 1 unsexed juvenile, and 3 hatchlings. Chin pattern was visible and clearly discernible in only two photographs of basking individuals in the Calcasieu drainage, both of which had the three-spot pattern.

In the Sabine drainage, chin pattern was photographed for 12 of the 14 turtles we captured. Nine individuals exhibited a three-spot chin pattern, two had the anterior, medial spot elongated as a longitudinal blotch, and one had an incomplete bar, with a small gap on the right side near the point of the chin. In photographs of basking individuals, three individuals exhibited the three-spot pattern. Likewise, both basking individuals photographed on the Mermentau drainage exhibited the three-spot chin pattern. Combining captured turtles and turtles photographed while basking, the difference in chin pattern between the Calcasieu drainage (12 three-spot or spot-line-spot patterns, three intermediate patterns, and nine complete bars) and its two adjacent drainages (16 three-spot or spot-line-spot patterns, one intermediate pattern, and 0 complete bars) was highly significant (Fisher's exact test, p = 0.0037).

Discussion.—Almost all of the *G. pseudogeographica* captured in the Calcasieu drainage exhibited dark-brown irises bisected by black lines and all basking specimens photographed on the Calcasieu drainage were consistent with the same coloration. No specimens from the two adjacent river drainages had dark-brown irises and the coloration has never been reported from other localities, thus iris color appears to be a highly consistent diagnostic feature of Calcasieu populations. Localities exhibiting the dark-brown iris that are reported herein encompass virtually the entire range of the species within the drainage (Fig. 1 and Appendix I), thus the dark-brown color is not merely a local anomaly, but appears to be indicative of a trait that is nearly fixed throughout the Calcasieu drainage. To date the genetic basis of iris color in *Graptemys* has not been studied.

There is only one previous report quantifying variation in eye color in species of *Graptemys*, for two syntopic species in the lower Tennessee River drainage in western Kentucky (Lindeman 2003). *Graptemys ouachitensis* was consistent in having a striped white iris, while most *G. pseudogeographica* had an unstriped white iris, with low incidence of black stripes (5%) or small black dots anterior or posterior to the pupil on the iris of one or both eyes (16%). Both species also had low incidence (<5%) of lightyellow coloration invading the white iris. Together with the present report and unpublished observations of other species by PVL, these results suggest that it is typical for *Graptemys* species to have fixed or nearly fixed conditions for iris color and markings at the levels of both local population and drainage-wide metapopulations.

In contrast to iris color and markings, chin patterns were highly variable within the Calcasieu drainage. Of 24 specimens examined or photographed while basking, nine had chin bars and three had intermediate, interrupted patterns more suggestive of a chin bar than of the three-spot pattern that is typical of G. pseudogeographica (Vogt 1993). The two adjacent drainages did not show variability, with none of 17 turtles captured or photographed while basking showing a chin bar. A chin bar has not been reported from any other population of G. pseudogeographica. Vogt (1993) did not report the condition among large samples of G. pseudogeographica collected from several localities throughout the species' range (not including the Calcasieu drainage). He did report that G. ouachitensis hatched under laboratory incubation conditions sometimes exhibited a chin bar instead of the three-spot pattern that is also characteristic of that species, but found no chin bars in wild-caught G. ouachitensis specimens taken range-wide. There are also no reports in the literature of any of the 6 Graptemys species that are characterized by chin bars having any individuals exhibiting a three-spot pattern (Carr and Marchand 1942; Cagle 1952, 1953a, b, 1954; Havnes and McKown 1974; Lovich and McCoy 1992). However, Ennen et al. (2010b) reported lack of the chin bar (without details regarding alternate patterns) at low frequencies in G. flavimaculata and more commonly in G. oculifera; in addition, in G. sabinensis, an intermediate pattern of interrupted chin bars forming two or three separate markings-albeit not spots widely separated by several intervening light lines or whorls-sometimes occurs (PVL, unpubl. data). For a mix of G. barbouri (typically a chin bar), G. ernsti (typically a spot-line-spot pattern), and their hybrids in the Choctawhatchee drainage, Godwin et al. (2015) reported a mix of chin patterns but unfortunately did not report which animals had which pattern according to their genetic classification as one species or the other, or a hybrid.

Overall, chin patterns appear to be highly consistent species characteristics in *Graptemys*, except in the case of the Calcasieu drainage populations of *G. pseudogeographica*. As with iris color and patterning, the genetic basis of chin patterns is unknown and awaits further study.

The genus Graptemys, as currently recognized, has 14 species, nine of which are confined to single Gulf Coastal drainages, with three others distributed in 2-3 adjacent drainages (Lindeman 2013). Only G. pseudogeographica and G. geographica are distributed over more drainages (seven and five, respectively; Lindeman 2013). One group of drainage-endemic species was long considered conspecific, as G. pulchra, with a distribution spanning four adjacent drainages in eastern Louisiana, Mississippi, Alabama, Georgia, and the panhandle of Florida (Baur 1893; Cagle 1952). Detailed analysis of morphological variation resulted in the splitting of G. pulchra into three species, with one of them, G. gibbonsi, occurring in two adjacent rivers (Lovich and McCov 1992), but subsequently a combination of morphological and molecular genetic analyses resulted in G. gibbonsi also being split into two species by drainage (Ennen et al. 2010a). The variable characters reported here appear to be indicators of unique variation in the Calcasieu drainage and further detailed morphological and molecular genetic analyses are warranted.

Irrespective of any possible taxonomic implications of the variation described herein, the unique dark eyes of Calcasieudrainage *G. pseudogeographica* likely pose a conservation challenge. Species of *Graptemys* are highly regarded in the pet trade and collectors have recently become aware of "black-eyed" Mississippi map turtles, with both online and pet expo dealers offering them for sale (C. Lechowicz, pers. comm.). Trade in herpetofauna has been known to spike coincident with the discovery and description of new variants (e.g., Stuart et al. 2006; Phimmachak et al. 2012). Monitoring of both commerce and field collecting will be necessary to assess the threat that the pet trade poses to Calcasieu populations of *G. pseudogeographica*.

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UF#	Drainage	Stream	Fig. 1 #	Class	ΡL	Data source	Iris color	Stripe	Chin
170269	Calcasieu	West Fork	18	Ь	209	Capture	Dark brown	Stripe	Dash-Dot-Dash
170270	Calcasieu	Houston	18	Ц	195	Capture	Dark brown	Stripe	Bar
174743	Calcasieu	West Fork	18	Ч	209	Capture	Dark brown	Stripe	Dash-Dot-Dash
174744	Calcasieu	West Fork	18	Μ	100	Capture	Dark brown	Stripe	Intermediate (3 dots)
174745	Calcasieu	Serpent	12	J	38	Capture	Dark brown	Stripe	Dash-Dot-Dash
174746	Calcasieu	Serpent	12	Μ	94	Capture	Dark brown	Stripe	Dash-Dot-Dash
174747	Calcasieu	Serpent	12	Ţ	82	Capture	Dark brown	Stripe	Bar
174748	Calcasieu	Serpent	12	Ц	187	Capture	Dark brown	Stripe	Dash-Line-Dash
174749	Calcasieu	Serpent	12	J	48	Capture	Dark brown	Stripe	Bar
174750	Calcasieu	Serpent	12	Μ	84	Capture	Dark brown	Stripe	Dash-Dot-Dash
174751	Calcasieu	Serpent	12	Н	178	Capture	Dark brown	Stripe	Dash-Dot-Dash
174752	Calcasieu	Calcasieu	12	Μ	102	Capture	Dark brown	Stripe	Intermediate (2 dots)
174753	Calcasieu	West Fork	18	Н	191	Capture	Dark brown	Stripe	Dash-Dot-Dash
174754	Calcasieu	West Fork	18	Н	136	Capture	Dark brown	Stripe	Dash-Dot-Dash
174755	Calcasieu	West Fork	18	Ţ	39	Capture	Dark brown	Stripe	NR
174756	Calcasieu	Calcasieu	12	J	62	Capture	Dark brown	Stripe	Bar
174757	Calcasieu	Calcasieu	12	Μ	94	Capture	Dark brown	Stripe	Dash-Dot-Dash
174758	Calcasieu	Calcasieu	12	ц	209	Capture	Dark brown	Stripe	Bar
174759	Calcasieu	Calcasieu	12	I	45	Capture	Dark brown	Stripe	Bar
174760	Calcasieu	Calcasieu	11	Ţ	66	Capture	Dark brown	Stripe	NR
174761	Calcasieu	Houston	19	I	58	Capture	Dark brown	Stripe	NR
174762	Calcasieu	Houston	19	I	56	Capture	Dark brown	Stripe	NR
174763	Calcasieu	Whiskey Chitto	17	Ц	NR	Capture	Dark brown	Stripe	NR
174764	Calcasieu	Whiskey Chitto	17	J	NR	Capture	Dark brown	Stripe	NR
174765	Calcasieu	Whiskey Chitto	17	J	NR	Capture	Dark brown	Stripe	NR
174731	Calcasieu	Whiskey Chitto	16	Ц	NR	Capture	Dark brown	Stripe	Bar
174732	Calcasieu	Whiskey Chitto	16	Ц	NR	Capture	Dark brown	Stripe	Intermediate (3 dots)
174733	Calcasieu	Whiskey Chitto	16	Ц	NR	Capture	Dark brown	Stripe	Bar
174734	Calcasieu	Whiskey Chitto	17	ц	NR	Capture	Dark brown	Stripe	NR
174735	Calcasieu	Whiskey Chitto	17	Ţ	NR	Capture	Dark brown	Stripe	NR
174766	Calcasieu	Houston	19	Μ	NR	Basking photo	Dark brown	NO	
170267	Calcasieu	Bundick	15	Μ	NR	Basking photo	Dark brown	NO	
174767	Calcasieu	Bundick	15	Ц	NR	Basking photo	Dark brown	NO	
170267	Calcasieu	Bundick	15	I	NR	Basking photo	Dark brown	ON	
170267	Calcasieu	Bundick	15	I	NR	Basking photo	Dark brown	ON	
170267	Calcasieu	Bundick	15	Ţ	NR	Basking photo	Dark brown	ON	
170281	Calcasieu	Bundick	16	Н	NR	Basking photo	Dark brown	NO	
170283	Calcasieu	Bundick	17	Ч	NR	Basking photo	Dark brown	NO	Dash-Dot-Dash

APPENDIX I

UF#	Drainage	Stream	Fig. 1 #	Class	ΡL	Data source	Iris color	Stripe	Chin
174768	Calcasieu	West Fork	18	F	NR	Basking photo	Dark brown	NO	
174770	Calcasieu	West Fork	18	Ţ	NR	Basking photo	Dark brown	NO	Dash-Dot-Dash
174771	Calcasieu	Calcasieu	10	Ц	NR	Basking photo	Dark brown	NO	
170271	Calcasieu	Calcasieu	6	Ţ	NR	Basking photo	Dark brown	NO	
174772	Calcasieu	Calcasieu	6	Μ	NR	Basking photo	Dark brown	NO	
174773	Calcasieu	Calcasieu	6	Ь	NR	Basking photo	Dark brown	NO	
174774	Calcasieu	West Fork	18	Ţ	41	Capture	White/Gray	Stripe	NR
174775	Calcasieu	West Fork	18	Ц	105	Capture	Yellow/Gray	Stripe	Bar
166405	Mermentau	Plaquemine Brule	20	Μ	1	Basking photo	White	Stripe	Dash-Dot-Dash
166403	Mermentau	Nezpique	21	Μ	1	Basking photo	White	None?	Dash-Dot-Dash
174776	Sabine	Sabine	1	Ţ	1	Basking photo	White	Stripe	
174777	Sabine	Sabine	5	Μ	1	Basking photo	White	Stripe	
174778	Sabine	Anacoco	co	Ţ	1	Basking photo	White	Stripe	
174779	Sabine	Anacoco	co	Ţ	1	Basking photo	White	Stripe	
174780	Sabine	Anacoco	co	Н	1	Basking photo	White	Stripe	
174781	Sabine	Anacoco	2	Μ		Basking photo	White	Stripe	
174782	Sabine	Anacoco	4	Μ	1	Basking photo	White	Stripe	
174784	Sabine	Sabine	5	Μ	1	Basking photo	White	None	
174786	Sabine	Sabine	2	Μ	110	Capture	White/Gray	Stripe	Dash-Dot-Dash
174787	Sabine	Sabine	5	Μ	102	Capture	White/Gray	Stripe	Dash-Dot-Dash
174788	Sabine	Sabine	IJ	Í	38	Capture	White/Gray	Stripe	Intermediate (2 dots)
174789	Sabine	East Sabine	7	Ţ	47	Capture	White/Gray	Stripe	Dash-Dot-Dash
174790	Sabine	East Sabine	7	ц	137	Capture	White/Gray	Stripe	Dash-Line-Dash
174791	Sabine	East Sabine	7	Μ	66	Capture	White/Gray	None	Dash-Dot-Dash
174792	Sabine	Sabine	5	Н	143	Capture	Yellow/Gray	Stripe	Dash-Dot-Dash
174793	Sabine	Sabine	2	ц	192	Capture	Yellow/Gray	Stripe	Dash-Dot-Dash
174794	Sabine	Sabine	5	Н	159	Capture	Yellow/Gray	Stripe	Dash-Dot-Dash
174795	Sabine	East Sabine	2	Н	233	Capture	Yellow/Gray	Stripe	Dash-Dot-Dash
174796	Sabine	East Sabine	7	Н	200	Capture	Yellow/Gray	Stripe	Dash-Dot-Dash
174797	Sabine	Sabine	9	ц	116	Capture	Yellow/Gray	Stripe	Dash-Line-Dash
174736	Sabine	Anacoco	2	Н	NR	Capture	Yellow/Gray	Stripe	NR
174737	Sabine	Anacoco	2	Ц	NR	Capture	Yellow/Gray	Stripe	NR
166437	Sabine	Village	8	Ц		Basking photo	Yellow/Gray	Stripe	Dash-Dot-Dash
166437	Sabine	Village	8	Н	1	Basking photo	Yellow/Gray	Stripe	Dash-Dot-Dash
174798	Sabine	Sabine	5	Н	1	Basking photo	Yellow/Gray	Stripe	
174799	Sabine	Sabine	2	ц	-	Basking photo	Yellow/Gray	Stripe	
174800	Sabine	Sabine	IJ.	Ч		Basking photo	Yellow/Gray	Stripe	
174802	Sabine	Anacoco	ŝ	Ц	-	Basking photo	Yellow/Gray	Stripe	
174803	Sabine	Anacoco	2	Ч		Basking photo	Yellow/Gray	Stripe	Dash-Dot-Dash

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