
Monitoring Methods for the Barton Springs and Austin Blind Salamanders (*Eurycea sosorum* and *Eurycea waterlooensis*): 1993–2014 and Beyond

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Abstract. – Population monitoring of the Barton Springs Salamander (*Eurycea sosorum*) and Austin Blind Salamander (*E. waterlooensis*) has consisted of repeated field surveys and retrospective analysis of counts to make inferences about salamander abundance. Qualitative data on habitat characteristics have been collected since 2002 during surveys in an attempt to infer how habitat characteristics influence salamander distribution and abundance. Here, we re-evaluate the previous monitoring approach and propose changes to maximize efficiency and the utility of new data collected for species management and conservation.

Background – Salamanders have been known to occur in Barton Springs Pool at least since 1946, when some of the first specimens were collected by Bryce C. Brown and Alvin G. Flury of the Strecker Museum, Baylor University (Chippindale et al. 1993). In his detailed analysis of morphological and life history variation in central Texas spring salamanders (*Eurycea*), Samuel S. Sweet first recognized that the population from Barton Springs Pool represented a new, undescribed species based on its distinctive morphology (Sweet 1978) (Fig. 1A). However it was Chippindale et al. (1993) who described this taxon, naming it *Eurycea sosorum* after the Save Our Springs (SOS) citizen initiative that resulted in the SOS ordinance passed by the City of Austin in 1992.

Since the description of *E. sosorum* in 1993, there were occasional sightings of juveniles of a morphologically distinct salamander at Barton Springs that appeared much more similar to the Texas Blind Salamander (*Eurycea* [*Typhlomolge*] *rathbuni*) than to *E. sosorum* (Hillis et al. 2001). This second form was described as a new species – *Eurycea* [*Typhlomolge*] *waterlooensis*, The Austin Blind Salamander – in 2001 (Hillis et al. 2001) (Fig. 1B).



Figure 1. A) *Eurycea sosorum* and B) *E. waterlooensis* from Upper Barton Spring.

Eurycea sosorum had been listed as a Category 2 candidate for federal protection by the U.S. Fish and Wildlife Service (hereafter, Service) under the Endangered Species Act since 1982 (as *Eurycea* sp.; Service 1982). Two separate petitions to list the species as Endangered were submitted in 1992 (Service 1992). The Service proposed an Endangered listing on February 17, 1994 (59 FR 7968), but then withdrew the proposed rule (Service 1996). A final Endangered listing was filed in 1997 for *E. sosorum* (Service 1997). *Eurycea waterlooensis* received endangered species status in 2013 (Service 2013).

Description of the Study Area and History of Population Monitoring

Monitoring—Barton Springs is fed by the Barton Springs Segment of the Edwards Aquifer in southern Travis County and northern Hays County (Fig. 2). Barton Springs consists of three perennial springs (Parthenia, Eliza, and Old Mill spring) and the ephemeral Upper Barton Spring (Fig. 3). Information about the environmental setting and history of these sites is reviewed in the City of Austin’s Habitat Conservation Plan (HCP; City of Austin 2013).

In July of 1993, City of Austin biologists began monitoring populations of *Eurycea sosorum* in Barton Springs Pool (City of Austin 1997). Monitoring in Eliza and Old Mill springs was initiated in 1995, and surveys at Upper Barton Spring began in 1997. A detailed history of population monitoring is provided in the City’s HCP (City of Austin 2013). In brief, monitoring from 1993–2002 consisted of regular (monthly or quarterly, depending on the site) abundance surveys, usually during base flow conditions. Surveys have been performed using SCUBA (Parthenia, Old Mill, Eliza springs) or wading (Upper Barton Spring). At some sites, the entire potential habitat was searched by carefully inspecting substrate (e.g., Upper Barton Spring). At other sites, only a portion of the habitat was searched using parallel transects of 1 m² quadrats spaced at 10-foot intervals (Eliza, Parthenia, Old Mill springs; City of Austin 2013). Individuals encountered were classified into different size classes. Other animals and plants, in addition to substrate composition, were noted. Results from 1993–1997 surveys are presented in the Barton Creek Report (City of Austin 1997). Beginning in July 1998, City of Austin biologists began distinguishing between *E. sosorum* and the morphologically distinct second species later described as *E. waterlooensis* (Hillis *et al.* 2001).

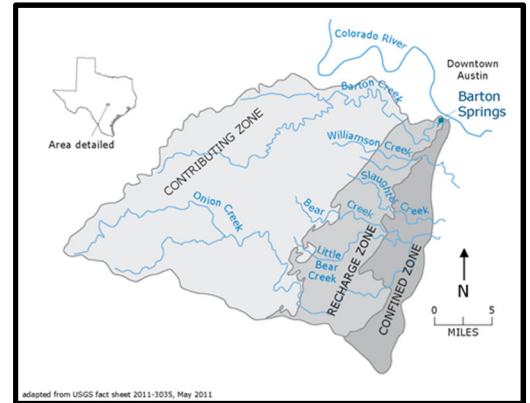


Figure 2. The Barton Springs Segment of the Edwards Aquifer. Adapted from USGS fact sheet 2011-3035. Used with permission from www.edwardsaquifer.net.



Figure 3. Aerial view showing the location of the four springs of the Barton Springs complex.

Additional data on habitat characteristics have been collected since 2002. These data include: percent of the survey area comprised of different types of substrate (e.g., bedrock, boulder, cobble, gravel, sand, silt/sediment); sediment depth; percent bryophytes, aquatic macrophytes, leaf litter, and algae; and relative abundance of other vertebrates and invertebrates. In 2003, the quadrat-transect sampling method was changed to a “modified drive method” where divers oriented themselves perpendicular to the current and moved upstream in parallel, searching through and moving all non-embedded substrate downstream (City of Austin 2013). This creates a moving strip 6–10” wide of open space free from cover. Salamanders that cross the line downstream

are counted; any individuals moving upstream from behind the line are subtracted from the total (City of Austin 2013). Beginning in 2014, surveys have been performed every two months instead of monthly.

Parthenia Spring. The impoundment of Barton Creek to create Barton Springs Pool in 1929 created the largest area of potential habitat for *Eurycea sosorum* (about 15,000 ft.²; Fig. 4). As a result of the upstream and downstream dams, the spring itself is now submerged under water that is much deeper (up to 17 feet maximum) than pre-dam conditions. Moss, algae, aquatic macrophytes, and woody debris are found throughout the pool. Habitat around Parthenia Spring consists of crevices, fissures, and a small cave about 5 feet in diameter where the largest spring outlet is located. This area closest to the main outlet is relatively free of excess fine sediment under base flow conditions due to the strong flow at the outlet. An area referred to as “the triangle” or “side springs” is characterized by numerous smaller spring outlets and a layer of gravel and cobble. The “fissures” area includes all of the fissures extending from the main and side spring area. These fissures contain numerous spring outlets. The potential habitat includes cobble, gravel, woody debris and moss.

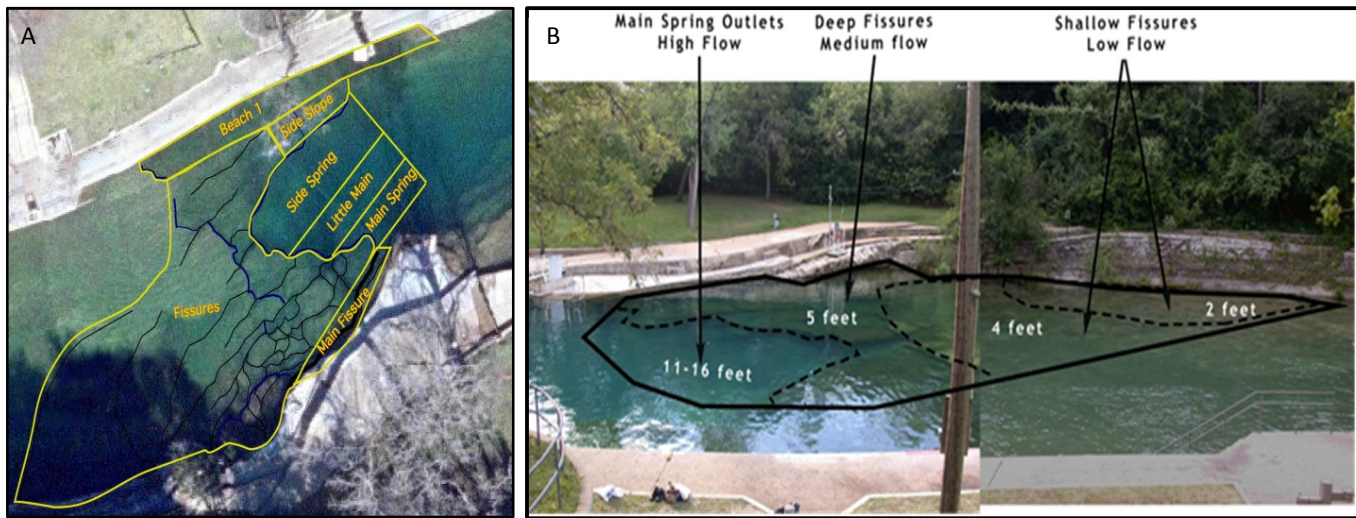


Figure 4. A) Aerial view of the central portion of Barton Springs Pool showing the location of the fissures area, springs, and beach 1. B) Composite photograph looking south showing same area. Typical water depths are shown for each area.

Eliza Spring. This spring is surrounded by an oval-shaped concrete amphitheater built in 1903, creating a small spring pool roughly 800 ft.² in size. A keyhole-shaped opening was left in one wall, allowing a small spring run to exit the amphitheater into Barton Creek. After initial construction, modifications to the amphitheater were made which included pouring a 12–18” thick concrete floor over the spring itself, and burying the spring run in a concrete pipe. Today, groundwater enters the spring pool through 15 1-foot wide openings around the diameter of the pool and seven 10” diameter holes in the concrete floor (City of Austin 2013).

Upper Barton Spring. This spring flows intermittently, stopping when flow at the main spring drops below about 45 ft³/s. This is the smallest of the four spring sites, average size of the main spring pool is about 500 ft², depending on discharge. *Eurycea sosorum* was first discovered at this spring on April 1, 1997 (City of Austin 1997). *E. waterlooensis* was not observed there until November 16, 2013 (pers. obs.). The spring pool is surveyed as well as portions of the spring run. Of the four springs, Upper Barton is the only one that has not been modified or impounded.

Current Survey Methods – Survey methods have changed little since 2003. There are advantages and disadvantages to the current “modified drive method.” One potential advantage is that searching through substrate by hand dislodges some deposited fine sediment from interstices used as retreats by salamanders. However, digging through substrate disturbs habitat and creates the potential to injure salamanders (especially small juveniles) and their eggs. Additionally, any salamander that is driven from its retreat becomes more susceptible to predation by sunfish (*Lepomis spp.*) which school around divers waiting for prey items dislodged from substrate (N. Bendik, pers. comm.). The “modified drive method” is also time-intensive, requiring about 6 hours with 4–5 divers, depending on the site. Moreover, data collection for some variables — especially

estimates of habitat characteristics — is not standardized, and thus inconsistent, both between observers and by the same observer across sampling events/sites.

Available Data from Surveys – Information gained from population monitoring includes data on (i) salamander density, abundance, size class, and distribution; (ii) habitat characteristics (e.g., substrate size, percent sediment); (iii) biotic factors (e.g., fish, algae and invertebrate presence, density, and abundance); and (iv) abiotic factors (e.g., flow). A list of the environmental and individual variables available in the City of Austin Field Sample Database (FSDB) from salamander population monitoring is provided in the Appendix.

Recommendations for Changes to Current Monitoring Approach – The current approach to population monitoring could be improved in a number of ways. In general, an effort should be made to simplify data collection by focusing on variables that are readily quantifiable in a standardized fashion. Specific recommendations include the following:

1. *Implement photographic capture-recapture data collection at all four spring sites.* Compared to existing census data, capture-recapture data have much greater potential to answer basic questions about the demography and natural history of the target species that will directly inform conservation and management. This method has been applied successfully in the closely related Jollyville Plateau Salamander (Bendik *et al.* 2013).
2. *Abandon “modified drive method” method at Old Mill.* SCUBA and snorkel surveys over the past 6 years have found very few salamanders at Old Mill Spring. Prior to 2008, salamanders were encountered during most surveys. Until populations begin to rebound at that site, artificial cover (cotton mopheads) could be deployed and checked weekly or monthly. Any captured individuals should be photographed and released. Artificial cover may also be utilized at other sites, particularly in areas that are not considered ideal habitat, where detectability may be low (e.g., Cold Spring).
3. *Standardize invertebrate surveys at all sites.* Current methods for estimating invertebrate diversity and relative abundance have been inconsistent over time and/or among observers. A better understanding of the invertebrate community should be made a priority in order to understand food web dynamics, predator/prey interactions, and changes in community composition over time.
4. *Quantify the rate of fine sediment accumulation.* The most serious immediate threat to salamander habitat at present is the deposition of excess fine sediment. Specific threats to salamanders and their habitat due to sedimentation are reviewed in the recovery plan for the Barton Springs Salamander (Service 2005). Rather than estimating the “percent sediment” or “embeddedness” of substrate by eye, it may be possible to quantify the amount of fine sediment and the rate of sedimentation using standardized, reproducible methods. This may be accomplished via collaboration with other WPD staff, and/or USGS personnel.

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Appendix. Sampling variables.

PARAMETER	CURRENT?	MIN_SAMPLE_DATE	MAX_SAMPLE_DATE	CT_MEASUREMENTS
AMPHIPODA	current	3/24/95	6/30/14	1805
ANNELIDA (WORM/LEECHES/PLANARIA)	current	3/24/95	6/30/14	1728
CHIRONOMIDAE	historical	10/17/05	10/17/05	1
CRAYFISH (ADULT)	current	3/24/95	6/30/14	2095
CRAYFISH (JUVENILE)	current	3/24/95	6/30/14	2068
DIPTERA (MIDGE/FLY)	current	3/24/95	6/30/14	1606
EPHEMEROPTERA (MAYFLY)	current	3/24/95	6/30/14	1682
MOLLUSCA	current	3/24/95	6/30/14	1690
ODONATA (DAMSELFLY/DAGONFLY)	current	3/24/95	6/30/14	1599
OTHER INVERTEBRATES	current	3/24/95	6/30/14	1350
PETROPHILA (MOTH)	current	2/15/04	6/30/14	1495
POLYCENTROPUS / CERNOTINA	historical	2/22/07	2/22/07	1
PSEPHENIDAE (WATER PENNIES)	current	3/24/95	6/30/14	1820
TRICHOPTERA (CADDISFLY)	current	3/24/95	6/30/14	1639
AVERAGE VELOCITY (LOW)	historical	11/13/08	1/8/09	8
ALGAE BLUE-GREEN	historical	4/18/04	4/18/04	1
FISH	current	3/24/95	6/30/14	1858
FLOW	current	3/24/95	6/30/14	39
VELOCITY	current	3/24/95	6/30/14	443
BEDROCK	current	3/24/95	6/30/14	1718
BOULDER(>256MM)	current	3/24/95	6/30/14	2072
COBBLE(64-256)MM	current	3/24/95	6/30/14	2205
CONCRETE	current	3/24/95	6/30/14	1121
GRAVEL/PEBBLE(2-64 MM)	current	3/24/95	6/30/14	2140
LEDGES	current	7/8/10	6/30/14	316
MOSS/ALGAE SUBSTRATE	historical	8/13/02	8/13/02	1
PERCENT ALGAE COVER	historical	3/5/02	1/5/04	202
PERCENT BRYOPHYTE COVER	current	3/24/95	6/30/14	2163
SAND (1/16-2MM)	current	3/24/95	6/30/14	1945
AQUATIC MACROPHYTE - EMERGENT	current	3/24/95	6/30/14	1697
AQUATIC MACROPHYTE - SUBMERGENT	current	3/24/95	6/30/14	1659
AVERAGE SEDIMENT DEPTH	current	3/24/95	6/30/14	1897
LEAF LITTER COVER	current	3/24/95	6/30/14	1954
MARL	current	1/5/04	6/30/14	130
SEDIMENT DEPOSITION	historical	8/13/02	12/7/03	176
SILT/SEDIMENT COVER	current	3/24/95	6/30/14	2228
SURFACE COVER - FILAMENTOUS ALGAE	current	3/24/95	6/30/14	1829
SURFACE COVER - NON FILAMENTOUS ALGAE	current	3/24/95	6/30/14	1873
AMBLYSTEGIUM RIPARIUM (MOSS)	historical	8/13/02	8/13/02	1
AREA SAMPLED	current	3/24/95	6/30/14	2051
AMPHIBIAN/REPTILE (ABUNDANCE)	current	3/24/95	6/30/14	1573
AUSTIN BLIND SALAMANDER (ADULT) IN LEAF LITTER SUBSTRATE	historical	12/7/03	12/7/03	5
AUSTIN BLIND SALAMANDER (ADULT) IN ROCK SUBSTRATE	historical	9/22/03	12/7/03	7
AUSTIN BLIND SALAMANDER (ADULT) IN VEGETATED	historical	5/22/03	12/7/03	21

SUBSTRATE

AUSTIN BLIND SALAMANDER (ADULT) ON EXPOSED SUBSTRATE	historical	12/7/03	12/7/03	5
AUSTIN BLIND SALAMANDER (UNKNOWN LENGTH)	current	3/23/95	6/30/14	2202
AUSTIN BLIND SALMNR (ADULT) > 1 INCH	current	3/23/95	6/30/14	2215
AUSTIN BLIND SLMNR (<1IN.) IN LEAF LITTER	current	3/24/95	6/30/14	410
AUSTIN BLIND SLMNR (<1IN.) ON EXPOSED SUBSTRATE	current	3/24/95	6/30/14	414
AUSTIN BLIND SLMNR (>=2IN.) IN COBBLE/BOULDER	current	3/24/95	6/30/14	613
AUSTIN BLIND SLMNR (>=2IN.) IN LEAF LITTER	current	3/24/95	6/30/14	404
AUSTIN BLIND SLMNR (>=2IN.) IN VEGETATION/MOSS	current	3/24/95	6/30/14	411
AUSTIN BLIND SLMNR (1-2IN.) IN COBBLE/BOULDER	current	3/24/95	6/30/14	633
AUSTIN BLIND SLMNR (1-2IN.) IN LEAF LITTER	current	3/24/95	6/30/14	404
AUSTIN BLIND SLMNR (<1IN.) (JUVENILE)	current	3/23/95	6/30/14	2221
AUSTIN BLIND SLMNR (<1IN.) IN COBBLE/BOULDER	current	3/24/95	6/30/14	640
AUSTIN BLIND SLMNR (<1IN.) IN VEGETATION/MOSS	current	3/24/95	6/30/14	508
AUSTIN BLIND SLMNR (>=2IN.)	current	3/23/95	6/30/14	2183
AUSTIN BLIND SLMNR (>=2IN.) ON EXPOSED SUBSTRATE	current	3/24/95	6/30/14	405
AUSTIN BLIND SLMNR (1- 2IN.) IN VEGETATION/MOSS	current	3/24/95	6/30/14	422
AUSTIN BLIND SLMNR (1-2IN.)	current	3/23/95	6/30/14	2189
AUSTIN BLIND SLMNR (1-2IN.) ON EXPOSED SUBSTRATE	current	3/24/95	6/30/14	405
BARTON SPGS SALMNR (ADULT) > 1 INCH	current	3/23/95	6/30/14	2376
BARTON SPRINGS SALAMANDER (ADULT) IN LEAF LITTER SUBSTRATE	historical	12/7/03	12/7/03	5
BARTON SPRINGS SALAMANDER (ADULT) IN ROCK SUBSTRATE	historical	3/5/02	1/5/04	118
BARTON SPRINGS SALAMANDER (ADULT) IN VEGETATED SUBSTRATE	historical	9/20/02	12/7/03	44
BARTON SPRINGS SALAMANDER (ADULT) ON EXPOSED SUBSTRATE	historical	9/24/02	12/7/03	16
BARTON SPRINGS SLMNR (TOTAL <1IN.)	current	3/23/95	6/30/14	2375
BARTON SPRINGS SLMNR (<1IN.) IN COBBLE/BOULDER	current	3/24/95	6/30/14	1219
BARTON SPRINGS SLMNR (<1IN.) IN LEAF LITTER	current	3/24/95	6/30/14	418
BARTON SPRINGS SLMNR (<1IN.) IN VEGETATION/MOSS	current	3/24/95	6/30/14	533
BARTON SPRINGS SLMNR (<1IN.) ON EXPOSED SUBSTRATE	current	3/24/95	6/30/14	423
BARTON SPRINGS SLMNR (>=2IN.) IN COBBLE/BOULDER	current	3/24/95	6/30/14	1144
BARTON SPRINGS SLMNR (>=2IN.) IN LEAF LITTER	current	3/24/95	6/30/14	414
BARTON SPRINGS SLMNR (>=2IN.) IN VEGETATION/MOSS	current	3/24/95	6/30/14	495
BARTON SPRINGS SLMNR (>=2IN.) ON EXPOSED SUBSTRATE	current	3/24/95	6/30/14	406
BARTON SPRINGS SLMNR (1-2IN.) IN COBBLE/BOULDER	current	3/24/95	6/30/14	1185
BARTON SPRINGS SLMNR (1-2IN.) IN LEAF LITTER	current	3/24/95	6/30/14	415
BARTON SPRINGS SLMNR (1-2IN.) IN VEGETATION/MOSS	current	3/24/95	6/30/14	516
BARTON SPRINGS SLMNR (1-2IN.) ON EXPOSED SUBSTRATE	current	3/24/95	6/30/14	407
BARTON SPRINGS SLMNR (TOTAL >=2IN.)	current	3/24/95	6/30/14	2107
BARTON SPRINGS SLMNR (TOTAL 1-2IN.)	current	3/24/95	6/30/14	2106
SALAMANDER (UNKNOWN LENGTH)	current	3/23/95	6/30/14	2347
SALAMANDER <1 INCH	historical	5/9/03	7/31/03	11
SALAMANDER >1 INCH	current	3/23/95	6/30/14	2255
SALAMANDER >2 INCHES	historical	7/3/03	1/5/04	66
SALAMANDER 1-2 INCHES	historical	7/3/03	1/5/04	89

SUM OF ABS SALAMANDERS PER TRANSECT	current	3/23/95	6/30/14	2331
SUM OF BSS SALAMANDERS PER TRANSECT	current	3/23/95	6/30/14	2469
SUM OF SALAMANDERS PER TRANSECT	historical	3/5/02	8/17/07	294
WATER DEPTH	current	3/24/95	6/30/14	1792
TOTAL TIME SPENT	current	3/24/95	6/30/14	2267
VASCULAR MACROPHYTES - % COVER	historical	9/26/02	12/7/03	49
# SALAMANDERS 20 FT FROM NORTH	historical	7/20/93	3/14/96	8
# SALAMANDERS 30 FT FROM NORTH	historical	7/20/93	3/14/96	25
# SALAMANDERS 40 FT FROM NORTH	historical	7/20/93	9/26/96	64
# SALAMANDERS 50 FT FROM NORTH	historical	7/20/93	9/9/97	85
# SALAMANDERS 60 FT FROM NORTH	historical	12/30/93	9/9/97	27
# SALAMANDERS 70 FT FROM NORTH	historical	1/25/94	1/29/96	13
# SALAMANDERS 80 FT FROM NORTH	historical	2/18/94	3/14/96	13
AUSTIN BLIND SALAMANDER (UNKNOWN LENGTH)	current	7/20/93	9/9/97	137
AUSTIN BLIND SALMNR (ADULT) > 1 INCH	current	7/20/93	9/9/97	137
AUSTIN BLIND SLMNR (<1IN.) (JUVENILE)	current	7/20/93	9/9/97	137
AUSTIN BLIND SLMNR (>=2IN.)	current	7/20/93	9/9/97	137
AUSTIN BLIND SLMNR (1-2IN.)	current	7/20/93	9/9/97	137
BARTON SPGS SALMNR (ADULT) > 1 INCH	current	7/20/93	9/26/96	136
BARTON SPRINGS SLMNR (TOTAL <1IN.)	current	7/20/93	9/26/96	136
BARTON SPRINGS SLMNR (TOTAL >=2IN.)	current	9/3/93	3/29/96	21
BARTON SPRINGS SLMNR (TOTAL 1-2IN.)	current	9/3/93	3/29/96	21
SALAMANDER (UNKNOWN LENGTH)	current	7/20/93	9/9/97	137
SALAMANDER >1 INCH	current	7/20/93	9/26/96	136
SUM OF ABS SALAMANDERS PER TRANSECT	current	7/20/93	9/9/97	137
SUM OF BSS SALAMANDERS PER TRANSECT	current	7/20/93	9/9/97	137