Observations of Freshwater Jellyfish, *Craspedacusta sowerbyi* Lankester (Trachylina: Petasidae), in a West Virginia Reservoir

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ABSTRACT. — A swarm of medusae of the freshwater jellyfish *Craspedacusta sowerbyi* was observed in a cove of a West Virginia reservoir in August and September, 1995. Medusae were abundant (>1000/m^3) but extremely localized. Distribution of medusae in the cove did not appear to be linked to water chemistry. Size of medusae ranged from 6-21 mm in diameter and increased significantly with distance from the center of abundance, suggesting that the localized distribution of medusae resulted from dispersion rather than from environmentally-induced aggregation. Measurements of mean diameter of medusae on separate dates indicated a growth rate of about 0.2 mm/d, and a medusa life cycle of approximately 102 days.

The freshwater jellyfish *Craspedacusta sowerbyi* Lankester 1880 is an exotic species first observed (as medusae) in the United States in 1908 (Kramp 1950, Pennak 1989). Native to the Yang-tse River system in China (Kramp 1950), *C. sowerbyi* has been reported from many localities worldwide between 45^{o} north and 45^{o} south latitude (Acker and Muscat 1976, Pennak 1989). True freshwater jellyfishes are few, limited to about a dozen species worldwide (Hutchinson 1967, Pennak 1989).

Craspedacusta sowerbyi has been reported from 31 states and the District of Columbia; it has not been reported from northern New England, the Northern Rocky Mountains, or the Northern Great Plains (DeVries 1992). In West Virginia there are records of *C. sowerbyi* from Barbour, Fayette, Mercer, Monogalia, Wayne, and Wood counties (Reese 1940, Lytle 1962, Koryak and Stafford 1981, and D. Tarter, Marshall University, personal communication).

Craspedacusta sowerbyi has two life stages, a free-swimming medusa (10-20 mm diameter), and a sessile hydroid polyp (1 mm long, Acker and Muscat 1976). Lytle (1959) reviewed the developmental biology of the species. Medusae of *C. sowerbyi* appear sporadically in lentic and even less frequently in lotic ecosystems in the United States (Acker and Muscat 1976, Beckett and Turanchik 1980, DeVries 1992). Usually a swarm of medusae appears in summer where it has never before been observed or where it has not been observed for many years (Slobodkin and Bossert 1991). Lentic systems in which the medusae have been observed include reservoirs, natural lakes, ponds, quarries, ornamental pools, and aquaria.

Specific environmental factors associated with the formation of medusae from polyps via asexual reproduction (budding) are poorly understood. Factors suggested include increasing water temperature (McClary 1959) increased alkalinity (Koryak and Clancy 1981, McCullough et al. 1981), increasing dissolved CO_2 (Acker and Muscat 1976), decreasing stream flow (Brussock et al. 1985), changing reservoir levels (Deacon and Haskell 1967) and increasing supply of zooplankton (Lytle 1959), on which the medusae prey.

Dispersal of *C. sowerbyi* among water bodies probably occurs via polyps attached to aquatic plants or waterfowl, or in tanks used to transport fish (Byers 1945, Bushnell and Porter 1967, Howmiller and Ludwig 1970). The polyps can survive in moving water (Hutchinson 1967), so once the polyps enter a river system, the medusae may eventually appear in downstream reservoirs (e.g., Yeager 1987).

Because the medusae occur unpredictably and the polyps are microscopic and easily overlooked, the complete geographic distribution and ecology of *C. sowerbyi* are not well known. Field studies have been mostly descriptive (e.g., Garman 1916, Deevy and Brooks 1943, Dexter et al. 1949, Chadwick and Houston 1953, Bushnell and Porter 1967, Koryak and Clancy 1981, McCullough et al. 1981, Dodds and Hall 1984). Deacon and Haskell (1967) examined diel activity patterns of medusae at Lake Mead, Nevada. Dodson and Cooper (1983) examined trophic relationships of the medusae in the laboratory. Acker and Muscat (1976) and DeVries (1992) reviewed the literature on the ecology of *C. sowerbyi*.

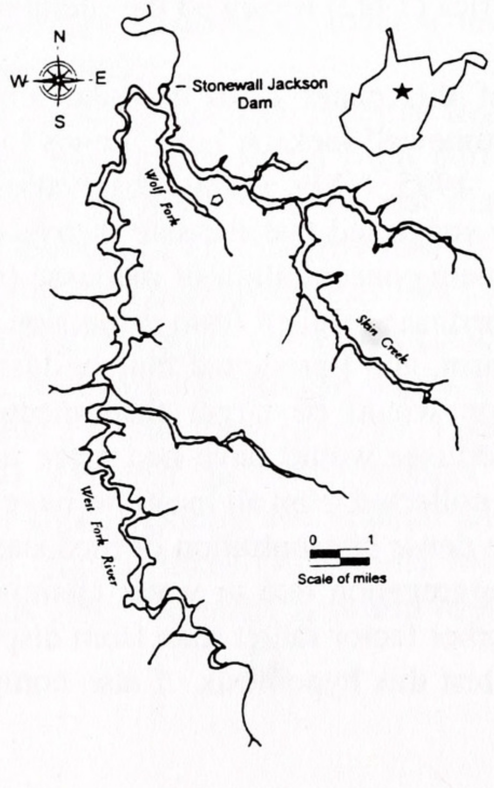
The purpose of this paper is to describe a swarm of *C. sowerbyi* medusae I observed at Stonewall Jackson Lake, Lewis County, West Virginia, in August and September 1995. My initial observations of the medusae at Stonewall Jackson Lake suggested that the size distribution of medusae varied with distance from the main concentration of medusae (swarm). I hypothesized that the distribution of medusae resulted from dispersion from the apparent population center at the swarm, and I predicted that medusae collected away from the main swarm location would be larger than medusae within the swarm because more distant medusae would have had more time to grow. The null hypothesis that medusae collected from all locations have the same size class distribution implies that the dense concentration of medusae at the swarm location results primarily from aggregation due to water chemistry, temperature, food, current, wind, or some other factor rather than from dispersion. I collected and measured specimens to test this hypothesis. I also compared the mean size of specimens collected on separate dates to calculate an approximate growth rate for the medusae.

METHODS

I observed the medusae at Wolf Fork (80°28'W, 38°59'N), a cove formed by a flooded tributary to Skin Creek which forms the east arm of Stonewall Jackson Lake (Fig. 1). Wolf Fork is about 1.5-km long and 30-150-m wide and has abundant flooded timber. The cove is well sheltered from winds and is a no-wake boating zone. A culvert connects Wolf Fork and the stream draining the upper watershed. Stonewall Jackson Lake is a 1,070-ha Army Corps of Engineers reservoir filled in 1986. The main West Fork River arm of the reservoir is a tributary of the Tygart River in the Ohio River drainage.

During my initial visit to Wolf Fork (16 August 1995) I estimated the density (number m^{-3}) of medusae using two methods. Where the medusae were abundant I used a 20-L plastic bucket. From a small boat I slipped the bucket into the water and withdrew it with minimal turbulence. I poured the bucket contents through a fine sieve and transferred the medusae to a tray for enumeration. Where the medusa were scarce, I estimated the density visually. Both methods are biased toward the upper 0.5 m of water surface because I could not see or sample medusa at greater depths. On the first visit to Wolf Fork I collected water samples and recorded water temperature and dissolved oxygen at several locations in the cove. Water samples were analyzed at the U.S. Forest Service Timber and Watershed Laboratory, Parsons, West Virginia.

Fig. 1 Map of Stonewall Jackson Lake showing the swarm location at Wolf Fork. Inset map shows location of the reservoir in West Virginia.



On subsequent visits to Wolf Fork (16 August and 12 September 1995) I collected medusae with an aquarium dip net from a small boat. I measured bell diameter of live specimens under a dissecting microscope by placing a ruler under a clear plastic petri plate containing a few medusae and a small amount of water. I judged measurement error to be ±1.0 mm.

RESULTS

On 16 August 1995, I observed a dense swarm of medusae near the head of Wolf Fork. Medusae decreased greatly in abundance with distance from the swarm. Density of medusae in three bucket samples was 1.2, 1.9, and 4.8 medusa/L. This is approximately equivalent to 1,000-5,000 medusae/m^3 in the upper 0.5 m of the water column within an area of about 25 m^2. At 100-200 m from the swarm (toward the main channel of the reservoir) there were 10-50 medusae/m^3; at 300-400 m medusae were scarce (<1 medusa/m^3). I did not observe medusae in lower Wolf Fork, the main channel, or in other coves of Skin Creek, although I did not make an exhaustive search. My conversations with anglers, reservoir managers, and local fish biologists suggest that this is the first record of *C. sowerbyi* at Stonewall Jackson Lake. The origin of *C. sowerbyi* in the drainage is unknown.

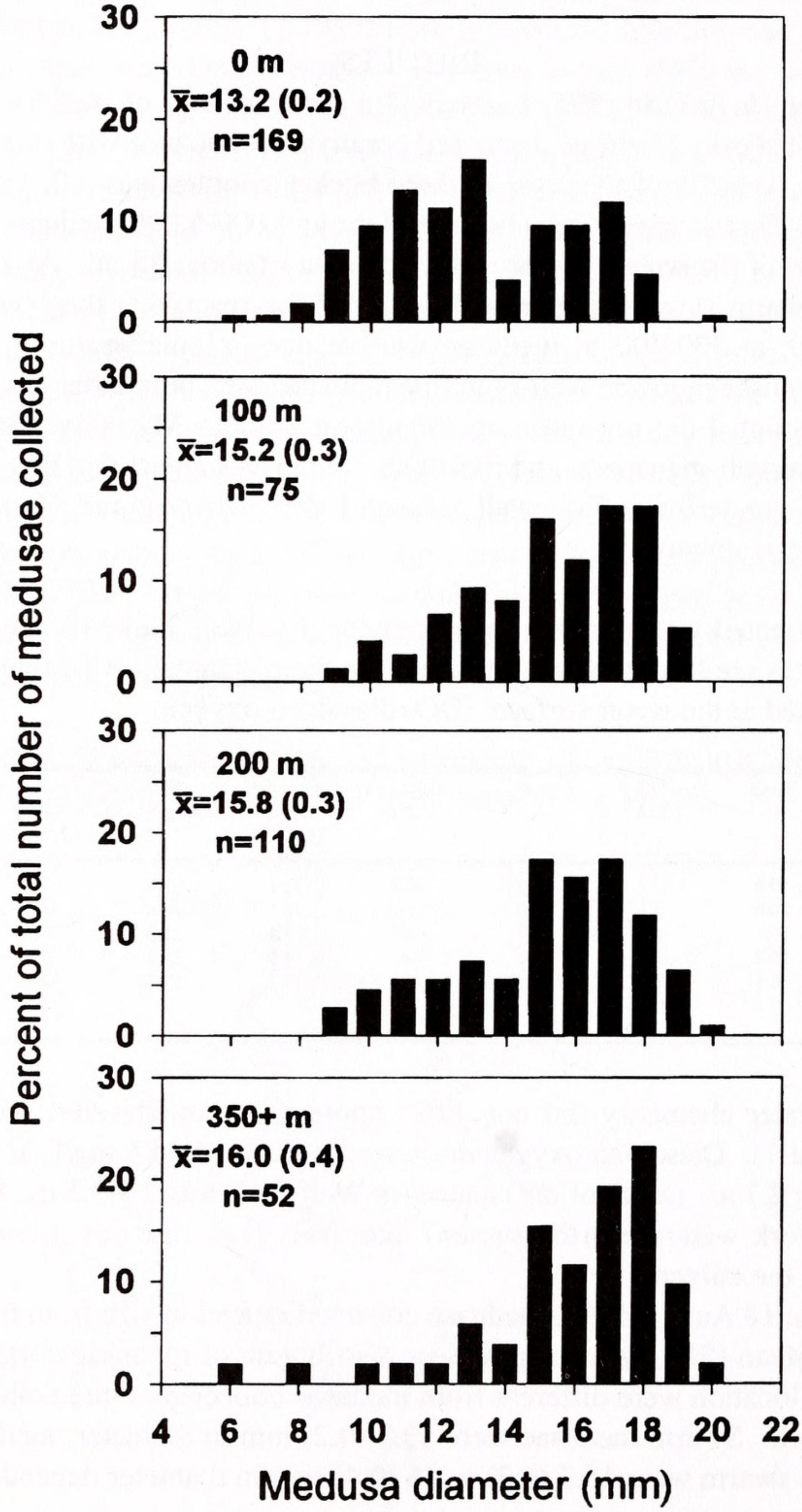
Table 1. Selected water quality measurements for Wolf Fork, 16 August 1995. Site distances are from the swarm toward the main channel. All values for samples collected at the water surface. DO=dissolved oxygen.

Site (m)	Temp C	DO (mg/L)	pH	Conductivity μS/cm	Alkalinity mg/L ($CaCO_3$)	SO_4 (mg/L)	Ca (mg/L)	Medusa abundance (#/m^3)
-100	30.0	7.7	7.0	98.3	19.1	21.9	12.1	<1
0	30.0	8.1	7.0	100.5	18.2	21.6	12.8	1000-5000
100	30.5	8.3	7.1	99.8	17.8	22.0	12.5	10-50
200	30.5	8.3	7.2	99.6	17.5	23.7	12.6	<1
300	30.5	8.3	7.2	98.1	17.2	22.6	12.7	<1

Water chemistry did not differ appreciably among sites within Wolf Fork (Table 1). Dissolved oxygen decreased with depth to 5 mg/L at 2.1 m and 1.8 mg/L at 2.7 m. Depth of the channel in Wolf Fork was 2.5-3.5 m. Flow from the Wolf Fork watershed (the stream) into Wolf Fork (the cove) could not be detected at the culvert.

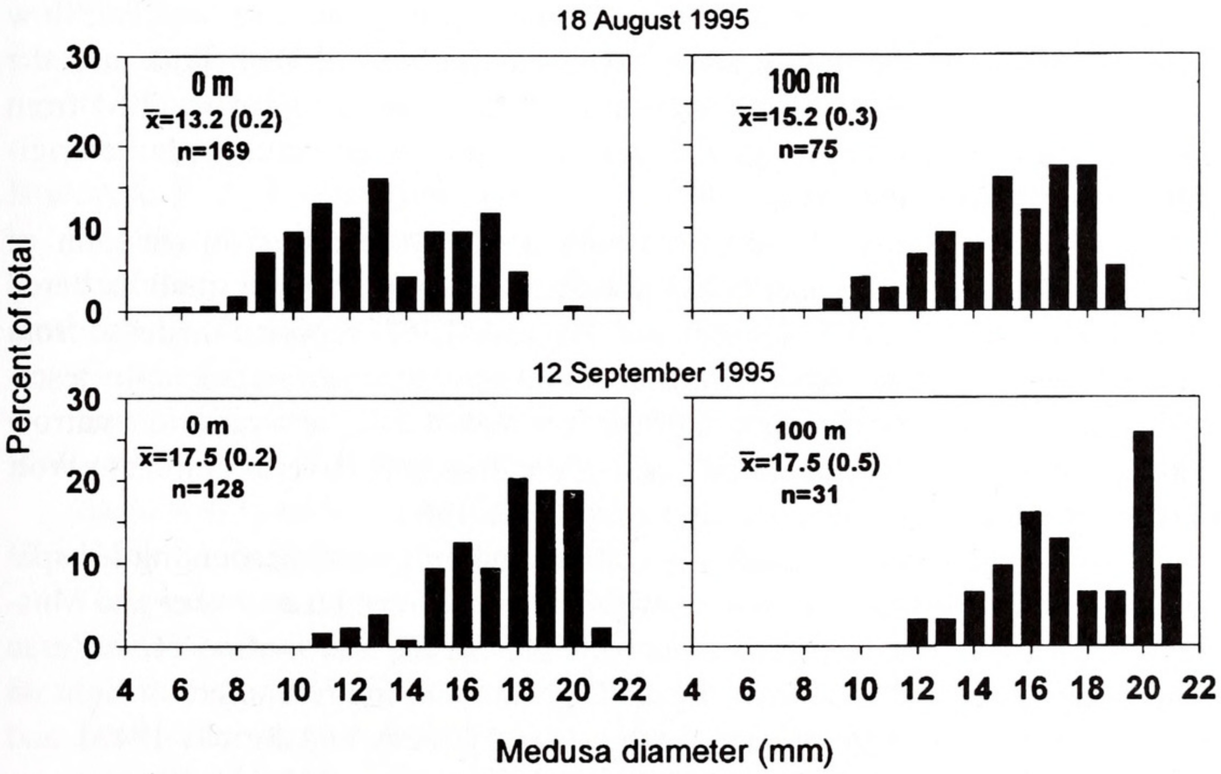
On 18 August 1995, medusae collected ranged in size from 6 to 20 mm (Fig. 2). Mean (SE) size and size class distribution of medusae collected from the swarm location were different from medusae collected at three other stations in Wolf Fork. Swarm medusae were 13.3 (0.2) mm in diameter; medusae from outside the swarm were 15.2 (0.3) to 16 (0.4) mm in diameter depending on col

Fig. 2 Size distribution of C. sowerbyi medusae collected 0, 100, 200, and 350+ m from a dense concentration (swarm) of medusae at Wolf Fork, Stonewall Jackson Lake, West Virginia on 18 August 1995. Figure legends give distance from the main swarm location, mean (SE) medusa diameter and sample size.



lection site, a significant difference (Kruskal-Wallis ANOVA on Ranks; $H = 75.1$, $P < 0.01$). Among sites outside the swarm location, there was also a trend of increasing size with distance from the swarm; mean medusa diameter was largest 350 m from the swarm, the location at which medusae were first observed when entering Wolf Fork from the reservoir. Within the swarm there was a bimodal size distribution of medusae concentrated in 9 - 13 mm and 15 - 18 mm size classes, with more medusae in the smaller size classes. Away from the swarm most medusae were in the larger size classes, but a semblance of the bimodal pattern was apparent (Fig. 2).

Fig. 3 Size distribution of C. sowerbyi medusae collected 0 and 100 m from a dense concentration (swarm) of medusa at Wolf Fork, Stonewall Jackson Lake, West Virginia on 18 August and 12 September 1995. Otherwise as for Fig. 2.



On September 12, I observed fewer medusae than on previous visits to Wolf Fork. Water temperature was 25 C, and reservoir level had dropped about 1 m since the previous visit. The sky was overcast and light rain was falling, whereas the sun shone on previous visits. Medusae were most abundant near the 18 August swarm site; at 100 m they were scarce, and were not observed elsewhere. Mean diameter of medusae was the same at both locations (Fig. 3), although more medusae from the 100 m site were in the largest size classes (20-21 mm). Between August 18 and September 12, mean diameter of medusae at the swarm location increased slightly more than 4 mm (Fig. 3). This is equivalent to an average growth rate of about 0.2 mm/d. Assuming the medusa stage originates at about 0.5 mm and attains a maximum size of about 21 mm (Pennak 1989), this rate of growth indicates a life cycle for the medusa of about 102 days. The apparently slower growth of medusae away from the main swarm (Fig. 3) may be attributed to disproportionate mortality of the full-growth medusae.

DISCUSSION

I observed great variation in abundance of medusae over a scale of a few meters that is not readily explained by available water chemistry data. My finding of larger individuals away from the main concentration of medusae is circumstantial evidence that spatial variation in abundance of the medusae results from dispersion from a highly localized swarm location.

If the polyps are lotic (Hutchinson 1967), then the distribution of the medusae in Wolf Fork results from events and conditions since delivery of immature medusae from upstream earlier in summer. During most of the year, flow from the stream would induce some current at the head of Wolf Fork, and the location and localization of the swarm at Wolf Fork may have resulted from flow-related concentration (e.g., in an eddy) of polyps or small medusae originally exported from the stream.

Several authors have also found a highly localized distribution of medusae. Dodson and Cooper (1983) found medusae only in one small sheltered cove of a Wisconsin Lake. Deacon and Haskell (1967) reported medusae from sheltered coves at Lake Mead, Nevada, and not from the open waters of the reservoir. Garman's (1916) description of the location of a dense swarm in a narrow flooded tributary of an impounded reach of the Kentucky River is similar to Wolf Fork and to other published accounts (e.g., Lytle 1962).

Few authors have explicitly commented on factors accounting for spatial variation in medusae abundance within a reservoir or lake. Acker and Muscat (1976) noticed an apparent effect of light on the distribution of medusae which they attributed to a direct light effect or to an indirect effect of light on food concentration. Other factors such as wind (Deevy and Brooks 1943), and ebbulition (Koryak and Stafford 1981) have been proposed. I noticed no apparent light effect at Wolf Fork, and the cove is well protected from wind and boat-wake disturbance; these factors are unsatisfactory for explaining the large local variation in abundance of medusae at Wolf Fork. My observations suggest instead that the distribution of medusae may result from the pattern of dispersion from a location that is determined by the habitat requirements of the polyps in the reservoir or in tributary streams.

My observation of a bi-modal size distribution of medusae (Fig. 2) suggest the possibility of more than one period of medusa formation at Wolf Creek, perhaps associated with variation in water temperature, water chemistry, or streamflow during early summer. McClary (1959) reported medusa budding only within a narrow temperature range, 26 C to 33 C. However, I found very few small (<8 mm) medusae in August while sampling within this temperature range (Fig. 2) suggesting that formation of medusae was not ongoing and most likely occurred during two periods in early summer.

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LITERATURE CITED

Acker, T. S., and A. M. Muscat. 1976. The ecology of *Craspedacusta sowerbii* Lankester, a freshwater hydrozoan. The American Midland Naturalist 95:323-336.

Beckett, D. C., and E. J. Turanchik. 1980. Occurrence of the freshwater jellyfish *Craspedacusta sowerbyi* Lankester in the Ohio River. Ohio Journal of Science 80:95- 96.

Brussock, P. P., L. D. Willis, and A. V. Brown. 1985. Flow reduction may explain sporadic occurrence of *Craspedacusta sowerbyi* (Trachylina) medusae. Proceedings of the Arkansas Academy of Science 39:120.

Bushnell, J. H., and T. W. Porter. 1967. The occurrence, habitat, and prey of *Craspedacusta sowerbyi* (particularly polyp stage) in Michigan. Transactions of the American Microscopy Society 86:22-27.

Byers, C. F. 1945. The fresh-water jellyfish in Florida. Proceedings of the Florida Academy of Sciences 7:173-180.

Chadwick, C. S., and H. Houston. 1953. A "bloom" of fresh water medusae *Craspedacusta ryderi* (Potts) in Kentucky Lake, Tennessee. Journal of the Tennessee Academy 28:36-37.

Deacon, J. E., and W. L. Haskell. 1967. Observations on the ecology of the freshwater jellyfish in Lake Mead, Nevada. The American Midland Naturalist 78:155-166.

Deevey, E. S., and J. L. Brooks. 1943. *Craspedacusta* in open water, Lake Quassapaug, Connecticut. Ecology 24:266-267.

DeVries, D. R. 1992. The freshwater jellyfish *Craspedacusta sowerbyi*: a summary of its life history, ecology and distribution. Journal of Freshwater Ecology 7:7-16.

Dexter, R. W., T. C. Surrarrer, and C. W. Davis. 1949. Some recent records of the freshwater jellyfish *Craspedacusta sowerbii* from Ohio and Pennsylvania. The Ohio Journal of Science 49:235-241.

Dodds, R. B., and K. D. Hall. 1984. Environmental and physiological studies of the freshwater jellyfish *Craspedacusta sowerbyi*. Bios 55:75-83.

Dodson, S. I., and S. D. Cooper. 1983. Trophic relationships of the freshwater jellyfish *Craspedecusta sowerbyi* Lankester 1880. Limnology and Oceanography 28:345-351.

Garman, H. 1916. The sudden appearance of great numbers of fresh-water medusa in a Kentucky Creek. Science 44:858-860.

Howmiller, R. P., and G. M. Ludwig. 1970. A record of *Craspedacusta sowerbyi* in Wisconsin. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 60:181-182.

Hutchinson, G. E. 1967. A treatise on limnology: Vol. II. Introduction to lake biology and the limnoplankton. John Wiley and Sons, Inc., New York, New York.

Koryak, M., and P. J. Clancy. 1981. *Craspedacusta sowerbyi* Lankester (Hydrozoa) medusoid generations in two western Pennsylvania impoundments. Proceedings of the Pennsylvania Academy of Science 55:43-44.

Koryak, M., and L. Stafford. 1981. Bubbles and jellyfish: ebullition and *Craspedacusta sowerbyi* Lankester (Hydrozoa) in Tygart Lake. Unpublished Report. U.S. Army Corps of Engineers, Pittsburgh District, Pittsburgh, Pennsylvania.

Kramp, P. L. 1950. Freshwater medusae in China. Proceedings of the Zoological Society of London 120:165-184.

Lytle C. F. 1959. Studies on the developmental biology of *Craspedacusta*. Ph.D. Thesis, Indiana University, Bloomington.

Lytle, C. F. 1962. *Craspedacusta* in southeastern United States. Tulane Studies in Zoology 9:309-314.

McClary, A. 1959. The effect of temperature on growth and reproduction in *Craspedacusta sowerbii*. Ecology 40:158-162.

McCullough, J. D., M. F. Taylor, and J. L. Jones. 1981. The occurrence of the freshwater- medusa *Craspedacusta sowerbyi* Lankester in Nacogdoches Reservoir, Texas and associate physical-chemical conditions. Texas Journal of Science 33:17-23.

Pennak, R. W. 1989. Freshwater invertebrates of the United States. Protozoa to mollusca. Third edition. John Wiley and Sons, New York, New York.

Reese, A. M. 1940. *Craspedacusta* again. American Naturalist 74:180.

Slobodkin, L. B., and P. E. Bossert. 1991. The freshwater Cnidaria — or Coelenterates. Pages 125-143 *in* Ecology and classification of North American freshwater invertebrates (J. H. Thorp and A. P. Covich, editors). Academic Press, Inc., San Diego, California.

Yeager, B. L. 1987. Drainagewide occurrence of the freshwater jellyfish, *Craspedacusta sowerbyi*, Lankester 1880, in the Tennessee River system. Brimleyana 13:94-98.