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ENVS 691 Laboratory Exercise No. 5

STURGEON NO. 15081

Observations on the movements of a marked Atlantic sturgeon (*Acipenser oxyrinchus*) were obtained via radiotelemetry data from a transmitter surgically implanted inside the individual and receivers mounted on buoys in the tidal portion of the James River. Whenever the individual was within range of a receiver (roughly between 1 and 2 km), the receiver would record the date and time of the hit as well as the depth (in meters) at which the sturgeon was located.

The individual, marked No. 15081, is described as a "big fish," with a length of 1.685 m and a mass of 40 kg at the time it was captured and tagged. Data were obtained from a 27-day period from Sept. 21, 2011, to Oct. 18, 2011. In all, 3,832 observations were recorded.

These data were analyzed both statistically using the software package SYSTAT (Wilkinson, 1988) as well as with a geographic information system, Quantum GIS (Quantum GIS Development Team, 2012), in order to identify patterns in No. 15081's movements during the observation period. In order to facilitate this analysis dates were converted to day numbers by summing the number of days since Jan. 1, 2011. Corresponding day numbers for Sept. 21 and Oct. 18 were 264 and 291, respectively.

Because many aquatic species engage in vertical diurnal migrations, the hour of observation was included in the analysis, but the raw hour value was deemed to be problematic. In 24-hour time, there is no difference between 0000 hours and 2400 hours. Likewise, there is little qualitative difference in light regime between, for example, 1000 hours and 1400 hours. Therefore the raw hour values were transformed into something more environmentally meaningful by first multiplying the hour by 15 degrees (as any given spot on the Earth rotates 15 degrees in an hour) and taking the cosine of that angular value. The cosine-transformed values

range from 1 at midnight to -1 at noon, and would be 0 at both 0600 and 1800 hours (6 a.m. and 6 p.m., respectively).

No. 15081 Results

Examples of the movements of No. 15081 are plotted in the maps in figures 1a through 1f. Most of the time the sturgeon stayed in the tidal freshwater portion of the James River upstream of its confluence with the Chickahominy River. Some days it appears to move little (figures 1b and 1c), other days it is quite mobile (figures 1d and 1f). Note that the periods of apparent inactivity may merely be artefacts of the sturgeon being out of range of the receivers. On day 291 (Oct. 18, 2011), No. 15081 appears to be heading downstream into the Chesapeake Bay. The last recorded observation of the day and data series was at 1959 hours (7:59 p.m.).

Because of the large number of observations, all but one of the correlation coefficients, though quite low, proved statistically significant, even when using Bonferroni-adjusted probability values to account for the effect of multiple comparisons (Table 1). (Note that there are likely strong serial autocorrelation effects here; a better way to assess significance would be to randomly select observations from the data set and repeat the correlation procedure.) The correlation that proved not significant was between depth and location. Despite the multiple statistically significant correlations, the only one that accounted for an appreciable amount of variance in the data was between day and location ($r = 0.417$), which accounts for just 17.4% of the variance in the observations.

Box plots were prepared of depth by day (Figure 2), depth by hour (Figure 3), depth by cosine-transformed hour (Figure 4), and depth by location (Figure 5). There is a considerable amount of overlap within each of the four box plots, as such revealing little or no pattern to No. 15081's movements. As might be expected based on the correlation results, there is less overlap

in the depth by location box plot (Figure 5), but it cannot be determined whether the pattern revealed in that plot reflects some meaningful behavior or whether it simply reflects the depth of the river, thus room for the sturgeon to roam, in those areas.

Comparisons with other "big fish"

The correlation results for No. 15081 were compared to four other "big fish" for whom depth data were also available: No. 16092, No. 16093, No. 16094, and No. 15080. The only uniform pattern was a statistically significant correlation between day by location. Among all five fish, this correlation consistently had the highest *r* values, ranging from 0.400 to 0.722). Four out of five fish exhibited significant correlations between depth by day and depth by location. This should not be surprising given the fact that river depth varies by location, and the strong correlations for all five fish of day by location.

Location data were available for at least four of the five fish during an 18-day period from day 265 (Sept. 22, 2011) to day 282 (Oct. 9, 2011). Net daily movement was calculated as follows:

$NM = d_i - d_{i-1}$

Where NM = net movement in miles along the river channel, d_i = location at the end of the day, and d_{i-1} = location at the end of the previous day. Positive NM values indicated a net movement upstream, while negative NM values indicated a net movement downstream. On nine of the 18 days at least three of the fish moved in the same direction: the majority moved upstream on days 270 and 276; the majority moved downstream on days 265, 273 through 275, and 280 though 282. A glance at precipitation data for the Richmond, Va., metropolitan area failed to detect any weather pattern that could explain the coincidental movement.

Lingering Questions

Aside from some of the aforementioned statistical flaws in this analysis, other problems worth noting include a lack of detail in characteristics of the river environment and lack of data to indicate the distance of the sturgeon from the telemetry receivers. Data on bottom type and structure (both natural and human) might help shed light on potential food or shelter sought by sturgeon. Distance data would enhance the ability to detect biologically meaningful patterns by setting limits (short of the James River's banks) on bottom area researchers need concern themselves with.

REFERENCES

Quantum GIS Development Team. (2012). Quantum GIS Geographic Information System: Open Source Geospatial Foundation Project.

Wilkinson, L. (1988). SYSTAT: the system for statistics. SYSTAT, Inc., Evanstaon, Illinois, USA.

Table 1. Correlation matrix of day (number from Jan. 1, 2011), hour (cosine transformation), depth (m), and location (miles from mouth of James River) for sturgeon No. 15081 from Sept. 21, 2011, to Oct. 18, 2011.

	Day	Hour	Depth	Location
Day	—			
Hour	0.054*	—		
Depth	0.047*	0.061*	—	
Location	0.417*	0.049*	0.041	—

* Bonferroni-adjusted $p < 0.05$

Table 2. Correlation matrix of day (number from Jan. 1, 2011), hour (cosine transformation), depth (m), and location (miles from mouth of James River) for five sturgeon from Sept. 20, 2011, to Nov. 1, 2011.

	No. 15081	No. 16092	No. 16093	No. 16094	No. 15080
Day*Hour	0.054*	0.049	0.123*	0.124*	0.006
Day*Depth	0.047*	0.174*	0.105*	0.107*	0.037
Day*Location	0.417*	0.400*	0.722*	0.511*	0.406*
Hour*Depth	0.061*	0.036	0.029	0.006	0.046*
Hour*Location	0.049*	0.053	0.044	0.076*	0.008
Depth*Location	0.041	0.071*	0.095*	0.147*	0.151*

* Bonferroni-adjusted $p < 0.05$

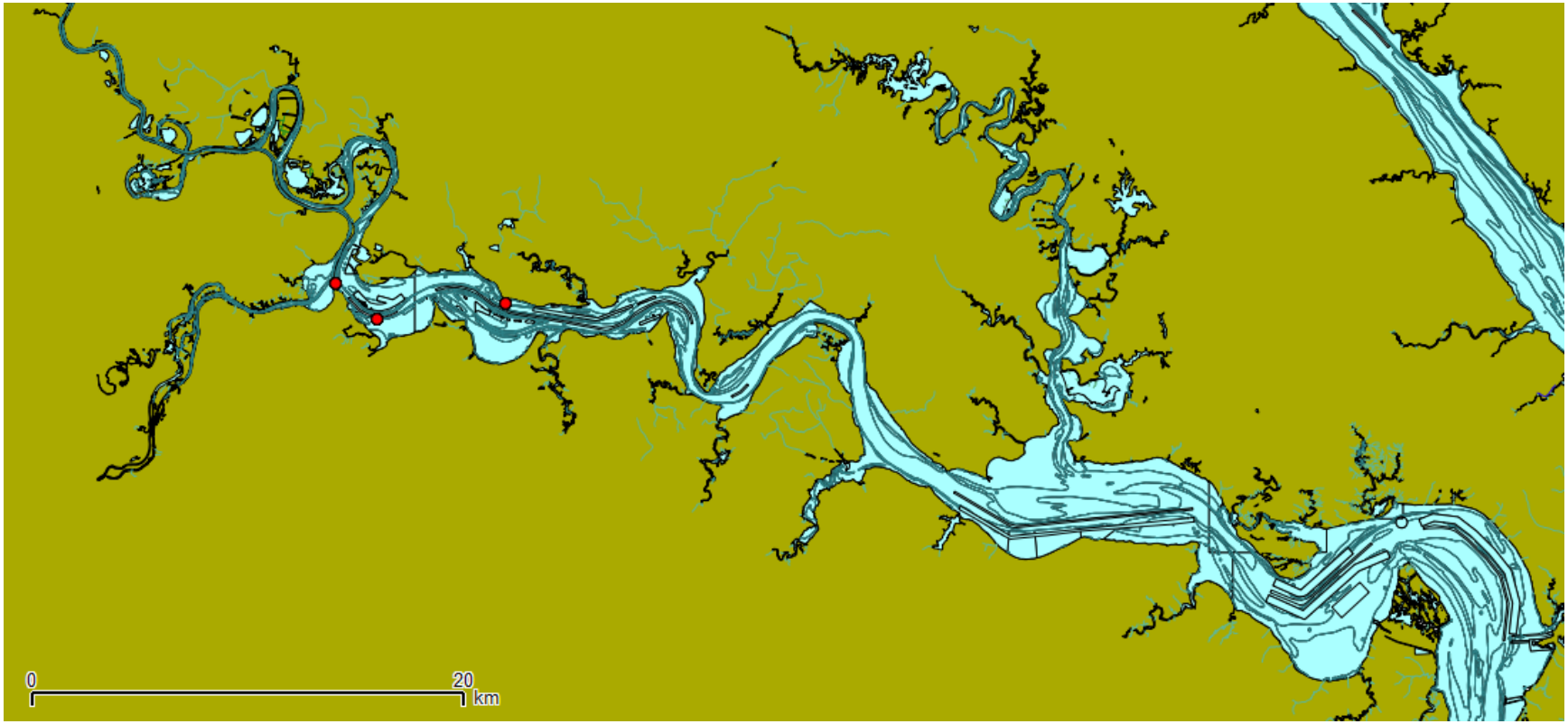

Figure 1a. Location of sturgeon No. 15081 (red dots) on day 265 (Sept. 22, 2011).

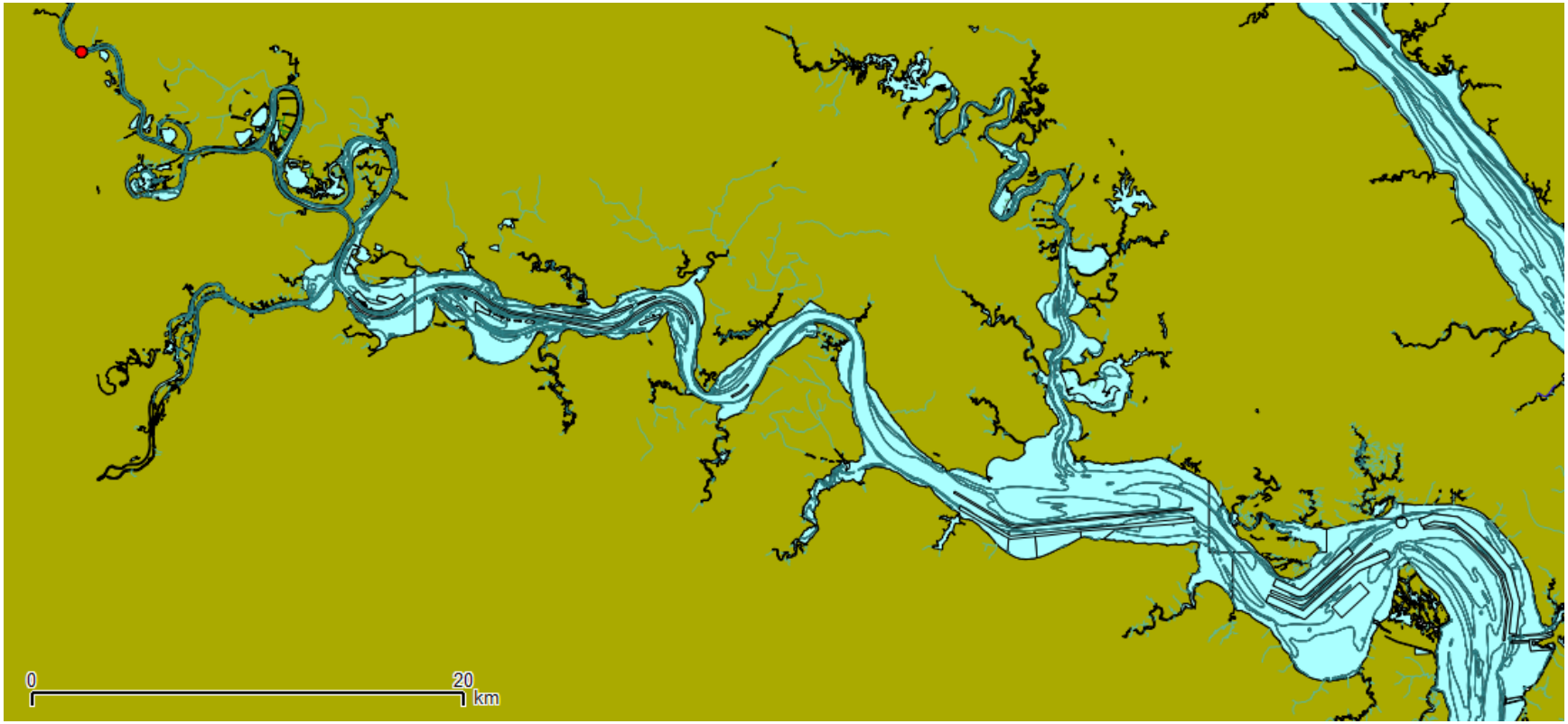

Figure 1b. Location of sturgeon No. 15081 (red dots) on day 270 (Sept. 27, 2011).

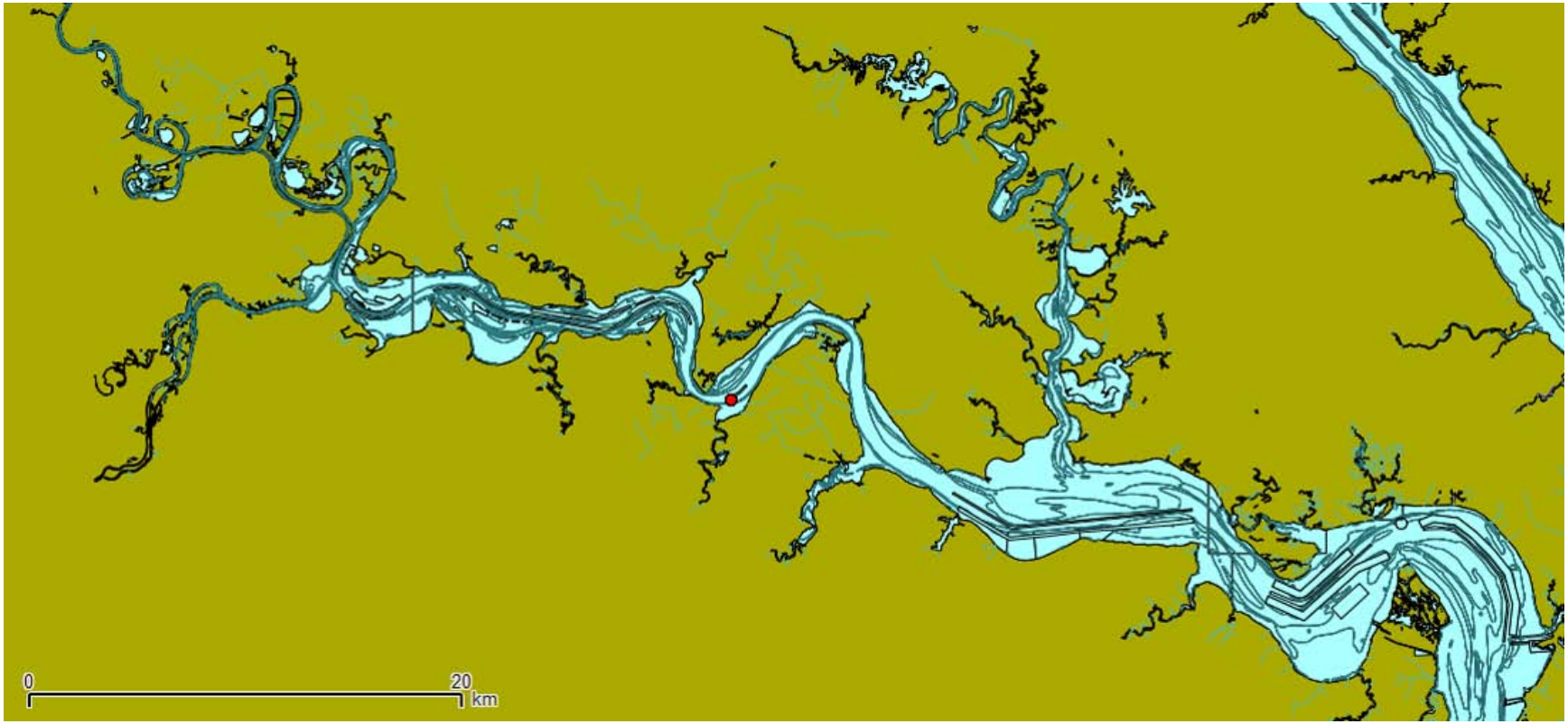

Figure 1c. Location of sturgeon No. 15081 (red dots) on day 275 (Oct. 2, 2011).

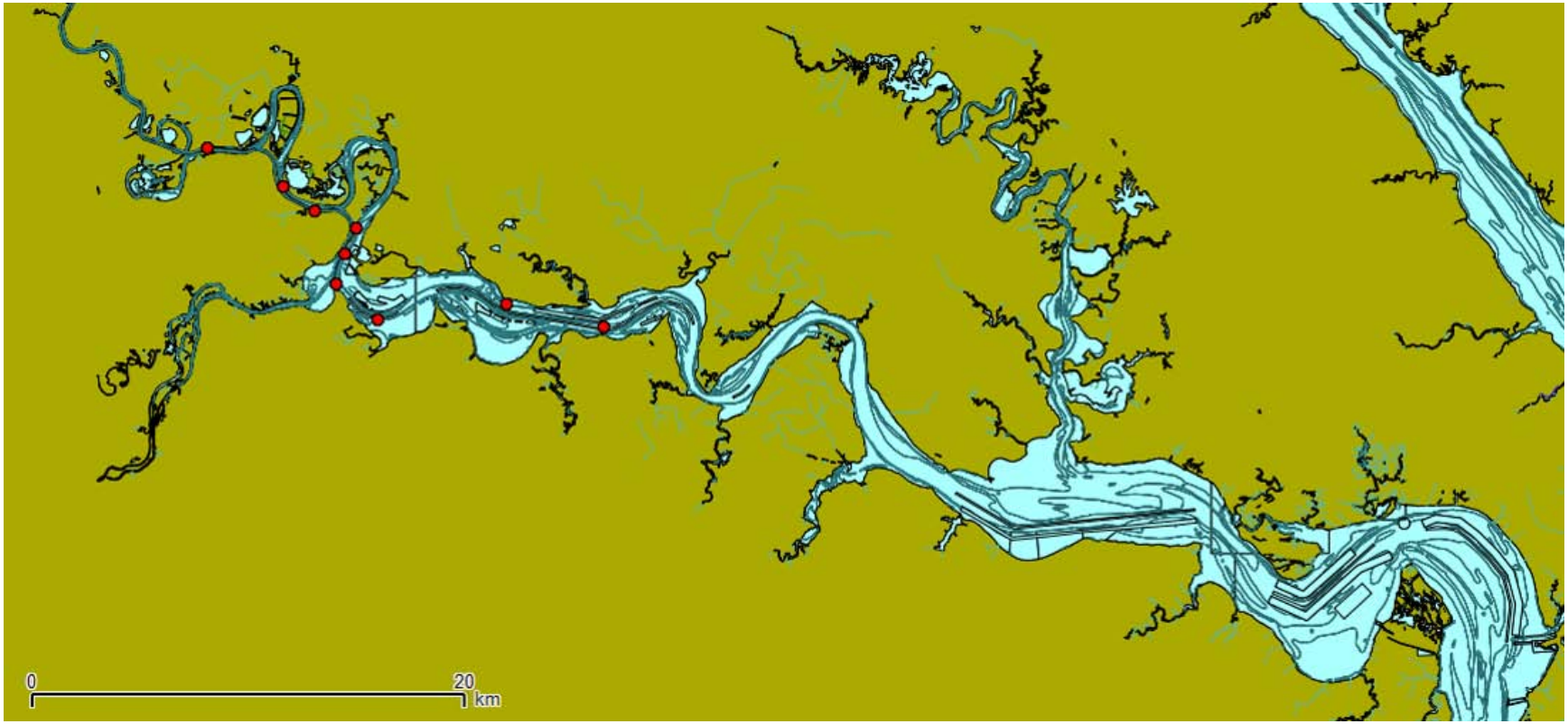

Figure 1d. Location of sturgeon No. 15081 (red dots) on day 280 (Oct. 7, 2011).

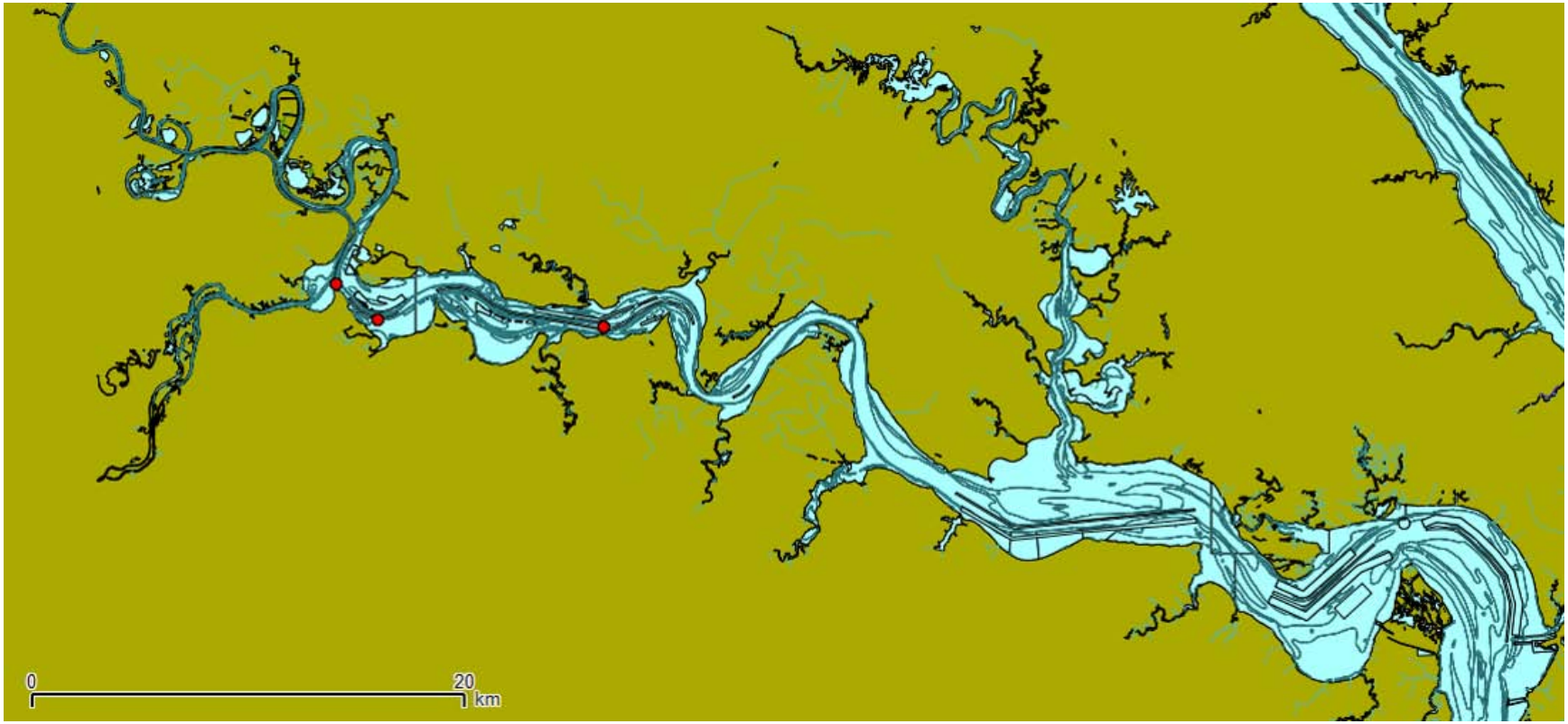

Figure 1e. Location of sturgeon No. 15081 (red dots) on day 285 (Oct. 12, 2011).

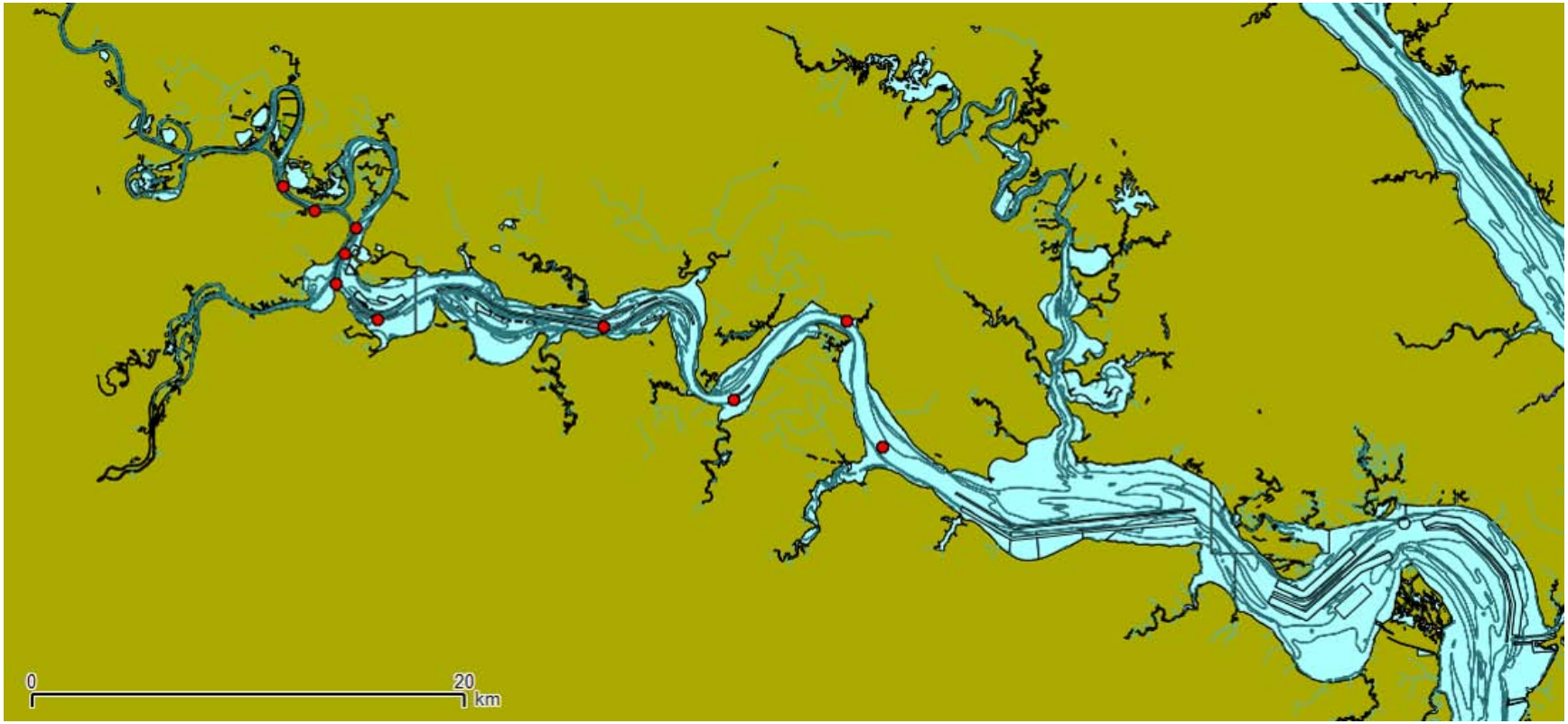

Figure 1f. Location of sturgeon No. 15081 (red dots) on day 290 (Oct. 17, 2011).

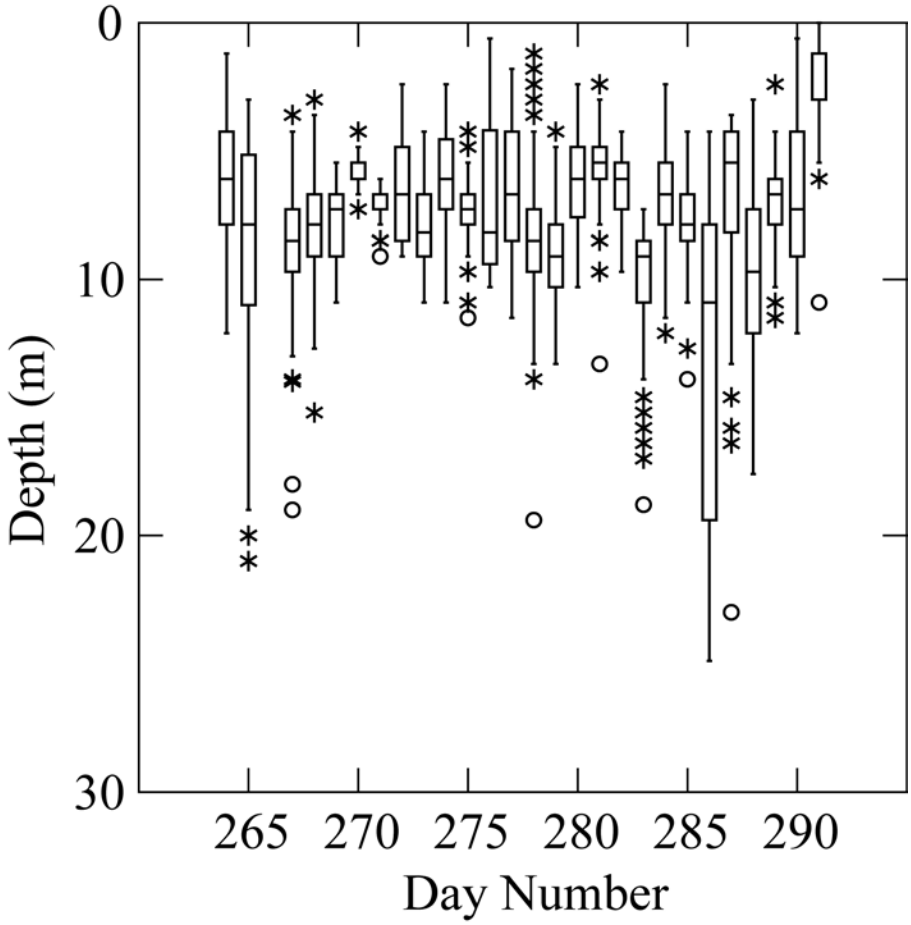

Figure 2. Box plot of depth versus day for the movements of No. 15081.

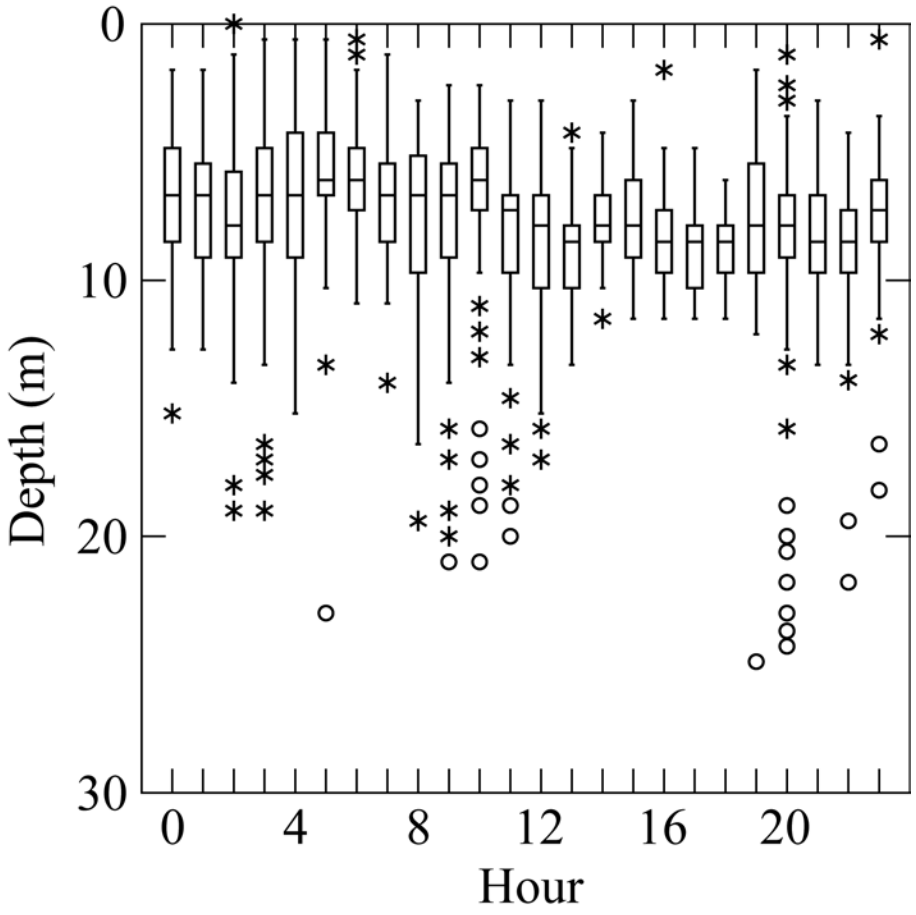

Figure 3. Box plot of depth versus hour for the movements of No. 15081.

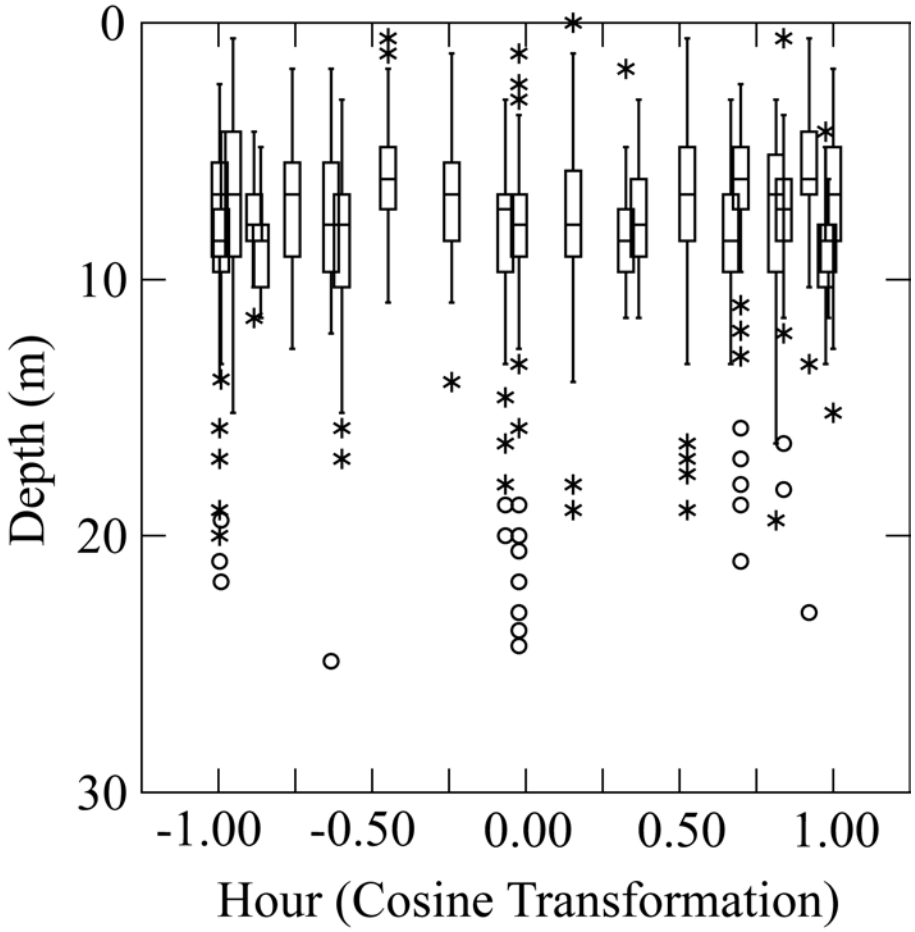

Figure 4. Box plot of depth versus cosine-transformed hour for the movements of No. 15081.

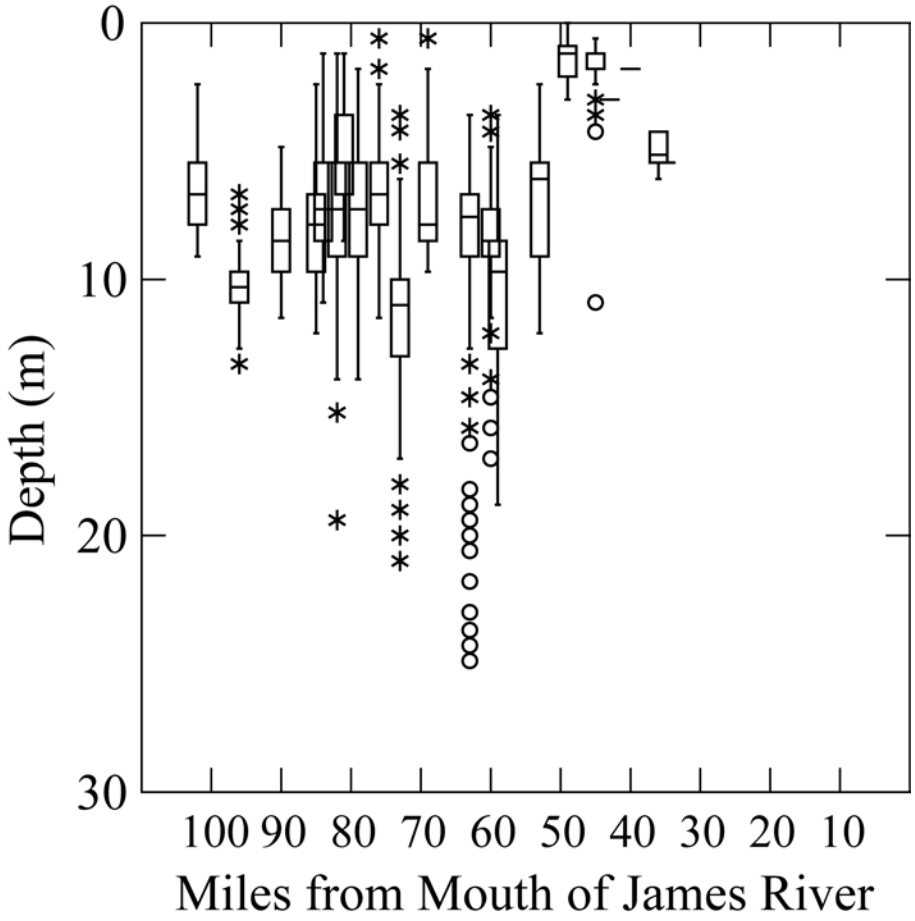

Figure 5. Box plot of depth versus location for the movements of No. 15081.