DEVELOPMENT OF A FLOW DEPENDENT INUNDATION MODEL FOR EVALUATING GAR (LEPISOSTEIFORMES) HABITAT SUITABILITY IN THE LOWER GUADALUPE RIVER, USA

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This study uses a high-resolution hydraulic flood model to develop spatially-explicit flood inundation maps of the Lower Guadalupe River to assess habitat and resource availability for a variety of flood dependent species including the alligator gar (*Atractosteus spatual*). We use the USACE 1D HEC-RAS/HEC-Geo-RAS model and the 2D hydrodynamic TUFLOW model. Four primary inputs were used to develop the hydraulic model: digital elevation data, discharge and stage data, flow resistance parameters, and boundary conditions that relate the terrain and flow data. The Digital Terrain Model (DTM) of the river and floodplain were developed from elevation data obtained from LiDAR and high-resolution digital imagery collected using an unmanned aerial system. We used USGS discharge and stage data for the hydrologic inputs. Flow resistance factors were derived from Manning's n roughness coefficients, and model boundary conditions were determined using the DTM and stage-discharge rating curves. Supplementary hydrologic and geomorphic data for model calibration, verification, and validation were collected in the field. Model results were compared to historical cohort strength estimated from otoliths and population monitoring of gar.

1 INTRODUCTION

We examined the flow-ecology relationship between floodplain inundation and suitability of floodplain habitat for Alligator Gar (*Atractosteus spatula).* Alligator Gar depend on lateral hydrologic connectivity between the river and floodplain to provide access to floodplain lakes (abandoned channel oxbow lakes), backwater tributaries, and other flood-activated environments for foraging and spawning. Alligator Gar are a species of economic and ecologic interest for the lower Guadalupe River, however there is minimal information on the flow-ecology dynamics of this species. This project uses a high-resolution hydraulic flood model to estimate floodplain inundation of various flow ranges over a 32 km segment of the Lower Guadalupe River floodplain in the alluvial Gulf Coast Plain of Texas. Spatially-explicit maps of flood extents and flood depths are combined with other spatial layers in a GIS and Alligator Gar life-history criteria to quantify suitable habitats for this species. This resulting flow-ecology information is used to develop environmental flow recommendations for the Lower Guadalupe River Basin to inform the state environmental agencies on sustainable management of this species and other flood-dependent biota.

A previous study [1] examined hydrologic connectivity of river and flood plain environments of the lower Guadalupe River using an empirical relationship between lake levels and main-stem river discharge. This study builds on that previous work by using a different methodological approach; by using a high-resolution, spatially-explicit flood inundation model – a method which is proven to be effective for understanding river-floodplain connectivity in large low-gradient coastal plain rivers similar to the Guadalupe [2; 3].

2 METHODS

2.1 Study Area

The Guadalupe River arises in the Edwards Plateau where it drains highly dissected Cretaceous limestone in a regional landscape referred to as the Texas Hill Country. From here, it crosses the Balcones Escarpment into the Gulf Coastal Plain where it flows 233 km to the Guadalupe/San Antonio Bay and eventually to the Gulf of Mexico. The lower Guadalupe drains Tertiary and Quaternary coastal plain sedimentary units and flows through a broad, low-gradient, alluvial valley characterized by a wide floodplain (0.2-0.4 km). The lower Guadalupe floodplain complex is topographically and geographically complex, and contains numerous Pleistocene to Holocene-age geomorphic units, including many abandoned channels and meander scroll features, which during high flows provide ecologically valuable flooded habitats.

Total drainage area for the basin near our study site at Cuero, Texas encompasses 12,780 km^2 . Discharge for the lower Guadalupe is highly variable with median discharge around 30 m^3/s and peak flows near 800 m^3/s, as recorded by the United States Geological Survey (USGS) Guadalupe River at Cuero, Texas gage 08175800 over the period of record, 1964-2015. A flood frequency curve computed using annual peak flows and a flow duration curve computed using mean daily flows illustrates this high range of flow variability (Figures 1 and 2).

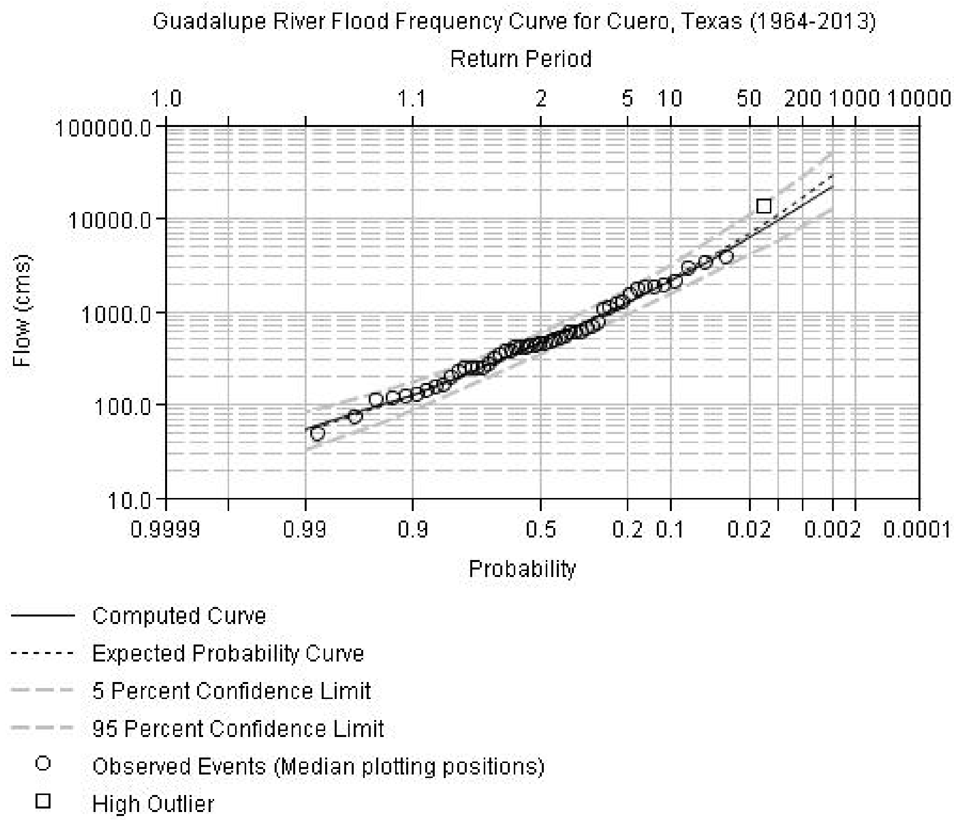

Figure 1. Guadalupe flood frequency curve for Cuero, Texas (1964-2013) gage ID 08175800. This was computed using peak annual flow data, floods from the one year recurrence interval up to the 500 year flood are modelled and mapped to examine their influence on available gar habitat.

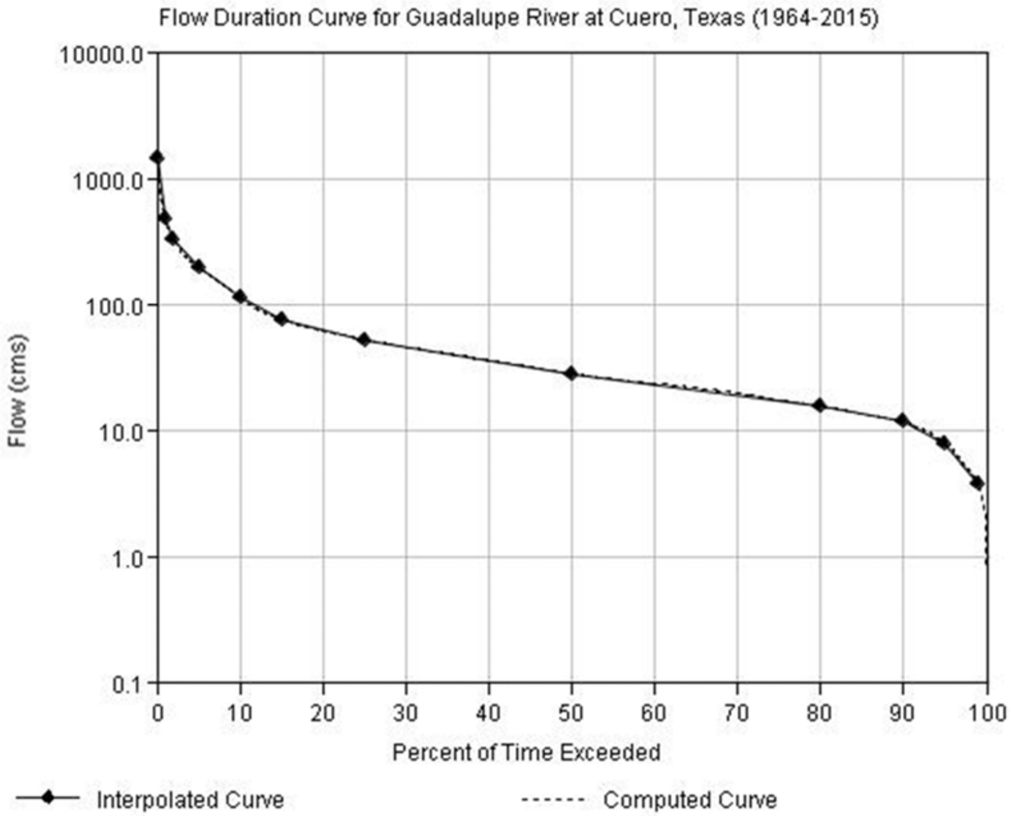

Figure 2. Guadalupe flow duration curve for Cuero, Texas (1964-2015) gage ID 08175800. This curve was calculated using mean daily flow data for the period of record, this analysis is used to examine the duration of flows in proximity to the 1-year recurrence interval (< 20% flow exceedence, >70 m^3/s) that are capable of producing high flow pulses that inundate backwater and oxbow lake habitats.

2.2 Modeling Methods and Data Sources

We used a high-resolution, hydrodynamic flood model to develop spatially-explicit flood inundation maps of the lower Guadalupe River for assessing habitat and resource availability for a variety of flood dependent species including the Alligator Gar (*Atractosteus spatula*).

We used the United States Army Corps of Engineer (USACE) 1D HEC-RAS/HEC-GeoRAS model and the 2D hydrodynamic TUFLOW model to develop the flood inundation model. The HEC-RAS models are useful for modeling static, 1D flood inundation extents and depths. TUFLOW also models flood inundation extents and depths, but is especially useful because of its ability to simulate wetting and drying processes that occur during and after the flood event. Both models are compatible with high-resolution elevation data covering large spatial extents; and each couples seamlessly with a Geographic Information System (GIS). Because of constraints with 2D model run-times, we first modelled the entire study area using the HEC-RAS, and then used TUFLOW to model a subset of river-floodplain segments identified as having higher habitat suitability for the species of interest.

Developing both models requires four primary inputs: digital elevation data, discharge and stage data, flow resistance parameters, and boundary conditions that relate the terrain and flow data. A digital terrain model (DTM) of the river and floodplain was developed from LiDAR-derived digital elevation models and additional elevation data collected using digital imagery obtained from an unmanned autonomous system (UAS). Collection and processing of the UAS derived data is part of a separate project occurring in conjunction with the present study.

We used USGS discharge and stage data from three gages, the Guadalupe River at Gonzales 08173900, the Guadalupe River at Cuero 08175800, and the Guadalupe River at Victoria, Texas 0817650, for the hydrologic inputs. Annual peak data, daily maximum data, and mean daily data for the period of record for each gage were used in the hydrologic analyses. All gages include greater than 30 years of flow data and provided sufficient data for the frequency and duration analyses. Flow resistance factors are derived from Manning's n roughness coefficients for the river channel and floodplain. Model boundary conditions are determined using the DTM and stage-discharge rating curves. Supplementary hydrologic and geomorphic data for model calibration, verification, and validation were collected in the field.

Alligator Gar life-history data was acquired from existing literature on the species, as well as expert advice from the Texas Parks and Wildlife Department fishery biologists. From this information we developed habitat criteria to use in conjunction with the flood inundation models to quantify flow-ecology relationships for the species. Additional hydrologic analyses quantified the historic frequency and duration for the ecologically significant flood flows of varying magnitudes. This information was compared to historical cohort strength estimated from otoliths and population monitoring of gar conducted by the state agencies and other researchers.

3 ANTICIPATED RESULTS

Results of the flood inundation modeling include static maps of flood extents and flood depths for a range of different discharges and flood recurrence intervals. These maps in combination with other hydrologic metrics are used to calculate the frequency, duration, and seasonal timing of different inundation discharges that link back to the flow-ecology dynamics of Alligator Gar. All of which are compatible with other environmental and biological data layers in a GIS framework. Additionally, the 2-D model provides time-step simulations of inundation events which are useful for analyzing the spatial hydrologic connectivity processes of different floods. We are using these results to develop environmental flow recommendations to sustainably manage river flows for flood-dependent species.

REFERENCES

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