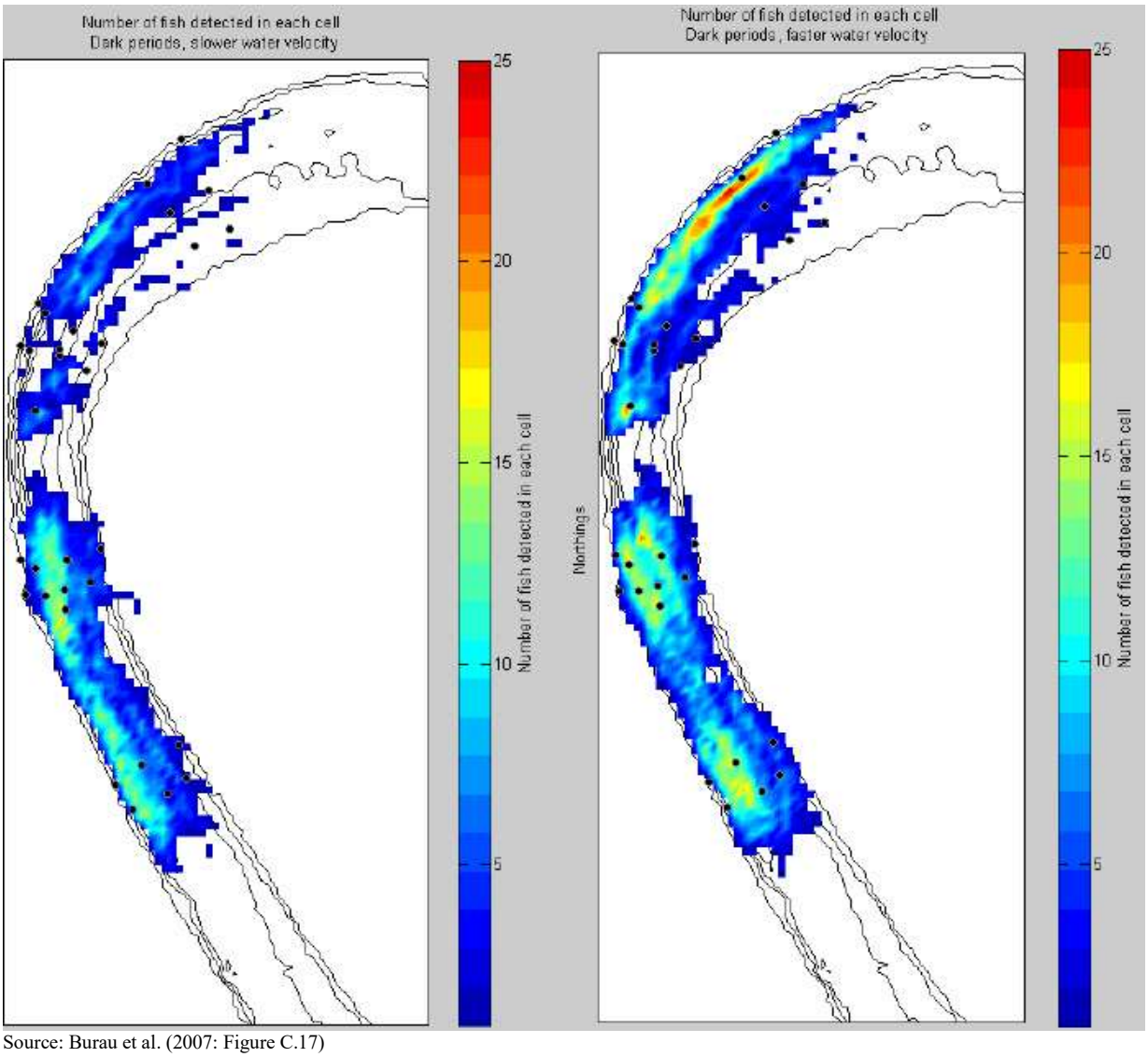
Analysis of River Bends and Fish Migration

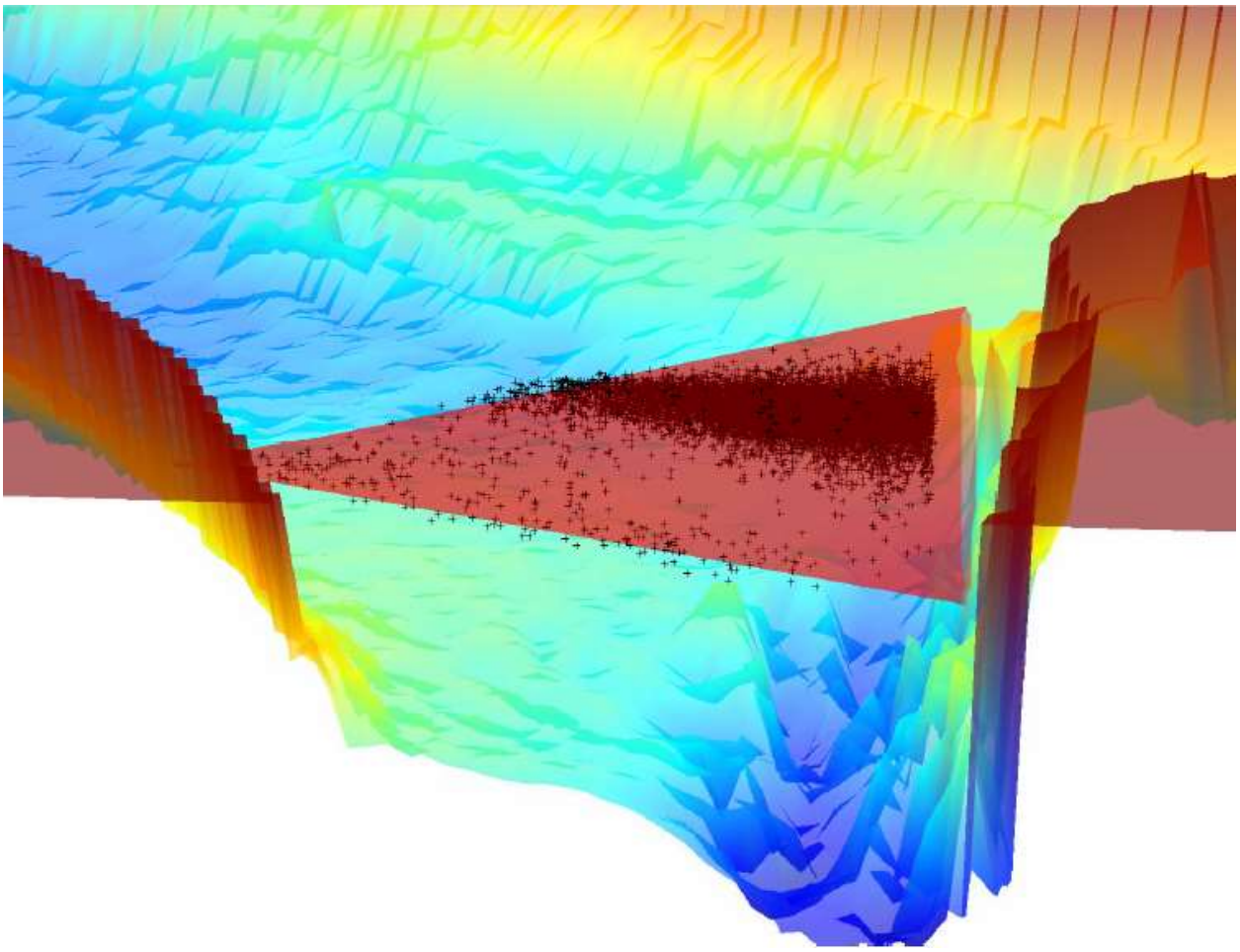
Comment: Is there any correlation with outside bends and in-migration and out-migration of fish?

Response: Several studies on the Sacramento River provide evidence for the distribution of outmigrating fish (specifically juvenile salmonids) toward the outer sides of bends, including at Clarksburg Bend (Figure clark1), the Delta Cross Channel (Figure DCC1), and near Fremont Weir (Figure fremont1). The distribution of fish towards the outside of bends is the result of centrifugal and pressure forces in bends which induce a secondary flow that lies in a plane perpendicular to the primary flow direction (Dinehart and Burau 2005) and is reflected in the bathymetry of such areas: the deeper areas, including the thalweg, coincide with the areas subject to the secondary flow (Figure clark2). These observations agree with the general pattern of downstream-migrating juvenile salmonids in the Pacific northwest often being distributed near the thalweg, or near the shoreline (Smith et al. 2009). However, when holding (e.g., during the day), juvenile salmonids could also occur on the inside of river bends, as illustrated at Clarksburg Bend (Figure clark3).



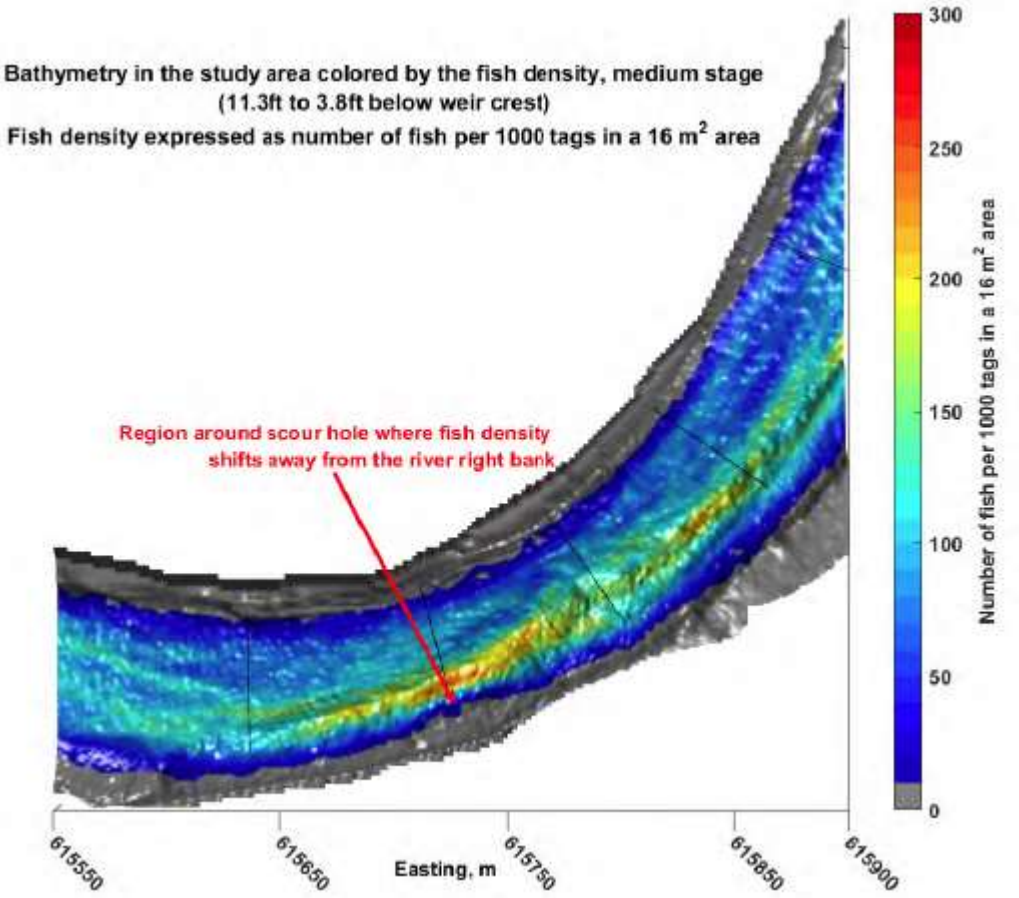
Source: Burau et al. (2007: Figure C.17)

Figure clark1. Clarksburg Bend Acoustic Tracking Study: Juvenile Chinook Salmon Distributions for Dark Periods, Separated into Fast (Greater than or Equal to Mean) and Slow (Less than Mean) Water Velocity Periods.



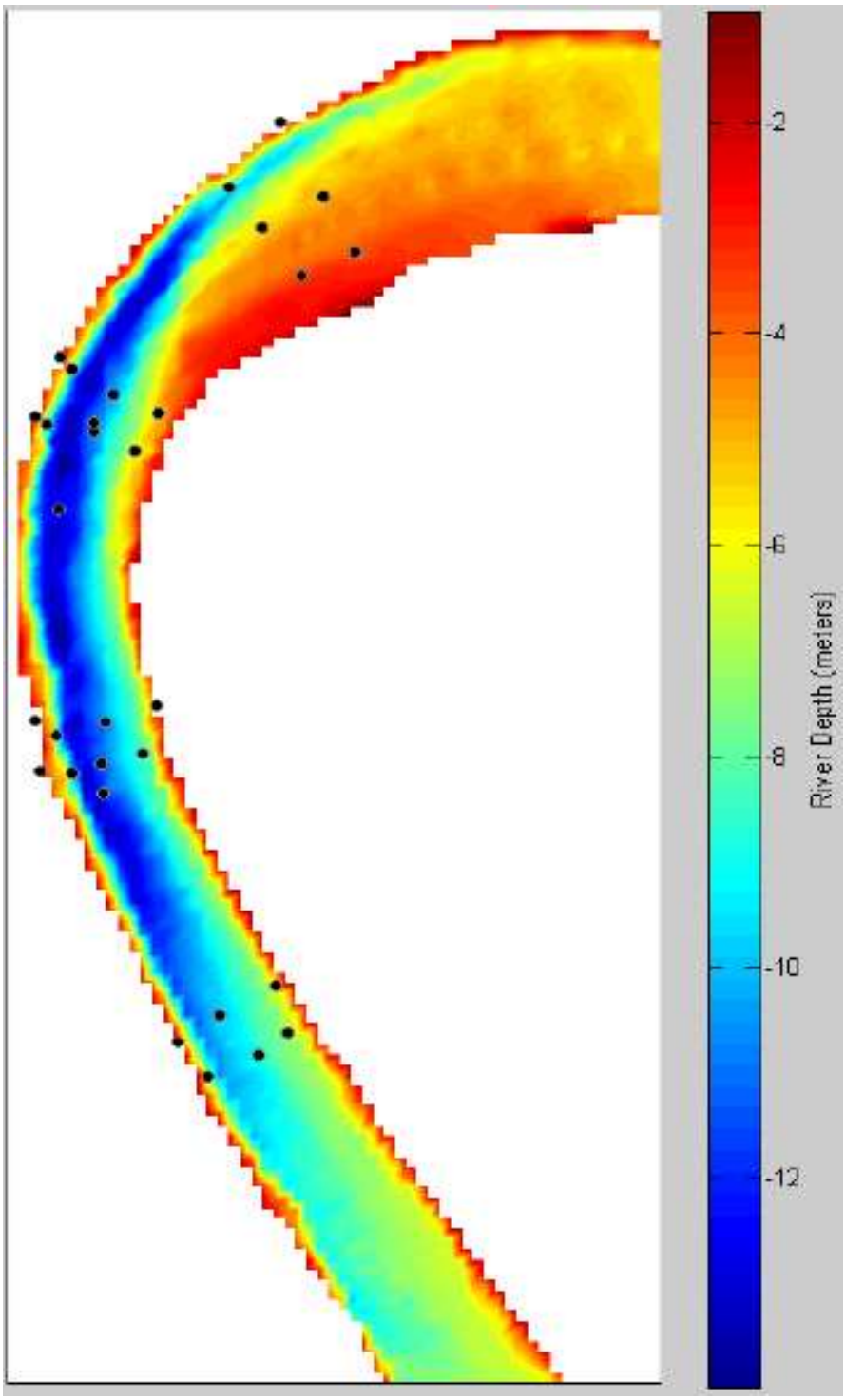
Source: Burau et al. (2007: Figure 2.5)

Figure DCC1. Delta Cross Channel Vicinity Hydroacoustic Study: Detections of Juvenile Salmon (+) on the Outside of a Bend in the Sacramento River Immediately Downstream of its Junction with Georgiana Slough (Upper Right).



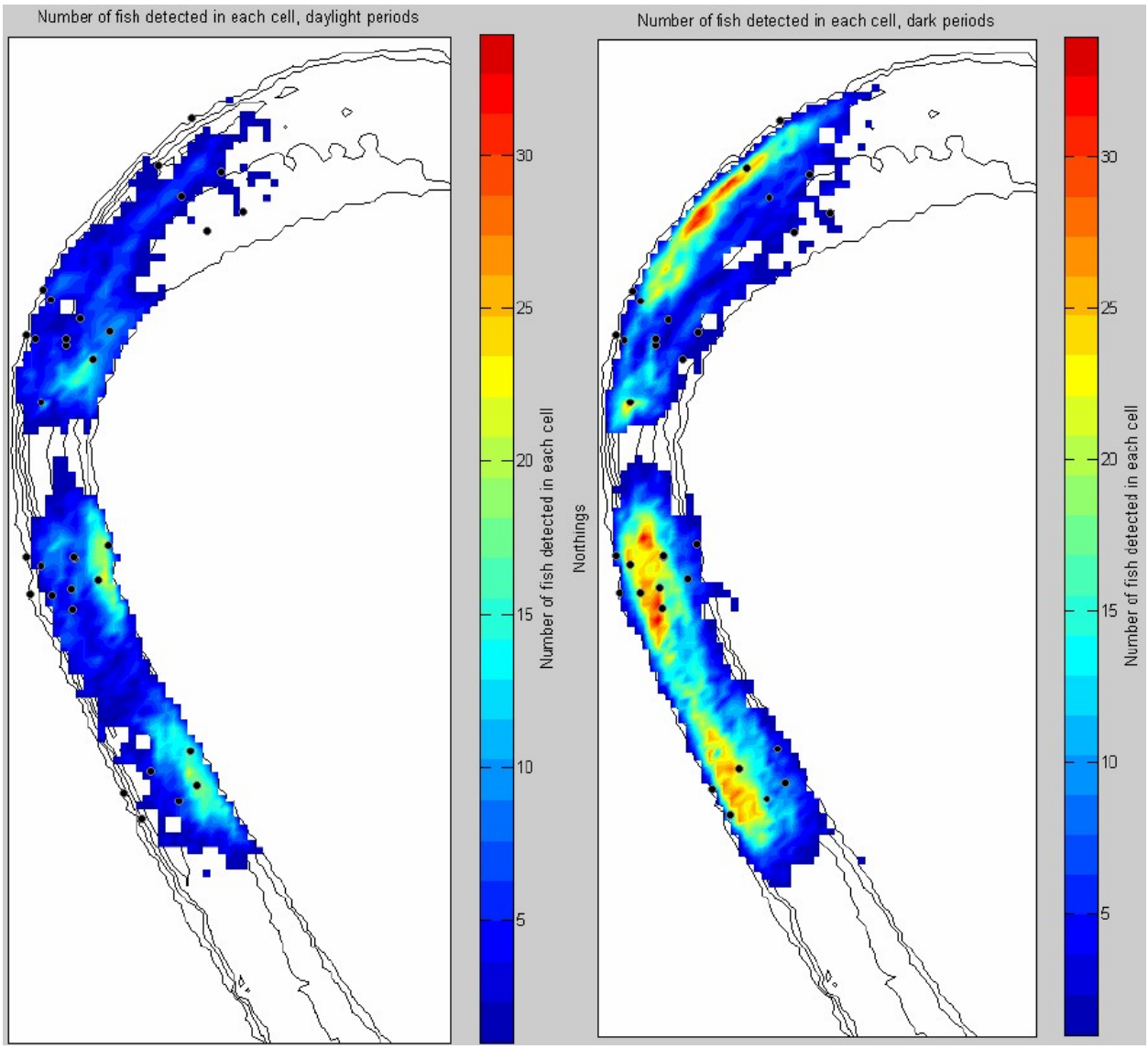
Source: Blake et al. (2017: Figures 2 and 20).

Figure fremont1. Bathymetry (Upper) and Juvenile Chinook Salmon Acoustic Detection Density (Lower) in the Sacramento River at Fremont Weir.



Source: Burau et al. (2007: Figure C.1)

Figure clark2. Clarksburg Bend Acoustic Tracking Study: Bathymetry and Hydrophone Locations.



Source: Burau et al. (2007: Figure C.15)

Figure clark3. Clarksburg Bend Acoustic Tracking Study: Juvenile Chinook Salmon Distributions for Daylight (Left) and Dark (Right) Periods.

With respect to in-migrating fish, Quinn (2005, p.80) reviewed available literature to suggest that salmon tend to adapt migration patterns to minimize energy expenditure by avoiding the fastest water and so generally swim near shore and near the bottom, based on literature from other systems. We are not aware of such patterns being confirmed in the Sacramento River system, but if correct, salmon could occur near the outside of bends in the river thalweg if this location provided an energetically efficient location relative to other parts of the river. For Delta Smelt, it is unknown if the species would occur at the outside of river bends during upstream migration; this may be dependent on the available velocity habitat in relation to the critical swimming velocity of up to approximately 28 cm/s (Swanson et al. 1998). Other factors such as predator avoidance and nocturnal loss of visual reference have also been hypothesized to influence potential distribution of in-migrating Delta Smelt in the river (USFWS 2017, p.318), although there are no empirical data with which to test these hypotheses.

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