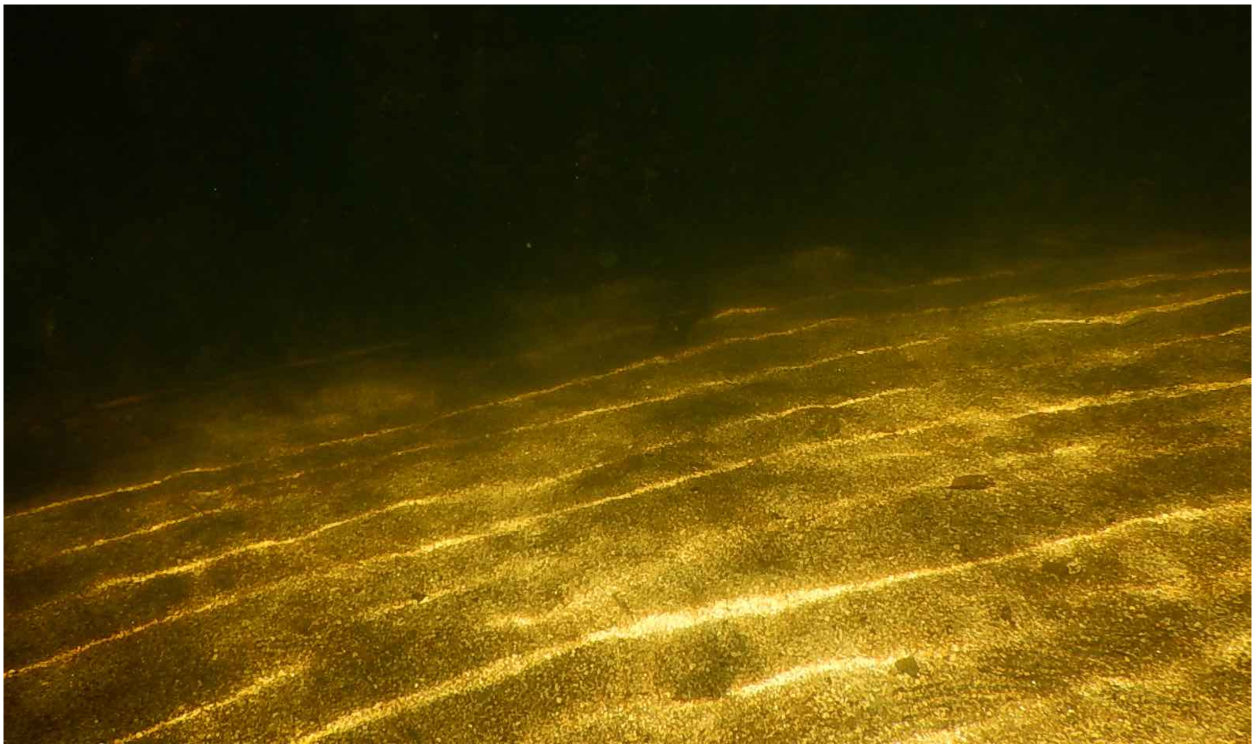
Habitat Use by Lamprey Ammocoetes in the Hamilton Ponds Grass Valley Creek (Trinity Basin CA),

including management recommendations to reduce impacts on lamprey



Submitted under Contract: Grass Valley Creek Anadromous Pacific Lamprey: sediment management and connectivity (Trinity River Resource Conservation District / funding Trinity River Restoration Program), 30 August 2017.

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Table of Contents

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List of Figures

Figure 1. Lamprey ammocoete (larvae).

Introduction

The Trinity Basin is home to three species of native lamprey: the large, migratory anadromous Pacific Lamprey, *Entosphenus tridentatus*; the Pit-Klamath Brook Lamprey, *E. lethophagus*, a resident non-parasitic species (identified in this project); and the Klamath River Lamprey, *E. similis*, a resident parasitic species. The Pacific Lamprey is of particular conservation concern in the Klamath Basin, where it is of traditional importance to local Native American cultures (Petersen-Lewis 2009, Goodman and Reid 2012, 2015). The other two species are each endemic to the Klamath Basin. A primary concern is loss of historical habitat due to passage barriers such as dams, road crossings and unsuitable fishways (Goodman and Reid 2012, Moyle et al. 2015). In the Trinity Basin an additional concern is loss of extensive rearing habitat in the upper Basin do to historical mining practices and retention of fines in large reservoirs (e.g. Trinity, Lewiston and Buckhorn reservoirs; Goodman and Reid 2012, 2015).

Lamprey larvae (ammocoetes; Figure 1) rear in areas located near or downstream of reaches where spawning occurred and are most abundant where the stream gradient is low (< 0.5%), and riparian canopy is open (Torgerson and Close 2004). At finer scales, larval occurrence corresponds positively with low water velocity, pool habitats, and availability of suitable burrowing habitat (Roni 2003; Torgersen and Close 2004; Stone and Brandt 2005; Graham and Brun 2007). Ammocoetes of all sizes are known to use depositional areas along stream banks having oxygenated fine sediments (silts and sands) often mixed with organic matter and detritus; this is generally referred to as Type I habitat (Potter 1980; Torgersen and Close 2004; Graham and Brun 2005; Cochnauer et al. 2006). Periodically, ammocoetes move into the water column and redistribute into suitable habitat. The ammocoete stage lasts for 4 - 7 yrs (Beamish and Levings 1991; Meeuwig and Bayer 2005). Pacific Lamprey generally transform at ≤ 17 sm; however, brook lampreys may reach 20 cm in the ammocoete life-stage (Kan 1975; van de Wetering 1999, Goodman et al. 2009, Reid unpub. data). There is no evidence that ammocoetes of different species occupy different habitat niches.

Grass Valley Creek is the first large tributary entering the Trinity River below Lewiston Dam from the south (Figure 3). It drains a region characterized by decomposing granite soils, resulting in a naturally high sand component to the bedload (Youngblood 1997, Gaeuman 2010). The drainage has been the focus of projects intended to reduce sand inputs to the mainstem Trinity River (Trso 2004, Gaeuman 2010). These include, Buckhorn Reservoir (constructed 1990), the two instream Hamilton Ponds near the mouth (constructed 1988-89) and extensive revegetation and soil stabilization efforts in the upper watershed (Trso 2004). Upper Hamilton Pond has a design capacity of 25,000 m^3 and the lower, which is deeper, a capacity of 35,500 m^3. Both ponds are roughly circular, with diameters of about 300 and 200 ft, respectively.

Maintaining the storage capacity of the ponds requires periodic dredging (Gaeuman 2010). The upper pond was last dredged in 2006, and the lower pond in 2007 (Figure 2). During the most recent dredgings large numbers of lamprey ammocoetes, as well as other fish, were removed with the dredged sediments (Martin and Gutermuth 2008, Gutermuth pers. com). Concerns were raised about the number of fish in the ponds and mortality due to dredging, as well as poor water quality, during these events. Assessment of the role the Hamilton Ponds plays in conservation of lampreys in the Trinity Basin, as well as development of appropriate management strategies are proposed as priority projects under implementation of the Pacific Lamprey Conservation Initiative (Goodman and Reid 2012, 2015).

The goals of the project are to:

1) Distribution: determine the distribution of and relative abundance of larval lampreys (ammocoetes) in the Hamilton Ponds,
2) Habitat: evaluate habitat use by ammocoetes in the Hamilton Ponds,
3) Management: development management suggestions to minimize impacts on lamprey during management operations (e.g. sediment removal).

This report focuses on the distribution of ammocoetes, habitat use and sediment management in Hamilton Ponds. A separate report addresses distribution and passage assessments in Grass Valley and Little Grass Valley creeks, including Buckhorn Dam (Reid 2017).

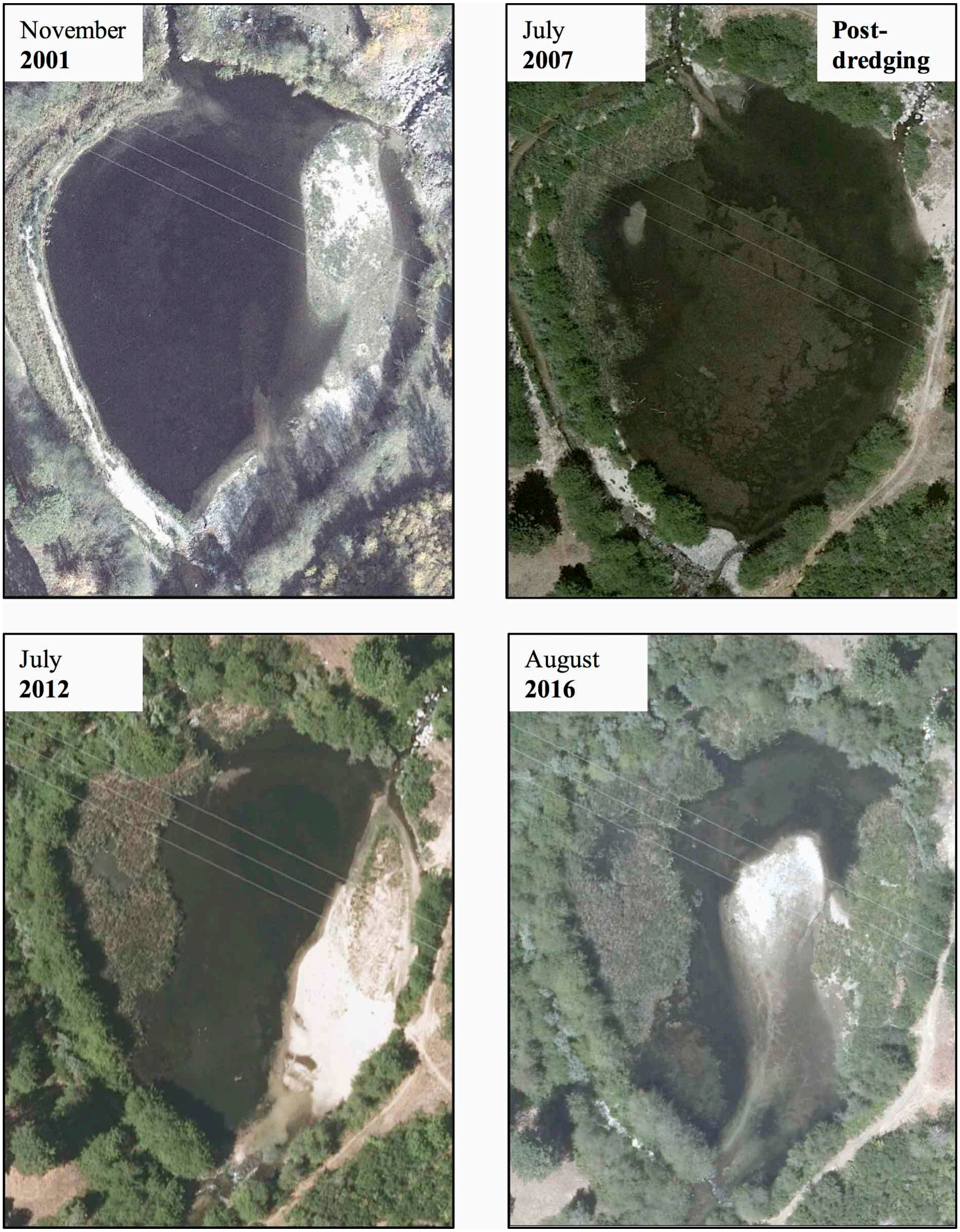

Figure 2. Upper Hamilton Pond, time series showing annual variation in distribution of sand and vegetation. Note that the 2007 image (upper right) was taken shortly after dredging in 2006. For conditions in 2017, see under Management Recommendations.

Methods: Ammocoete surveys were based on standard methods established by extensive field surveys for lampreys in western North America (Reid and Goodman 2015). Sampling used a Badger ABP-2 (ETS Electrofishing), with a modified 1 m^2 circular electrode hoop frame on extended cables to allow sampling at depths not accessible with a backpack e-fisher. The electronics box was carried on an inflatable boat. The hoop was placed on the sampling site by a snorkeler, which allowed precise positioning in selected sites and avoided disturbance of the bottom. The electrodes were turned on from the boat and the sampling area was observed for two minutes, as well as filmed for later review, emerging ammocoetes were counted over the entire period. The Badger ABP-2 is specifically designed for lamprey ammocoetes (larvae, 1-18 cm TL; Figure 1). It uses a weak, slow-pulse electrical current to draw ammocoetes out of the sediment, targeting shallow areas of fine sediment and sands and avoiding impacts to other fishes. Settings were: Rate S - 3.00, Duty S - 25.0, Voltage 150-250. We georeferenced the centroid of each sample site using a mapping grade GPS with sub-meter accuracy (Trimble Pro-XH) and also calculated distance from the pond inlet. Depth was measured to 0.1 ft with a surveying rod. Each sampling site was photographed to document benthic habitat conditions.

Four additional physical habitat variables were selected that were potentially relevant to ammocoetes and showed variability across the pond, including:

Velocity - Since ammocoetes are filter-feeders, they presumably must find a balance between velocities sufficient to bring suspended food near their burrow and those that are too strong to overcome with their intake rates. Water flow also affects near-bottom dissolved oxygen levels, particularly in backwaters or dense rooted vegetation where decaying organic debris tends to settle onto the bottom. Mean column water velocity ($ft*sec^{-1}$) was measured using a hand-held Acoustic Doppler Velocimeter (Flow Tracker, SonTek).

Substrate - Substrate characteristics affect the physical burrowing habitat of ammocoetes (e.g. silt-sand vs. gravel-cobble) as well as the chemical characteristics of the sediment (e.g. well-aerated sands vs. potentially anoxic organic debris. Bottom type was characterized as: organic debris (e.g. decaying aquatic vegetation, leaves), silt, sand-fine, sand-coarse, gravel, cobble, or a mix of types, when appropriate; approximating an ISO sediment scale (ISO 2002). Thin overlayment of woody debris were characterized by the underlying substrate.

Vegetation - Rooted aquatic vegetation affects the physical character of the substrate (e.g. dense root mats), the degree of physical cover and dissolved oxygen levels, which are influenced by diurnal photosynthesis cycles and accumulation of decaying vegetation (duff). Presence of rooted vegetation was characterized as: none; sparse aquatic macrophytes (AM), moderate AM, or dense AM; and cattails, which formed thickets along most of the shoreline.

Substrate gas content (bubbles) - Decay of accumulated organic material on the bottom can result in anoxic conditions near the substrate surface. Little is known about burrow depth, but ammocoetes probably tend to burrow primarily within the upper 6 in, based on their total length of < 8 in. A byproduct of anaerobic decomposition is production and release of various gases, including carbon dioxide, methane and hydrogen sulfide. Substrate gas content was checked qualitatively after sampling by pressing on the bottom and characterized as none (0), a few scattered bubbles noted (1), moderate bubbles seen (2), or highly gaseous (3), similar to the progression one sees in a pot of boiling water.

Identification of transformed or adult specimens is relatively easy in the field, but ammocoetes are more difficult to distinguish (Bond and Kan 1975, Lorion et al 2000, Reid 2014, Reid and Goodman unpublished data). The principal distinguishing character for congeneric ammocoetes is generally muscle segments (myomere) counts (Reid et al. 2011). Pacific and Pit-Klamath Brook lampreys have similar counts (65-72 and 63-71, respectively), while Klamath River Lampreys generally have lower counts than the other two species (60-65). Ammocoetes were not identified to species due to need to capture and preserve specimens for lab examination. All three species may be present in the Hamilton Ponds (see discussion in Reid 2017).

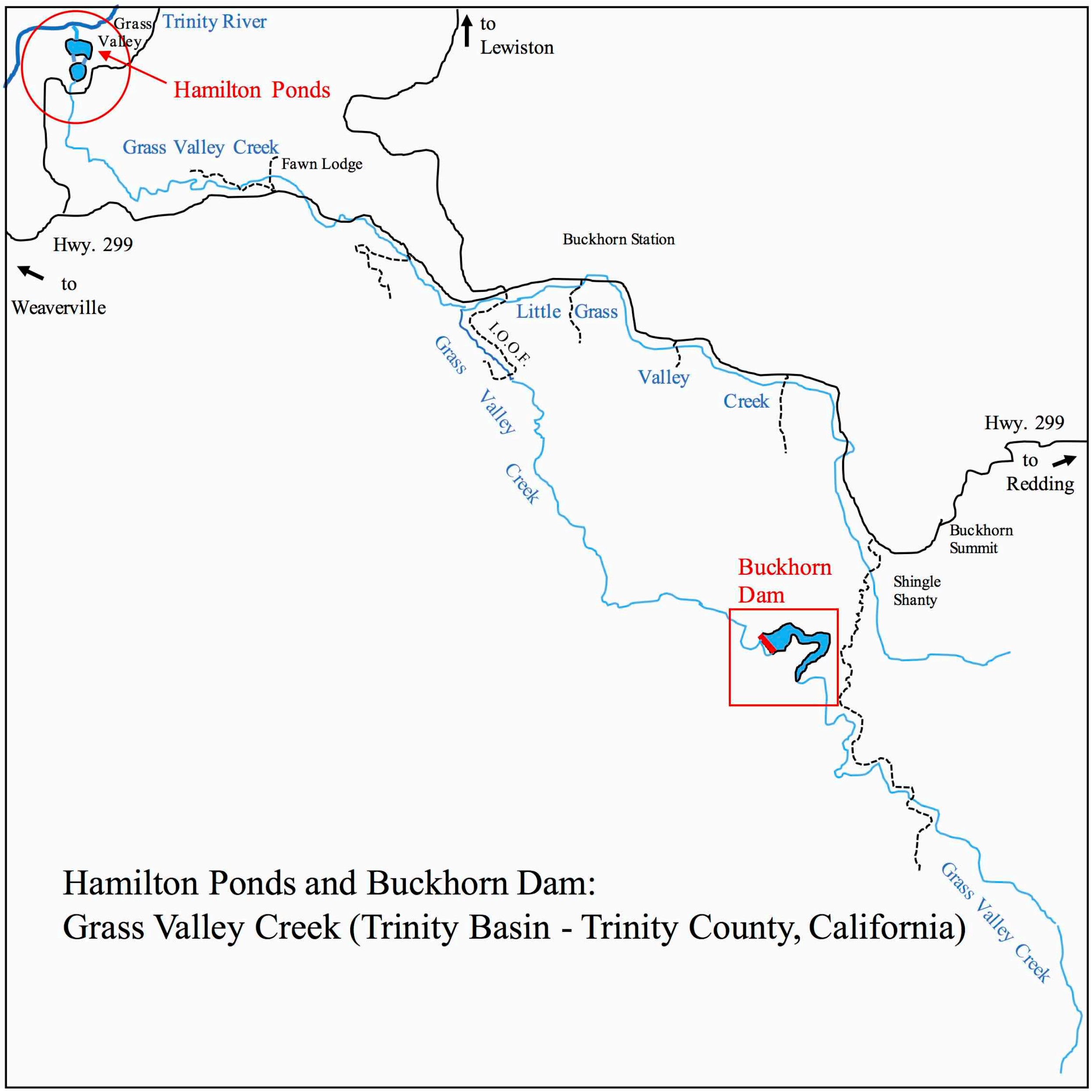

Figure 3. Grass Valley Drainage (Tributary to the Trinity River - Trinity County CA). The Hamilton Ponds are just upstream of the confluence with the Trinity River.

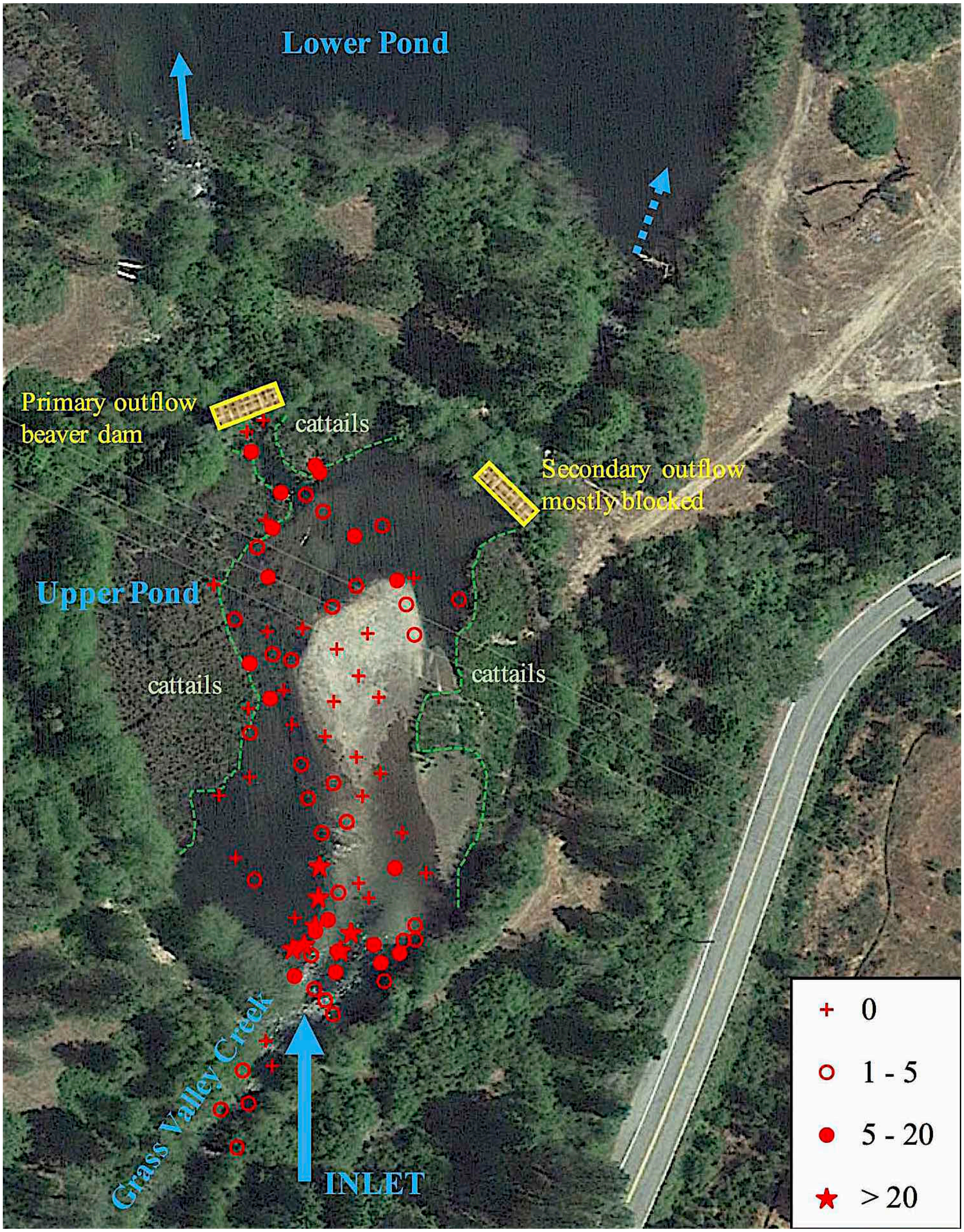

Figure 4. Sample sites (1 m^2; n=90) and ammocoete abundance (#/m^2) in upper Hamilton Pond (Grass Valley Creek, Trinity Basin, California) - 28 May 2016. Sampling 28 Sept - 4 Oct 2016; sand bar was submerged due to beaver dam activity about two weeks earlier.

Results: Surveys of the upper Hamilton Pond were done from 28 Sept - 4 Oct 2016. Eighty-seven sites were sampled, including: 81 Sites in the pond itself, of which 13 turned out to be on a recently submerged sandbar (see below), and 6 sites in Grass Valley Creek at the pond inlet (Figure 4). Exploratory sampling of the much deeper lower pond found high densities of tall submerged macrophytes that precluded representative sampling of the bottom. All analyses were limited to the upper pond and the inlet of Grass Valley Creek.

The density of ammocoetes varied considerably across the pond (Figure 4). Median abundance was 2.5 ammocoetes/m^2 (range 0-45/m^2, n=68) due to high numbers of low counts (Figure 5). However, the upper quartile ranged from 9-45/m^2. All notably higher abundances 27-45/m^2 (n=7) were in the upper fourth of the pond, near the inlet (Figure 6-7).

Water column velocities were only detectable near the inlet from Grass Valley Creek (Figure 6), where they ranged from 0.02-0.34 ft*sec^{-1} (mean 0.15 ft*sec^{-1}; n=12).

Hundreds of young-of-year ammocoetes (15-20 mm) were observed in the silty shallows near and to the east of the inlet during a visit that included some exploratory sampling in July 2017 (Reid pers. obs.). This area had densities of only 1-5/m^2 in 2016 (all size classes).

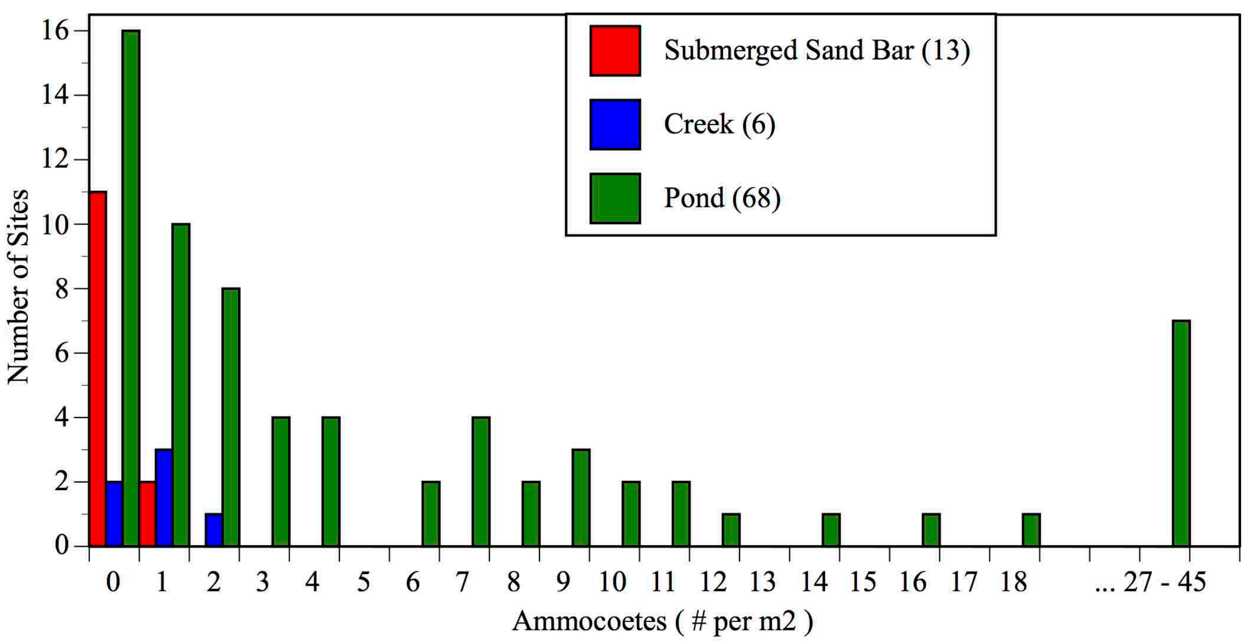

Figure 5. Ammocoete abundance (#/m^2) in 1) upper Hamilton Pond, 2) the lowest reach of Grass Valley Creek just above the pond, and 3) on the sand bar in the pond that was dry prior to beaver dam activity about two weeks earlier.

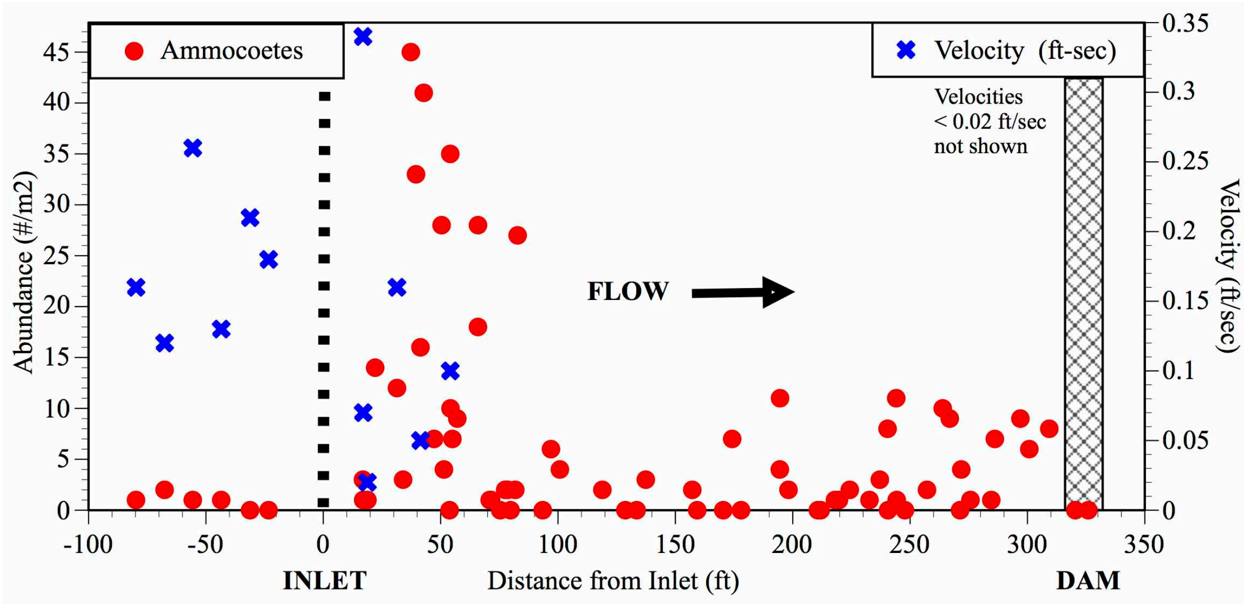

Figure 6. Ammocoete abundance (#/m^2) in upper Hamilton Pond relative to distance from the inlet of Grass Valley Creek and flow velocities. Negative distances are sites in the creek itself and were otherwise excluded in graphs. Velocities below 0.02 ft*sec^{-1} are not shown.

Figure 7. Grass Valley Creek inlet as it enters upper Hamilton Pond (2017). High densities of young-of-the year ammocoetes were found to the left (see Figure 16).

Water depth analysis was complicated by the construction of beaver dams on the outlets about two weeks prior to sampling, according to local residents. This raised water level by about 1.25 ft, submerging a previously dry sandbank (Figure 8). In the analyses we have not adjusted for water depth. However, sand bank sites (0.45-1.22 ft depths, n=13) were excluded due to their atypical lack of ammocoetes; only two individual ammocoetes were found at these sites. In our experience, ammocoetes are generally present in shoreline habitat at these depths. Abundance in consistently submerged sites was not significantly correlated with depth ($r^2 = 0.055$).

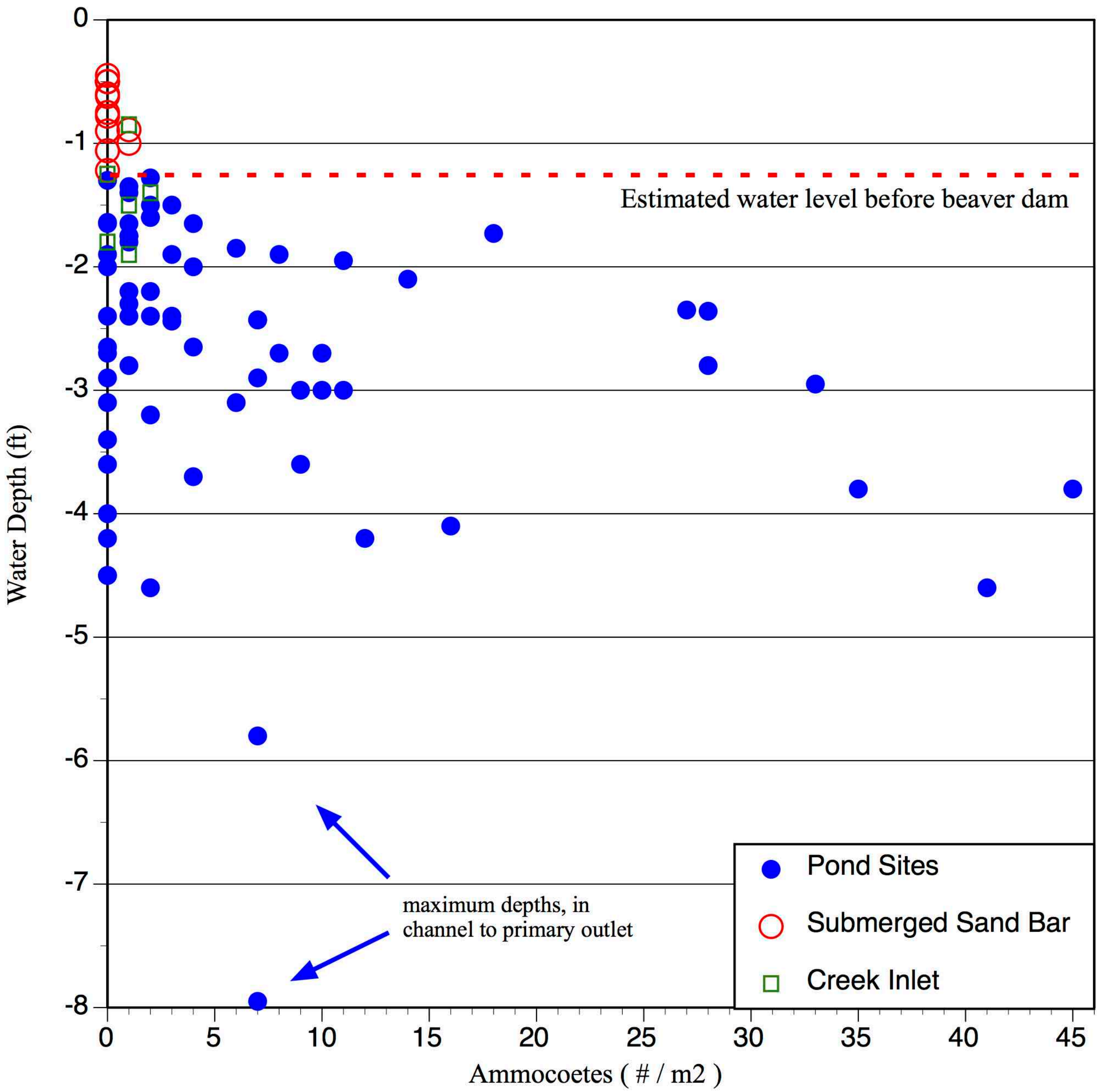

Figure 8. Depth vs. ammocoete abundance (#/m^2) in upper Hamilton Pond. Sites in red were on the sand bar that was submerged due to beaver dam activity about two weeks earlier. Depths and absence of ammocoetes suggest that water level was about 1.25 ft lower. These sites are excluded in habitat graphs and analyses.

The pond bottom was mostly composed of fines (i.e. sand, silt) or loose organic material (i.e. organic ooze and decaying vegetation; Figure 9). There were differences in location of sand vs. silt, dependent on flow; however, ammocoete densities on sand were not significantly higher than on silt ($p > 0.05$, U-test, $n = 30, 12$), when limited to areas with no to moderate vegetative cover (see below). Six sites had rocky substrates (i.e. cobble, gravel; 0-3/m^2), all at or above the inlet of Grass Valley Creek. Ammocoetes were not in the five sites with organic substrates.

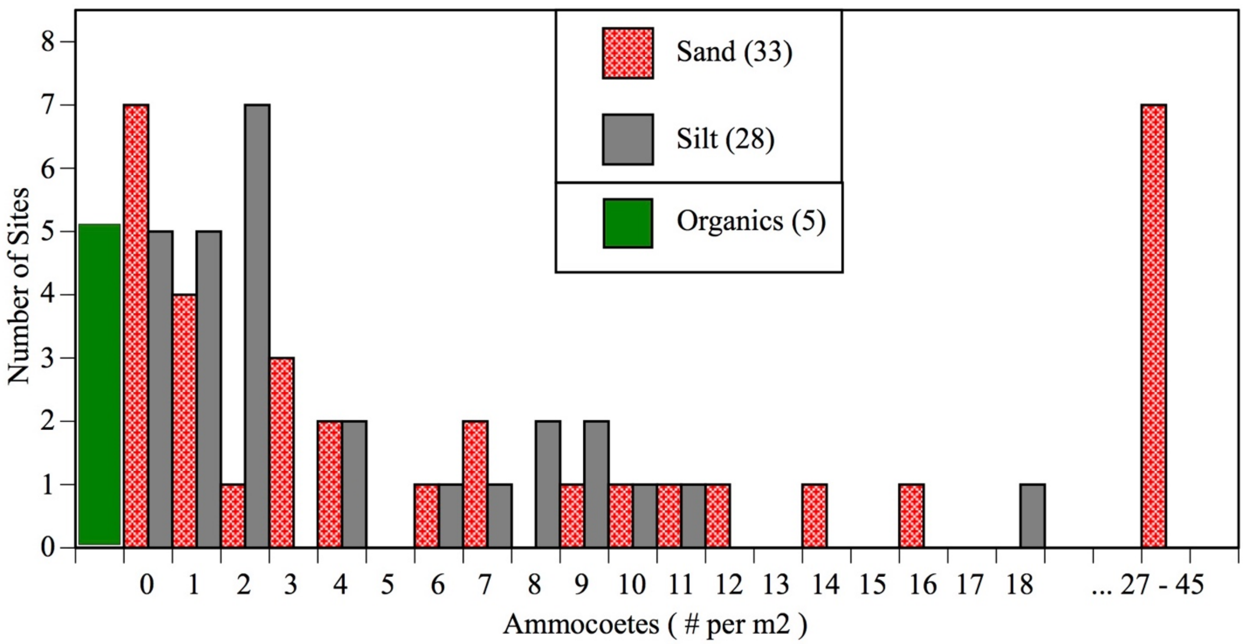

Figure 9. Substrate types and ammocoete abundance. Two sites (not shown) had gravels with 1-3 ammocoetes; both were at head of the pool (inlet). See photos (Figure 11).

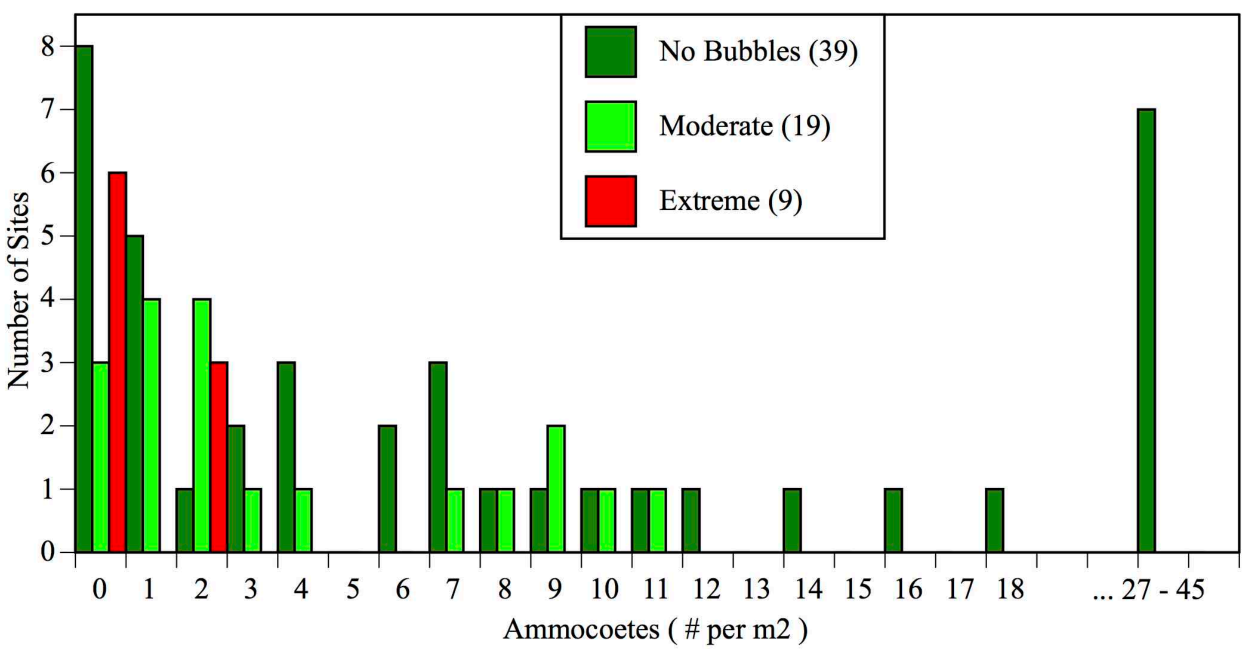

Figure 10. Sediment gas levels. Most sites had no, or only scattered, bubbles when pressed with the hand. Higher levels were considered moderate. Extreme bubble sites created a bubble curtain.

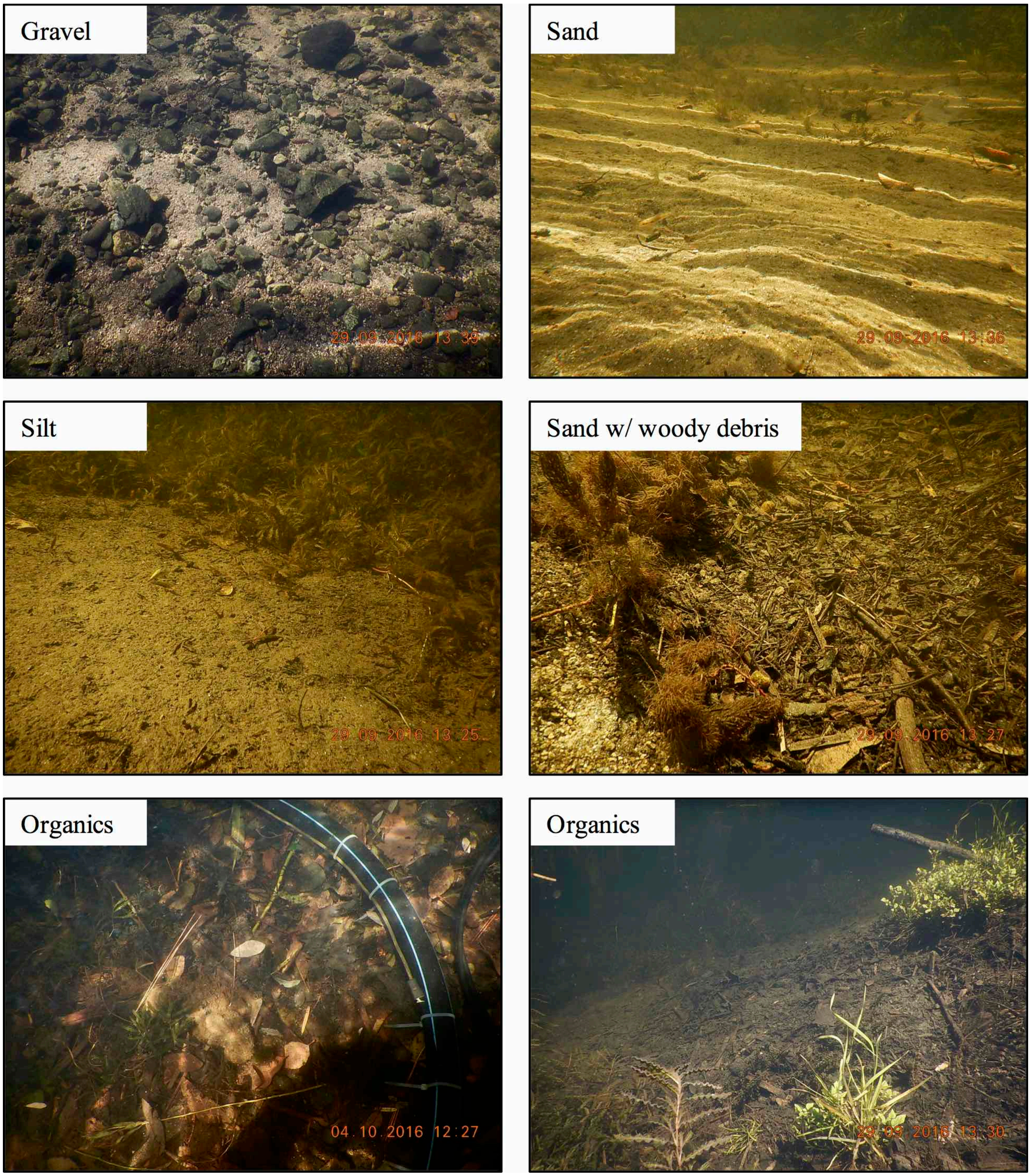

Figure 11. Sediment types. Note beaver dropping in photo at lower left.

Sediment gas levels were assessed by pressing on the substrate. In most cases this caused few if any bubbles to emerge. In extreme cases the bubbles filled the water column like boiling water (n=9). In these sites we encountered few or no ammocoetes (Figure 10). High bubble sites either had silt bottoms, with dense aquatic macrophytes (n=6), or had highly organic bottoms in cattail thickets (n=3).

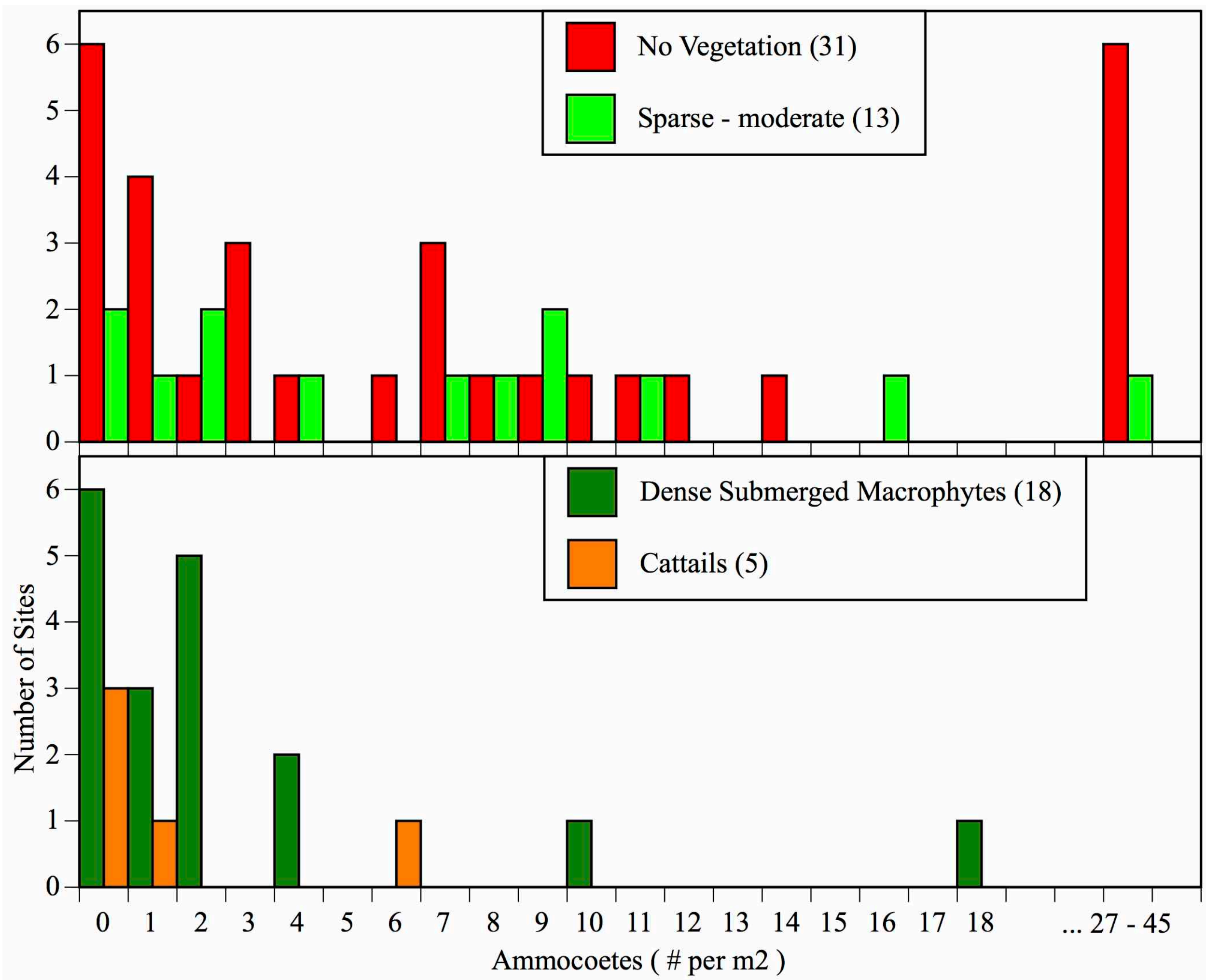

Figure 12. Vegetation types and ammocoete abundance. Note that sparse vegetation and cattails each had relatively lower number of sites. See photos (Figure 13).

About half the sites were bare, with no rooted vegetation or algal carpet (n=31), an additional set had sparse to moderate vegetation, in which the bottom was clearly visible (n=13). These sites had similar densities of ammocoetes (Figure 12, top). The other group of sites had either dense beds of aquatic macrophytes (*Elodea*, *Myriophyllum* and *Potamogeton*; n=18) or were embedded along the edge of cattail thickets (n=5) - all cattail sites were just inside the outer edge of the thicket. This group tended to have low densities of ammocoetes (Figure 12, bottom).

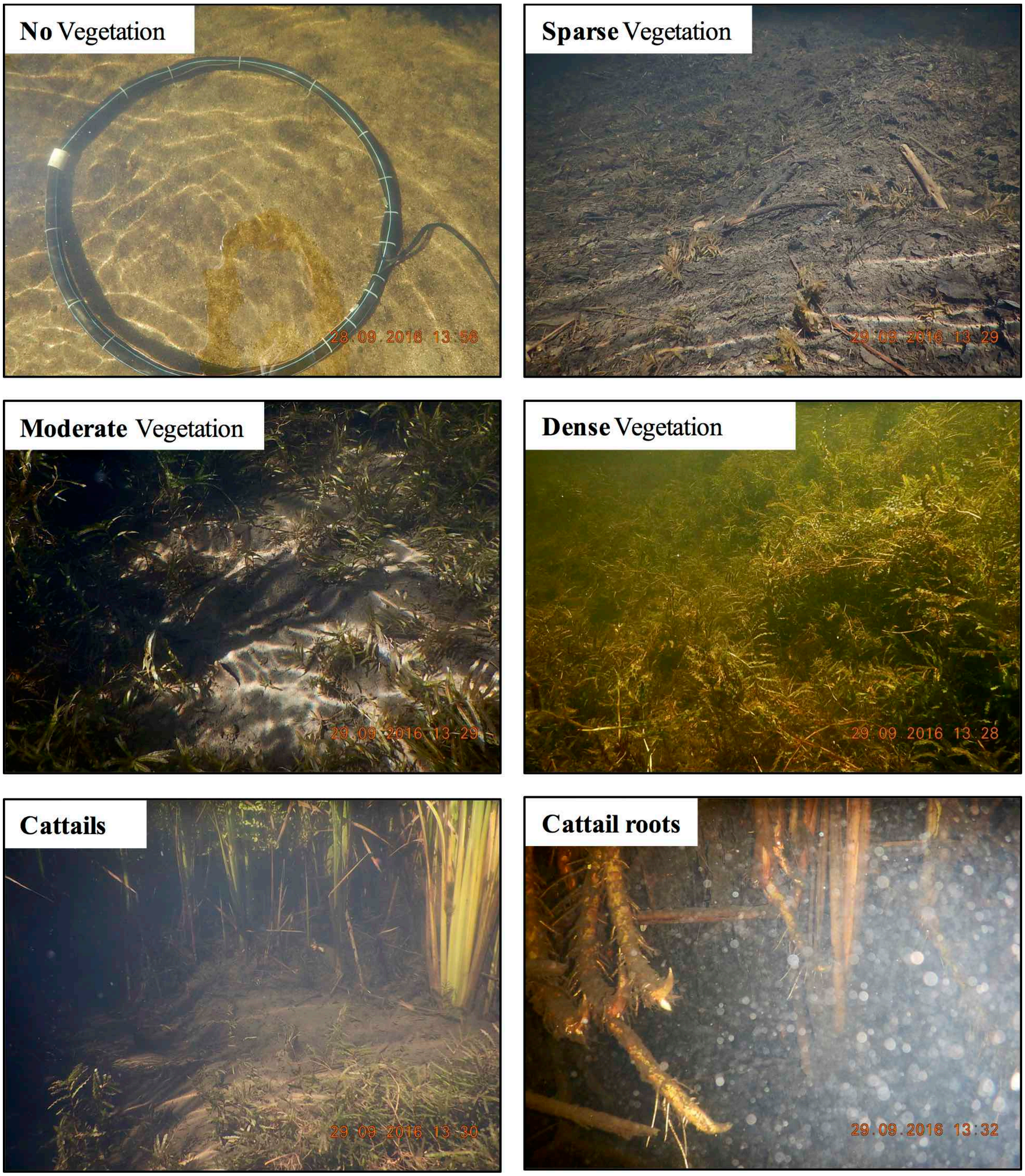

Figure 13. Vegetation types. Note sampling hoop at top left.

Transformed juveniles were occasionally seen in upper Hamilton Pond (n=2) and at the inlet to the lower pond (n=1). All appeared to be Pit-Klamath Brook Lampreys, *Entosphenus lethophagus*, a species not previously recorded from the Trinity Basin (Figure 14, Reid 2017). No juvenile or adult Klamath River Lamprey or Pacific Lamprey were observed. Other fishes observed in the upper pond included Klamath Smallscale Sucker, *Catostomus rimiculus* (YOY), Speckled Dace, *Rhinichthys osculus*, and Three-spine Stickleback, *Gasterosteus aculeatus*, all native as well as various salmonids, including Rainbow Trout, *Oncorhynchus mykiss*, Chinook Salmon, *Oncorhynchus* tshawytscha, and Coho Salmon, *Oncorhynchus kisutch*.

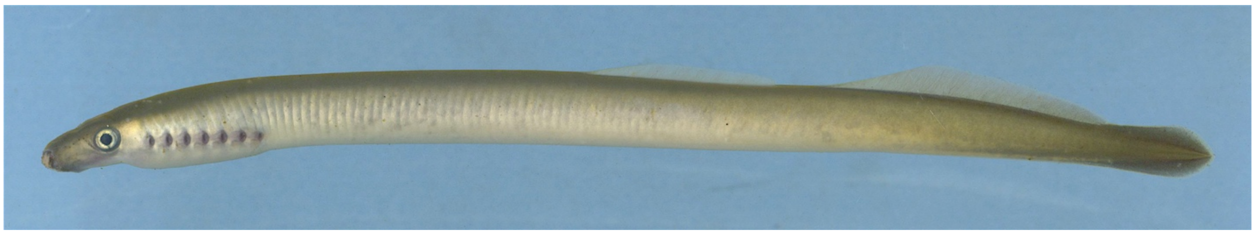

Figure 14. Pit-Klamath Brook Lamprey, *Entosphenus lethophagus*, recently transformed, from Grass Valley Creek, September 2017.

Discussion:

Ammocoetes were present throughout the pond, though abundance varied in different habitat types and relative to distance from the inlet and outlet, which may have been due to flow characteristics. The low abundance of ammocoetes in the gravel and cobble sites, including Grass Valley Creek, is not surprising given their well-established preference for finer grain sediments. Open sand and silt substrates had similar densities. The most notable negative association was in areas of dense vegetation or high sediment gas levels, generally encountered in slack waters off the main channel.

Dense vegetation and cattails thickets tended to have low abundances of ammocoetes. Low abundance of ammocoetes in dense vegetation beds and in cattail thickets may be due to various causal factors. Dense vegetation is often associated with lower dissolved oxygen levels, particularly during hours of darkness when photosynthesis is not taking place. The adverse impact of anoxic sediment gases was supported by the very low frequency of ammocoetes at sampling sites with high bubble contents. All sites with > 2 ammocoetes/m^2 exhibited none to moderate bubbles, while those with high bubbles had 0-2 ammocoetes. The reduction of water movement near the sediment interface in dense vegetation beds may also limit the effectiveness of filter-feeding. The relatively dense root masses of both rooted aquatic macrophytes and cattails may limit burrowing activity. In the aquatic vegetation beds some ammocoetes may have been using the vegetation above the substrate for cover, without having to burrow in the substrate itself. The authors have observed this in other areas, particularly with larger ammocoetes.

The role of flow regimes is further demonstrated by the higher densities of ammocoetes near the inlet where velocities had dropped to allow deposition of sands and silts and near the outlet where the channel again became more constricted (Figure 6). Possible benefits of lower energy habitats that still retain some flow may include effective filter-feeding, without high sweep rates, and aeration of sediments. However, there is no information on this with regard to ammocoetes.

Incidental observation of hundreds of young-of-year ammocoetes (15-20 mm) near the inlet to the upper pond in July 2017 (Reid pers. obs.) indicate active spawning upstream of the ponds in 2017. Actual spawning was probably within the low-gradient upstream reaches of Grass Valley itself, which contain abundant redd-building habitat, but little rearing habitat (Reid 2017). Observations in other California drainages suggest that 2017 was a particularly successful year for Pacific Lamprey, following a series of dry years (Reid and Goodman pers. obs.). This flow pattern was also true in Grass Valley Creek, where 2012-15 had notably low summer flows (Figure 15).

The potentially poor spawning conditions in 2012-15 also suggests that following higher flow years we can expect higher ammocoete abundances in the ponds than encountered in the 2016 surveys. As summer flows decline, pond level drops, exposing more sandbar, and reducing open bottom habitat availability. Low-flow conditions also reduce flushing and promote stagnant water, dense vegetation and accumulated organics, all less suitable for ammocoetes.

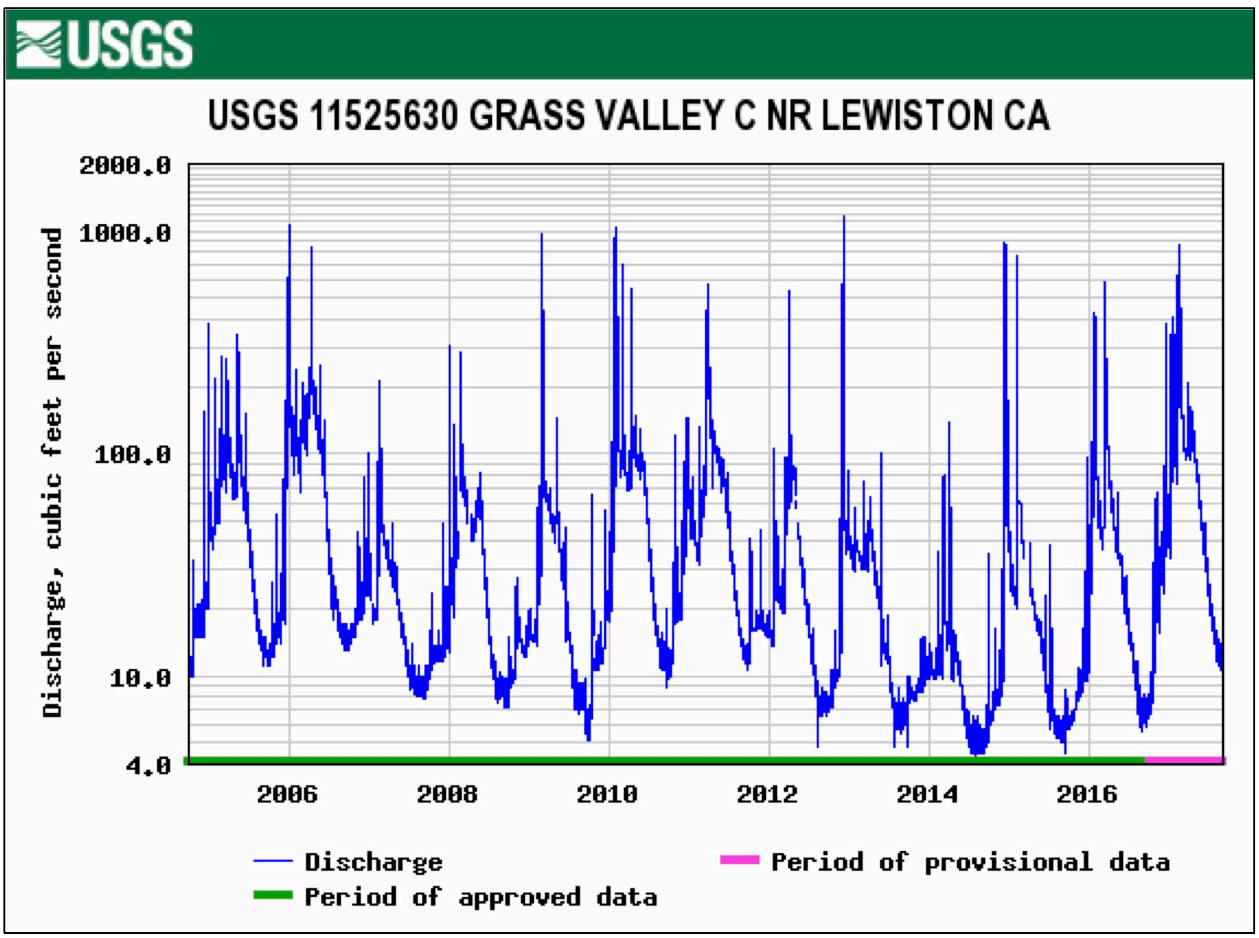

Figure 15. Grass Valley Creek, flow record January 2005 thru August 2017 (USGS Gauge 11525630; at Lewiston Road, just above ponds; 40.68618° N 122.86130° W).

Presence of Klamath River Lamprey was not confirmed during the surveys. No transformed juveniles were seen during the Hamilton Pond habitat use surveys. We are aware of no observations of lampreys feeding on fishes (or fresh scars) in Grass Valley Creek or the Hamilton Ponds, which would otherwise establish the presence of Klamath River Lamprey, the only species in the lower Klamath Drainage that is parasitic in freshwater. However, an apparent free-swimming adult Klamath River Lamprey was observed in the lower pond in 2008 and the species is common in the mainstem Trinity River below Lewiston Dam (Goodman, Pers. Obs.).

The character, habitat distribution and bathymetry of upper Hamilton Ponds changes frequently with seasonal inlets of sediment from upstream and with water level changes caused by flows or beaver dam activity on the outlets (Figures 2 and 16, 2017). This was demonstrated during the study by the submersion of the large east-side sandbank two weeks before surveys began. Then, in 2017, high flows brought considerable amounts of sand and gravel into the upper pond, changing the flow patterns and substrate composition within the pond, and also creating an additional large central exposed sandbank with a central flow channel of sufficient velocity to create a gravel-bedded riffle (Figure 16). The inter-annual variability of habitat conditions makes planning difficult for dredging operations, but may also create opportunities through the creation of large dry sandbanks, which naturally exclude ammocoetes and allow excavation outside the existing stream channel.

In conclusion, this study found ammocoetes throughout the pond, with higher densities in open sands and silts, particularly within about 80 ft of the inlet and, to a lesser degree, the outlet. Ammocoetes did not use highly organic substrates or those with high gas content and had not recolonized the dry sandbar within two weeks of it being submerged by beaver dam activity. These habitat preferences and additional behavioral considerations should allow development of management suggestions that benefit or minimize impacts on lamprey during management operations at the ponds (see below).

Figure 16. Upper Hamilton Pond, July 2017. **Top**) Inlet. Note shallow sand delta in mouth and silty backwater to left, where high densities of young-of-the year ammocoetes were found in 2017. **Middle**) New central sandbar and gravel channel (no gravel in 2016). Remaining pool behind sandbar is similar to that area in 2016. **Bottom**) Looking down towards outlet at right.

<u>Management Recommendations and Effectiveness Monitoring</u>:

A primary goal of this project is to develop management strategies to improve habitat for lampreys in the Hamilton ponds and to specifically mitigate adverse effects of sediment dredging as part of the pond's management. We provide a provisional experimental framework for the next dredging project, including relevant aspects of lamprey biology, site preparation and effectiveness monitoring. While this project focuses on the specifics of upper Hamilton Pond, it also provides an opportunity to develop and validate approaches that would be protective of lampreys at other projects. Development of BMP's for sediment removal are considered a high priority information gap under the Pacific Lamprey Conservation Initiative. Minimization of physical impacts to lamprey habitat is also an objective of the Trinity Integrated Assessment Plan (TRRP 2009). We recommend discussions between the pond managers, equipment operators and biologists prior to final project implementation and coordination with the authors for planning and monitoring on aspects regarding lampreys.

<u>Considerations relative to habitat use and behavior of lamprey ammocoetes</u>:

Ammocoetes of up to seven year-classes (10-18 cm TL) are present year-round in the pond and will be impacted by any instream activities, particularly sediment removal.

Preferred habitat is open sands and silts at all depths.

Higher densities occur in areas of low velocities associated with flow channels.

In upper Hamilton pond highest densities occur within about 80 ft of the inlet and outlet.
- dependent on flow patterns.

Dense vegetation and slack water with organic ooze or rotting vegetation are avoided.

Ammocoetes move out of dry sandbanks, however it is not known how long this takes
- emerge into the water column and reposition themselves downstream as water drops.
- may also move horizontally through the sediment - unknown.

Ammocoetes are primarily nocturnal.

<u>Site preparation</u>:

Place sandbags (hand-placed, filled from dry sandbar, tarp wrap) across top of central channel, leaving GVC inlet area and west channel open for occupation by ammocoetes and creek flow.

Divert flow to west side of pond to allow access from road, dry out nearside sandbar, and stop flow in central channel, prompt emigration downstream to holding area on west side and outlet.

Habitat surveys suggest that highest abundance is within 80 ft of inlet. This can be checked at time of project to help guide placement of diversion sandbags (see Effectiveness monitoring).

Drop pond surface-level slowly by lowering outlet barrier sequentially, ideally to point where central and east-side channel are dry, maybe 1-2" per night,

Drop water at dark to allow ammocoetes to move out in darkness.

Use a funnel escape net placed at the lower end of the central channel to allow movement out of the embayment as water recedes. Ammocoetes are unlikely to swim upstream through gap.
- Could be made of turbidity barrier and closed off immediately before excavation.

Excavate only in areas where surface sand is dry.

Initially, check a test excavation to see whether ammocoetes are present in wetted subsurface.
- If so, what is there distribution on a transect away from wetted edge.

Ideally, all excavation will take place behind an undisturbed berm.

<u>Effectiveness Monitoring for mitigation of impacts to lampreys</u>:

Pre-project:
- survey ammocoete distribution in upper Hamilton Pond to provide baseline for post project assessment and to delineate higher abundance radius in proximity of inlet and upper channel before placement of sandbags.

During site preparation:
- night monitoring to assess ammocoete reaction to dropping water levels.
- survey pond in activity zone where water has receded to assess emigration of ammocoetes prior to excavation
- test excavation to check for ammocoetes in wetted subsoil under dry sandbank.
- check whether ammocoetes migrate into excavated pits laterally thru sand.
- check for ammocoetes behind turbidity curtains.

During Project:
- check for presence in dredged spoils.

Post-project:
- survey distribution of ammocoetes at pre-dredge sites one year later, including deeper dredged habitat to assess project effects and recolonization patterns.

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