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Minnow Pond: A Brush Park Aquaculture Case Study

Project Location: Floating Island Research Center, Shepherd, Montana, USA

This study focused on the impacts of a floating streambed on nutrient removal and habitat enhancement in a northern freshwater pond (Figure 1). Floating streambeds are a new version of the BioHaven® technology developed in 2005 by Floating Island International (FII). The combined benefits of aeration and horizontal circulation through a brush park ecosystem resulted in stable dissolved oxygen levels and an improved fishery.

Figure 1 – The floating streambed at Minnow Pond, 9/12/13

Background

Goals of the study were to:

1. Increase dissolved oxygen (DO) levels,
2. Reduce phosphorus concentrations by cycling it into minnow biomass, and
3. Note changes in the ecological community.

The study area focused on Minnow Pond, a wetland at the FII Research Center near Shepherd, Montana (Figure 2). Feed water for this pond comes from two sources –

a 60-mile irrigation canal off the Yellowstone River, and South Creek, a surface flow stream that meanders through agricultural lands. The canal water flows through the property in a wide, shallow irrigation ditch (noted as the Irrigation Spiral) that winds through farm fields and enters Minnow Pond at the northeast corner. South Creek water is pumped from a collection basin through the Boxcar Ditch, where it is aerated by cascading riffles before entering Minnow Pond at the southwest corner. Both feed waters have high nutrient concentrations and would be considered eutrophic. South Creek is consistently rich in nitrogen (N), while the irrigation ditch is high in phosphorus (P).

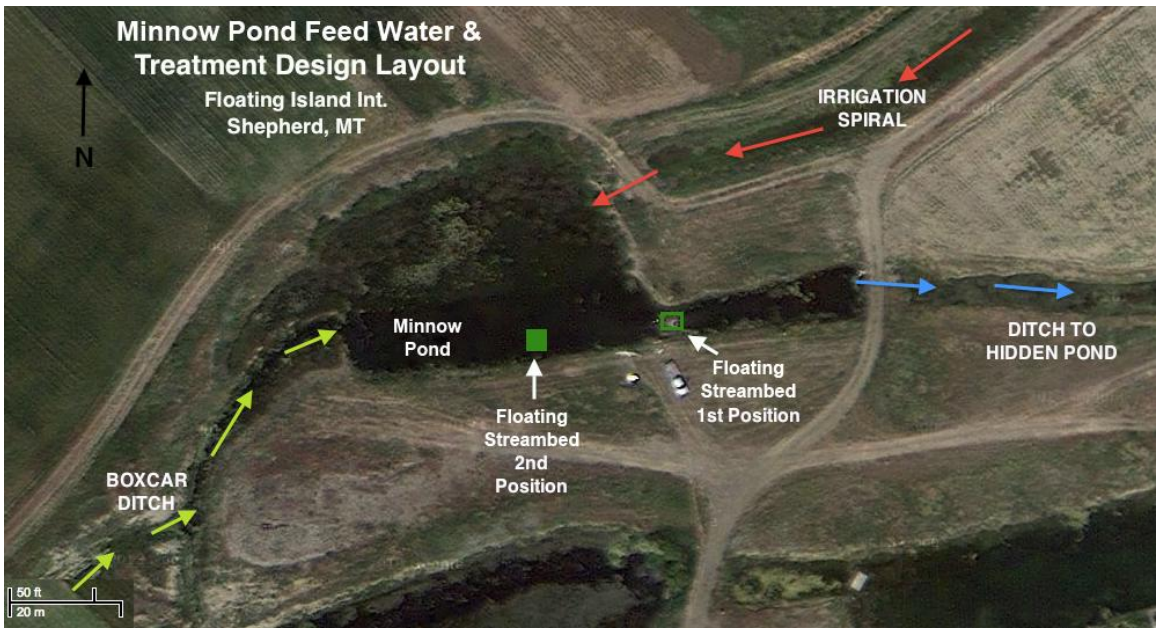


Figure 2 – Aerial view of Minnow Pond and feed water sources

Minnow Pond has an area of approximately 5,400 ft^2 with an average depth of four feet. The northern edge of the pond is shallow and dominated by an expanse of cattail and bulrush species. A brush park was installed in the deeper, open water section in the middle of Minnow Pond. The narrow end on the east side, where the water flows out of Minnow Pond, contains an air diffuser. The floating streambed was originally positioned at the western end of this narrow section (Figure 2), with the streambed flow directed towards the larger open water section. It was thought that prevailing westerly winds and the direction of water flowing through the pond (both opposing the flow of the floating streambed) would thoroughly mix the aerated water and de-stratify the deeper zones. Later in the study, the floating streambed was moved to a second position (Figure 2), which is directly above the brush park with the stream channel directed towards the cattail/bulrush expanse. This change was made to promote aeration and circulation in the brush park, and to reduce the chance of a potentially harmful anoxic or anaerobic zone.

Brush park aquaculture is practiced throughout the world as a simple and low-cost means of enhancing fisheries. The practice involves use of dried brush, bamboo or

other substrata in waterways to grow periphyton communities, a primary food source for many species and life stages of fish. Periphyton is a complex mixture of organisms – particularly bacteria, algae, cyanobacteria, heterotrophs and other microbes – that grow on submerged surfaces and develop into three-dimensional communities. These communities are responsible for a significant amount of nutrient cycling and removal as they form the foundation for diverse food webs. Besides nutrient uptake, periphyton has been shown to play a major role in the accumulation of organic detritus, suspended solids and even contaminants – and is used as an indicator of water quality. The potential for periphyton to support enhanced fisheries derives from its ability to provide a nutrient-rich food source for grazers – the only required inputs being surface area and available nutrients (Azim 2005).

Therefore, Minnow Pond presented an opportunity to improve fishery productivity due to its surplus nutrients (eutrophic feed water). This study was able to combine the benefits of increased surface area (island matrix and brush park) and available nutrients to grow periphyton which could be used to support a higher fish population – in this case, fathead and stickleback minnows. This strategy had been attempted in 2012 but due to a drop in DO levels, the majority of the fish had died. The floating streambed technology was implemented to provide additional aeration and circulation, as well as surface area for periphyton development and nutrient cycling.

Minnows were chosen for the study because they feed upon periphyton, and they spawn frequently and prolifically. By heavily grazing periphyton, minnows consume nutrients that have been cycled out of the water (particularly phosphorus) and concentrate them in their bodies. While nitrogen (N) can be removed from waterways through nitrification/denitrification, the most effective means of phosphorus (P) removal may be to grow and harvest biomass, i.e., physically removing it from the aquatic environment. Therefore, one of the goals of this study was to remove P by cycling it into minnows, which were then harvested and used to feed larger fish on the property – mainly yellow perch, white and black crappie, bluegill and red-ear sunfish. These larger fish are then harvested (for recreation) to continue cycling P out of the water. The fish are consumed and their offal is processed into fertilizer, among other uses.

Materials and Methods

Approximately 1,000 pounds of black cottonwood (90%) and Russian olive (10%) brush and branch material was positioned in Minnow Pond as a brush park in early June 2013. A small floating streambed, including a newly designed blower unit and deflector plate, was then installed on June 17th. The bottom layer of the floating streambed comprised two modules attached via joiner plates; the top layer consisted of two modules separated by a 30-inch stream channel and fastened to the bottom layer by chain with rebar cross-braces. The floating island/streambed comprised 22,500 square feet of surface area of recycled polyester, and contained a 1-hp airlift pump with a capacity of 800 gallons per minute (gpm). The island was

planted with cattail, bulrush, willow and aspen transplants, and seeded with a mixture of wildflowers and grasses.

DO, N and P were measured every weekday. N and P were measured with a Hach spectrophotometer.

Minnows were collected in traps (Figure 3) and transferred to nearby Fish Fry Lake to support its fish population. The level of minnows in a bucket was measured, and varied from one-half inch to 14 inches per sampling event. A total of 170 inches of minnows was harvested from June 7-November 20, 2013, when the pond iced over. This equals about 54,000 minnows or 520 pounds.

Figure 3. Minnows captured in Minnow Pond.

On August 1st, addition of granular urea fertilizer (46-0-0 N:P:K) began via the floating streambed. This was done in an attempt to increase the initial N:P molar ratio (typically less than 10) to the Redfield ratio of 16:1, which FII theorized would foster biomass growth (Cleveland and Liptzin, 2007). Fertilizer addition was gradually increased to eight cups (about three pounds) per weekday.

Achieving a higher N:P ratio may not only reduce P levels and therefore eutrophication, but may also increase the integrity of a system by favoring for or against certain communities. Cyanobacteria are known to fix atmospheric N, so are unaffected by a low N:P ratio in water and can outcompete other species. Cyanobacteria blooms can be toxic as well as contribute to low DO levels as the blooms die off – both of which are extremely detrimental to fish populations. By raising the N levels to allow other algal species a chance to compete (as well as

increasing P uptake), FII anticipated preventing cyanobacteria blooms and increasing fish populations through higher periphyton growth rates.

Results

Dissolved Oxygen

Based on DO readings, this study showed that a floating streambed can significantly increase the chance of a fishery surviving through the "boom and bust" cycles of a eutrophic pond. In 2012, Minnow Pond experienced large fluctuations and an eventual aquatic life die-off as a late-season algal bloom reduced DO to anoxic levels (data not shown). However, average DO concentrations in 2013 remained above 4 mg/L (Figures 4 and 5), which is sufficient for minnows and most other fish. DO levels were typically 2-5 mg/L in the mornings and 8-12 mg/L in the afternoons. The only low DO levels recorded during the case study were immediately following several large flushing events.

Nutrients

P and N concentrations immediately upstream and downstream of the floating streambed are shown in Figures 6 and 7.

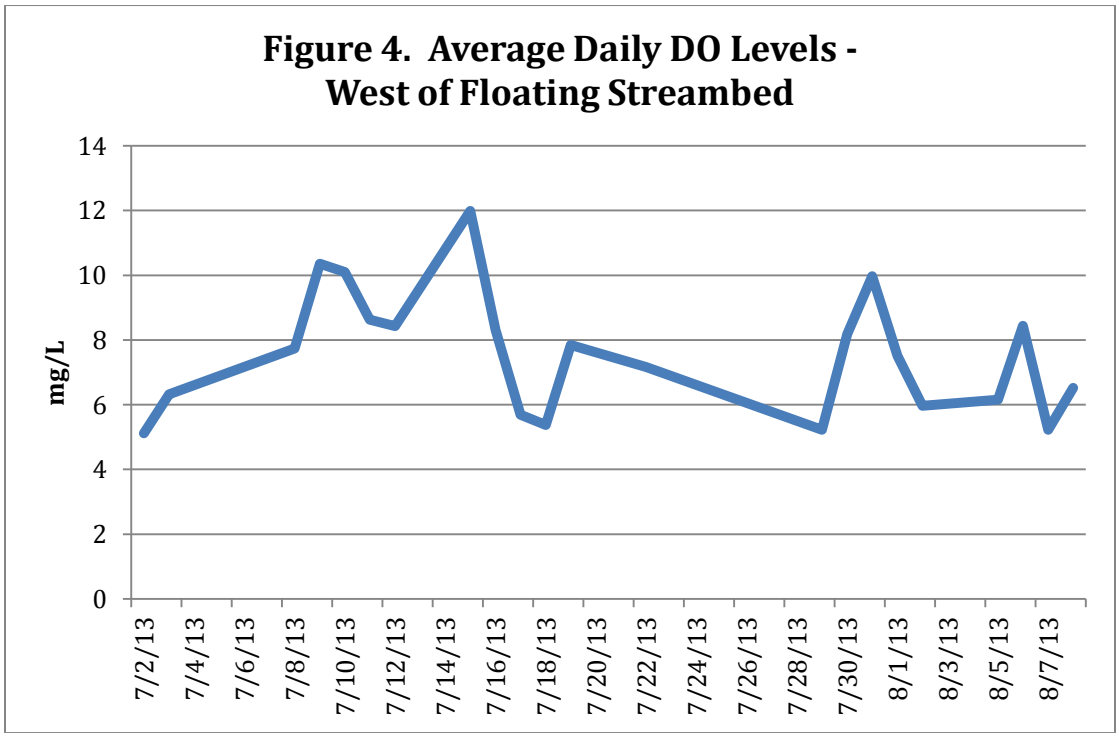


Figure 5. Average Daily DO Levels - East of Floating Streambed

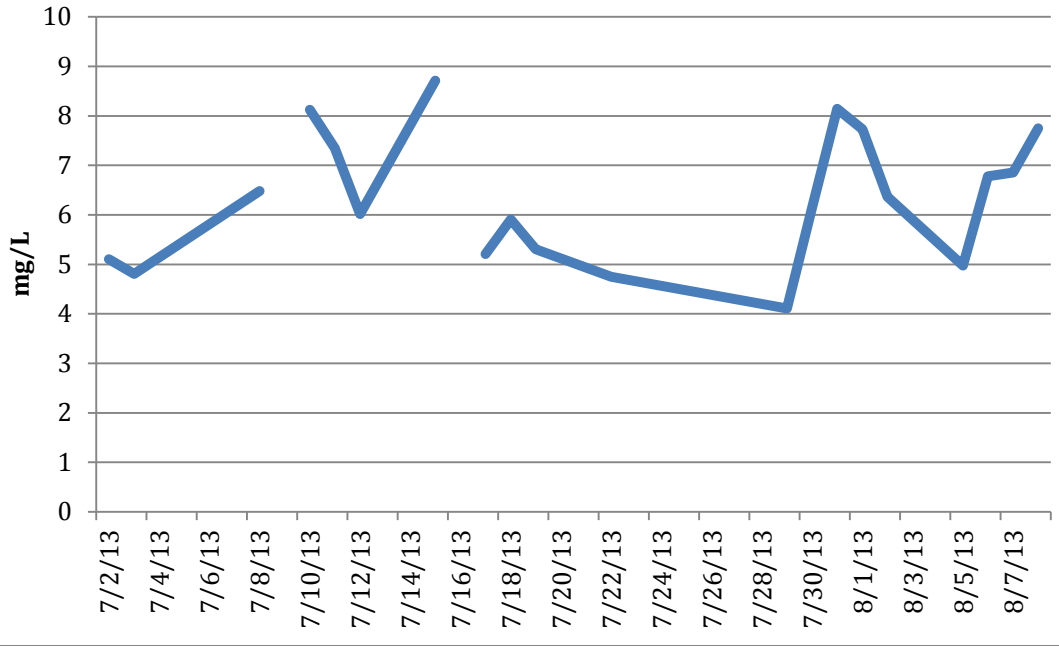
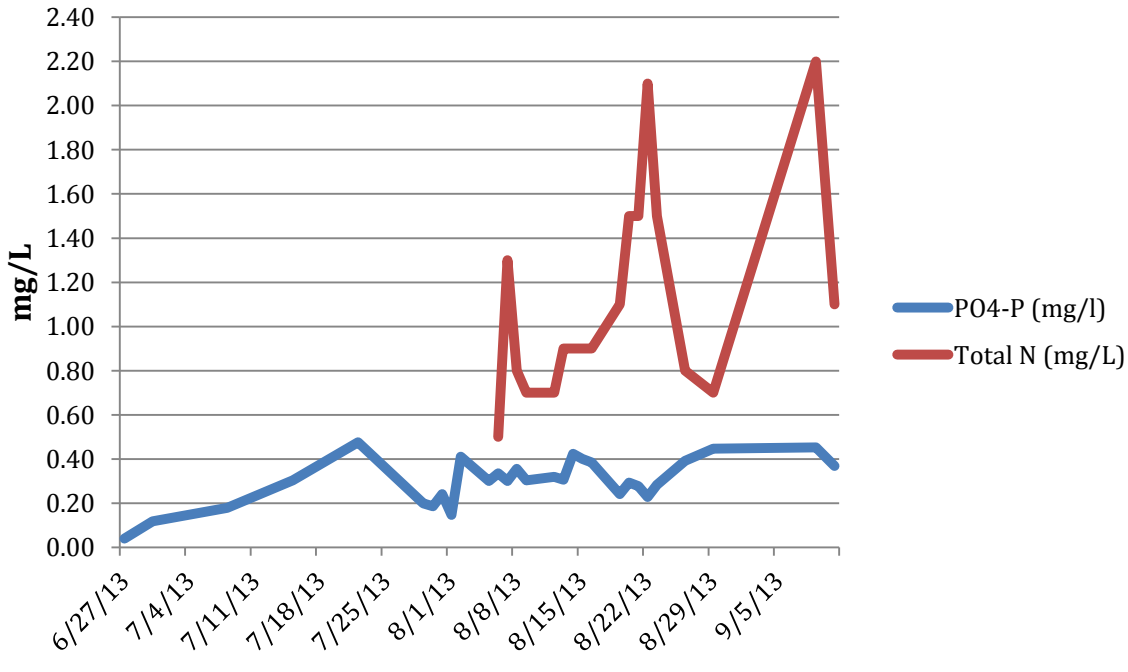
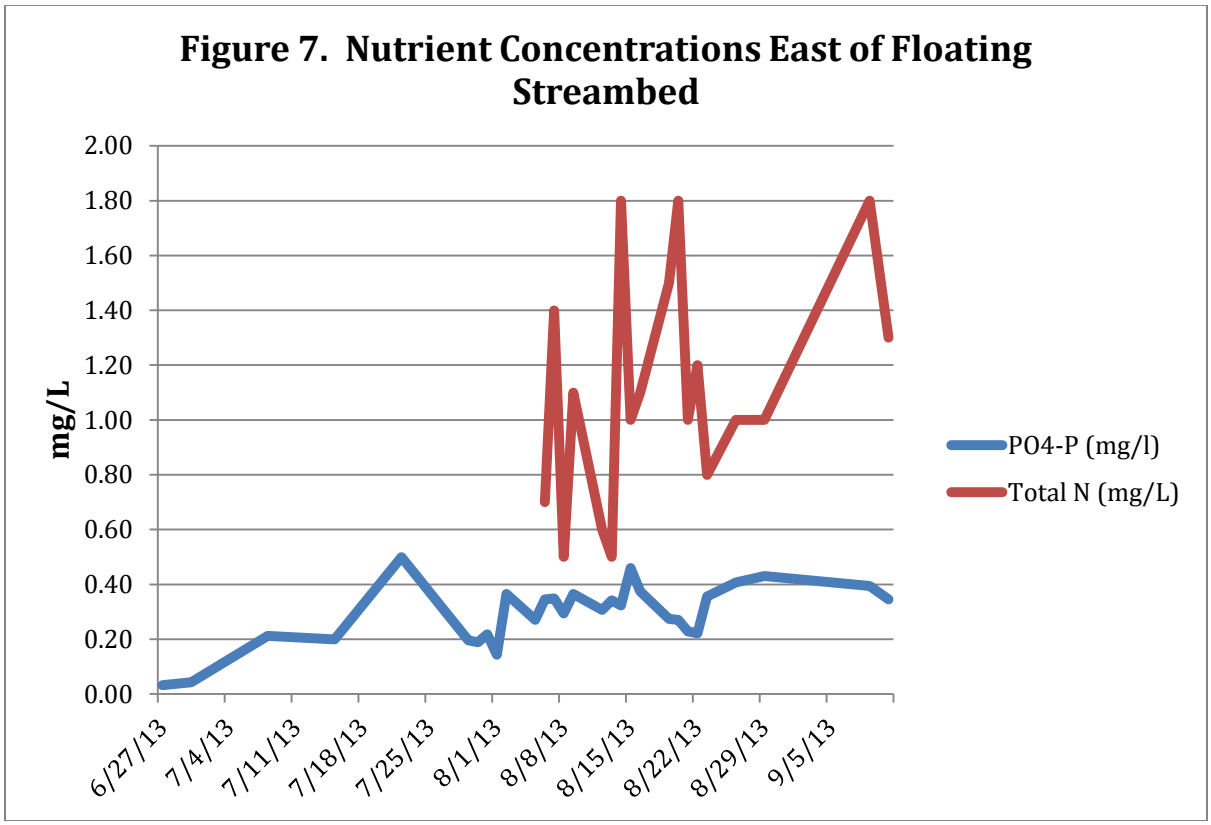


Figure 6. Nutrient Concentrations West of Floating Streambed





By adding nitrogen to increase the N:P ratio in the pond, FII hoped to increase the biomass-growing capacity of the system and allow higher P removal rates. This hypothesis was confirmed in a series of tank tests, which reduced P levels by 84% – versus 43% in the control – by using a nitrogen-based fertilizer. In Minnow Pond, however, fertilizer addition did not consistently increase N levels or decrease P levels.

Habitat

Beginning in July, caddis fly, midge, mayfly, damselfly and dragonfly nymphs were visible in the shallows of Minnow Pond. Mosquito larvae were less noticeable. By September, the following habitat changes were noted at Minnow Pond:

- Wildflowers, herbaceous groundcovers, rush and cattails were established and spread throughout the floating streambed.
- Dragonflies and damselflies were seen resting and breeding on the vegetation.
- Turtles, frogs and birds inhabited the island.
- Minnows congregated at the streambed outflow and grazed on periphyton growing on the matrix.

Implementing a floating streambed benefitted the fishery population as well. Although there were no harvest numbers from previous seasons, the fishery did not

experience a die-off – an event that had been a recurring issue in Minnow Pond. Constant water transfer from the floating streambed through the island matrix provided a form of circulation and aeration that is typically found in nature. The floating streambed mimicked the hydrology of a river: cascading and aerating the water over a cobble streambed and efficiently mixing the available nutrients. Additionally, an airlift pump drew water from the bottom of the pond, vertically circulating before it was sent horizontally through a dense matrix of periphyton, plant roots and grazing macro-invertebrates.

SUMMARY

After installing a brush park and floating streambed in Minnow Pond at the Floating Island Research Center, higher dissolved oxygen (DO) concentrations were maintained than previously observed. Average DO levels exceeded 4 mg/L and levels did not drop below 2 mg/L.

In less than six months, about 54,000 minnows (520 pounds of minnows and 4.7 pounds of P, based on an estimated 0.9% P content in minnow biomass) were harvested from Minnow Pond and transferred to Fish Fry Lake. This permanently removed nutrients from Minnow Pond and enhanced the food web in Fish Fry Lake.

The brush park and floating streambed created a much more active ecosystem in Minnow Pond, in terms of vegetation, insects, minnows and invertebrates. The floating streambed stabilized the oxygen content of the pond, allowing more complex ecological relationships to develop and increasing the diversity of the system.

Nitrogen-based fertilizer was added daily to influent water in the pond to increase N concentrations. Subsequent P and N removal from Minnow Pond water was inconclusive. Lab tests showed that fertilizer addition increased N concentrations and increased P removal from the system (data not shown).

REFERENCES

Azim, 2005. Periphyton: Ecology, Exploitation and Management.

Cleveland, C.C. and D. Liptzin, 2007. *C:N:P stoichiometry in soil: Is there a "Redfield ratio" for the microbial biomass?* Biogeochemistry, 85:235-252.