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Evaluating a Three-Fold Continuum of Fry Stocking Density for Rearing Walleye in Lined Ponds

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Abstract

Fry stocking density can affect harvest metrics for fingerling walleye (*Stizostedion vitreum*) reared in drainable ponds, but few studies have examined these relationships with the use of elevated walleye fry stocking densities in lined ponds. Correlation and regression analyses were used to assess how a three-fold change in walleye fry stocking density (234,375 to 703,125 per hectare) relates to harvest metrics and length of the culture period, as well as the tradeoff experienced between walleye size (grams) and harvest density in 0.32-hectare lined ponds over a nine-year period at Blue Dog State Fish Hatchery, South Dakota. As fry stocking density increased, so did harvest metrics for both number (r = 0.85, $P < 0.01$) and yield (r = 0.81, $P < 0.01$). Length of the culture period varied between 24 and 35 days and was negatively related to stocking density (r = −0.66, $P < 0.01$). The linear relationship between harvest density and yield was highly correlated (r = 0.95, $P < 0.01$) with highest values measuring 617,625 walleye and 173 kilograms per hectare. Harvest density explained 61% of the variation in walleye size ($P < 0.01$) and exhibited a decreasing curvilinear relationship such that continued increases in harvest density resulted in smaller reductions in fish size. Increasing fry stocking density from 234,375 to 703,125 per hectare in lined ponds coincided with increased rearing efficiencies for number and yield, as well as a reduced culture period. Minimal reduction in walleye size occurred once harvest density exceeded 300,000 per hectare.

Keywords

Walleye Culture, Lined Ponds, Rearing Efficiencies, Pond Stocking Density

1. Introduction

Drainable ponds are used for walleye (*Stizostedion vitreum*) propagation by government agencies across the midwestern region of North America. Ponds are filled, fertilized to promote appropriate invertebrate forage, and stocked with fry at relatively high densities to rear small fingerling walleye to lengths varying from 25 to 50 mm [1] [2] [3] [4]. These small fingerlings are used to enhance recreational fisheries [5] or grown to larger sizes in hopes of increasing stocking success [6]. Further propagation of small fingerlings to larger sizes can be completed in ponds by restocking small fingerlings at lower densities to facilitate growth on natural forage [1] or transferring to tanks to habituate fish to formulated feeds [4].

The practice of lining drainable ponds with plastic or synthetic rubber material has become more common and can lead to increased efficiencies involving lowered pumping costs and reduced problems with rooted vegetation [4]. Some hatcheries have also reported enhanced walleye fingerling production metrics in lined compared to earthen-substrate ponds [3] [7]. The major drawbacks to lining a pond involve cost and the annual maintenance of repairing the liner [4] as well as removing the accumulated organic material that can contribute to reduced water quality in future seasons [8]. The increased cost and maintenance incurred from pond liner installation, however, may be acceptable if production efficiencies are increased such that more or larger fish are produced [7] [9] [10].

An understanding of the relationship between fish size and number at harvest is necessary so that the culturist can manipulate stocking density and attempt to maximize production of number of fish for a given size. The tradeoff between size and numbers has been well documented for percids reared in earthen-substrate ponds [2] [11] [12]. While the relationship is initially negative indicating density-dependent growth, the relationship can change such that increases in harvest density occur with little, if any, reduction in fish size [12]. In lined ponds, density-dependent growth has been observed for yellow perch (*Perca flavescens*) [10] and walleye [9] [13], but limited harvest metrics are available for walleye as fry stocking density exceeds 375,000 per hectare. The highest reported fry stocking density for walleye in lined ponds occurred in Iowa at a rate of 494,200 per hectare and produced walleye with weights that averaged 0.33 grams [13]. The use of higher stocking density has the potential to provide higher harvest densities [9] and a more efficient utilization of pond space. Here we assess how a threefold change in fry stocking density (234,375 to 703,125 per hectare) relates to harvest metrics for walleye reared in lined ponds and highlight the tradeoff observed between walleye size and number at harvest.

2. Methods

This study was conducted at Blue Dog State Fish Hatchery (BDSFH), near Waubay, South Dakota, USA in 0.32-hectare, lined ponds between 2013 and 2021. Over this time, we measured walleye harvest metrics (fish size, kilograms harvested, number harvested, and length of the culture period) in 15 ponds that were stocked with fry at densities between 234,375 and 703,125 per hectare. All ponds were filled during May with unfiltered water from Blue Dog Lake (eutrophic, [14]) and were stocked within 4 days with 1 - 3 d old fry (220 per mL) that were enumerated by volumetric displacement [15]. Organic fertilizer was used in all ponds, but the amount and type varied each year depending upon water temperature, dissolved oxygen concentration, and previous experience (**Table 1**). Most (*i.e.*, ≥80%) of the fertilizer was applied within the first 15 days of the culture period when water temperature tends to be lower, and dissolved oxygen and pH tend to be higher [3]. Walleye harvest metrics for each pond were calculated by first collecting a random sample of at least 150 walleyes from the catch basin. These walleyes were weighed together and the number per kilogram was determined. Total kilograms (*i.e.*, yield) from each pond were determined by weighing nets filled with walleye to the nearest 0.22 kg. The following formula was used to calculate number of walleyes harvested.

$$\text{Number harvested} = \text{number per kilogram} * \text{total kilograms harvested}$$

After calculation, number and yield were expressed on a per hectare basis and fish per kilogram was converted to grams per fish.

Linear correlation analyses were used to assess how walleye fry stocking density may influence pond harvest metrics, length of the culture period, and the relationship between harvest density and yield. Nonlinear regression was used to assess the relationship between walleye harvest density and individual fish size. Significance was set at alpha = 0.05.

3. Results

Fry stocking density varied from 234,375 to 703,125 per hectare during the course of this study. As walleye fry stocking density increased, so did harvest density and yield with highest harvest metrics measuring 617,625 walleye and 173 kilograms per hectare (**Figure 1(a)** and **Figure 1(b)**). Length of the culture period varied between 24 and 35 days and was negatively related to walleye fry stocking density (**Figure 2**). The linear relationship between walleye harvest density and yield exhibited a strong, positive correlation (**Figure 3**). Finally, harvest density explained 61% of the variability in walleye size at harvest and exhibited a decreasing curvilinear relationship where continued increases in walleye harvest density occur with progressively smaller reductions in walleye size (**Figure 4**).

4. Discussion

The use of increased walleye fry stocking density in lined ponds exhibited strong,

Table 1. Mean (± standard deviation) organic fertilizer applied (kg/ha) and protein content (%) in 0.32-hectare lined ponds between 2013 and 2021 at Blue Dog State Fish Hatchery.

	Alfalfa meal	Soybean meal	Yeast
kg/ha	576 (112)	144 (107)	30 (30)
% protein	17	46	15

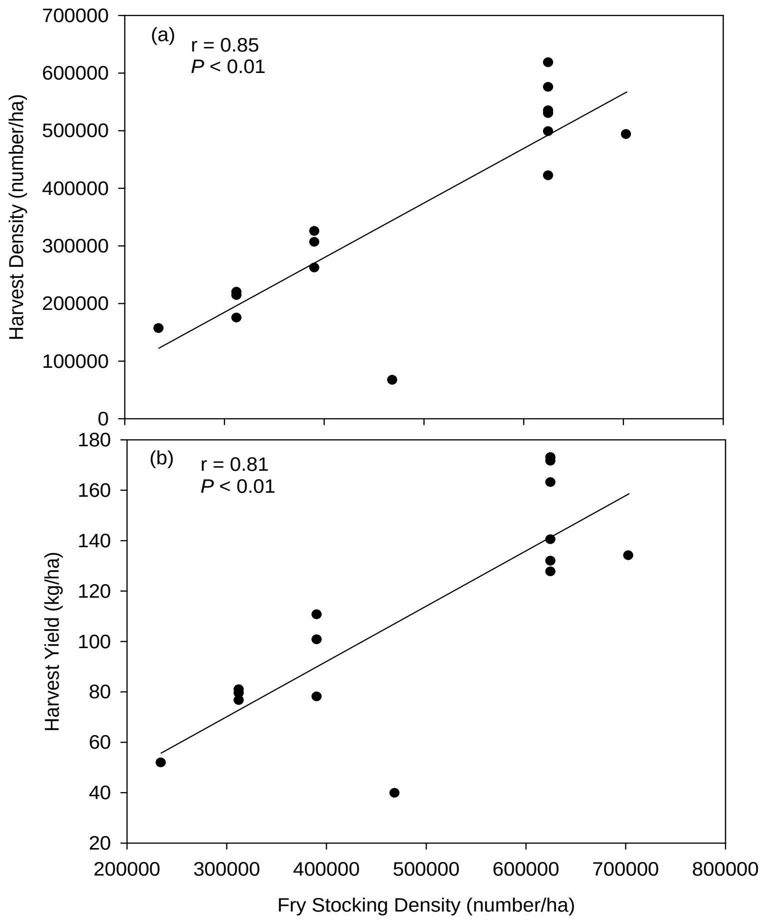

Figure 1. Linear correlations between fry stocking density and harvest metrics for walleye reared in 0.32-hectare lined ponds at Blue Dog State Fish Hatchery between 2013 and 2021.

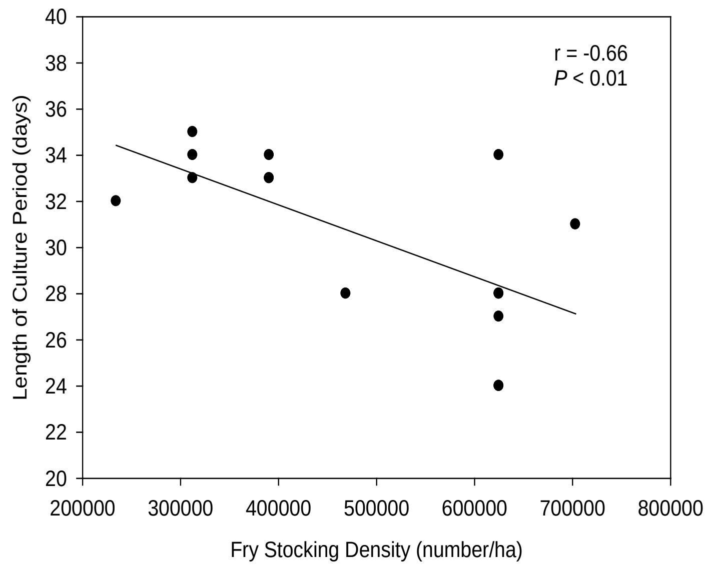

Figure 2. Linear correlation between fry stocking density and length of the culture period for walleye reared in 0.32-hectare lined ponds at Blue Dog State Fish Hatchery between 2013 and 2021. Three data points have an additional data point beneath them.

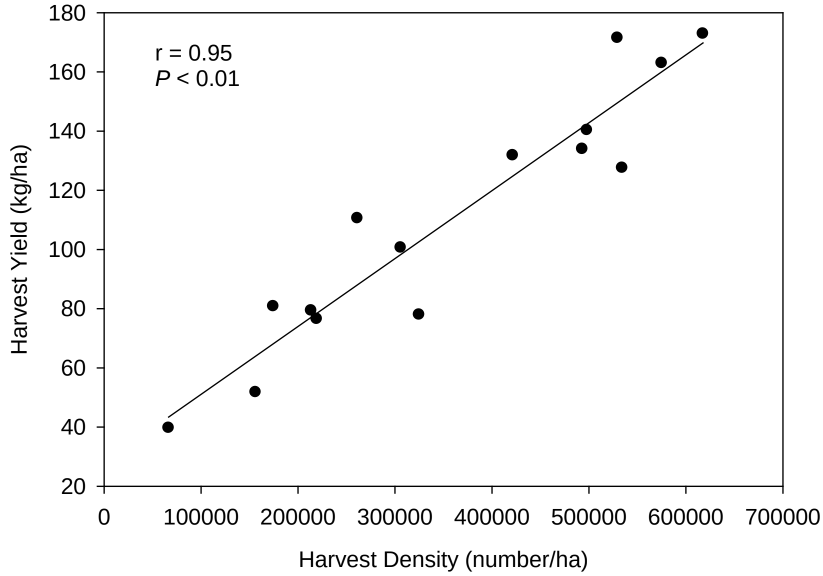

Figure 3. Linear correlation between harvest metrics number per hectare and kilograms per hectare in 0.32-ha lined ponds at Blue Dog State Fish Hatchery between 2013 and 2021.

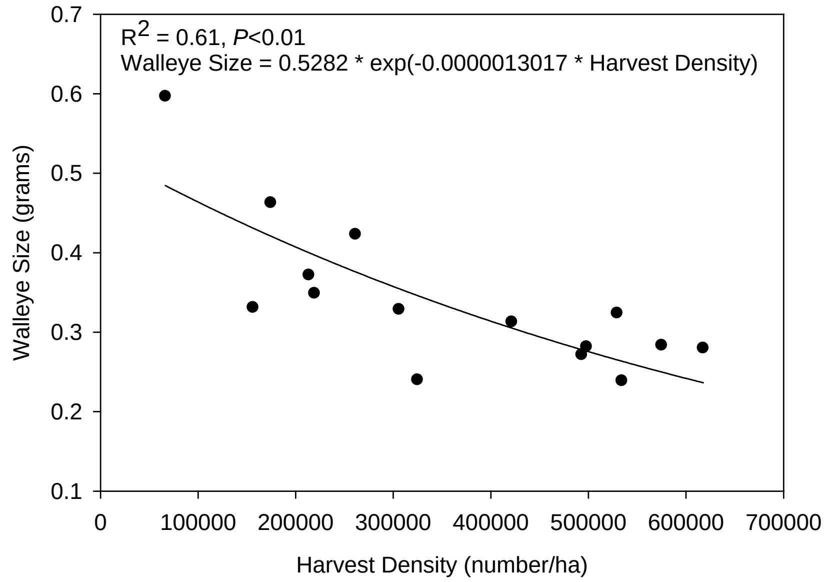

Figure 4. Decreasing curvilinear relationship between walleye harvest density and size in 0.32-hectare lined ponds at Blue Dog State Fish Hatchery between 2013 and 2021.

positive relationships between harvest density and yield. These findings are consistent with previous research in lined-substrate ponds at BDSFH where increasing stocking density from 187,500 to 375,000 per hectare resulted in higher walleye yield and number harvested [9]. Higher fry stocking densities are also known to increase harvest densities for percid fingerlings in earthen-substrate ponds in Nebraska [16] and Ohio [2] [12]. Moreover, these data suggest that a relatively short timeline (≤4 days) between pond filling and stocking remained an effective strategy even as fry stocking density increased in lined ponds. Harvest density increased nearly proportionally with fry stocking density indicating that a reduction in survival was not apparent. Others have reported a decreasing trend in walleye survival as stocking density increased from 123,000 to 494,200 per hectare in lined ponds, but the lowest survival in that study remained relatively high at 69% [13]. Culturists rearing walleye in lined ponds at BDSFH can expect an increase in harvest metrics for number of fingerlings and yield when fry stocking density is increased from 234,375 to 703,125 fry per hectare.

As fry stocking density increased, the length of the culture period decreased. In this study, the culture period lasted between 24 and 34 days for ponds stocked at rates greater than 600,000 fry per hectare indicating variation even at higher densities. A shorter culture period for walleye occurred when mean water temperature increased from 15˚C to 20˚C [17] and temperature patterns can exhibit large annual variation in ponds [2]. This study did not examine the influence of temperature on this relationship, so it is possible that higher fry stocking densities were used more so when warmer pond temperatures occurred. Furthermore, higher fry stocking densities (e.g., 375,000/ha) can lead to density-dependent growth in lined ponds once walleye exceed 30 mm [9]. The tendency of the culture period to be reduced with higher fry stocking densities could also be a result of initiating pond harvest when walleye approach 30 mm in total length rather than trying to achieve 40 mm and risk harvesting walleye with reduced body condition.

The harvest metrics of density and yield exhibited a positive linear relationship in lined ponds when metrics measured between 66,500 to 617,625 walleye and 40 to 173 kilograms per hectare. These same walleye production metrics also exhibited a positive relationship in earthen-substrate ponds among three Ohio hatcheries [11]. Harvest metrics for saugeye (walleye × sauger (*S. canadense*)) in lined ponds have measured 704,609 fish and 220 kilograms per hectare at BDSFH (unpublished data), which suggest it may be possible to use higher stocking densities to increase walleye harvest density and yield above those measured in this study.

Walleye harvest density and their size exhibited a decreasing curvilinear relationship indicating that continued increases in harvest density occur with progressively smaller reductions in walleye size. A similar tradeoff has been well documented for percid fingerlings reared in earthen-substrate ponds [2] [11] [12]. As walleye harvest density increased from 250,000 to 500,000 per hectare in lined ponds, the equation predicted that walleye size would decrease from 0.38 to 0.27 grams (≈1200 to 1700 fish per lb). Thus, harvesting walleye with a size of 0.37 grams is not likely when harvest density exceeds 250,000 walleye per hectare. The slope of the regression line suggests that walleye size will continue to decrease over the range of harvest densities measured in this study. However, there was essentially no change in observed walleye size when harvest density increased from 300,000 to roughly 600,000 per hectare. Further examination of the observed data points indicates that most of the reduction in walleye size occurs at harvest densities below 300,000 per ha. The prey base of a lined pond is thus capable of producing vastly larger numbers of walleye that weigh 0.24 to 0.32 grams compared too much lower numbers of walleye greater than 0.37 grams. This relationship certainly reflects the exponential increase in consumption that occurs overtime as walleye continue to grow [18].

Higher fry stocking densities in lined ponds coincided with increased walleye production efficiencies for number and yield, as well as a reduced length of the culture period. At higher harvest densities, walleye size is reduced but not linearly such that essentially no change occurred for walleye size when harvest density was roughly between 300,000 and 600,000 per hectare. Increasing fry stocking density above 703,125 per hectare deserves consideration in 0.32-hectare, lined ponds at this hatchery if harvested walleye size of 0.23 to 0.3 grams (2000 to 1500 fish per lb) is acceptable.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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