Potential of Triploid Rainbow Trout (*Oncorhynchus mykiss*) Under Cage Culture in Afromontane Reservoirs of Eastern Highlands, Zimbabwe

Tinashe Chapinduka, Everson Dahwa, Rachel Gwazani, Clarice P. Mudzengi, and Banele T. Maya

Abstract Rainbow trout, a sport fish naturally grows well in cool and flowing water. However with decreasing water flows and pollution in many rivers due to climate change and variability, suitability of the natural habitat is threatened. Alternative production systems can be necessary to mitigate the negative impact. In this study we aimed to test the production potential of trout using cages in an inland dam. We selected fingerlings weighing 94 ± 5 g and compared production of trout in floating cages versus raceways with flowing water. Using non-parametric methods, we tested if there were differences in feed and growth patterns on fish in raceways and cages. Mann–Whitney U test showed that there was no significant difference ($U = 40$, $p = 0.118$) between feed intake for race ways and cages. Feed conversion ratio differently increased but did not differ among the two groups. Mann–Whitney U test showed that there was no significant difference ($U = 87$, $p = 0.410$) on overall fish mortality between raceway and cage groups. While care is needed on the initial handling of fingerlings and stocking to reduce mortalities, cages provide an alternative inexpensive method for growing trout in cool temperature environments.

Keywords Rainbow trout · Cage · Raceway · Fish · Climate change

Introduction

Rainbow trout is a cold water fish native to North America and belongs to the Salmonidae family. It has a fusiform body and blue to olive green colour with pink lateral line (FAO 2012). Globally Rainbow trout is used as a sport fish and its pink and white flesh is highly valued. The species require pristine, well oxygenated unpolluted and flowing water (Picker and Griffiths 2011). Minimum required amount of water

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X. Poshiwa and G. Ravindra Chary (eds.), *Climate Change Adaptations in Dryland Agriculture in Semi-Arid Areas*, https://doi.org/10.1007/978-981-16-7861-5_24

in a through flow system to raise a tonne of trout is 600 L per minute. A through put less than 600 L per minute will reduce the stocking density which will automatically reduce the final yield (Boujard et al. 2002). However, due to climate change and variability, human and animal population pressure on inland water resources, the conditions for optimum production for trout are quickly diminishing. Decreasing rainfall due to climate change has reduced the flow of water in many inland water systems.

The species was introduced in Zimbabwe in early twentieth century initially for recreational purpose but later on adopted for commercial aquaculture (Skelton 2001). It was tried in various parts of the country before the seed was planted successfully in the headwaters of Nyangani Mountain where there is abundant pristine rushing water (Jonnalgada and Mhere 2001). Despite the lucrative remuneration potential that can be offered by culturing rainbow trout (Singh et al. 2016), there are few trout farms in Zimbabwe. Reasons commonly cited include high investment capital, lack of good sites, lack of good feed and seed as well as knowledge (Wallat et al. 2004; Maleri 2009). On the basis of these reasons, it is thus important we explore alternative and sustainable ways of producing trout fish to possibly enhance adoption as a farming venture.

Cage culture is an alternative method gaining attention and enhancing adoption of trout culture in various parts of the world (Offori et al. 2010) mainly due to its low capital demand for use in existing water reservoirs. Cages also allow agro diversification in a water conservative way. According to Maleri (2009) small scale cage culture in Western Cape, also sub-Saharan Africa has increased adoption of trout by small scale farmers contributing to high yield, poverty alleviation and food security. However, the inherent weakness of cages is their failure to fully protect the ecosystem. For instance, rainbow trout is carnivorous and invasive, if allowed to escape the cages they can threaten endemic species. Sterile triploid rainbow trout can be used instead but reported to be a poor adaptor to some conditions (Galbreath et al. 2006).

Production performance of triploid rainbow trout under cage culture in a temperate-afromontane inland water body was evaluated. Since large water bodies in cooler environments have an enormous surface area for gaseous exchange, they should have the potential to support trout production. Specifically we examined if growth patterns of fish reflect the success of using cages in inland water bodies. The expectation was that there would be no variation between cages and the conventional raceways.

Materials and Methods

Study Area

The study was done in an Afro-montane reservoir (Rhodes dam) and raceways at Trout Research Centre, located in Nyanga National Park, Zimbabwe. Altitude is

1500 m above the sea level, cool montane/temperate climate with mean annual rainfall >1200 and mean annual temperature of 20–25 °C prevail in the region (Meteorological Department 2010). The region has ultra-oligotrophic lotic and lentic waters. Little anthropogenic pollution and geochemistry of the watershed reduce eutrophication and maintain the pristine status of the reservoirs (Nhiwatiwa 2017). Zimbabwe's Eastern Highlands has biodiversity legacy harbouring threatened native and exotic endemic aquatic fauna (Kadye and Magadza 2008). Also the agro-climate of the area is congenial for cold water aquaculture including rainbow trout farming (Blow and Leonard 2007). Numerous reservoirs in this region were constructed for agricultural purpose, domestic and for recreational use.

Research Design

A quantitative research design was used whereby measurable data was collected and analysed to determine the potential of triploid rainbow trout under cage culture in Eastern Highlands. Two treatments that are cage culture and conventional raceways were set, replicated twice. Raceways (conventional system) were used as a bench mark for comparison with the cage system. Two small cages (1.80 m^2 each) were launched in the dam using judgmental selection of the site. Also two raceway compartments (3.6 m^2 each) arranged in series were used. Following sections describe in detail the methodology procedures that were used in site survey, stocking, feeding, data collection and procession.

Site Survey and Cage Launching

Criteria that were used to select the site for launching the cages include security, water depth, water exchange capacity and accessibility. Illegal harvesting of cages is one of the social constraints and can result in loss to the farmer (Ofori et al. 2010). Site of water depth of at least 2.5 m was selected. Water depth is important in disposal of uneaten feed and faecal wastes from the cage (Maleri 2009; Murathan et al. 2007). Site free from water plants was also selected. Densely vegetated areas are not suitable for launching the cages.

Stocking

Triploid rainbow trout fingerlings with an average weight of 94 g were obtained from the hatchery at Nyanga Trout Research Centre. The fingerlings were transported to the dam in polyethylene plastic bags. The plastic bags were filled with about 9 L of water and oxygen was added. Each replicate was stocked with 500 fish using a density of 277.78 and 138.89 fish per cubic meter in cages and raceways respectively. Different stocking densities were deduced based on literature guidelines for cage cultures and raceways. Stocking density determines fish welfare, production as well as the economics of the culture system being used (Boujard et al. 2002). Wallat et al. (2004) suggested that a profitable stocking density in cages range from 200 to 600 fish per cubic meter. However, the stocking densities used in this research were determined by minimum stock required to break even after considering input cost of feed and seed only.

Feeding

Extruded commercial feed supplied by ProFeeds Company was used throughout the project. Growers 1 & 2 pellets with a crude protein content of about 35% were used until harvest. Fish were fed three times a day following recommendations by Sung-Yong and Venmathi (2015). Satiation feeding method was used whereby feed was weighed before and after feeding to determine the amount of feed given to the fish. During feeding the feed would be broadcasted manually in the cages and raceways whilst observing fish response. Fish were fed up to 75% satiation.

Data Collection

The project focused on live weight increment (growth parameters), feeding efficiency and mortality of triploid rainbow trout reared in cages and raceways.

Growth: Fish growth was observed through weight gain. Fish were weighed on two weeks interval using an electronic scale. During fish weighing, a bucket was filled with water up to ¾ full. The bucket placed on the switched on scale. The scale would then be tarred to determine only the weight of fish. Fish were then caught using a scoop/hand net and put in the bucket. The total weight recorded on the scale representing fish weight only was divided by the total number of fish (sample number) put in the bucket. Thus how average body weight was obtained. The following formulae were used to compute growth parameters;

$$\mathbf{AG = Y_2 - Y_1} \tag{1}$$

where AG is the absolute growth; Y_2 is the final weight and Y_1 is the initial weight. (Lugert et al., 2016)

$$\mathbf{AGR = (Y_2 - Y_1)/(period)} \tag{2}$$

where AGR stands for absolute growth ratio; Y_2 is the final weight, Y_1 is the initial weight. (Lugert et al., 2016).

Feed efficiency: Feed intake was recorded on daily basis. Since satiation method was being used, feed was weighed before feeding and after feeding to determine amount of feed given to the fish. Feed was weighed using an electronic scale.

Feed conversion ratio was calculated as the fraction of feed used and weight gain. It was calculated using the following formula

$$\mathbf{FCR} = \mathbf{FC}/(\mathbf{W_2} - \mathbf{W_1}) \quad (3)$$

where FCR stands for feed conversion ratio, FC is the feed consumed, W_2 is the final weight and W_1 is the initial weight.

Mortality: Dead fish were picked from the experimental units. In cages some floated and some sank at the bottom and were removed using a harpoon. Dead fish were counted and recorded for each replicate. Mortality was then expressed as the percentage of the initial stock.

Temperature: Temperature was recorded using a water thermometer in cages and raceways during the culture period. The daily maximum and minimum recordings were averaged to determine daily average temperature. The daily average temperature was then recorded.

Data analysis: Data for growth, feed efficiency and mortality were captured in excel, sorted and statistically analysed in SPSS version 20. Data exploration was done to test for normality. A Mann–Whitney U then done to test for differences between the two test groups (Raceways and Cages) since date failed the normality test even after data transformation.

Results

Feeding Efficiency

Feed intake: Mann–Whitney U test showed that there was no significant difference ($U = 40$, $p = 0.118$) between feed intake for race ways and cages. Feed intake over the experimental period is illustrated (Fig. 1).

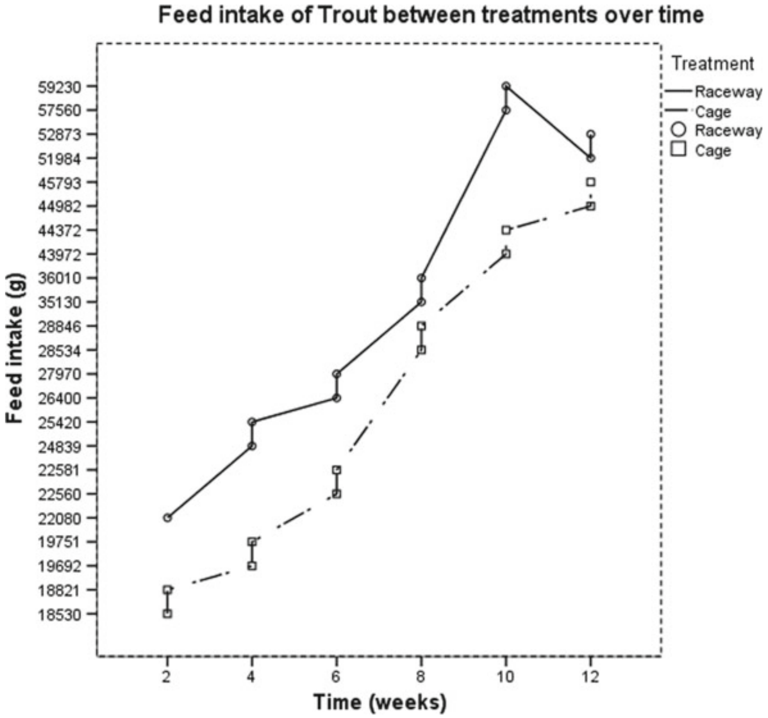

Fig. 1 Feed intake between treatments over time

Feed Conversion Ratio (FCR): FCR Mann–Whitney U test showed that there was no significant difference (U = 70, $p = 0.932$) between feed conversion ratio for fish in race ways and cages.

Temperature: Mann–Whitney U test showed that temperature did not differ (U = 84, $p = 0.514$) between the categories of race ways and cages.

Absolute growth (AG): Fish in raceways were slightly heavier (261, 5 g) than fish in cages (232, 8 g). However, Mann–Whitney U test showed that there was no significant difference (U = 61, $p = 0.551$) between these final weights for fish in race ways and cages. Weekly growth rate of trout over the experimental period is illustrated below (Fig. 2).

Mortality: Mortality was recorded throughout the experiment in both treatments (Fig. 3). Highest number of dead fish in cages was recorded within the first two weeks of stocking adding up to 8 fish in cages and 6 fish in raceways. Mann–Whitney U test showed that there was no significant difference (U = 87, $p = 0.410$) on overall fish mortality between raceway and cage groups.

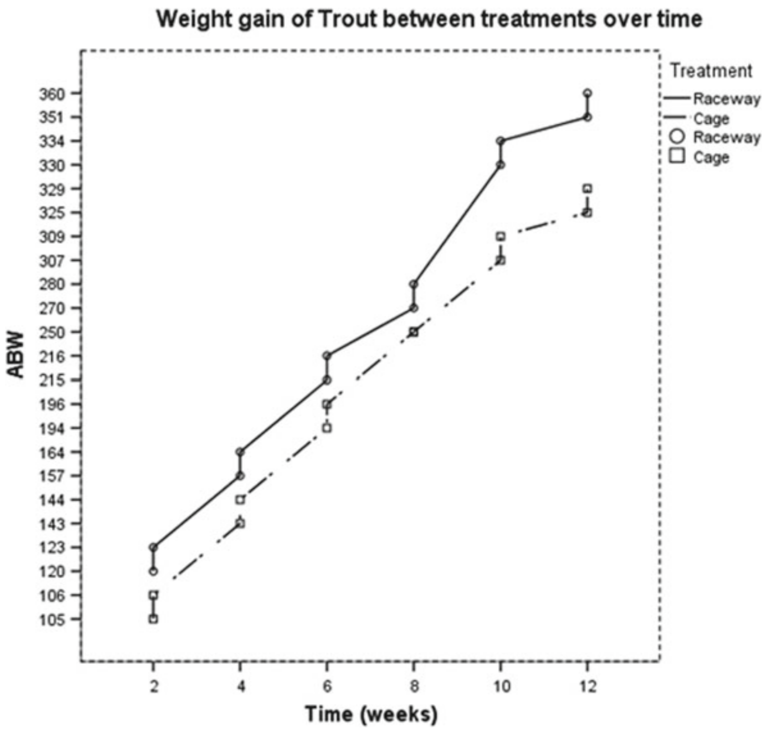

Fig. 2 Weight gain in cages and raceways over time

Discussion

Growth

Growth is one of the productivity factors measured to determine success or viability of the culture method with regards to fish farming economics (Baer et al. 2010). Growth can be defined as the gradual increase in the living system of an organism over time (Lugert et al. 2014). In this study, growth performance of triploid rainbow trout in cages was compared to the conventional raceway method. Results indicated that fish in both cages and raceways surpassed the market size (200 g) during the culture period of 90 days. In this study, individual fish gained more than 2 g per day. Findings of this study fall within the range of 2–6 g reported by Maleri (2009) for Trout cage culture in Western Cape, South Africa. Since temperature is one of the critical factors that determine performance of triploid fish (Cotter et al. 2002), it remained in the ideal range that made it possible to achieve such Absolute growth ratios in both cages and raceways.

Although the market size was achieved in both treatments, cages had a slightly lower growth rate than the raceways throughout the culture period. Possible factors

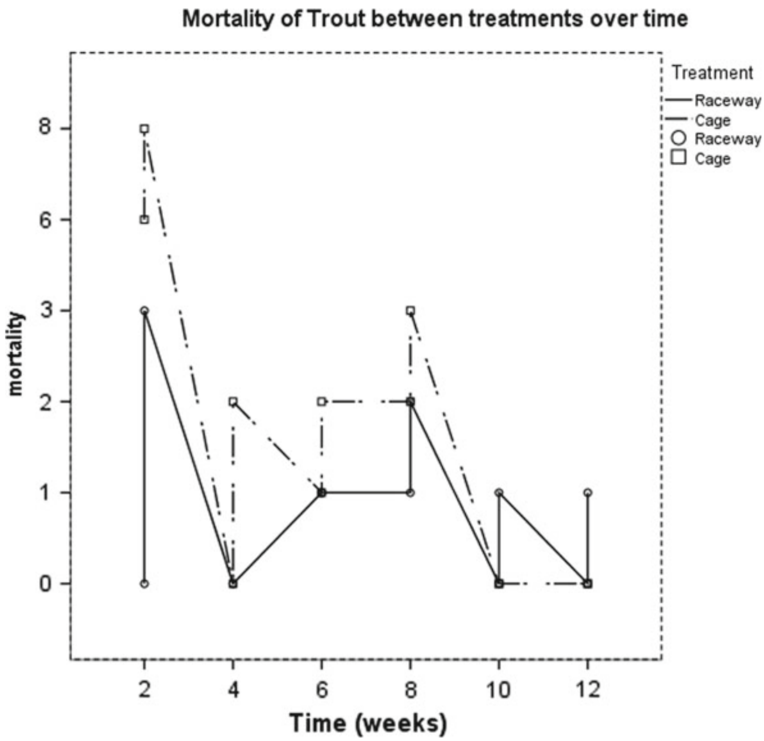

Fig. 3 Mortality of triploid rainbow trout between treatments over time

that might have contributed to the slight growth variation between the groups include slow adaptation of the fish in cages during the first days after stocking. This is indicated by low feeding intake (18,675.5 g), low weight gain (11.45 g) and high slightly higher mortalityin the first two weeks after stocking in cage treatment. The fingerlings that were used in this study were taken from the raceways. Raceways generally have got higher water flow and exchange rates than cages (FAO 2011). The batch that was taken for cage stocking took some time to adapt whilst the batch that was stocked in raceways had their environment maintained and did not reduce their feeding rate very much as in the case of the cage stock.

Again, the capturing and transportation of the cage stock may have contributed to the poor performance during the first days. The fingerlings were transported a distance of 8 km in polyethylene plastic bags filled with water and additional oxygen whilst those stocked in the raceways were moved by hand nets from their previous raceway to the experiment compartment. Although, fish were handled anaesthetically as recommended by Wallat et al. (2004) to reduce stocking stress, the above low growth performance was observed and linked to the factors described.

Feeding Efficiency

Amount of feed used by the fish gradually increased with period in both cages and raceways, although the former had a slightly lower total feed intake at the end of the experiment the groups did not differ. The temperature during the experimental period remained ideal and did not differ for the two groups. Temperature affects functioning of the enzymes for digestion and can as well influence release or suppress anti-stress hormones (Guderly and St-Pierre 2002). Since there was no variation in temperature between the treatments during the culture period it is assumed that the culturing environment were similar in terms of temperature hence similar digestion and quest for feed. More importantly, the water conditions in which the cages were launched are relatively good quality. Limnochemistry studies by Nhiwatiwa (2017) showed that reservoirs in Nyanga have good condition that is high oxygen, clear water and very little pollution since most of the water originates in Nyangani Mountain which does not have any agriculture or industries nearby.

Temperature determines feeding rate of fish. Fish are poikilotherms and the environmental temperature has effect on their homeostatic functioning. It therefore explains why low feeding rates were observed during the morning (before 10:00 h) and late afternoon (after 15.00 h) which was suspected to be correlated to the low temperature <14 °C. Stickney (2000), states that trout do not feed well when the temperature is very low or too high. The feeding frequency was then adjusted to two times a day in both cages and raceways to avoid feed loss. Variation of feed intake between recorded intervals was the effect of growth. As the fish grow the amount of feed that is consumed increase as well. Young fish have low feed intake whilst older fish have high feed intake, this was also observed in this study.

Feed conversion ratio (FCR) is an indicator for fish farm success (Murathan et al. 2007). FCR determines production cost and farm profitability. A high FCR indicates poor feeding efficiency and it means that more feed is required to achieve a small weight. In this study, feed conversion ratios 1.66 and 1.70 were observed in cages and raceways respectively. Our results are consistent with FCR of 1.63 reported by Murathan et al. (2007) but higher than the 0.92 observed by Kljajić et al. (2016). Maleri (2009) also reported an FCR range of 1.1 to 2.5 for fresh water small scale trout cage culture of studied farms in Western Cape. Eighty per cent of the studied farms achieved FCR less than two which indicated viability of the farms. FCR during the culture period in both treatments was within the widely observed and FAO (2011) recommended range of less than 2. Quality of the feed used (35% crude protein) and pristine water condition as well as maintenance of congenial temperature (15–21 °C) during the culture period can be credited for achieving good FCR in cages.

Mortality

Mortality rate can determine the yield obtained at the farm. It is also used as an indicator for culture method viability. Mortality can be density dependent or independent (occur due to lethal temperature or poisoning). In this study mortality of 5.4% and 1.8% were recorded in cages and raceways respectively. Mortality in cages recorded was higher than other findings such as 2.9% (Murathan et al. 2007); 2.28% (Kljajić et al. 2016). Wallat et al. (2004) reported survival rates of 96.7% and 94.2% for low and high stocking densities in trout cage culture. The high mortality in cages occurred in the first two weeks and this is possibly linked to handling myopathy. As also noted by Kljajić et al. (2016) high stocking mortality can occur due to the handling and transportation stress.

Conclusion

The study showed that triploid rainbow trout can be grown successfully using cage culture in small reservoirs in Eastern Highlands. The fish achieved the market size within the culture period. Farmers can adopt the system in order to maximize use of the existing reservoirs and generate more income. However, farmers are required to follow anaesthetic procedures in handling of fish during transportation and stocking to reducing stocking mortality. Again farmers are recommended to observe fish response when feeding especially during harsh weather conditions as this can raise the feed conversion ratio. Future research can focus on possibility of growing trout in cages during winter in marginal areas of Eastern Highlands that cannot support trout farming throughout the year.

Acknowledgements The study was made possible with funding and research materials from the Nyanga National Park of Zimbabwe Parks and Wildlife Authority. Support and encouragement from Mr. Sibanda and Mr. Maya is greatly appreciated.

Author Contributions Tinashe Chapinduka conceptualised, conducted field work and developed the script, Everson Dahwa analysed the data, interpreted the results and helped to draft the manuscript. Rachel Gwazani Supervised the research process and assisted in drafting script. Clarice Mudzengi helped in drafting the script. Maya co supervised the process. All authors revised the manuscript, read and approved the final version and takes accountability of for the contents in this article.

Funding The authors acknowledge funding from the Zimbabwe Parks and Wildlife Authority to carry out the research work.

Availability of Data and Materials The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate Approval to carry out the survey was granted through the Zimbabwe Parks and Wildlife Authority. Great Zimbabwe University approved the research proposal through its Departmental panel of examiners.

Competing Interests The authors declare that they have no competing interests.

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