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FIELD REPORT

GROWTH PERFORMANCE OF HYBRID BASS AND HYBRID TILAPIA IN CONVENTIONAL AND ACTIVE SUSPENSION INTENSIVE PONDS

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Abstract

Recently developed, active suspension intensive ponds are based on the idea that fish ponds (aerated and mixed as required for the well-being of the fish) can also serve as water purification units. The present paper compares water quality and fish growth in conventional intensive ponds (daily water exchange 500%), with active suspension intensive ponds (daily exchange 8%). The fish tested were hybrid tilapia (*Oreochromis niloticus* x *O. aureus*), already known to perform well in active suspension units, and hybrid bass (*Morone saxatilis* x *M. chrysops*), which is commercially cultured in conventional intensive ponds.

Water quality in the two types of intensive ponds differed as a result of the “internal water purification” vs “external water purification” approach. Bacterial development was greater in the active suspension ponds. Several parameters were affected by the different rate of water exchange, including temperature and removal of ammonium. The latter was lower in active suspension ponds due to reduced washout of particles and their associated nitrifying bacteria. Nitrification was greater in tilapia active suspension ponds because of grazing by this fish. Active suspension units operated with less than 2% of the water used in the conventional intensive ponds. Hybrid bass and hybrid tilapia performed similarly well in both types of pond, indicating the economic advantage of culturing them in the water-saving active suspension system. Tilapia graze on suspended particles, leading to additional savings in feed costs. The good performance of hybrid bass in active suspension ponds is herein reported for the first time.

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Introduction

Conventional intensive fish culture systems consist of a series of rather small ponds (usually concrete or plastic-covered) with a central outlet. The water circulates around the outlet, concentrating suspended particles in the center of the pond from which they are periodically drained out. Water continually enters and leaves the intensive units, the water volume being replaced twice to 8 times per day. The water source for intensive units may be clear water from springs, rivers or lakes and/or "green water" from earthen fish culture ponds or reservoirs. Water leaving intensive units may recirculate into the intensive units (closed water cycle) or leave the system for other uses (open water cycle). In a closed water cycle, before re-entering the intensive units, the water is purified in biofilters or other cleaning structures, or returns to the source pond or reservoir which serves as a natural purification unit (Hepher, 1985; Mires et al., 1990; Milstein et al., in press).

In recent years, active suspension intensive ponds have been developed. They are based on the idea that well-aerated mixed pond water can contribute to its own purification. Water is mixed to keep particles continually in suspension, and water exchange is greatly reduced (to about 10% per day). Under these conditions, dense microbial flora develop, functioning both as a bioreactor controlling water quality (Avnimelech et al., 1989), and as a protein food source for the fish (Avnimelech et al., 1994). Active suspension intensive ponds are used in Israel mostly to grow hybrid tilapia (*Oreochromis niloticus* x *O. aureus*) since such filter feeders are known to ingest suspended particles (Beveridge et al., 1989). Elsewhere, the same principle is used for intensive shrimp culture (McIntosh, 2000).

Due to water and land limitations and high feed costs, and because active suspension intensive ponds are thrifty in respect to these resources, it was decided to test the performance of hybrid bass (*Morone saxatilis* x *M. chrysops*) – a predator that is commercially cultured in conventional intensive high exchange ponds. Tilapia was cultured as the control fish, and conventional ponds served as the control for the active suspension ponds. Since conventional and active suspension ponds may be part of an open or closed water cycling system, comparisons herein are restricted to the pond units. Fish performance, pond water quality and quantity of water required by both pond types were compared.

Materials and Methods

The trial was carried out at the Fish and Aquaculture Research Station in Dor in two conventional and two active suspension intensive ponds. The ponds are experimental units of 30 m^3 each, located in a greenhouse. Each pond has a 1 hp aerator and four airlifts to give the water a circular movement. Ponds were filled with green water from earthen fish ponds (total area 12 ha). In the conventional intensive ponds, the water exchange rate was 500% per day, and particles settling in the center of the pond were flushed out twice a day. In the active suspension intensive ponds, the water exchange rate was 8% per day, sediment was drained only once a day, and settled particles were continually suspended by three extra airlifts located in the center of the pond above the outlet. Water and sediments leaving the intensive units returned to the earthen fish pond area.

Before fish stocking, each pond was inoculated with ten liters of mud taken from the bottom of an earthen pond. It was kept closed (no water input or output) and aerated for ten days to promote microbial development (mainly nitrifiers). One conventional and one active suspension pond were stocked with hybrid bass, the other pair of ponds with hybrid tilapia, with an initial biomass of 6.3 kg/m^3. Bass were fed floating trout feed with a protein content of 40%; tilapia were fed floating tilapia feed with a 30% protein content. Half of the daily feed was offered in the morning, and the second half in the afternoon, provided that the fish finished the morning fraction. Fish were weighed every ten days and feed was adjusted according to feeding tables used in commercial farms.

Samples for water quality analyses were taken twice a week, and daily when inorganic nitrogen compounds were suspected to be high. Whenever ammonium or nitrite exceeded 2 mg-N/l, 500 g corn flour was added to the pond to provide a larger carbonaceous source to the bacterial biomass, and thereby promote inorganic nitrogen removal (Avnimelech et al., 1994).

Factor analysis and ANOVA were run on 51 observations to characterize the water quality of both systems. Factor analysis is a multivariate statistical technique; its purpose is to explain the relationships among a set of variables in terms of a limited number of new variables (called factors) assumed to be responsible for the covariation among the observed variables. The new variables are a combination of the original variables multiplied by coefficients calculated from the correlation matrix of the data. High positive and negative coefficients indicate that the original variables are strongly correlated. These coefficients, together with previous knowledge of the system, enable us to see which process or processes may be responsible for the correlations they indicate. The first calculated factor is the linear combination that accounts for as much of the variation contained in the samples as possible. The second factor is a second linear function that accounts for most of the remaining variability, and so on. The factors are independent of one another, have no units and are standardized variables (normal distribution, mean = 0, variance = 1). Once identified the factors, their differences between treatments (active suspension or conventional intensive ponds) and sampling dates were tested with the General Linear Model (GLM) used as analysis of variance (ANOVA). Differences between treatments and dates were tested with the Duncan multicomparison test of means. These methods are standard techniques available in most statistical packages. In the present case, the analyses were run using the procedures FACTOR and GLM of the SAS statistical package, documented in SAS (1990).

Results

Fish performance. Both fish species had high survival, good growth rates and reasonable feed conversion ratios in both types of intensive ponds (Table 1). Although there were no replications and no statistical test is possible, it can be observed that for each species similar harvesting weight and biomass, survival, daily growth rate and growth curves were obtained in both kinds of pond (Fig. 1). The fact that hybrid bass not only can survive but also can grow well in water with a high level of suspended solids is herein demonstrated for the first time. To confirm this finding, the following year an experiment with three replicates per intensive pond type was carried out. Smaller hybrid bass were stocked at the density needed to reach a biomass of 20 kg/m^3 (400 g average fish weight) within seven months, assuming an average growth rate of 2 g/day. After 77 culture days, the survival of the bass was equally high in both pond types, while the harvest weight, biomass and growth rate were significantly higher and the feed conversion ratio significantly lower in the active suspension ponds (Table 2).

Water quality. Little water is exchanged in active suspension ponds, thus a greater amount of decomposition products from unutilized feed might be expected to accumulate than in conventional ponds where water is exchanged five times each day. Nevertheless, the water quality in the active suspension ponds was acceptable for fish growth. Ammonium levels were generally lower in the active suspension ponds than in the conventional ponds (Fig. 2), indicating the development of an efficient ammonium removal mechanism in the active suspension ponds. Nitrite levels were generally higher in the active suspension than in the conventional ponds. During the first days of the observation, there were high nitrite levels in the active suspension ponds; within a few days, the nitrification process was established and nitrite levels decreased to the level in the conventional ponds. Later, there were several nitrite peaks in the active suspension ponds, indicating defective aeration. As expected, nitrate accumulated in the active suspension ponds, reaching levels of about 20-30 mg NO_3-N/l, which are high but not dangerous to the fish. Mineral nitrogen was higher in the active suspension ponds than in the conventional ponds. In the active suspension ponds, total mineral nitro-

Table 1. Tilapia and bass, stocking and harvesting data for the year 2000, one pond per treatment.

	Active suspension		*Conventional*	
	Tilapia	*Bass*	*Tilapia*	*Bass*
Stocking (May 16, 2000)				
Weight (g)	125	209	126	206
Number (per pond) per m^3	(1500) 50	(900) 30	(1500) 50	(900) 30
Biomass (kg/pond) kg/m^3	(188) 6.3	(188) 6.3	(190) 6.3	(186) 6.2
Harvesting				
Number of culture days	114	93	114	94
Weight (g)	415	419	417	400
Number (per pond) per m^3	(1359) 45	(913) 30	(1284) 43	(897) 30
Biomass (kg/pond) kg/m^3	(564) 18.8	(383) 12.8	(535) 17.8	(359) 12.0
Growth rate (g/day)	2.54	2.26	2.55	2.07
Survival (%)	91	101	86	100
Feed conversion ratio, FCR	2.3	2.4	2.2	2.6

gen and nitrate were higher in bass than in tilapia ponds. This might indicate that the protein level in the bass feed was higher than required by this species in this type of system, where microbial protein might be an additional protein source. If so, it may be possible to reduce the protein content in the feed, saving costs and reducing the nitrogen output in the bass ponds. Organic nitrogen, organic carbon and suspended solids, probably composed of microbial protein, were higher in the active suspension ponds, as expected (Fig. 3).

Results of the factor analysis and the factors' differences in time and between treatments are presented in Table 3, where the coefficients used for factor interpretation are shown in bold type. The first factor (FACTOR1, bacterial development) explains 33% of the overall data variability. Bacterial development mainly accounts for the correlations with the highest coefficients. High levels of suspended solids, organic carbon and nitrogen indicate that remnants of feed and wastes served as substrates for the development of bacterial biomass, whose activity in the aerated environment increased the inorganic oxygenated nitrogen compounds (variables with a high positive value) and reduced the pH through respiration (variable with a high negative value). Although oxygen is consumed in bacterial processes, it had no correlation with this factor (its coefficient was close to zero) because oxygen was supplied to the ponds in larger amounts than required by the bacteria. The ANOVA model accounts for 90% of FACTOR1 variability, half of it due to time and half of it due to pond type. Bacterial development activity increased with time. This trend correlated with electrical conductivity (which also has a high coefficient in FACTOR1), and increased during the warm season when evaporation caused an increase in the salt content of the water. Bacterial development was higher in the active suspension ponds than in the conventional high exchange intensive ponds. Among the former, bacterial biomass was

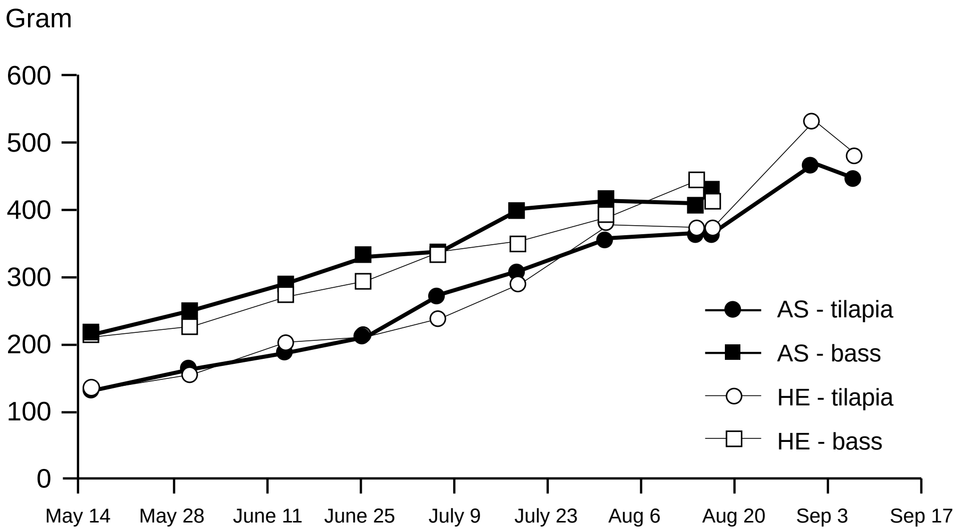

Fig. 1. Tilapia and bass weight vs time in conventional high exchange (HE) and active suspension (AS) ponds.

lower in the tilapia ponds; the omnivorous tilapia considerably grazed on suspended particles, while the predator bass did not.

The second factor (FACTOR2, water exchange management) accounts for 21% of the remaining overall data variability. It had a negative correlation with temperature, dissolved oxygen, ammonium and electrical conductivity (variables with a high negative value) and a positive correlation with turbidity and organic nitrogen (variables with a high positive value). This combination illustrates the differences between the two kinds of intensive ponds resulting from differences in the water exchange management. Open-air, earthen ponds were the water source for the ponds. This water contains heat and dissolved oxygen. Since more water entered the conventional ponds, their water temperature and dissolved oxygen level were higher than those in the active suspension ponds. On the other hand, the lower water exchange in the active suspension ponds resulted in higher electrical conductivity and turbidity. In this turbid environment, bacteria removed ammonium from the water and transformed it into organic nitrogen for body-building. The differences between conventional and active suspension ponds accounted for one third of the FACTOR2 variability. The remaining variability was due to time. Temperature, conductivity and ammonium were lower and turbidity was higher in June than in July-August, the latter related to the mud inoculums used to start bacterial development in the ponds.

The third factor (FACTOR3), which accounts for a further 10% of the overall data variability, is nitrification, which transforms ammonium (positive coefficient) into nitrate in an oxygenated environment with high oxido-reduction potential (negative coefficients). Most (88%) of the variability of this factor was related to time, with nitrification improving until mid-June and worsening from mid-July onwards. A small amount of the variability of this factor was related to pond type, with better nitrification conditions in the active suspension pond with tilapia. This might be due to tilapia grazing on the suspended particles, thereby keeping the bacterial population in continuous reproduction in the log-stage of the population growth curve.

Water amounts. Table 4 shows the amount of water used in each pond unit. The active suspen-

Table 2. Bass stocking and harvesting data for the year 2001, three ponds per treatment.

	Active suspension	*Conventional*
Stocking (June 4, 2001)		
Weight (g)	21	21
Number (per pond) per m^3	(1150) 38	(1150) 38
Biomass (kg/pond) kg/m^3	(24) 0.8	(24) 0.8
Harvesting (August 21, 2001)		
Number of culture days	77	77
Weight** (g)	100	89
Number (per pond) per m^3	(1135) 38	(1139) 38
Biomass* (kg/pond) kg/m^3	(113) 3.8	(101) 3.4
Growth rate** (g/day)	1.02	0.88
Survival (%)	99	99
Feed conversion ratio, FCR*	1.7	1.9

*ANOVA significant at 0.05, r^2 = 0.84 for biomass and 0.77 for FCR (rank-transformed data to normalize ratio)
**ANOVA significant at 0.01, r^2 = 0.85 for weight and 0.86 for growth

sion ponds operated with 1.8% of the water used in the conventional ponds. This comparison is valid whether the ponds are operated as an open or a closed water system. If the water is recirculated and re-used several times, the efficiency of water utilization is high in both types of units. The energy required to recycle the water, however, is much lower for the active suspension ponds. If water availability and/or storage capacity for recirculation are low, then there is a further advantage in using active suspended ponds.

Discussion

Super-intensive fish culture systems that use pure oxygen and other sophisticated techniques achieve high yields but also involve high investment and production costs. Hence, they are profitable only when culturing a relatively highly priced species with a sufficient market to cover the costs incurred. When the target is production of less valuable species with a large established market, or investments must be kept low, or available manpower is unable to handle sophisticated technology, intensive systems seem to be more appropriate.

Among intensive systems, active suspension units are a relatively inexpensive way to intensify aquaculture in a water-limited country. The fact that water is purified within the fish ponds eliminates expenses related to biofilters or external water-cleaning structures, or reduces the storage capacity required for natural purification in a reservoir. The huge savings of water as compared to conventional intensive systems results in decreased costs, better utilization of a scarce resource and, if the cultured fish is able to utilize suspended particles as food, possibly further cost reductions.

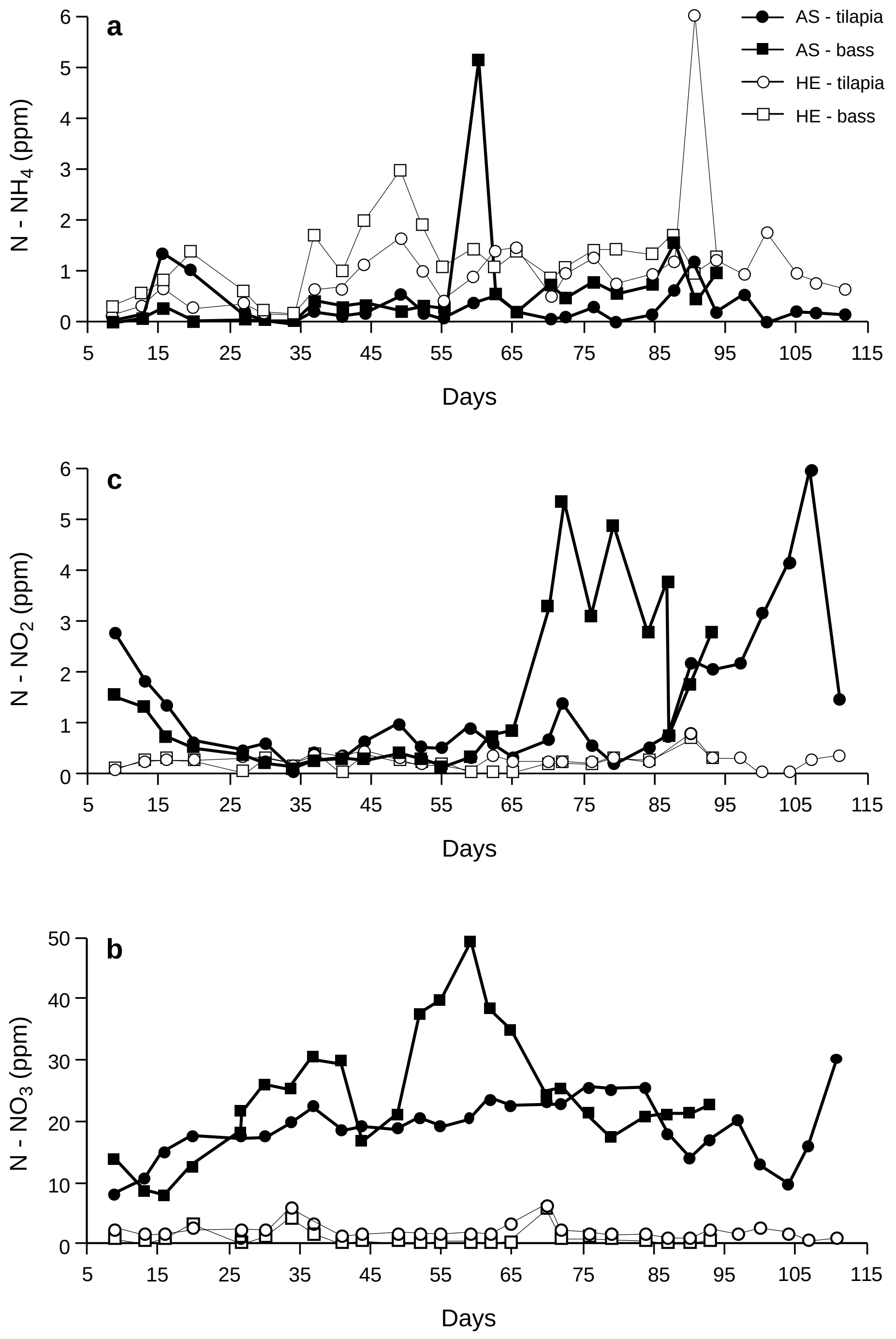

Fig. 2. Ammonium (a), nitrite (b) and nitrate (c) in active suspension (AS) and conventional high exchange (HE) ponds vs time.

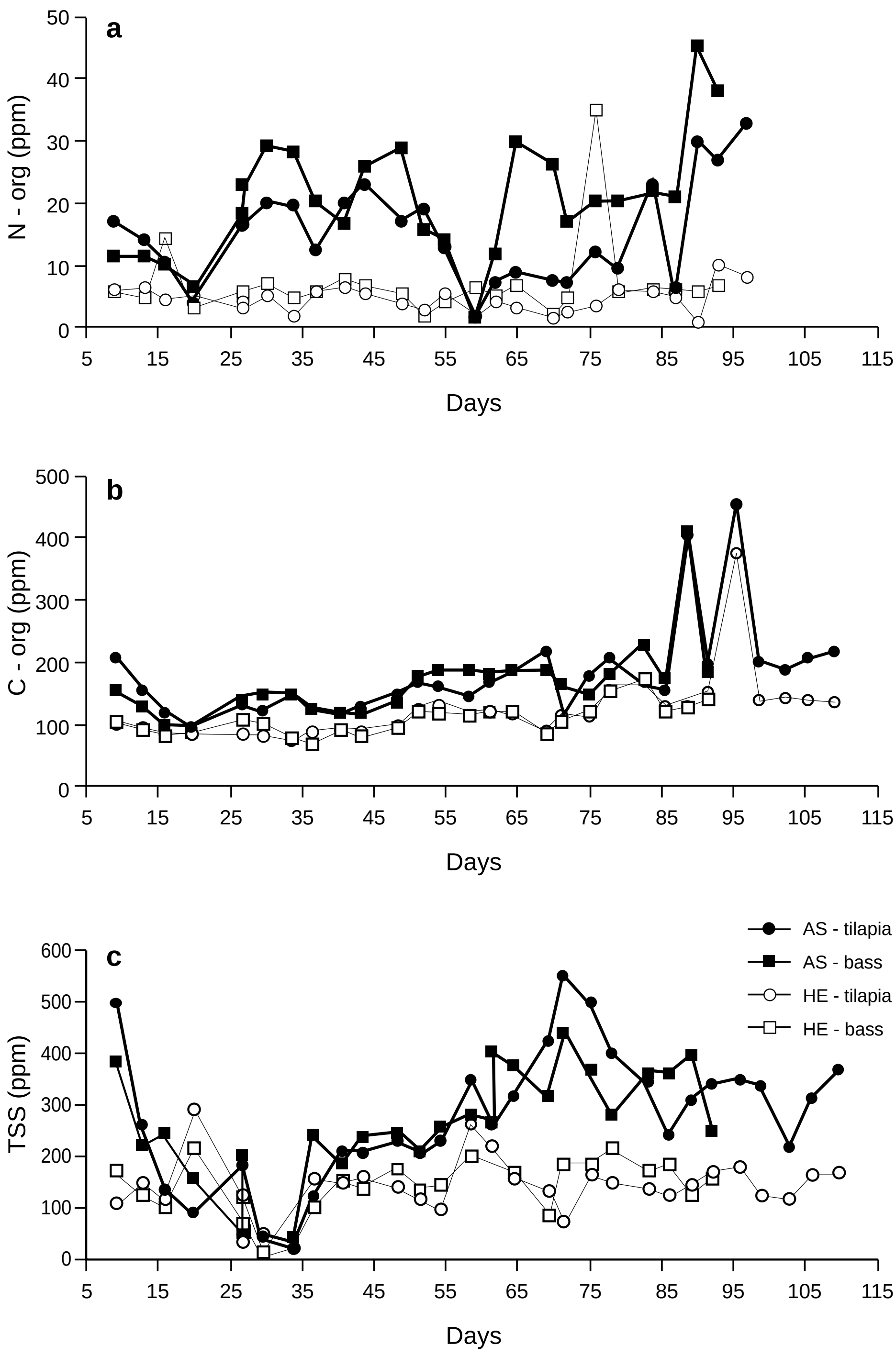

Fig. 3. Organic nitrogen (a), organic carbon (b) and total suspended solids (c) in each pond vs time.

Table 3. Factor analysis and ANOVA models of water quality data.

	FACTOR1	*FACTOR2*	*FACTOR3*
pH	**-0.81**	0.28	0.26
Conductivity	**0.79**	**-0.44**	0.05
Turbidity	-0.01	**0.69**	0.31
Dissolved oxygen	0.03	**-0.55**	**-0.54**
Temperature	0.11	**-0.70**	0.22
Oxido-reduction potential	-0.37	0.44	**-0.46**
Ammonium	0.12	**-0.54**	**0.40**
Nitrite	**0.63**	0.34	0.28
Nitrate	**0.72**	0.31	**-0.45**
Organic nitrogen	**0.60**	**0.45**	0.10
Organic carbon	**0.79**	0.16	0.13
Suspended solids	**0.81**	0.09	-0.09
Variance explained (%)	33	21	10
Interpretation	Bacterial development	Water exchange management	Nitrification
ANOVA models[1]			
Significance level	***	***	***
r^2	0.90	0.84	0.84
Variance source			
Treatment (sig.) %SSq	(***) 50	(***) 34	(***) 12
Date (sig.) %SSq	(***) 50	(***) 66	(***) 88
Mean multicomparisons by treatment (Duncan test)[2]			
Active suspension - bass	a	a	a
Active suspension - tilapia	b	a	b
Conventional - bass	c	b	a
Conventional - tilapia	c	b	a
Mean multicomparisons by date (Duncan test)[2]			
May 29	c	abc	bc
June 5	c	ab	bc
June 8	c	a	cde
June 15	c	bc	h
July 14	ab	f	efg
July 17	b	ef	gh
July 20	b	def	fg
July 25	b	def	def
July 27	ab	de	bcd
July 31	ab	def	cde
August 3	ab	def	cde
August 11	b	cd	b
August 14	a	de	a

Coefficients used for interpretation are in bold type.

1 %SSq = % of total sum of squares accounted by each variability source; Sig. = Significance level: ***< 0.001.

2 Means with the same letter are not significantly different at the 0.05 level.

Table 4. Water used in each intensive pond unit in 2000.

	Active suspension		*Conventional*	
	Tilapia	*Bass*	*Tilapia*	*Bass*
Pond volume (m^3)	30	30	30	30
Daily addition (m^3)	2.4	2.4	144	144
Number of culture days	114	93	114	94
Total water used (m^3)	304	253	16,450	13,570
Water/yield (m^3/kg)	0.8	1.3	44	78

Water quality in the two kinds of intensive systems differed as a result of whether the water was purified internally or externally: (a) they had different bacterial development (FACTOR1); (b) parameters including temperature and ammonium removal were affected by the different water exchange rate (FACTOR2); (c) nitrification was improved in tilapia active suspension ponds because of grazing by this fish (FACTOR3). The high nitrate levels in intensive ponds were related to the continuous aeration; a continuous supply of oxygen promotes nitrification better than the fluctuating conditions in conventional ponds (Avnimelech et al., 1986). The high ammonium removal in the active suspension ponds is related to the reduced wash-out of particles and associated nitrifying bacteria when water exchange is low. A high water exchange rate may be undesirable from the point of view of water quality and extra costs incurred for energy and washed-out feeds (Avnimelech et al., 1994). In an experiment in the Ein HaMifratz conventional intensive pond system, Diab et al. (1992) found that when the water exchange rate was high, nitrifying bacteria were flushed out, leading to reduced nitrification (i.e., less nitrite and nitrate) and increased ammonium in the ponds. This finding was confirmed in a study of a wide range of commercial conventional intensive systems (Milstein et al., in press) and by the present results.

Bass and tilapia, which are already being cultured in conventional intensive ponds in Israel, performed similarly well in conventional and active suspension ponds. This indicates the economic advantage of culturing them in the water-saving active suspension system. Rasing tilapia in active suspension ponds may result in a further economic advantage, i.e. additional savings in feed costs, since tilapia graze on suspended particles (as indicated by FACTOR1 and FACTOR3). A few commercial farms in Israel already culture tilapia in active suspension ponds. The good performance of hybrid bass in active suspension ponds is herein reported for the first time.

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