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Cost Analysis of Forced-Air Systems for Incubation of Channel Catfish Eggs[1]

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Abstract.—Cost estimates were developed for equipping egg incubation troughs for channel catfish (*Ictalurus punctatus*) to operate with forced air delivered via air stones or perforated pipe rather than with traditional gear motors and shaft-mounted paddles. Capital and operating costs were compared on a per-trough basis for the three configurations. A partial budget was developed to evaluate conversion from the traditional configuration to each of the forced-air configurations. Although forced-air configurations appear to be less expensive to install and operate, cost estimates suggest that two to four operating seasons may be required to recover the cost of converting an existing motor-and-paddle configuration to forced air.

Although production of channel catfish (*Ictalurus punctatus*) in the southeastern United States increased from 46 million pounds in 1980 to 459 million pounds in 1993 (USDA 1994), the industry continues to use incubation technology that has remained virtually unchanged for over 60 years (Clapp 1929; Huner and Dupree 1984). Fluctuations in fingerling inventories have added to overall price and supply volatility in the industry in recent years. Improving the efficiency and lowering the cost of fingerling production would be positive steps toward the industry's goal of reducing supply volatility.

Current incubation techniques involve electric gear motors that turn one or several metal shafts. Each shaft, mounted on bearings, extends above the water surface along the longitudinal axis of a hatching trough and is configured with regularly spaced metal or plastic paddles. Channel catfish eggs, bound together in masses by a gelatinous matrix, are suspended below the water surface in wire mesh baskets mounted between the rotating paddles; as the paddles rotate, they stir and splash the water to provide aeration and circulation (Huner and Dupree 1984). The agitation and aeration are intended to simulate the protective behavior of a brooding male channel catfish under natural conditions (Clemens and Sneed 1957). Although this technique has proven adequate for successful hatching, it results in a number of safety hazards, as well as increased noise levels (Carmichael et al. 1993).

In a comparison of traditional motor-and-paddle system for incubation of channel catfish eggs with an air stone-based system, Carmichael et al. (1993) found no differences in hatching rate, survival, weight of sac and swim-up fry, or total weight after 21 d feeding. Ongoing research, the previous experience of the authors, and industry trials suggest that similar results can be achieved by forcing air through submerged polyvinyl chloride (PVC) pipe that has small holes drilled on the underside at regular intervals.

The cost and performance efficiencies of various oxygen diffusers have been evaluated for fish-hauling tanks (Carmichael et al. 1992) and salmonid raceway systems (Dwyer and Peterson 1993). However, because of the continuous flows used to maximize water quality during incubation (Huner and Dupree 1984) and the comparatively small oxygen demand of channel catfish eggs and sac fry, pure oxygen is not used in commercial catfish hatcheries except when oxygen cylinders are bled through air stones for emergency aeration of swim-up fry. Many catfish hatcheries do, however, use air stones to deliver forced air to swim-up fry prior to stocking in ponds.

Little detailed information has been published regarding costs for constructing traditionally con-

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figured catfish hatcheries (Moore and Waldrop 1994), and no information has been published on the costs of alternative configurations for hatching troughs. Objectives of this study were (1) to develop and compare capital cost estimates for a traditional motor-and-paddle configuration and two forced-air configurations, (2) to estimate operating costs for these three configurations, and (3) to estimate costs and annual savings, if any, of conversion from the traditional configuration to either of the forced-air configurations.

Cost estimation.—Cost estimates were developed on a per-trough basis for a motor-and-paddle hatching trough configuration and two alternative configurations that used forced air from a low-pressure, high-volume regenerative blower. All estimates were based on outfitting a 10-ft-long hatching trough. One forced-air configuration employed separate ceramic or glass air stones (6 × 1 × 1 in) to supply aeration to each of 10 hatching baskets. The second forced-air configuration pumped the same volume of air through two lengths of submerged 1-in PVC pipe, which had 0.05-in holes drilled at 3-in intervals on the underside of the pipe, along the entire length of the trough (M. Mulvilhill, AREA, Inc., personal communication).

Catalogs (1994 editions) from a number of industry suppliers were used to estimate capital costs of equipment and materials. Where quoted costs for similar equipment or materials varied greatly, intermediate values were used in estimates. In instances where material or equipment prices were not directly available from vendors, commercial producers were contacted to establish estimates of prevailing costs. Costs of materials used across all trough configurations, such as hatching baskets and the troughs themselves, were not included in capital costs. Depreciation values were based on life expectancy estimates from industry sources and on personal experience. Depreciation estimates were used to describe capital costs on an annualized basis.

To cover a range of hatchery sizes, blower costs per trough were estimated based on forced-air volume and horsepower requirements for supplying 5, 10, or 20 hatching troughs from a single, appropriately sized blower. The highest value was then used in the cost analysis. Estimated operating costs for a 90-d hatchery season included predicted electricity consumption as a function of gear motor or blower horsepower and repair and maintenance costs based on an estimate of 10% of the initial cost of equipment and materials. Operating costs were combined with annualized capital costs (depreciation) to provide estimates of total costs per hatching season for each configuration.

TABLE 1.—Blower size, cost ($US), and cost per 10-ft-long trough for an incubation system for catfish eggs configured for 5, 10, or 20 troughs per blower.

Number of troughs	Blower size (hp)	Blower cost	Cost per trough
5	0.3	$390	$78
10	1.0	$760	$76
20	2.0	$1,580	$79

Costs and savings associated with conversion from traditionally configured hatching troughs to the two forced-air configurations were evaluated by means of a partial budget based on annualized capital (depreciation) and operating cost estimates. The cost of removing existing motors, shafts, and paddles was assumed to be offset by the salvage value of the equipment.

Cost comparisons and implications.—Carmichael et al. (1993) demonstrated identical incubation performance in channel catfish hatching troughs using air stone or motor-and-paddle aeration. Cost estimates developed in the present study suggest that the economic benefits of incubating channel catfish eggs with forced air and air stones could be substantial. If we assume that the drilled-pipe configuration would perform as well as the air stone system, costs of incubation and fry production could be further reduced.

Blower costs on a per-trough basis were similar for configurations using a single, appropriately sized blower for every 5, 10, or 20 troughs (Table 1). Although Moore and Waldrop (1994) identified 60-, 140-, and 200-trough systems as being representative of the majority of commercial catfish operations in the Mississippi Delta region, servicing more than 20 troughs per blower could increase the risks associated with mechanical failure to unacceptable levels. Accordingly, multiples of 5, 10, or 20 troughs per blower may be an appropriate extrapolation of these cost estimates to larger hatchery operations.

Investment cost estimates for the motor-and-paddle configuration (Table 2) appeared to be similar to those developed by Moore and Waldrop (1994), although direct comparisons were not possible. Estimates developed in a similar manner for hatching troughs supplied with forced air through air stones or drilled pipe were 50% and 71% lower, respectively (Table 2).

Depreciation estimates and component life expectancies for the three configurations, describing

TABLE 2.—Capital costs ($US) and cost and depreciation (annualized capital cost) estimates per 10-ft-long trough for three aeration and agitation systems for incubating channel catfish eggs.

Item or total	Cost per unit	Units per trough	Cost per trough	Depreciation per trough	Years of life
Motor-and-paddle system					
Motor mount	$35.00	1	$35.00	$3.50	10
Paddle	$1.25	9	$11.25	$1.61	7
Bearing unit	$17.00	3	$51.00	$7.29	7
Shaft (¾ in diameter)	$2.00	10	$20.00	$2.00	10
Belts, etc.	$35.00	1	$35.00	$8.75	4
Electrical hardware	$40.00	1	$40.00	$4.00	10
Motor (1/10 hp)	$145.00	1	$145.00	$29.00	5
Total			$337.25	$56.14	
Air stone system					
Blower (2 hp)	$1,580.00	0.05	$79.00	$7.90	10
Air stone	$5.00	10	$50.00	$10.00	5
Pipe	$0.30	10	$3.00	$0.30	10
Pipe fitting	$2.00	10	$20.00	$2.00	10
Nipple	$0.50	10	$5.00	$0.50	10
Tubing	$0.20	10	$2.00	$0.40	5
Supply pipe	$0.50	20	$10.00	$1.00	10
Total			$169.00	$22.10	
Drilled-pipe system					
Blower (2 hp)	$1,580.00	0.05	$79.00	$7.90	10
Drilled pipe	$0.30	20	$6.00	$1.20	5
Pipe fitting	$1.00	4	$4.00	$0.40	10
Supply pipe	$0.50	20	$10.00	$1.00	10
Total			$99.00	$10.50	

annualized capital costs, are outlined in Table 2. Although these estimates were developed on a straight-line basis corresponding to life expectancies, state and federal regulations may require different approaches to depreciation of hatchery equipment for tax purposes.

Repair and maintenance estimates (assumed to be 10% of capital costs) accounted for most of the estimated operating cost for the motor-and-paddle configuration (Table 3). In practice, actual repair and maintenance costs may be different from costs estimated as a percentage of initial outlay. Substantial variation in these costs would be expected from hatchery to hatchery, depending on humidity levels, the knowledge and experience of hatchery personnel, water chemistry, and other factors. Traditional motor-and-paddle configurations involve more moving parts than the forced-air systems and, therefore, have a greater potential for wear and tear.

The total cost-per-season estimate for the traditional motor-and-paddle configuration was 87% higher than for the air stone system and 182% higher than for the drilled-pipe configuration (Table 3). Cost advantages in various categories for the air stone and drilled-pipe configurations combined for total seasonal, per-trough savings of US$47.74 and $66.34, respectively (Table 4).

As is the case with repairs and maintenance, actual life expectancies of system components can be expected to vary from hatchery to hatchery. Large deviations in depreciation, and repair and maintenance costs, could change projected differences in total costs per season among the configurations.

Costs of materials and equipment for the air stone configuration totalled $169 per trough while those for the drilled-pipe configuration totalled only $99 per trough (Table 2). Per-season estimates of net changes in income, generated by partial bud-

TABLE 3.—Total aeration system costs ($US), on a per-trough basis, over the 90-d hatching season for channel catfish eggs.

Cost item	System: Motor-and-paddle	Air stone	Drilled-pipe
Capital (depreciation)[a]	$56.14	$22.10	$10.50
Operation			
Maintenance and repair[b]	$33.73	$16.90	$9.90
Electricity[c]	$12.96	$16.09	$16.09
Total	$102.83	$55.09	$36.49

[a] See Table 2.
[b] Calculated as 10% of initial cost (Table 2).
[c] Calculated at $0.08/kWh.

TABLE 4.—Partial budget analysis ($US), on a per-trough basis, of converting from a motor-and-paddle system to an air stone or drilled-pipe aeration system for incubating channel catfish eggs.

Credits or debits	System: Air stone	Drilled-pipe
Credits		
Additional annual receipts	$0.00	$0.00
Reduced annual costs		
Depreciation	$34.04	$45.64
Maintenance and repair	$16.83	$23.83
Total	$50.87	$69.47
Debits		
Reduced annual receipts	$0.00	$0.00
Additional annual costs		
Electricity	$3.13	$3.13
Total	$3.13	$3.13
Net change in income	$47.74	$66.34

get analysis, suggest that these outlays could be recovered over four or two hatching seasons, respectively (Table 4).

Initial costs of installing each of the three configurations were assumed to be the same. Depending on the skill levels of available labor, this may not be a valid assumption. Our experience suggests that installation of forced-air systems is somewhat easier than mounting gear motors and bearings to troughs, attaching shafts and paddles, and running electrical service to each gear motor.

Although blower costs per trough were comparable when based on supplying forced air to 5, 10, or 20 troughs from a single, appropriately sized blower (0.3, 1.0, or 2.0 hp), smaller or greater numbers of troughs per blower might substantially alter blower costs on a per-trough basis. Including a backup blower for each blower in service (equivalent to doubling blower costs in capital cost estimates) would not alter the relative economic rankings of the three configurations on a per-season basis, even if a backup gear motor were not considered in the comparison.

To the extent that a backup blower would remain idle throughout most or all of the operating season, a combined depreciation estimate for two blowers would be somewhat less than twice the amount included for a single blower in Tables 2 and 3. The actual ratio of backup blowers (and therefore backup outlays) to those in primary service would depend on hatchery capacities, numbers of troughs serviced per blower (blower size), and the level of risk an individual manager is comfortable with.

Based on estimated per-season costs, forced-air incubation of channel catfish egg masses is an economical alternative to traditional motor-and-paddle technology. Costs to convert traditionally configured hatcheries to forced air can be recovered within two to four operating seasons. Although forced-air configurations probably offer little advantage over the motor-and-paddle configuration in degassing supersaturated well water, several other potential benefits are apparent. The elimination of electricity and moving parts from the immediate area around hatching troughs improves hatchery safety. Additionally, reduced noise levels would be expected in hatcheries where forced air is used instead of motors and paddles.

Most hatcheries rely on the physical transfer of newly hatched fry from incubation troughs to separate rearing troughs in order to accommodate successive lots of egg masses, which are collected at intervals of 3–4 d through the spawning season (Huner and Dupree 1984). The forced-air configurations evaluated in the present study would allow hatching baskets, rather than fry, to be removed from an incubation trough after hatching was complete, resulting in uninterrupted rearing through the swim-up stage. Although egg and fry numbers per trough would have to be adjusted accordingly, all troughs in a hatchery could be interchangeable, which would provide more flexibility in hatching and rearing, with no loss in capacity. This technical change would reduce labor requirements and handling losses at the sac fry stage.

Lower investment and operating costs associated with forced-air incubation would allow smaller growers, who may be at a competitive disadvantage, to produce their own supply of fingerlings more economically. Based on simple economies of scale, however, the cost of acquiring fry from a large hatchery would generally be sufficiently lower than on-site production to rule out construction of hatching facilities with extremely small capacities. Nonetheless, a small, 1/8-hp blower could supply forced air for two incubation troughs at an approximate cost of $165 per trough. This figure, in conjunction with the other materials required on a per-trough basis, would still result in a more economical system than the motor-and-paddle configuration. On an industry-wide basis, more economical fingerling production and greater fingerling supplies would eliminate a destabilizing factor in traditional pond-bank price cycles.

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