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Application of bioenergetics modelling to fish growth in ponds

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Resumen: Se desarrolló un modelo de crecimiento basado en la bioenergética para la corvina roja *Sciaenops ocellatus* (L) cultivada en Panamá durante 1987-1989. El modelo fue capaz de predecir el crecimiento del pez en forma significativa $r^2 = 0.921$ to 0.999, n = 14), a pesar de existir gran variabilidad en las condiciones de cultivo. El modelo fue usado como una herramienta para explorar los efectos de diferentes estrategias de manejo utilizadas durante la fase de engorde del pez. Se encontró que cambios en el orden de 1.0 ppm en el nivel de oxígeno disuelto ocasiona un 60% de ganancia o disminución en el peso promedio observado. El uso de una dieta balanceada con cambios en el orden de un 10% de la energía total suministrada ocasiona un 75% de ganancia o disminución en el peso promedio observado. Los parámetros de crecimiento de este modelo pueden ser fácilmente cambiados para simular alguna otra especie de pez de interés acuícola.

Key words: Bioenergetics, modelling, pond culture, red drum, Panamá.

Applications of bioenergetics modelling to aquacultural systems demonstrate great potential of this technique for solving management problems (Schuur 1991). Bioenergetics modelling has been applied to wild populations of coho and chinook salmon, brown and lake trout, cod, haddock, largemouth bass, yellow perch, walleye, and skipjack and yellowfin tunas, and to a few cultured species like rainbow trout, channel catfish, and gilthead seabream. Mechanistic growth models potentially applicable to red drum have been developed by Kitchell *et. al.* (1978) for tunas and by Cuenco (1982) for channel catfish. Doerzbacher *et al.* (1988) developed a temperature-compensated von Bertalanffy model to describe growth of tagged drums in Texas bays. However, there seems to be very little published information available for parameterizing a mechanistic growth model for red drum in aquacultural pond systems. Here I present the applications of a bioenergetics-based model developed to simulate growth of red drum cultured in Panama.

Red drum production trials (total of 14 ponds) were conducted at Agromarina and MIDA stations, near Aguadulce, Coclé Province, and the methods are reported elsewhere (Garcés 1991, 1992). Growth (1.8 g/day) and survival (70%) of red drum during these grow-out trials (lasting 4-12 months) in Panama were comparable to the best published values for other semi-intensive aquaculture efforts with this species. All of the environmental parameters measured (oxygen, temperature, salinity, ammonia, nitrite, phosphorus, and pH) were within the tolerable limits for red drum. Least-squares regression of weight against time gave better goodness-of-fit for the linear ($r^2 = 0.92$) than the power ($r^2 = 0.89$) or the exponential ($r^2 = 0.62$) growth models; all other curves fitted (Curvefit, Polyfit and SAS programs) were not significant ($p>0.05$). However neither of the significant regression models was very satisfactory, in that neither could account for short-term variation in growth rate.

The bioenergetics-based growth model developed (Garcés 1991) was based on a modified energy budget equation (Kitchell *et. al.* 1978) with parameters derived from laboratory research on red drum and other fishes:

$$Ag = c * Apc * F - 2 s * e^{qT} * W^{b},$$

Where:

Ag = growth of red drum in g fish/day;
c = 0.65 (assimilation coefficient) (Winberg 1956);
Apc = where Apc is potential feed consumption (this study);
F = fraction of Apc actually consumed (this study);
s = 5.386 cal/ (g fish * day) (standard metabolism coefficient) (Schlechte 1989):
q = 0.07 (i.e. assumed Q_{10} = 2.0) (Winberg 1956);
T = temperature in °C;
b = -0.20 (Warren 1971);
w = live weight of fish in grams.

This model hypothesized that growth of red drum in the production ponds was the difference between assimilated feed and metabolized feed. If more feed was assimilated than used in metabolic work, the fish grew; otherwise, the fish lost weight. If part of the feed given to the fish was not actually consumed, then Ac was equal to Apc * F, where Apc never reached the maximum feed consumption rate, or Acmax = 0.18 * ($W^{-0.27}$), and F is the proportion of feed eaten ($0 \leq F \leq 1$). Feed consumption rate was not to exceed the calculated Acmax.

The bioenergetics-based model was able to account for marked differences in red drum growth among 14 grow-out trials (r^2 = 0.921 to 0.999), in spite of the wide variety of culture conditions: pond size, 0.10-4.05 hectare; average stocking weight, 1.6-46.0 g; stocking density, 2,400-48,000 fish/hectare; number of days in ponds, 109-336 days; and, no aeration versus supplemental aeration (in one 4.05 hectare pond).

The model is useful as a tool to explore the effect of changing conditions on fish growth. As an example, the model was used to explore some hypothetical situations, such as having a constant dissolved oxygen (DO) value during the whole grow-out period. Three constant levels of DO -- 2.5, 3.5 and 4.5 ppm -- were used for simulation of the average pond trial. It was found that a 1.0 ppm deviation from 3.5 ppm of DO caused simulated fish weight on day 336 to be 60 % more or less than the 656 g mean weight actually observed at the end of 48 weeks (Fig. 1). The 3.5

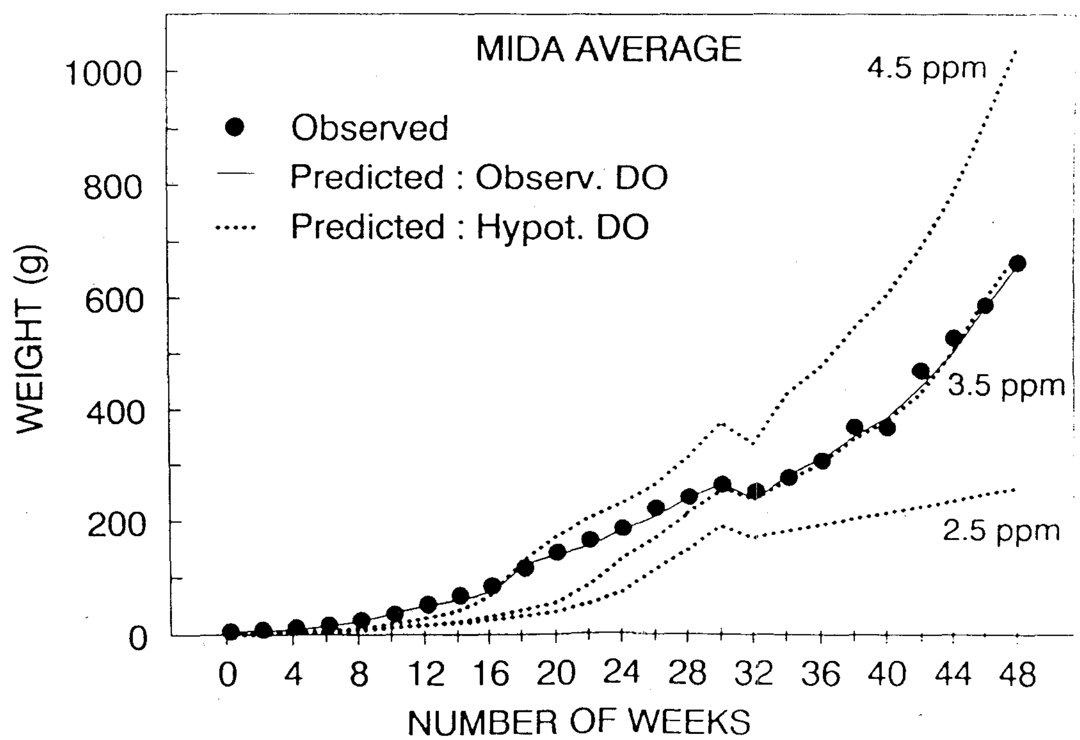

Fig. 1. Effect of "DO" on simulated fish weight (sec text for definitions).

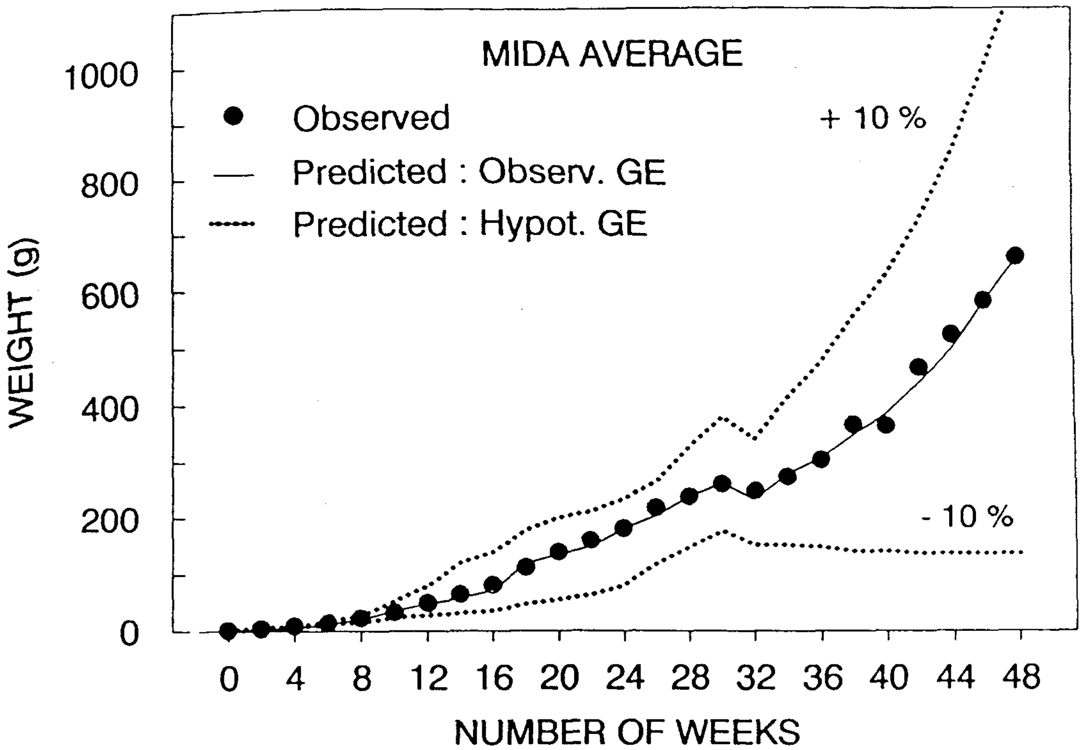

Fig. 2. Effect of "GE" on simulated fish weight (see text for definition).

ppm level, which was the closest to the observed average DO of 3.2 ppm, gave the simulation that was closest to the observed pattern (Fig. 1) The model was also used to simulate the effects of altered energy content of feed on the growth of red drum in the average pond trial. A series of hypothetical feeds with 10 % more or less than the gross energy values of the feeds actually used (a 35-38 % protein floating pellets) would have yielded fish averaging about 75 % more or less than the 656 g mean weight actually observed at the end of 48 weeks (Fig. 2). Thus, differences in the level of DO on the order of only 1.0 ppm or a 10% gross energy value change may directly and drastically affect the performance of a red drum grow-out operation. This study support the view that a bioenergetics-bases model developed to simulate growth of red drum in aquacultural ponds can be useful as a managing tool.

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