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Techniques to Assess Fish Productivity in Aquaculture Farms and Small Fisheries: An Overview of Algebraic Methods

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Abstract: The main goal of aquaculture and small fisheries is the bioaccumulation of chemical elements in edible tissue. Fish, shellfish, decapods and/or algae are commonly cultivated organisms in marine and freshwater aquaculture systems. Total biomass is the best indicator of production system performance. However, due to the high variation of technologies and methods used in aquaculture, special techniques are required to make thorough studies. The present study is a summary of algebraic fish biometric techniques to assess fish biomass production. Numerical computations were carried out for didactical purposes.

Key words: Fish growth, relative density, metabolic growth rate, von Bertalanffy's growth function

INTRODUCTION

Fisheries and aquaculture both involve the production of high quality fish protein (Obaroh and Achionye-Nzeh, 2011; Bozoglu *et al*., 2006; Huda *et al*., 2002). Fisheries are based on the extraction of living resources in water bodies (Bostock *et al*., 2010; Akca *et al*., 2006). Aquaculture is the farming of aquatic plants and animals (Iwama, 1991). Both disciplines provide most of the world's aquatic edible resources (Food and Agriculture Organization of the United Nations (FAO, 2010).

Aquaculture productivity is commonly measure as total biomass. However, in many cases additional parameters are required to make thorough studies (Alagaraja, 1991). Simple algebraic models can be used to make important decisions in farm (Roomian and Jamili, 2011). These methods are relative easy to carry out and their implementation requires basic mathematical background. In scientific research they can be used to compare similar experimental procedures (Alatorre-Jacome *et al*., 2011).

In the case of fisheries, direct and indirect methods to assess productivity have been extensively developed (Cochrane, 2002; Sparre and Venema, 1998; Pauly, 1983). But as for inland, small-scale aquaculture systems, the application of large and complex fisheries analysis could be far to be done.

The purpose of the present study was to propose a synthetic methodology in order to assess small-scale fish productivity. Formulae for collective and individual fish growth determination are presented. A case study in aquaculture is analyzed for collective growth performance indexes. A small-fisheries study case is analyzed to explain the procedure for individual fish growth determination.

MATERIALS AND METHODS

Data measurement: For the following parameters, there were required four types of response variables: Fish total length (mm), fish wet weight (g), time (days) and number of fish measured. The correct techniques for accurate measures can be found in the literature (Sparre and Venema, 1998; Brander, 1975). For explicative purposes, examples on calculations were analyzed on results.

Total biomass production: According to Ricker (1971) biomass is the amount of substance in a population expressed in material units, such as living or wet weight, dry weight, ash-free weight, nitrogen contents, etc. It is also termed as standing crop.

For the total biomass wet weight (W_t) we use:

$$W_t\,(g) = \sum_{i=1}^{n} W_i \qquad (1)$$

where, W_i is the weight of the ith fish in the system.

Because the aquacultural systems are very heterogeneous about its size and capacity, is useful apply

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the term relative density (prel) per volumetric unit (kg m^{-3}) to compare among them:

$$\text{prel}(g) = \frac{W_t}{V} \tag{2}$$

where, W_t is the total biomass on the system and V is its volume. In extensive systems if often used the area instead volume.

Akinwole and Faturoti (2007) use the next equations as useful indicators for the system productivity. The Total Weight Gain (TWG) function indicated the gain of biomass in a given time:

$$\text{TWG (g)} = M_f\text{-}M_i \tag{3}$$

where, M_f is the final mass of the fish and M_i is the initial mass.

The Average Daily Growth Rate (ADGR) indicate the average weight gained each day:

$$\text{ADGR (g day}^{-1}) = \frac{\text{TWG}}{D} \tag{4}$$

where, TWG is the total weight gain (from Eq. 3) and D are the culture day (Shnel *et al*., 2002).

According to Bwala and Omoregie (2009), the Specific Growth Rate (SGR) is:

$$\text{SGR (kg}^{0.8}\text{ day}^{-1}) = \frac{100 * (l_n M_f - l_n M_i}{D} \tag{5}$$

where, M_f is the final weight of the fish, M_i is the initial mass of the fish, l_n is the natural logarithm and D are the culture.

Metabolic Growth Rate (MGR) and the Feed Conversion Efficiency (FCE) can been computed with the methodology exposed on the work of Frei and Becker (2005):

$$\text{MGR} = \frac{\left[(M_f - M_i)/((M_f + M_i/2000))^{0.8}\right]}{D\{\text{kg kg}^{-0.8}\text{day}^{-1}\}} \tag{6}$$

where, M_f is the final mass of the fish, M_i is the initial mass of the fish and D are the interval time (in days). For FCE:

$$\text{FCE} = F/(M_f\text{-}M_i) \tag{7}$$

where, M_f is the final mass of the fish, M_i is the initial mass of the fish and F is the dry weight of the feed.

Individual fish growth: In hatchery or nursery system is also important the length of the fish. Both variables (weight and length) are related by the next equation (Sparre and Venema, 1998):

$$W_{(i)} = a \times L(i)^b \tag{8}$$

where, $W_{(i)}$ is the weight for the ith fish, L(i) is the total length of the fish and the letters a and b are the growth parameters obtained by linearization.

In many cases is useful to predict the increment of the length and weight of the fish in a given time. It can be achieve using potential growth model. A very popular model among fish researchers is the von Bertalanffy's growth function:

$$L_t\text{ (mm)} = L_l\,(1\text{-exp}^{(-k\,(t\text{-}to))}) \tag{9}$$

where, L_t is the total length of the fish on time t, L_l is the maximum total length at infinite time, k is the growth constant, t_0 is the initial time to growth and t is time. In the case of weigh, the equation is the following:

$$W_t\text{ (g)} = W_l\,(1\text{-exp}^{(-k\,(t\text{-}to))})^2 \tag{10}$$

where, W_t is the total weight of the fish on time t, W_l is the maximum total weight at infinite time, k is the growth constant, t_0 is the initial time to growth and t is time (Pauly, 1983).

RESULTS AND DISCUSSION

Total biomass production: Soto-Zarazua *et al.* (2010) cultivated 1,200 tilapia fish fingerlings on circular tanks with a capacity of 20 m^3. The average initial weight was 20 g and after 180 days the weight of all the fishes was measured. Applying the formula 1, the total biomass production on one tank was 580.33 kg. For relative biomass production (Eq. 2):

$$\text{Prel} = \frac{W_t}{V} = \frac{580.33\text{kg}}{20\text{m}^2} = 29.016\text{kgm}^{-1} \tag{11}$$

The initial total weight gain assumed 1,200 fish and 20 g per fish was 24 kg. For Eq. 3:

$$\text{TWG} = M_f\text{-}M_i = 580.33\text{ kg-}24\text{ kg} = 556.33\text{ kg} \tag{12}$$

And the average daily growth rate per tank, according to Eq. 4:

$$\mathrm{ADGR} = \frac{\mathrm{TWG}}{\mathrm{D}} = \frac{556.33\mathrm{kg}}{180\mathrm{days}} = 3.09\mathrm{kgm}^{-1} \qquad (13)$$

The Specific Growth Rate (SGR) was:

$$\mathrm{SGR} = 100 \times \frac{l_n\mathrm{M_f} - l_n\mathrm{M_i}}{\mathrm{D}} = 100 \times \frac{(l_n(580.33) - l_n(24\mathrm{kg}))}{180} = 1.77 \qquad (14)$$

Metabolic Growth Rate (MGR) and the feed conversion efficiency (FCE) can been computed with the methodology exposed on the work of Frei and Becker (2005):

$$\mathrm{MGR} = \frac{\left[(580.33\ \mathrm{kg} - 24\ \mathrm{kg}) / ((580.33\ \mathrm{kg} + 24\ \mathrm{kg}/2000))^{0.8}\right]}{180} = 1.173\ \mathrm{kg\ kg^{-0.8}\ day^{-1}} \qquad (15)$$

In addition, there was reported 940.13 kg of feed consumed during the experiment, so the feed conversion efficiency was:

$$\mathrm{FCE} = \frac{940.13\ \mathrm{kg}}{(580.33\ \mathrm{kg} - 24\ \mathrm{kg})} = 1.6899 \qquad (16)$$

Individual fish growth: In 2006, Alatorre-Jacome measured the following data for length and weight on *M. salmoides* located in a small lake in center México (Table 1).

Fitting the data for an exponential model ($r^2 = 0.97$) the specific length-weight relation was:

$$W_{(i)} = 1.08(10^{-5})\, L(i)^{2.05} \qquad (17)$$

To obtain the parameter for Von Bertalanffy equation, K and L_0 there are several methods. In this case we used the following. In literature, the propose value $L_\infty = 358.4$. With the data of age and length (Table 2), in a third column there was calculated:

$$y = -[\mathrm{In}\,(1 - l_t/l_{1t})]\ 1.08\ (10^{-5})\, L(i)^{2.05} \qquad (18)$$

Plotting the values of the first and the third column, there was obtained by linear regression ($R^2 = 0.9971$) the parameters a = 0.33, which is the value x at y = 0 and b = 0.3255, the slope of the line. The value K = b and T_0 was:

$$t_0 = -\frac{a}{b} = -1.015 \qquad (19)$$

And the Von Bertalanffy's weight equation for this population is:

$$L_t = 358.4\ (1 - \exp^{(-0.32s(t+1.01s))}) \qquad (20)$$

Table 1: Length and weight measured on largemouth bass (*M salmoides*) on Camecuaro Lake, 2006

No.	Length (mm)	Weight (g)	No.	Length (mm)	Weight (g)
1	158	55	18	193	89
2	164	73	19	194	95
3	166	68	20	197	102
4	167	76	21	200	118
5	172	73	22	205	120
6	175	68	23	212	121
7	176	71	24	213	138
8	176	67	25	215	136
9	177	80	26	220	134
10	179	84	27	228	157
11	183	86	28	233	173
12	183	79	29	238	171
13	186	87	30	241	212
14	186	88	31	254	246
15	188	93	32	264	271
16	189	83	33	340	606
17	189	83			

Table 2: Linearization of time (age) and length values to parameter determination on von Bertalanffy's equation

t (x)	Lt	-[Ln (1-(Lt/L∞))] (y)
1	174.3	0.666170593
2	221.4	0.961668755
3	262.4	1.31730149

Calculating the fish weight at L_∞, we obtain $L_\infty = 652.07$, so the Von Bertalanffy's weight equation is:

$$W_t = 652.07\ (1 - \exp^{(-0.32s(t+1.01s))}) \qquad (21)$$

DISCUSSION

There are many different values for productivity index on literature, which explained the global performance for one system. In this case, the value of 29 kg m^{-3} is obtained. Timmons *et al.* (2002) recommended less than 40 kg m^{-3} for systems with blower. However, Rakocy *et al.* (2006) reported densities of 60 kg m^{-3} for aquaponic systems. In extensive systems, Sarker *et al.* (2005) reported lower values (479 kg ha^{-1}) even with strains of genetically improved farm tilapia. The principal causes of productivity are due to managing practices, temperature (Ghosh *et al.*, 2008; Sarkar *et al.*, 2007) and water quality factors in culture water (Hossain *et al.*, 2007).

In ADGR, the index can be used to make more accurate feed management schedules. A variation can be made with the data, dividing ADGR by number of fishes. Then the average day growth rate per fish can be obtained. In this case, 2.57 g day^{-1} fish^{-1} is reported. Rezk *et al.* (2002) reported ADGR from 1.87 g day^{-1} fish^{-1} in *O. aureus* after 35 days of culture. This value is lower than the observed on Soto-Zarazua *et al.* (2010) but the main difference is than Rezk cultured fingerlings, who have a different metabolism than adults. In other hand, Liti *et al.* (2005) reported ADGR from 0.06 to 1.5 g day g day^{-1} fish^{-1} found on tilapia fed on two formulated diets with locally available feed in Kenia.

From SGR, Akinwole and Faturoti reported SGR from 2.656 to 2.86 measured on *C. gariepinus* cultivated in recirculating aquaculture system. Velazquez and Martinez (2005) reported 0.97 and 0.86 for *C. auratus*. Hlophe *et al.* (2011) reported SGR values lower than 1.7 in *T. rendalli* fed with kikuyu grass.

On the other hand, Cho and Bureau (2001) suggested the elimination of the parameter due to the non-realistic approaching of its calculation. In MGR, the index is used in nutritional studies. Richter *et al.* (2002) reported several index (From 1.76 to 5.04 g kg^{-1} day^{-1}) in order to assess a more convenient maintenance diet formulations in red tilapia. At last, the feed conversion efficiency of 0.59 means that almost 60% of the mass provided for the tilapia was assimilated as tissue. This is very convenient, due the requirements of the fish to its energy for respiration and the balance of non-assimilated food.

In the example presented for individual fish weight, it can be observed that in Eq. 16 the parameter b˜3.05. When the parameter $b = 3$, the growth is called isometric and if $b<3$ is called allometric negative and if $b>3$ is allometric positive (Pauly, 1983). So we can see that the fish measured have a good increment of weight. For the equations of von Bertalanffy's equations, the parameter k is very important, because is the growth constant and is species specific (Lv and Pitchford, 2007). For this case, in the study of Guzman-Arroyo made 35 years earlier in the same place, the value was $k = 0.56$, so we can assume that the conditions were more favorable to a faster growth for *M. salmoides*.

CONCLUSION

Selected fish biometric indexes were presented in this work. The use of the parameters mentioned can bring more information for the intrinsic factors in the fish culture that influenced growth. They also allow the comparison between different populations in space and time. This paper can be used as a quick guide to measure fish productivity in small systems. The following parameters can be used by scientist or producers to compare different systems each other.

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