MULTIPLE COMPARISONS OF MEANS VS. REGRESSION ANALYSIS IN AQUACULTURE RESEARCH

Steeve Pomerleau

Extension Aquaculture Specialist
All I have to do is compare treatment means to see whether they are significantly different from each other.
WARNING
This approach is often inappropriate for the type of data being analyzed

What?
Tip of the Day

- Research Objectives
- Experimental Designs
- Data Analysis

Need to be adapted to the type of treatment variables under study
Comparing treatment means for significant differences is appropriate ...

- in “unstructured” experiments
- with qualitative treatment variables
  - species
  - brands of feed
  - chemicals
  - Etc.
Comparing treatment means for significant differences is appropriate ...

- in “unstructured” experiments
- with qualitative treatment variables
  - species
  - brands of feed
  - chemicals
  - Etc.

**OBJECTIVE:** Find which treatment gave the best results.
Comparing treatment means for significant differences is **inappropriate** ...

- in “structured” experiments
- to compare several levels of a **quantitative or continuous** variable.
  - Nutrient input levels
  - Stocking densities
  - Feeding rates
  - Etc.
Regression Analysis should be performed

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- to compare several levels of a quantitative or continuous variable.
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Regression Analysis should be performed:

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  - Etc.

OBJECTIVE: Estimate and identify trends or relationship.
• Multiple comparisons of treatment means are too often inappropriately used.

• Regression analysis is too often ignored.
Comparing treatment means in structured experiment is not wrong per se...
When comparing several levels of a quantitative variable

• more valuable information can be attained with the same amount of resources if…
  – a regression analysis
  – optimized experimental design
were used.
This problem has been raised in the literature


“multiple range test is very often inappropriately used to compare treatments that are factorial in nature or that correspond to several levels of a quantitative or continuous variable.”

“Pairwise, multiple comparisons are appropriate only for comparing unstructured, qualitative treatments.”
This problem has been raised in the literature


“How do we persuade biologists of the futility of significance testing between mean responses (ordinate value of \( y \)), at series of dose-rates (abscissa values of \( x \)), along response curves?”
This problem has been raised in the literature


“The sad consequence of this syndrome is that useful inferences are usually lost”
This problem has been raised in the literature


“Although the statistical community is quite clear on this point, the aquaculture community (among other scientific disciplines) has yet to appreciate the inappropriateness and gross inefficiency of multiple range test usage in analyzing structured experiments.”
This problem has been raised in the literature


“too often scientists use multiple range tests to compare treatment means for structured experiment, completely ignoring hypothesized relationships and interactions incorporated into the experimental design.”
This problem has been raised in the literature


“It has gotten out of control via a positive feedback loop; the more scientists see multiple range tests used, the more they feel encouraged to use them.”
Production of Stocker-Size Channel Catfish: Effect of Stocking Density on Production Characteristics, Costs, and Economic Risk

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Pine Bluff, Arkansas, 71601, USA

Abstract—A study of the production of stocker channel catfish Ictalurus punctatus in earthen ponds was conducted to analyze the effect of stocking density on net yield, growth, final size, feed conversion ratio, and cost of production. Var-graded catfish fingerlings averaging 2.5 g (6.7 cm) were stocked into twelve 0.1-ha earthen ponds at 50,000, 100,000, or 150,000 fingerlings/ha. Fish were fed to satiation and harvested 166–171 d after stocking. Net yields (±SD) for the low-, medium-, and high-density treatments were 4.34 ± 1.025, 6.220 ± 399, and 7.231 ± 1.490 kg/ha, respectively. Fingerlings stocked at the lowest density reached a size significantly larger (176 ± 29 g or 26.9 ± 1.4 cm) than fingerlings stocked at medium density (135 ± 10 g or 24.8 ± 0.6 cm) or high density (114 ± 23 g or 23.4 ± 1.4 cm). Mean condition factors ranged from 0.88 to 0.91. Mean survival rates ranged from 45% to 51%. The equation that best (R² = 0.97) predicted fish length from weight was \( \log(L) = 1.649 + 0.318 \log(W) \), where \( L \) = total length in centimeters and \( W \) = fish weight in grams. Bar spacings of 16.1, 22.2, 25.4, 28.6, 31.8, and 34.9 mm retained fish predominantly larger than 16, 18, 21, 23, 26, and 28 cm, respectively. The lowest break-even cost per kilogram of fish produced ($1.57) came with the medium-density treatment. Break-even costs for the low- and high-density treatments were $1.68/kg and $1.60/kg, respectively. The probability of break-even costs per kilogram being above the stocker market price of $2.20/kg ranged from 0% to 9%. The study suggested that the medium stocking density (100,000/ha) gave the lowest cost and lowest risk strategy in terms of cost per kilogram. However, additional research is necessary with whole-farm modeling to determine whether this strategy would be the most profitable farm-level strategy for a grow-out operation.

The U.S. channel catfish Ictalurus punctatus industry has experienced tremendous growth since the 1980s. The total round weight of catfish processed increased from 21,000 metric tons in 1980 to 271,000 metric tons in 2001 (USDA). Despite a general increase in total catfish production, yield (production per unit of water area) appears to have leveled off in recent years within a range of 3,000–4,000 kg/ha (USDA). Generally increasing costs over time, combined with an apparent lack of gain in productivity, have resulted in declining profit margins in catfish farming over time (Engle and Kouka 1996). Hence, catfish farmers are seeking refined management strategies to improve farm efficiency and profitability. Production of stocker triple-batch grow-out ponds, a few farmers have added an intermediate step of producing stockers in single-batch production. In this three-phase system, fingerlings are raised to stocker size in separate ponds for one growing season before being transferred to grow-out ponds. Keeping accurate inventory records in such a three-phase system is easier when a larger portion of the cycle is under single-batch production. Moreover, using stocker-size fish increases control and predictability of the grow-out phase. Producing stockers in separate ponds may also be justified on the basis of more efficient use of rearing pond space and an increase in overall productivity of the pond. Periodic division of the stock reportedly
Production of Stocker-Size Stocking Density on Prof. and Econ.

STEVE POMERLEAU AND

Agriculture/Fish
University of Arkansas
Post Office Box 4912, 126
Pine Bluff, Arkansas

Abstract.—A study of the production of stocker ponds was conducted to analyze the effect of size, feed conversion ratio, and cost of production. Various stocking rates were used, with fish weighing 150-171 g and high-density treatments were 4.3 kg/m². High stocking rates resulted in lower yields and higher costs. The study suggested that the lowest cost and highest productivity in terms of the lowest cost and highest productivity in terms of economic benefits is necessary with whole farm modeling to determine profitability and final economic efficiency.

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The objective was... 

To analyze the effect of stocking density of catfish fingerlings on yield, fish size at harvest, survival, and FCR.
Method

• Three treatments
  – 20,000 fing./ac
  – 40,000 fing./ac
  – 60,000 fing./ac

• Four replicate ponds per treatments
## Results

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- ANOVA was used to test for treatment effect
- Fisher’s LSD test was used to evaluate the difference among means
The objective was...

To analyze the effect of stocking density of catfish fingerlings on yield, fish size at harvest, survival, and FCR.
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Did I really get a good understanding of the relationship between stocking density and the various production parameters?
The objective was...

To analyze the effect of stocking density of catfish fingerlings on yield, fish size at harvest, survival, and FCR.

Did I really get a good understanding of the relationship between stocking density and the various production parameters?

NOT REALLY
$y = 0.0634x + 2769$

$R^2 = 0.5898$
$y = 2349.7 \ln(x) - 19380$

$R^2 = 0.6095$
Replication

- Replication in “structured” experiment is not necessary.

- In fact, there is often only one treatment, with several levels of that treatment.

- In a regression analysis, there is no reason to replicate each level since the residual (experimental error) is not based on within-level variation.

- The residual is based on the differences between observed and predicted values of the model.
**Sources of Variation in ANOVA testing**

To test treatment means:

- **Total**
  \[
  [X_{ij} - \bar{X}]
  \]

- **Groups (i.e. among groups)**
  \[
  [\bar{X}_i - \bar{X}]
  \]

- **Error (i.e. within-groups)**
  \[
  [X_{ij} - \bar{X}_i]
  \]

To test a regression:

- **Total**
  \[
  [Y_i - \bar{Y}]
  \]

- **Linear Regression**
  \[
  [\hat{Y}_i - \bar{Y}]
  \]

- **Residuals**
  \[
  [Y_i - \hat{Y}_i]
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| **Error (i.e. within-groups)** | \[X_{ij} - \bar{X}_i]\(|\]

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| **Residuals**      | \[Y_i - \hat{Y}_i]\(|\]

\[XX \] refers to the total variation, \[XXi\] refers to the variation among groups, and \[iij XX\] refers to the variation within groups.
Net Yield (lb/ac)

Stocking Rate (fish/ac)

\[ y = 0.0634x + 2769 \]

\[ R^2 = 0.5898 \]
Net Yield (lb/ac) vs. Stocking Rate (fish/ac)

Regression Equation:
\[ y = 0.0634x + 2769 \]

Coefficient of Determination:
\[ R^2 = 0.5898 \]
The relationship between Stocking Rate (fish/ac) and Net Yield (lb/ac) can be described by the linear equation:

\[ y = 0.0675x + 2654.5 \]

with a coefficient of determination, \( R^2 = 0.8068 \). This indicates a strong positive correlation between the two variables.
Advantages of the Regression Analysis

If the regression is significant then all levels are significantly different in their effect.
The relationship between the net yield (lb/ac) and the stocking rate (fish/ac) is given by the linear equation:

\[ y = 0.0675x + 2654.5 \]

with a coefficient of determination \( R^2 = 0.8068 \).
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Conclusion

Is it more meaningful to you…

to find the relationship between the quantitative variables under study?
or
to establish which is significantly different?