# Species Selection for Smallholder Aquaculture

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### Introduction

Systems for selection of species for translocation or aquaculture based on estimates of their growth rates under natural and/or culture conditions were proposed (Moreau et al. 1986; Pauly et al. 1988). Mathews and Samuel (1990, 1992) fused these estimates with data on the market value of a species to generate a general bioeconomic selection index for identifying candidate species for aquaculture.

The general approach of combining a growth-rate estimator and an economic indicator is probably a good one for situations where it is possible and/or economically realistic to simulate natural diets with prepared foods. Most commercially-cultured species are grown on prepared diets which have been formulated to optimize growth and flesh quality and are often expensive. With experience, one should theoretically be able to estimate the cost of such a diet for any particular species based on its natural food preferences and/or tissue analyses and combine this with an index such as that suggested by Mathews and Samuel (1992).

In subsistence-level aquaculture, feed materials are in short supply and many potential ingredients have competitive uses in other farm enterprises. Matching a fish's optimal needs with a prepared diet is thus often impractical or impossible. Under these conditions, comparing the availability of natural foods in the pond with the food preferences of a species (combined, of course, with growth and profitability factors) might be more useful for making decisions about culture species and management.

Tang (1970) compared food resources and dietary habits in multispecies carp polyculture using rough estimates of food preference, categorizing the various carp species as phytoplanktophagic, zooplanktophagic, detritophagic, etc., but without considering that individual species actually take advantage of a range of foods.

### Food Fits

This contribution suggests categorizing pond food resources into a few categories based loosely on the intrinsic traits of the food which affect their "selectivity" by predators as discussed by Ivlev (1961). For example, for the species and pond systems in Malaŵi, food resources might be categorized as follows:

I. Plankton (phyto + zoo)
II. Macro-invertebrates (insects, aquatic crustaceans, etc.)
III. Macrophytes (including filamentous algae)
IV. Vertebrates (especially other fish)

The logic of using such groups is that fish may not actually be choosing individual species as much as they choose a feeding habit which then determines what food items they will gather. To give an indication of how well a particular fish species might fit into the pond culture environment, the frequencies of organisms of these "food groups" in the stomach and/or gut and in the pond system to which they would be stocked might then be compared. The following example uses *Oreochromis shiranus* stomach content data from Bourn (1974) and aquatic food resource data from Tang (1970). The numbers represent frequency of individual groups within the total stomach contents, or representative portion thereof.

| | Plankton | Inverte-brates | Plants | Fish |
|---|---|---|---|---|
| Tainan Pond | 0.925 | 0.05 | 0.015 | 0.01 |
| Taoyuan Reservoir | 0.59 | 0.06 | 0.32 | 0.03 |
| *O. shiranus* stomach | 0.67 | 0.00 | 0.28 | 0.05 |

Taking the average of the absolute value of the difference between food available and food consumed for each food group gives a general indication of the fish's "food fit" ($F_f$) with the proposed culture environment:

Pond: (0.925-0.67) + (0.05-0) + (0.015-0.28) + (0.01-0.05)/4 = 0.15
Reservoir: (0.59-0.67) + (0.06-0) + (0.32-0.28) + (0.03-0.05)/4 = 0.05

A perfect fit using this method would be represented by zero value. A perfect mismatch would give a value of 0.5. In this case, the reservoir would be the better of the two environments for growing *O. shiranus.*

Stomach content data from Brummett and Katambalika (1996) for adult *Barbus paludinosus,* a small planktivorous cyprinid, indicate the pond to be the better environment:

Pond: (0.925-0.97) + (0.05-0.03) + (0.015-0) + (0.01-0)/4 = 0.023
Reservoir: (0.59-0.97) + (0.06-0.03) + (0.32-0) + (0.03-0)/4 = 0.19

Working an example for *Clarias gariepinus* with data from Bruton (1979) gives the following:

Pond: (0.925-0) + (0.05-0.25) + (0.015-0) + (0.01-0.75)/4 = 0.47
Reservoir: (0.59-0) + (0.06-0.25) + (0.32-0) + (0.03-0.75) = 0.46

These numbers, being close to maximal mismatch, indicate that neither environment is good nor adequate, but the reservoir has slightly more of what is needed than does the pond.

The *Aristichthys nobilis* x *Hypophthalmichthys molitrix* hybrid is even more restricted in its feeding habit (being entirely planktivorous) than is the predominantly piscivorous *C. gariepinus* (at least as it is described in Bruton (1979), but see comments from Munro (1967)). The use of stomach content data from Bayne et al. (1991) in which these hybrids were grown in cages suspended in ponds of differing trophic status resulted in $F_f$ values of 0.04 for the pond and 0.21 for the reservoir, reflecting the greater abundance of plankton in the pond and hence greater suitability for the filter-feeding hybrid.

In selecting a culture species for Tainan Pond, a comparison of the $F_f$ values for *O. shiranus, B. paludinosus, C. gariepinus* and Chinese carp hybrids would lead to the planktivorous barb ($F_f$ = 0.023) over the hybrid carp ($F_f$ = 0.04), followed by the more omnivorous tilapia ($F_f$ = 0.15), and the piscivorous catfish ($F_f$ =0.47). For growing in the reservoir, tilapia ($F_f$ = 0.05) would be selected over the barb ($F_f$ = 0.19), the carp ($F_f$ = 0.21), and the catfish ($F_f$ = 0.46) (Fig. 1).

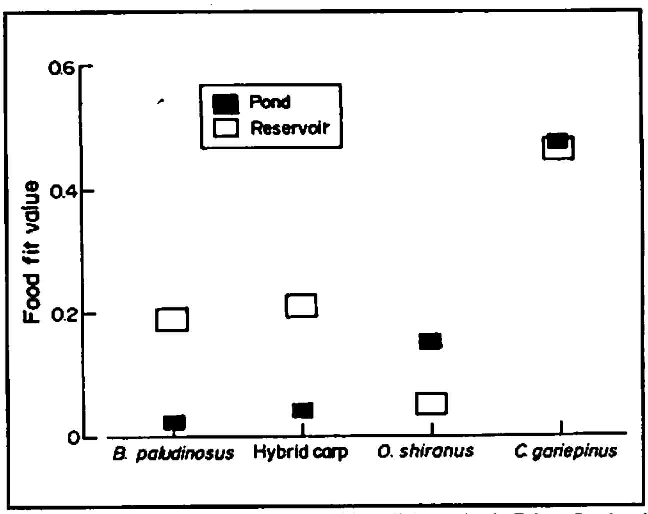


*Fig. 1. Theoretical food fits ($F_f$) of four African fish species in Tainan Pond and Taoyuan Reservoir in Taiwan.*

## Management Decisions

Using this technique, potential polycultures might also be compared with each other and with monocultures. For example, if 1 000 *O. shiranus* (average weight 25 g) are stocked together with 100 *C. gariepinus* (average weight 50 g), discounting the food value to the catfish of tilapia fry, the polyculture would have an $F_f$ of 0.19 for the pond and 0.07 for the reservoir:

| | Plankton | Invertebrates | Plants | Fish |
|---|---|---|---|---|
| Tainan Pond | 0.925 | 0.05 | 0.015 | 0.01 |
| Taoyuan Reservoir | 0.59 | 0.06 | 0.32 | 0.03 |
| *O. shiranus* stomach | 0.67 | 0.00 | 0.28 | 0.05 |
| *C. gariepinus* stomach | 0.00 | 0.25 | 0.00 | 0.75 |
| Polyculture stomach* | 0.56 | 0.04 | 0.23 | 0.17 |

* Polyculture stomach content frequencies = $\frac{[(W_t \times FF_t) + (W_c \times FF_c)]}{(W_t + W_c)}$

where $W_t$ = weight of tilapia, $W_c$ = weight of catfish, $FF_t$ = food frequency in tilapia stomach, and $FF_c$ = food frequency in catfish stomach.

A qualitative examination of imbalances between food needs and availability might be used to design input regimes. For example, adding chopped macrophytes to the Tainan Pond at a rate which would balance the need and availability of this food for *O. shiranus* improves the $F_f$ for that species in that environment from 0.15 to 0.09. If *O. shiranus* offspring in the polyculture example satisfy the need of catfish, the whole system has an $F_f$ of 0.15 in the pond and 0.04 in the reservoir. Adding chopped macrophytes to the polyculture to meet the needs of the tilapia further improves the match to 0.09 in the pond and 0.01 in the reservoir.

## Economic Criteria

Under a specific environmental regime, and for species known in local markets, one could combine the $F_f$ values of various species under monoculture with their particular market price to get a proper "bioeconomic" selection index: (marked price x $1/F_f$). Price data from Domasi, Malaŵi, and the inverse of the $F_f$ values in Tainan Pond for each of the three species indicates that the higher the bioeconomic index, the better the candidate:

| | Market price (Mk/kg)[a] | 1/Pond $F_f$ | Bioeconomic index |
|---|---|---|---|
| *O. shiranus* | 5.0 | 6.67 | 33.35 |
| *C. gariepinus* | 15.0 | 2.13 | 31.95 |
| *B. paludinosus* | 3.3 | 43.48 | 143.48 |

[a]US$1 = Malaŵi Kwacha 15.

Although tilapia fits much better into the pond ecosystem than does the catfish (0.023 *vs.* 0.47, see above), its relatively low market value renders it only slightly better as an aquaculture candidate. On the other hand, the low market value of *B. paludinosus* is more than compensated for by the high efficiency of the production system for this species.

A final decision as to which species to choose would, of course, have to be made based on the carrying capacity of the system for each of these species. One might be able to make some assumptions based on the trophic level at which each species feeds, although this information has been largely submerged in the choice of the food categories used here. It might also be possible to use natural standing stocks or calorific value of stomach contents, but these are more labor-intensive methods. Since other factors in addition to growth and market value (particularly stress resistance and a ready supply of seed) can be of critical importance to the success or failure of a culture candidate, it might be just as rewarding to bring the leading candidates onto the experiment station at this point and make direct measurements of carrying capacity and other important traits.

## Conclusions

The simple method of using the frequency of individual items from the various food groups is, admittedly, not very precise for describing a fish's diet. For example, differences in digestibility between food groups could be a major source of error. Detritus in the diet is difficult to quantify and overlaps with other food groups. However, the advantages of this simple technique may outweigh the disadvantages. At least some of the disadvantages are common to most techniques of stomach content analysis. For the omnivorous and detritivorous species, which are important in small-scale tropical aquaculture, these limitations can only be overcome by using much more resource- and labor-intensive methods (Krebs 1989; Ahlgren and Bowen 1992). With the simple method described here, for example, it is not necessary to have data on degree of stomach fullness or to have measures of number or weight of food items per unit weight of stomach contents. Thus, very different sorts of datasets can be utilized, making it unnecessary to repeat work that has already been published under different standard conditions.

Munro (1967) points out the changing dietary patterns of *C. gariepinus* over time and suggests that generalizing their diet would thus be extremely difficult. This argument is probably equally valid for any opportunistic species, within which group the majority of tropical aquaculture fish species could arguably be placed. On the other hand, the categories suggested are broad enough to take into consideration seasonal changes in the availability of specific food items, as long as the alternative to which a fish species turns is in the same grouping; a condition which is probably not too difficult to meet. At any rate, too high a precision is even ecologically meaningless since, as Ivlev (1961) points out: "[While] it must be admitted that the selective faculty is...to be found in all animals without exception...[its manifestation] depends upon a whole number of features, of which some...are characteristic of the feeding animal, whereas others are wholly the traits of the food objects." It would certainly be important to review data from as wide a variety of ecosystems as possible when making selection decisions, and for species which are more omnivorous or opportunistic, non-dietary criteria might turn out to be more valuable.

It would be unwise to risk large amounts of time or money on a dogmatic adherence to this or any other recipe for choosing culture species. However, as a preliminary screening and management tool this approach may have some merit. To test it further, more stomach content and pond resource data from more species and environments are needed.


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