Four Economic Models of Fisheries Management Programs for Ponds or Small Lakes

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On the Hoosier National Forest in the late 1950's and early 1960's, wildlife waterholes (generally too small or shallow for efficient fish production) began to be supplemented by small fishing ponds of 1 to 3 acres. After initial stocking, these waters generally received little fish management attention. Often the State fisheries agency was too restricted by lack of time, funds, and personnel to devote much management attention to these mini-waters. The Forest Service lacked personnel to do this work, and also had doubts that its responsibilities extended to manipulation and management of this pond fishery resource. These ponds were constructed, stocked, and orphaned (i.e., largely ignored), except that Forest wildlife biologists noted the beaten paths around the shores.

This angler-use, despite the absence or insufficiency of management, has led Forest Service wildlife and fisheries personnel to wonder how much recreational use these small ponds (under 5 acres) could provide if properly managed. In addition, are there recreational benefits sufficient to make them economically feasible? The economic measurement of these small waters is more difficult than the environmental, because small ponds have seldom been evaluated on a benefit/cost scale. Even rarer, or non-existent, is an economic evaluation of a complete program consisting of a large series of ponds. Even when ponds or small lakes have been evaluated economically, they have been judged on the before-and-after change in fishing use (a quantitative factor) rather than any change in fishing quality, or better still, a combination of both quantitative and qualitative changes.

In measuring recreational benefits of lakes or ponds, fisheries managers have usually assigned a mean figure as the value of a "fishing day." If, for instance, the assigned value of a fishing day (or trip) is $7.00, this figure is applied equally to waters of low fishing quality as well as to waters of highly productive fishing. It would seem obvious that more productive waters have a higher intrinsic value to the fisherman.

These economic models developed in this study are based upon four arbitrary fishing quality categories (poor, medium, good, and excellent) with different trip values assigned to each. By basing the value of a fishing trip on the potential quality of the experience, the fisheries manager can measure economically the impact of his management practices, and determine their cost effectiveness.

Th subsequent pond program models are based upon a series of 50 ponds (roughly equating to the Hoosier National Forest situation). For convenience, the average size used is one acre, which may be slightly lower than the actual forest average. An explanation of various components of these models (many having arbitary judgment factors) may best be done by taking each of the basic elements (horizontal elements A-D and vertical elements I-VIII) in order.

Horizontal Elements of Models (A-D)

Qualitative: Gives a value preference to waters of good fishing quality over those waters of poorer fishing quality. (No fishing: 0%; poor fishing quality: 25%; medium: 50%; good: 75%; and excellent: 100%).

Vertical Elements of Models (I-VIII)

Element 1: This is merely an arbitrary assignment of categories for a 50-pond program which had largely been in place for eight years or more years with no management. The assignment of ponds to quality categories is based on my forecast of what I would expect to find were I to survey these 50 ponds at present (Table 1).

Element II: The fishing use component (U) is measured in visitor-days (i.e., the aggregate of 12 hours of fishing, whether by one individual fishing 12 hours or 12 individuals fishing one hour each). I have used an average fishing use of .125 V-D per day per pond, which represents 1½ fisherman-hours/pond/day.

D = Days in fishing season (without ice fishing considered).

V = Value: The value assigned to a day of fishing; in these models the value used is $21/day for a 12-hour fishing day.

G = Value Gradient: The quality index (a percentage of potentially attainable fishing quality). The percentage gradient for the particular category × the value of a visitor-day of excellent fishing ($21) gives the fishing day value for other categories (e.g., good: $21 × 75% = $15.75; medium: $21 × 50% = $10.50; poor: $21 × 25% = $5.25).

P = Number of ponds in the particular category. In these models: 0 in excellent; 5 in good; 10 in medium; and 35 in poor.

Element III: Surveys (S). This is the cost of determining the present status of ponds by fisheries surveys. This is based on one crew-day per pond.

Biologist	$ 60.00
Assistant	30.00
Operation and Maintenance	40.00
	$130.00/survey

Element IVa: Renovation (R). This is the cost of chemical renovation of ponds. It is estimated that a two-man crew could do 2 ponds per day. Further, it is assumed that renovation would be needed every eight years. Total costs for a renovation process are prorated over the eight-year cycle to get an annual cost figure.

Biologist	$30.00
Assistant	15.00
Chemicals	25.00
Operation and Maintenance	10.00
	$80.00/Renovation

TABLE 1. *"Core" data—vertical elements I-IV.*

Economic Model I For Small Pond Program	(A) Ponds of Excellent Fishing Quality (Value Gradient : 100%)	(B) Ponds of Good Fishing Quality (Value Gradient : 75%)	(C) Ponds of Medium Fishing Quality (Value Gradient : 50%)	(D) Ponds of Poor Fishing Quality (Value Gradient : 25%)	(T) Annual Totals For 50-Pond Management Program
I Estimated present acres of:	0	5	10	35	50
II Present fishing benefits per year (B_A, B_B, B_C, B_D, B_T @ $21/visitor-day for excellent quality fishing:	(1) .125 V-D•200•$21 = $525 (2) $525•100%•0 = $0	$1968.75 (1) .125 V-D•200•$21 = $525 (2) $525•75%•5 = $1968.75	$2625.00	$4593.75	$9187.50
III Cost of determining present status (i.e., fisheries surveys) @ $130/pond:	a. Annual surveys: $0/yr	$650/yr	$1300/yr	$4550/yr	$6500/yr
	b. Biennial surveys: $0/yr	$325/yr	$650/yr	$2275/yr	$3250/yr
	c. Triennial surveys: $0/yr	$217/yr	$433/yr	$1517/yr	$2167/yr
IV a. Cost of renovation @ $80/acre/or. $10/acre/yr.	$0/yr	$50/yr	$100/yr	$350/yr	$500/yr
b. Cost of restocking @ $40/acre or $5/acre/yr.	$0/yr	$25/yr	$50/yr	$175/yr	$250/yr
c. Cost of other management @ $20/acre/yr.	$0/yr	$100/yr	$200/yr	$700/yr	$1000/yr

Element IVb: Restocking (R_s). The cost of the restocking project is, like renovation, based upon an eight-year cycle, and costs prorated over the period to calculate annual costs.

Element IVc: Other management (O_m). This component includes costs of other management practices such as aquatic weed control, creel censuses, structure examination and maintenance, access maintenance, etc. These are combined into a single, arbitrary estimate of $160 for the eight-year period ($20/pond/year).

Element V: Total Management Costs. The foregoing elements (I-IV and A-D) make up the data base or "core" of the models (Table 1). This element and those that follow (V-VIII) I have termed "subcore" data (Table 2). Element V is the summation of III and IV and merely makes their combined values more evident and visible.

Element VI: Benefits-Foregone (B′). Benefits-Foregone is a means of measuring benefits *that would have accrued* had we done something differently (e.g., if we had provided 6 lakeshore picnic tables; had we installed a mile-long nature trail; or if we had provided management which maintained ponds at excellent fishing quality). If by installing a certain facility or practice, we could attract a certain number of additional users, at a certain cost per user, then this amount (over and above what we presently have) is benefits-foregone—we forego them by lack of a picnic table, a trail, or a pond management program. In these models I have supposed that intensive fisheries management of small ponds could raise a pond's fishing quality no more than one category except that ponds having no fishing or having "poor" quality fishing could be raised 2 classes to "good." This is the postulate upon which B′ computations are based. I have assumed that with a pond management program in operation, the "poor" and "medium" ponds would be improved to "good" quality and the "good" ponds to "excellent." It is a simple matter then to derive the annual lost benefits (B'_A, B'_B, B'_C, B'_D, B'_T). From benefits accruing under management, one merely subtracts present benefits in the absence of management.

Element VII: This (like Element V) is simply an addition of two elements from the model (II and VI). Again, the intent is merely to make the total recreational benefits more visible in the model.

Element VIII: The benefit-cost ratio has become so prevalent in the past twenty years that I doubt that it needs any explanation. The projected benefits of a proposed project are divided by the costs of that proposal and it is presumed that a project having a ratio greater than 1.0 is economically feasible. Herein, I have not included Element II benefits, since they are actually benefits accruing under a system of no management, thus are not legitimately attributable to the pond management program being measured in the model. Only the benefits-foregone (i.e., the calculated additional benefits that would accrue were the management program installed) are weighed against the costs of that management program.

These elements are the data required to build an economic model of most recreational activities, not merely for fishing.

TABLE 2. *"Sub-core" data—vertical elements IV-VIII.*

Economic Model I For Small Pond Program	(A) Ponds of Excellent Fishing Quality (Value Gradient : 100%)	(B) Ponds of Good Fishing Quality (Value Gradient : 75%)	(C) Ponds of Medium Fishing Quality (Value Gradient : 50%)	(D) Ponds of Poor Fishing Quality (Value Gradient : 25%)	(T) Annual Totals For 50-Pond Management Program
V Survey and management costs (III & IV) with:					
a. Annual surveys.	$0/yr	$825/yr	$1650/yr		$8250/yr
b. Biennial surveys	$0/yr	$500/yr	$1000/yr		$5000/yr
c. Triennial surveys:	$0/yr	$392/yr	$783/yr		$3917/yr
VI Benefits-foregone: (i.e., potential recreation benefits that *could* be gained by instituting a management program that would improve	$0/yr	$656.25/b-f/yr "Excellent" fishing value/pond/yr ($525•100% = $525) — present fishing value/pond/yr ($525•75% — $393.75) = $131.25•No. of ponds in category (5) = $656.25	$1312.50/b-f/yr	$9187.50/b-f/yr	$11,156/b-f/yr

"poor" and "medium" quality fishing to the "good" category, and "good" to "excellent.") (B'_B, B'_C, B'_D, B'_T)					
VII Accrued recreational benefits with pond management program (II+VI):	$0/yr	$2625/yr	$3937.50/yr	$13,781.25/yr	$20,343/yr

VIII Benefit-cost ratios with:			Undiscounted		Discounted (10%)		
a. Annual surveys and management	$\frac{\text{annual benefits-foregone}}{\text{annual surveys + annual mgt.}}$	=	$\frac{\$11,156}{\$\ 8,250}$	=	$\frac{\$10,142}{\$\ 7,500}$	=	1.35 b/c ratio
b. Biennial surveys and annual management:	$\frac{\text{annual benefit-foregone}}{\text{biennial surveys + annual mgt.}}$	=	$\frac{\$11,156}{\$\ 5,000}$	=	$\frac{\$10,142}{\$\ 4,546}$	=	2.23 b/c ratio
c. Triennial surveys and annual management:	$\frac{\text{annual benefit-foregone}}{\text{triennial surveys + annual mgt.}}$	=	$\frac{\$11,156}{\$\ 3,917}$	=	$\frac{\$10,142}{\$\ 3,609}$	=	2.85 b/c ratio

MODEL I

In Model I, certain assumptions are made which permit the construction of a model around these assumptions. First, I assumed that the program included 50 ponds or small lakes. Second, these bodies of water had received no management for the past 10 years. Third, these ponds or small lakes had segregated into several quality classes in the following manner: 5 were still in the "good fishing" category; 10 were "medium fishing;" and 35 had degraded to "poor fishing." None were still "excellent" in fishing quality. Fourth, renovation (R) and restocking (R_S) could be performed one year and the waters (all 50 ponds or lakes) would be "good fishing" the following year (Program Year I). Fifth, all waters would consistently retain their good fishing rating throughout the period considered by the model. Sixth, program costs and benefits have not been discounted as generally required in most governmental economic analyses. Seventh, there are some serious doubts that the use-level of 300 hrs./acre/year and the quality categories that we have projected are concurrently sustainable.

At the time of formulation it was recognized that some of these assumptions were either invalid or questionable. However, Model I is merely a primary model to serve as a base for modification and sophistication of later, more realistic models. Model I (Fig. 1) was built with these assumptions, and Table 3 indicates the benefit-cost array for this model. It would have a favorable b/c ratio, but, as previously noted, it has a number of inherent weaknesses that make it unrealistic for field use.

The most flagrant weakness involves assumption No. 4. There is a time lag in the "start-up" of a program which is not considered in Model I. It takes time to survey a body of water; determine from the survey data that reclamation is indicated; do the reclamation work; then restock. The most critical time lag, however, is the period required for fish to grow from the fingerling stage (usually stocked) to a size desirable to the sport fisherman. This is generally about 3 years in a reclaimed lake or pond.

Let's construct another model (Model II) which corrects this "instantaneous conception" an error, and includes instead a "start-up" or Pre-model Stage. In addition, I have extended the program period to a 16-year cycle to compare to a later 16-year cycle model. Another weakness, in the view of economists, is that Model I benefits and costs have not been discounted. Discounting can have a significant effect on the cost effectiveness of a program (i.e., the b/c ratio).

Model II (Fig. 2) is a more logical program than Model I, and also produces a favorable b/c ratio (Table 3). In Model II, the instantaneous start-up defect has been corrected by preceding the active model years with a pre-model, developmental stage. In addition, all benefits and costs have been discounted. One can see (Table 3) that in this more realistic model the costs in the developmental (Pre-model) stage exceed the benefits for this period. Additionally, when discounted, these high early costs in the forward part of the program life significantly affect the b/c ratio.

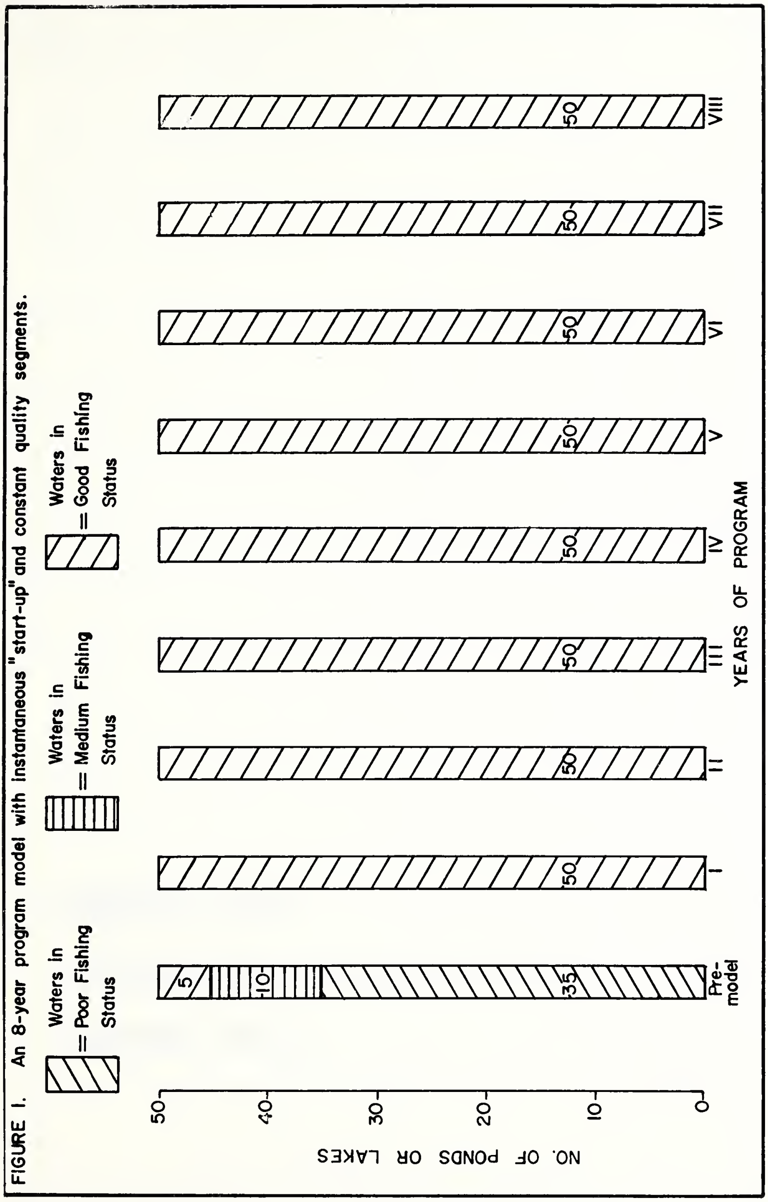

FIGURE I. An 8-year program model with instantaneous "start-up" and constant quality segments.

FIGURE 1.

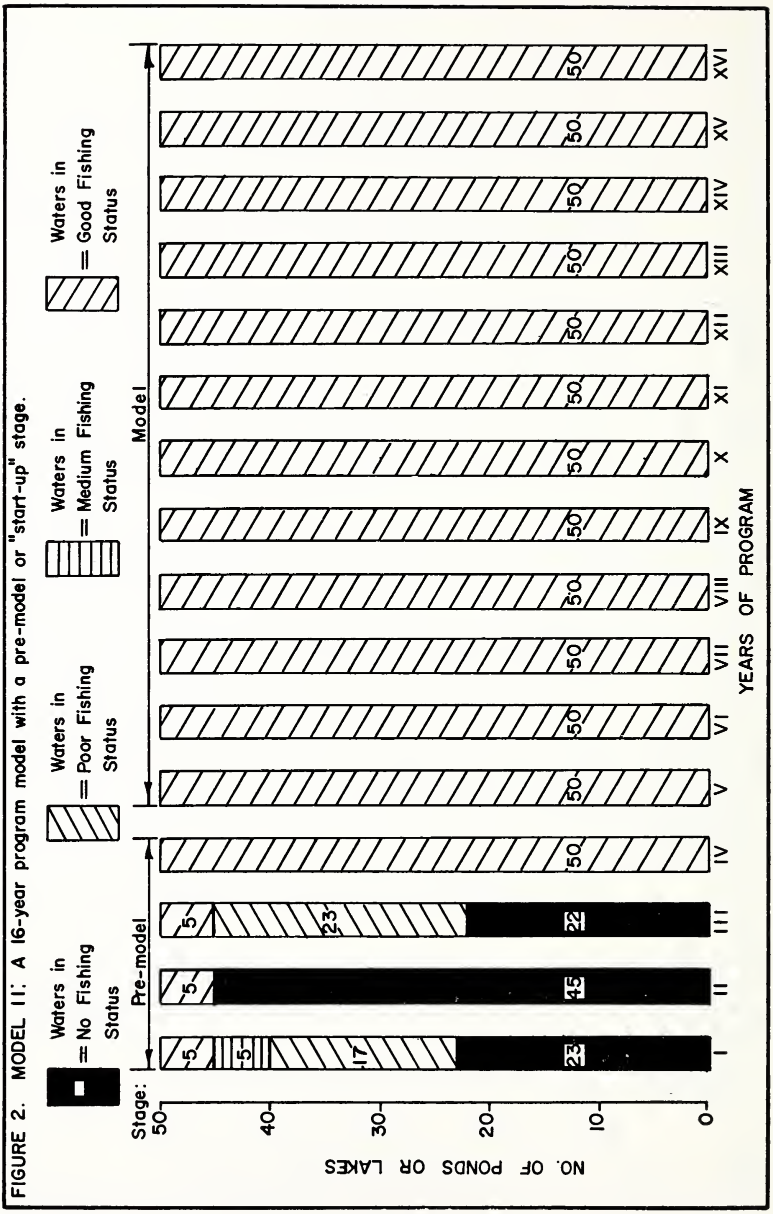

FIGURE 2. MODEL II: A 16-year program model with a pre-model or "start-up" stage.
= Waters in No Fishing Status
= Waters in Poor Fishing Status
= Waters in Medium Fishing Status
= Waters in Good Fishing Status
Stage:
Pre-model
Model
NO. OF PONDS OR LAKES
50
40
30
20
10
0
5
5
17
23
5
45
5
23
22
50
YEARS OF PROGRAM
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI

FIGURE 2.

TABLE 3. *Discounted Costs and Benefits for Model II (using Biennial Surveys Only.)*

	Year	6%	10%	15%	20%
		COSTS			
Pre-model	1	$ 5,708[1]	$ 5,500	$ 5,261	$ 5,041
	2	5,331	4,950	4,529	4,159
	3	3,568	3,193	2,794	2,459
	4	3,366	2,903	2,430	2,050
Model Stage	5	3,737	3,105	2,486	2,010
	6	3,525	2,823	2,162	1,675
	7	3,325	2,566	1,880	1,396
	8	3,137	2,333	1,635	1,163
	9	2,960	2,121	1,422	969
	10	2,792	1,928	1,236	808
	11	2,634	1,753	1,075	673
	12	2,485	1,593	935	561
	13	2,344	1,449	813	467
	14	2,212	1,317	707	390
	15	2,087	1,197	615	325
	16	1,969	1,088	535	271
		$51,180	$39,819	$30,515	$24,417
		BENEFITS			
Pre-model	1	$ 4,210	$ 4,057	$ 3,881	$ 3,719
	2	4,205	3,094	3,573	3,281
	3	0	0	0	0
	4	4,470	3,855	3,227	2,722
Model Stage	5	8,337	6,927	5,547	4,484
	6	7,865	6,298	4,823	3,736
	7	7,420	5,725	4,194	3,114
	8	6,999	5,204	3,647	2,595
	9	6,603	4,731	3,172	2,162
	10	6,230	4,301	2,758	1,802
	11	5,877	3,910	2,397	1,502
	12	5,545	3,554	2,085	1,252
	13	5,230	3,232	1,813	1,043
	14	4,934	2,937	1,576	869
	15	4,656	2,671	1,371	724
	16	4,392	2,428	1,117	604
		$86,973	$63,734	$45,181	$33,609

[1]All dollar values rounded to the nearest dollar.

	6%	10%	15%	20%
b/c Ratio:	1.70	1.60	1.48	1.38

There are, however, assumptions in this latest model that still trouble me. After the Pre-model development stage, there is an implicit assumption that the management program would keep fishing quality at a high level indefinitely (to the *i*th year). Even after we chopped the program to a 16-year management cycle with subsequent replications, there is an assumption that from Years V-XVI there is no decline in fishing quality. I am not at all confident that the level of management funded in this model can maintain this quality (i.e., without highly intensive management such as increasingly intensive weed control; remedial stocking of game species; removal of infesting species by trapping, netting, or electro-fishing; etc.).

An Improved Version of the 16-year Model (Model III)

I am going to explore another 16-year model which includes what appears to me to be a more normalized relationship between fishing quality and program age. Let's assume that management funded as indicated in the model *cannot* indefinitely hold fishing quality in the Good (or Excellent) category. In spite of this level of management, fishing quality will fall in later years of the program. Let's hypothesize that during the 16-year management cycle, these waters pass through four stages:

(1) Developmental (Pre-model): Years I-IV
(2) "Good" (Peak): Years V-X
(3) "Medium" (Early Decline): Years XI-XIV
(4) "Poor" (Pre-renovation): Years XV and XVI

This may be an overly-severe affront to our management capabilities, but let's run the model for this situation, anyway. It may be instructive and give us ideas on how to improve future models. Table 4 shows that in Model III the temporal decline in quality has a significant effect on the b/c ratio, lowering it from 1.70 to 1.27 at the 6% discounting rate. The ratio figure is, however, still on the profitable side.

By running Model III another probable modification becomes obvious. In terms of present worth, by Year XV all fishing benefits are valueless. Conversely, costs of $1149-$4055 are still accruing (dependent upon the interest rate used). Model III tells us plainly that this should be a 14-year program rather than a 16-year one. By chopping the management cycle to 14-years we avoid 2 years of losses totaling $1100 to $4000. Model III (Fig. 3), based upon biennial surveys, corrects most of the defects of previous models and retains a favorable cost effectiveness. However, it has a potential weakness concerned with the seventh assumption upon which these models have been based. It calculates benefits on a high use-level of 300 hrs./acre/year. I have some doubts that we can sustain the quality of fishing that we have projected in these models at a fishing pressure of 300 hrs./acre/year.

Model IV-A: An Automatic Octennial Management Program

In addition to lowering the use-level to 200 hrs./acre/year, there is one more frequency interval for surveys that we should consider. It has its genesis in the high percentage of management costs that are tied up in inventorying these waters (surveys). We found annual surveys to be very expensive (nearly 80% of all management costs) and we had some doubts about the biological sufficiency of surveying these waters every third year (triennial surveys). We used biennial survey costs as a compromise in Models II and III. However, even

TABLE 4. *Discounted Costs and Benefits for Model III (using Biennial Surveys Only).*

	Year	6%	10%	15%	20%
		COSTS			
Stage 1	1	$ 5,708[1]	$ 5,500	$ 5,261	$ 5,041
	2	5,331	4,950	4,529	4,159
	3	3,568	3,193	2,794	2,459
	4	3,366	2,903	2,430	2,050
Stage 2	5	3,737	3,105	2,486	2,010
	6	3,525	2,823	2,162	1,675
	7	3,325	2,566	1,880	1,396
	8	3,137	2,333	2,635	1,163
	9	2,960	2,121	1,422	969
	10	2,792	1,928	1,236	808
Stage 3	11	2,634	1,753	1,075	673
	12	2,485	1,593	935	561
	13	2,344	1,449	813	467
	14	2,212	1,317	707	390
Stage 4	15	2,087	1,197	615	325
	16	1,969	1,088	535	271
		$51,180	$39,819	$30,515	$24,417
		BENEFITS			
Stage 1	1	$ 4,210	$ 4,057	$ 3,881	$ 3,719
	2	4,205	3,904	3,573	3,281
	3	0	0	0	0
	4	4,470	3,855	3,227	2,722
Stage 2	5	8,337	6,927	5,547	4,484
	6	7,865	6,298	4,823	3,736
	7	7,420	5,725	4,194	3,114
	8	6,999	5,204	3,647	2,595
	9	6,603	4,731	3,172	2,162
	10	6,230	4,301	2,758	1,802
Stage 3	11	2,420	1,620	987	618
	12	2,283	1,464	859	515
	13	2,154	1,331	746	430
	14	2,032	1,210	649	358
Stage 4	15	0	0	0	0
	16	0	0	0	0
		$65,228	$46,316	$38,063	$29,536

[1]All dollar values rounded to the nearest dollar.

b/c Ratio	1.27	1.27	1.25	1.21

biennial inventories consume 65% of total management costs. We need to explore a management system that eliminates surveys entirely.

Model IV-A is based upon a management system that eliminates fisheries surveys, and routinely reclaims the ponds or lakes on a set time schedule of 8 years. Bass-bluegill populations of the average pond or lake go through temporal changes in sport fishing quality. I have

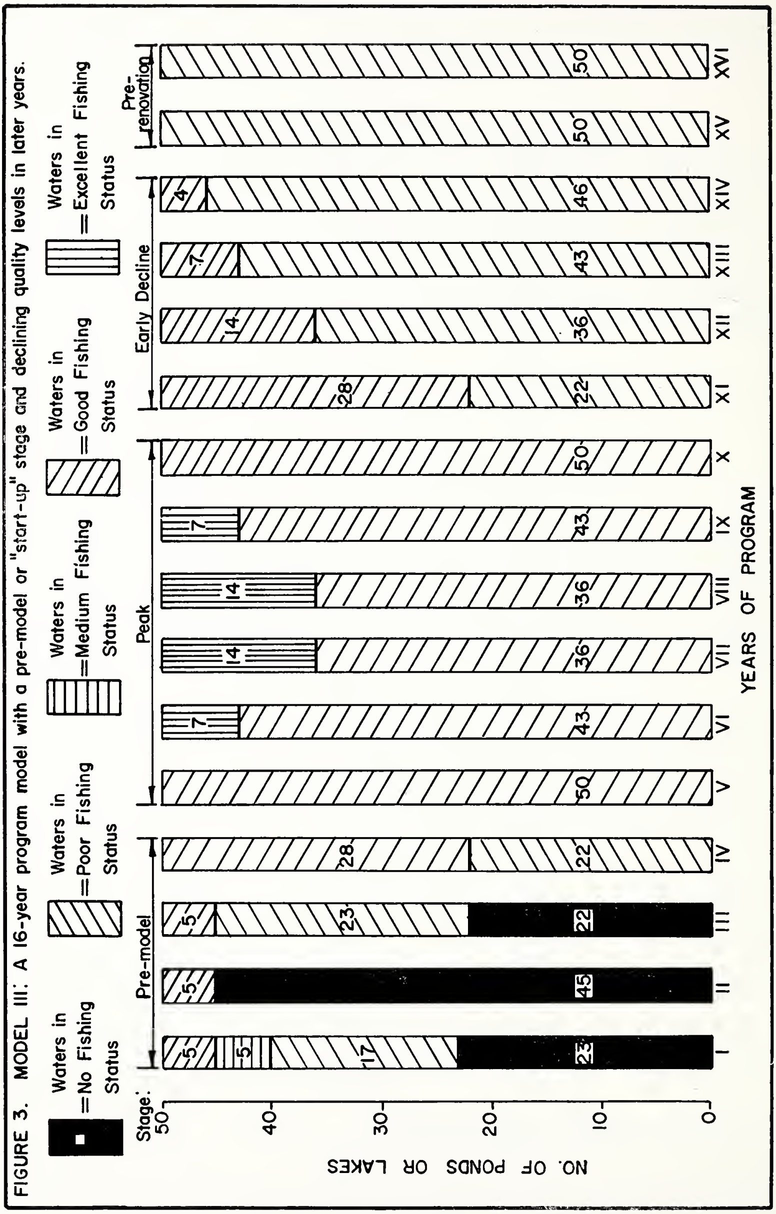

FIGURE 3. MODEL III: A 16-year program model with a pre-model or "start-up" stage and declining quality levels in later years.

FIGURE 3.

theorized that a pond (stocked in Year 0 with fingerling bass and bluegills) goes through an unmanaged cycle approximated by the following schedule:

Year I:	No fishing
Year II:	Poor quality
Year III:	Medium quality
Year IV:	Good or excellent quality
Year V:	Good or excellent quality
Year VI:	Good quality
Year VII:	Medium quality
Year VIII:	Poor quality

I suspect that the unmanaged cycle presented above is somewhere near the average. Some ponds will have only a year or two of quality production; conversely, some may go 10 or 12 years before declining. (The user may want to modify the arrangement of quality levels to suit his own ideas on the rise and decline of pond populations.) When one runs Model IV-A (Fig. 4) at a realistic discount rate of 10%, it shows a profitability of more than $20,000 over the 8-year cycle (Table 5).

TABLE 5. *Model IV-A: 1st Cycle Totals*

Year	Discounted Costs (10%)	Discounted Benefits (10%)	Difference
I	$ 2,418	$ 4,932	+$ 2,514
II	2,855	3,543	+ 1,688
III	1,687	3,418	+ 1,731
IV	1,533	3,944	+ 2,411
V	1,394	4,238	+ 2,844
VI	1,267	4,445	+ 3,178
VII	1,252	4,221	+ 3,069
VIII	1,047	3,755	+ 2,708
	$12,353	$32,496	$20,143

$$\text{b/c ratio} = \frac{32{,}496}{12{,}353} = 2.63$$

The cost effectiveness of Model IV-A looks impressive upon cursory examination. Table 5 does not, however, give adequate consideration to impacts of the program—both costs and benefits. Table 5 merely shows the benefit-cost efficiency of a single cycle program put into operation with the assumed composition of quality class ponds. What, for instance, is the cost differential between the Model IV-A program and the present non-management situation? The latter, if continued through another 8-year period in place of the Model IV-A program, would produce $23,340 of present worth benefits, without (theoretically) any costs. Should not the benefits from a system of non-management be subtracted from the benefits of a management program to derive the differences between them?

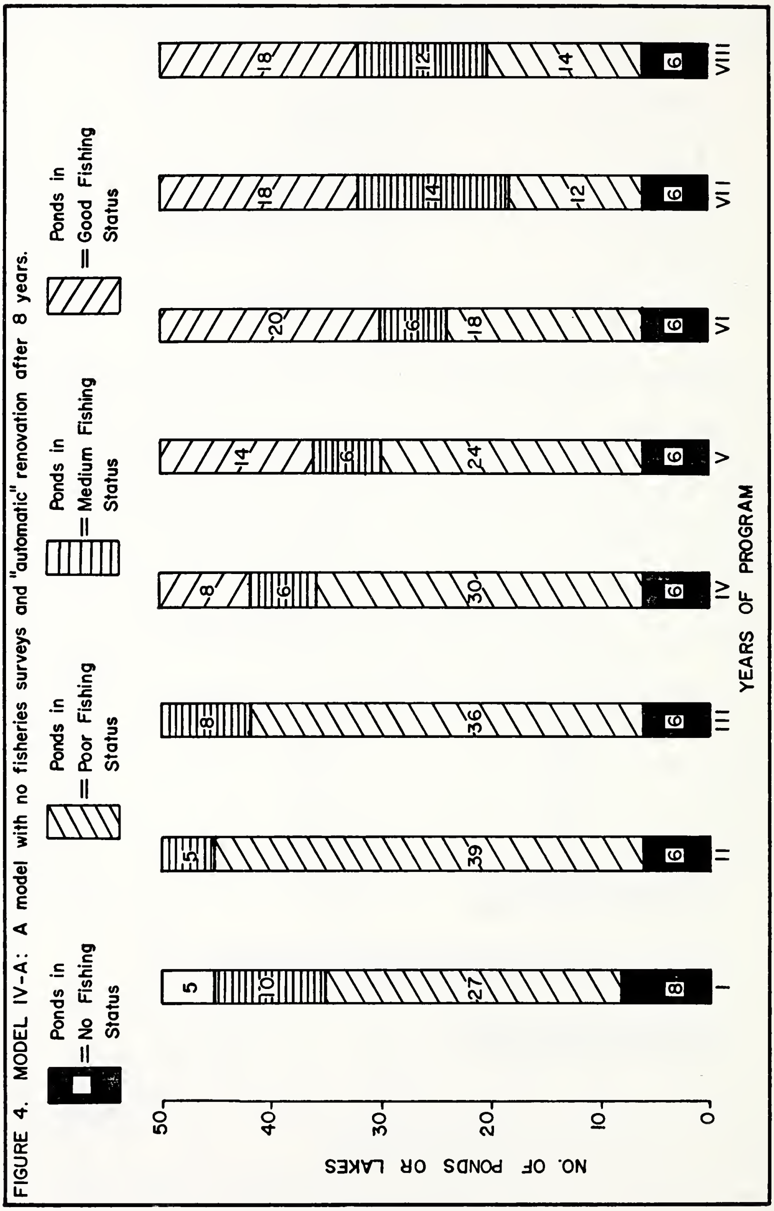
FIGURE 4. MODEL IV-A: A model with no fisheries surveys and "automatic" renovation after 8 years.
= Ponds in No Fishing Status
= Ponds in Poor Fishing Status
= Ponds in Medium Fishing Status
= Ponds in Good Fishing Status
NO. OF PONDS OR LAKES
0
10
20
30
40
50
YEARS OF PROGRAM
I
8
27
10
5
II
6
39
5
III
6
36
8
IV
6
30
6
8
V
6
24
6
14
VI
6
18
6
20
VII
6
12
14
18
VIII
6
14
12
18

FIGURE 4.

In weighing the two systems in this manner, the Model IV-A system shows benefits of $32,496 minus $12,353 in costs, or a profit of $20,143. The nonmanagement system gives $25,293 in benefits, minus no costs, or a profit of $25,293. On the basis of these figures alone, it would appear more profitable to forego management. Let's look more closely at the management model, however. Notice (Fig. 5) that in the non-management cycle, ponds are in the descending leg of their quality curve, and that from Year III on, we will be faced with 50 consistently poor ponds. The 10 medium ponds and 5 good ponds will in one or two years be poor fishing. Practically all the benefits assigned to these ponds come from consistently poor fishing. Further, the volume of these benefits (despite the low value: $87.50 V-D/acre/yr) comes from the assumption of a high intensity of fishing activity (i.e., a fishing intensity of 200 hrs./acre/yr.). It is not realistic to expect fishing pressure to remain near capacity when quality has fallen to low levels.

Conversely, at the end of the 8-year management cycle many of the Model IV ponds are still at their peak or even on the ascending leg of their quality curve. This fact insinuates that we should follow them through a longer period. Let's compare the non-management and Model IV management systems through another 8-year period *without* any further renovation-restocking operations in the Model IV version (i.e., we will let Model IV ponds settle back to "poor" by their own gravity, and we will term this modification Model IV-B).

Model IV-B, then, is merely Model IV-A hooked to a subsequent 8-year cycle with no costs except Other Management. It is Year XV before all ponds settled into the "poor" category (Fig. 6). The Model IV-B renovation-restocking operations of the first cycle (Years I-VIII) carry higher recreational benefits (i.e., "good" and "medium" quality levels) through Years IX to XIV. This is, of course, because it takes six years for a group of ponds to go from "poor" to higher categories and back to "poor" again. The precipitation or "fall-out" of these groups extends the effects considerably beyond the termination of the $R\text{-}R_s$ operations—a time-lag or "coasting" situation.

This modification (Model IV-B) is attractive economically since it eliminates $R\text{-}R_s$ costs in the second cycle while retaining higher quality benefits induced by first cycle operations. This is basically a 16-year program with all $R\text{-}R_s$ operations in the first half; only O (Other management) costs are incurred in the second half of the program. One should consider, however, that these management programs parallel physical laws of inertia. It takes considerable "energy" (time and funds) to overcome the inertia of a resting stage (poor quality) and get the program functioning. We need to examine whether or not it requires more energy to maintain a relative velocity in a program than to coast to "poor" fishing, then have to overcome the inertia of low production, and start up again. This can be tested by hooking two Model IV-A cycles together. (Although this was really what was anticipated for Model IV-A, for the sake of clarification let's call this 16-year model Model IV-C).

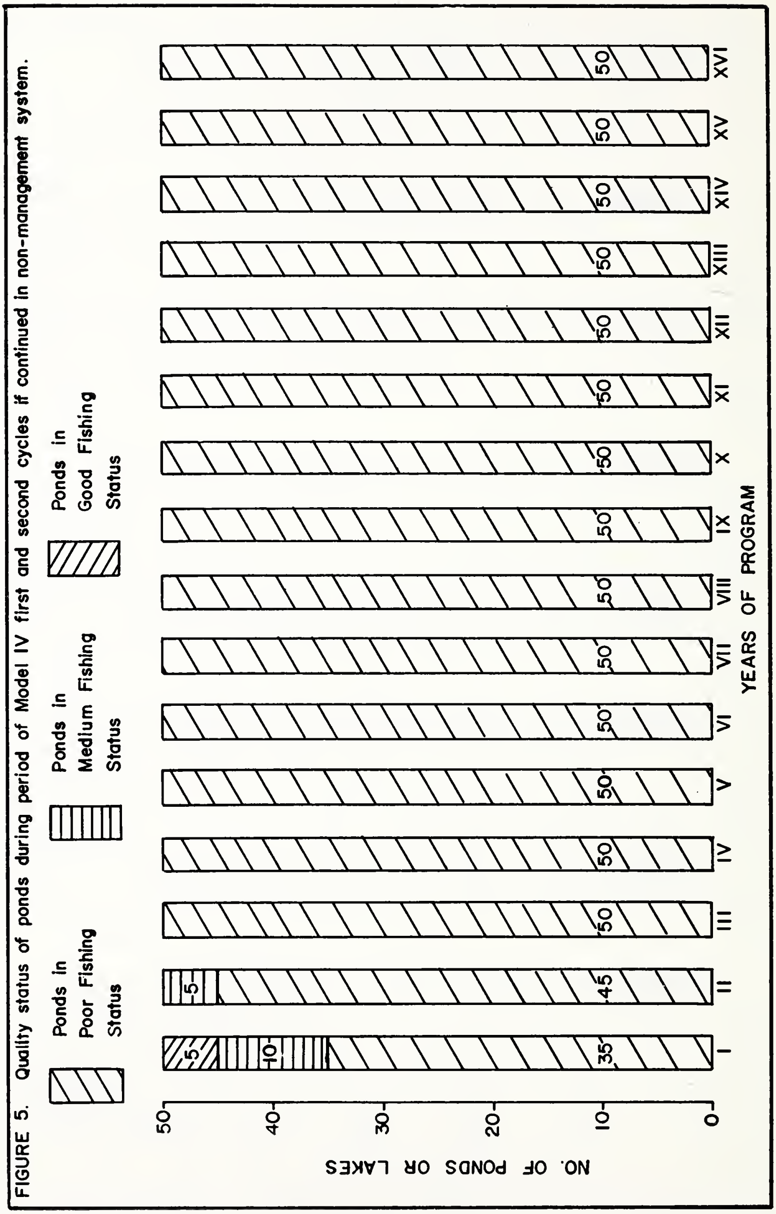
FIGURE 5. Quality status of ponds during period of Model IV first and second cycles if continued in non-management system.
Ponds in Poor Fishing Status
Ponds in Medium Fishing Status
Ponds in Good Fishing Status
NO. OF PONDS OR LAKES
50
40
30
20
10
0
5
10
35
5
45
50
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI
YEARS OF PROGRAM

FIGURE 5.

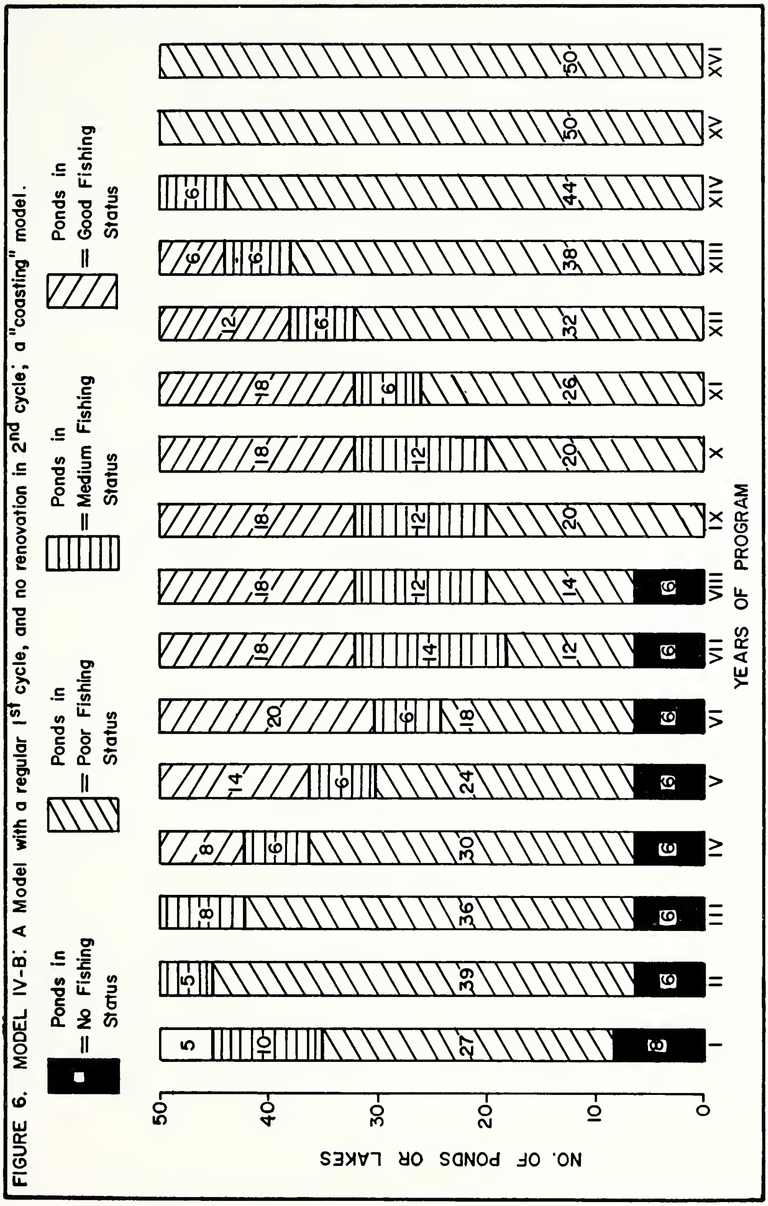

FIGURE 6. MODEL IV-B: A Model with a regular 1st cycle, and no renovation in 2nd cycle; a "coasting" model.

Figure 6.

We mentioned that it requires considerable management energy (i.e., time and funding) to move a program from a resting stage (low productivity) to a desirable level of recreation output. In these situations a constant flow of recreation products (herein, good fishing) may be preferable even though a more cyclic program might show some small financial advantages.

Comparing Model IV-B (Fig. 6) and Model IV-C (Fig. 7) on the basis of flow constancy, we can see that Model IV-C is much more consistent. After the start-up period of the first six years, 60%-64% of the ponds are producing acceptable fishing (medium, good); 24%-28% have degraded to poor fishing; and 12%-16% are out of production. If a second 16-year cycle is hooked to Model IV-C, the flow of Years XVII-XXXII would be similar to Years VII-XVI (i.e., a relatively constant flow). For most fisheries managers, the continuity of the IV-C program makes it preferable to Model IV-B, even if the latter had minor economic advantages.

The formula (Fig. 8) for the formulation of these models is a relatively simple one. In addition, it is one which can be used to measure many recreation activities, not fishing alone. In discussions of these models, I have been asked several questions concerning their use. Could you model larger lakes by the same technique? One can if he can provide the basic core data to the formula. On large lakes with multiple access points, accurate use data (U) may be the most difficult component to provide.

Can the arbitrary categories, or value gradients (G), that I have used be made more definitive? Although I have not defined the basis for my categorization in this paper, it has basically been as follows: "Excellent" fishing: a catch rate >1.1 fish/hour/angler; "good": 0.9-1.1 fish/hour/angler; "medium": 0.75-0.9; and "poor": <0.75. If one has good harvest data he can use my scale, or revise it to harvest rates that he equates with excellent, good, medium, and poor fishing. Can other forms of recreation be modeled by using this formula? I think that most can. I could model grouse hunting, picnicking, or wildlife photography of rare animals with this formula, if the core data were available or could be realistically estimated.

The formula could be strengthened in special cases by inserting coefficients to more accurately describe factors such as aesthetic values, difficulty of access, or user attitude. There is much room for improvement of the modeling system, and the formulations explored in this paper are merely a start toward more sophisticated and accurate models.

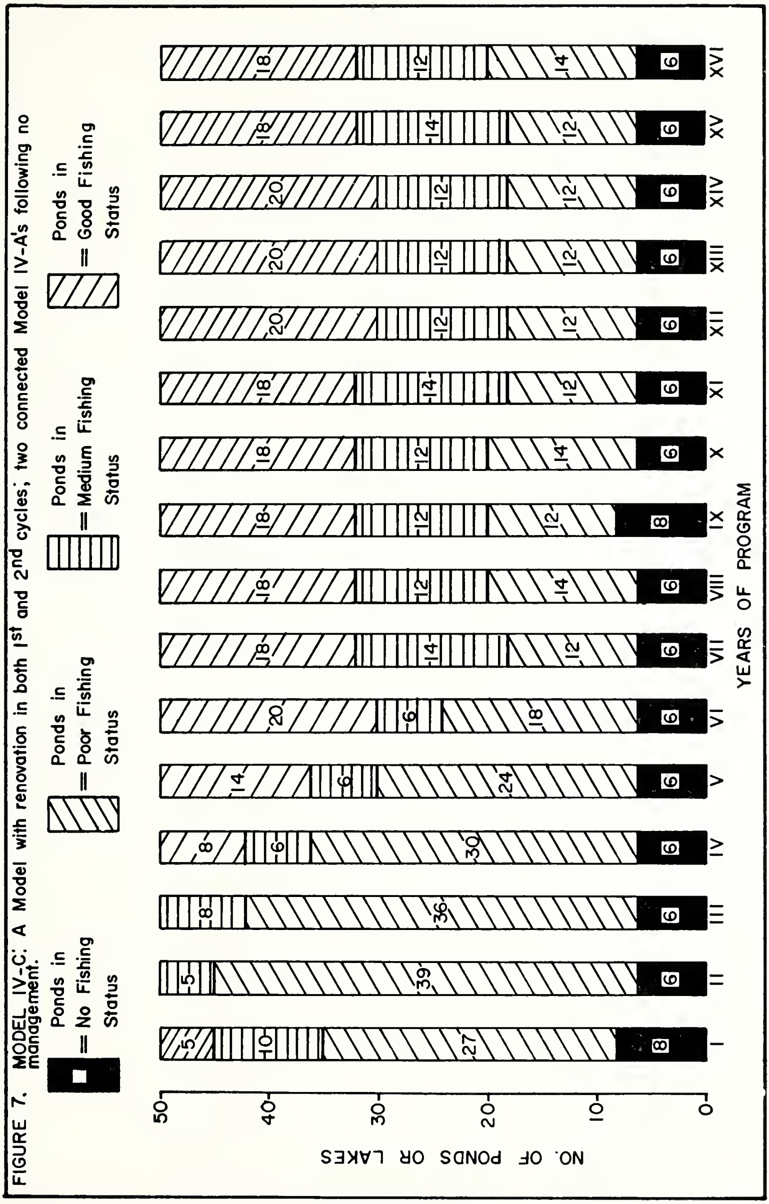
FIGURE 7. MODEL IV-C: A Model with renovation in both 1st and 2nd cycles; two connected Model IV-A's following no management.
= No Fishing Status Ponds in
= Poor Fishing Status Ponds in
= Medium Fishing Status Ponds in
= Good Fishing Status Ponds in
NO. OF PONDS OR LAKES
YEARS OF PROGRAM
I II III IV V VI VII VIII IX X XI XII XIII XIV XV XVI

FIGURE 7.

FIGURE 8. Formula For Pond or Lake Management Program

$$(1)\quad \frac{\sum_{i=1}^{n}(P_B\cdot[U\cdot D\cdot V\cdot G-B]_B)+\sum_{i=1}^{n}(P_C\cdot[U\cdot D\cdot V\cdot G-B]_C)+\sum_{i=1}^{n}(P_D\cdot[U\cdot D\cdot V\cdot G-B]_D)\cdot\sum_{i=1}^{n}(1-\lambda)^i}{\sum_{i=1}^{n}(S+R+R_s+O)\cdot P_T\cdot\sum_{i=1}^{n}(1-\lambda)^i} = \frac{D_C B'_T}{D_C C_T}$$

which reduces to:

$$(2)\quad \frac{\sum_{i=1}^{n}(P_B\cdot B'_B)+\sum_{i=1}^{n}(P_C\cdot B'_C)+\sum_{i=1}^{n}(P_D\cdot B'_D)\cdot\sum_{i=1}^{n}(1-\lambda)^i}{\sum_{i=1}^{n}(S+R+R_s+O)\cdot P_T\cdot\sum_{i=1}^{n}(1-\lambda)^i} = \frac{D_C B'_T}{D_C C_T}$$

FIGURE 8.