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Lake Michigan Salmonid Stocking Costs in Wisconsin

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Abstract *The costs of stocking salmonids in the Wisconsin waters of Lake Michigan are estimated for 1985. Estimation procedures and costs per stocked and captured fish are presented.*

Fingerlings of a species were found in most cases to cost more per captured fish *than yearlings. However chinook salmon fingerlings were least expensive at an average cost of only $0.35 per captured fish. Most expensive were brook yearlings and fingerlings at $12.67 and $10.14, respectively.*

While a full policy evaluation awaits additional research on species-specific benefits, three tentative conclusions can be drawn for the Wisconsin fishery. First, the role of brook trout in the fishery should be reviewed. Second, despite difficulties with lake trout rehabilitation, the role of lake trout in the sport fishery is encouraging and may justify continued stocking. Finally, increased stocking of the popular chinook salmon may be justified if the recent problems of low capture-per-release rates can be solved.

Keywords restocking costs, benefit-cost methodology, sport fisheries, salmonids, Lake Michigan.

Introduction

Wisconsin's Lake Michigan trout and salmon fishery is supported entirely by stocking from hatcheries. Lake, brook, brown, rainbow, and steelhead[1] trout, as well as chinook and coho salmon are now stocked. These different salmonid species contribute in different ways to the fishing experience (Samples and Bishop 1981) and thus affect benefits in different ways. Costs of stocking them may also

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[1] Steelhead trout are reared from wild brood stock, although they are of the same species as the rainbow trout reared from captive brood stock.

vary across species. Thus, one important set of issues surrounds how many fish of each species to stock.

Numerous broader issues can be identified. Programs to stock trout and salmon compete with other Great Lakes and inland fisheries for angler participation and the limited public funds available for managing the state's fishery resources. Native lake trout populations were extirpated from Lake Michigan in the 1950's due to the effects of an exotic parasite, the sea lamprey, on fish stocks already heavily stressed by overfishing. So far unsuccessful attempts to restore naturally reproducing lake trout have not only cost millions of dollars but have required restrictions on sport and commercial fishing. Managers are asking whether continued attempts to achieve natural reproduction are worthwhile, given the successes of the recreational fishery based on hatchery reared fish. Other issues arise because recreational fishing for stocked salmonids conflicts with commercial fishing. While commercial harvest of the salmonids is prohibited, there is a long-standing controversy over the commercial use of gill nets because of incidental mortality to the salmonid stocks. Furthermore, the forage base for the salmonid fishery is composed of alewives, which are also harvested by commercial fishing. The potential conflict between those who would prefer to "harvest" alewives by catching salmon and trout and those who want to harvest alewife commercially has reached a climax. The catch of very popular chinook salmon has declined precipitously over the last three years, and state and other biologists believe that stress due to lack of forage at critical points in its life history is a probable cause.

Clearly, adequate measures of the benefits, both in total and at the margins, are important to economic analysis to support fisheries management decisions. Research on the benefits has been and continues to be an apparent priority on the national research agenda (see, for example, Samples and Bishop, 1985; Kealy and Bishop 1986; Talhelm 1988). A recent survey by Walsh, Johnson, and McKean (1988) identified more than 40 studies of recreational fishing benefits conducted in the U.S. since 1968.

Much less attention has been given to the costs of fishery management and exploitation. This is probably as it should be, since the benefit side is fraught with theoretical and empirical challenges which make research there more interesting and appealing. However, if there is an implicit assumption that costs are well understood, this assumption should be rejected. Management agencies do calculate some costs, but they are based on accounting rather than economic concepts, are typically calculated as average rather than marginal (*i.e.* species variable) costs, and are expressed in terms of fish stocked rather than fish caught. Economists studying recreational fish management need to understand costs as well as benefits.

The present study focuses on the costs of stocking salmon and trout in Wisconsin waters of Lake Michigan. Methods for researching such costs are summarized in the next section. Data sources and assumptions used in the analysis are described. Total, average, and marginal costs by species are estimated. Average and marginal cost estimates are for fish caught, as well as fish stocked. Some conclusions follow for policies related to brook trout, lake trout, and the current problem in the chinook fishery, but further conclusions must await better estimates of benefits to combine with the cost analysis presented here.

Overview of the Methodology

Detailed records from the stocking programs for salmonid species in the Wisconsin waters of Lake Michigan were compiled for 1985 from the Wisconsin Department of Natural Resources (WDNR). The WDNR program stocked brook, brown, rainbow, and steelhead trout, as well as chinook and coho salmon (Claggett and Dehring 1984). Results from a United States Fish and Wildlife Service study (USFWS 1986) of lake trout stocking costs are included for comparison.

Stocking costs were calculated for the 1985 year class. The term "1985 year class" as used by WDNR field personnel and in WDNR records refers to fish spawned in late 1984 and stocked in 1985 as fingerlings or early 1986 as yearlings. Capture-per-release rates were used to adjust results to stocking costs per captured fish. Such rates have been calculated for various species and stocking ages by a number of authors (Elrod *et al.* 1988, Seelbach 1985, Belonger 1988, Krueger and Dehring 1986). Rates used here are from Hansen *et al.* (1990), and are those currently used by the WDNR.

Care should be taken in interpreting the capture-per-release rates, as well as the cost figures derived from them. Capture-per-release rates are affected by numerous factors, including the weather, water contaminant levels, predator control efforts, and angler effort. These factors have an effect on such things as survival of newly stocked fish after the shock of release from the controlled environment of the hatchery, the aggressiveness of natural predators, natural reproduction rates, and the food supply. Contaminant levels, prevalence of predators (*e.g.* the sea lamprey), angler effort, and even the food supply are at least partially subject to government control. For example government might be able to increase the capture-per-release rate, at least in the short run, by permitting higher bag limits or lower minimum size restrictions. The longer run effect, however, might be to reduce natural reproduction resulting in lower capture-per-release rates in the future. Analysts should consider these factors when incorporating the cost figures generated by this study. In some applications, it may be more appropriate to use costs-per-stocked fish rather than costs-per-captured fish.

The USFWS (1986) study covered costs in the 1984 calendar year. Only total costs were provided in that study, and were adjusted here to conform to the results obtained from analysis of the WDNR data. Stocking data were obtained separately from the USFWS to determine average costs. Overlapping year class costs were treated here by simple averaging. These cost figures were adjusted to 1985 US dollars using the producer price index.

Fingerlings are here differentiated from yearlings at 12 months in chronological age for both salmon and trout species. Coho and chinook (*i.e.* all salmon) are stocked as smolts, with the smolting period occurring earlier in the life cycle of chinook. Thus chinook are considered biologically mature at less than one year in age. The WDNR reports used to prepare this study refer to all species by their chronological age, and thus this practice is continued here.

Current expenditures on major equipment and facilities maintenance were included for both WDNR and USFWS results. It was assumed that these costs were stable at each facility over time. Conversations with WDNR officials suggest that such an assumption is not unreasonable.

Depreciation on facilities and equipment was excluded for both WDNR and

USFWS results except in the case of vehicles used to transport fish to the stocking sites. Most facilities and equipment used in the stocking programs are quite old and unlikely to be sold or replaced. Vehicles in use today were acquired more recently and are periodically replaced, justifying inclusion of a depreciation allowance. For other major capital items and facility maintenance, current expenditures are more economically relevant than depreciation. This reflects the intended target audience of WDNR planning managers. Others may wish to reflect carefully upon this treatment of expenditures associated with facilities and equipment, making adjustments where appropriate for alternative applications.

Specific algorithms used to calculate WDNR costs are presented in the next section. The fourth section covers the USFWS study modifications necessary to permit comparison with WDNR figures. Results from this study are presented in the fifth section, and then compared to other studies in the sixth section. See Appendix I for a description of data sources. Appendix II contains a description of procedures used to resolve problems with the data. Table 1 presents weight and number stocked by species and age class for the 1985 year class. Table 2 lists species produced by production facility. Figure 1 indicates the location of each production facility.

Wisconsin Department of Natural Resources Program

Feed Costs

Monthly feed costs and feed consumption in pounds by species were available directly from WDNR records at each hatchery-rearing facility. In months where portions of fish at a particular facility were transferred or stocked, weighted

Table 1
Fish Stocked[a]

Species	Age[b]	Number	Weight[c]
Brook	FGL	130739	6492
Brook	YLG	162836	18682
Brown	FGL	581096	62712
Brown	YLG	549735	113640
Rainbow	YLG	240202	26602
Coho	YLG	136673	7955
Steelhead	YLG	189626	26410
Chinook	FGL	2740800	22539
Lake	FGL	453274	11332
Lake	YLG	1050929	42910
Total		6235910	339274

[a] 1985 Year Class, Wisconsin Lake Michigan.
[b] FGL = fish stocked as fingerling, YLG = fish stocked as yearling.
[c] Weight in pounds.

Table 2
1985 Fish Production Stations and Species

1. Facilities which handle spawning and incubation:	
Bayfield	Brook, Brown, Lake Trout, Splake
Brule	Brown
Iron River	Lake Trout
Kettle Moraine	Coho
Osceola	Rainbow
St. Croix	Brook, Brown
Westfield	Chinook, Coho
Wild Rose	Brown, Chinook
2. Facilities which handle incubation but not spawning:	
Kettle Moraine	Brook, Rainbow
Lake Mills	Coho
Lakewood	Rainbow
Nevin	Brook, Brown, Rainbow
3. Facilities which handle stocking spring fingerlings:	
Nevin	Brook, Rainbow, Brown
St. Croix	Brown, Brook
Westfield	Chinook
Wild Rose	Chinook
4. Facilities which handle stocking fall fingerlings:	
Brule	Brown, Brook
Green Lake	Brown
Iron River	Lake Trout
Kettle Moraine	Coho
Lakewood	Rainbow, Brook
Langlade	Rainbow
Nevin	Brook, Rainbow, Brown
Osceola	Rainbow
St. Croix	Brown, Brook
Thunder River	Brown
Westfield	Lake Trout, Splake
Wild Rose	Brown
5. Facilities which handle stocking yearlings:	
Bayfield	Lake Trout, Brook, Splake, Brown
Brule	Brown, Rainbow, Brook
Green Lake	Brown
Iron River	Lake Trout
Kettle Moraine	Brook, Rainbow
Lake Mills	Coho
Lakewood	Rainbow, Brook
Langlade	Brown
Lima Pond	Rainbow
Nevin	Brook, Rainbow, Brown
Osceola	Rainbow
St. Croix	Brown, Brook
Token Creek	Brown
Westfield	Splake
Wild Rose	Rainbow, Brown

averages were used to allocate the total feed cost up to that date between the portion remaining in the facility and the portion leaving. Feed costs for monthly within-facility mortalities were added to remaining fish. All feed costs were totalled by species and age class for fish stocked in Lake Michigan. Feed

Figure 1. 1985 Fish Production Stations for Wisconsin waters of Lake Michigan.

costs for fish stocked in Lake Superior or in inland waters were excluded. Total costs were divided by fish stocked to determine average costs. Table 3 presents rates of capture-per-release which were used to determine feed costs per captured fish.

Table 3
Capture-per-Release Rates

Species	Age[a]	% Captured
Brook	FGL	2.50%
Brook	YLG	5.70%
Brown	FGL	3.60%
Brown	YLG	7.80%
Rainbow	YLG	5.10%
Coho	YLG	5.90%
Steelhead	YLG	9.80%
Chinook	FGL	12.90%
Lake	FGL	2.80%
Lake	YLG	6.80%

[a] FGL = fish stocked as fingerling, YLG = fish stocked as yearling.

SOURCE: M. J. Hansen, Changes in Wisconsin's Lake Michigan Salmonid Sport Fishery, 1969–1985, *North American Journal of Fisheries Management* 5:442–457, 1990.

Labor Costs (Excluding Distribution Labor[2])

Labor costs by species and by age class of stocked fish could not be calculated directly. Quarterly data were generally available by facility or by district of facilities for total labor hours and expenditures. Labor hours (but not expenditures) were broken down into hours devoted to detailed activities by species. Data were also available on rearing duration, number and weight of fish stocked, and percentage labor allocation between year classes. The algorithm used to determine labor costs from these data is developed below.

Labor hours by year class and species. Quarterly data by species were available on production related hours broken down into spawning (brood capture, weighing, spawning, incubation loading and maintenance, loading of fry into rearing tanks), rearing (tank cleaning and maintenance, feeding, moving of fingerlings into larger tanks, periodic enumeration), brood stock maintenance (tank cleaning and maintenance, feeding, periodic enumeration), and stocking preparation (removal from holding tanks, weighing, loading into transport vehicles). Since a given year class of fish has a life cycle of roughly one and one half years from spawning to final stocking of yearlings, year classes typically overlap in a facility. For example, while the 1985 year class is being spawned in late 1984 or early 1985, the 1984 year class yearlings are waiting to be stocked in the spring of 1985. The data did not distinguish labor hours by year class.

Consultation with senior WDNR technical staff suggested that a specific labor activity in a particular fiscal quarter (say, preparation for stocking in the first quarter of 1984–1985) could be associated with a particular year class of fish (e.g. the 1984 year class). Other activities (e.g. labor for rearing in the third quarter of 1984–1985) were associated with up to two year classes maintained in a facility at any one time (e.g. 1984 year class yearlings and 1985 year class fingerlings). Based on these relationships, estimates were developed of the percentage of labor time allocated between year classes by activity for each quarter. These percentages were used to exclude labor expenditures for the 1984 and 1986 year classes, permitting isolation of labor hours for the activities of the 1985 year class of interest. These percentages were applied to quarterly aggregate data to determine 1985 year class labor hours by activity and species. The percentages are presented in Table 4.

Labor hours by facility. Data were available by facility in the case of production activities, but only by district for stocking preparation labor. District stocking preparation hours were allocated to each facility within the district according to the weight of fish stocked.

Labor hours by age class. Labor allocation was differentiated in the data by species, but not by the age class (fingerling or yearling) of the species at the time of stocking. Labor hours devoted to spawning and brood stock activities were allocated to age classes in proportion to the number of fish stocked. Rearing hours were allocated in proportion to the length of time spent in the hatchery-rearing

[2] Distribution labor is included below under distribution costs.

Table 4
Percentage Allocations of Labor Time to the 1985 Year Class

1984–85 Fiscal Year	Quarter	Jul–Sep	Oct–Dec	Jan–Mar	Apr–Jun
Activity					
Spawning		100%	100%	100%	100%
Rearing		0%	10%	50%	100%
Brood Stock		50%	50%	50%	50%
Stocking Prep		0%	0%	0%	25%
1985–86 Fiscal Year	**Quarter**	**Jul–Sep**	**Oct–Dec**	**Jan–Mar**	**Apr–Jun**
Activity					
Spawning		0%	0%	0%	0%
Rearing		100%	90%	50%	0%
Brood Stock		50%	50%	50%	50%
Stocking Prep		100%	100%	100%	75%

system. Stocking preparation hours were allocated to age classes in proportion to stocking weight.

Wage rate estimation. Quarterly facility labor expenditures (including benefits) and labor hours were broken down in the data by major production activity (spawning, rearing, brood stock maintenance) for the 1984–85 fiscal year. These were used to calculate a wage rate by facility and production activity for each quarter. This permitted an allowance for seasonal fluctuations in the hiring of temporary workers, reallocation of higher paid skilled workers to alternative activities, and so on. This method also resulted in the estimation of different wage rates for each facility.

Similar data were available for expenditures and labor hours devoted to stocking preparation, but broken down by district rather than by facility. District stocking preparation expenditures and labor hours were allocated to facilities in proportion to the weight of fish stocked. A wage rate was then determined for this activity by facility.

Data in a form permitting comparison of expenditures and hours worked by production activity were not available for the 1985–86 fiscal year. The wage rate determined from 1984–85 data was used throughout without adjustment for inflation. The 1984–85 fiscal year ran from July 1984, roughly the time that facilities began the task of preparing for the 1985 year class, until June 1985, at which time most 1985 year class fingerlings had been stocked. The 1985 year class fish to be stocked as yearlings remained in rearing facilities until the spring of 1986. Thus the wage rate for the 1984–85 fiscal year covered much of the intensive production period for the 1985 year class. A six month adjustment for inflation to correspond with the 1985 calendar year was felt to be unnecessary.

Labor costs by species and age class. The wage rate by facility and activity was applied to labor hours by species, age class, activity, and facility. Labor costs were then totaled by activity and across facilities for each species and age class, and divided by the number stocked adjusted by the estimated capture-per-release rate to determine the labor cost per captured fish by species and age class.

Correction for in-house distribution labor. In nearly every instance, labor associated with fish production was managed by hatchery-rearing facilities up to the point of transportation to stocking sites. At that point, actual distribution of fish to stocking sites was managed by a different section of the WDNR Bureau of Fisheries Management.

At a few facilities, however, a portion of this distribution labor was provided in-house, and was recorded in facility financial reports as a stocking preparation labor cost. Facility managers were interviewed and asked to provide an estimate of the in-house labor contribution to distribution. These estimates were used to make the necessary correction to the labor cost results.[3]

Distribution Costs

Distribution costs are sometimes excluded from calculations of the cost of stocking programs (*e.g.* USFWS 1986). These costs are included here since they are relevant to the planning decision for stocking rates. The interested reader may easily subtract these costs from our results if desired using information provided in the tables.

As noted in the previous section, distribution operations were generally managed separately from hatchery-rearing facility operations of the WDNR. Distribution records did not permit direct calculation of costs. An estimation procedure based on mileage to stocking sites and weight of fish at stocking was used.

Round trip mileage was estimated from each facility to each stocking site using road maps. The total weight stocked was used to estimate the number of truck loads required using a standard truck size having an 800 pound carrying capacity. The WDNR 1985 standard vehicle mileage assessment of $0.68 for this truck size was used to calculate the vehicle expense by species and age class. This mileage assessment included an allowance for depreciation, maintenance, and fuel. The rationale for including depreciation is discussed above in the introduction.

The distribution labor expenditure was similarly calculated using mileage and a WDNR estimate of the number of work hours required per mile. According to a WDNR labor use study, 0.022 labor hours were allocated for each distribution mile. A permanent employee average wage rate of $12, including benefits, was applied to calculate distribution labor costs. Labor and vehicle costs for each facility's stocking sites were totaled across facilities by species and age class, divided by the number of fish stocked, and adjusted by the capture-per-release rate to determine the distribution cost per captured fish.

Fixed Costs

Fixed costs are here defined as those periodic costs which do not vary (at the margin) with the stocking rate for a particular species. Increasing or decreasing

[3] Kettle Moraine Springs facility provided 33% of its own distribution labor, Wild Rose provided 20% to stockings in Lake Michigan south of Sheboygan, and Thunder River provided 50%. All others provided none of their own labor for transportation to the stocking sites.

brook trout stocking rates, for example, will not alter fixed expenditures for repainting of buildings, grass mowing, and so on. Depreciation on major equipment and facilities (except vehicles as noted above in the section on distribution) was not included, as was pointed out in the introduction, because of the extreme age of most facilities and major equipment, and because of the remote likelihood that they would be replaced, sold or converted to alternative use. Essentially, depreciation is not relevant to the planning manager's decision with respect to stocking rates.

Total costs for feed and labor[4] were aggregated by facility. These costs were subtracted from total facility expenditures, the remainder representing costs not associated with feed, labor, or distribution. These fixed costs were allocated by species and age class in proportion to the number of months from spawning to stocking, and then adjusted as with other types of costs to determine the fixed cost per captured fish by species and age class. Note that time spent in a facility from spawning to stocking is not the only method available for the allocation of fixed costs to each species and age class, but does seem to be the most appropriate for the stocking rate planning decision.

Special situations at a number of facilities necessitated further adjustments. Operations at nearly all facilities were devoted exclusively to the rearing of salmonids. Major infrastructure (tanks, incubators, raceways, ponds) required for all species of salmonids reflects the capital-intensive nature of their production. At two facilities[5] salmonid production was mixed with non-salmonid, inland lake species (*e.g.* walleye and muskellunge). Production of these species is typically less capital intensive than salmonid production, requiring less equipment but more land for large ponds. Conversations with WDNR technical staff suggested that costs associated with extensive production methods varies primarily according to labor requirements. Data were difficult to interpret, but it was estimated through conversations with WDNR technical staff that 75% of total labor hours at the mixed-operation facilities was devoted to salmonids. As a rough approximation, this percentage was applied to adjust fixed costs at the two facilities in question.

At many facilities, salmonid production was allocated to stocking in both Lake Michigan and Superior. Fixed costs were allocated to the Lake Michigan stocking program in proportion to the weight of fish stocked.

United States Fish and Wildlife Service Program

All lake trout stocked from the 1985 year class in Lake Michigan were reared in federal facilities in Wisconsin and Michigan. The USFWS (1986) study covered costs of stocking in 1984. Since the federal facilities involved in the lake trout rehabilitation program reared lake trout exclusively, it was a much simpler matter to determine costs for that species. Some adjustments were necessary to facilitate comparison with the WDNR results.

The federal study provided a cost per pound for all lake trout stocked, representing an average of both fingerlings and yearlings. Additional data were ob-

[4] —but not distribution. Recall that distribution costs were not included in the financial reports of most hatchery-rearing facilities. Adjustments were made in the few instances where they were included. See the discussion above in the section on labor costs.
[5] Lake Mills and Wild Rose.

tained directly from the USFWS Minnesota office covering total number of fish stocked by age class for the years in question. Managers of each facility provided an average number of fish-per-pound stocked by age class from their records. This information was used to calculate the total weight of yearlings and fingerlings stocked. Total weight and cost per pound were used to calculate total cost by age class.

Distribution costs were not included in the federal study, and it was thus necessary to estimate them using the same method as in the WDNR analysis. In addition to vehicle and labor costs of transportation from the facility to the stocking site for both fingerlings and yearlings, the information on the cost of the rental of a barge used to plant lake trout yearlings offshore was obtained from the USFWS Minnesota office and added to yearling costs. Total costs by age class were divided by the number stocked and adjusted by the capture-per-release rate to determine the stocking cost per captured fish for lake trout. Finally, the 1984 costs were converted to 1985 dollars using the producer price index.

Note that the USFWS results did not permit a distinction between marginal and fixed costs of production. Fixed costs were totaled across all species produced by the WDNR, and then divided by WDNR total costs. It was assumed that this ratio would hold as well for USFWS operations. Total USFWS production costs were multiplied by the fixed-to-total cost ratio to determine fixed costs for lake trout.

Results

Over $1 million was spent by the WDNR and the USFWS in the stocking into Lake Michigan of 6.2 million fish from the 1985 year class. Table 5 lists total costs by species and age class. The species with the highest estimated total cost was brown trout, with fingerlings and yearlings costing roughly $186,000 and $188,000 respectively.

Brook and steelhead trout yearlings at over $0.70 per fish were the most

Table 5
Total Stocking Costs[a]

Species	Age[b]	Feed	Labor	Distn[c]	Fixed	Total
Brook	FGL	1832	14177	4984	12148	33143
Brook	YLG	9286	14968	8779	84590	117624
Brown	FGL	13740	44399	15717	111908	185765
Brown	YLG	46723	61339	31699	48383	188146
Rainbow	YLG	9184	17469	10884	20335	57873
Coho	YLG	3261	19963	3152	43067	69444
Steelhead	YLG	3263	4279	2208	127671	137423
Chinook	FGL	8081	14300	5673	97477	125532
Lake	FGL	NA	NA	NA	NA	42856
Lake	YLG	NA	NA	NA	NA	188662
Total		NA	NA	NA	NA	1146473

[a] In US$ (1985), 1985 Year Class, Wisconsin Lake Michigan, NA = not available.
[b] FGL = fish stocked as fingerling, YLG = fish stocked as yearling.
[c] Distn = distribution.

expensive fish in terms of cost per fish stocked, as shown in Table 6. Lowest cost per fish stocked were chinook salmon and lake trout fingerlings. In all cases fingerlings were found to be less expensive per fish stocked than yearlings of the same species.

Table 7 presents costs per captured fish. These figures reflect the estimated higher capture-per-release rate of fish stocked as yearlings. In nearly all cases, despite higher total costs, costs per captured fish were found to be lower for yearlings than for fingerlings. However, brook trout yearlings were found to be more expensive than fingerlings, at a cost of $12.67 versus $10.14 per captured fish. Lowest cost of all species and age classes was the chinook salmon fingerling at only $0.35 per captured fish. Key to this result were the limited time spent in the facility and small size at stocking of chinooks, resulting in lower costs across all categories. Chinook have a higher estimated capture-per-release rate. Chinook salmon were also spawned and reared close to their stocking sites, leading to very low distribution costs. Chinook were the most heavily stocked species with over 2,700,000 stocked, compared to 1,500,000 lake trout of both age classes, and only about 300,000 brook trout of both age classes.

If fixed costs are excluded, remaining costs reflect the marginal cost of production within a limited range, provided facilities are not currently at capacity. Table 7 displays marginal stocking costs per captured fish. Brook trout fingerlings at a marginal cost of $6.42 were highest, followed by brown trout fingerlings at $3.53 and brook yearlings at $3.56. Chinook salmon fingerlings were lowest at a marginal cost of $0.08. The lowest marginal cost trout species was the steelhead at $0.52. Rainbow trout yearling marginal cost was $3.06, while lake trout yearlings were $1.07.

The steelhead trout result warrants additional discussion, particularly because it is so different from the rainbow result. Steelhead trout were reared from brook stock captured in the wild, but are of the same species as rainbow trout reared from captive brood stock. Rainbow trout marginal cost was found to be much higher than steelhead, possibly because rainbows remained in the hatchery-rearing facility on average three months longer than steelhead, leading to higher

Table 6
Average Stocking Costs per Fish Stocked[a]

Species	Age[b]	Feed	Labor	Distn[c]	Fixed	Total
Brook	FGL	0.01	0.11	0.04	0.09	0.25
Brook	YLG	0.06	0.09	0.05	0.52	0.72
Brown	FGL	0.02	0.08	0.03	0.19	0.32
Brown	YLG	0.08	0.11	0.06	0.09	0.34
Rainbow	YLG	0.04	0.07	0.05	0.08	0.24
Coho	YLG	0.02	0.15	0.02	0.32	0.51
Steelhead	YLG	0.02	0.02	0.01	0.67	0.72
Chinook	FGL	0.00	0.01	0.00	0.04	0.05
Lake	FGL	NA	NA	NA	NA	0.09
Lake	YLG	NA	NA	NA	NA	0.18

[a] In $US (1985), 1985 Year Class, Wisconsin Lake Michigan, NA = not available.
[b] FGL = fish stocked as fingerling, YLG = fish stock as yearling.
[c] Distn = distribution.

Table 7
Average Costs per Captured Fish[a]

Species	Age[b]	Feed	Labor	Distn[c]	Fixed	Total	Marginal
Brook	FGL	0.56	4.34	1.52	3.72	10.14	6.42
Brook	YLG	1.00	1.61	0.95	9.11	12.67	3.56
Brown	FGL	0.66	2.12	0.75	5.35	8.88	3.53
Brown	YLG	1.09	1.43	0.74	1.13	4.39	3.26
Rainbow	YLG	0.75	1.43	0.89	1.66	4.72	3.06
Coho	YLG	0.40	2.48	0.39	5.34	8.61	3.27
Steelhead	YLG	0.18	0.23	0.12	6.87	7.39	0.52
Chinook	FGL	0.02	0.04	0.02	0.28	0.35	0.08
Lake	FGL	NA	NA	NA	NA	3.38	1.36[d]
Lake	YLG	NA	NA	NA	NA	2.64	1.07[d]

[a] In $US (1985), 1985 Year Class, Wisconsin Lake Michigan, NA = not available.
[b] FGL = fish stocked as fingerling, YLG = fish stocked as yearling.
[c] Distn = distribution.
[d] Estimated from fixed-to-total cost ratio of other species.

feed and labor costs. Finally, the steelhead trout rearing facility was located very close to stocking sites compared to the principal rainbow trout facility, leading to lower distribution costs.

Other Studies

Table 8 presents results from other studies. Adjustments were made for inflation and method of calculation to permit comparison.

The USFWS (1986) study used here to derive lake trout costs also provided costs for other species at federal and state hatchery-rearing facilities in the United States. 1984 costs were converted to 1985 dollars using the producer price index. As with lake trout costs, these other species costs excluded distribution. The average WDNR distribution cost by species and age class was added to the USFWS results, which were then converted to cost per captured fish as above.

The American Fisheries Society (AFS 1982) computed monetary values of freshwater fish based on a nationwide commercial fish producer survey of production costs. The purpose of the study was to calculate compensation which should be paid in the event of a fish-kill. Costs were listed according to fish size. The size closest to WDNR or USFWS stocking size was chosen for the comparison. 1980 costs were converted to 1985 dollars and then adjusted by the capture-per-release rate to cost per captured fish.

Weithman (1986) compiled results for costs per captured fish from several different studies from as far back as 1959. In each case costs were converted to 1985 dollars. The Weithman study does not list sizes of fish, making comparison difficult. The results are provided which seemed most appropriate given the magnitude of the cost.

Variation from one study to the next is high. Given that studies tend not to give a detailed account of methods used to calculate costs, the variation in results is difficult to explain. One of the purposes of this study has been to provide a clear

Table 8
Comparison of Costs per Captured Fish to Other Studies

Species	Age	This Study	USFW 1986	AFS 1982	Weithman
Brook	FGL	10.14		17.78	
Brook	YLG	12.67		11.48	
Brown	FGL	8.88		18.74	
Brown	YLG	4.39		12.06	13.94
Rainbow	YLG	4.72	4.94	12.71	5.50
Coho	YLG	8.61	2.58	6.03	3.79
Steelhead	YLG	7.39	4.26	6.65	18.06
Chinook	FGL	0.35	1.87	1.25	
Lake	FGL	3.38		13.74	
Lake	YLG	2.64		6.57	

[a] In $US (1985).
Sources:
American Fisheries Society, *Monetary values of freshwater fish and fish-kill counting guidelines,* American Fisheries Society Special Publication 13, 1982.
USFWS (United States Fish and Wildlife Service), *Artificially propagated fish for national fishery programs: an analysis of source, cost, purpose, and use,* United States Fish and Wildlife Service, Washington, D.C., 1986
S. A. Weithman, "Economic benefits and costs associated with stocking fish," in *Fish culture in fisheries management,* 357–365, ed. R. C. Stroud, American Fisheries Society, Bethesda, MD., 1986.

explanation of methods used to calculate costs so that future analysts can assess where such costs should be adjusted to suit local conditions.

Conclusions

Before discussing specific policy issues, some caveats are in order. Only costs associated with production and stocking were examined here. Depending on the specific policy issue under consideration, researchers and planners who wish to use these results may also wish to explore the additional costs of sport fisheries such as the costs of boat landings, pest management (*e.g.* lamprey control programs), or angler equipment. They should consider available physical plant carefully when interpreting figures indicated here as fixed and marginal costs; marginal costs must include the capital cost of expansion if facilities are already at maximum production capacity. Decisions to reduce or eliminate production at a facility must take into consideration the alternative uses to which the facility might be put, and the level of fixed cost that will remain irrespective of the level of fish production. Care in using these results should also be exercised if a policy under consideration might affect the capture-per-release rates; for example, a policy to double the number of chinook stocked might result in a precipitous drop in the chinook capture-per release rate.

Some of the costs reported here may be specific to Wisconsin, and they would necessarily require adjustment if applied elsewhere. Even such seemingly generalizable costs as those for feed may be affected by water temperatures in hatcheries.

By itself, this study does not provide a basis for many policy decisions. It does *not* follow from this analysis, for example, that stocking of other species should be reduced in favor of increased chinook stocking. While the other species do have higher costs, they may fulfill important roles in the fishery. Brown trout and coho salmon provide spring fisheries when chinooks are harder to catch. Rainbows and steelhead provide stream fishing opportunities that some anglers prize, and are becoming increasingly popular in the lake fisheries as well. Rainbows and steelhead also tend to carry lower burdens of PCBs than the other salmonids. The species to be stocked and the rates of stocking should, from an economic perspective, be based on benefits as well as costs.

Within this general caveat, three tentative conclusions about stocking can be drawn. First, managers might wish to review the slightly more than ten percent of the budget devoted to brook trout. Unlike the other species just discussed, brook trout do not appear to play any special role in the fishery for the vast majority of anglers, and are relatively quite expensive on a per-captured-fish basis.

Second, as noted at the outset, Lake Michigan currently has little or no natural reproduction of lake trout. This is very discouraging given the years and dollars that have been devoted to attempts to restore naturally reproducing stocks. However, our results are rather encouraging in this regard. Lake trout turn out to be a relatively cost-effective way to support a substantial portion of the sport fishery, and restoration of some naturally reproducing stocks may eventually be achieved in the bargain. Provided that substantial further restrictions on sport and commercial fishing are not required as part of rehabilitation efforts, any proposals to reduce lake trout stocking rates should be carefully reviewed.

Third, the outstanding economic performance of chinook salmon is especially noteworthy, particularly given their popularity with Wisconsin anglers, as verified by Samples and Bishop (1981). Solving problems that have led to very poor catches in the past three years deserves a high priority. If the forage base is adequate in future years and sport catches would be improved, increased stocking of chinooks may be affordable.

Fisheries management involves consideration of numerous factors. Only one such factor has been examined here, albeit an important one. Species-specific benefit studies in the Wisconsin waters of Lake Michigan will be required in order to develop a more complete picture for the policy debate, but, as this study seeks to emphasize, careful consideration of economic costs must also play a significant role.

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APPENDIX I: Data Sources

1 Wisconsin Department of Natural Resources

1.1 Coldwater fish production audit
Basic information about each facility is provided.

1.2 Fish distribution summary 1985, 1986
Weight, number, length, and age class of fish by species, facility, and destination are provided for each calendar year stocking.

1.3 Workload analysis and cold water propagation program time-task spread sheets 1987
Results of a WDNR study include key production parameters such as the number of employee hours per mile travelled to stock fish.

1.4 Lot history reports 1984, 1985, 1986
Each lot of fish is followed from the moment of entry to the moment of exit at a facility. A lot is defined as all fish spawned from the same brood stock at the same time. A lot history report is created for each lot at a facility. Portions of a lot transferred to a new facility are issued a new lot history report, so that more than one report can exist for a given lot. Lot history reports provide a monthly record of food consumption and type, number of fish in the lot, and mortality.

1.5 Quarterly hatchery financial reports 1985, 1986
For the 1985 report, quarterly data are provided on labor hours and expenditures by major work category and facility. The 1986 report provides only expenditures by work category and facility. Both reports provide total labor and non-labor expenditures by facility.

1.6 Quarterly time analysis reports 1985, 1986

Reports indicate hours worked broken down by major work category, specific activity within a work category, facility, and species.

1.7 Stocking receipts
Rearing facility, weight and number of fish stocked, and stocking site are provided for each lot transported to a given county stocking site

2 United States Fish and Wildlife Service

2.1 Distribution Summary 1985, 1986
Weight, number, length, and age class of fish by species, facility, and destination are provided for each calendar year stocking.

APPENDIX II: Procedures Used in Resolving Data Problems

The distribution summary for the 1985 calendar year listed the stocking of coho salmon fingerlings in 1985, but it was believed that these should have been recorded as yearlings from the 1984 year class. These coho were not included in this analysis.

Chinook salmon stocked from two facilities were listed in the distribution summary without weight, leading to erroneous total weights in the report. The weights of these chinook were estimated based on their length using conversion tables in Piper (1982) and included in the analysis.

The distribution summary and monthly hatchery reports listed numerous rainbow trout stocked as fingerlings in Lake Michigan in 1985. Conversations with managers indicated that these were in fact yearlings from the 1984 year class. These rainbows were removed from the analysis.

Splake were stocked, but constituted only a small part of the stocking program. 35,000 fingerlings and 20,000 yearlings were stocked in Lake Michigan. Due to an error in WDNR records, it was not possible to include splake in this analysis.