EVALUATION OF A PILOT FISH HANDLING SYSTEM AT BRUCE NGS 'A'

Report No 85-258-K

J.S. Griffiths
Biologist
Biological Research Section
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ABSTRACT

A pilot fish recovery system using a *Hidrostal fish pump* was tested in the Bruce NGS 'A' forebay during June, 1984. Despite low forebay fish concentrations, the system was capable of capturing 97 000 alewife/day (3900 kg) if operated continuously. Post-pumping survival averaged 97%. It is estimated that a single pump could handle alewife runs in the 40 000 to 70 000 kg range, but multiple pumps or a single larger pump would be required to assure station protection *from the largest runs* (>100 000 kg). Results indicate that tank/trailer return of pumped fish is feasible, but other alternatives for returning fish to Lake Huron are also being considered.

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EXECUTIVE SUMMARY

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This study describes the construction and evaluation of a pilot fish recovery system which was tested in the forebay of Bruce NGS 'A' during June, 1984. The system consisted of a 13 cm (5") inlet diameter open-impeller Hidrostal fish pump, associated inlet structure, discharge piping, a large (6625 L) flow-through collecting tank, and return piping. The system was capable of continuous operation at flow rates approximating 4200 L/min.

Alewife visually avoided capture by opaque PVC intakes (average catch = 1.2 fish/hour) even at night. Use of a 1 meter long clear acrylic intake pipe (set at 2 meters depth in the forebay) increased catch to 599 alewife/hour. A substantial further increase (to 3683 fish/hour) resulted when the clear intake was set at 1 meter depth and extended to 1.5 meters length. With this intake, best catches occurred in daylight (5981/hour in morning, 3666/hour in afternoon) when alewife schools formed near the surface. Lower night catches (1615/hour) resulted when fish were dispersed throughout the forebay. A mercury vapour lamp successfully attracted fish to the pump at night, increasing catch to 2816 fish/hour.

Post-pumping mortality (3%) was very low for alewife held at forebay temperatures. Significant mortality of discharge-held fish (16.5%) suggests that return of pumped fish to Lake Huron via the Bruce 'A' thermal discharge should be viewed with caution.

Results for the optimal intake configuration indicate that continuous pump operation would have resulted in a daily capture of 97 000 alewife (3900 kg), although forebay fish densities were

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quite low at the time of testing. During May and June, 1984, Bruce 'A' captured only about 1000 kg of alewife in each month. Computations based on present results suggest that a single 5" Hidrostal pump may be capable of handling alewife runs as large as 40 000 to 75 000 kg (these amounts were impinged in May of 1981 and 1983). However, extremely large runs (350 000 kg were impinged in May 1979) would require use of multiple pumps or a single larger pump to assure station protection. Results indicate that tank/trailer return of pumped fish is feasible, but other alternatives, such as use of site drainage ditches, are being considered.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

91601
new 82-10

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To Dr. A.J.U. Grange
Superintendent
Environmental Protection
Technical and Training Services Division

EVALUATION OF A PILOT FISH HANDLING SYSTEM AT BRUCE NGS 'A'

1.0 INTRODUCTION

This study was conducted at the request of the Radioactivity Management and Environmental Protection Department, Technical and Training Services Division (Memo: Garcia to Vascotto, 84/02/22). The objective of the study was to evaluate the effectiveness of a pilot fish pump/return system located at the eastern end of the Bruce 'A' forebay. The system consisted of a Hidrostal fish pump, associated inlet structure, pipe connections and a large (6625 L) flow-through collection tank. The study had the following detailed objectives:

1.1 Determine the optimum intake configuration to maximize fish capture.

1.2 Determine suitable pumping speeds and durations to maximize capture and maintain high survival.

1.3 Determine fish survival immediately after pumping and over a period of at least 24 hours. These tests were to be conducted in ambient temperature holding tanks (simulated shoreline release) and in discharge holding pens (simulated discharge release).

1.4 Evaluate the suitability of the collection tank for transport of pumped fish back to Lake Huron. These tests were to determine the maximum fish holding capacity of the tank, the rate of oxygen depletion during a simulated transport period, and the need for aeration during fish transport.

1.5 Evaluate the capabilities of the system as a whole to remove live alewife from the Bruce 'A' forebay in relation to station impingement at the time of sampling and past impingement events.

2.Ø METHODS

2.1 Apparatus

Construction of the fish handling system was begun in early May of 1984. Delays in delivery of the fish collection tank prevented start-up of testing until early June. However, station records indicate that few alewife (approximately 1ØØØ kg = 25 ØØØ fish) were impinged during May of this year. A similar level of impingement was observed in June. During the June test period, Bruce NGS 'A' operated four units at 791 MW each, with a combined cooling water flow of 17Ø m^3/s. A minor outage occurred on Unit 1 for 43 hours on June 23-24. However, experiments were not being conducted during the outage.

The fish handling system is shown in Figures 1, 2, and 3. The collection pump, a Hidrostal model H5F, was mounted approximately 2 meters above the water surface at the east end of the Bruce 'A' forebay. The 15 cm diameter inlet pipe extended 3 meters over the forebay, then entered the water at a 45° angle. Intake depths varied from approximately 2 meters to 1 meter. The pump discharge was increased to 25 cm diameter in order to reduce turbulence in the collection tank. A bottom drain (1 meter square) in the collection tank was screened with a perforated metal plate to retain collected fish. Flexible ABS plastic pipe (3Ø cm diameter) returned the flow to the intake forebay. As installed, the system was capable of continuous operation at pump speeds up to 85Ø rpm (approximately 42ØØ L/min).

Three large fish holding pools (3.7 m diameter x Ø.8 m deep) were erected on level ground east of the forebay. These were fitted with drains (leading back to the forebay) and were supplied with a flow of intake (ambient temperature) water by a 1 hp centrifugal pump. These pools were used for determination of post-pumping mortality. Four nylon mesh cages (1 m square x 1 m deep) were also set up at the dock in the Bruce 'A' discharge channel. These were also used for post-pumping mortality estimates. Four different intake structures were tested to determine the optimum inlet configuration (Figure 4). These were:

a) A straight 15 cm diameter PVC pipe.
b) A cone shaped PVC structure (which could be tested with or without a mercury vapour (MV) lamp).
c) A 1 meter long x 15 cm diameter clear acrylic pipe.
d) A 1.5 meter long x 15 cm diameter clear acrylic pipe.

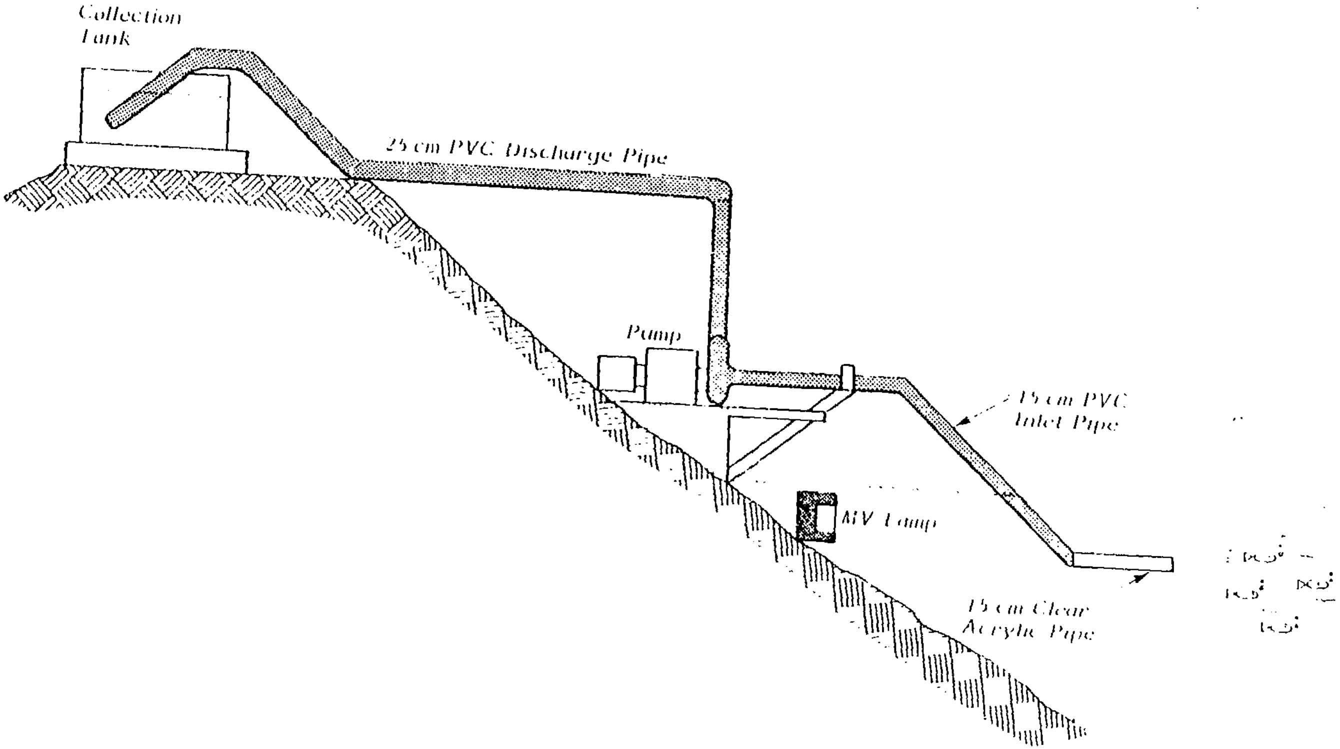

FIGURE 1
SCHEMATIC DRAWING OF FISH HANDLING SYSTEM

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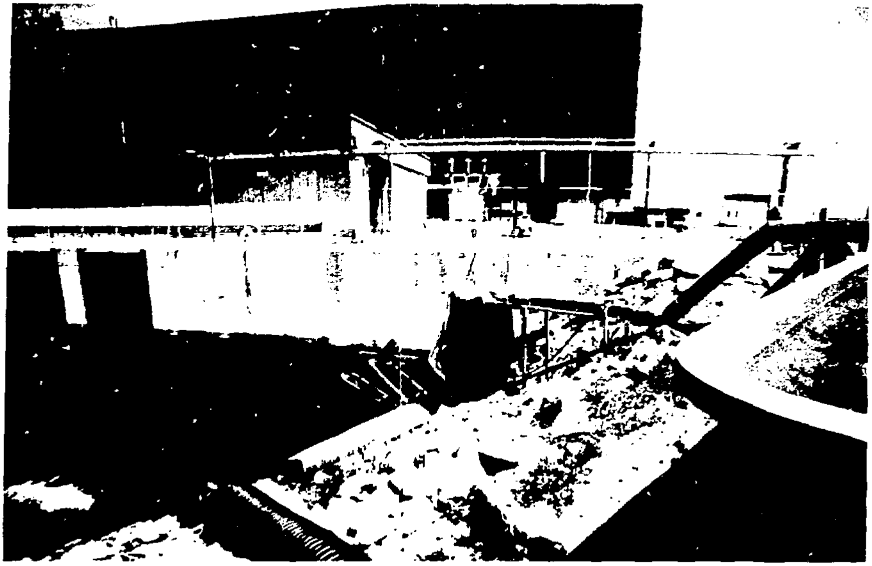

FIGURE 2

VIEW OF HIDROSTAL FISH PUMP LOOKING NORTHEAST
ALEWIFE SCHOOL LOCATED BETWEEN LAST SCREENWELL OF
BRUCE 'B' UNIT 4 AND FISH PUMP INTAKE

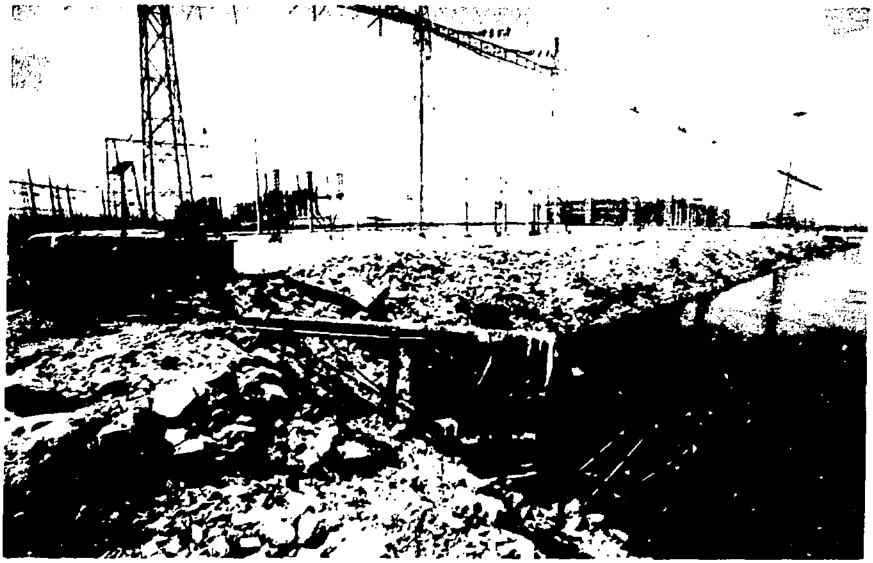

FIGURE 3

VIEW OF HIDROSTAL FISH PUMP LOOKING NORTHWEST
FISH COLLECTION TANK IS AT LEFT OF PHOTO

The use of a small diameter (15 cm) inlet pipe resulted in high inlet velocities. At a pump speed of 850 rpm, inlet velocities approximated 3.8 m/sec. The PVC cone structure was similar in design (but smaller in dimension) to the cone-shaped inlets which proved effective in laboratory flume tests (Ontario Hydro Research Division Report 84-207-K). The cone used in present studies tapered (over a 1 meter length) from the 15 cm inlet dimension to a mouth opening 60 cm wide by 30 cm high. At the 850 rpm pump speed, expected inlet velocity (at the cone mouth) was 39 cm/sec. The cone was equipped with a clear PVC window which allowed the light from an attached mercury vapour lamp to illuminate the inside of the cone (Figure 4). Reflective tape was also added to the inside of the cone to enhance illumination.

2.2 Test Procedures

2.2.1 Determination of Optimum Inlet Configuration

Initial tests indicated that the maximum pumping speed for continuous operation was 850 rpm. Higher pump speeds resulted in massive overflow of the collecting tank (even with the tank standpipe drain removed). Apparently, the size of the tank drain (15 cm diameter moulded fiberglass outlet) was the critical factor limiting pumping capacity. The size of this outlet could not be readily altered. Although this pump speed was above that yielding optimal alewife survival in previous laboratory studies (Ontario Hydro Research Division Report 82-295-K), 850 rpm was selected as the initial speed for inlet evaluation. Lower speeds were to be considered if substantial mortality occurred, but the highest priority task was simply to capture fish. Results proved that consideration of lower pump speeds was not necessary.

The various intake configurations were compared using a standard pump speed (850 rpm) and test duration (45 minutes). For each test, the number of fish of each species captured was recorded. Notes were also made of initial mortalities and damage attributable to the pump (bruises, descaling). In tests where large numbers of fish were captured, fish were counted (during each 5-minute interval) as they exited the pump discharge pipe. This method of enumeration appeared accurate at low to moderate capture rates (<1000 fish/hour) but probably underestimated true capture rates at high fish densities (up to 9000 fish/hour). Alternate counting methods, such as post-test dewatering of the holding tank and direct counting of captured fish, or weight/volume estimation of numbers, were not considered feasible

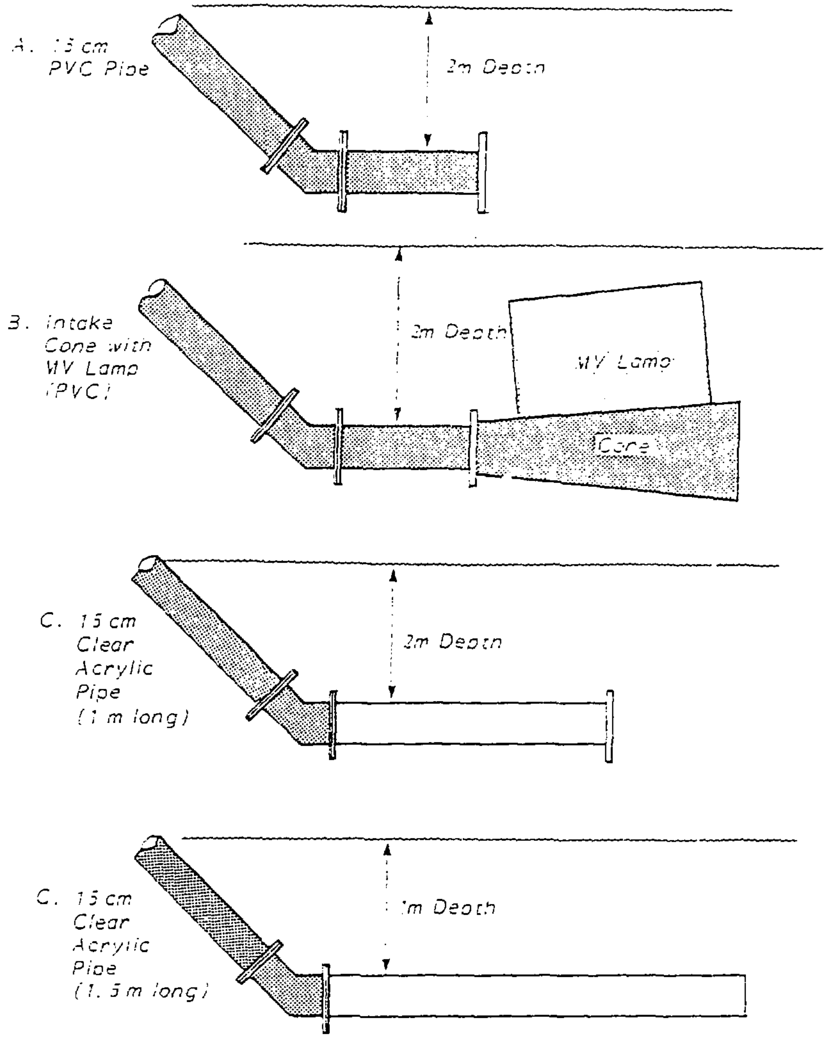

FIGURE 4

INTAKES USED WITH HIDROSTAL FISH PUMP

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due to the large number of tests (50) conducted during the three-week experimental period.

2.2.2 Determination of Post-Pumping Mortality

Following pump passage, sub-samples of alewife were transferred to ambient temperature holding tanks or discharge holding nets. Fifty fish were used for each test. Any seriously damaged individuals were excluded from these tests, as the percentage of serious damage or immediate mortality was extremely low. Thus, inclusion of one or more damaged alewife in a sample of 50 fish would unrealistically bias post-pumping mortality estimates. Fish held in the discharge nets were transferred by truck in a 200 L barrel. Aeration was not necessary, as transfer was completed in approximately 15 minutes. The fish were handled carefully, and our previous experience suggests that little, if any, handling mortality would be expected from the transfer, as alewife used in these tests appeared vigorous and quite healthy. Hence, an additional 'handling' control was not included in the experimental design.

Six replicate groups were tested for post-pumping mortality in the ambient temperature holding pools. As mortalities were extremely low after 24 hours, observations were extended to 72 hours. Post-pumping observation of fish in discharge pens did not extend beyond 24 hours due to predation problems. Initial losses of test fish were blamed on seagulls. However, as progressive improvements in the net coverings of the discharge pens only partially alleviated the problem, it is suspected that a mink was responsible for loss of the test fish. Two groups of fish, each 4 replicates x 50 alewife, were successfully tested (without predation losses) in the discharge, for durations of 9 hours and 24 hours, respectively. The shorter duration tests were included as it was felt unlikely that fish released in the discharge would remain there for extended periods.

2.2.3 Collection Tank Capacity and Oxygen Depletion

For these tests, the Hidrostal pump was turned off, and oxygen depletion in the collection tank was monitored over periods ranging from 40 to 60 minutes (simulating transport to the thermal discharge or some other lakeside release point). Water depth in the collection tank was lowered to approximately 40 cm (half full) for these tests, as it would not be possible to move the tank in a full condition unless a close-fitting lid were added. Three tests were run, at alewife densities of 1200, 4100 and 8700 fish. In the latter test, aeration (with pure O_2) was begun after 28 minutes duration, as oxygen drawdown had exceeded 3 mg/L and it was apparent that the fish were experiencing some respiratory difficulty.

3.0 RESULTS

3.1 Determination of Optimum Intake Configuration

3.1.1 Tests of Cone and Pipe PVC Intakes

Initial tests conducted with the PVC intakes (cone, 15 cm diameter pipe) proved disappointing, as very few fish were captured (Appendix 1). In this test series, 12 tests were run over the period June 11 to June 13. In the fourth test (15 cm pipe, daylight), three fish were caught (1 alewife, 1 smelt, 1 stickleback). Fish were captured by the cone-shaped intake only when the mercury vapour (MV) lamp was operating. One rock bass was caught in a daylight test, and 14 fish (10 alewife, 2 suckers, 1 burbot, 1 perch) were captured in a night MV test. No fish were captured in the remaining nine tests conducted in this series.

Substantial numbers of alewife were observed in the forebay during these tests. The current structure in the Bruce 'A' forebay is such that with Unit 4 operating, some flow continues past the last pumphouse screenwell. Due to the sloping end of the forebay, this flow rises towards the surface and turns clockwise (towards the bank opposite the screenwells). During daylight, alewife appear to concentrate near the surface in this upwelling area. Consequently, the pump intake was placed such that the intake mouth was within the area normally occupied by the edge of the fish school. However, observation indicated that alewife avoided approaching closer than about 1 meter from the intake mouth. Although the fish could not be observed at night, substantial illumination exists from nearby floodlamps. Poor night catches (no fish when MV lamp was off) suggested that the fish were able to avoid the intake structures during darkness as well.

3.1.2 Tests of the 1 Meter Clear Intake

As the above results suggested a strong visual avoidance of the intake, the PVC cone was replaced by a 1 meter long clear acrylic pipe (15 cm diameter). A substantial increase in catch resulted (Appendix 2). In 10 tests conducted over the June 13 to June 18

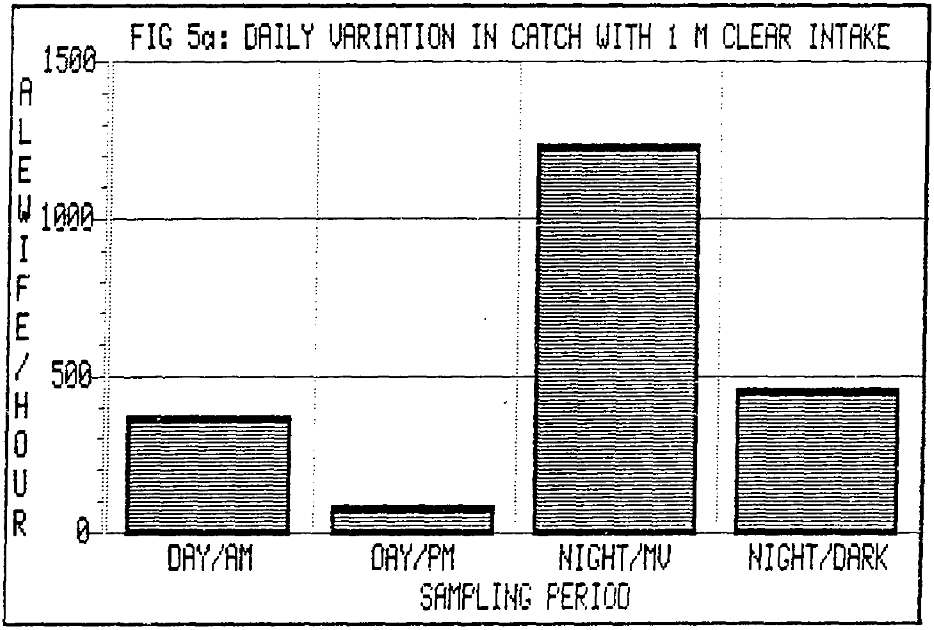
FIG 5a: DAILY VARIATION IN CATCH WITH 1 M CLEAR INTAKE
ALEWIFE/HOUR
1500
1000
500
0
DAY/AM
DAY/PM
NIGHT/MV
NIGHT/DARK
SAMPLING PERIOD

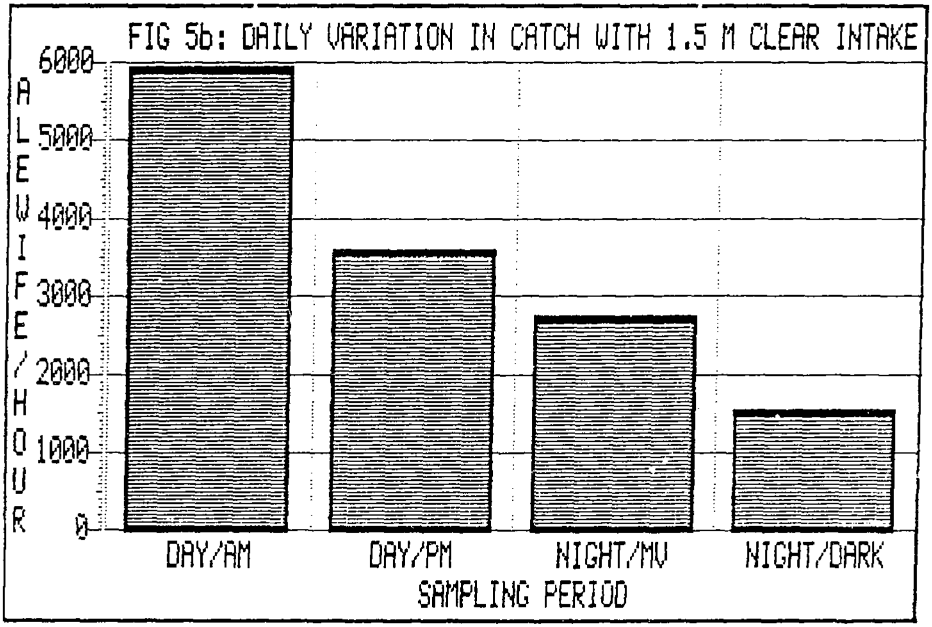
FIG 5b: DAILY VARIATION IN CATCH WITH 1.5 M CLEAR INTAKE
ALEWIFE/HOUR
6000
5000
4000
3000
2000
1000
0
DAY/AM
DAY/PM
NIGHT/MV
NIGHT/DARK
SAMPLING PERIOD

period, average alewife catch was 599 fish/hour. An apparent diurnal component existed in the catch data (Figure 5a). Average alewife captures ranged from 100 fish/hour in afternoon tests to 1245 fish/hour in night tests with the MV lamp operating. For these experiments, the mercury vapour lamp was submerged near shore and appeared to illuminate an area extending somewhat beyond the intake mouth. Average night catch without the MV lamp (483 fish/h) was better than daylight results, but well below the catch in night MV tests.

While the data in Figure 5a suggest substantial diurnal differences in catch rate, high variability and low replicate numbers prevented these differences from being statistically significant. Also, it was apparent that within the course of most tests, the rate of catch varied widely (over successive 5-minute counting intervals). This, combined with the capture of bottom-oriented fish species (suckers, catfish) in some tests (Appendix 2) suggested that the intake location (approximately 2 meters deep) was not optimal. Further modifications of the clear intake were made.

3.1.3 **Tests of the 1.5 Meter Clear Intake**

A longer (1.5 meter x 15 cm diameter) clear intake pipe was installed. The PVC downpipe was also shortened, resulting in the intake mouth being positioned at a depth of 1 meter (Figure 4d). Tests of this intake configuration were begun on June 19 and continued until June 28. A total of 29 tests was run, yielding an average alewife catch of 3683 fish/hour (Appendix 3). This value was significantly greater than catches for the previous test series (Appendix 4).

Best catches with the 1.5 m clear intake (average = 5981 alewife/hour) occurred during morning tests (Figure 5b), when fish were concentrated near the surface. In the afternoon, alewife appeared to be less concentrated, and somewhat deeper, resulting in a significant decline in average catch to 3666 fish/hour (Appendix 5). Night catches without the MV light (1615 fish/hour) were significantly lower than daylight catches. Addition of the MV lamp almost doubled the night catch (2816 alewife/hour). This value was not significantly different from the average afternoon catch (Appendix 5).

During daylight tests, both the alewife school in the forebay and the intake structure were clearly visible. Alewife showed no signs of avoidance, as the school often completely surrounded the acrylic inlet pipe. Observations suggested that most of the fish carried by the forebay current to within 0.5 to 1 meter of the pump intake mouth were extremely vulnerable to capture. As the fish were oriented into the forebay current, most appeared to be drawn into the intake tail-first. Few fish were able to avoid capture. Apparently, the gradient of velocities created at the mouth of the intake pipe was sufficiently sharp that once fish came within the influence of the flow, they were unable to respond before being swept into the pump inlet.

Temporal variation in catch (within a test) was considerably lower than that observed with the previous (1 meter long) deeper intake. Thus, it appears that the 1.5 meter acrylic intake (at 1 meter depth) was in an optimal (or near-optimal) location, as the intake was capturing fish continuously throughout the duration of each test.

Temporal variations in catch were next considered to determine whether the present 45-minute test results might differ from results of prolonged pumping, ie., continuous operation of the fish recovery system. To minimize the effects of variations in total catch between replicate tests, results for each 5-minute counting period were computed as a percentage of the total catch (for that test). Regressions and scatter plots for each time period are shown in Figure 6. Input data, associated regressions and F-tests are listed in Appendix 7. In daylight tests (Figures 6a, 6b), there were no significant trends to the results, and variations between replicates and between time intervals were quite small. Higher variation was observed during night tests (Figures 6c, 6d). In night dark tests (no MV light) there is a suggestion that catch declined during the course of a test, but the regression was not significant due to high between-replicate variability. In contrast, night MV results indicated a substantial and significant increase in catch as the test proceeded (Figure 6d, Appendix 7).

3.2 Determination of Post-Pumping Mortality

The incidence of immediate post-pumping mortality (or severe pump damage) was extremely low. Records of immediate mortality were not kept for all tests, as when fish numbers were high (especially in night tests) the screen over the tank drain was removed, allowing fish to return to the forebay throughout the test. This minimized fish accumulation in the collecting tank, improving the efficiency of enumeration (of incoming fish). In eleven tests where immediate mortality records were kept, a

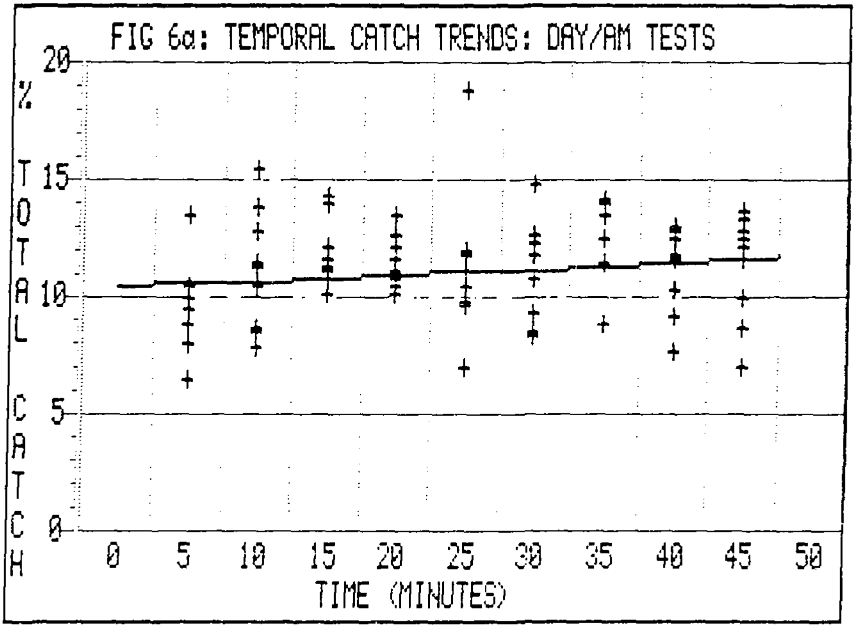
FIG 6a: TEMPORAL CATCH TRENDS: DAY/AM TESTS
% TOTAL CATCH
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50
TIME (MINUTES)

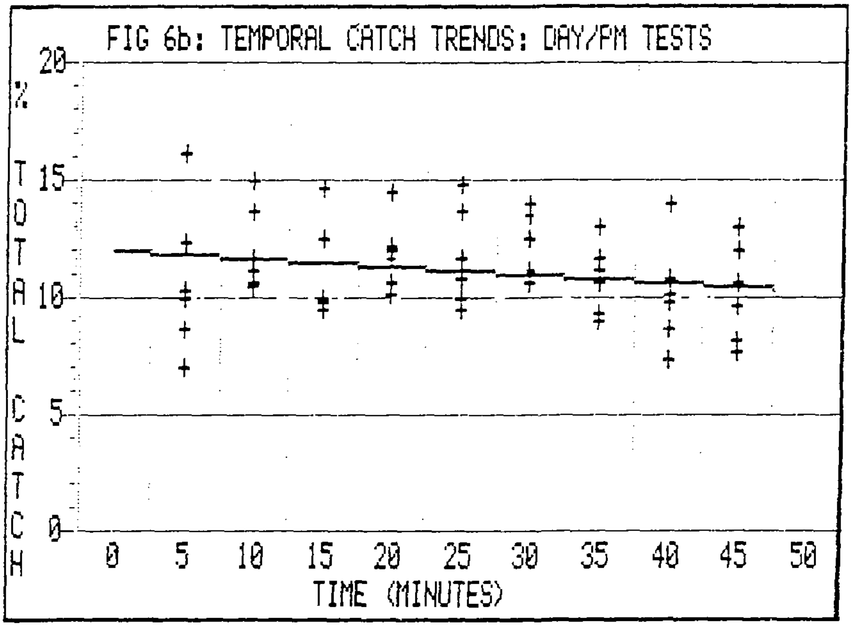
FIG 6b: TEMPORAL CATCH TRENDS: DAY/PM TESTS
% TOTAL CATCH
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50
TIME (MINUTES)

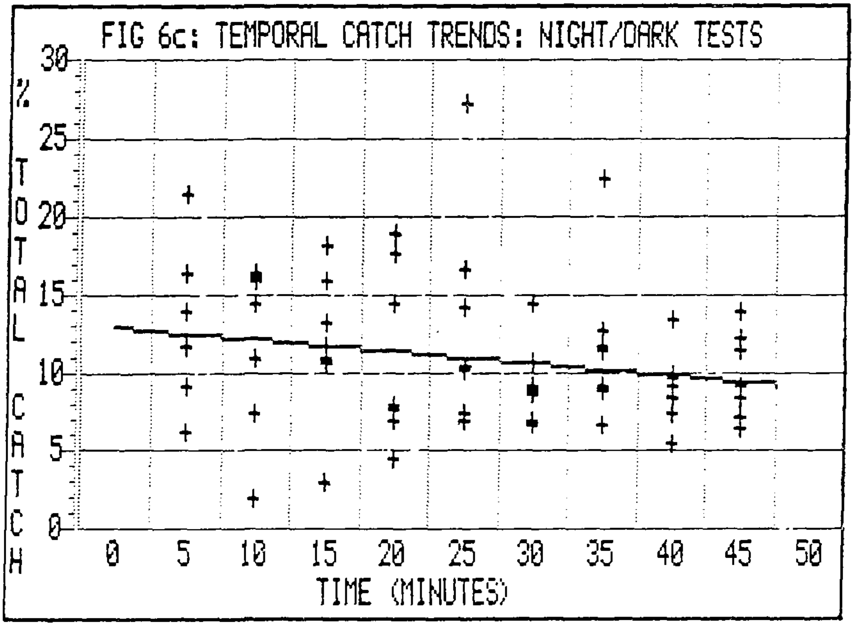
FIG 6c: TEMPORAL CATCH TRENDS: NIGHT/DARK TESTS
% TOTAL CATCH
30
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50
TIME (MINUTES)

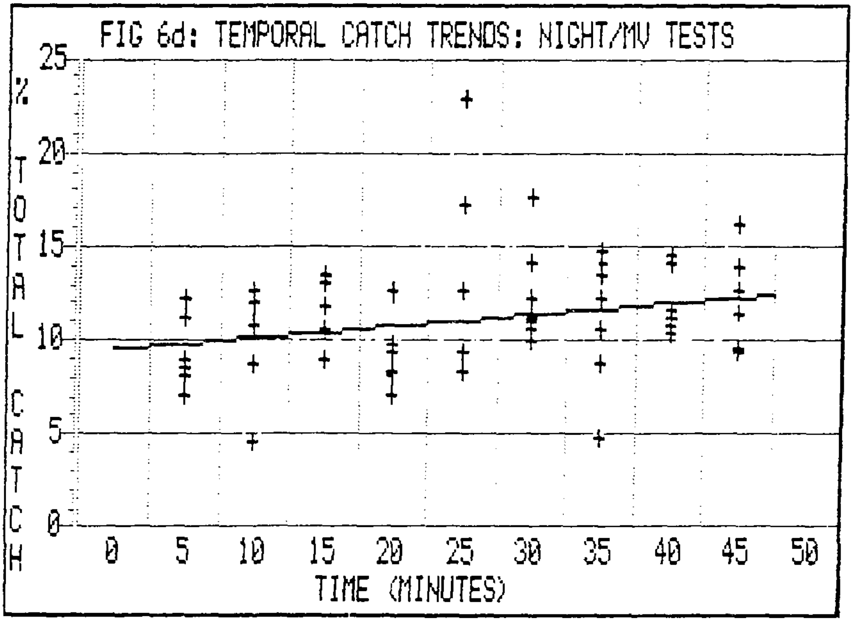
FIG 6d: TEMPORAL CATCH TRENDS: NIGHT/MV TESTS
% TOTAL CATCH
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50
TIME (MINUTES)

total of 18 473 alewife were captured, and only 51 of these were dead or severely injured (0.28%). The incidence of minor bruises or descaling was somewhat higher. In 5 tests examined in detail, 79 fish of 1838 captured showed these minor injuries (4.3%).

Detailed records of mortality and pump damage were not kept for all incidental species captured. However, a high frequency of substantial damage was apparent for large fish (from 500 g to over 1 kg) such as suckers and catfish. At least 30% of these fish were damaged, and many were killed outright. Head injuries and broken spines (directly behind the head) were the most common form of severe injury. It is believed that large fish with severe injuries were those which entered the pump head-first. These fish would be travelling at approximately 3.8 m/s and their momentum would carry them forward into the spinning impeller. One exceptionally large sucker (over 1 kg) was seen to be captured tail-first during a daylight test. It passed through the pump completely unharmed.

While severely damaged alewife were excluded from post-pumping mortality tests, no attempt was made to exclude fish with minor injuries. Thus, it may be assumed that approximately 4% of the alewife used for mortality studies had minor injuries (slight bruises or minor descaling) which were assumed to be the result of pump passage.

In six replicate tests of alewife (50/test) held at ambient intake temperatures, average mortalities at 24, 48 and 72 hours were 1.7, 2.7 and 3.0%, respectively. However, these mortalities occurred in only 2 tests (72 hour values of 10 and 8%), while no mortality occurred in the other 4 tests. As a result, the average mortality values did not differ significantly from zero (Appendix 6).

Alewife held in the Bruce 'A' discharge (4 replicates of 50 fish each) showed no significant mortality after 9 hours (average = 1.0%). However, mortality for those fish held 24 hours averaged 16.5%, a significant increase. At the time of these tests, temperatures in the discharge holding pens (16.3^{o}C) were only about 5^{o}C above ambient forebay temperatures. As previously discussed, predation problems prevented discharge mortality studies from extending beyond 24 hours.

3.3 Collection Tank Holding Capacity and Oxygen Depletion

Results for three oxygen depletion tests with 1200, 4100 and 8700 alewife are shown in Figure 7. Input data and fitted regressions are listed in Appendix 8. At densities of 1200 and 4100 alewife, the decline in tank oxygen levels with time was clearly linear (Figure 7). During the holding period, fish cruised slowly throughout the tank and showed no signs of alarm or respiratory difficulty. With 8700 alewife in the holding tank, the rate of oxygen depletion appeared to accelerate over the first 30 minutes. As this test progressed, the fish began to respire more deeply, swam faster, and appeared to become more agitated. These attempts to obtain more oxygen would increase metabolic demands and lead to the progressive increase in the O_2 depletion rate apparent in Figure 7.

Aeration of the holding tank with pure oxygen (started after 28 minutes) decreased the rate of O_2 depletion, but it is evident that the aeration system used in this test (3 air stones, each approximately 15 cm in length) was not adequate to supply the respiratory demands of 8700 alewife. While the absolute maximum holding capacity of the tank was not determined in the present study, physical crowding was quite substantial with 8700 alewife in the tank and the water level dropped to 40 cm (Figure 8).

4.0 DISCUSSION

4.1 General System Requirements

Present results have demonstrated that the Hidrostal pump system is capable of collecting large numbers of alewife from the Bruce 'A' forebay. Low post-pumping mortality (average = 3% for fish held 72 hours at ambient temperature) indicates that few alewife were damaged by the system, despite the use of a relatively high pump speed (850 rpm). The high incidence of serious injury (above 30%) for large fish suggests that a larger pump would be required to successfully pass these incidental species (suckers, catfish, burbot). However, these species were caught in very low numbers.

This study clearly indicates that fish avoid pump capture primarily by visual means, even at night. Use of a clear acrylic intake was necessary to collect substantial numbers of alewife. The cone-shaped inlet used in the present study was not effective, as fish clearly avoided the grey PVC structure. While a transparent cone could be effective, observations of the present study suggest that high inlet velocities (3.8 m/s used here), combined with a transparent inlet structure, resulted in little or no avoidance. The straight, small diameter, clear inlet tube

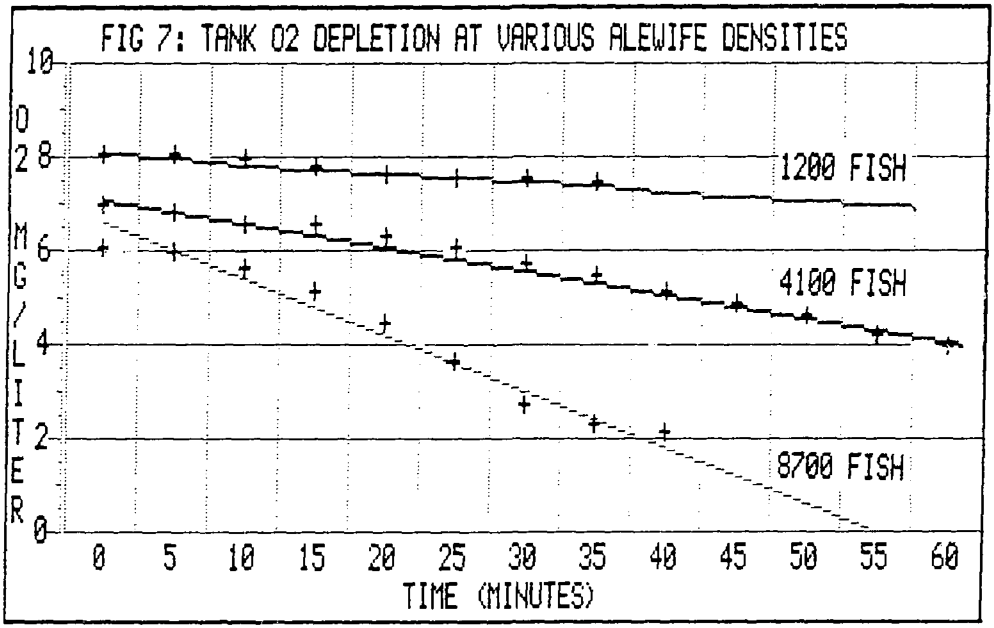
FIG 7: TANK O2 DEPLETION AT VARIOUS ALEWIFE DENSITIES
O2 MG/LITER
10
8
6
4
2
0
1200 FISH
4100 FISH
8700 FISH
0
5
10
15
20
25
30
35
40
45
50
55
60
TIME (MINUTES)

FIGURE 8

FISH COLLECTION TANK DURING OXYGEN DEPLETION EXPERIMENTS
TANK IS APPROXIMATELY HALF-FULL AND CONTAINS 8700 ALEWIFE (350 kg)

used here appeared to offer the combined advantage of minimal structure (reducing visibility to fish) and high inlet velocities, resulting in substantial catch under all light conditions. Regardless of the exact inlet configuration used, it is suggested that the features of minimal visibility and high inlet velocity be maintained. For a permanent system, it may be necessary to periodically clean the inlet structure (prior to spring fish runs) in order to maintain transparency.

Present results with 1.0 and 1.5 m long clear intakes also indicate the importance of locating the intake mouth at precisely the correct spot, as a small change in intake length and depth increased catch more than 6-fold. Impingement records indicate that since the start-up of Unit 4, most fish-related outages have occurred at this unit (Garcia, pers. comm.). Our observations also suggest that the highest alewife densities were located near the downstream end of the forebay adjacent to the Unit 4 pumphouse. Thus, a fish pump inlet would be most effective if located at or near the spot used in the present studies. While intake depth was clearly important in the present study (conducted under low forebay densities) it is likely that during a large fish run, high fish densities throughout the forebay may reduce the importance of precise inlet positioning. As a general guide, it is suggested that the pump inlet be located at 1 meter depth. Provision could be made, through use of a short section of flexible pipe, to allow some vertical and horizontal adjustment of the pump inlet. However, it is the opinion of this author that precise intake location will not be of great importance during periods of high forebay density (assuming that Unit 4 is operating). If Unit 4 is not operating, distribution of fish in the forebay may change substantially, and manual adjustment of the inlet location may be required.

Use of a mercury vapour lamp is advisable during darkness, as catch was almost doubled in night tests when the MV lamp was operating.

Comparison of post-pumping mortality results suggests no significant difference between fish held at discharge and ambient temperatures in the short term (9 hours) but discharge mortality (16.5%) in 24-hour tests was significantly higher. Thus, if fish are to be transported and released in the Bruce 'A' discharge, attempts should be made to determine their residence time and subsequent survival.

Oxygen depletion experiments indicated that at high fish densities, the collection tank should be equipped with an efficient aeration system for transporting fish back to Lake Huron. The aeration system used in the present study was not capable of maintaining constant O_2 levels in the tank with 8700 alewife present. However, a more efficient system could readily be constructed with commercially available materials.

4.2 System Capacity

It was not possible to determine the maximum collection capacity of the 5" Hidrostal pump system, as only low to moderate alewife numbers were present in the Bruce 'A' forebay during the June 11 to June 28 test period. However, the data obtained do provide some indication of the minimum capabilities of the system. If the best intake configuration (1.5 m clear intake at 1 m depth) were operated continuously, it can be assumed that the average morning catch (5981 alewife/hour) would apply from dawn (5 am) until noon, that the average afternoon catch (3666 alewife/hour) would apply from noon to dusk (9 pm) and that the average night MV catch (2816 alewife/hour) would apply from 9 pm to 5 am. Using these values, the estimated catch per 24-hour period would approximate 97 000 alewife (3900 kg). In comparison, in May and June of this year, Bruce 'A' Unit 4 (which accounts for most station impingement) caught only 1000 kg of alewife in each month.

The temporal catch data indicated no substantial trends in the daylight tests. This suggests that in daylight, fish were being continuously delivered to the pump intake by upwelling currents in this area. The continued presence of a large alewife school directly in front of the pump intake provides supporting visual evidence. In dark tests, a more substantial temporal decline in catch (which approached statistical significance) suggested that movement of fish into the area of the pump inlet was occurring at a rate slower than the rate of removal. Thus, the pump tended to 'fish out' the immediate area during the course of a test. In contrast, the progressive increase in catch over time during MV tests indicated a build-up of alewife numbers due to attraction to the mercury vapour lamp. Presumably, prolonged operation of the MV light (over several hours) would result in somewhat higher catches than those observed in present 45 minute MV tests.

During a large fish run, it appears likely that alewife density in the upwelling area adjacent to the pump inlet would rise, resulting in higher pump catch rates. However, this increase in fish density would probably not be in direct proportion to the overall increase in forebay numbers. In a large run, fish would spread out to occupy less favourable forebay areas. This would likely result in station screenhouse catches rising more rapidly than pump catches. It is difficult to estimate the maximum capacity of the 5" Hidrostal pump in such situations. Assuming that the average 24-hour catch would equal the average morning catch of the present study yields a daily catch of 143 000 alewife (5700 kg). This estimate is most likely extremely conservative. If the highest hourly catch (8975/hr) is assumed, a daily catch of 215 000 alewife (8600 kg) results. Again, this value is probably conservative, as it is only approximately double the average catch obtained in the present study, when both forebay densities and screenhouse catches were low.

Consideration of historical impingement data puts these estimates in perspective. At Bruce 'A', most alewife impingement has occurred over the months of May and June. Since 1979, even-numbered years (1980, 1982, 1984) have yielded low alewife catches, ranging from 10 kg/month (June 1982) to 1900 kg/month (June 1980). The 1000 kg/month in May and June of 1984 appears to be an average value for even-year catches. In contrast, odd-year catches over this period have been much higher in May. In May of 1983, alewife impingement was 75 000 kg, while 40 000 kg were impinged in May of 1981. A total of 350 000 kg of alewife were impinged in May of 1979.

It is clearly impossible to accurately estimate the performance of the 5" Hidrostal pump during periods of high fish concentration in the forebay. However, assuming that pump capture rates would at least equal the highest estimate above (8600 kg/day), it would take 4.7 days to remove an alewife run of 40 000 kg, 8.7 days to remove a 75 000 kg run and 41 days to remove a 350 000 kg run.

Massive increases in fish density appear to develop over a period of only a few days. These fish then appear to remain in the forebay (in front of Unit 4) and impinge over a period of several days. Present results suggest that the 5" Hidrostal pump could remove most of an alewife run in the 40 000 kg range and make a substantial impact on runs up to 75 000 kg. However, unless capture rates increase very substantially over the 8600 kg/day estimated, it must be concluded that the system would not have a significant impact on massive (100 000 kg or larger) impingement events.

Increased fish pumping capacity could be obtained through use of multiple 5" Hidrostal pumps (2 or 3 could be mounted in the available area). Alternatively, a single, larger (8" or 12") Hidrostal pump could be used. Operated at a similar speed, a 12" pump should deliver approximately 4X the flow of the present pump. There is no reason to believe that catch rates would not increase in direct proportion to this increased flow. The option selected may be dependent upon cost, although other factors, such as the effect on the fish return system used, flexibility and operational efficiency should also be considered.

4.3 Fish Return System

Use of the collection tank for transport of fish back to Lake Huron appears feasible, but difficulties and limitations of this approach must be recognized. In order to use the tank as a means of transport, it must be mounted on a sturdy trailer. If the collection tank were half full (as tested in the oxygen depletion experiments) the tank plus water would weigh approximately 4000 kg. Some baffling may be required to prevent overflow even when the tank is only partially filled. However, it may be possible to equip the tank with a close-fitting lid and transport the tank in a nearly full condition without the use of baffles. Weight of tank and water may then exceed 8000 kg.

While the absolute maximum holding capacity of the tank was not determined in the present study, it is suggested that to minimize damage from abrasion and descaling, maximum densities should not exceed the highest density tested by more than about 50%. Thus, if the tank water level were held at 40 cm for transport, approximately 13 000 alewife (500 kg) could be transported at one time, assuming that an adequate aeration system was used. If the tank was equipped with a close-fitting lid, allowing transport in a nearly full condition, it may be possible to nearly double this figure, yielding 1000 kg/trip.

If two tank/trailer systems were used, and required a one hour/trip, a maximum transport of 24 000 kg/day could be attained. Thus, tank transport would appear feasible, even if a catch rates during a large fish run are substantially greater than the 8600 kg/day previously estimated for a single 5" pump.

Assuming that a transport rate of 24 000 kg/day was sufficient to handle a large fish run (it appears to approach the required level), it may be possible to construct a twin system, using two 5" Hidrostal pumps to increase catch rates. However, this system would require the use of 3 transport/holding tanks and operation would involve substantial labour.

The size of the pump drain opening appeared to limit pump capacity in present tests to approximately 4200 L/minute. While modifications to increase drain size would be possible, a substantial increase in tank flow rate might create undesirable conditions in the tank, as excessive flows may result in fish being impinged on the outlet screen. Thus, it is unlikely that the tank used in present studies would be suitable if substantial flow increases (those possible with a 12" pump) are desired. Larger collection/transport tanks could be considered, but would require large trucks and trailers and may prove difficult to operate.

If tank transport is used, the Bruce 'A' thermal discharge is the most readily accessible release point, but the significant mortality increase for alewife held (24 hours) in the discharge suggests that other shoreline release sites should be considered. However, the depth and current of the discharge channel may provide protection from predation by gulls, and alewife released in the channel may be quickly carried into the open lake.

Construction of a pipeline to return fish to Lake Huron has been considered, but costs may be prohibitive (V. Garcia, pers. comm.). However, an alternative method of return may exist. A system of surface ditches remove runoff from the site, channeling the flow to Lake Huron between the Bruce Steam Plant and the Bruce Heavy Water Plants. This ditch system, which is about 800 m to 1000 m in length, comes to within approximately 30 m of the Hidrostal pump location. At present, the ditches are partially filled with silt and vegetation, which would require removal. Additional modifications which may be required before the ditches can be used to return fish to Lake Huron are presently being investigated (Garcia, pers. comm.).

5.0 CONCLUSIONS

5.1 The clear acrylic intake (15 cm diameter x 1.5 m long) mounted horizontally at a depth of 1 meter appeared optimal for capturing alewife in the Bruce 'A' forebay. Factors which contributed to the high capture success of this system were the presence of an upwelling current at the end of the forebay (causing fish to form schools facing away from the pump mouth), the low visibility of the clear intake, the high inlet velocity (3.8 m/s), and precise location of the intake (at the edge of the alewife school). The mercury vapour lamp used at night was effective in attracting alewife to the vicinity of the pump, almost doubling night catches.

5.2 Present results demonstrate that a simple transparent inlet pipe provides a combined advantage of minimum structure (difficult for fish to see) and high inlet velocity, resulting in high capture rates under all light conditions. While a transparent intake cone could be effective, present results with an opaque intake cone indicated that fish were able to avoid capture even at night, whether the cone was illuminated (with MV light) or not. A possible disadvantage of all cone-shaped inlets is the difficulty of maintaining high inlet velocities at the mouth of the structure.

5.3 The frequency of severe damage or immediate mortality was extremely low for alewife passed through the pump at 850 rpm. Post-pumping mortality (72 hours) averaged only 3% and was not significantly different from zero. Due to flow rate limitations of the collecting tank, it was not possible to test higher speeds. Prolonged pumping (in excess of 2 hours) did not appear harmful to fish in the collecting tank.

5.4 Although short term (9 hour) mortality of discharge-held alewife was not significant, higher mortality (16.5%) of fish held for 24 hours suggests that return of alewife to Lake Huron via the Bruce 'A' thermal discharge must be viewed with caution.

5.5 The high incidence of immediate mortality or severe damage (over 30%) for large fish (suckers, catfish, burbot) suggests that a larger diameter pump would be required to successfully pass these incidental species.

5.6 Under conditions of low forebay fish density, using the optimal intake configuration, average catches with the 5" Hidrostal pump were equivalent to 97 000 alewife/day (3900 kg). While the increase in catch during a large fish run can only be roughly estimated, calculations based on the highest catches attained (equivalent to 215 000 alewife/day or 8600 kg/day) suggest that a single 5" Hidrostal pump would be capable of handing fish runs in the 40 000 to 75 000 kg range over a period of several days. Complete protection of the station from very large runs (over 100 000 kg) would require multiple 5" pumps or a single larger pump.

5.7 While use of the collecting tank as a means of transport appears feasible, it will be necessary to equip the tank with an efficient aeration system, and a close-fitting lid to maximize fish transport (up to 1000 kg/trip). To minimize pump 'down-time' two tanks would be required for each pump.

5.8 Existing site drainage ditches may be used to return pumped fish to Lake Huron. This approach, if cost-effective, would require some ditch modification to improve flow and prevent erosion.

6.0 RECOMMENDATIONS

6.1 As large alewife runs have been encountered at Bruce 'A' during odd-numbered years over the 1979-1984 period, it would seem prudent to install an operational fish handling system as soon as possible.

6.2 As projections based on present studies suggest that a single 5" Hidrostal pump would not be capable of handling massive alewife runs (over 100 000 kg), it is suggested that a system of larger capacity be considered. This could include multiple 5" Hidrostal pumps or a single larger (12") pump.

6.3 The pump(s) should be installed in the location used for the present studies, in order to take advantage of the tendency of alewife to school in currents at the end of the forebay. Extension of the forebay is not recommended, as fish may be more difficult to capture if currents are reduced. A transparent inlet pipe should be used. Addition of a section of flexible piping between the pump and the inlet pipe would allow adjustment of intake location to maximize fish capture.

6.4 A tank/trailer fish return system could be considered if two 5" pumps are used. If a single 12" pump is used, fish return via the drainage ditches (or a pipeline) appears to be the most reasonable approach.

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APPENDIX 1

FISH CAPTURE SUMMARY - TEST SERIES 1 - PVC INTAKES

Test	Intake Type	Date/Time	Alewife	Incidental Species
1.	cone	Ø6-11/d-pm	Ø	Ø
2.	cone	Ø6-11/d-pm	Ø	Ø
3.	pipe	Ø6-12/d-am	Ø	Ø
4.	pipe	Ø6-12/d-am	1	1 smelt 1 stickleback
5.	pipe/45°	Ø6-12/d-am	Ø	Ø
6.	pipe/45°	Ø6-12/d-pm	Ø	Ø
7.	cone/MV	Ø6-12/d-pm	Ø	1 rock bass
8.	cone	Ø6-12/d-pm	Ø	Ø
9.	cone/MV	Ø6-12/night	1Ø	2 suckers 1 burbot 1 yellow perch
1Ø.	cone	Ø6-12/night	Ø	Ø
11.	cone/MV	Ø6-13/d-am	Ø	Ø
12.	cone/MV	Ø6-13/d-am	Ø	Ø

APPENDIX 2

FISH CAPTURE SUMMARY - TEST SERIES 2 - 1.Ø M CLEAR PIPE

Test	Intake	Date/Time	Alewife	(/hour)	Incidental Species
1.	pipe	Ø6-13/d-am	29Ø	(387)	2 yellow perch 1 sucker
2.	pipe	Ø6-13/d-pm	179	(239)	1 sucker
3.	pipe/ 45°	Ø6-13/d-pm	27	(36)	3 suckers 1 yellow perch
4.	pipe	Ø6-13/night	614	(819)	2 smelt 1 sucker 1 burbot
5.	pipe/MV	Ø6-13/night	18Ø8	(2411)	1 sucker
6.	pipe	Ø6-18/d-pm	29	(39)	1 catfish
7.	pipe	Ø6-18/d-pm	17	(23)	2 suckers
8.	pipe	Ø6-18/night	111	(148)	7 suckers 5 catfish 1 burbot
9.	pipe/MV	Ø6-18/night	72Ø	(96Ø)	2 suckers
1Ø.	pipe/MV	Ø6-18/night	273	(364)	4 suckers 1 catfish

APPENDIX 3

FISH CAPTURE SUMMARY - TEST SERIES 3 - 1.5 M CLEAR PIPE

Test	Intake	Date/Time	Alewife	(/hour)	Incidental Species
1.	pipe	06-19/d-am	1296	(1728)	1 sucker
2.	pipe/MV	06-19/night	2774	(3699)	1 sucker
3.	pipe/MV	06-19/night	2553	(3404)	4 suckers
4.	pipe	06-20/d-am	6731	(8975)	1 sucker
5.	pipe	06-20/d-am	4227	(5636)	1 round whitefish
6.	pipe	06-20/night	1395	(1860)	1 sucker
					1 catfish
7.	pipe	06-20/night	1771	(2361)	0
8.	pipe	06-21/d-am	5310	(7080)	1 sucker
9.	pipe	06-21/d-am	6210	(8280)	0
10.	pipe	06-21/night	963	(1284)	1 catfish
11.	pipe/MV	06-21/night	790	(1053)	5 suckers
					1 catfish
12.	pipe	06-25/d-pm	1389	(1852)	1 sucker
13.	pipe	06-25/d-pm	1497	(1996)	1 sucker
14.	pipe	06-25/night	873	(1164)	2 suckers
15.	pipe/MV	06-25/night	1938	(2584)	2 suckers
					1 catfish
16.	pipe	06-26/d-am	5020	(6693)	1 sucker
17.	pipe	06-26/d-am	2543	(3391)	1 sucker
18.	pipe	06-26/d-pm	3258	(4344)	0
19.	pipe	06-26/d-pm	2895	(3860)	0
20.	pipe	06-26/night	274	(365)	7 suckers
21.	pipe/MV	06-26/night	526	(701)	2 suckers
22.	pipe	06-27/d-am	3898	(5197)	1 sucker
					1 smallmouth bass
23.	pipe	06-27/d-am	5136	(6848)	0
24.	pipe	06-27/night	1916	(2555)	3 suckers
25.	pipe/MV	06-27/night	3219	(4292)	1 sucker
26.	pipe	06-28/d-pm	3875	(5167)	0
27.	pipe	06-28/d-pm	3585	(4780)	0
28.	pipe	06-28/night	1286	(1715)	3 catfish
					2 suckers
29.	pipe/MV	06-28/night	2985	(3980)	0

APPENDIX 4

COMPARISON OF MEAN ALEWIFE CATCH/HR FOR PVC (PIPE, CONE) INTAKES; SHORT (1.0 M) AND LONG (1.5 M) CLEAR ACRYLIC INTAKES

Analysis of Variance
Bruce Alewife/Intake Comparison

Source	Sum Sqrs	D F	Mean Sqr	F Ratio
Treat	144824030	2	72412012	21.927**
Within	155207650	47	3302290.3	
Total	300031670	49		

<u>Multiple Range Test</u>

```
PVC      S/CLR     L/CLR

1:22     599       3683
                   ****
****************
```

F-Test: NS = not significant
* = significant at 5% level
** = significant at 10% level

Multiple Range Test:
Means underlined by a common row of asterisks do not differ significantly.
Comparison is made from the largest mean to the smallest.

APPENDIX 5

ANALYSIS OF DAILY VARIATION IN CATCH
FOR CLEAR ACRYLIC INTAKES

Analysis of Variance
Alewife/hr 1.5 M Clear Intake

Source	Sum Sqrs	D F	Mean Sqr	F Ratio
Treat	82724820	3	27574940	10.138**
Within	67996198	25	2719847.9	
Total	150721020	28		

Multiple Range Test

```
N/DK   N/MV   D/PM   D/AM

1615   2816   3666   5981
                     ****
       *************
************
```

Analysis of Variance
Alewife/hr 1 M Clear Intake

Source	Sum Sqrs	D F	Mean Sqr	F Ratio
Treat	2007944.4	2	1003972.2	2.3678 NS
Within	2532666.5	6	422111.08	
Total	4540610.9	8		

Multiple Range Test

```
DAY    N/DK    N/MV

172    483     1245
*********************
```

F-Test: NS = not significant
* = significant at 5% level
** = significant at 10% level

Multiple Range Test:
Means underlined by a common row of asterisks do not differ significantly.
Comparison is made from the largest mean to the smallest.

APPENDIX 6A

ALEWIFE MORTALITY AFTER PUMP PASSAGE

1. FISH HELD AT INTAKE TEMPERATURES

Test	# Fish	% Mort:	0 hrs	24 hrs	48 hrs	72 hrs
1	41		0	0	0	0
2	50		0	6	6	8
3	50		0	4	10	10
4	50		0	0	0	0
5	50		0	0	0	0
6	50		0	0	0	0
Mean:			0	1.67	2.67	3.00

2. FISH HELD IN DISCHARGE

Test	# Fish	% Mort:	0 hrs	9 hrs	24 hrs
1	50		0	----	4
2	50		0	----	30
3	50		0	----	16
4	50		0	----	16
5	50		0	0	----
6	50		0	2	----
7	50		0	2	----
8	50		0	0	----
Mean:			0	1.0	16.5

APPENDIX 6B

ANALYSIS OF ALEWIFE MORTALITY AFTER PUMP PASSAGE.
FISH HELD AT INTAKE OR DISCHARGE TEMPERATURES.

Analysis of Variance
Percent Mort/Time-Intake

Source	Sum Sqrs	D F	Mean Sqr	F Ratio
Treat	32.666667	3	10.888889	0.9124 NS
Within	238.66667	20	11.933333	
Total	271.33333	23		

<u>Multiple Range Test</u>

0 HRS	24 HRS	48 HRS	72 HRS
0	1.667	2.667	3

****

Analysis of Variance
Percent Mort/Time-Discharge

Source	Sum Sqrs	D F	Mean Sqr	F Ratio
Treat	786.75	2	393.375	14.909**
Within	343	13	26.384615	
Total	1129.75	15		

<u>Multiple Range Test</u>

0 HRS	9 HRS	24 HRS
0	1	16.5

(16.5 underlined: ****)
(0 and 1 underlined: *****************)

F-Test: NS = not significant
* = significant at 5% level
** = significant at 10% level

Multiple Range Test:
Means underlined by a common row of asterisks do not differ significantly.
Comparison is made from the largest mean to the smallest.

APPENDIX 7A

TEMPORAL CATCH DATA - 1.5 M CLEAR INTAKE

DAY/AM TESTS

Test #	1		2		3		4		5	
Time (min)	No	%	No	%	No	%	No	%	No	%
5	101	7.79	430	6.39	413	9.77	520	9.79	640	10.31
10	147	11.34	520	7.73	470	11.12	675	12.71	520	8.37
15	184	14.20	775	11.51	470	11.12	585	11.02	660	10.63
20	172	13.27	720	10.70	489	11.57	550	10.36	680	10.95
25	124	9.57	635	9.43	290	6.86	630	11.86	680	10.95
30	158	12.19	981	14.57	495	11.71	440	8.29	570	9.18
35	182	14.04	930	13.82	590	13.96	650	12.24	830	13.37
40	117	9.03	860	12.78	490	11.59	620	11.68	790	12.72
45	111	8.56	880	13.07	520	12.30	640	12.05	840	13.53

Test #	6		7		8		9	
Time (min)	No	%	No	%	No	%	No	%
5	465	9.26	340	13.37	403	10.34	450	8.76
10	515	10.26	390	15.34	335	8.59	700	13.63
15	505	10.06	350	13.76	434	11.13	615	11.97
20	535	10.66	304	11.95	389	9.97	640	12.46
25	930	18.52	297	11.68	400	10.26	495	9.64
30	630	12.55	207	8.14	418	10.72	470	9.15
35	570	11.35	222	8.73	543	13.93	585	11.39
40	380	7.57	260	10.22	481	12.34	590	11.49
45	490	9.76	173	6.80	495	12.70	591	11.51

APPENDIX 7B

TEMPORAL CATCH DATA - 1.5 M CLEAR INTAKE

DAY/PM TESTS

Test #	1		2		3		4		5	
Time	No	%	No	%	No	%	No	%	No	%
5	119	8.57	103	6.88	330	10.13	285	9.84	470	12.13
10	205	14.76	165	11.02	338	10.37	335	11.57	405	10.45
15	202	14.54	184	12.29	470	14.43	280	9.67	360	9.29
20	147	10.58	173	11.56	328	10.07	415	14.34	465	12.00
25	159	11.45	220	14.69	305	9.36	310	10.71	520	13.42
30	152	10.94	161	10.75	342	10.50	385	13.30	535	13.81
35	128	9.22	172	11.49	415	12.74	320	11.05	340	8.77
40	99	7.12	207	13.83	345	10.59	290	10.01	375	9.68
45	178	12.81	112	7.48	385	11.82	275	9.50	435	10.45

Test #	6	
Time (min)	No	%
10	485	13.53
20	425	11.85
30	440	12.27
35	375	10.46
40	305	8.51
45	285	7.95

APPENDIX 7C

TEMPORAL CATCH DATA - 1.5 M CLEAR INTAKE

NIGHT/MV TESTS

Test #	1		2		3		4		5	
Time (min)	No	%	No	%	No	%	No	%	No	%
5	232	8.36	204	7.99	55	6.96	216	11.14	46	8.75
10	296	10.67	217	8.50	93	11.77	243	12.54	23	4.37
15	357	12.87	328	12.85	70	8.86	201	10.37	61	11.60
20	192	6.92	314	12.30	73	9.24	154	7.94	50	9.51
25	226	8.15	230	9.01	134	16.96	174	8.97	119	22.62
30	333	12.00	354	13.87	88	11.14	337	17.39	55	10.46
35	386	13.91	342	13.40	67	8.48	236	12.18	25	4.75
40	307	11.07	274	10.73	111	14.05	197	10.17	75	14.26
45	445	16.04	290	11.36	99	12.53	180	9.29	72	13.69

Test #	6		7	
Time (min)	No	%	No	%
5	387	12.02	265	8.88
10	385	11.96	315	10.55
15	430	13.36	350	11.73
20	264	8.20	375	12.56
25	293	9.10	370	12.40
30	315	9.79	325	10.89
35	470	14.60	310	10.39
40	370	11.49	340	11.39
45	305	9.49	335	11.22

APPENDIX 7D

TEMPORAL CATCH DATA - 1.5 M CLEAR INTAKE

NIGHT/DARK TESTS

Test #	1		2		3		4		5	
Time (min)	No	%	No	%	No	%	No	%	No	%
5	297	21.29	159	8.98	112	11.63	101	11.57	38	13.87
10	220	15.77	286	16.15	138	14.33	139	15.92	5	1.82
15	221	15.84	204	11.52	126	13.08	157	17.98	8	2.92
20	61	4.37	254	14.34	180	18.69	68	7.79	19	6.93
25	96	6.88	180	10.16	134	13.91	63	7.22	74	27.00
30	124	8.89	151	8.52	66	6.85	79	9.05	18	6.57
35	92	6.59	155	8.75	87	9.03	109	12.49	61	22.26
40	116	8.31	235	13.27	52	5.40	78	8.93	20	7.30
45	168	12.04	147	8.30	68	7.06	79	9.05	31	11.31

Test #	6		7	
Time (min)	No	%	No	%
5	117	6.11	208	16.17
10	138	7.20	138	10.73
15	205	10.70	135	10.50
20	337	17.59	98	7.62
25	314	16.39	129	10.03
30	275	14.35	134	10.42
35	221	11.53	144	11.20
40	189	9.86	123	9.56
45	120	6.26	177	13.76

APPENDIX 7E

ANALYSIS OF TEMPORAL CATCH DATA - 1.5 M CLEAR INTAKE: REGRESSIONS OF % CATCH VS TIME INTERVAL

Time vs Catch: Day/AM
Regression:

Y = A + BX
A = 10.475723
B = 0.025355555
R**2 = 0.023681027
R = 0.15388641

F-Test: with 1,79 DF
F = 1.9161782

Time vs Catch: Day/PM
Regression:

Y = A + BX
A = 11.957361
B = 0.033872222
R**2 = 0.045141049
R = 0.21246423

F-Test: with 1,52 DF
F = 2.458305

Time vs Catch: Night/Dark
Regression:

Y = A + BX
A = 13.005992
B = 0.07585238
R**2 = 0.044406729
R = 0.21072904

F-Test: with 1,61 DF
F = 2.8346896

Time vs Catch: Night/MV
Regression:

Y = A + BX
A = 9.5941667
B = 0.060671428
R**2 = 0.071801643
R = 0.26795829

F-Test: with 1,61 DF
F = 4.7187114

APPENDIX 8A

OXYGEN DEPLETION IN COLLECTION/TRANSPORT TANK

Time (min) (x)	Test # 1: 1200 Fish — O_2 mg/L (y)	Test # 2: 4100 Fish — O_2 mg/L (y)
0	8.0	6.9
5	8.0	6.7
10	7.9	6.5
15	7.7	6.5
20	7.6	6.2
25	7.5	6.0
30	7.5	5.7
35	7.4	5.4
40	---	5.1
45	---	4.8
50	---	4.6
55	---	4.2
60	---	3.9

Test # 3: 8700 Fish

Time (min) (x)	O_2 mg/L (y)	Time (min) (x)	O_2 mg/L (y)
0	6.0	20	4.4
1	6.0	21	4.2
2	6.0	22	4.1
3	6.0	23	4.0
4	5.9	24	3.8
5	5.9	25	3.6
6	5.8	26	3.3
7	5.8	27	3.1
8	5.7	28*	3.0
9	5.7	29	2.8
10	5.6	30	2.7
11	5.6	31	2.6
12	5.4	32	2.5
13	5.3	33	2.4
14	5.2	34	2.3
15	5.1	35	2.3
16	5.0	36	2.3
17	4.9	37	2.2
18	4.7	38	2.2
19	4.6		

* Aeration with pure O_2 started at 28 minutes.

APPENDIX 8B

OXYGEN DEPLETION IN COLLECTION/TRANSPORT TANK - REGRESSIONS:

Oxygen Depletion: 1200 Fish
Regression:

Y = A + BX
A = 8.0333333
B = -0.019047619
R**2 = 0.95238129
R = 0.97590025

O_2 vs Time: 4100 Fish
Regression:

Y = A + BX
A = 7.0934066
B = -0.050549451
R**2 = 0.98336277
R = 0.9916465

O_2 vs Time: *8700 Fish*
Regression:

Y = A + BX
A = 6.5798781
B = -0.11935272
R**2 = 0.9686907
R = 0.9842241

F-Test: with 1,38 DF
F = 1175.244