

**GUIDE FOR DETERMINING
APPLICATION RATES OF
LAMPRICIDES FOR CONTROL OF
SEA LAMPREY AMMOCETES**



Great Lakes Fishery Commission

TECHNICAL REPORT No. 52

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GUIDE FOR DETERMINING APPLICATION RATES OF LAMPRICIDES FOR CONTROL OF SEA LAMPREY AMMOCETES

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ABSTRACT

The toxicity of two chemicals that are used extensively for the control of larval sea lampreys (*Petromyzon marinus*) in the Great Lakes-3-trifluoromethyl-4-nitrophenol (TFM) and 2',5-dichloro-4-nitrosalicylanilide (Bayer 73) - is markedly influenced by chemical characteristics of the water. We conducted toxicity tests in waters of 40 to 200 mg/L alkalinity (as CaCO_3) on sea lampreys, rainbow trout (*Salmo gairdneri*), yellow perch (*Perca flavescens*), channel catfish (*Ictalurus punctatus*), and immature mayflies (*Hexagenia* sp.). This information was used to calculate the relation between levels of alkalinity and lethal concentrations of TFM plus Bayer 73. "Safe and effective" concentrations of TFM ranged from 0.8 mg/L at 40 mg/L alkalinity to 7.0 mg/L at 200 mg/L alkalinity. We used the resulting equation to calculate toxicities at intervals of 5 mg/L of alkalinity and develop a predictive graph for each of the organisms at 33 alkalinities. The charts produced will help sea lamprey control personnel choose the appropriate test species and concentration of lampricide for the stream to be treated, and establish effective control of sea lampreys without significant harm to non-target aquatic organisms.

INTRODUCTION

The sea lamprey (*Petromyzon marinus*) control program, administered by the Great Lakes Fishery Commission, has involved the use of 3-trifluoromethyl-4-nitrophenol (TFM) since 1958 and 2',5-dichloro-4-nitrosalicylanilide (Bayer 73) since 1963 (Howell et al. 1964). These chemicals are used either singly or in combination to decrease the sea lamprey population to levels that permit acceptable survival of lake trout (*Salvelinus namaycush*) and other valuable fishes in the Great Lakes.

The toxicity of TFM and Bayer 73 to sea lampreys and other aquatic organisms is influenced by alkalinity, pH, turbidity, temperature, dissolved oxygen, and the presence of other toxic substances (Dawson et al. 1975; Marking and Bills 1985). Because toxicity is strongly correlated to alkalinity and because alkalinity is quite stable in any given stream, alkalinity measurements have been widely used to help predict the concentrations of lampricides needed to effectively treat a stream.

Treatments of streams within the Great Lakes basin involve a broad range of stream types and water chemistries. Effective concentrations of lampricides must therefore be determined for each stream, each time it is treated. Sea lamprey control personnel conduct toxicity tests with sea lampreys and a

non-target species of fish, using water from the stream to be treated (Smith et al. 1974). The correlation between the alkalinity of the water and the toxicity of lampricides to fish has been calculated, and this relation is used to predict the minimum lethal concentration (MLC)¹ for sea lampreys and the maximum allowable concentration (MAC)² for non-target organisms (Kanayama 1963). The regression equation developed from field data works well for predicting the amount of TFM required to treat a stream. However, the relations of the various possible combinations of TFM and Bayer 73 to a broad range of alkalinities have not been defined sufficiently to enable the calculation of a regression equation. The present study was conducted to define these relations and develop the needed equation.

MATERIALS AND METHODS

Toxicity tests were conducted at the Hammond Bay Biological Station during the winters of 1983-1985. Sea lamprey ammocetes 60 to 110 mm long were collected from tributary streams of the Great Lakes and rainbow trout 20 to 30 mm long were from the Oden (Michigan) State Fish Hatchery. Yellow perch (*Perca flavescens*) 20-40 mm long and channel catfish (*Ictalurus punctatus*) 25-50 mm long were from the National Fisheries Research Center, La Crosse, Wisconsin. Nymphs of the mayfly *Hexagenia*, collected from tributaries of Lake Michigan, came from a commercial supplier. They were held in flowing water from Lake Huron for at least 20 days before the toxicity tests were conducted.

Reconstituted waters (Committee on Methods for Toxicity with Aquatic Organisms. 1975) were buffered to 40, 60, 100, and 200 mg/L total alkalinity. We conducted the toxicity tests at 17 C, using 15 L of reconstituted water in 20-L glass aquaria.

Each toxicity test included no fewer than five concentrations of TFM at each alkalinity. Concentration ranges of TFM (mg/L) used were 0.5-10.0 for sea lampreys, 2.0-20.0 for rainbow trout, 5.0-30.0 for yellow perch, 2.0-16.0 for channel catfish, and 0.5-5.0 for mayfly nymphs. For each TFM concentration, no fewer than four concentrations of Bayer 73 were used. The concentrations of Bayer 73 (ug/L) in the complete array of toxicity tests were 12, 24, 36, 48, 72, 96, and 120. At the beginning and end of each test, we measured the concentrations of TFM spectrophotometrically (Smith et al. 1960) and those of Bayer 73 by gas-liquid chromatography (Luhning et al. 1979).

Animals were held in specific waters for 48 hours without food, before the toxicity tests were begun. Static acute toxicity tests were conducted according to the American Society for Testing and Materials (1980) including the aeration of test vessels. Mortalities (lack of branchial pulse) were estimated at 9, 12, 16, and 24 h; for non-target species, the MAC values were calculated according to the

¹ Minimum concentration (mg/L) required to kill 100% of the sea lampreys in 9 hours.

² Maximum concentration (mg/L) that kills no more than 25% of the test organisms (e.g., rainbow trout, (*Salvelinus gairdneri*) in 24 hours.

method of Litchfield and Wilcoxon (1949). The lethal concentration for sea lampreys was the lowest test concentration that killed all of the sea lampreys in 9 h. From 10 to 20 animals were used in each test vessel. Loading never exceeded 0.8 g of animals per liter of water.

To interpolate between the four alkalinities, we defined the linear relations between alkalinity and the toxicity of TFM and Bayer 73 mixtures to aquatic organisms. A regression equation was calculated for alkalinity versus mixtures of TFM and Bayer 73, and toxicities were calculated at 5-mg/L intervals of alkalinity.

RESULTS AND DISCUSSION

The relations between alkalinity, the toxicity of TFM, and the toxicity of Bayer 73 were plotted to produce Figure 1. Each group of four graphs describes the toxicity of TFM and of Bayer 73 to sea lampreys and four non-target organisms at one alkalinity. Concentrations of TFM were reported as parts per million (ppm; = mg/L) and those of Bayer 73 as parts per billion (ppb; = ug/L). The intersections of the vertical axis (TFM concentration) with the LC-100 line for sea lampreys and the LC-25 line for the non-target organisms indicate the lethal concentrations of TFM alone. Proceeding from left to right in each graph, the concentration of Bayer 73 increases as indicated along the horizontal axis. The downward slope of the LC-25 lines for the non-target organisms and the LC-100 lines for the sea lamprey ammocetes indicates the decreasing amount of TFM required as the amount of Bayer 73 is increased. The diagonal line, starting at the origin, represents the concentrations of Bayer 73 equal to 2% of the TFM concentrations-the maximum treatment level for Bayer 73 allowed in the United States.

The LC-25 values for non-target species are for toxicity tests of 24-h-the maximum duration of a stream treatment. The LC-100 values for sea lampreys are for 9-h toxicity tests-the minimum duration of treatment time for a stream at concentrations that are selectively toxic to sea lampreys.

Applegate and King (1962) established the LC-25 as a maximum allowable concentration. It can be estimated more accurately and more precisely than the LC-0.01, by using statistical techniques such as those provided by Litchfield and Wilcoxon (1949). We estimated the LC-100 (or minimum lethal concentration) for sea lampreys empirically. A comparison of minimum lethal concentrations for sea lampreys and maximum allowable concentrations for rainbow trout from our data and from data produced during routine pretreatment toxicity tests in the field before 1981 are shown in Figure 2. The two sets of data agree within 15%-generally within 10%-at all alkalinities. The LC-100 and LC-25 for the toxicity of TFM to sea lampreys and rainbow trout agree well with those of Kanayama (1963). Among the five species tested, sea lampreys were the most sensitive to all combinations of TFM and Bayer 73. Mayfly nymphs ranked next, followed by channel catfish, rainbow trout, and yellow perch, in that order. This relative sensitivity remained the same at all alkalinities. The sensitivity of channel catfish

fingerlings exposed to mixtures of TFM and Bayer 73 was similar to that of rainbow trout. The rainbow trout has been used extensively for pretreatment toxicity tests and is a good, cold-water test species. The channel catfish is more tolerant of warm water than the rainbow trout, and could be used when warmer streams are to be treated.

The addition of Bayer 73 to TFM decreases the amount of TFM required to kill the four species of test fish. Mayfly nymphs, however, showed little response to the addition of Bayer 73 to the lampricide mixture (Bills et al. 1985). This lack of sensitivity to Bayer 73 could be used to advantage in streams that contain large populations of mayfly nymphs. Since the use of Bayer 73 decreases the amount of TFM required to kill the sea lampreys, it could be used to reduce the mortality of mayfly nymphs when other stream conditions allow the effective use of Bayer 73 (Dawson et al. 1986). The sensitivity of mayfly nymphs to Bayer 73 becomes more important as the alkalinity of the water increases. The safe "Treatment Zone" (Fig. 1) - i.e., the area below the LC-25 for non-target organisms and above the LC-100 for sea lampreys-becomes smaller and nearly disappears at high alkalinities. This means that TFM is only marginally selective for sea lampreys, over exposed mayfly nymphs, in highly alkaline streams and that a significant number of the mayfly nymphs would be killed if only TFM were used. The mayfly nymphs used in these studies were not in burrows, and thus were only about half as resistant as burrowed nymphs (Bills et al. 1985) to TFM. An added safety factor thus exists, and less than 25% of the mayfly nymphs would be killed when treatments with higher quantities of Bayer 73 are used, according to the graphs provided here.

The information provided in Figure 1 should be generally useful in sea lamprey control. When planning pretreatment toxicity tests, one should first select the appropriate test organism and alkalinity from the figure. The amount of TFM, or TFM plus Bayer 73, can then be determined from the appropriate graph, and a treatment supervisor can set up pretreatment toxicity tests by using the predicted lethal concentrations. Changes in water chemistry during treatments (as might be caused by rainstorms, for example) could be accommodated by using the appropriate graph(s) for the change in alkalinity to predict the adjustments that must be made to maintain an effective treatment.

Alkalinity is but one of the factors that must be considered when a stream treatment is planned; water temperature, pH, dissolved oxygen, nitrite, and ammonia may also significantly affect the range of "safe and effective" concentrations of TFM. Whenever feasible, on-site bioassays should be run with water and fish from the stream to be treated.

REFERENCES

- AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM). 1980. Standard practice for conducting acute toxicity tests with fishes, macroinvertebrates, and amphibians. p. 1-25 in Annual book of ASTM standards. Philadelphia, PA.

- APPLEGATE, V. C., and E. L. KING, JR. 1962. Comparative toxicity of 3-trifluoromethyl-4-nitrophenol (TFM) to larval lampreys and eleven species of fishes. *Trans. Am. Fish. Soc.* 91:342-345.
- BILLS, T. D., L. L. MARKING, and J. J. RACH. 1985. Toxicity of the lampricides 3-trifluoromethyl-4-nitrophenol (TFM) and 2',5-dichloro-4'-nitrosalicylanide (Bayer 73) to eggs and nymphs of the mayfly (*Hexagenia* sp.). *Great Lakes Fish. Comm. Tech. Rep.* 47: 11 p.
- COMMITTEE ON METHODS FOR TOXICITY TESTS WITH AQUATIC ORGANISMS. 1975. Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians. *Ecol. Res. Ser.*, EPA-660.3-75-009. U.S. Environ. Prot. Agency, Washington, D.C. 61 p.
- DAWSON, V. K., D. A. JOHNSON, and J. L. ALLEN. 1986. Loss of lampricides by adsorption on bottom sediments. *Can. J. Fish. Aquat. Sci.* 43:1515-1520.
- DAWSON, V. K., K. B. CUMMINGS, and P. A. GILDERHUS. 1975. Laboratory efficacy of 3-trifluoromethyl-4-nitrophenol (TFM) as a lampricide. *U.S. Fish Wildl. Serv., Invest. Fish Control* 63: 13 p.
- HOWELL, J. H., E. L. KING, JR., A. J. SMITH, and L. H. HANSON. 1964. Synergism of 5,2'-dichloro-4-nitrosalicylanilide and 3-trifluoromethyl-4-nitrophenol in a selective lamprey larvicide. *Great Lakes Fish. Comm. Tech. Rep.* 8: 21 p.
- KANAYAMA, R. K. 1963. The use of alkalinity and conductivity measurements to estimate concentrations of 3-trifluoromethyl-4-nitrophenol required for treating lamprey streams. *Great Lakes Fish. Comm. Tech. Rep.* 7: 10 p.
- LITCHFIELD, J. T., Jr., and F. WILCOXON. 1949. A simplified method of evaluating dose-effect experiments. *J. Pharmacol. Exp. Ther.* 96:99-113.
- LUHNING, C. W., P. D. HARMAN, J. B. SILLS, V. K. DAWSON, and J. L. ALLEN. 1979. Gas-liquid chromatographic determination of Bayer 73 in fish, aquatic invertebrates, mud, and water. *J. Assoc. Off. Anal. Chem.* 62:1141-1145.
- MARKING, L. L., and T. D. BILLS. 1985. Effects of contaminants on toxicity of the lampricide TFM and Bayer 73 to three species of fish. *J. Great Lakes Res.* 11:171-178.
- SMITH, B. R., J. J. TIBBLES, and B. G. H. JOHNSON. 1974. Control of the sea lamprey (*Petromyzon marinus*) in Lake Superior, 1953-70. *Great Lakes Fish. Comm. Tech. Rep.* 26: 60 p.
- SMITH, M. A., V. C. APPELLEGATE, and B. G. H. JOHNSON. 1960. Calorimetric determination of halogenated nitrophenols added to streams as a lamprey larvicide. *Anal. Chem.* 32:1670-1675.

ALKALINITY 40 PPM

ALKALINITY 45 PPM

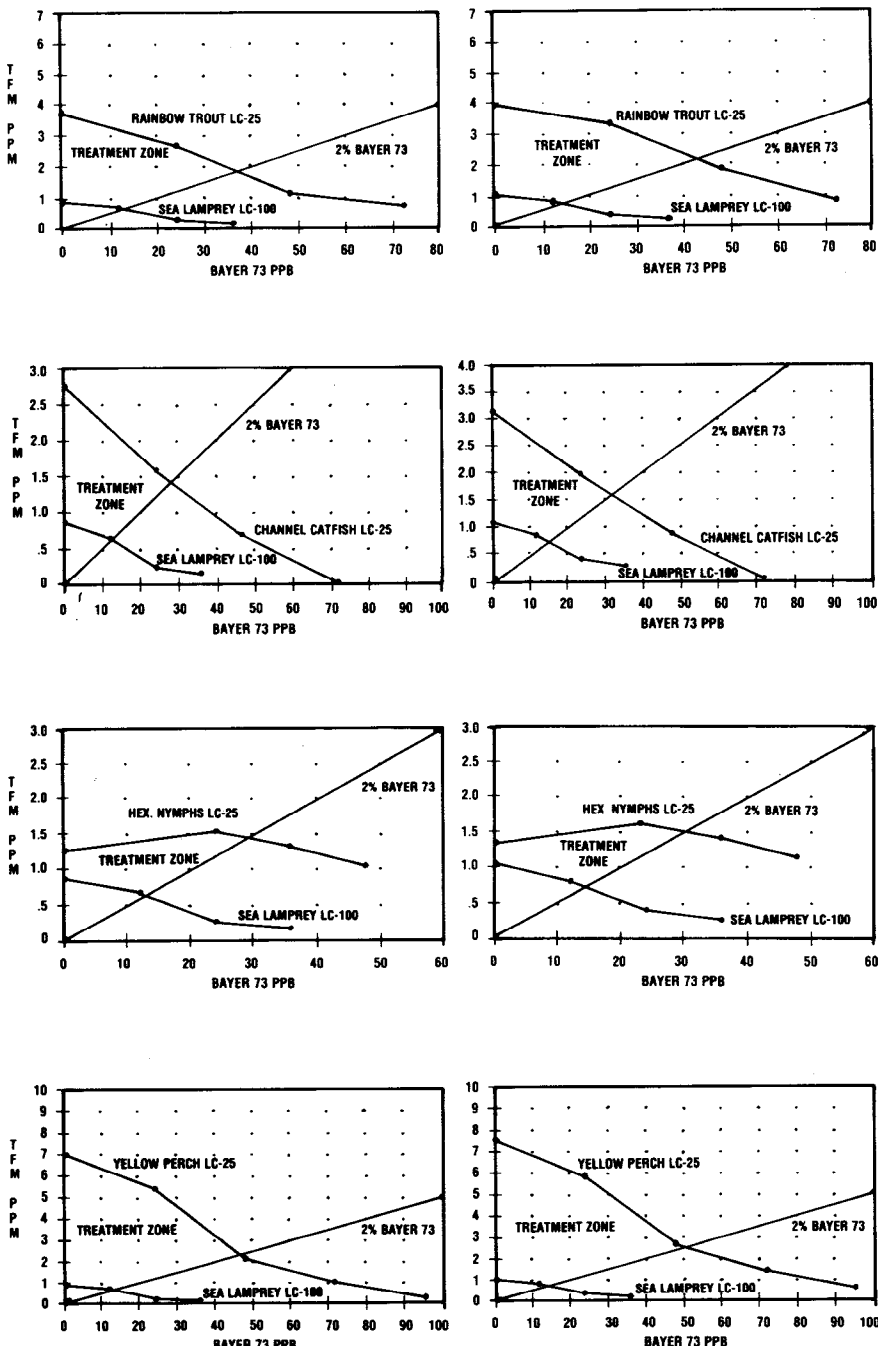


FIGURE 1. Graphical representation of the toxicity of TFM Bayer 73 at specified alkalinities.

ALKALINITY 50 PPM

ALKALINITY 55 PPM

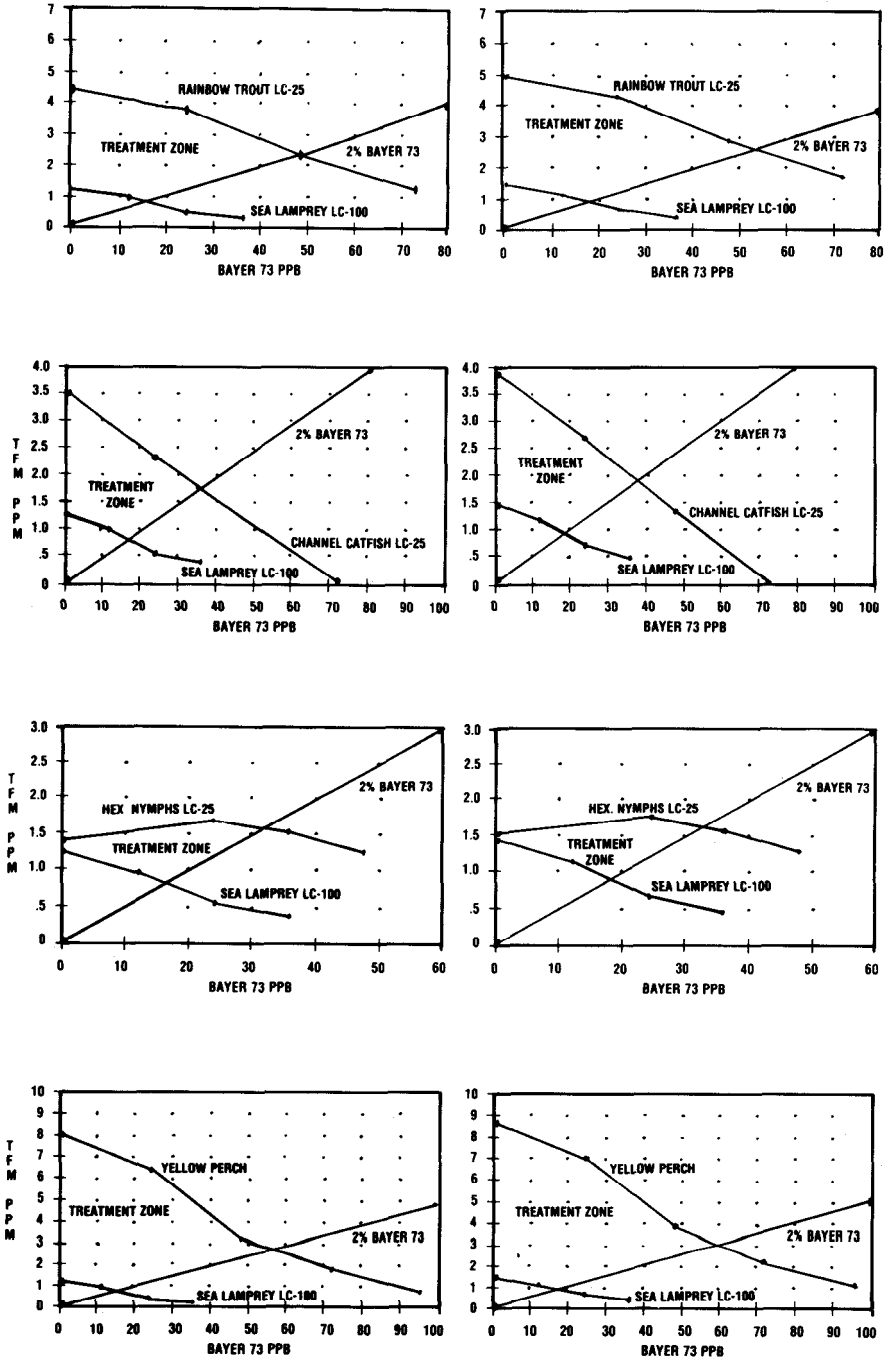
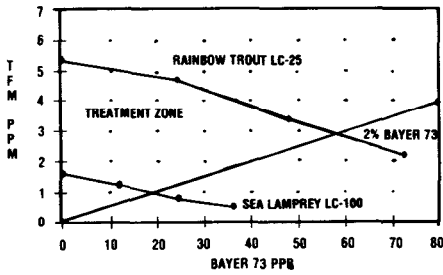


FIGURE 1 (CON'T)

ALKALINITY 60 PPM



ALKALINITY 65 PPM

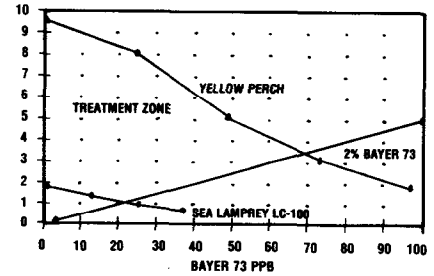
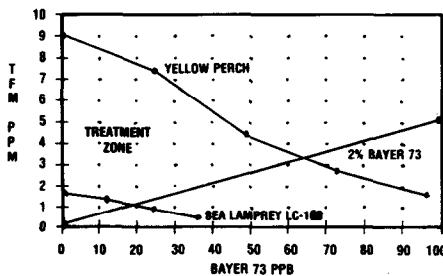
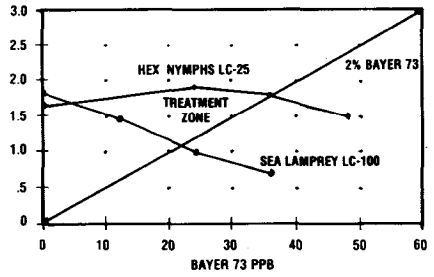
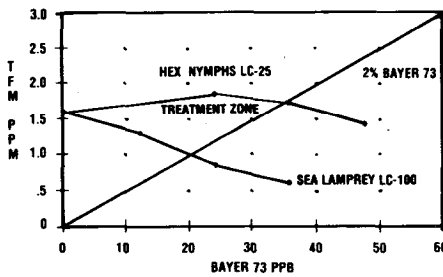
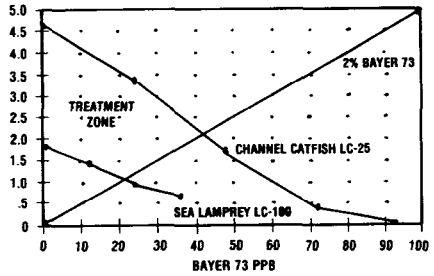
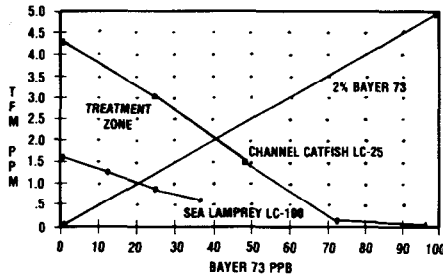
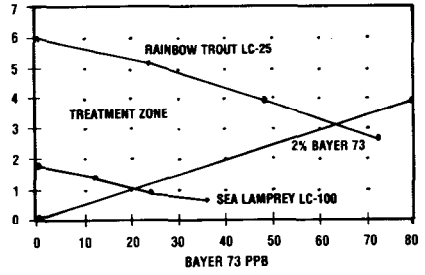
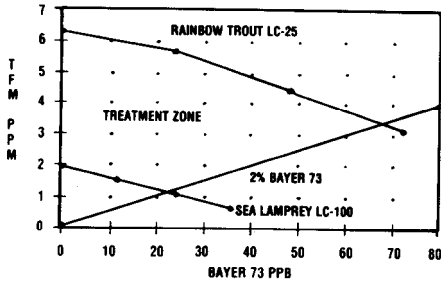


FIGURE 1 (CONT)

ALKALINITY 70 PPM



ALKALINITY 75 PPM

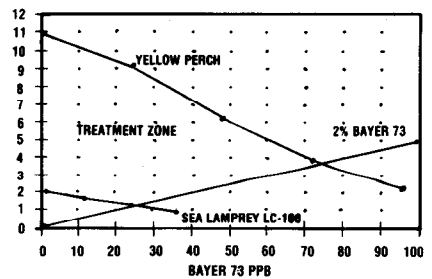
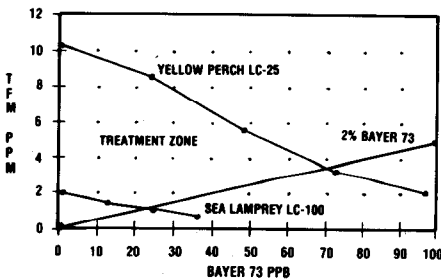
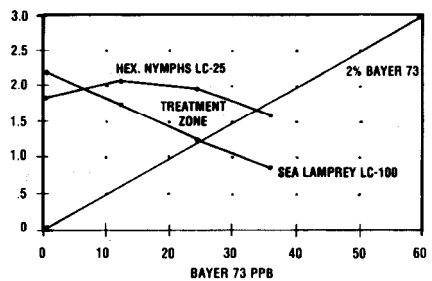
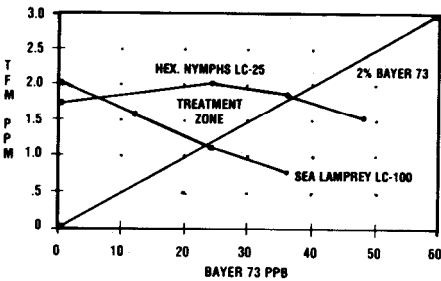
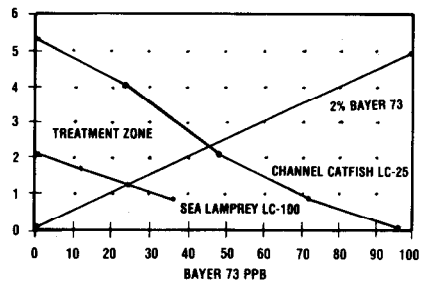
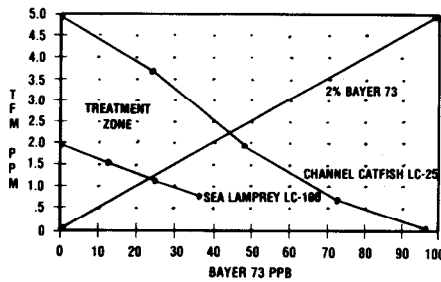
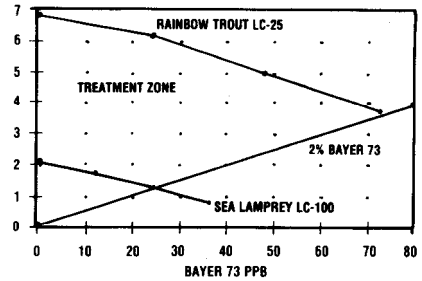


FIGURE 1 (CON'T)

ALKALINITY 80 PPM

ALKALINITY 85 PPM

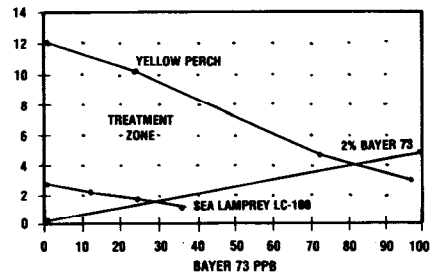
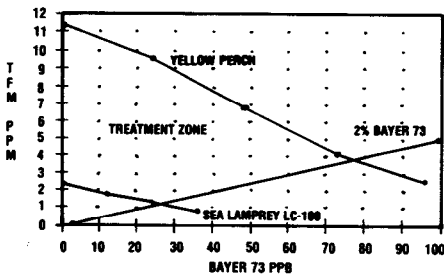
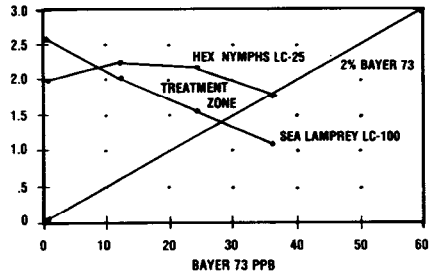
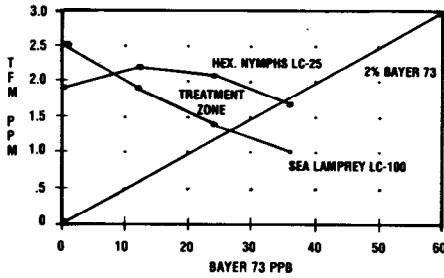
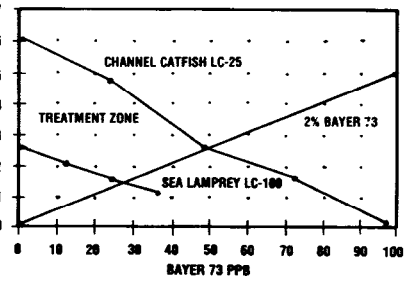
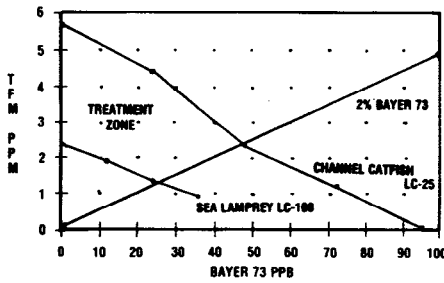
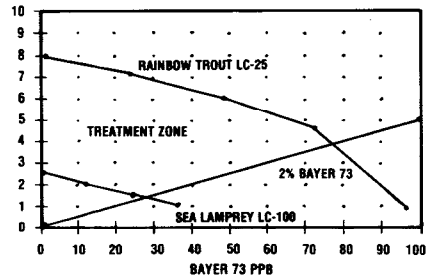
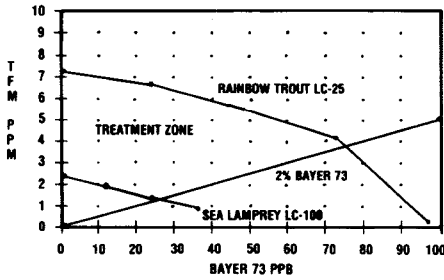


FIGURE 1 (CON'T)

ALKALINITY 90 PPM

ALKALINITY 95 PPM

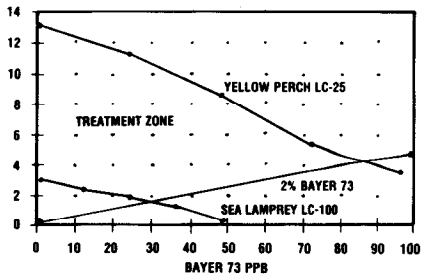
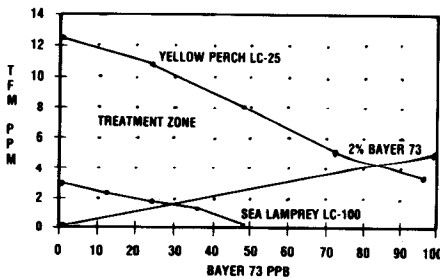
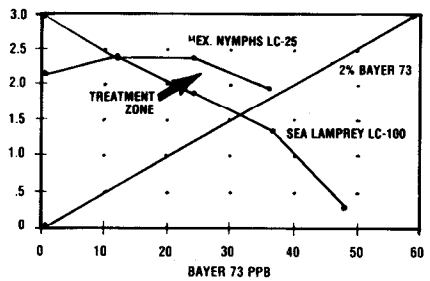
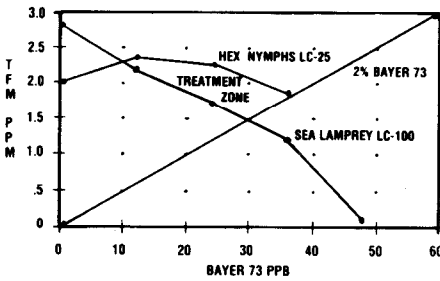
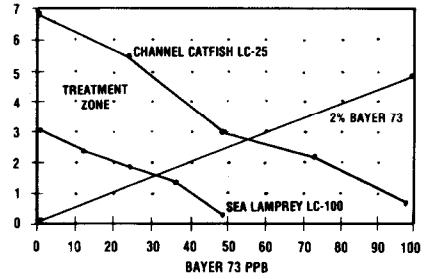
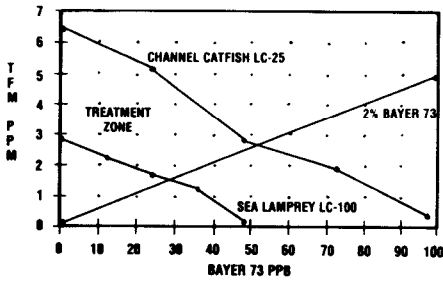
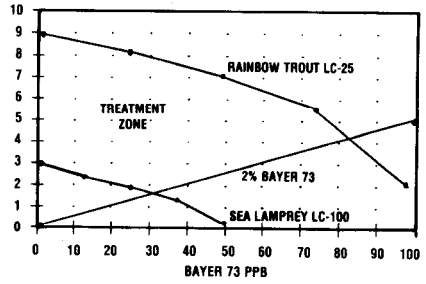
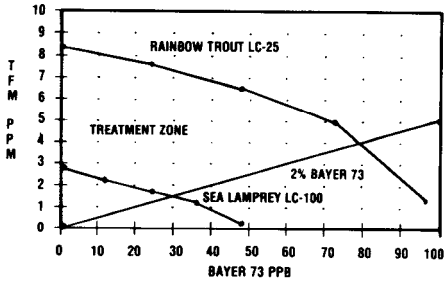


FIGURE 1 (CONT)

ALKALINITY100 PPM

ALKALINITY105 PPM

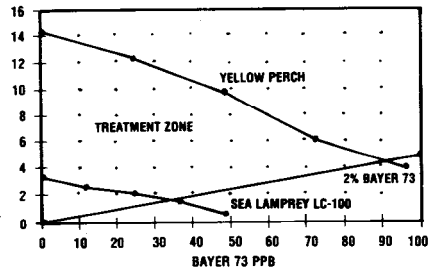
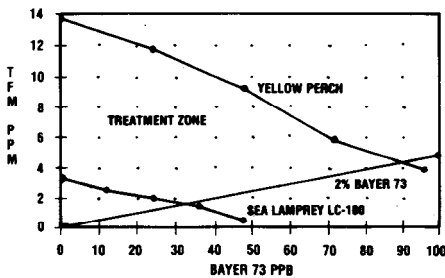
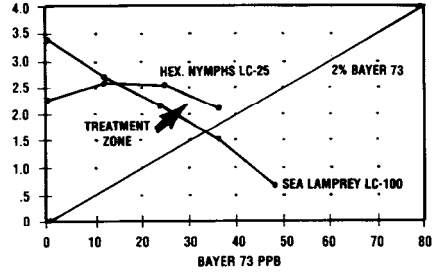
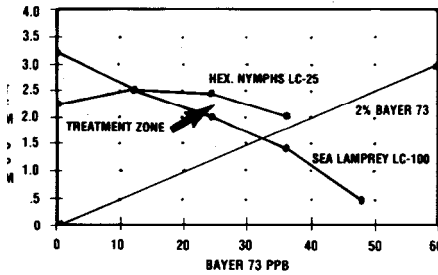
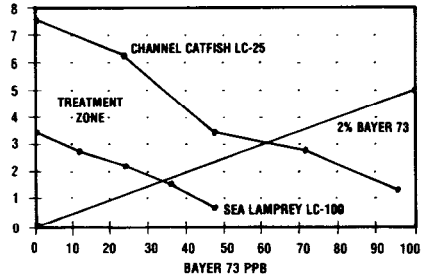
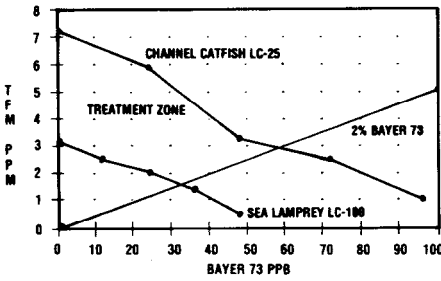
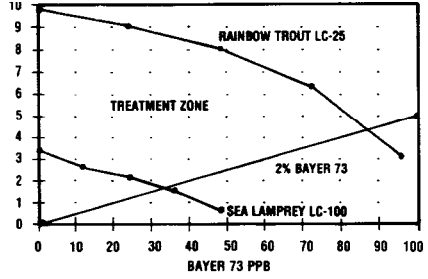
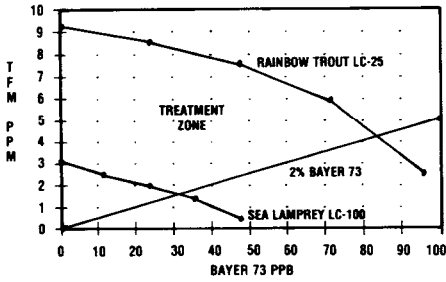


FIGURE 1 (CONT)

ALKALINITY 110 PPM

ALKALINITY 115 PPM

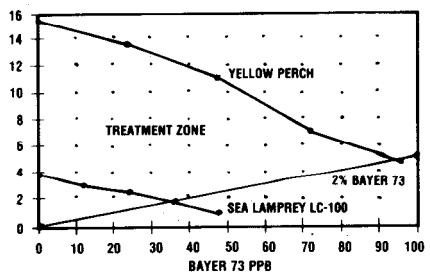
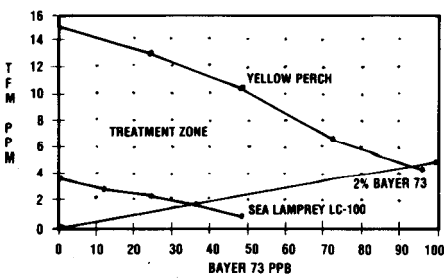
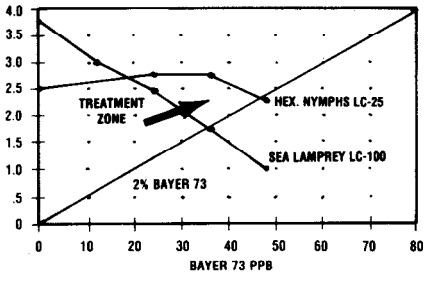
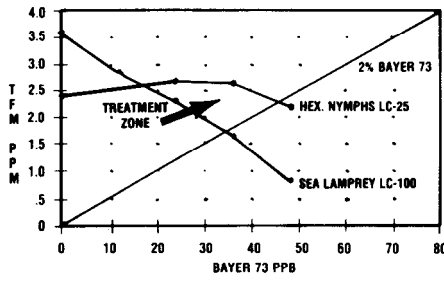
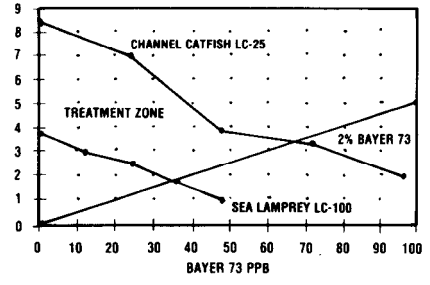
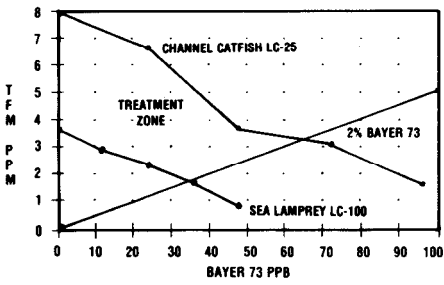
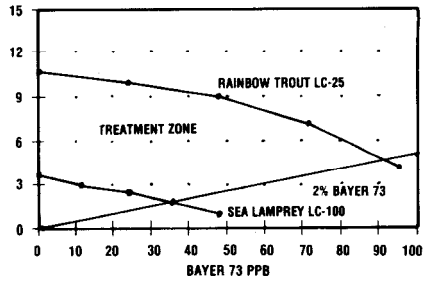
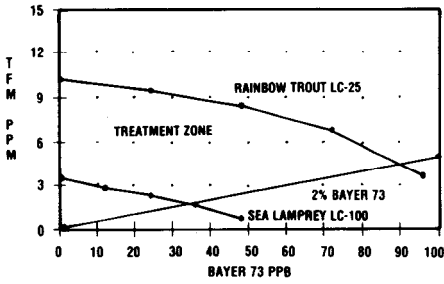
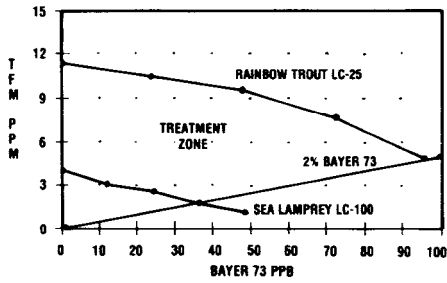


FIGURE 1 (CON'T)

ALKALINITY 120 PPM



ALKALINITY 125 PPM

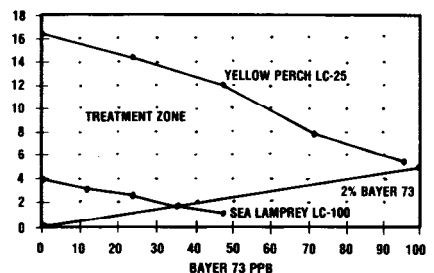
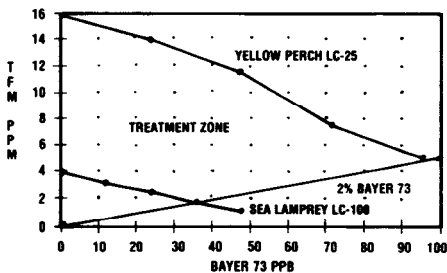
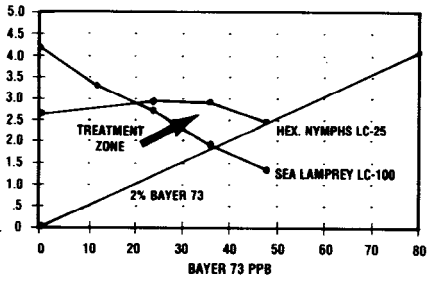
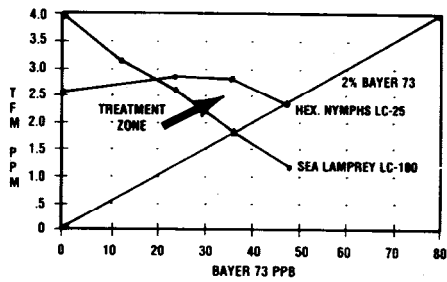
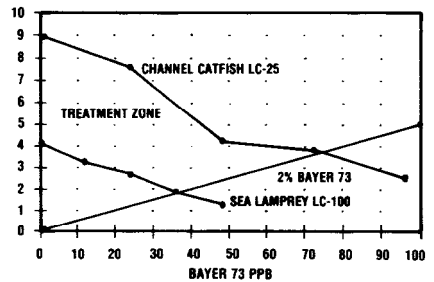
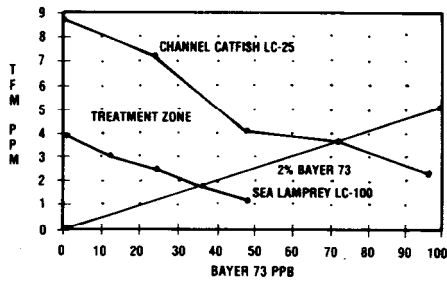
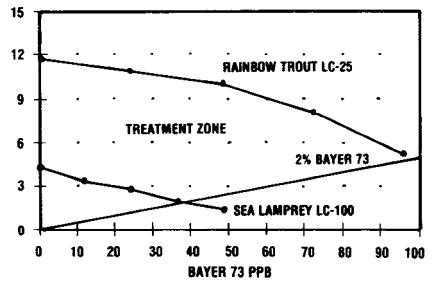


FIGURE 1 (CON'T)

ALKALINITY 130 PPM

ALKALINITY 135 PPM

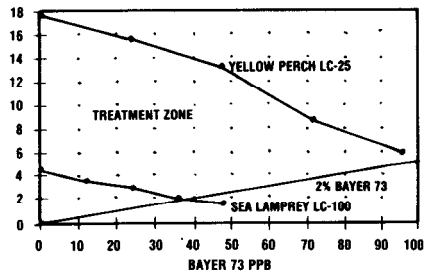
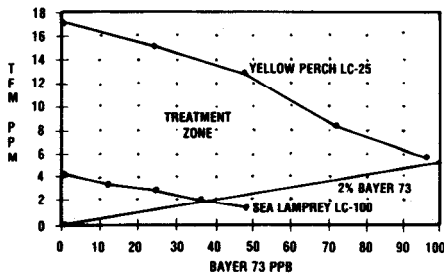
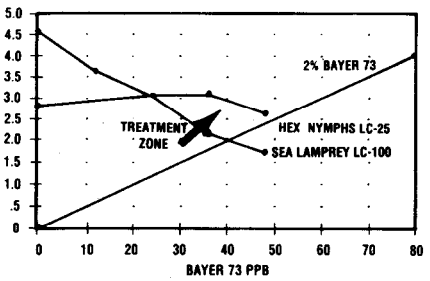
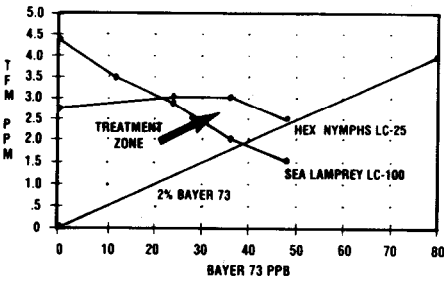
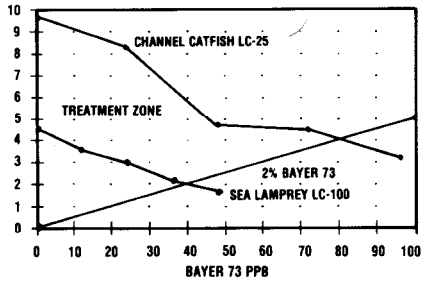
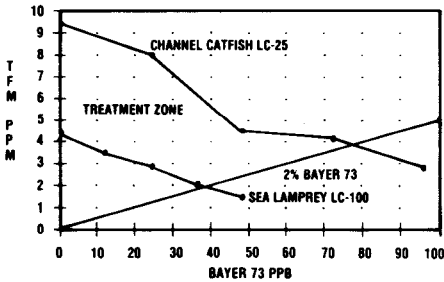
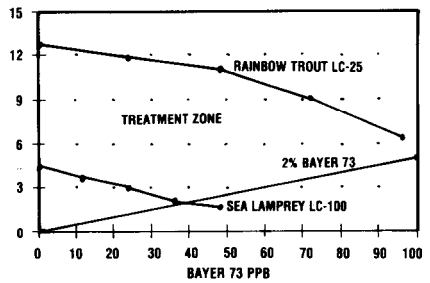
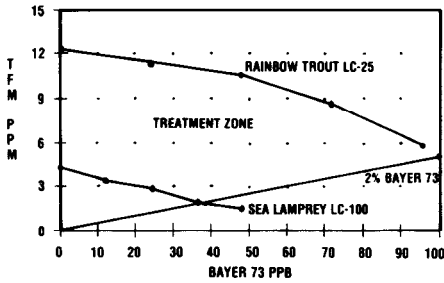
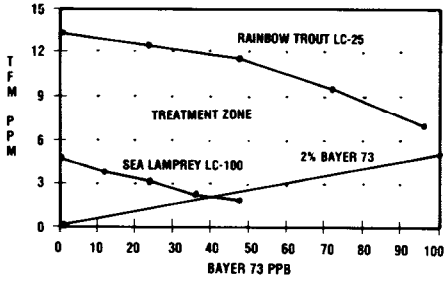


FIGURE 1 (CONT)

ALKALINITY 140 PPM



ALKALINITY 145 PPM

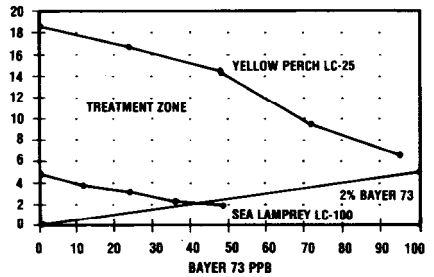
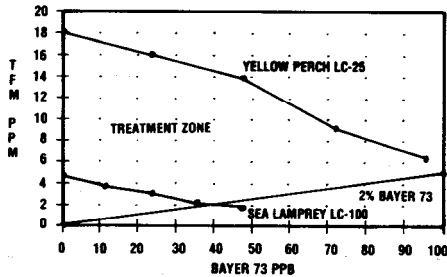
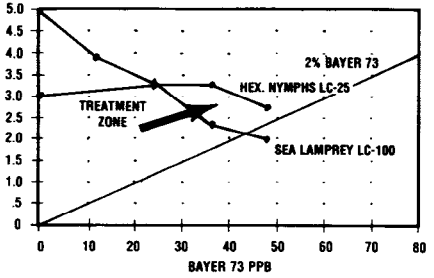
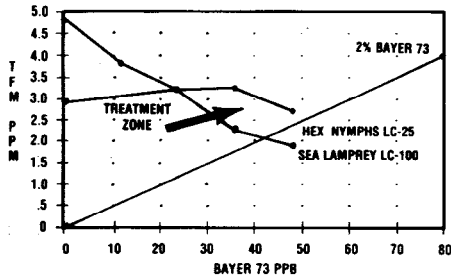
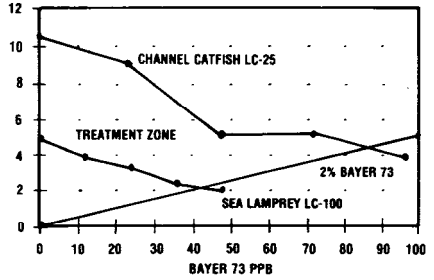
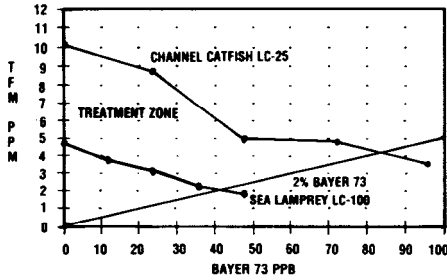
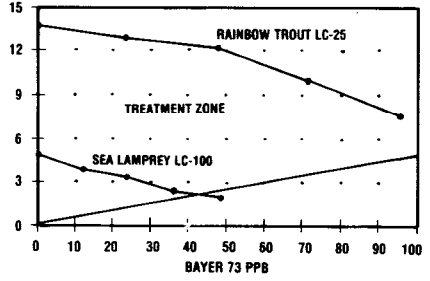


FIGURE 1 (CON'T)

ALKALINITY150 PPM

ALKALINITY155 PPM

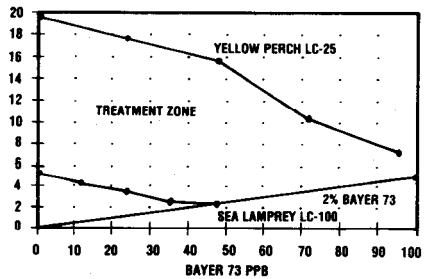
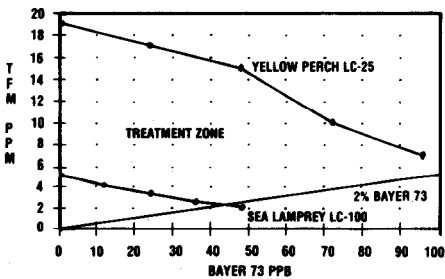
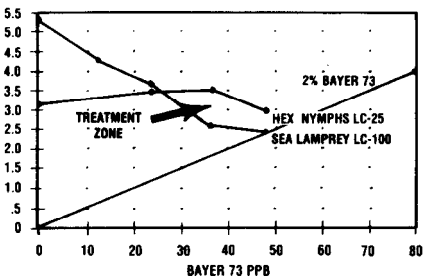
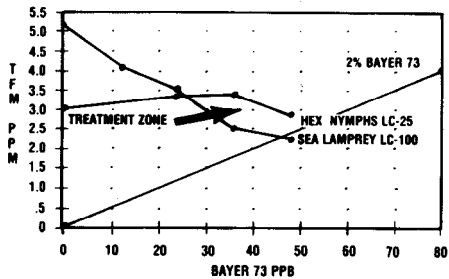
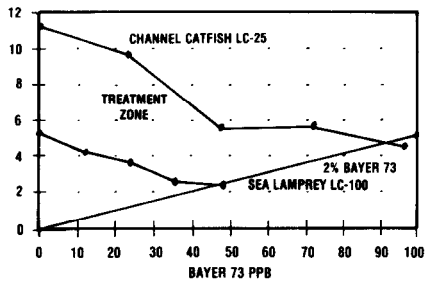
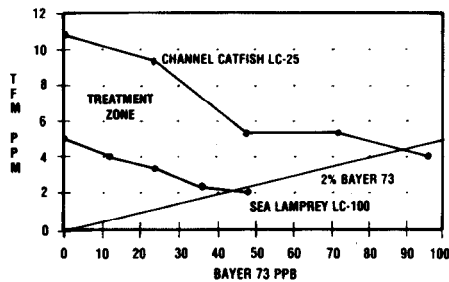
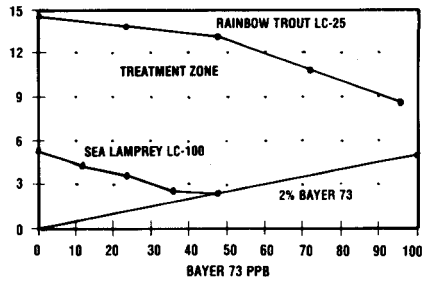
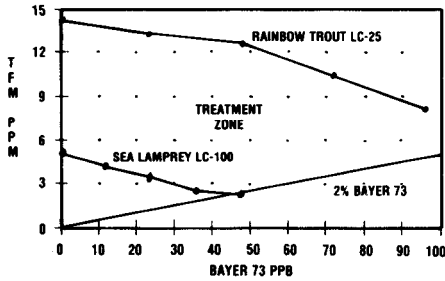


FIGURE 1 (CON'T)

ALKALINITY 160 PPM

ALKALINITY 165 PPM

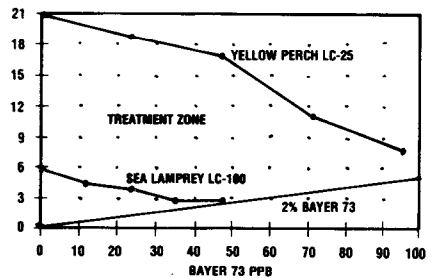
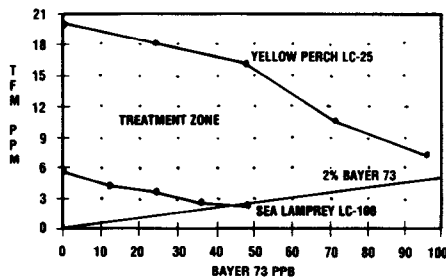
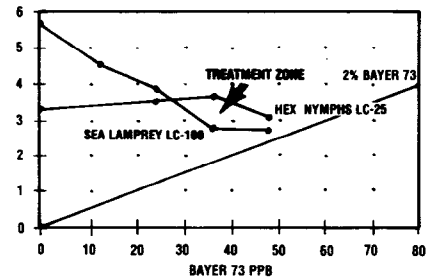
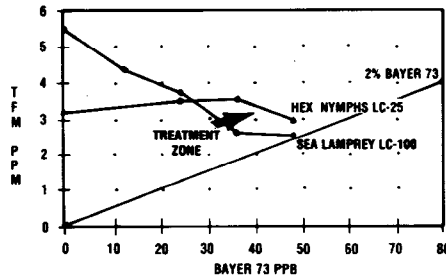
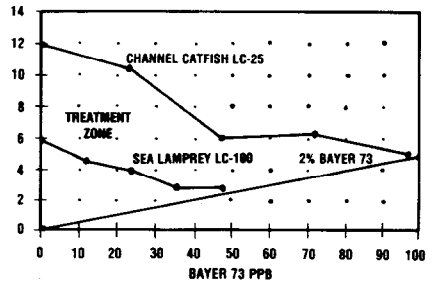
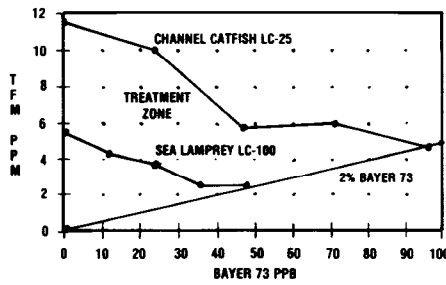
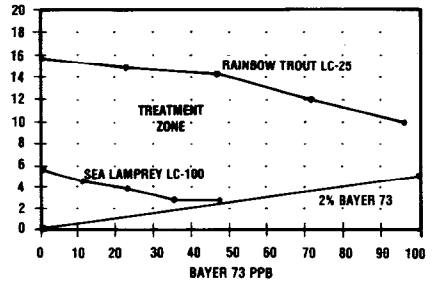
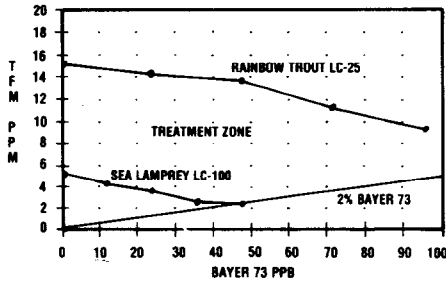


FIGURE 1 (CON'T)

ALKALINITY 170 PPM

ALKALINITY 175 PPM

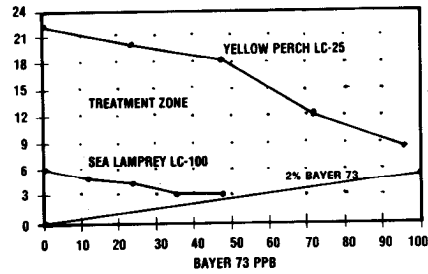
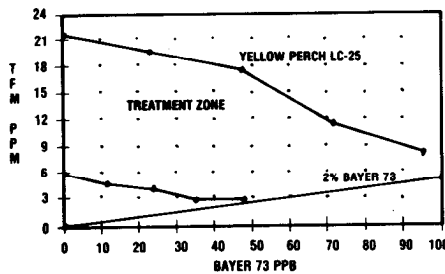
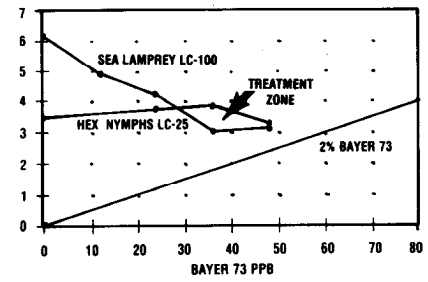
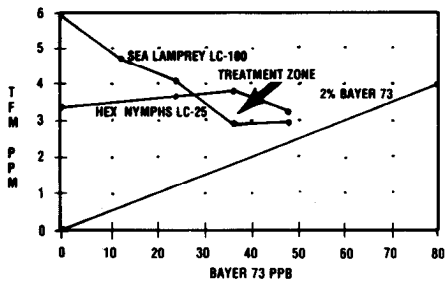
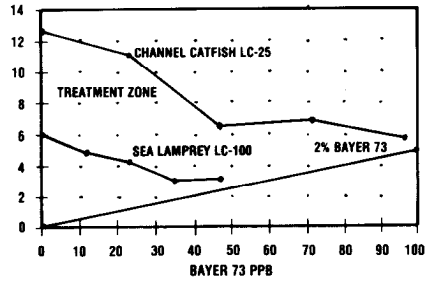
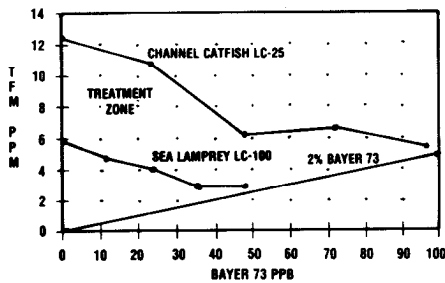
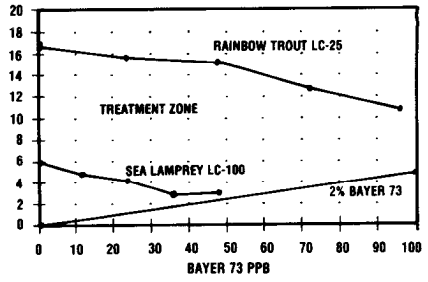
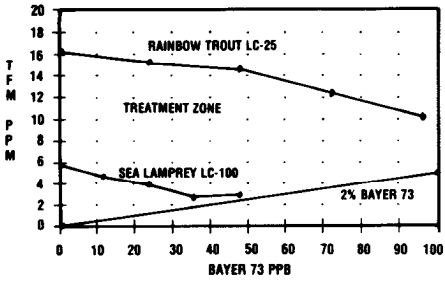
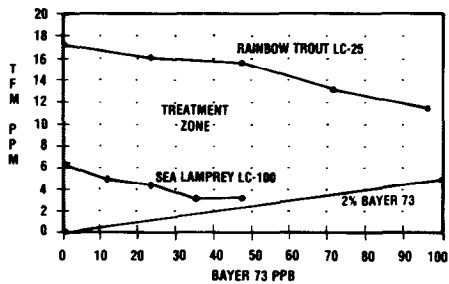


FIGURE 1 (CON'T)

ALKALINITY 180 PPM



ALKALINITY 185 PPM

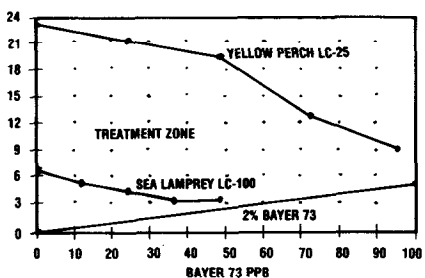
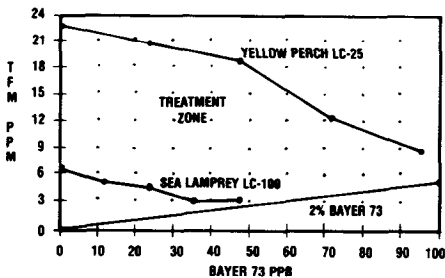
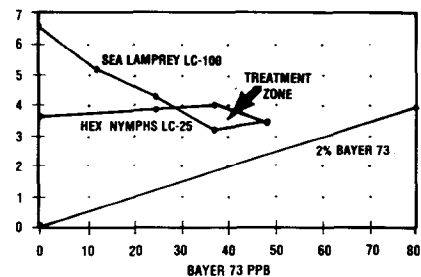
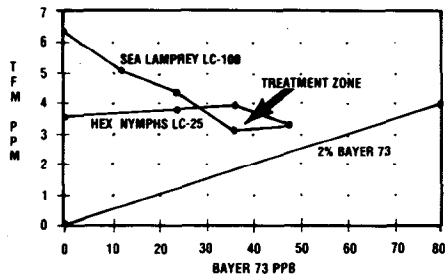
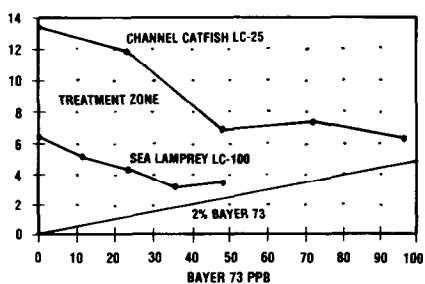
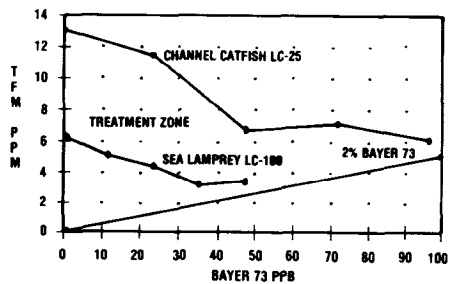
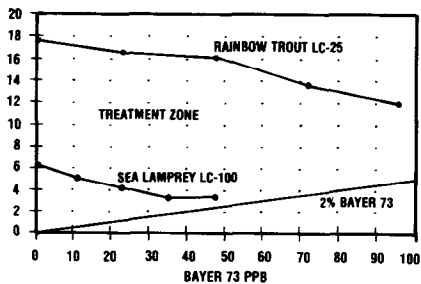


FIGURE 1 (CON'T)

ALKALINITY 190 PPM

ALKALINITY 195 PPM

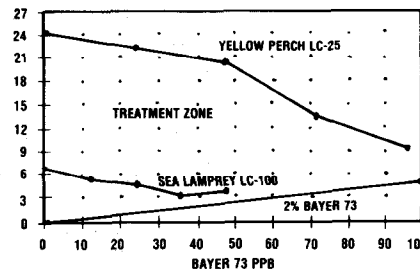
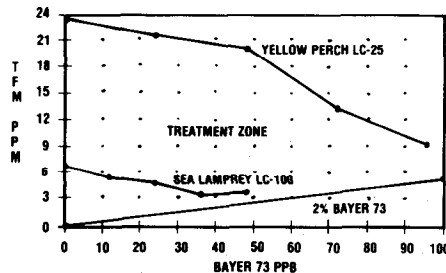
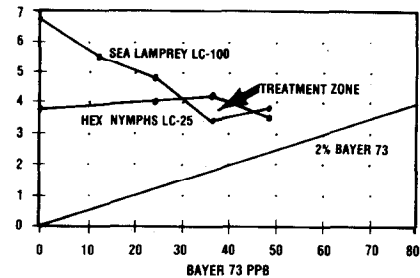
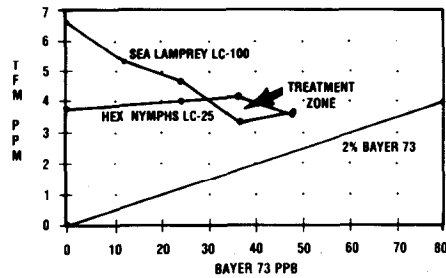
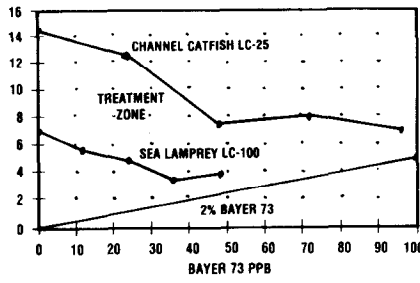
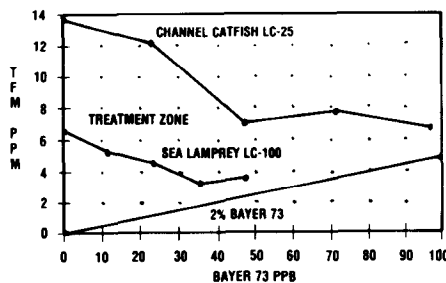
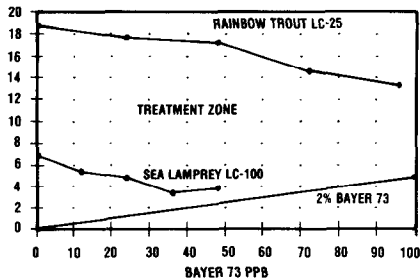
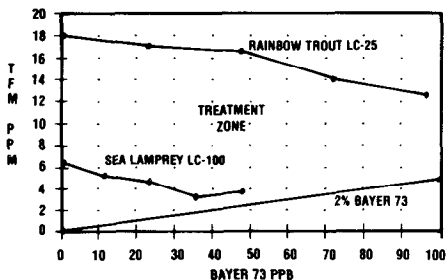


FIGURE 1 (CONT)

ALKALINITY 200 PPM

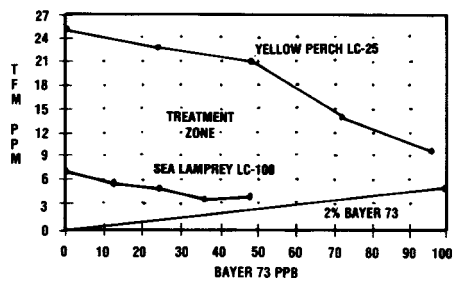
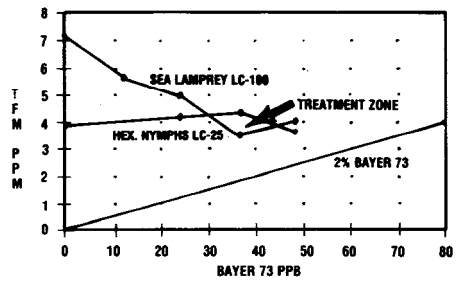
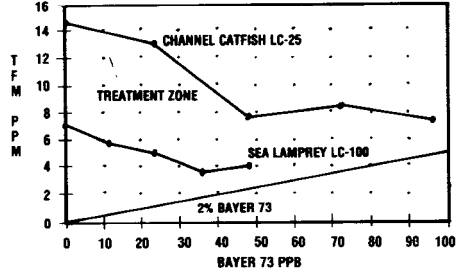
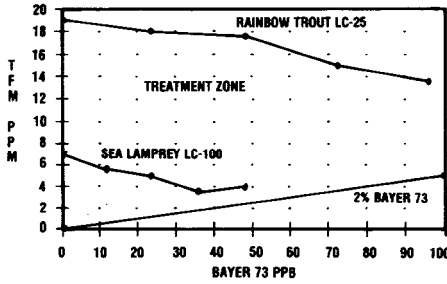
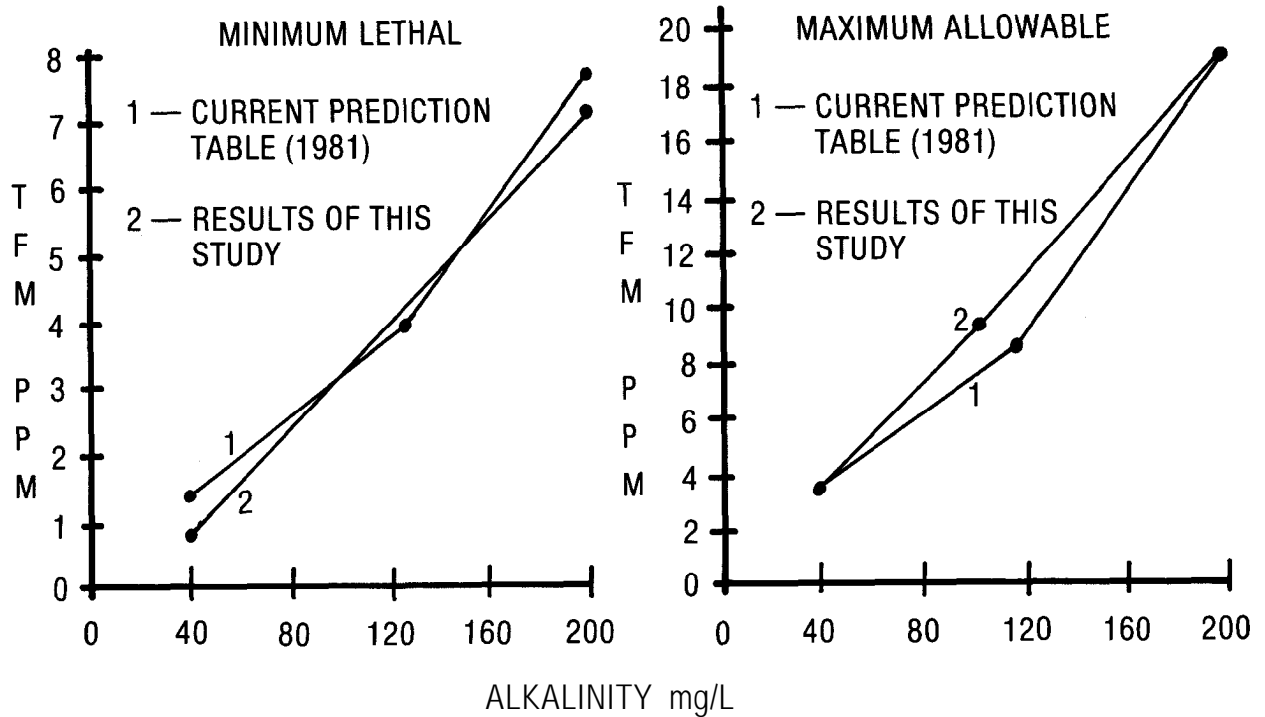


FIGURE 2. Maximum allowable concentrations for rainbow trout and minimum lethal concentrations for sea lampreys from current prediction table (TFM only) and results of this study.



GREAT LAKES FISHERY COMMISSION

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