

SG - 218-04

LAKE ERIE PROTECTION FUND

FINAL REPORT – DECEMBER 2004

Evaluation of gamete quality in yellow perch collected from Lake Erie

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1. Introduction

The yellow perch (*Perca flavescens*) fishery in Lake Erie is considered world class by the Lake Erie Protection and Restoration Plan. However, yellow perch stocks declined sharply lakewide in the 1990s (Ryan *et al.*, 2003). Reduction of exploitation and protection of spawning fish are directives currently underway to restore yellow perch stocks. Low yellow perch recruitment is also observed in the other Great Lakes (e.g., Lake Michigan and Lake Huron). Therefore, it is imperative to understand how the yellow perch population may be regulated or better controlled to maintain a high yield recreational fishery. Although in some lakes recruitment of yellow perch was related to alewife abundance (Shroyer and McComish, 2000) and affected by maternal traits (Heyer *et al.*, 2001), other evidence suggests that shifts in zooplankton numbers and taxonomic composition may also affect yellow perch recruitment (Dettmers *et al.*, 2003). These shifts in density and composition of species constituting the food chain may be related to several human-induced alterations. Of particular interest are food-web changes that may be occurring due to the appearance of exotic invasive species that may act as food-web disruptors, especially in combination with other anthropogenic environmental changes.

We hypothesized that the combination of increased UV penetration due to the changes in limnological characteristics of Lake Erie (Allen and Smith, 2002; Hiriart *et al.*, 2002) and the introduction of several exotic species in the food web of this ecosystem may alter the transfer of polyunsaturated fatty acids (PUFA) to higher trophic levels, top predators. These changes may result in a PUFA deficiency in the food chain leading to impaired larval yellow perch viability. Therefore, high mortalities during early life resulting from deficient PUFA levels can be an important reason for a decreased recruitment of yellow perch. Thus, the objectives of this study were to evaluate the variability in PUFA levels in eggs of individual yellow perch collected in Lake Erie, and to correlate those values with hatching rates and survival of offspring.

2. Materials and Methods

Adult yellow perch females were collected throughout their spawning season in commercial trap nets from the Western (2003) and Central (2004) basins of Lake Erie. Fish were trapped on May 14 and May 20 in 2003 and 2004, respectively. Fish may have spent up to 96 h in the trap nets at approximately 30 feet depth. Females with signs of ovulation were stripped of eggs (3 and 7 in 2003 and 2004, respectively) within a short time after lifting traps. Prior to fertilization, a subsample of eggs was frozen on dry ice for further lipid and fatty acid analysis. Remaining eggs were fertilized with a mixture of sperm from 3 males using the dry method described by Dabrowski *et al.* (1994). Fertilized eggs were incubated in separate PVC jars with a screen bottom placed in California hatching trays (Flex-a-Lite Consolidated, Inc., Tacoma, WA). Recirculating, UV sterilized water at $18 \pm 1^\circ\text{C}$ was used. Fertilization rate was assessed at advanced (pigmented) eyed stage (4 days after fertilization at 18°C).

Matured, preovulating females were also collected (14 and 20 in 2003 and 2004, respectively). Fish were frozen immediately on dry ice and brought back to the laboratory. Fish were individually weighed and their gonads were removed and weighed. Gonadosomatic index (GSI) was calculated as $\text{GSI} = (\text{gonad weight} \times 100) / \text{total weight}$. A subsample of oocytes was frozen (-83°C) for lipid and fatty acid analysis.

Total lipids from yellow perch ovary or eggs prior to fertilization were extracted after homogenization in chloroform-methanol according to the procedure of Folch *et al.* (1957). Total lipid extracts were then separated into polar (phospholipids) and neutral (mostly triglycerides) fractions using silica sep-pak cartridges (Waters, Division of Millipore Corp., Milford, MS) and determined gravimetrically. Fatty acid methyl ester mixtures were prepared from both fractions of lipids according to the method described by Metcalfe and Schmitz (1961). The gas chromatograph analyses of the fatty acid methyl esters was performed on a Varian 3900 Gas Chromatograph (Varian Chromatography Systems, Walnut Creek, CA) equipped with a Varian Chrompack capillary column (WCOT fused silica 100 m x 0.25 mm coating CPSIL 88 for FAME,

DF=0.2) using helium as carrier gas at a flow of 30 ml/min. The following temperature conditions are routinely used for the GC: 270°C (injector), 175°C for 26 min, then increase by 2°C/min to 205°C and held at 205°C for 30 min (oven), 300°C (detector). The fatty acids were quantified by comparing their peak areas with that of the peak of a known amount of an added internal standard, C19:0 (nonadecanoic acid).

Results are expressed as mean \pm standard deviation (SD). Prior to statistical analysis, percentage data were arc sine transformed. Homogeneity of variances was tested using the Bartlett's test. All parameters measured were subjected to one-way analysis of variance (ANOVA) followed by Scheffe's test to compare means. The significance level α was set at 0.05. Multiple linear regression analysis was used to test whether egg fatty acid composition in both neutral and phospholipid fractions could predict embryo survival. This analysis was conducted only on the data collected in 2004 (n=7). All statistical analyses were performed using SPSS 12.0 software (SPSS Inc., Chicago, IL).

3. Results

The reproductive characteristics of yellow perch collected in 2003 and 2004 are reported in Table 1. To accurately compare the data between the two locations (Western basin in 2003 and Central basin in 2004), females of similar size were selected. The statistical analysis revealed that female size did not differ significantly ($P>0.05$) regardless of the stage of maturity (preovulating or ovulating) or the sampling location and date (Western basin-2003 or Central basin-2004). GSI's in preovulating females were similar in 2003 and 2004 ($P>0.05$). The mean concentration of total lipids in yellow perch oocytes did not differ significantly between 2003 and 2004. In contrast, the total lipid concentrations in eggs were significantly ($P<0.01$) lower in 2004 (Table 1). Regardless of the stage of maturity (oocytes or eggs) or the sampling location and date, the proportion of both lipid fractions remained constant (73 to 75% of neutral lipids vs 27-25% of polar lipids).

In 2003, three females were spawned on the boat and their eggs fertilized with an excess of sperm. Fertilization rate measured at eyed stage averaged $93.0 \pm 3.6\%$. In 2004, seven females were spawned and fertilization rate measured at eyed stage averaged $89.3 \pm 5.7\%$ ($n = 6$). Survival of eggs at the eyed stage was very low for one female (11.0 %). Moreover, eggs from one female with survival reaching 87% exhibited a high percentage of abnormal embryos (77%). Embryo survival did not differ significantly ($P > 0.05$) regardless of the sampling location and date.

The fatty acid concentrations in yellow perch oocytes and eggs from both lipid fractions are reported in Tables 2 and 3. In both lipid fractions, palmitic acid (16:0) was the most abundant saturated fatty acids. The monounsaturated fatty acids were represented by two major compounds, palmitoleic acid (16:1) and oleic acid (18:1). Arachidonic acid (20:4n-6, AA), eicosapentaenoic acid (20:5n-3, EPA), and docosahexaenoic acid (22:6n-3, DHA) were the most abundant PUFA (~90% of total PUFA) in the phospholipid fractions, whereas in the neutral lipid fraction, linoleic acid (18:2n-6) and DHA dominated (~60% of total PUFA). The polar lipid fraction contained a higher proportion of saturated and n-3 PUFA than the neutral lipids. In contrast, monounsaturated fatty acids were more abundant in the neutral lipid fraction than in the phospholipid fraction due to the higher proportion of palmitoleic and oleic acids present in the neutral lipid fraction. Fatty acid profiles in oocytes and eggs were consistent regardless of the sampling date and location.

In the polar lipid fraction (Table 2), the concentrations of saturated and monounsaturated fatty acids were significantly different between the sampling location and date. The levels of stearic acid (18:0) were significantly higher ($P < 0.01$) in 2004 in comparison to those in 2003, whereas palmitoleic acid levels showed the opposite trend. The major fatty acid in the phospholipid fraction was DHA (~30%). The concentrations of fatty acids from the n-6 family (18:2n-6, 20:4n-6, and 22:5n-6) did not differ significantly ($P > 0.05$) regardless of the stage of maturity and the sampling location and date. In contrast, the levels of some fatty acids from the n-3 family (e.g., 20:5n-3; 22:5n-3) differed significantly ($P < 0.01$) with higher levels in 2004 than in 2003. However, the

sums of n-3 PUFA and the n-3/n-6 ratio were similar regardless of the stage of maturity and the sampling location and date.

In the neutral lipid fraction (Table 3), the concentrations of saturated, monounsaturated, and polyunsaturated fatty acids were significantly different between the sampling location and date. The levels of saturated and polyunsaturated fatty acids were significantly higher ($P < 0.01$) in 2004 than in 2003, whereas the levels of monounsaturated fatty acids were significantly lower ($P < 0.01$) in 2004. Palmitoleic acid was the most abundant fatty acid in the neutral lipid fraction of yellow perch eggs and oocytes. Although fatty acids from the n-6 family differed significantly ($P < 0.01$) with regard to the sampling location and date, the sum of n-6 did not differ significantly ($P > 0.05$). The n-3/n-6 ratio was significantly lower ($P < 0.01$) in the neutral lipid fraction than in the phospholipid fraction. Moreover, it was significantly lower ($P < 0.01$) in 2003 than in 2004.

Multiple linear regression analysis revealed that fatty acid concentrations in yellow perch eggs collected in 2004 from the polar lipid fraction did not explain variation in embryo survival ($F = 0.82$, $df = 6$, $P = 0.51$, $r^2 = 0.29$). In contrast, in the neutral lipid fraction, multiple linear regression revealed that saturated fatty acids correlate with embryo survival ($F = 6.82$, $df = 6$, $P = 0.04$, $r^2 = 0.58$). The concentrations of myristic acid (14:0) and total saturated fatty acids from the neutral lipid fractions were significantly ($P < 0.05$) and negatively correlated with embryo viability at the pigmented eyed stage (14:0: $F = 8.56$, $df = 6$, $P = 0.03$, $r^2 = 0.63$ and total saturated: $F = 9.74$, $df = 6$, $P = 0.02$, $r^2 = 0.66$) (Figure 1). In the phospholipids fraction, only oleic acid (18:1) was significantly and positively correlated with embryo viability at the pigmented eyed stage ($F = 8.76$, $df = 6$, $P = 0.03$, $r^2 = 0.64$) (Figure 1).

4. Discussion

The goal of this project was to study yellow perch reproduction in Lake Erie with a special emphasize on lipid and fatty acid compositions of their gonads (oocytes and

eggs). During two reproductive seasons (2003 and 2004), preovulating females were sampled and their gonadosomatic index determined. GSI's were similar to those reported earlier by Ciereszko *et al.* (1997) and Dabrowski *et al.* (1994) for yellow perch under culture conditions. In most freshwater fish, eggs contain between 2 to 10% lipids based on wet weight. The lipid concentrations in yellow perch eggs from Lake Erie were similar to those reported in yellow perch eggs from Lake Michigan (Czesny *et al.*, 2004; Rinchar *et al.*, unpublished data), as well as those reported in the Eurasian perch *Perca fluviatilis* (Kaitaranta and Ackman, 1981).

The quality of fish eggs is largely influenced by their fatty acid composition (Kjorsvik *et al.*, 1990). Polyunsaturated fatty acids from the n-6 and n-3 families are important for the normal embryonic development of fish. DHA is a structural component of fish brain and retina lipids (Bell *et al.*, 1996; Mourente *et al.*, 1999). DHA deficiency may result in impairment of larval behaviors (Bell *et al.*, 1995) and brain development (Ishizaki *et al.*, 2001). EPA and AA also play an important role as eicosanoid precursors, and the ratio of these two fatty acids is usually considered to impact embryo viability (Sargent *et al.*, 1995). A deficiency of n-3 fatty acids, particularly 20:5n-3 (EPA) and 22:6n-3 (DHA), caused physiological dysfunctions of the developing embryo and increased the incidence of early embryonic mortality (Watanabe, 1982). In the present study, the survival of yellow perch embryos was generally very high suggesting that the fatty acid composition of egg lipids satisfied the embryonic nutritional needs in most females. Moreover, we were not able to establish any relationship between DHA or EPA and embryo survival. In Lake Michigan, Czesny *et al.* (2004) reported that fertilization rates of yellow perch under laboratory conditions evaluated at the time of pigmented eyed stage ranged from 47 to 95%. However, it would be more conclusive, in terms of progeny viability, if embryo survival was followed up to 7-20 days posthatch.

Regardless of the sampling location and date, we observed a high consistency in fatty acid profiles in both lipid fractions. The most abundant fatty acids in the neutral and polar lipids of yellow perch eggs in the present study were the same as those described previously for yellow perch raised in ponds (Dabrowski *et al.*, 1993) and collected in

Lake Michigan (Czesny *et al.*, 2004; Rinchard *et al.*, unpublished data). Several studies have shown that the nutritional status of broodstock fish has a direct influence on their egg quality and, ultimately, on their embryo and larvae survival (Navas *et al.*, 1997; Rodriguez *et al.*, 1998). The results of the present study provide a baseline for future studies not only in Lake Erie but also in other Great Lakes (e.g., Lake Michigan) in which yellow perch recruitment has been affected. As mentioned in the introduction, any change in fatty acid composition (e.g., PUFA such as DHA, AA, and EPA) in yellow perch food web has a potential to affect their egg quality, and subsequently impairing yellow perch larval viability. A continuous monitoring of the lipid and fatty acid composition of yellow perch eggs is therefore recommended as annual variations were observed during this two year study.

5. Acknowledgements

We thank Mr. J. Herr and J. Smith, fishermen from Sandusky, Ohio, for their generous supply of fish and their technical assistance.

6. References

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Table 1: Reproductive characteristics of yellow perch collected in 2003 and 2004 in the Western and Central Basin of the Lake Erie, respectively. Means across rows with different superscript differ significantly at $P < 0.05$.

Reproductive characteristics	Western Lake Erie - 2003		Central Lake Erie - 2004	
	Preovulating	Ovulating	Preovulating	Ovulating
	n = 14	n = 3	n = 20	n = 7
Weight (g)	130.1 ± 42.7 ^a	144.1 ± 47.0 ^a	160.1 ± 76.0 ^a	147.3 ± 49.9 ^a
GSI (%) ¹	26.1 ± 3.2 ^a	-	26.5 ± 3.1 ^a	-
Total lipids (% of wet weight)	4.9 ± 0.3 ^a	5.0 ± 0.4 ^a	5.0 ± 0.5 ^a	4.2 ± 0.3 ^b
Phospholipids (% of total lipids)	26.3 ± 2.5 ^a	24.8 ± 1.8 ^a	25.9 ± 2.7 ^a	27.4 ± 3.4 ^a
Survival (%)	-	93.0 ± 3.6 ^a	-	89.3 ± 5.6 ^a (n=6) 11 (n=1)

¹GSI = Gonadosomatic index = ((gonad weight)x100/body weight)

Table 2: Fatty acid composition of yellow perch ovary or egg polar lipids (expressed as % of total polar lipids \pm SD). Means across rows with different superscript differ significantly at $P < 0.05$.

Fatty acids	Western Lake Erie - 2003		Central Lake Erie - 2004	
	Ovary	Egg	Ovary	Egg
	n = 14	n = 3	n = 20	n = 7
14:0	1.5 \pm 0.2 ^a	1.4 \pm 0.0 ^{ab}	1.3 \pm 0.1 ^b	1.3 \pm 0.1 ^b
16:0	20.9 \pm 0.8 ^{ab}	20.9 \pm 0.4 ^{ab}	20.8 \pm 0.7 ^b	21.8 \pm 0.4 ^a
18:0	5.9 \pm 0.3 ^c	6.3 \pm 0.5 ^{bc}	7.1 \pm 0.4 ^a	6.5 \pm 0.3 ^b
16:1*	5.6 \pm 0.5 ^a	5.3 \pm 0.4 ^{ab}	4.8 \pm 0.5 ^b	4.5 \pm 0.8 ^b
18:1*	10.6 \pm 0.4 ^a	10.4 \pm 0.4 ^a	10.5 \pm 0.5 ^a	9.4 \pm 0.5 ^b
18:2n-6	1.8 \pm 0.6 ^a	1.4 \pm 0.5 ^a	1.5 \pm 0.3 ^a	1.5 \pm 0.4 ^a
20:4n-6	10.1 \pm 1.5 ^a	9.3 \pm 1.7 ^a	10.3 \pm 0.8 ^a	10.1 \pm 0.9 ^a
22:5n-6	1.4 \pm 0.3 ^a	1.1 \pm 0.2 ^a	1.2 \pm 0.3 ^a	1.0 \pm 0.1 ^a
18:3n-3	0.5 \pm 0.1 ^a	0.4 \pm 0.1 ^{ab}	0.4 \pm 0.1 ^b	0.3 \pm 0.1 ^b
20:5n-3	8.8 \pm 0.3 ^b	10.0 \pm 0.9 ^{ab}	9.3 \pm 0.9 ^b	10.9 \pm 1.3 ^a
22:5n-3	2.6 \pm 0.3 ^b	2.6 \pm 0.5 ^{ab}	3.1 \pm 0.4 ^a	3.2 \pm 0.6 ^a
22:6n-3	30.0 \pm 1.3 ^a	30.4 \pm 1.2 ^a	29.1 \pm 1.2 ^a	29.0 \pm 1.9 ^a
Total saturated	28.3 \pm 0.9 ^b	28.6 \pm 0.9 ^{ab}	29.2 \pm 0.8 ^a	29.6 \pm 0.5 ^a
Total monounsaturated	16.2 \pm 0.7 ^a	15.7 \pm 0.7 ^{ab}	15.2 \pm 0.8 ^b	13.9 \pm 0.8 ^c
Total polyunsaturated	55.1 \pm 1.0 ^a	55.3 \pm 0.4 ^a	55.0 \pm 0.7 ^a	56.0 \pm 0.7 ^a
Total n-6	13.2 \pm 1.4 ^a	11.9 \pm 1.4 ^a	13.1 \pm 0.9 ^a	12.6 \pm 0.9 ^a
Total n-3	41.9 \pm 1.4 ^a	43.5 \pm 1.0 ^a	41.9 \pm 1.0 ^a	43.4 \pm 0.9 ^a
n-3/n-6	3.2 \pm 0.4 ^a	3.7 \pm 0.5 ^a	3.2 \pm 0.3 ^a	3.4 \pm 0.3 ^a

*includes both (n-7) and (n-9) isomers

Table 3: Fatty acid composition of yellow perch ovary or egg neutral lipids (expressed as % of total polar lipids \pm SD). Means across rows with different superscript differ significantly at $P < 0.05$.

Fatty acids	Western Lake Erie - 2003		Central Lake Erie – 2004	
	Ovary	Egg	Ovary	Egg
	n = 14	n = 3	n = 20	n = 7
14:0	3.0 \pm 0.7 ^b	2.6 \pm 0.9 ^b	3.7 \pm 1.2 ^b	8.6 \pm 1.4 ^a
16:0	3.6 \pm 0.5 ^b	3.4 \pm 0.3 ^b	4.7 \pm 0.5 ^a	2.9 \pm 0.3 ^b
18:0	1.8 \pm 0.3 ^a	1.9 \pm 0.3 ^a	0.9 \pm 0.2 ^b	1.3 \pm 0.9 ^{ab}
16:1*	32.9 \pm 4.1 ^a	34.3 \pm 1.7 ^a	25.5 \pm 3.3 ^b	24.7 \pm 2.8 ^b
18:1*	19.1 \pm 1.4 ^a	18.8 \pm 0.7 ^a	16.0 \pm 1.0 ^b	15.6 \pm 1.7 ^b
18:2n-6	11.0 \pm 2.4 ^a	10.6 \pm 2.8 ^a	10.3 \pm 1.8 ^a	11.1 \pm 1.9 ^a
20:4n-6	2.5 \pm 0.8 ^b	2.4 \pm 1.0 ^b	4.2 \pm 0.6 ^a	3.3 \pm 0.5 ^{ab}
22:5n-6	1.7 \pm 0.7 ^a	1.3 \pm 0.4 ^{ab}	1.1 \pm 0.3 ^b	1.6 \pm 0.3 ^{ab}
18:3n-3	3.0 \pm 1.1 ^b	3.1 \pm 1.4 ^{ab}	4.4 \pm 1.2 ^a	4.0 \pm 0.8 ^{ab}
20:4n-3	0.6 \pm 0.2 ^a	0.6 \pm 0.2 ^a	0.7 \pm 0.2 ^a	0.8 \pm 0.2 ^a
20:5n-3	4.5 \pm 1.1 ^c	5.0 \pm 1.0 ^{bc}	7.3 \pm 1.3 ^a	7.1 \pm 1.5 ^{ab}
22:5n-3	1.9 \pm 0.4 ^b	2.1 \pm 0.5 ^{ab}	2.6 \pm 0.3 ^a	2.5 \pm 0.4 ^a
22:6n-3	14.0 \pm 1.7 ^b	13.3 \pm 0.8 ^{bc}	17.8 \pm 1.4 ^a	16.0 \pm 1.9 ^{ac}
Total saturated	8.4 \pm 0.7 ^b	7.9 \pm 0.5 ^b	9.3 \pm 1.4 ^b	12.8 \pm 1.5 ^a
Total monounsaturated	51.9 \pm 4.0 ^a	53.1 \pm 2.0 ^a	41.5 \pm 3.6 ^b	40.3 \pm 3.3 ^b
Total polyunsaturated	39.2 \pm 4.3 ^a	38.5 \pm 2.3 ^a	48.6 \pm 3.3 ^b	46.3 \pm 2.9 ^b
Total n-6	15.3 \pm 2.1 ^a	14.4 \pm 1.5 ^a	15.7 \pm 1.8 ^a	15.9 \pm 1.7 ^a
Total n-3	23.9 \pm 4.1 ^c	24.1 \pm 3.7 ^{bc}	32.9 \pm 3.4 ^a	30.3 \pm 2.9 ^{ab}
n-3/n-6	1.6 \pm 0.4 ^b	1.7 \pm 0.5 ^{ab}	2.1 \pm 0.4 ^a	1.9 \pm 0.3 ^{ab}

*includes both (n-7) and (n-9) isomers

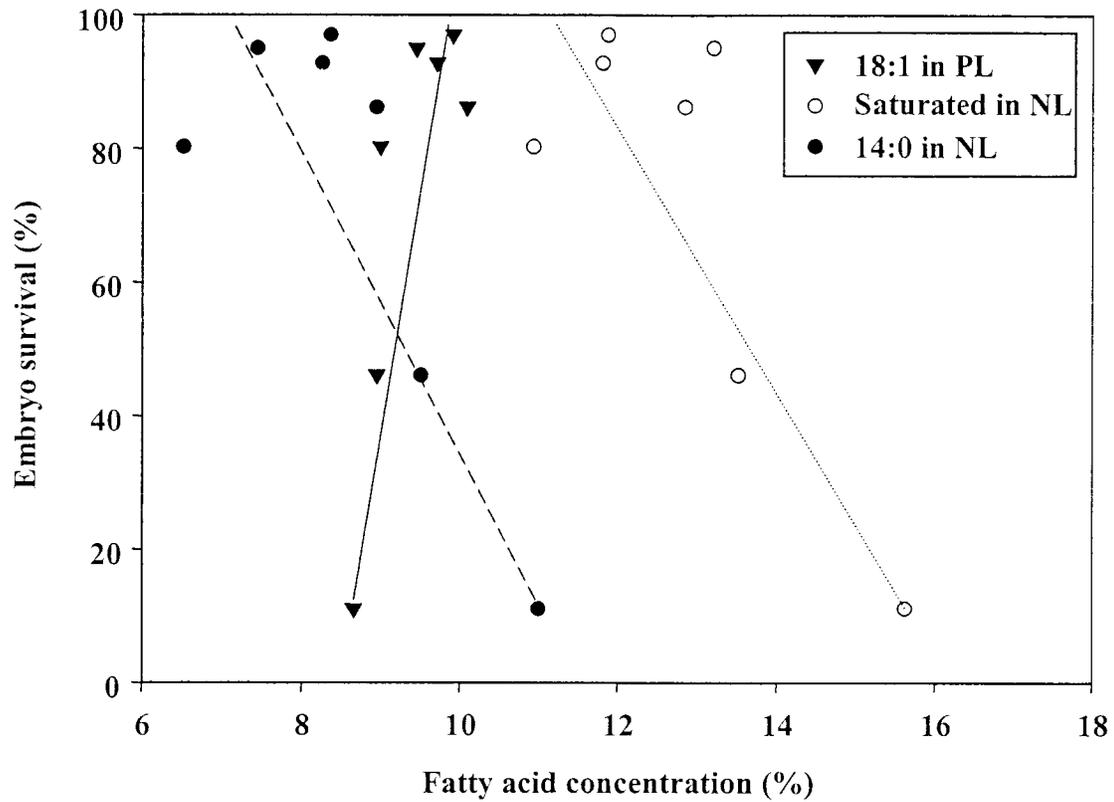


Figure 1: Relationships between the percentages of myristic acid (14:0) and saturated fatty acids in the neutral lipid (NL) fraction or oleic acid (18:1) in the polar lipid (PL) fraction and embryo survival at pigmented eyed stage.