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Comparative fatty acid composition of eggs from domesticated and wild striped bass (*Morone saxatilis*) [1]

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Abstract

Fatty acid profiles from eggs of wild striped bass, *Morone saxatilis*, were compared with eggs from domesticated striped bass fed a commercial diet and found to be significantly higher in total lipid (mg/g dry weight [dwt]), *n*-3 HUFA, EPA, and DHA (all mg/g dwt). The mean ratio of *n*-3/*n*-6 fatty acids from wild fish was almost an order of magnitude higher than that of domesticated fish (10.99 vs. 1.27 mg/g), indicating the wild female dietary input to the egg's endogenous levels more closely approximated marine species than freshwater species. Domesticated fish eggs more closely reflected the fatty acid *n*-3/*n*-6 ratios of a freshwater species. In addition to fatty acid and lipid levels being significantly different between fish groups, total lipid, *n*-3 HUFA, EPA, and DHA were significantly different among each group (except EPA of the domesticated fish). Even though total lipid, *n*-3 HUFA, EPA, and DHA levels of domesticated fish eggs were considerably lower than conspecific wild eggs, the levels in domestic eggs were still considerably higher than reported minima needed for larval growth and survival.

Keywords: Feeding and nutrition — fish, metabolism; *Morone saxatilis*; Fats and fatty compounds; Egg, fish — composition

1. Introduction

Knowledge of the factors that influence hatchability of eggs, as well as growth and survival of larvae, can provide insight into the dietary requirements or other factors that

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Table 1
Total lipid determined gravimetrically and reported as % dry weight

Fish number	Total lipid	EPA 20:5*n*-3	DHA 22:6*n*-3	Total *n*-3 HUFA
1	55.83 (1.4)^{c,d}	18.87 (0.3)^{e}	41.63 (0.7)^{d,e}	69.83 (0.5)^{c,d}
2	52.53 (2.0)^{d}	19.15 (0.7)^{e}	40.08 (1.0)^{e}	68.58 (1.8)^{d}
3	57.30 (1.8)^{c,d}	20.93 (0.9)^{e}	41.2 (0.6)^{d,e}	71.97 (2.1)^{c,d}
4	60.33 (1.2)^{a,b,c}	20.37 (1.9)^{e}	43.37 (0.3)^{c,d,e}	72.6 (2.7)^{c,d}
5	59.23 (0.7)^{b,c}	22.4 (0.2)^{e}	46.6 (0.6)^{c,d,e}	80.6 (1.6)^{c}
6	63.08 (0.5)^{a,b,c}	43.55 (1.5)^{a,b}	66.65 (1.6)^{a,b}	136.8 (2.0)^{a}
7	60.39 (1.1)^{a,b,c}	32.47 (1.7)^{c,d}	51.4 (1.3)^{c}	99.23 (2.7)^{b}
8	66.57 (0.4)^{a}	37.9 (1.3)^{b,c}	72.93 (3.0)^{a}	128.07 (2.8)^{a}
9	65.0 (0.6)^{a,b}	44.57 (1.3)^{a}	61.17 (3.3)^{b}	125.17 (2.4)^{a}
10	67.13 (0.7)^{a}	30.33 (0.8)^{d}	49.4 (0.4)^{c,d}	95.9 (0.2)^{b}
$\bar{X}$ Domestic	56.76 (0.9)^{a}	20.27 (0.5)^{a}	42.42 (0.7)^{a}	72.46 (1.3)^{a}
$\bar{X}$ Wild	64.53 (0.7)^{b}	37.35 (1.7)^{b}	59.86 (2.7)^{b}	115.62 (4.5)^{b}

EPA, DHA, and *n*-3 HUFA are reported as mg/g dwt of eggs from domesticated (1-5) and wild (6-10) striped bass. Values presented are means (±s.e.) from 3 samples per fish, except fish number 6 which had only two samples

*Different superscript letters within column values denote significant (LSM) difference.

influence production in cultured species or recruitment success in wild populations. For example, it is well known that highly unsaturated fatty acids are largely responsible for membrane fluidity, which is critical during tissue differentiation. They also act as a major energy source in fish larvae (Watanabe, 1982).

Egg size has been shown to be influenced maternally in salmonids (Gall, 1974; Pitman, 1979; Kazakov, 1981; Wallace and Aasjord, 1984; Springate and Bromage, 1985); cod, *Gadus morhua* (Knutsen and Tilseth, 1985); channel catfish, *Ictalurus punctatus*, (Reagan and Conley, 1977); tilapia, *Oreochromis mossambicus* (Rana, 1985); and striped bass, *Morone saxatilis* (Rogers and Westin, 1981; Young and Hoff, 1988; Zastrow et al., 1989). The endogenous energy in eggs and egg viability have also been directly correlated to maternal factors of size and diet and whether the fish is of marine or freshwater origin (Watanabe, 1982; Eldridge et al., 1983; Tocher and Sargent, 1984; Castell and Kean, 1986; Fraser et al., 1988; Ulvund and Grahl-Nielsen, 1988; Zastrow et al., 1989; Monteleone and Houde, 1991; Tuncer and Harrell, 1992; Tuncer et al., 1993). Katoh et al. (1989) found that egg lipids of cultured ayu, *Plecoglossus altivelis*, differed from captured wild specimens with the latter having higher levels of C16:1, C18:3*n*-3, and C20:5.

Striped bass have received considerable attention in the United States from both a management and culture perspective (Woods, 1987; Harrell et al., 1990). Efforts are currently underway to domesticate the species for food fish production (Woods, 1987; Woods et al., 1990, 1992; Woods and Sullivan, 1993). One of the factors affecting the success of the fish's culture in general is delineation of the dietary nutrient requirements, including essential fatty acids, for all life stages of the fish.

In striped bass, the largest component of the egg is lipid which comprises 52-69% on a dry weight basis (Rogers and Westin, 1981; Eldridge et al., 1983; Zastrow et al., 1989). It has also been demonstrated these fish emulate marine species in that they cannot synthesize the needed essential fatty acids *de novo* from shorter-chain fatty acids (Tuncer and Harrell,

1992; Tuncer et al., 1993). Therefore, larvae require dietary supplementation of these nutrients, especially the *n*-3 highly unsaturated fatty acids (*n*-3 HUFA).

The amount of dietary supplementation of *n*-3 HUFA required is apparently dependent on the original maternal contribution to the initial endogenous levels of fatty acids found in the egg (Tuncer and Harrell, 1992). Tuncer et al. (1993) found that pre-feeding (yolksac) larvae from striped bass females taken from a freshwater system (e.g., Coosa River, AL) had about one-half the level of endogenous *n*-3 HUFA found in conspecific fish from an estuarine environment (e.g., Chesapeake Bay, MD [Tuncer and Harrell, 1992]). The inference was that the differences in endogenous levels were the result of differing diets.

We compared fatty acid profiles of eggs taken from mature domestic Chesapeake Bay brood stock fed a commercially available diet with eggs taken from mature Chesapeake Bay striped bass captured on the spawning grounds. The objective of the study was to determine if a commercially available trout diet used in striped bass culture resulted in egg fatty acid profiles approximating those of wild brood stock that had been feeding on natural forage.

2. Materials and methods

Egg procurement

Mature eggs from 10 different striped bass (5 domesticated and 5 wild caught females) were collected from spawning fish during April 1990. Domesticated females were from part of the 1983 year-class stock of the University of Maryland Agricultural Experiment Station Crane Aquaculture Facility, Baltimore, MD, and ranged in size from 5.0 to 6.1 kg. Wild females, 4.8-12.3 kg, were taken from the Choptank River, MD a major tributary of the Chesapeake Bay. Gravid wild females were collected by electrofishing, transported to the University of Maryland Horn Point Environmental Laboratory Aquaculture Facility, Cambridge, MD, and artificially spawned in accordance with Rees and Harrell (1990). Eggs (ca. 7 ml) were immediately placed in glass vials under nitrogen gas to prevent oxidation and frozen at $-20°C$ until analysis.

Fatty acid and statistical analysis

Quantitative estimations of total lipid and fatty acid analyses were expressed as mg/g dry weight of the eggs. Lipids were extracted in accordance with Bligh and Dyer (1959). The lipid residue was weighed for total lipid determination and a subsample was removed for fatty acid analyses. Fatty acids were saponified with 0.5 M NaOH, and esterified with 14% boron trifluoride in methanol (Morrison and Smith, 1964). Quantitative analysis of specific fatty acids was accomplished by the addition of an internal standard (C20:0 free fatty acid) during the initial Bligh and Dyer extraction procedure. Response correction factors were used to calculate the amount of egg fatty acid after a calibration run was conducted with known amounts of 14:0, 16:0, 18:0, 18:2*n*-6, 18:3*n*-3, 20:4*n*-6, 22:0, 24:0, and 22:6*n*-3. Analyses of fatty acid methyl esters were made with a Hewlett Packard 5890A gas chromatograph equipped with flame ionization detector and Supelcowax 10 column (60 m $\times$ 0.75 mm i.d., 1 μm film).

Three replicates of each sample (except fish number 1 of the wild sample in which there was sample material for only 2 replicates) were taken to estimate total lipid content and fatty acid profiles (mg/g dwt). Statistical differences were compared by an analysis of variance (ANOVA) and least squares means (LSM) procedures. Rejection level for all statistical evaluations was set at $\alpha = 0.05$.

3. Results

Total lipid content

The total lipid, EPA (eicosapentaenoic acid 20:5*n*-3), DHA (docosahexaenoic acid 22:6*n*-3), and *n*-3HUFA (≥ 20 carbon fatty acids with 3 or more double bonds) were significantly different between eggs from the two groups of fish (Table 1). All above mentioned characteristics were higher in wild striped bass eggs than in the eggs from domesticated fish fed a commercial diet.

There were also significant differences within each of the two groups (Table 1). With the exception of the EPA levels in the domesticated fish, total lipid, *n*-3HUFA, EPA, and DHA were significantly different among the 5 fish for each group (Table 1). However, the within-group variability for the lipid characteristics did not fluctuate as much for the domesticated fish as it did for the wild fish (Fig. 1, Table 1).

In addition to the *n*-3 HUFA, EPA, and DHA levels being different, the total *n*-3 levels of eggs from the wild fish were also higher than in eggs from the domesticated fish (Table 2). The total *n*-6 levels of the domesticated fish eggs was considerably higher than the levels

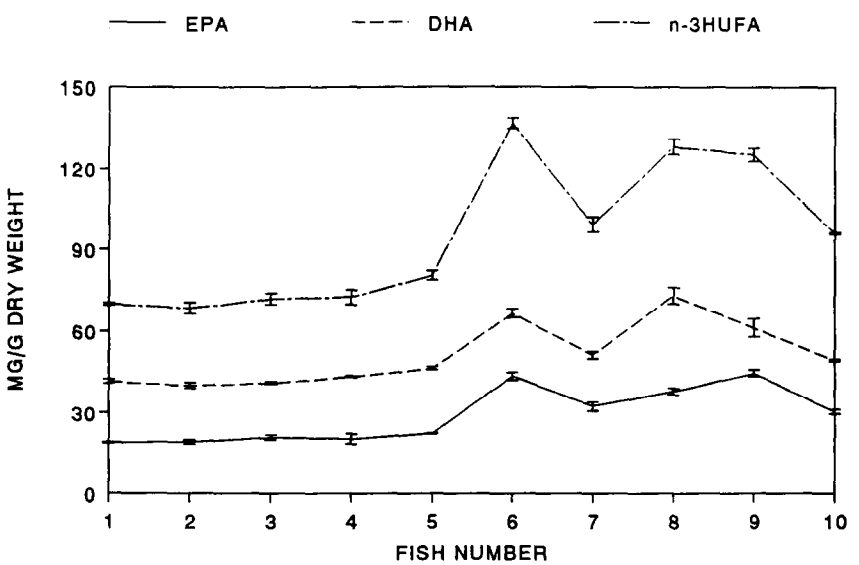

Fig. 1. Mean *n*-3 highly unsaturated fatty acids (HUFA), eicosapentaenoic acid (EPA: 20:5*n*-3), and docosahexaenoic acid (DHA: 22:6*n*-3) of eggs from domesticated (fish 1–5) and wild captured (fish 6–10) striped bass. See Table 1 for replications (mean values are from 3 replicates from each fish).

Table 2
Mean fatty acid profiles (mg/g dwt) of eggs taken from domesticated and wild striped bass

Fatty acid	Feed ($n=2$)	Domestic ($n=14$)	Wild ($n=16$)
14:0	3.5 (0.2)	7.11 (0.45)	10.07 (0.53)
16:0	15.35 (0.65)	23.59 (1.06)	26.11 (1.29)
16:1*n*-7	5.2 (0.3)	36.03 (2.20)	61.04 (2.79)
18:0	3.05 (0.15)	5.45 (0.13)	5.84 (0.46)
18:1*n*-7	12.65 (0.45)	8.2 (0.28)	16.21 (0.62)
18:1*n*-9	2.3 (0.1)	107.22 (4.48)	82.3 (3.84)
18:2*n*-6	16.0 (0.4)	62.28 (2.80)	7.24 (0.52)
18:3*n*-3	1.7 (0.0)	6.46 (0.31)	5.87 (0.19)
18:4*n*-3	1.05 (0.05)	5.13 (0.28)	11.0 (0.58)
20:1*n*-11	1.4 (0.1)	3.64 (0.13)	3.96 (0.27)
20:4*n*-6	0.35 (0.05)	2.73 (0.1)	5.35 (0.29)
20:4*n*-3	0.5 (0.0)	2.43 (0.14)	6.37 (0.45)
20:5*n*-3	7.3 (0.4)	20.27 (0.49)	37.35 (1.65)
22:5*n*-3	1.15 (0.05)	7.04 (0.41)	12.06 (1.13)
22:6*n*-3	4.8 (0.2)	42.42 (0.66)	59.86 (2.66)
n-3 HUFA*	13.76 (0.65)	72.46^{a} (1.29)	115.64^{b} (4.53)
n-3	16.53 (0.75)	84.04^{a} (1.78)	133.01^{b} (3.74)
n-6	16.43 (4.5)	67.18^{b} (2.96)	12.51^{a} (0.57)
n-3/*n*-6	1.01	1.27^{a}	10.99^{b}*

Domestic and wild fish are represented by 5 fish each. The feed column contains the values obtained for the commercial diet analysis. Values presented are means (± s.e.), n = number of replicate analyses performed by group; HUFA = 20 or more carbon fatty acids with at least 3 double bonds; *n*-3 and *n*-6 = mean total *n*-3 and *n*-6 fatty acids, respectively
*Different superscripts in rows denote significant LSM differences.

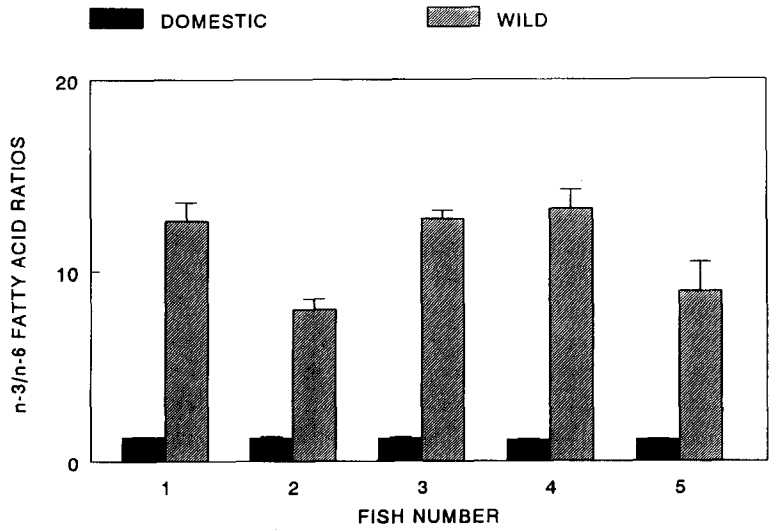

Fig. 2. *n*–3/*n*–6 fatty acid ratios of eggs from domesticated and wild striped bass. Numbers 1–5 with solid bar correspond to fish numbers 1–5 for the domesticated fish and the hatched bar corresponds to the wild fish numbered 6–10. Error bars represent standard error.

in eggs of wild fish (Fig. 2). This difference resulted in an *n*-3/*n*-6 ratio of the domesticated fish being significantly lower than in the wild fish (Table 2). This *n*-3/*n*-6 difference is better demonstrated in Fig. 2 where the magnitude of the difference is more evident.

4. Discussion

It is apparent from our results that the fatty acid profiles of the domesticated striped bass eggs are significantly different from the profiles for eggs from wild captured striped bass. The lower levels of the *n*-3 fatty acids found in eggs of the domesticated fish are a reflection of their dietary intake. The commercial diet contained high levels of corn oil as a major lipid source which contributed to this low *n*-3/*n*-6 ratio (Table 2, Fig. 2). Castell (1982) indicated that a body profile with a high *n*-3/*n*-6 ratio was indicative of a marine species (diet-related) while the converse indicated a dietary intake of more terrestrial origin. Recent research (Tuncer and Harrell, 1992; Tuncer et al., 1993) has demonstrated that larvae from wild striped bass have a high *n*-3/*n*-6 ratio.

In comparative studies on the essential fatty acid requirements of marine and freshwater organisms, Watanabe (1982) recognized that *n*-3 HUFAs, in particular EPA and DHA, were superior to shorter-chain fatty acids (i.e., linoleic [18:2*n*-6] and linolenic [18:3*n*-3] acids) in terms of feed efficiency ratios, survival, and growth enhancement. Because marine species have a limited ability to chain-elongate and desaturate the shorter-chain fatty acids (Owen et al., 1975; Kanazawa et al., 1980; Yamada et al., 1980; Simpson et al., 1982), the beneficial nature of the dietary *n*-3 HUFAs is even more pronounced.

Our findings of high concentrations of *n*-3 HUFA in the lipid of the wild striped bass eggs corroborates the findings of other research (Eldridge et al., 1983; Martin et al., 1984; Tuncer and Harrell, 1992), which is that larval striped bass need *n*-3 HUFAs as essential fatty acids. Webster and Lovell (1990) stated that there was a minimum dietary level of *n*-3 HUFA, in particular EPA, that was needed for striped bass larvae species to survive and grow. Their recommended dietary level of EPA for larvae fed *Artemia* was a minimum of 3% of the lipid source or 0.5% on a dry matter basis. Comparing the egg endogenous fatty acid profiles to those recommended for dietary levels on a percent dry matter basis, the mean percentages of EPA of the domesticated fish was 2.03% (3.57% of the lipid source), while that of the wild fish was 3.74% (5.7% of the lipid source). Although the wild fish had almost twice the levels of EPA that the domesticated fish had, the latter still had 4 times the minimal level of endogenous EPA recommended by Webster and Lovell (1990).

Striped bass survive on endogenous yolk for the first 5 days of life. We did not measure the EPA levels of larvae at first feeding. For comparative purposes, however, Tuncer et al. (1993) found that the EPA/total fatty acid level in 4-day-old larvae from wild female striped bass was 3% and by 9-day-old (4 days of feeding on *Artemia*) the level dropped to 2%. They did not report the EPA/total fatty acid levels for the eggs.

The higher levels of short-chain fatty acids found in the eggs of fish fed the commercial diet are reflective of the corn and soy oils normally found in these diets as lipid sources, which apparently do not provide as large a contribution of *n*-3 HUFAs to the eggs of striped bass as do natural diets. However, even with the high levels of terrestrially based lipids there appears to be sufficient levels of fish oils included in commercial diets to meet the

metabolic and physiological needs of developing larvae, at least to transition to the exogenous feeding stage.

Even though larvae from domesticated parental stock fed commercial diets appear to suffer no adverse affects from hatch until exogenous feeding begins, we cannot conclude that the commercial diets provide adequate levels for the long-term survival and growth of the fry. Neither can we conclude that the trout diets used in this study meet the nutritional needs of the brood fish. However, fecundity of domesticated fish is similar to that of wild fish; approximately 200 000 eggs/kg (Woods, unpublished data). Whether the lower levels of *n*-3 HUFA adversely impact the long-term survival or growth rate of larvae was not tested in this study and requires further investigation.

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