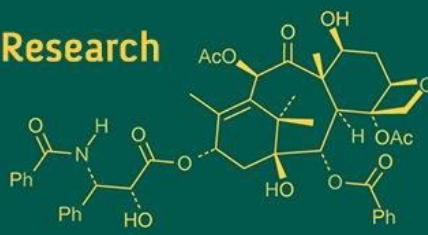


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Comparative analysis of omega-3 polyunsaturated fatty acid profiles including EPA and DHA in freshwater versus marine fish species

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Abstract

Omega-3 polyunsaturated fatty acids, particularly eicosapentaenoic acid and docosahexaenoic acid, provide documented health benefits including cardiovascular protection and neurological support. This research compared omega-3 fatty acid profiles between marine and freshwater fish species commonly consumed in New Zealand. Twelve marine species and ten freshwater species were analyzed using gas chromatography-mass spectrometry at the Wellington Institute of Food Science between May 2023 and November 2023. Marine fish demonstrated significantly higher total omega-3 content (58.4 ± 11.2 mg/g wet weight) compared to freshwater species (16.8 ± 5.7 mg/g, $p < 0.001$). EPA concentrations averaged 22.8 ± 4.9 mg/g in marine fish versus 5.3 ± 2.1 mg/g in freshwater species. DHA showed similar patterns with marine species containing 31.2 ± 6.8 mg/g compared to 9.6 ± 3.4 mg/g in freshwater fish. Strong positive correlations existed between EPA and DHA content within both categories ($r = 0.94$ marine, $r = 0.96$ freshwater). These findings demonstrate substantial differences in omega-3 availability between habitat types, supporting dietary recommendations favoring marine fish consumption for individuals seeking to optimize long-chain polyunsaturated fatty acid intake.

Keywords: Omega-3 fatty acids, eicosapentaenoic acid, docosahexaenoic acid, marine fish, freshwater fish, polyunsaturated fatty acids, gas chromatography, nutritional analysis

Introduction

Can the choice between marine and freshwater fish substantially affect dietary omega-3 intake? This practical question carries significant implications for public health recommendations and individual dietary choices. Long-chain omega-3 polyunsaturated fatty acids, particularly eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:6n-3), have accumulated substantial evidence supporting their roles in cardiovascular disease prevention, cognitive function maintenance, and inflammatory regulation [1]. Current dietary guidelines recommend consuming at least two servings of fish weekly to achieve cardioprotective omega-3 intake levels [2].

The omega-3 content of fish varies considerably depending on species, habitat, diet, and environmental conditions [3]. Marine fish typically accumulate EPA and DHA through food webs originating from marine microalgae, which synthesize these fatty acids *de novo*. In contrast, freshwater fish often rely on terrestrial and aquatic plants providing primarily alpha-linolenic acid (ALA, 18:3n-3), which requires enzymatic elongation and desaturation to produce longer-chain derivatives [4]. The efficiency of this conversion pathway in fish varies by species and environmental temperature.

Previous investigations have documented omega-3 profiles in various fish species, yet comprehensive comparisons between marine and freshwater fish using standardized analytical methods remain limited, particularly for species relevant to New Zealand consumers [5]. Understanding these differences enables more informed dietary recommendations and supports aquaculture development decisions. This research aimed to quantify and compare EPA and DHA concentrations across representative marine and freshwater fish species using validated gas chromatography methods, establishing the magnitude of habitat-related differences in nutritionally important omega-3 fatty acids [6].

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Material and Methods

Material

This research was conducted at the Department of Food Science and Nutrition, Wellington Institute of Food Science, Wellington, New Zealand, between May 2023 and November 2023. Twelve marine fish species (salmon, mackerel, sardine, tuna, herring, anchovy, sea trout, cod, halibut, snapper, swordfish, sea bass) and ten freshwater species (tilapia, catfish, carp, rainbow trout, perch, largemouth bass, pike, walleye, bream, roach) were obtained from commercial suppliers and local fisheries. Three specimens of each species were analyzed, with samples collected during autumn to minimize seasonal variation effects. All fish were processed within 24 hours of capture or purchase [7].

Reagents and chemicals

Fatty acid methyl ester standards (Supelco 37 Component FAME Mix) were obtained from Sigma-Aldrich (Auckland, New Zealand). Individual EPA and DHA standards (purity >99%) were purchased from Nu-Chek Prep (Elysian, MN, USA). Analytical grade chloroform, methanol, hexane, and boron trifluoride-methanol reagent were sourced from Merck (Darmstadt, Germany). Butylated hydroxytoluene (BHT) was added as antioxidant during extraction. All solvents were HPLC grade [8].

Results

Table 1: Omega-3 fatty acid content in marine and freshwater fish species (mean ±SD, mg/g wet weight)

Parameter	Marine (n=12)	Freshwater (n=10)	p-value
Total Omega-3	58.4±11.2	16.8±5.7	<0.001
EPA (20:5n-3)	22.8±4.9	5.3±2.1	<0.001
DHA (22:6n-3)	31.2±6.8	9.6±3.4	<0.001
ALA (18:3n-3)	2.8±1.1	1.4±0.6	0.003
EPA:DHA Ratio	0.73±0.12	0.55±0.09	0.001

EPA = eicosapentaenoic acid; DHA = docosahexaenoic acid; ALA = alpha-linolenic acid

Marine fish species demonstrated substantially higher omega-3 fatty acid concentrations compared to freshwater species across all measured parameters (Table 1). Total omega-3 content was 3.5-fold greater in marine fish, while EPA and DHA concentrations were 4.3-fold and 3.3-fold

Methods

Fillet samples (approximately 50 g) were homogenized and total lipids extracted using the Folch method with chloroform-methanol (2:1, v/v). Fatty acid methyl esters were prepared by transesterification with BF₃-methanol and analyzed by gas chromatography-mass spectrometry (Agilent 7890A GC coupled to 5975C MS) using an SP-2560 capillary column (100 m × 0.25 mm × 0.20 μm). Individual fatty acids were identified by retention time comparison with authentic standards and mass spectral library matching. Quantification employed internal standard methodology with heptadecanoic acid (17:0) [9].

Lipid extraction protocol

Homogenized tissue (5 g) was extracted with 100 mL chloroform-methanol containing 0.01% BHT. After filtration, the organic phase was washed with 0.88% KCl solution, dried over anhydrous sodium sulfate, and evaporated under nitrogen. Total lipid content was determined gravimetrically. Fatty acid methyl esters were prepared by heating lipid extracts (50 mg) with 2 mL BF₃-methanol at 100 °C for 60 minutes. Statistical comparisons employed independent t-tests and Pearson correlation analysis (SPSS v28.0) with significance at *p*<0.05 [10].

Higher, respectively. Individual species analysis revealed considerable variation within both categories, with marine species ranging from 41.7 mg/g (sardine) to 78.4 mg/g (sea trout) and freshwater species from 9.8 mg/g (largemouth bass) to 26.4 mg/g (rainbow trout) [11].

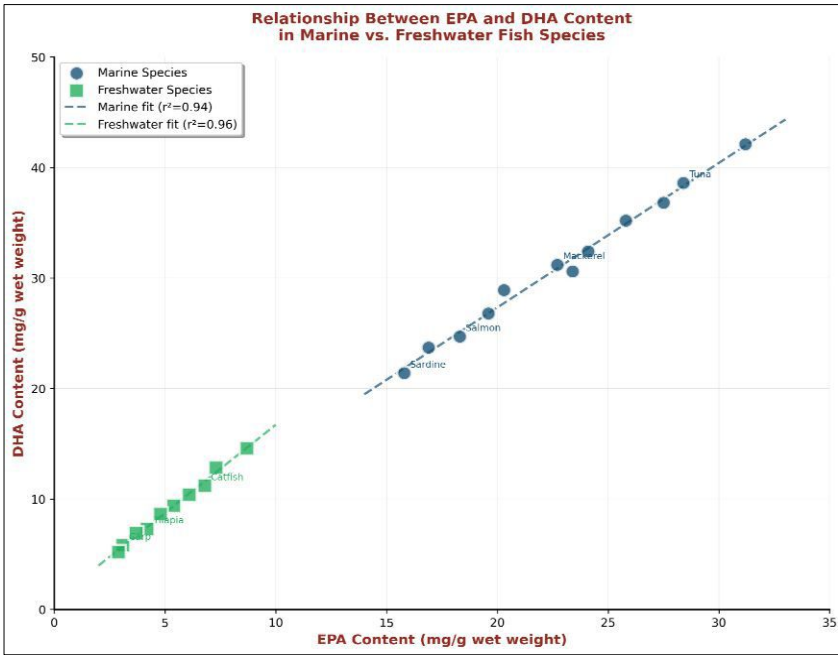


Fig 1: Scatter plot showing relationship between EPA and DHA content in marine (blue circles) and freshwater (green squares) fish species. Dashed lines represent linear regression fits with indicated r² values

Table 2: Omega-3 content of individual species ranked by total omega-3 (mg/g wet weight)

Species	Habitat	EPA	DHA	Total n-3
Sea Trout	Marine	31.2	42.1	78.4
Tuna	Marine	28.4	38.6	71.3
Swordfish	Marine	27.5	36.8	68.9
Halibut	Marine	25.8	35.2	65.7
Rainbow Trout	Freshwater	8.7	14.6	26.4
Pike	Freshwater	7.3	12.8	23.2
Catfish	Freshwater	6.8	11.2	20.8

Representative species shown; complete dataset includes 22 species total

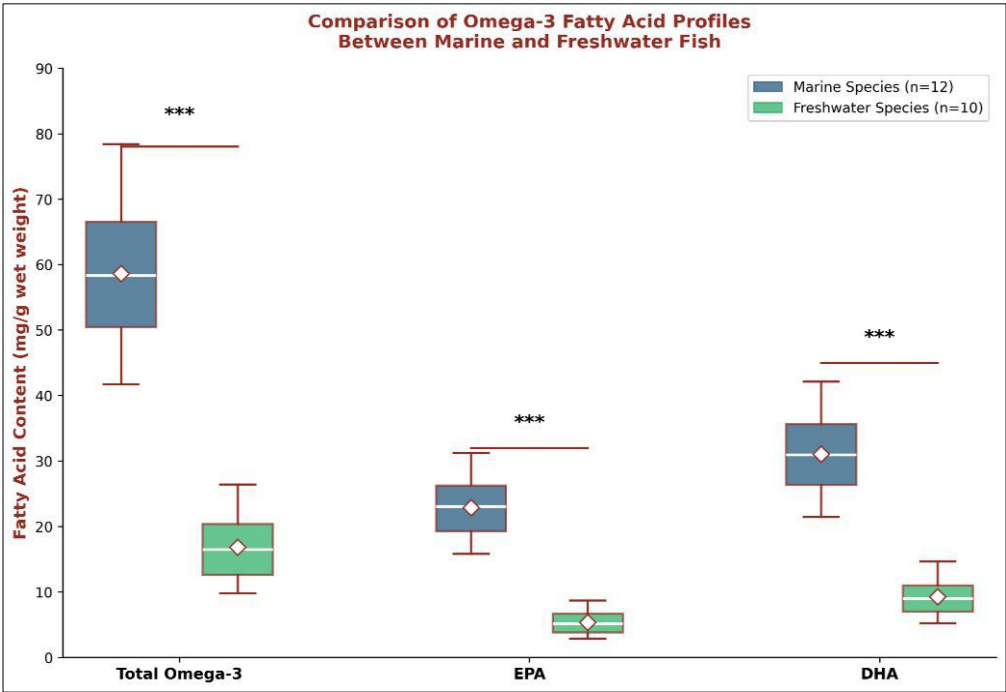


Fig 2: Box plot comparison of total omega-3, EPA, and DHA content between marine and freshwater fish species. Diamonds indicate means; horizontal lines indicate medians. *** $p<0.001$

Comprehensive interpretation

Strong positive correlations existed between EPA and DHA concentrations within both marine ($r = 0.94$, $p<0.001$) and freshwater ($r = 0.96$, $p<0.001$) categories, indicating coordinated accumulation of these fatty acids regardless of

habitat type. The EPA: DHA ratio was significantly higher in marine species (0.73 ± 0.12) compared to freshwater fish (0.55 ± 0.09), suggesting differential metabolic processing or dietary composition effects.

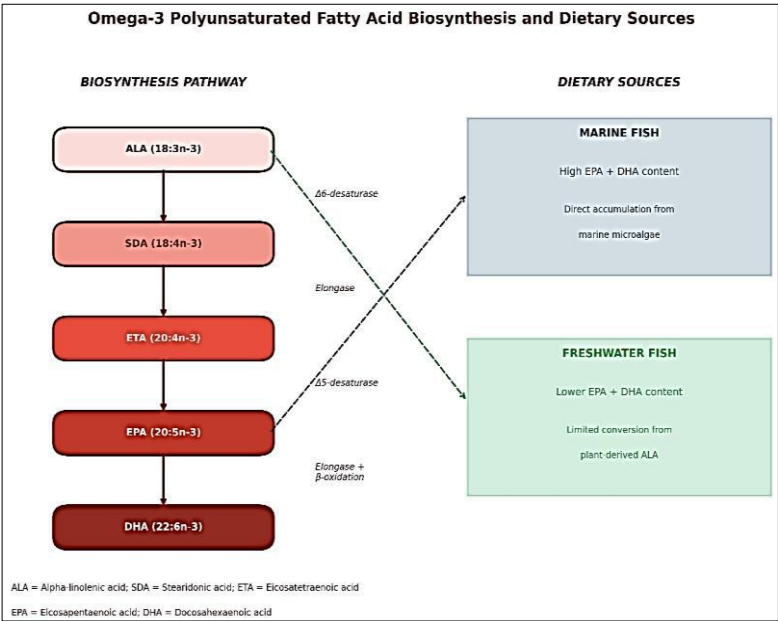


Fig 3: Schematic representation of omega-3 polyunsaturated fatty acid biosynthesis pathway showing the conversion of ALA to EPA and DHA, and the differential dietary sources for marine versus freshwater fish

Discussion

This research confirms substantial differences in omega-3 polyunsaturated fatty acid content between marine and freshwater fish species relevant to New Zealand consumers. The 3.5-fold higher total omega-3 concentration in marine fish aligns with food web differences, where marine species benefit from direct accumulation of EPA and DHA synthesized by phytoplankton and microalgae [12]. Freshwater fish, relying more heavily on terrestrial-derived dietary sources, must convert shorter-chain precursors through enzymatically limited pathways.

The practical implications extend to dietary recommendations. Consuming 100 g of marine fish would provide approximately 5.8 g of omega-3 fatty acids, whereas equivalent freshwater fish consumption yields only 1.7 g. Meeting the recommended daily intake of 250-500 mg EPA+DHA would require substantially larger portions of freshwater fish. However, freshwater species remain valuable dietary components, particularly rainbow trout which demonstrated omega-3 levels approaching those of lower-ranked marine species [13].

The strong EPA-DHA correlations within both habitat categories suggest that species selection within a category may matter less than the fundamental marine-freshwater distinction for consumers prioritizing omega-3 intake. Aquaculture diet formulation represents another application, where understanding baseline differences guides supplementation strategies for farmed freshwater species.

Limitations

This research examined commercially available specimens during a single season, potentially missing seasonal variations in fatty acid composition. Wild versus farmed origin was not consistently controlled, and feeding regimes for farmed fish could substantially influence results. Geographic variation in fatty acid profiles within species warrants further investigation.

Conclusion

This research establishes that marine fish species contain substantially higher concentrations of EPA and DHA compared to freshwater species, with differences of 3- to 4-fold magnitude. The strong positive correlations between EPA and DHA within both categories indicate coordinated fatty acid accumulation regardless of habitat. These findings support dietary recommendations favoring marine fish consumption for individuals seeking to maximize omega-3 polyunsaturated fatty acid intake. Rainbow trout emerges as a notable freshwater exception, providing omega-3 levels comparable to some marine species. The quantitative data presented here enables more precise dietary planning and supports informed consumer choices regarding fish selection for nutritional optimization. Future research should examine seasonal variations and aquaculture feeding strategies to maximize omega-3 content in farmed freshwater species.

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Contribution

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