

## Letter

Aquatic Predators  
Influence Micronutrients:  
Important but  
Understudied

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In a recent paper on ecosystem function and services of aquatic predators in the Anthropocene [1], Hammerschlag and colleagues highlight a set of 16 outstanding research needs, including strengthening our understanding of the mechanisms and extent to which aquatic predators influence micronutrient and trace element fluxes within ecosystems. Závorka *et al.* [2] persuasively point out that within the realm of micronutrients, there is strong evidence that aquatic predators play a central role in the transfer of essential fatty acids (EFAs) such as docosahexaenoic acid (DHA, 22:6 $\omega$ 3) and eicosapentaenoic acid (EPA, 20:5 $\omega$ 3) in food webs, and that EFAs are vitally important neurologically for many consumers including humans. We agree that EFAs are an exciting and significant area of research, and we embrace their suggestion to extend the social and ecological framework presented in [1] to incorporate what is known about fluxes of EFAs as micronutrients.

EFAs have been studied in aquatic systems from a variety of perspectives [3]. Linkages between photoautotrophs and lower trophic levels have been studied for some time [4], and recent work on egg-rafts in the ocean provide a fascinating mechanism for satisfying EFA demands of some consumers [5]. Future EFA research can increase its impact on research across ecological subdisciplines by including a broader set of taxa within aquatic systems and

by moving beyond the water's edge to examine linkages between aquatic and terrestrial systems. Moreover, most experimental studies evaluating EFA limitation on consumer growth and productivity have been conducted in laboratory settings, and ecologists should work to link analogous effects on organism performance in nature, with studies that quantify natural EFA sources and fluxes. For example, recent work by Twining and colleagues [6,7] on aquatic sources of EFAs as food web subsidies for riparian bird species illustrates some of the exciting insights as well as the challenges of thoroughly understanding complex interactions involving EFAs and aquatic predators. Through integrated laboratory and field studies based on bulk and compound-specific isotope analyses, this work demonstrated how EFA sources for tree swallows (*Tachycineta bicolor*) and Eastern phoebes (*Sayornis phoebe*) originate from aquatic primary producers, with emerging aquatic insects enriched in EFAs serving as micronutrient conveyor belts to riparian consumers [6,7]. Moreover, controlled diet experiments revealed that chick growth rate and condition were substantially improved when diets were supplemented by EFAs [6], and extensive field observations over a 24-year period suggested that EFA-rich aquatic insects are fundamental to bird population success [7].

Even with recent progress in EFA studies, micronutrients remain highly understudied in food webs, and our knowledge about interactions involving many key elements, including predator effects, is woefully inadequate, despite their importance as vital building blocks for life [8,9]. Fatty acids are just one of many physiologically important and potentially limiting organic compounds, including amino acids, sterols, and vitamins, that remain understudied in natural ecosystems. For example, thiamine (vitamin B<sub>1</sub>) deficiency is also known to impair neurological function, which can result in high mortality of early life stages in fishes [10], and has been hypothesized as a driver

of extirpation of some predators [11]. Nevertheless, there are still remarkably large knowledge gaps about thiamine in ecosystems, starting with the range of natural concentrations found in most natural waters, thiamine requirements of aquatic predators from wild populations, especially those found high in food chains, and how thiamine deficiency can affect predator secondary production [12].

Závorka *et al.* [2] correctly emphasize how the decline of predators in aquatic food webs has critical implications for human health through the loss of vital sources of micronutrients such as EFAs. Indeed, aquatic predators represent a key provisioning ecosystem service via linkages with human nutrition, which serves as a major rationale as to why further research aimed at elucidating mechanisms and extent to which aquatic predators influence micronutrients and trace element fluxes within ecosystems is an urgent priority [1].

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