Lake Food Webs – Fact Sheet

Linking lake restoration with end users for positive environmental outcomes

Lake Ecosystem Research New Zealand

Food Webs

The classic "food chain" concept describes trophic feeding relationships in simple terms, where organism 'A' is fed on by organism 'B' which in turn sustains organism 'C' (Figure 1). This approach, however, does not capture the complex inter-relationships among organisms. This is where analyses of food webs are important – they can be used to resolve the interactions between different trophic levels, such as producers like algae and various levels of consumers like aquatic invertebrates and fish (e.g., Figure 2). In other words, food webs describe the often complex inter-connected food chains operating within ecosystems.

Food-web structure can be driven by 'bottom-up control' where the supply of resources regulates energy flow (e.g., algae responding to nutrient enrichment), or through 'top-down control' where predation releases resources from consumer control. For example, fish preying on large zooplankton which feed on phytoplankton can lead to algal blooms due to loss of grazer control (the classic 'trophic cascade' in Figure 1). Other organisms may consume resources but grow too quickly to be significant prey leading to 'trophic dead-ends', while other species may display 'trophic overlap' indicating the potential for competition if resources are limiting. In some cases, 'trophic bottlenecks' may occur where certain life-stages of multiple, co-occurring species require the same limited resource at the same time.

Energy flow through food webs is commonly resolved through (i) the analysis of gut contents which provide insights into what has recently been ingested, and (ii) analyses of naturally-occurring stable isotopes, such as $\delta^{13}C$ and $\delta^{15}N$, which move predictably through food webs. Analyses of these isotopes can give an indication of basal resources supporting nutrition (e.g., relative importance of algae versus terrestrial organic matter), dietary items assimilated into tissue over time, and the trophic position of species within a food web (e.g., primary, secondary or tertiary consumer).

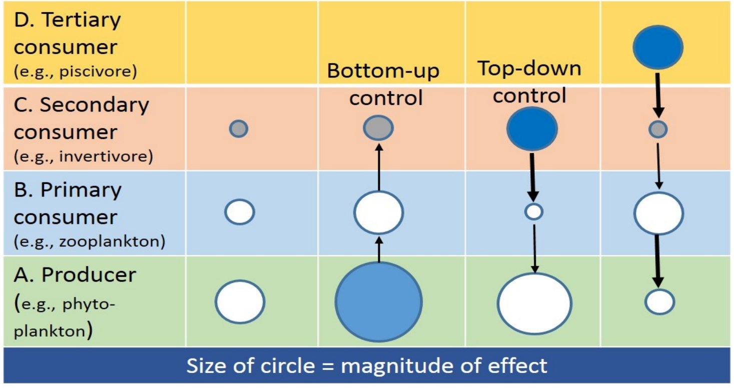

Figure 1. Schematic showing the influences of different controls on the magnitude of energy flow in lake food webs.

Research Questions

Recent developments have advanced our ability to understand human pressures on food webs by enabling (i) species compositions of ingested food items to be resolved more efficiently and accurately through DNA analyses, (ii) complex pathways of energy flow to be quantified through the use of Bayesian mixing models, and (iii) the structure of food webs to be described using metrics derived from stable isotope values.

LERNZ has applied these recent advances to resolve fundamental questions relating to energy flow and species interactions within New Zealand lakes. This work has involved the analysis of a national scale stable isotope dataset for lakes, and targeted studies of lakes with different invasive fish assemblages, including lowland shallow lakes in the Waikato and Wellington regions and high-country lakes in Canterbury. Key questions being asked include:

- How does food web structure and energy flow in lakes change in relation to human pressure?
- What effect does eutrophication have on basal resource supply and quality in contrasting lakes?
- What effects do non-native species have on native species through trophic interactions?
- Do food webs in different lake types respond differently to land-use pressure and species invasions?

Lake Food Webs – Fact Sheet Continued

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Key Findings

Analysis of 18 shallow, lowland lakes has shown that nutrient enrichment can have both positive and negative effects on lake food webs. At lower levels of enrichment, food-web niche-space occupied by consumers can increase through the enhancement of pelagic productivity (zooplankton and mid-water column predators), whereas at higher levels of nutrient enrichment benthic food-web pathways become diminished, particularly in lakes where macrophyte community loss has occurred. Overall, food webs in lakes that have experienced macrophyte loss had shorter food chain lengths and lower complexity compared with unenriched or moderately-enriched lakes.

Studies of two contrasting shallow Ashburton lakes showed that macrophyte loss was associated with drastically changed energy pathways supporting the lake food web, likely due to the loss in epiphytic algae associated with macrophytes. Bullies showed more consistent and generalised diets in the lake that experienced macrophyte collapse, leading to increased competition among consumers and likely reducing food-web resilience to further perturbations.

Analysis of basal resource supply in Waikato shallow lakes has highlighted that eutrophication is associated with increased levels of high quality, pelagic food dominated by phytoplankton and zooplankton (seston) that is of higher nutritional value than benthic organic matter derived from terrestrial and marginal vegetation. Larvae of several species of invasive fish that breed in lakes feed on pelagic seston, suggesting that this abundant and high quality food source driven by nutrient enrichment could reduce lake resilience to invasive fish proliferation through bottom-up effects.

Analyses of trophic overlap between brown bullhead catfish and eels in Waikato shallow lakes has highlighted the potential for a trophic bottleneck to occur among intermediate-sized fish which occupy similar trophic positions and utilise similar sources of nutrition. However, a broad trophic niche occupied by eels in some lakes may provide resilience to the effects of overlapping consumption patterns.

Key Findings continued

Sampling of Lake Taupō demonstrated that common smelt, a primarily pelagic fish that is the main food resource sustaining the rainbow trout fishery, switched to consuming predominantly littoral resources when pelagic food supplies (i.e., zooplankton) were low. In deep lakes where littoral habitat is limited and pelagic fish form a large proportion of the biomass, this seasonal diet switching could have significant top-down impacts on littoral food webs, highlighting the importance of considering littoral zones in restoration of deep lakes.

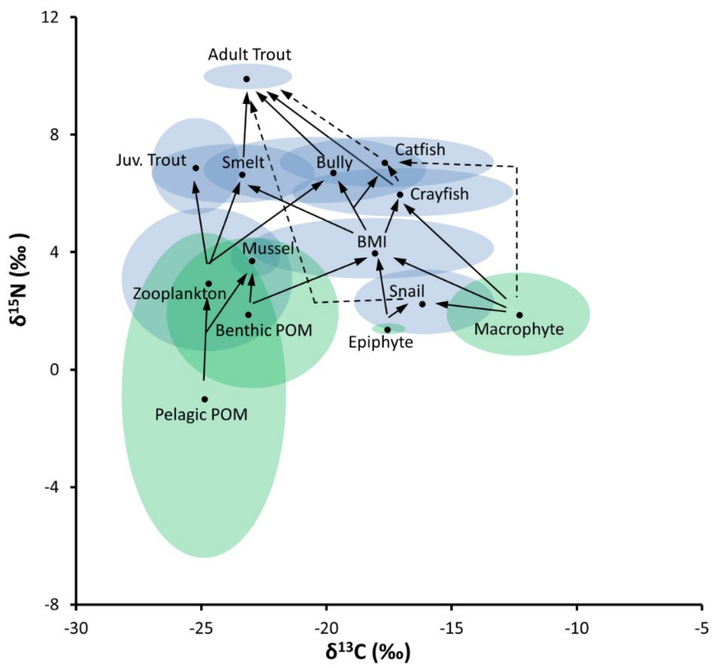

Figure 2. Stable isotope bi-plot showing trophic ranges and pathways leading to fish nutrition in Lake Taupō (see Stewart et al. 2017)

Recent Publications

Collier KJ, Garrett-Walker J, Özkundakci, D, Pingram MA. (2018). Characteristics of consumer trophic resources for Waikato shallow lake food webs. New Zealand Journal of Marine and Freshwater Research doi.org/10.1080/00288330.2018.1517098

Collier KJ, Pingram MA, Francis L, Garrett-Walker J, Melchior M. (2018). Trophic overlap between non-native brown bullhead (*Ameiurus nebulosus*) and native shortfin eel (*Anguilla australis*) in shallow lakes. Ecology of Freshwater Fish 27: 888-897.

Stewart SD, Hamilton DP, Baisden WT, Verburg P. (2017). Variable littoral-pelagic coupling as a food-web response to seasonal changes in pelagic primary production. Freshwater Biology 62: 2008–2025.