Food web resilience in Lake Taupō: responses to prolonged stratification and implications of climate warming

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Lake ecosystems are strongly seasonally influenced, generating large fluctuation in resource supply. Deep oligotrophic New Zealand lakes stratify in warm seasons; nutrients accumulate in bottom waters while primary productivity in surface waters eventually declines as nutrient limitation increases. Surface water cooling during winter then engenders mixing of the entire water column, re-introducing bottom-water nutrients into the euphotic zone and stimulates primary production when light permits. Food web responses to this seasonal pattern are complex. Small zooplankton grazers, which have short life-cycles and can undergo diapause, respond rapidly to changes in productivity. However little is known about the response of fish, which are relatively long-lived and large. Fish can switch to littoral-based (near-shore) resources; an alternative expected to be critical for their resilience to seasonal and long-term climatic changes. Lake Taupō, a deep oligotrophic lake supporting a significant rainbow trout fishery, presents an ideal case study for examining food web responses to stratification. We quantified two responses to stratification: firstly, the degree of surface water nutrient-recycling; secondly, resource switching to littoral resources by fish. Stable isotope data indicated that during stratification, phytoplankton (while reduced in biomass relative to mixing periods) was sustained mostly by nutrient-recycling within surface waters. Although phytoplankton-based resources were the major component of fish diet, littoral-based resources were increasingly important during stratification (> 40% of fish diet). Climate change is expected to prolong lake stratification. While this might increase hypoxia and sediment nutrient release, exacerbating eutrophication in many lakes, for Lake Taupō and similar deep oligotrophic lakes, it may extend periods of low productivity. Our results suggest that littoral habitats could become increasingly important in maintaining resilience in the presence of climate-driven prolonged stratification. Restoration of littoral habitats is often overlooked in management of large lakes yet may be important for lake food web resilience to climate change.