Invasive Fish and Nutrients – Fact Sheet

Linking lake restoration with end users for positive environmental outcomes

LERNZ
Lake Ecosystem Restoration New Zealand

Koi Carp and Nutrients in Lakes

Invasive fish such as koi (or common) carp (*Cyprinus carpio*) are large fish as adults (typically 1–3 kg) and can exist at high biomass (commonly 1000–2000 kg/ha). Because of their large size, high biomass, and suctorial feeding behaviour that disturbs the lake bed, koi carp have the potential to contribute a significant amount of plant nutrients (nitrogen (N) and phosphorus (P)) to lake waters. To estimate the potential of koi carp to inhibit lake restoration, we estimated the rates of excretion relative to other processes contributing nutrients to lakes.

Figure 1. A. Dai Morgan (left) and Brennan Mahoney preparing to sample water for nutrients. B. A koi carp incubating in a fish bin.

Nutrient Measurement

We devised experiments to measure nutrient excretion rates by koi carp directly. In this method, fish were captured by boat electrofishing and immediately transferred to tanks where the water had been pre-filtered to remove algae. Changes in nutrient concentrations (ammonia, phosphate, total N and total P) were measured before and after introducing the fish (Figure 1).

Body Mass and Temperature

Excretion rates are expected to increase with increasing water temperature and fish mass. Knowing the strength and slope of these relationships is important for their use in ecological models. Experiments with koi carp of different sizes at two water temperatures showed consistent increases in nutrient excretion rates with increasing fish mass and water temperatures (Figure 2). We combined the results from different temperatures to make a single temperature- and mass-dependent model for each nutrient. These models can be used to determine the relative contribution of in-lake nutrient cycling by koi carp and to predict the effects of koi carp control measures on water quality (Figure 3).

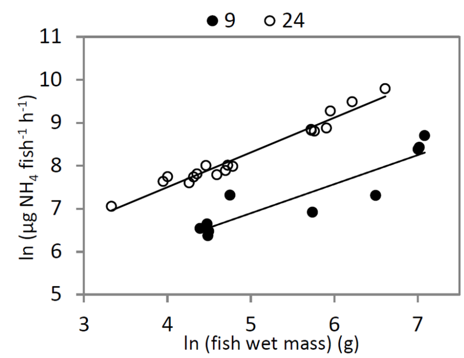


Figure 2. Whole-body ammonia (NH_4) excretion rates for koi carp incubated at 9 and 24°C.

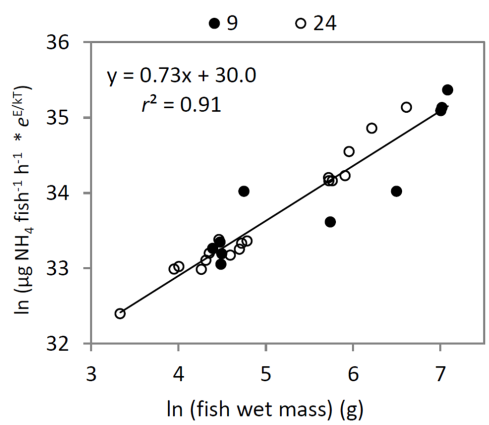


Figure 3. Temperature-corrected whole-body NH_4 excretion rates for koi carp incubated at 9 and 24°C.

Modelling Nutrient Dynamics

Lake Ohinewai is a shallow, hypertrophic riverine Waikato lake (surface area 16.9 ha, catchment area 331 ha, maximum depth 4.5 m) that has been the subject of a koi carp removal experiment. Our study showed that koi carp excrete N and P primarily in soluble forms, which can create algal blooms.

Using the excretion rates from Morgan and Hicks (2013) we calculated the nutrient contributions from the original biomass of koi carp (374 kg/ha). We also modelled external nutrient loads using the catchment model INCA (Integrated Catchment Model, www.reading.ac.uk/).

Internal loads were modelled with DYRESM/CAEDYM (DYnamic REservoir Simulation Model - Computational Aquatic Ecosystem DYnamics Model, University of Western Australia), and water temperature was simulated hydrodynamically with DYRESM. Sediment resuspension rates were estimated from published information on koi carp. It was estimated that at a biomass of 374 kg/ha, for instance, koi carp in Lake Ohinewai can suspend 14.5 tonnes of sediment per day. We also included a term in the model for translocation, which is the release of nutrients in sediment pore water by koi carp feeding activity.

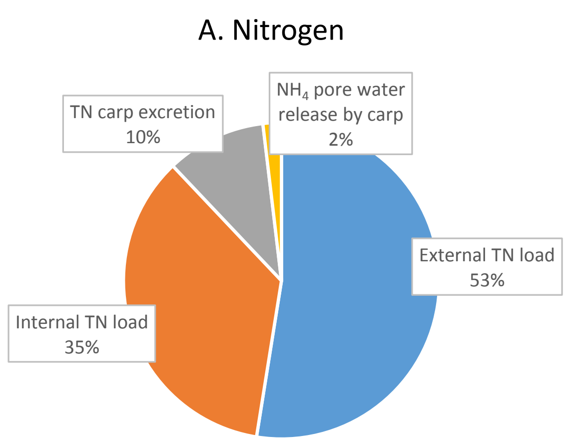
Scenarios

Using our excretion models, we investigated seven alternative scenarios for carp removal, warming temperatures, and catchment restoration. Before our koi carp removal efforts, carp contributed about 10% of the total annual budget of N (Figure 4A) and about 25% of the total annual budget of P (Figure 4B). Translocation of pore water was a significant source of N, but not P.

Although koi carp removal was predicted to decrease suspended sediment concentration by about two thirds, the accompanying nutrient reduction would be insufficient to initiate a return the lake to a stable, clear-water state. When combined with catchment restoration, e.g., 10-m stream riparian buffers or 2.5% of the catchment converted into wetland, koi carp removal was predicted to significantly improve water clarity to the point where macrophytes would re-establish and the lakes would return to a stable, clear-water state. These model results indicate that integrated catchment management coupled with invasive fish management are required to improve lake health.

Reference

Morgan DKJ, Hicks BJ 2013. A metabolic theory of ecology applied to temperature and mass-dependence of N and P excretion by common carp. *Hydrobiologia 705*: 135-145.



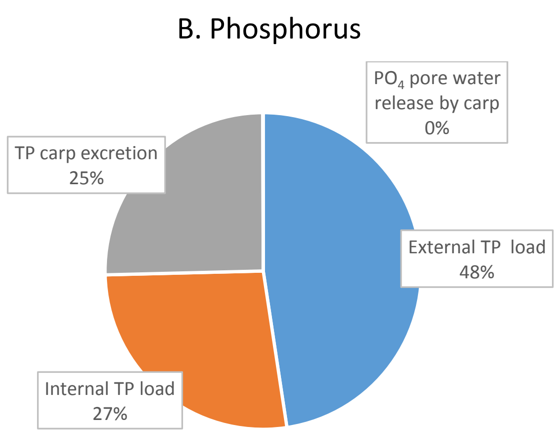


Figure 4. Modelled total A. nitrogen and B. phosphorus contributed to Lake Ohinewai by koi carp at a biomass of 374 kg/ha compared to external (catchment) and other internal (in-lake) nutrient sources.