Characterization of food webs in limestone springs using stable isotopes

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ABSTRACT
Limestone springs of Pennsylvania support productive ecosystems and fisheries. Autochthonous primary production is dominated by amphibians in less impaired springs, and isopods in more impaired springs. In less impaired springs, vertebrates at higher trophic levels are abundant, with dominants including slimy sculpin, wild trout, herons, and egrets. The objective of this study was to characterize food webs in springs of varied impairment and stocking status using stable isotopes of C, N, and S. Near active state fish hatcheries or after stocking of trout, isopods and herons relied strongly on C from hatchery waste or fish (δ13C near -21‰). Amphipods and wild fish in Big Spring following hatchery closure ranged from -35 and -40‰, δ13C, more depleted than vascular C3 photosynthetic plants, indicating >50% reliance on non-vascular plants or algae (δ13C -37 to -49‰), δ15N in these ecosystem components is being investigated along with δ13C to trace marine organic subsidies (via hatchery material) to the springs. Hatchery effluent may be utilized, via sediment, by pollution tolerant isopods that dominate under impaired conditions. Stocking or raising trout results in opportunistic foraging by predatory birds on raised fish, that may be traced by stable isotopes, but herons rely primarily on wild fish where available. Shading of springs by riparian plantings could reduce autochthonous primary and secondary production in less impaired spring foodwebs, although allisochthonous C from riparian litter of lesser quality could be utilized by invertebrates given adequate water quality.

METHODS
Potential C sources (algae, mosses, vascular plants, and hatchery feed, fish and effluent sediment), along with dominant invertebrates, fish, and heron guano were collected on three limestone spring or spring-influenced streams of Cumberland County, Pennsylvania between 2001 and 2006. Following freezing, drying, and homogenization with mortar and pestle, Samples were analyzed for natural abundance 13C and 15N, and %C and %N at Cornell Boyce Thompson Stable Isotope Laboratory (European Scientific GEO 29-20 isotope ratio mass spectrometer, European Scientific ANCA SL solid-liquid elemental analyzer). Where appropriate, a two-endmember mixing analysis utilizing δ13C was utilized to estimate diet contributions to consumers (hatchery waste to isopods, stocked fish to herons, and non-vascular plants to amphipods in Big Spring four years after hatchery closure), where:

\[ \%C_{\text{source}} = \frac{C_{\text{source}} - C_{\text{mix}}}{C_{\text{source}} - C_{\text{endmember}}} \times 100 \]

δ13C Source 2 - δ13C Source 1

Parametric one-way ANOVA and Tukey’s studentized range test was used to compare individual means for each stream across sample dates by organic matter type using Statistical Analysis System (SAS).

RESULTS

CONCLUSIONS
- Hatchery C is most enriched in δ13C, and a bi-variate plot of δ13C and δ15N showed sediment C enriched by hatcheries on all three streams, even after closure at Big Spring.
- Three distinct C sources may occur on spring creeks receiving hatchery effluent, precluding broad use of a simple 2-endmember, single tracer mixing analysis to determine hatchery contribution to invertebrates and sediments.
- On the Yellow breeches where algae and vascular plants were similar in δ13C, a 2-endmember model estimated 40-70% contribution of hatchery C to isopod diet.
- Heron Guano collected at the Yellow Breeches near Huntsdale hatchery indicated a heavy reliance on stocked fish by herons.
- Herons were less dependant on hatchery fish at Big Spring (26%), although individual sample units had δ13C near -20 on earlier sampling dates following stockings. This result is consistent with Hodgens et al. (2004).
- Tracing hatchery C with stable isotopes may provide useful prediction of bioaccumulated, marine-based contaminants associated with hatcheries (Carlene and Barry 2003; Embeck 2000).
- Four years after hatchery closure on Big Spring, dominant amphipods relied primarily on non-vascular, autochthonous production (67%), and are important links to higher trophic levels. This result suggests the need to manage riparian areas to allow infiltration of sunlight in order to maximize secondary production.

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REFERENCES

A great egret on Big Spring and heron/egret-injured rainbow trout from Big Spring (photo credit Bill Ferris)