Energy density of freshwater Patagonian organisms

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ABSTRACT: We assessed by using a bomb calorimeter the energy density of the main species of Patagonian freshwater ecosystems, including fish, crustaceans, gastropods, oligochaetes, and insects. Fish (5048-5789 Cal/g) were the most energy density group, followed by insects (5062-5232), crustaceans (3364-3994), oligochaetes (3471) and gastropods (1143). These data consist on the first direct energy density estimations of freshwater species and are intended as a baseline information for modelling the energy fluxes in Patagonian freshwater ecosystems.

[Keywords: bomb calorimeter, bioenergetic model]

RESUMEN: Densidad energética de los organismos Patagónicos de agua dulce. La densidad energética de los organismos puede ser utilizada con distintos fines como evaluar la calidad de la dieta, comparar la importancia de distintas presas para un predador, corregir las tasas de evacuación gástrica de modelos, explicar el comportamiento de forrajeo de ciertos predadores o determinar su estado fisiológico. Consiste en un parámetro fundamental para el modelado bioenergético de ecosistemas. En este trabajo estimamos la densidad energética de los principales grupos de los ecosistemas de agua dulce de la Patagonia, incluyendo peces, crustáceos, gasterópodos, oligoquetos e insectos. Encontramos que los peces (5048-5789 Cal/g) es el grupo energéticamente más denso seguido de los insectos (5062-5232), crustáceos (3364-3994), oligoquetos (3471) y finalmente los gasterópodos (1143).

[Palabras clave: calorímetro de bomba, modelo bioenergético]

INTRODUCTION

Energy density has been used to evaluate diet quality (Wanless 2005), compare relative importance of prey items (Harris & Hislop 1978), correct gastric evacuation rates in models (Pedersen & Hislop 2001), explain foraging behaviour of predators (Benoit-Bird 2004) and determine the physiological status of organisms. During the last 20 years bioenergetically-based food web models, when coupled with direct sampling for diet, growth, size structure, thermal experience and estimates of relative or absolute abundance, have provided an ef-fective method for quantifying trophic interactions in a temporal, spatial, and ontogenetic framework. Bioenergetics models have also been used to investigate ecological problems such as the potential effects of fish introductions (Ruzycki et al. 2003), global warming (Hill & Magnuson 1990), predation as a factor in recruitment failure (Hartman & Margraf 1993), and several other problems in fish ecology (Brandt 1993; Hayes et al. 2000; Trudel & Rasmussen 2001; Harvey et al. 2002). Bioenergetic models require the estimation of individual size and growth rate, water temperature, energy density in prey and predator, and 10–30 parameters to represent food consump-

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tion, metabolic costs and waste production (Trudel et al. 2004).

Adiabatic bomb calorimeter (direct) and proximal composition (indirect) are frequently used methods to assess energy density in organisms (Craig et al. 1978). In Patagonia, few attempts have been made to estimate energy density of freshwater aquatic ecosystems organisms (only indirect measured by the proximal composition as described by Baez 1988 and Dorscht 1988), in spite of an increasing demand of information to feed models that explore different fisheries and conservation managing actions (Shuter & Meisner 1992; Koen-Alonzo & Yodzis 2005). In this paper we used and adiabatic bomb calorimeter to present the first data based on energy density of freshwater aquatics animal species of Patagonian waters (including mollusks, arthropods, insects and fish). The results presented in this work are the first step of 'bioenergetic modelling'; one way to assess the ecological effects of diverse human actions that are threatening freshwater diversity such as salmonid introduction (Pascual et al. 2002).

Methods

Organisms were collected from different rivers and lakes of Patagonia from November to April in 2000-2001 (Rivers: Limay (L), Santa Cruz (SC), Tecka (T), Corcovado (C), Lakes: Gutierrez (G), Moreno (M), Nahuel Huapi (N), Strobel Plateau lagoons (S)). Invertebrates were captured using a surber trap, and fish and crayfish using a fishing basket. (Table 1). Samples were placed in bags to avoid dehydration and were frozen. Samples were chopped, homogenized, dried in a stove at 60-80 °C for 24-72 hours and then ground to powder. *Chilina* spp. were homogenized including shells. Wet and dry weights were registered with precision of 0.001 g and were determined by weighing the homogenate before and after drying. One-gram pellets were made and burned at 30 atmospheres of oxygen in a calorimeter bomb (Parr model 1241) to determine gross energetic content. Fuse wire corrections were determined after each combustion event. One to three pellets of each sample were burned and the mean

was used to estimate energy density of the sample. For small individuals, i.e. insects, amphipods and gastropods, a sampling unit consisted of whole-body samples of numerous individuals. For large individuals such as fish, a sampling unit consisted of a sample of a single individual from a whole-body homogenate. Energy density (ED) is expressed in calories per gram dry weight and joules per gram wet weight.

In order to validate the results of the calorimetric analyses, the caloric content of several prey was also estimated based on their proximal composition of protein, lipids and carbohydrates (Table 1), as reported elsewhere (Baez et al. 1988; Dorscht 1988), multiplied by the corresponding gross energy contents (protein: 5640 *Cal/g* DW; lipid: 8700 DW; carbohydrates: 4111 *Cal/g* DW) (Higgs et al. 1995), or compared with analogous species of North America.

Results

According to their energy densities, prey species can be separated into four groups (Table 1). The most energy-rich prey group (5502-5789 *Cal/g* DW) contains exclusively fish. The following group (5062-5290 *Cal/g* DW) is composed by fish and insects. The third group is composed by crustaceans and oligochaetes (3364-3994 *Cal/g* DW). Snails were the least-caloric group (1143 *Cal/g* DW). Calorific contents based on proximal composition match direct measures closely (Table 1). Also, the calorific contents reported are similar to those of homologous groups of North America (Probst et al. 1984), such as fish, crayfish, and insects. Most of the species included in the analysis are conspicuous prey item of salmons in Patagonia (Macchi et al. 1999). For example, the endemic macro-crustaceans *Aegla* spp. have been regarded as high quality food for trout both by biologists (Burns 1972; Ferriz 1993) and by sport fishermen (several articles from Chile and Argentina in internet search for "Aegla" or "pancora"). This work indicates that the energy density of *Aegla* spp. (3880 *Cal/g* DW) is significantly lower than those of fish, insects and amphipods, but significantly higher than that of crayfish both from Patagonia (*Samasta-*

Table 1. Groups included in calorimetric analysis and their gross energy values determined both by bomb calorimeter (Cal/g Dry Weight and Joules/g wet weight) and proximal composition (Cal/g DW) (Baez et al. 1988; Dorscht 1988) (95% confidence interval for the mean CI). Crayfish NA (Genus *Orconectes*), Stoneflies NA (*Plecoptera*), Mayflies NA (*Ephemeroptera*) and fish NA (*Cyprinidae*) correspond to homologous species of North America (Probst et al. 1984).

Tabla 1. Densidad energética de los grupos determinada por calorimetría mediante el uso de una bomba adiabática de oxígeno (Cal/g Dry Weight calorías por gramo de peso seco y Joules/g wet w. Joules por gramo de peso húmedo) y por su contenido proximal (Proximal, Expresado en Cal/g peso seco) (Baez et al. 1988; Dorscht 1988). CI: intervalo de confianza del 95% para la media. Crayfish NA (Genus *Orconectes*), Stoneflies NA (*Plecoptera*), Mayflies NA (*Ephemeroptera*) and fish NA (*Cyprinidae*) corresponden a especies homólogas de Norte América (valores tomados de Probst et al. 1984).

Taxonomic group	Place	Common name	Cal/g Dry Weight	CI	Joules/g wet w.	Proximal
Fishes						
Cyprinidae		fish NA	5800			
Diplomystes viedmensis	L-C	velvet catfish	5789	60	5658	
Percichthys trucha	L	small-mouthed perch	5695	67	5917	5065
Galaxias maculatus	L	small puyen	5502	76	3443	
Hatcheria macraei	T	torrent catfish	5290	37	3795	
Odonthestes hatchery	M	silverside	5048	81	5783	4955
Oncorhynchus mykiss	G	rainbow trout	5745		6318	
Crustaceans						
Aegla spp.	T-C-N	aegla	3880	71	3680	3668
Hyalella spp.	N-S	scuds	3994		2547	5171
Samastacus spinifrons	L-N	crayfish	3364	45	3892	3862
Genus Orconectes		Crayfish NA	2950			
Gastropods						
Chilina gibbosa	C-T-N	snail	1143	142	1661	1587
Oligochaetes		earthworms	3471	77	1954	
Insects						
Ephemeroptera		mayflies NA	5580			
Ephemeroptera	T	mayflies	5232	39	2725	
Plecoptera		stoneflies NA	5300			
Plecoptera	SC	stoneflies	5066		5366	
Odonata	M	dragonflies	5062		1334	

cus spinifrons, 3364 *Cal/g* DW) and North America (*Orconectes spp.*, 2950 *Cal/g* DW). The quality of a particular species as prey is not given exclusively by its energy content. Other factors will also determine its intrinsic value, such as proximal composition, availability, handling time, and individual size.

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