

# Determining the trophic levels of Tarr Inlet, Glacier Bay, Alaska by measuring the isotopic enrichment of $^{15}\text{N}$

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## Abstract

The trophic levels of a food web can be estimated through the measurement of  $^{15}\text{N}$  enrichment. During March 2008, phytoplankton, zooplankton, suspended particulate organic matter, and seafloor sediments were sampled for analysis of  $^{15}\text{N}$  enrichment in the West Arm of Glacier Bay, Alaska. An enrichment of  $^{15}\text{N}$  was found between phytoplankton and zooplankton but there was little difference between the phytoplankton and the seafloor. This can occur when the dominant form of sinking particles is unprocessed phytodetritus depleted of  $^{15}\text{N}$  sinks to the seafloor. The enrichment of  $^{15}\text{N}$  for per trophic level ranged from 3.2-4.8 ppt with an average of 4.0 ppt. Locations near a glacier will receive a higher rate of sedimentation than those located away from a glacier. The sedimentation rate has a negative effect on  $\delta^{15}\text{N}$  with increased sedimentation resulting in decreased  $\delta^{15}\text{N}$  values.

## Introduction

Nitrogen isotope ratios become enriched in  $^{15}\text{N}$  as trophic levels increase with predators having higher  $\delta^{15}\text{N}$  values (Cabana and Rasmussen 1996). When organic matter is consumed the isotopic composition is changed and for nitro-

gen there will be an increase in  $\delta^{15}\text{N}$  values (Mintenbeck et al. 2007). As the trophic level increases there will be nitrogen enrichment creating the possibility of estimating the trophic level of consumers in that area and has improved our understanding of aquatic food webs (Vander Zanden and Rasmussen 2001).

Glacier Bay is a highly productive fjord and is an important area for many marine organisms some of which are endangered or threatened (Etherington et al. 2007). Though it is a national park commercial fishing has continued but is currently being phased out (Etherington et al. 2007). With commercial fishing being phased out it is unknown how that will affect the food web structure in Glacier Bay. Any changes in one level of the food web can have major effects on other levels of the web. With a better understanding of what changes in the food web are occurring better conservation or environmental actions could be taken.

Using nitrogen isotope ratios, trophic levels will be estimated and will give further insight into the dynamics of the food web in Glacier Bay. Glacier Bay is very productive and has a high concentration and diversity of marine predators present (Etherington et al. 2007) which should result in a significant enrichment of  $^{15}\text{N}$ . This study will measure nitrogen isotope ratios at locations at different distances from the glaciers at the head of Tarr Inlet to observe difference in the food web at different distances from the glaciers.

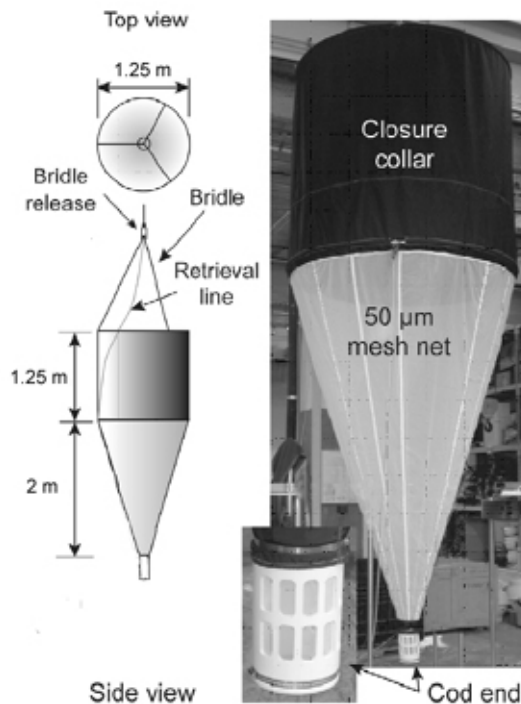


**Figure 1:** Map of Glacier Bay from Hooge and Hooge (2002) altered to show only stations sampled and their locations.

A study by Minagawa and Wada (1984) measured enrichment of nitrogen from several different consumers and found that there was an enrichment of 1.3-5.3 ppt with an average of 3.4 ppt per trophic level. In Glacier Bay nitrogen isotope ratios have not previously been measured. The data collected will be used to determine the enrichment of  $^{15}\text{N}$  per trophic level and used along with the average value from Minagawa and Wada (1984) to estimate the number of trophic levels in the bay.

## Methods

Samples were collected from two stations, one at the toe of the glaciers in Tarr Inlet, station 21, and one far away from the glacier in the West Arm, station 8 (Fig 1). Phytoplankton were collected using a 24  $\mu\text{m}$  mesh size hand net to a maximum depth of about 3 m. The zooplankton samples were collected with a 0.5 m diameter, 64  $\mu\text{m}$  mesh size net tow from a



**Figure 2:** A modified version of the net trap from Peterson et al. (2005). The dimensions of the trap have been changed.

depth of 75 m. The samples were then stored and frozen in glass jars. To collect sediment from the water column, 1.25 m diameter net traps were deployed at a depth of 150 m for approximately 24 hours (C. Biladeau unpubl., Fig 2). The traps were secured to the seafloor and held vertical by a set of subsurface floats at 30 m. A float at the surface with a flag marked the location of the trap. Prior to recovery the trap was closed to prevent the collection of particles above it. After recovery of the net trap, the cod end was emptied into a plastic bottle and frozen. Sediment samples were taken from a Soutar core. Two samples were collected from each core, one at the surface and one from the bottom of the core. The samples were put into glass jars and dried in an oven at 60°C. After samples were dry they were stored in a desiccator.

After returning to the lab the samples were processed and prepared for analysis at the

University of Washington. Plankton samples were filtered through 0.7  $\mu\text{m}$  GFF glass fiber filters and dried in an oven at 60°C for several hours. The dried samples were scraped off of the filter into a mortar and ground up for a more homogenous sample. Net trap samples were thawed by first microwaving for 15 minutes then in a hot water bath (C. Biladeau unpubl.). Samples were centrifuged at 4000 rpm at 15°C in increments of 11 minutes for station 8 and 22 minutes for station 21 (C. Biladeau unpubl.). The excess water was decanted off using a 10 ml pipette and samples were freeze dried for 3 days before being added to glass vials (C. Biladeau unpubl.). Sediment and net trap samples were weighed out to 150 mg then acid treated with 10% HCl to remove the carbonate from the sample then filtered onto 0.7  $\mu\text{m}$  GFF glass fiber filters and dried overnight at 50°C. The dry samples were weighed into tin capsules, 2 mg for plankton and 150mg for sediment. Some of the sediment samples were too large to fit into the capsule so as much as would fit was added. Samples were analyzed for  $\delta^{15}\text{N}$  on an isotopic mass spectrometer with continuous flow combustion elemental analyzer. Nitrogen ratios were reported in del notation where,

$$\delta^{15}\text{N} = \left( \frac{R_{\text{sample}}}{R_{\text{standard}}} - 1 \right) \times 1000$$

and  $R = \frac{^{15}\text{N}}{^{14}\text{N}}$ . The standard used was atmospheric nitrogen.

## Results

Nitrogen isotope ratios were consistently higher at station 8, ranging from 4.13 to 8.91 ppt (Fig 3). At both stations there was enrichment of nitrogen between the phytoplankton and zooplankton samples but a decrease from the zooplankton to the sediment samples. The net trap samples had a much higher  $\delta^{15}\text{N}$  value than the surface sediment at station 8, with a difference of 2.91 ppt (Fig 3). At station

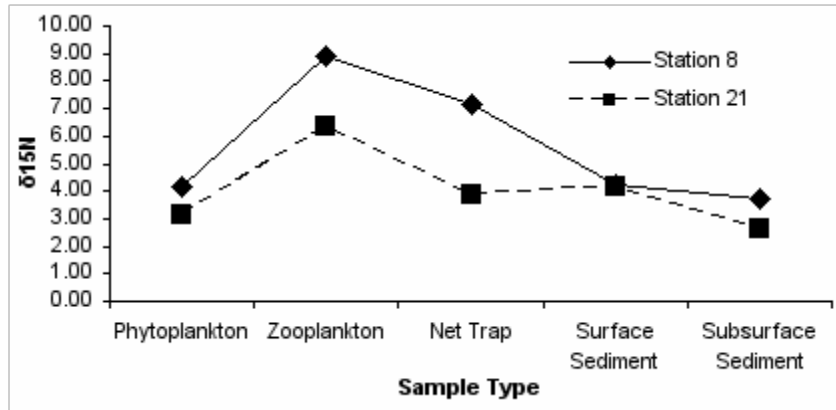
21 the difference was much smaller with the sediments higher by 0.28 ppt. The  $\delta^{15}\text{N}$  values for zooplankton were higher for zooplankton than for net traps at both stations. At station 21 the two sediment samples were almost equal with the surface sediment only 0.6% higher. The trophic level of each sample was calculated in two different ways (Table 1). Assuming that the phytoplankton sample was representative of primary producers, or trophic level (TL) =1 and zooplankton, primary consumers, or TL=2, the difference between zooplankton and phytoplankton were used as the enrichment of one trophic level. The second method was to use the average measured enrichment from the Minagawa and Wada (1984) study of 3.4 ppt enrichment per trophic level. Where trophic levels were calculated by,

$$TL = \left( \frac{\delta^{15}\text{N}_{\text{sample}} - \delta^{15}\text{N}_{\text{phytoplankton}}}{^{15}\text{N}_{\text{enrichment per TL}}} \right) + 1$$

and  $^{15}\text{N}$  enrichment per TL is either the value from Minagawa and Wada (1984), 3.4 ppt, or the difference between the zooplankton and phytoplankton  $\delta^{15}\text{N}$  values measured in this study. Using both methods the number of trophic levels decreased from the zooplankton sample to the sediments (Table 1). The difference between the number of trophic levels using the two different methods was small, 3.01% or less at Station 8. However at Station 21 the difference was large, with the calculated method lower by as much as 16.9%. The enrichment per trophic level was 3.2 ppt at station 21 and 4.8 ppt at station 8 with an average of 4.0 ppt.

## Discussion

In a productive environment with many different marine predators an increase in  $\delta^{15}\text{N}$  would be expected. Contrary to this the enrichment of  $^{15}\text{N}$  only occurred between phytoplankton and zooplankton. Sediment samples were depleted. In Glacier Bay chlorophyll concentrations are



**Figure 3:** Comparison of  $\delta^{15}\text{N}$  values for each sample type at both stations. The maximum is the zooplankton sample and the phytoplankton and sediment samples are nearly equal and the minimum for both stations. There is a net depletion of  $^{15}\text{N}$  below the zooplankton sample.

	Station 8			Station 21		
	Trophic Levels		% Diff	Trophic Levels		% Diff
	Zoo-Phyto	Est. M&W		Zoo-Phyto	Est. M&W	
Phytoplankton	1.00	1.00	0.00	1.00	1.00	0.00
Zooplankton	2.00	2.41	-16.90	2.00	1.94	3.01
Net Trap	1.63	1.89	-13.59	1.22	1.21	1.06
Surf Sed	1.02	1.03	-0.88	1.31	1.29	1.39
SubSurf Sed	0.91	0.87	4.32	0.82	0.83	-1.23

**Table 1:** Table 1. Calculated trophic levels using both the average value from Minagawa and Wada (1984) and the value calculated from the data collected in this study. The percent difference was calculated for a comparison of the two different studies.

usually high in the spring around March and April (Etherington et al. 2007). High concentrations of phytoplankton will result in large amounts of phytodetritus sinking to the seafloor. This flux of  $^{15}\text{N}$  depleted particulate matter results in the decrease in  $\delta^{15}\text{N}$  values on the seafloor (Voss et al. 1996). This causes a seasonal variability in the  $\delta^{15}\text{N}$  of sediments with depletion of  $^{15}\text{N}$  during phytoplankton blooms.

Sedimentation rates also affect the nitrogen isotope ratios. Sedimentation rates decrease exponentially with distance away from the glacier terminus (Cowan and Powell 1991), therefore

higher sedimentation rates should be expected at station 21. A study done in the Kara Sea measured nitrogen isotope ratios and sedimentation rates. The resulting data revealed a correlation between sedimentation rates and  $\delta^{15}\text{N}$  values where increased sedimentation results in lower  $\delta^{15}\text{N}$  values (Gaye et al. 2007). With higher sedimentation rates expected at station 21 and with lower  $\delta^{15}\text{N}$  values than at station 8, Glacier Bay appears to have the same correlation between sedimentation rates and  $\delta^{15}\text{N}$  values.

The number of trophic levels were estimated

using a method that contains a large amount of variability. With a large flux of  $^{15}\text{N}$  depleted phytodetritus decreasing  $\delta^{15}\text{N}$  of the seafloor at variable rates, the number of levels will be difficult to measure. When the flux of  $^{15}\text{N}$  depleted phytodetritus is decreased  $\delta^{15}\text{N}$  values will be easier to measure and calculating a better estimation for the number of trophic levels will be possible. During this study samples were collected in March during the beginning of the spring bloom. The winter months, November through February, have the lowest chlorophyll concentrations throughout all of Glacier Bay (Etherington et al. 2007). This would be the best time to get quality measurements from sinking particles or seafloor sediments. There was also variability in the amount of enrichment in one trophic level between the two stations. This variability was also found in the Minagawa and Wada (1984) study where they had a range of 1.3-5.3 ppt enrichment per trophic level averaging to 3.4 ppt. This is lower than the average found in this study of 4.0 ppt. With all of this variability there is a lack of precision and difficult to say how accurate the measurements are.

## Conclusions

The enrichment of  $^{15}\text{N}$  is affected by several variables. In this study the high productivity at the start of the spring bloom resulted in a large flux of  $^{15}\text{N}$  depleted phytodetritus to sink to the seafloor. This will result in seasonal variability of the enrichment of  $^{15}\text{N}$  of sediments. High sedimentation rates resulted in lower enrichment and were directly correlated to the distance from the glacier terminus, as sedimentation rates decrease exponentially with distance from the glacier (Cowan and Powell 1991). The enrichment of  $^{15}\text{N}$  occurs with increasing trophic level though it is quite variable. Using the enrichment of  $^{15}\text{N}$  to estimate the number of trophic levels can be useful for measuring the number of active trophic levels but due to the variability in the

enrichment per trophic level it is difficult to be accurate.

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