

# Geochemical Signatures as Natural Fingerprints to Aid in Determining Tanner Crab Movement in Glacier Bay National Park, Alaska

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**Abstract.** The migration of Tanner crabs (*Chionoecetes bairdi*) with ontogeny is poorly understood but could have important implications for fisheries management. Relatively dense populations of juvenile Tanner crabs have been found in several areas within Glacier Bay; these could be nursery areas from which maturing crabs disperse. Geochemical signatures imparted to the carapace during molt or to the muscle tissue during growth could serve as a natural fingerprint that identifies the area where molting or growth occurred. These signatures may reflect subtle but unique elemental or isotopic compositions that arise from hydrologic, geologic, or nutritional variations in Glacier Bay. For this pilot study, recently molted Tanner crabs were collected from Scidmore Bay, Charpentier Inlet, Hugh Miller Inlet, Wachusett Inlet, and Bartlett Cove. Leg muscle tissue and the entire dorsal carapace were retained for elemental and stable isotopic (C and N) analysis. If geochemical signatures differ among crabs from different sample sites, this signature could aid in understanding Tanner crab migration. Here we present preliminary data and baseline information needed to determine the feasibility of establishing a geochemical signature for use as a natural fingerprint.

## Introduction

Elemental and isotopic variations in biota arise from differences in local environmental conditions. In some instances, these “geochemical fingerprints” are sufficiently unique to serve as life-history markers. Geochemical fingerprints have been used to distinguished stock and migration patterns for a variety of fish and marine invertebrates (Edmond and others, 1989; Campana and Gagne, 1995; Thorrold and others, 1997; DiBacco and Levin, 2000). Stable isotopic studies have been carried out on a variety of topics related to aquatic and terrestrial ecosystems (Fry and Sherr, 1984, Peterson and Fry, 1987, Fry, 1988, Carmichael and others, 2004). Environmental conditions that may result in unique geochemical signatures include food source, C source (e.g. shelf or oceanic) salinity and temperature differences, and differences in the local geology.

The success of geochemical fingerprinting tools in other studies led us to consider the possibility that such signatures in Tanner crabs may aid in understanding their migration within Glacier Bay. Tanner crab life-history characteristics make them well suited for a geochemical fingerprinting approach. Female Tanner crabs do not molt again after they molt to sexual maturity. Therefore, if a female Tanner crab leaves the area where she molted to maturity (e.g., a nursery area), the geochemical signature in her carapace could be used as

a marker for the area in which she molted. It is highly likely that males also undergo a terminal molt (Tamone and others, 2007), in which case the technique could be applied to males as well. In addition, isotopic variations in the muscle tissue could serve as an indicator of crab movement and thus could complement the geochemical information from the carapace. For example, if crabs leave the nursery area after molting, the carapace should reflect the signature of the nursery area, while the muscle may reflect both the terminal molt and a more recent environment. Based on the geological and hydrological heterogeneity present in Glacier Bay and the life history of the Tanner crab, there is a reasonable chance geochemical variations imparted to the crab body tissue can be used to determine the area where the terminal molt occurred.

## Physical Setting and Methods

Tanner crabs were collected from five sites within Glacier Bay: Scidmore Bay, Charpentier Inlet, Hugh Miller Inlet, Wachusett Inlet, and Bartlett Cove (fig. 1). Sedimentary rock units that include the Point Augusta Formation and surficial deposits dominate the area around Barlett Cove. The geology of the region surrounding Wachusett Inlet, Hugh Miller Inlet, Charpentier Inlet, and Scidmore Bay is a mix of magmatic, metamorphic, and sedimentary rocks and surficial deposits (Dave Brew, U.S. Geological Survey, 2004, unpub. data). Cu and Mo, Ag, and Ag-Cu-Pb mineral occurrences are known in the area surrounding Wachusett Inlet and Cu and Cu-Mo occurrences are known near Scidmore Bay and Charpentier Inlet (Alaska Resource Data file; <http://ardf.wr.usgs.gov>). Tanner crabs (*Chionoecetes bairdi*) were collected using herring-baited crab pots in late October 2003.

Crabs were sorted, sexed, measured, and shell condition noted (table 1). Recently molted juvenile crabs were selected from the overall catch and field processed for later elemental

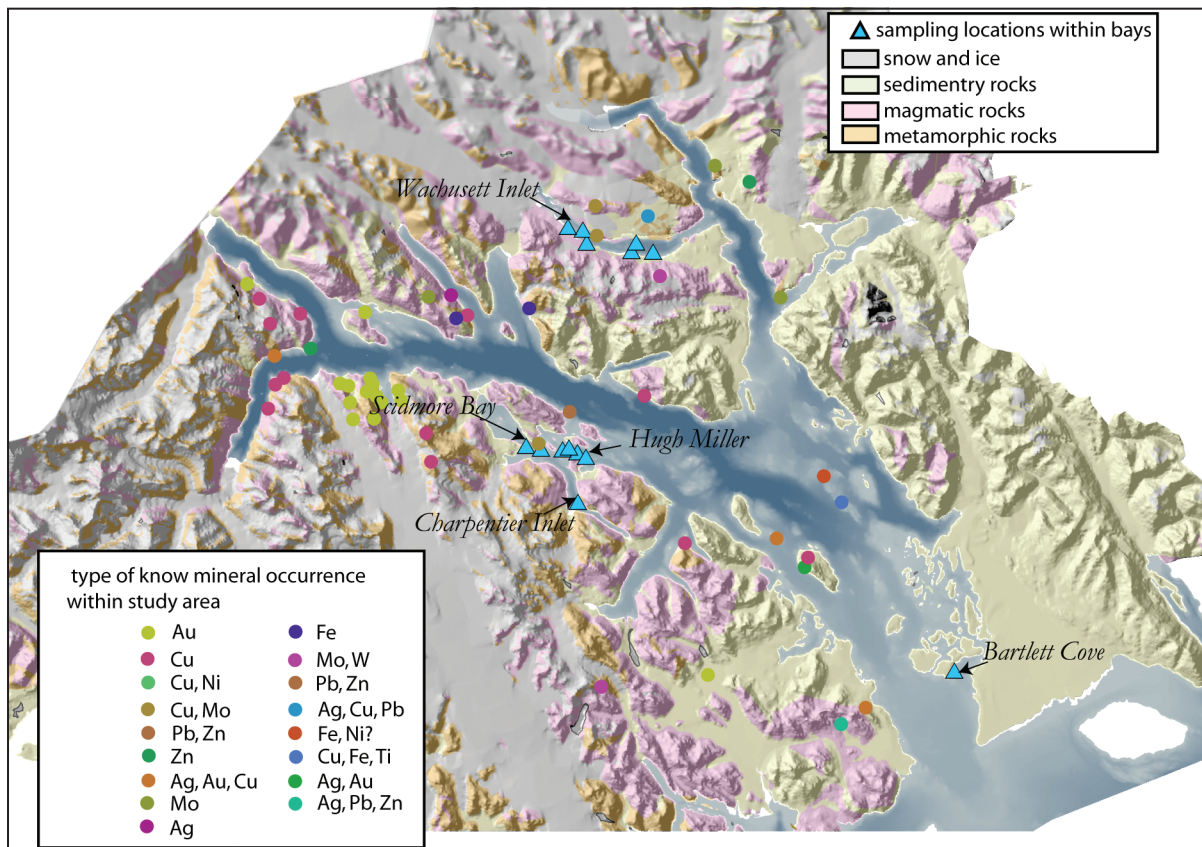
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**Figure 1.** Sampling locations for Tanner crab relative to generalized bedrock geology and the locations of known mineral occurrences in Glacier Bay National Park, Alaska.

and isotopic analysis. Field processing consisted of removing carapace and legs from the selected crabs, rinsing the pieces in sea water, labeling and bagging the pieces in plastic bags, and freezing.

In the laboratory, the carapace was washed with deionized water and tissue residue was removed using a nylon bristle brush. The eye area was removed, as was the shell edge,

**Table 1.** Size range, number of individuals, shell condition, and sex distribution of Tanner Crab for individual bays, Glacier Bay National Park, Alaska.

[Abbreviation: mm, millimeter]

Sampling location	Size range, (mm)	Total number of crabs	Shell condition	Sex males/females
Barlett Cove	82–122	10	10 new	10/0
Charpentier Inlet	95–119	9	2 new, 7 soft	9/0
Hugh_Miller	82–122	10	10 new	7/3
Scidmore Bay	119–144	9	1 new, 8 soft	9/0
Wachusett-Inlet	71–108	10	7 new, 2 soft, 1 premolt	6/4

to insure that all extraneous tissue was completely removed. Samples were air dried at room temperature and ground to a fine powder using a nonmetallic mortar and pestle. Muscle tissue was extracted from the leg by splitting the shell with a stainless steel knife and removing the muscle tissue between the body and the first joint. The leg shell and muscle tissue from the body cavity also were taken from some individuals. The muscle tissue was placed into test tubes, freeze dried for four days, and ground to a powder. One gram of ground carapace material was digested in ultra-pure nitric acid and hydrogen peroxide under reflux conditions in metal-free polypropylene tubes for elemental analysis. Samples were diluted to 20 mL with ultra-pure water and further diluted with 1.6 N ultra-pure nitric acid prior to analysis by ICP-MS and ICP-AES.

Samples for isotopic analysis were sealed in tin cups, combusted in a Carlo-Erba elemental analyzer, and the C and N isotopes were determined by continuous flow on a Thermo-Finnigan Delta Plus mass spectrometer. The isotopic ratios in the sample are evaluated relative to a reference standard and stable isotope measurements are reported in “delta” notation;  $\delta^aX = \{ [ ( ({}^aX / ({}^bX) )_{\text{sample}} / ( ({}^aX / ({}^bX) )_{\text{standard}} ] - 1 \} * 10^3$  where  ${}^aX$  and  ${}^bX$  are  ${}^{13}\text{C}$  and  ${}^{12}\text{C}$  or  ${}^{15}\text{N}$  and  ${}^{14}\text{N}$  for the C or N stable isotopic systems, respectively. These values may be positive,

negative, or zero depending on the isotopic ratio in the sample relative to the reference standard. Reference standards used were Vienna Pee Dee Belemnite (VPDB) for C and atmospheric nitrogen for N.

A Kruskal-Wallis multiple means comparison test was used to determine if significant differences existed in the elemental concentrations of the carapace collected from the different locations. The concentration of some elements correlated with size and it was necessary to normalize these elements for the crab size. Correlation between the logarithm of element concentration and crab size was used to normalize element concentration.

## Results

### Preliminary Results and Interpretation of Carbon and Nitrogen Isotope Data

Carbon and nitrogen isotopic analyses were made for both carapace and muscle tissue samples (fig. 2). The carbon isotopic signatures of the carapace have a greater range ( $\delta^{13}\text{C}=-15.0$  to  $-9.1\text{‰}$  [permil]) than those of the muscle ( $\delta^{13}\text{C}=-17.1$  to  $-14.8\text{‰}$ ). Similarly, the nitrogen isotopic signatures of the carapace also have a greater range ( $\delta^{15}\text{N}=2.8$  to  $9.6\text{‰}$ ) than those of the muscle ( $\delta^{15}\text{N}=9.9$  to  $13.5\text{‰}$ ). For muscle tissue and carapace material, the carbon and nitrogen isotopic variations do not appear to be significantly correlated. No significant differences in the carbon and nitrogen isotopic composition were determined

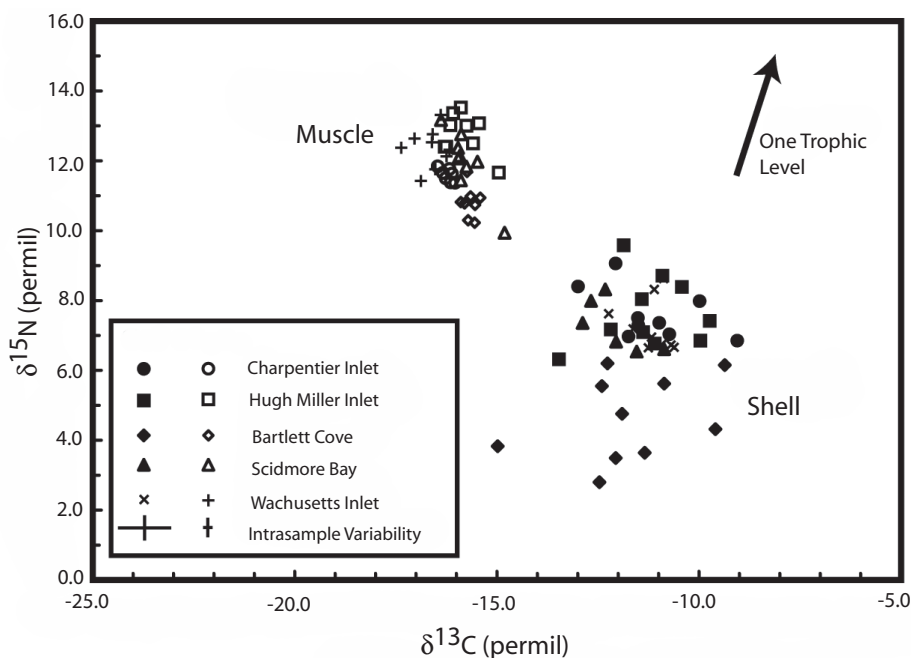
between the different shell parts (carapace versus leg shell), or between the different muscle tissue (leg versus knuckle/body muscle).

Carapace analyses were done on whole shell material. Therefore, the carbon isotopic signatures for the shells represent a mixture of both the chitin and biogenic carbonate contained in the shell. Because the proportions of chitin and carbonate will vary from sample to sample, the range of carbon isotope values likely is a reflection of the varying proportions of the admixtures, than of isotopic variations of the chitin or carbonate itself. The carbonate fraction should have a  $\delta^{13}\text{C}$  value near that of marine carbonate (i.e.,  $\delta^{13}\text{C}=0\text{‰}$ ), and the  $\delta^{13}\text{C}$  value of the chitin will depend upon the diet of the crab. The nitrogen isotopic signature for the shells should be unaffected by the diluting effects of the biogenic carbonates and should be dominated by the isotopic composition of the chitin, with minor contributions from proteinaceous and other organic compounds.

The carbon isotope signatures of the muscle tissue show subtle differences among the various sample locations. Samples from Wachusett Inlet have the lowest mean  $\delta^{13}\text{C}$  value ( $-16.6\pm 0.3$  ( $1\sigma$ ) $\text{‰}$ ,  $n=9$ ). Mean values from the other sites are less distinctive and collectively average  $-15.9\pm 0.4$  ( $1\sigma$ ) $\text{‰}$  (fig. 2). Differences in  $\delta^{13}\text{C}$  of up to  $1\text{‰}$  can be attributed to differences in trophic level of an individual animal or its food sources (DeNiro and Epstein, 1978; Fry and Sherr, 1984); however, the corresponding increase in  $\delta^{15}\text{N}$  with trophic level (approximately 3-4 $\text{‰}$ ; Minagawa and Wada, 1984) is absent in the muscle tissue from the Wachusett Inlet and the observed difference in the  $\delta^{13}\text{C}$  value may reflect isotopic differences in the carbon isotopic signature at the

base of the food chain. Factors that can lower  $\delta^{13}\text{C}$  values of particulate organic carbon and phytoplankton include; increased contributions of terrestrial carbon, temperature of primary production, and species-dependent effects (Fry and Sherr, 1984). The carbon isotope signature for the carapace material from Wachusett Inlet is indistinguishable from the other sites. Differences in the isotopic signature between the carapace and the muscle may be related to the presence of both chitin and carbonate in the shells, or may be an indication that the muscle and carapace carbon-isotope signatures reflect different time periods.

The  $\delta^{15}\text{N}$  values of carapace and muscle from most sites fall within a similar range, except Bartlett Cove, which has lower values for both muscle and carapace (fig. 2). The 3.6 $\text{‰}$  range of nitrogen isotope values



**Figure 2.**  $\delta^{15}\text{N}$  versus  $\delta^{13}\text{C}$  for the meat and carapace of juvenile Tanner crabs, Glacier Bay National Park, Alaska.

for the muscle tissue and the 6.8‰ range for the carapace material suggest that the Glacier Bay Tanner crabs span roughly one trophic level (Fry, 1988), and the Bartlett Cove crabs represent a lower-end feeding level than for the rest of Glacier Bay population. The greater range of  $\delta^{15}\text{N}$  values for the carapace material from Bartlett Cove (3.4‰) compared to the corresponding muscle (1.5‰) may reflect the dynamic nature of nitrogen isotope composition of newly formed chitin as found in other crustaceans (Schimmelmann and DeNiro, 1986) or may be an indication that the muscle and carapace nitrogen-isotope signatures also reflect different time periods. If the former is true then the nitrogen isotopic signature of the carapace may not provide the most robust indicator of the site of origin for crabs.

### Preliminary Evaluation of Elemental Data and Discriminant Factor Analysis

The carapace material was analyzed for 51 elements. Small but significant differences (family  $\alpha=0.05$ ) are detected in numerous elements among the different locations. Elements that are significantly different in at least one location are Al, Ba, Ca, Cd, Li, Mn, Mo, Ni, Sb, Sc, Sr, U, Y and rare earth elements La, Ce, Nd, and Eu. The crab carapace contains both chitin and biogenic calcite. Calcite is primarily  $\text{CaCO}_3$  but

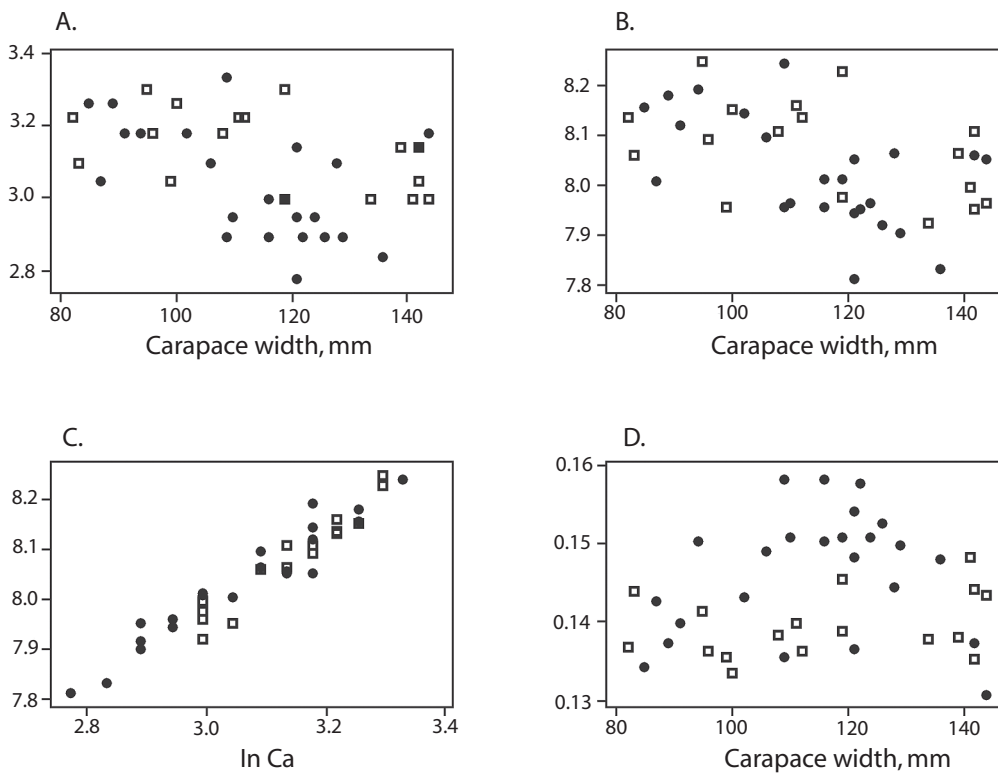
other cations, such as Sr, may substitute for Ca in the calcite matrix. The Sr/Ca ratio of fish otolith has been used to identify stocks from different regions and differences in the Sr/Ca ratio in the otolith are thought to arise from differences in the aqueous Ca and Sr concentration, and water temperature (Thorrold and others, 1997; Campana and Gagne, 1995; Edmond and others, 1995). In addition to these environmental conditions, carapace size and time since molt could affect the concentrations of Ca and Sr in the carapace. The natural logarithm of carapace Ca and Sr concentrations are inversely correlated with carapace width, but there is no difference in their relation with size between soft or new shell individuals (fig. 3) (here we are taking the shell condition of the recently molted crab as an indicator of time since molt with soft shell being more recently molted than new shell). One possible explanation for the inverse relation between concentrations of Ca and Sr and size is a smaller proportion of calcite relative to chitin in the larger crabs. Consequently, chitin in larger crabs could be diluting the concentrations of the Ca and Sr associated with the calcite thereby giving a negative relation with size.

Ca and Sr show a strong linear correlation. However, the Sr/Ca ratio is not correlated with carapace size or time since molt. Consequently, there is no indication of changes in substitution rate of Sr into the calcite lattice with time or shell maturation.

In addition to Ca and Sr, Al, Ba, Eu, Mn, Mo, and Y also are inversely correlated with carapace size. Significant differences in the carapace size among bays require that the size influence on the concentrations of these elements be removed in order to determine correctly if difference based on locations exists. Small but significant (family  $\alpha=0.05$ ) differences were still found among the bays for the size-adjusted concentrations of these elements.

### Discussion and Conclusions

Elemental and isotopic differences were detected in crabs collected from the five locations within Glacier Bay, and it appears promising that a



**Figure 3.** Plots showing (A) ln Ca versus carapace width, (B) ln Sr versus carapace width, (C) ln Sr versus ln Ca, and (D) ln Sr/ln Ca ratio versus carapace width. Open squares are soft shelled individuals and solid circles are new shelled individuals.

geochemical fingerprint of molt location may be identified. To fully evaluate the potential of geochemical fingerprinting as a tool in understanding crab movement within Glacier Bay more work is necessary to examine the stability of the elemental and isotopic signature with time, changes of the isotopic signature with diet, isotopic signature of different prey types, the possibility of sex as a confounding factor, and the role of biogenic calcite on the elemental signature and isotopic signatures through separation of the calcite and chitin. In addition other isotope systems such as S and Sr isotopes, and other tissue, such as gill tissue, could be useful in discriminating among bays.

## Management Implications

Recent developments in area-based fisheries management (e.g. marine protected areas and essential fish habitat designation) require an increased understanding of spatial processes, such as rearing areas and movement during the course of an organisms development. Long-term movements of juvenile Tanner crabs are difficult to quantify, because tags that can be reliably retained through the molt have not been developed. Movement of females and sub-legal males cannot be detected in traditional tagging studies that use fisheries to recapture tagged animals based on sex and size regulations of the fishery. Multi-year sonic tagging studies are expensive and relatively few animals can be tracked. If geochemical fingerprinting eventually can be used to determine movement with ontogeny, it will be an elegant, robust, relatively cost-effective tool that can achieve results in a short time (i.e., one survey as opposed to several years of sonic tracking).

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