Carbon and nitrogen sources supporting food webs of spotted seatrout (Cynoscion nebulosus) in Galveston Bay and the Laguna Madre : Preliminary Observations

By

Scott A. Holt and Ellery D. Ingall
The University of Texas at Austin
Marine Science Institute

MANAGEMENT DATA SERIES
No. 172
2000

Texas Parks and Wildlife
Coastal Fisheries Division
4200 Smith School Road
Austin, Texas 78744

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Acknowledgments

We thank each staff member of Texas Parks and Wildlife (TPW), Coastal Fisheries Division Galveston Bay and upper Laguna Madre study groups who collected spotted seatrout tissues. These tissues samples were collected in conjunction with TPW routine sampling that is partially funded by the U. S. Fish and Wildlife Service under the Federal Aid in Sport Fish Restoration Act (Project F-34-M). We also thank Cameron Pratt and Felicia Goulet-Miller for processing the isotope samples. Funding for sample processing was provided through TPW.

Abstract

Stable carbon and nitrogen isotopic ratios in animals are largely determined by the isotopic composition of their diet and the effects of metabolic processes. Ecologists have used measurements of carbon isotopic ratios to study the sources of nutrition for consumers and nitrogen isotopic ratios to determine trophic relationships among organisms. The objective of this study was to determine whether significant differences exist in isotopic ratios of spotted seatrout from the Upper Laguna Madre, which is dominated by seagrasses, and Galveston Bay, where few if any seagrasses exist. Tissue samples were collected from spotted seatrout from the Upper Laguna Madre and the same number from Galveston Bay. The fish ranged from 350 to 650 mm total length (TL). Spotted seatrout $\delta^{13}C$ and $\delta^{15}N$ values differed significantly between the two estuaries. The $\delta^{13}C$ values from the Upper Laguna Madre are heavier (i.e. more enriched in ^{13}C and therefore less negative) than those from Galveston Bay. The $\delta^{15}N$ values of spotted seatrout from the Upper Laguna Madre are lighter (i.e. less positive; more depleted in ^{15}N) than those from Galveston Bay. These data suggest that the food web supporting spotted seatrout in the Upper Laguna Madre is based largely on seagrasses or benthic and epiphytic algae. In contrast, the data suggest that the food web supporting spotted seatrout production in Galveston Bay is based largely on phytoplankton. Nitrogen isotopic composition of Galveston Bay spotted seatrout may reflect a greater contribution of sewage-derived nitrogen to the ecosystem compared to the Upper Laguna Madre.

Introduction

Relative abundance of the two naturally-occurring stable isotopes of carbon, ^{13}C and ^{12}C , in plants is determined by the biochemistry of the photosynthetic processes and differs among phytoplankton, algae, seagrasses, and terrestrial plants. For analytical purposes, the relative abundance of the two isotopes is given as the ratio of the heavy isotope (i.e.^{13}C) to the lighter one (i.e. ^{12}C) relative to a predetermined standard and is expressed as $\delta^{13}C$. The relative abundance of the two stable isotopes of nitrogen, ^{15}N and ^{14}N (expressed as $\delta^{15}N$), in primary producers is determined largely by the isotopic composition of the sources of inorganic nitrogen utilized. The stable carbon and nitrogen isotopic ratios in animals are largely determined by the isotopic composition of their diet and the effects of metabolic processes (Fry and Sherr 1984). At each trophic step, isotopic enrichment occurs as a result of selective excretion or respiration of the lighter isotopes leaving relatively more of the heavier isotope. For carbon, the enrichment is small, <1.0 ‰ per trophic level. For nitrogen, the enrichment is greater, about 3.0 ‰ per trophic level. Ecologists have used measurements of carbon isotopic ratios to study the sources of nutrition for consumers and nitrogen isotopic ratios to determine trophic relationships among organisms. Simultaneous use of the two isotopes allows for the assessment of trophic relationships in the ecosystem.

We propose that these two isotopes could be used to determine the indirect role of seagrasses in the diet of spotted seatrout in Texas estuaries. The objective of this study was to determine whether significant differences exist in isotopic ratios of spotted seatrout from the Upper Laguna Madre, which is dominated by seagrasses, and Galveston Bay, where few if any seagrasses exist.

Methods

Tissue samples were collected by Texas Parks and Wildlife (TPW) biologists from approximately 35 spotted seatrout from the Upper Laguna Madre and the same number from

Galveston Bay. Fish were caught by recreational fishermen and tissues were taken from fish being cleaned at dockside cleaning stations. The fish ranged from 350 to 650 mm total length (TL) and most were in the range of 400 to 550 mm TL. Dorsal muscle tissue was removed from just posterior to the head. Samples were frozen and delivered to the University of Texas Marine Science Institute (MSI). TPW also provided 50 small juvenile trout from the CCA-CPL Marine Development Center at Flour Bluff and Perry R. Bass Marine Fisheries Research Station at Palacios. Four fish from each hatchery were analyzed for comparison with the wild fish. At MSI, each sample was freeze-dried, ground into a powder, and analyzed in a Carl Erba elemental analyzer connected to a Finnigan-Mat Delta Plus continuous flow stable isotope ratio mass spectrometer.

Results and Discussion

Spotted seatrout $\delta^{13}C$ and $\delta^{15}N$ values (Figure 1) differed significantly between the two estuaries (carbon - t,-22.914; d.f.,77; $p<0.001$; nitrogen - t,25.460; d.f.,77; $p<0.001$). The $\delta^{13}C$ values from the Upper Laguna Madre are heavier (i.e. more enriched in ^{13}C and therefore less negative) than those from Galveston Bay. The $\delta^{15}N$ values of spotted seatrout from the Upper Laguna Madre are lighter (i.e. less positive; more depleted in ^{15}N) than those from Galveston Bay. Fish size had no significant effect on δ13C values (Figure 2) or δ15N (Figure 3) values in the spotted seatrout examined here. The lack of any size effect in the nitrogen values indicates that the trophic level at which fish are feeding is similar for the range of fish size examined. Hence isotopic differences most likely reflect differences in carbon sources for the fish.

We did not take samples of the primary producers from either estuary so we must rely on published values for various potential carbon and nitrogen sources. Marine phytoplankton in coastal waters of the northeastern Gulf of Mexico generally have $\delta^{13}C$ values of -18 to -22 ‰ (Fry and Parker 1979, Fry et al. 1977). Seagrass $\delta^{13}C$ values can range from -5 to -20 ‰ but typically are between -10 and -11 ‰ (Hemminga and Mateo 1996). Street et al. (1997) reported a

$\delta^{13}C$ value of -10 ‰ for seagrasses in the Upper Laguna Madre. Del ^{13}C values of benthic macroalgae and epiphytic algae, both potential sources of carbon in estuarine food webs, can range widely but are generally in the range of -10 to -18 ‰ (Fry et al. 1984, Kitting et al. 1984.), Assuming these values generally apply to the sites studied here, our data suggest that the food web supporting spotted seatrout in the Upper Laguna Madre is based largely on seagrasses or benthic and epiphytic algae. In contrast, the data suggest that the food web supporting spotted seatrout production in Galveston Bay is based largely on phytoplankton.

Fish from the hatcheries differed from the wild fish in both carbon and nitrogen isotopic composition. The isotopic composition of the hatchery fish are influenced by both the composition of the source water and any fertilizers added to the ponds. The differences observed between hatchery fish and wild fish would likely disappear quickly, however, once the fish are released into the wild since the turnover of biomass in these small fish is fairly rapid. The isotopic composition of newly deposited tissue reflects that of the new food source (Herzka and Holt 2000) and would result in the dilution and fairly rapid elimination of the isotopic signal corresponding to the hatchery period.

The nitrogen values are intriguing from another aspect as well. An enrichment factor of 3 ‰ is typically used to determine the trophic level at which organisms feed. The approximately 6 ‰ difference in the $\delta^{15}N$ values for spotted seatrout from the two estuaries suggest that fish in Galveston Bay were feeding at two trophic levels higher than fish from the upper Laguna Madre. Such large differences in feeding habits within a species are unlikely to occur, however, and these results may reflect the contribution of anthropogenic nitrogen to the ecosystem. The $\delta^{15}N$ of primary producers in estuarine systems is dependent on the $\delta^{15}N$ of the dissolved inorganic nitrogen (DIN) pool. It has recently become apparent that anthropogenic nitrogen loads in the ecosystem can significantly skew the isotopic composition of the inorganic nitrogen pool and hence that of primary producers (McClelland and Valiela 1998). Septic tank and waste-water effluents were shown to increase DIN $\delta^{15}N$ values from 0.5 to 9.5 ‰ over an entire estuarine

basin and this increase was reflected in the $\delta^{15}N$ values of the local primary producers (McClelland and Valiela 1998). Thus, nitrogen isotopic composition of Galveston Bay spotted seatrout may reflect a greater contribution of sewage-derived nitrogen to the ecosystem compared to the Upper Laguna Madre.

These preliminary conclusions are tentative and somewhat simplistic. The distinctly different values for both elements support development of a larger project to describe the dominant food sources and investigate the trophic relationships of spotted seatrout, and possibly investigate the pervasiveness of anthropogenic N loading in Texas bays using stable isotopes.

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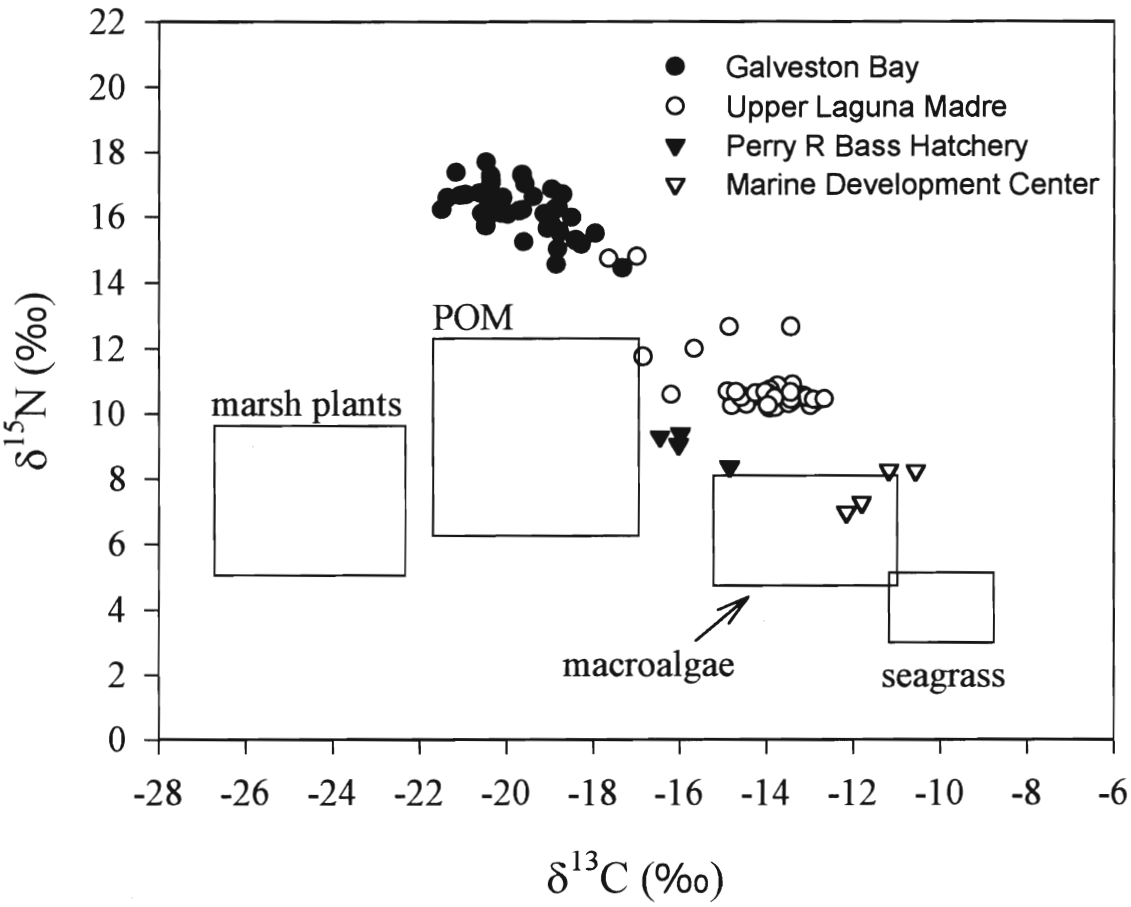

Figure 1. Plot of nitrogen (δ^{15} N) and carbon (δ^{13}C) isotopic composition for spotted seatrout taken from Galveston Bay, the upper Laguna Madre, and two TPW hatcheries. The open squares represent the typical range of carbon and nitrogen isotopic composition values for representative primary producers along the Texas coast (adapted from Hezrka 2000).

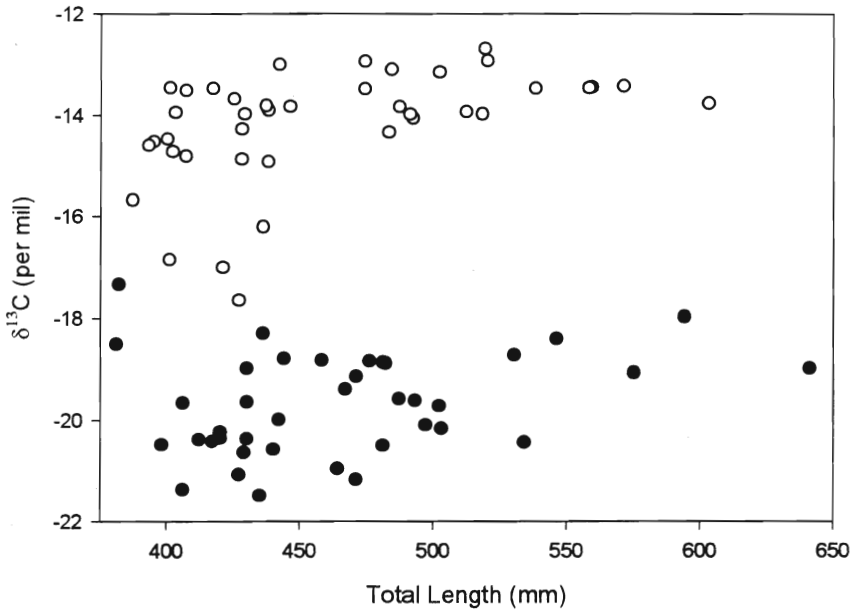

Figure 2. Carbon isotopic composition of spotted seatrout from Galveston Bay and the upper Laguna Madre by total length.

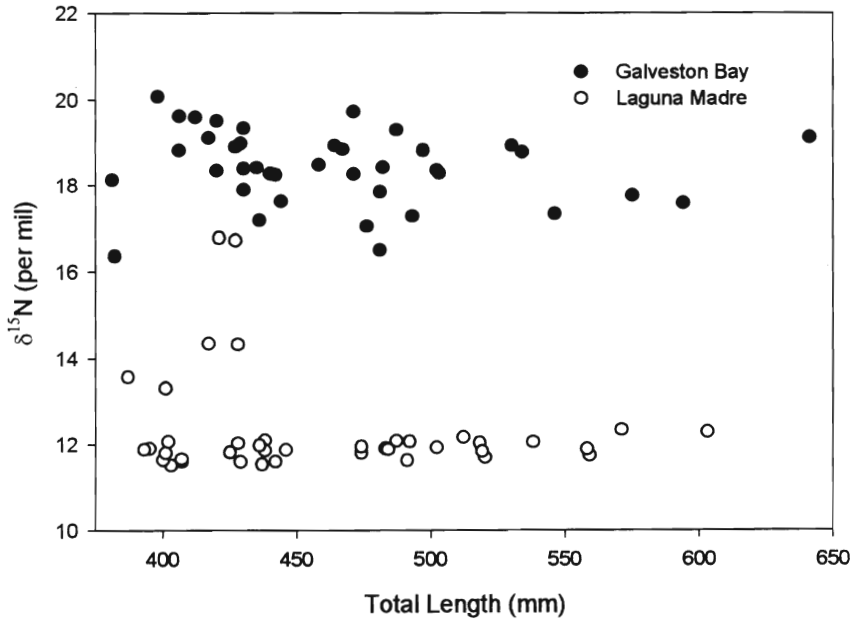

Figure 3. Nitrogen isotopic composition of spotted seatrout from Galveston Bay and the upper Laguna Madre by total length.