# FEEDING BIOGEOGRAPHY OF NORTHEASTERN PACIFIC OPISTHOBRANCHS

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## INTRODUCTION

Long-term longitudinal studies are increasingly becoming recognized as significant in determining biodiversity variations, population extinctions, habitat degradation and conservation priorities. Hendriks *et al.* (2006) state, "We must improve our understanding of how the global ocean ecosystem works in order to design networks of protected areas that effectively preserve biodiversity."

Published studies on opisthobranch molluscs from the northeastern Pacific are primarily taxonomic and morphology descriptions, short-term field and laboratory observations and experiments (e.g., feeding preferences and egg masses), and field guides or regional checklists and range extensions (see Behrens, 2004, Camacho-García *et al.*, 2005, Behrens & Hermosillo, 2005, and Hermosillo *et al.*, 2006, for a summary of, and introduction to, the literature).

## MATERIALS AND METHODS

Three significant long-term baseline studies at Pacific Grove (PG), CA, USA (intertidal, Nybakken, 1974 & 1978), Bahía de los Ángeles (BLA), BC, EUM (subtidal, Bertsch, 2007), and Bahía de Banderas (BB), Jal–Nay, EUM (subtidal, Hermosillo-González, 2006), of opisthobranch abundance and natural history provide the basis for correlating opisthobranch biodiversity differences with ecosystem trophic structures. All 3 studies used the same density/search time index. The BLA and BB regions actually consist of 2 distinct areas with different species compositions (Bertsch, Miller & Grant, 1998, and Hermosillo-González, 2006), hence providing us with 5 latitudinal and habitat zones.

We compared and contrasted the distribution of opisthobranch species abundances according to their feeding preferences from these 5 different NE Pacific locations (Table 1), which span 15° of latitude and the temperate Oregonian and the sub- and tropical Panamic (*s.l.*) Provinces (*sensu* Briggs, 1974, and Keen, 1971). We arranged and correlated the raw data of opisthobranch abundances (a total of 35,189 specimens) with their prey items (herbivores, sponges, cnidarians and bryozoans) and calculated percentages of occurrences (Online Supplemental Material, Tables S 1-4: www.slugsite.us/hans/Hans_Page_01.htm ).

## RESULTS AND DISCUSSION

Abundances by prey preference differ among all sites (Table II). For all 5 orders of Opisthobranchia (Nybakken only reported Nudibranchia; this portion compares the 4 sites in México), the herbivores (36%) and spongivores (34.7%) were dominant at BLA Punta la Gringa/Cuevitas [PG/C]) because of the abundant presence of *Elysia diomedea* (33% of all specimens). Cnidarivores dominated at BB, but bryozoan–feeders (dominated by *Tambja abdere*) and spongivores were, respectively, second in abundance at sites Group 1 and Group 2; bryozoan-feeders were overwhelmingly dominant at BLA Islands, due to nearly co-dominant high numbers of *T. abdere* and *T. eliora*).

Prey preferences for only nudibranchs (Table II) reveal just one abundance change at BLA and BB: the complete absence of herbivores at BLA PG/C, which organisms are "replaced" by spongivores and cnidarivores. At the three sites BLA Islands, BLA PG/C, and BB Group 2, the predominant feeding associations (accounting for over 60% of all specimens at each site) were respectively bryozoans, sponges, and cnidarians. There was a more even distribution among prey preferences at PG (spongivores 43%, bryozoan-feeders 36%), and BB Group 1 (cnidariavores 46%, bryozoan-feeders 30.6%).

The 10 most common species at the 5 sites (note that this is not tabulated in Nybakken, 1974) show latitudinal provincial-level affinities (Online Supplemental Material, Table S-5).

The distribution of species' abundance based on feeding preference varies between all locations, even within the BLA sites and the BB sites. We find no evidence of a consistent latitudinal gradient, except the fact that prey preferences differ in each habitat. In contrast, among the 10 most common species at each site, there are species-level affinities among the faunal provinces (Online Supplemental Material, Table S-5). Seven species occur in both BB Group 1 and Group 2; 5 species are in both BLA

Islands and BLA PG/C, and 3 species are found in both BLA Islands and BB Group 1. *Berthellina ilisima* occurs in all 4 Mexican study sites, and *Phidiana lascrucensis* in 3 of them. *Tambja abdere* is the most common species in both BLA Islands and BB Group 1.

Understanding the eco-evolutionary causes of opisthobranch biodiversity and biogeography requires long-term studies in multiple regions. Generalizations based on our data seem to be limited to each site or habitat; similar analyses from sites in other provincial-level faunal regions are required.

Knowledge of N–S distributional range limits is only the starting point to determine density and abundance patterns. "End-point" range descriptions can be biased by El Niño temperature conditions, which reflect a temporally anomalous climatically-caused distribution pattern (Bertsch, 1993). It should be noted, that the data for BLA, collected over the period 1992–2001, show no abundance variations attributable to the 1997–1998 El Niño event (Bertsch, 2007, and pers. obser.).

Long-term baseline studies have been routinely done for "popular" or highly visible groups of organisms, such as birds, fish, butterflies, corals reefs, etc. (see Bertsch, 2007). We suggest similar research effort for opisthobranch molluscs, utilizing the cadre of sea slug aficionados who are underwater scuba divers and photographers. "Long careful collecting...is necessary before the true picture of the background of life can be established" (Steinbeck, 1951).

In addition to vicariance and dispersal biogeography, feeding biogeography is an important natural selection factor in the evolutionary ecology of Opisthobranchia (Bertsch & Ghiselin, 1985).

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TABLE I: Study Sites and Specimen Densities. References: [1]Nybakken, 1974 & 1978; [2]Bertsch, 2007; [3]Hermosillo, 2006.

| SITE | LATITUDE & LONGITUDE | #SPECIMENS | DENSITY |
|---|---|---|---|
| Pacific Grove, CA, USA[1] | 35° 37' N; 121° 56' W | 4719 | 39.3/hr |
| BLA Islas, BC, MX[2] | 29° 06'–28° 58' N; 113° 26'–32' W | 656 | 12.46/hr |
| BLA Pta la Gringa/Cuev.[2] | 29° 03' N; 113° 32' W | 6088 | 15.08/hr |
| BB, Grupo 1, Jal–Nay[3] | 20° 42'–30' N; 105° 33' W | 7021 | 30.08/hr |
| BB, Grupo 2[3] | 20° 43'–29' N; 105° 14–23' W | 16705 | 32.6/hr |

TABLE II. Distribution of species' abundances according to its feeding preference (%), for the 5 study sites. Key: Br—bryozoans; Cn—cnidarians; He—herbivores; Sp—sponges.

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|---|---|---|---|---|---|---|---|---|
| **Nudibranchs Only** | | | | | | | | |
| Pacific Grove: | Sp | 43% | Br | 36% | Cn | 19% | | |
| BLA Islas: | Br | 77% | Sp | 10.4% | Cn | 8.8% | | |
| BLA LaGringa/Cuevitas: | Sp | 61.1% | Cn | 33.2% | Br | 4.9% | | |
| BB, Grupo 1: | Cn | 46% | Br | 30.6% | Sp | 21% | | |
| BB, Grupo 2: | Cn | 63% | Sp | 31% | Br | 3.4% | | |
| **All Opisthobranchs** | | | | | | | | |
| BLA Islas: | Br | 65.6% | Sp | 8.8% | Cn | 7% | | |
| BLA LaGringa/Cuevitas: | He | 36% | Sp | 34.7% | Cn | 18.9% | Br | 2.8% |
| BB, Grupo 1: | Cn | 40% | Br | 26.5% | Sp | 23% | He | 4% |
| BB, Grupo 2: | Cn | 51% | Sp | 30.5% | He | 5.5% | Br | 2.8% |