



**A continued study on the abundance and population structure  
of the functionally important holothurian *Elpidia minutissima*,  
at the long-term abyssal study site Station M.**

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**ABSTRACT**

Long-term monitoring of abyssal plain epibenthic megafaunal species dynamics is limited to several study sites worldwide. Presented here is a continuation of work that has been conducted at the North East Pacific site Station M, with a focus on the holothurian species *Elpidia minutissima*. This genus's phylogeny, physiology and documented global distribution make it an ideal animal for studying evolutionary and ecological dynamics in deep-sea habitats in the context of on-going temporal monitoring of the local ecosystem parameters.

**INTRODUCTION**

Abyssal plain habitats are primarily depositional systems that rely on sinking organic matter for the basis of heterotrophic metazoan and bacterial food webs (Rex, 2010).

Collecting sufficient temporal data on major functional metazoan taxon within these ecosystems, in conjunction with appropriate ecosystem parameters is notoriously difficult to conduct due to logistical constraints; as such current insights on community dynamics of dominant epibenthic animal phyla are limited to two major study sites world wide, Station M in the N.E. Pacific and The Porcupine Abyssal Plain in the N.E. Atlantic. Station M is characterized by, silty clays, low bathymetric variance, and an average depth of 4100 meters (Drazen, et al., 1998). Work at Station M provides the temporal component necessary to elucidate long-term trends in dominant mobile invertebrate megafauna as well as key components of the infauna in the context of basin scale temporal abiotic process and organic flux measurements Ruhl and Smith, (2004) presents a comprehensive study of both the dominant megafauna and ecosystems parameters from 1989 – 2002, at station M. This work suggests increasing correlation of various species representative of local megafauna, to decreasing scale hierarchical ecosystem parameters including; ocean basin climate indices, regional upwelling indices and above bottom site specific particulate organic carbon (POC) flux. Ruhl, (2008) gives further resolution on community shifts in the ten most dominant epibenthic megafauna, primarily holothurians, through tracking overall abundance and dominance of these species, body size frequency for each; in relationship to POC flux and time.

The selectivity for non-echinoderm prey items by two of the locally prevalent omnivorous Macrourid fishes (Drazen et al., 2008), during periods of varying abundance of dominant holothurians as well as *Elpidia m.*, indicates that top down predator control of holothurian populations is minimal or of low impact. This study supports similar conclusions in that are found in the primary expeditionary literature.

Holothurian's as a class specialize in detrital feeding, and comprise a majority of abyssal and hadal megafauna. (Torben Wolff, 1952) (Belyaev, 1972). Extrapolation of activity patterns, areal coverage, and abundances by Kaufman & Smith (1997) suggests that several specific, and locally occurring holothurians have the ability to rapidly turnover the top layer of sediment and redistribute organic material, and therefore are important functionally components in abyssal habitats, and at this site. *Elpidia m.*, despite its relatively small individual footprint, ranks third in total net impact, when considering

high abundances and activity patterns it accounted for approximately 22% of total areal coverage of the species examined. Research by Jamieson et al. (2011), indicates that a congener in hadal environments shows similar activity and abundance patterns despite the obvious differences in depths.

The genus *Elpidia* belongs to the order Elasipodia. The order is ubiquitous in abyssal habitats and has the highest percent dominance of all species of holothurians at bathyal and abyssal depths. They exhibit a suite of specialized adaptations and unique traits: reduced ossicles size and presence, often resulting in the absence of a true test, specialized ventral podia which allow for increased movement across the sea floor, sail like projections, and above bottom swimming behaviors. (Torben Wolff, 1952), (Hyman 1955). The taxon is defined by the absence of respiratory trees and mesentery with dorsal attachment throughout the length of their bodies, which has been suggested as physiological adaption for efficient method of oxygen transfer to the intestine, and/or as a mechanism that keeps the intestines out of contact of the body wall and does not interfere with the movement of the animal's body contraction and use of specialized locomotive ventral podia (Lawrence 1987). Species of the genus *Elpidia*, are an especially interesting model group because of their high level of basin to regional endemic nature, their relatively restricted intestinal diameters occupying a small percentage of their body cavity, and distribution to areas with pulsed or seasonal food supply (Torben Wolff, 1952).

The goal of this project was fill in species abundance and body length frequency data in order to provide baselines to further examine the correlation between species specific dynamics to larger global environmental change (Smith et al., 2009).

Secondly the data is presented here, to document the beginning of an upward shift and possible return in abundance of *Elpidia m.* to pre 1996 abundance levels to illuminate the possibility that decadal and inter-annual variation in food availability and type can suggested as a possible mechanism of diversification/speciation in abyssal plain habitats of endemic genus representative of the ubiquitous deep-sea Elasipodia.

## MATERIALS AND METHODS

### Video Transects and VARS

Transects were conducted on the R/V Western Flyer utilizing the ROV vehicles Tiburon or Doc Rickets as part of the continued monitoring of Station M, at varying time intervals, depending on logistical constraints, from late winter 2006 to summer 2012. (Table 1). All transects from this period were sampled within a 2 by 3 kilometer rectangular area that only varied in depth by a total of 15 meters (data collected from ROV). Multi day cruises were conducted where 1-3 dives were made. Transect dives were not always feasible, and errors in appropriate navigation data, or ROV deviation from auto-pilot control could be limiting. All data was collected utilizing VARS (Video Annotation Reference System), the proprietary system developed within MBARI. ROV transects allowed for measurements of length for each animal using 29 cm reference ladders. Measurements were made from the anterior to posterior end of the body axis of the animal, excluding anterior feeding tentacles, in line with previous measurements by Ruhl (2007). The calculation of length measurements was made utilizing VARS video to JPG capture and measurement tools. Animal lengths were assigned to 5mm bins. Linear calculations of possible measurement errors based on pixelation of images, and cryptic nature of animals supports this size designation.

### Analysis of data

Density estimates were extrapolated by fitting video transects to strip transect theory in concurrence with required assumptions for accurate sampling (Buckland 1993). Effective total width of the transects was set at one meter for analysis assuming that no truncation was needed, (half normal model) such that no loss of detection occurs in the one meter width of viewable transect, this also assumes that any fluctuation in width of transect over the length of the transect cancels to 1 meter. ROV transects are conducted to best maintain a 1 meter width visual field.

When more than one transect was conducted within one cruise, i.e. one time period, combination of multiple transects into one, were taken for densities based on length of total effective transect (TABLE 1). It is important to note that when multiply

transects were conducted in situ, they were completed such that they best replicated a single continuous line.

Length frequency data and abundance data could not always be gained from the same transects due to previously mentioned logistical constraints. For periods of low abundance weighted body size medians were computed for the median date of those individual temporal sampling events. (TABLE 2)

Two specimens of *Elpidia m.* were collected near the end of the most recent transect (6/12/12), and were later analyzed via stereo-microscopy for general descriptive characteristics. Detailed images were taken of dendrite feeding tentacles, oral openings, ventral surfaces, and whole specimens, although those images are not presented here.

## RESULTS

**Table 1:** Abundance Transects: sequential dates, number of animals, effective transect length and calculated densities of animals per time period. When dives were repeated for multiply days they were combined into one effective transect.

	12/13/06	2/3/07	6/13/07	9/22/07	5/24/11	11/17/11	6/12/12
<b>N</b>	1	0	4	1	770	1009	187
<b>Transect Length M</b>	1130	235	500	455	4700	1220	400
<b>Density M<sup>2</sup></b>	0.0009	0	0.0080	0.0022	0.1638	0.8271	0.4675

### Abundance

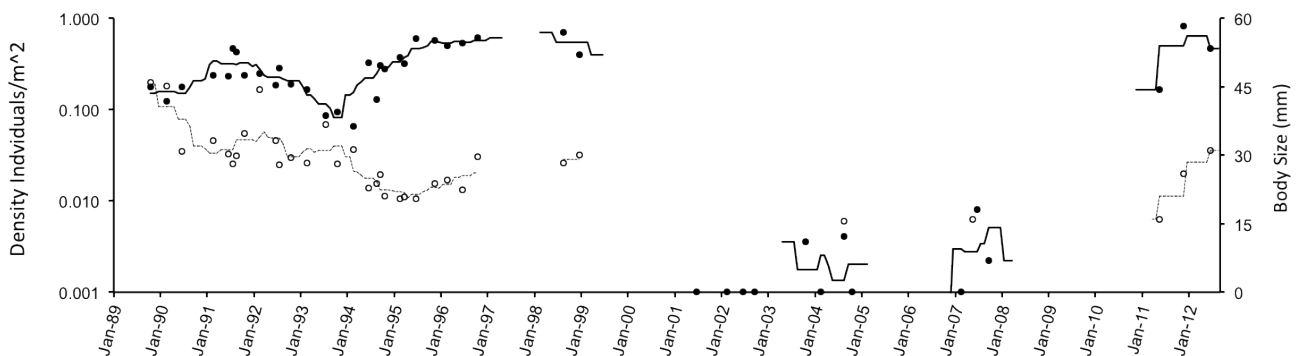
Table 1 gives a summary of measurements for all density estimates used here. There was a prolonged period of low abundance from spring 2001 until fall 2007 followed by a marked increase in densities by the spring of 2011 (FIG 1). The rapid increase in density from spring 2011 to fall 2011, a five fold increase in under 6 months, is repeated only once in the time series from late winter 94' to late summer of that same year, and the density during fall 2011 is the highest recorded in the time series by 0.12 animals per m<sup>2</sup> (FIG 1). The increase between fall 2007 and spring 2011 is a three-fold increase per 6 months. The decrease from fall 2011 to summer 2012, is a halving of abundance in 6 months (FIG 1). The cumulative median calculated for the multiyear

period of low abundance (12/13/06----9/22/07) was 16 millimeters, which differed from individual and non-weighted median calculations by no more than 2.5 millimeters.

**Table 2:** Time periods for length frequency measurements, season and year are used here to indicate where time periods were combined (winter 2006-winter 2007). All Low Abundance is the combination of winter 2006-2009.

	Winter 2006	Summer 2007	Fall 2007	Winter 2009	All Low Abundance	Spring 2011	Fall 2011	Summer 2012
N	16	4	16	22	58	709	1003	171
STD (mm)	8.5	4.4	7.8	4.3	6.8	8.5	6.5	10.2
MEAN (mm)	18.6	11.5	19.4	16.8	17.7	17.9	25.8	32.3
MEDIAN (mm)	16.5	10	18	16	16	16	26	31

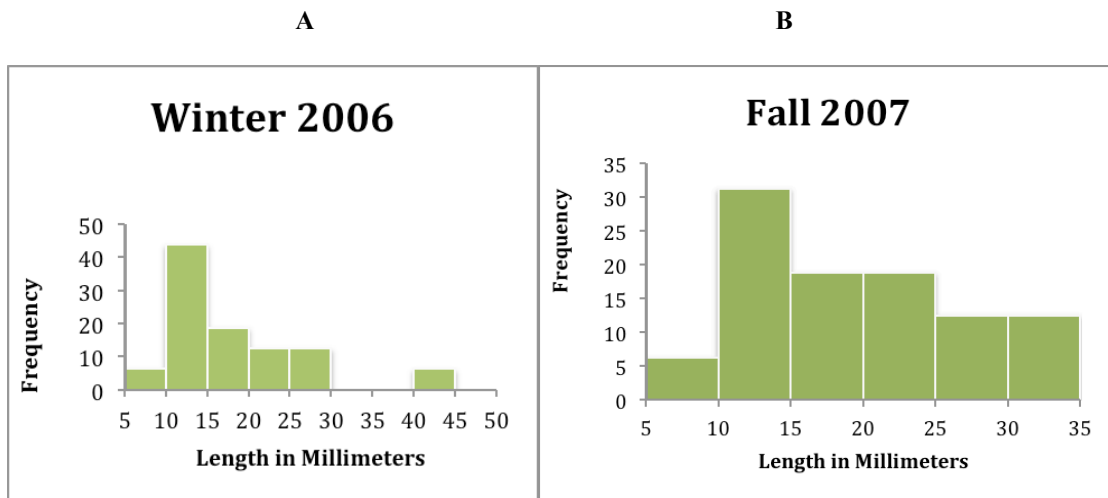
**Figure 1:** Abundance (log scale) and body size of *E. Minutissima*. From this project post JAN-06, incorporated with previous work by Henry Ruhl and the Smith Lab. Solid circles and thick solid lines are monthly (for Ruhl data set only) abundance estimates and 3-Month running means and open circles and thin broken lines are 13 month running means. (Courtesy Smith Lab)

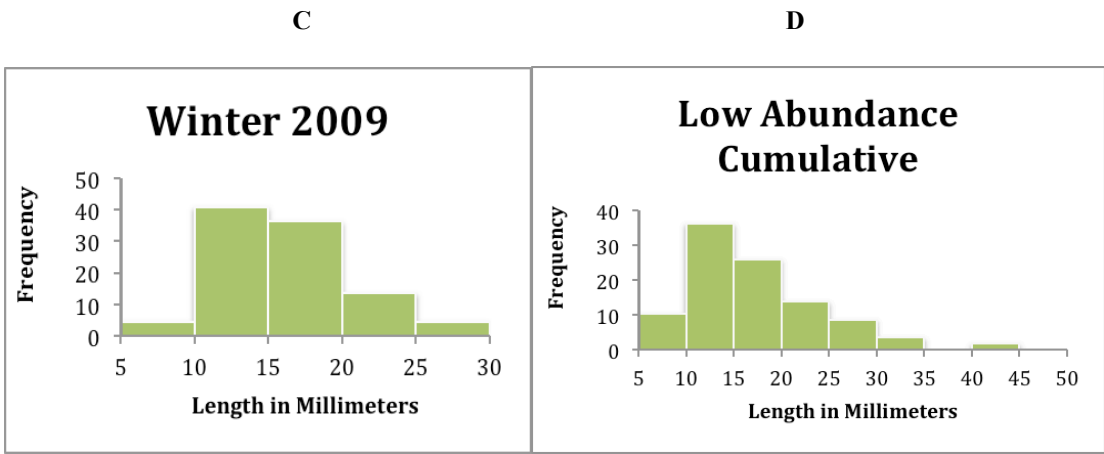


## Length Frequency

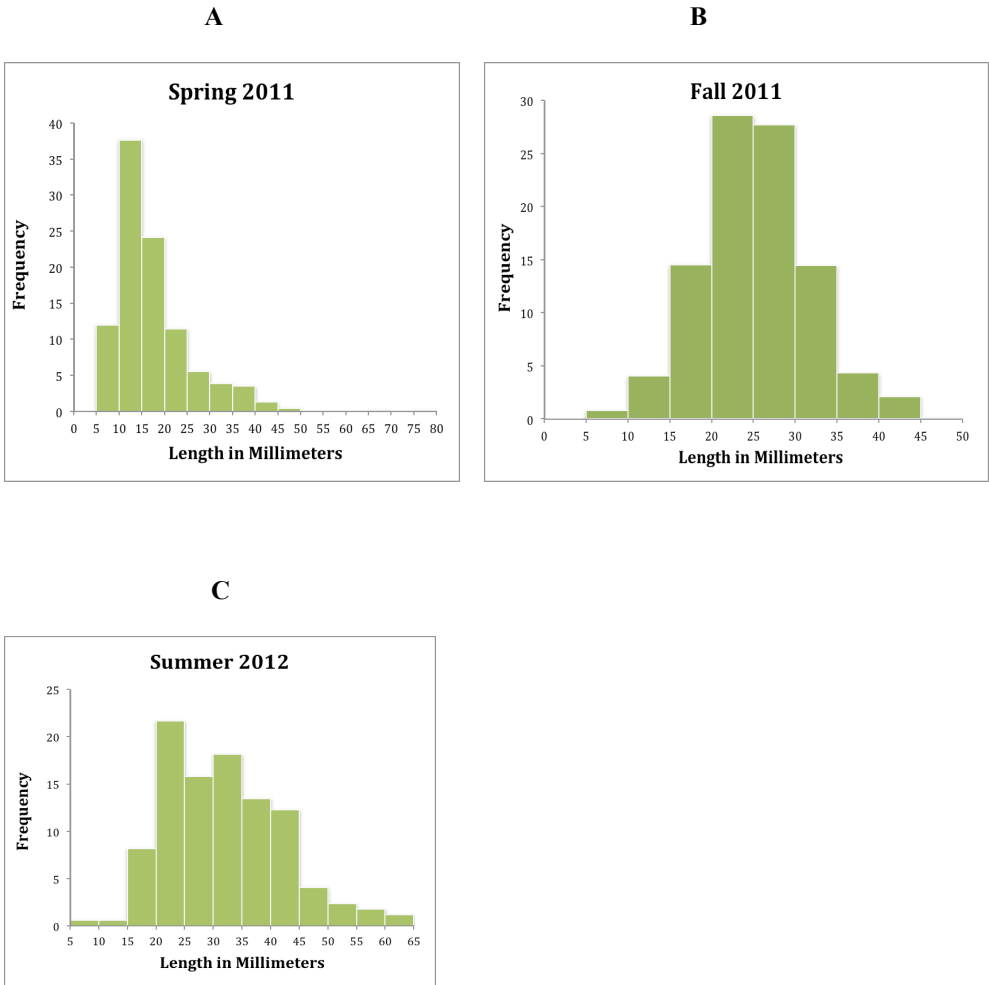
The histograms for the periods of low abundance are marked by a small sample size for each time period sampled (TABLE 2). They tend to show a similar population distribution all with the highest frequency size bins below their respective means and medians at the 10-15 mm range. (FIG 2 A-C). The relative similarity in structure between the periods of low abundance is summarized in the cumulative histogram (FIG D). The low sample size for each of these time periods is presented in Table 2. The difference of 6 months between the sampling points makes tracking size cohorts difficult. What is most distinct is the change from a dominance of a small size animals, left weighted distribution at the beginning of the abundance increase, to a normalized distribution at the highest peak in abundance, followed by a left weighted lateral expanded, but close to normal distribution as the abundance fluctuates downwards.

**Figure 2** A-C: Relative frequency histograms body size classes of the three periods of low abundance. 2 D is the cumulative histogram of the four time periods of low abundance.





**Figure 2 A-C:** Relative frequency histograms body size classes of the three periods of high abundance.





#### Specimen collection

The two specimens collected at the last sampling period had four dorsal podia and four ventral podia, with the rear (aboral) ventral pair of podia  $\frac{3}{4}$  length of the forward 3 pairs. Gut length was roughly 40 mm and 2 mm in diameter. Close to total length of each animal. 1<sup>st</sup> (oral orientation), ventral podia was close to 5 mm long in both animals, ossicles were examined but no resolution on size or scale was made with available measurement tools.

#### **DISCUSSION**

Specimens collected offer no clear resolution, on exact species designation. The expeditionary literature describes *Elpidia minutissima* from specimens taken in the Aleutian trench as averaging 13 mm in length with only three pairs of dorsal podia. The number of dorsal podia on the collected specimens, four, matches the general observations of the vast majority of animals seen on video-tapes (close to 2000). Dorsal podia are a traditional descriptor in this genus, yet they are a more plastic characteristic at higher taxa, and rank below ossicles as a species descriptor. Ruhl, (2004) shows increase in mean body size across holothurians as abundance decreases. Secondly the variation in mean body size collected in this study discourages use of body size, without environmental context, as a key descriptor. Finally as the most similar species described in the literature, to samples collected here is described from samples in the South West Pacific, and the Antarctic, it seems prudent to continue calling this species *Elpidia minutissima*, whether or not is in fact a different species. As no bimodal size distribution occurs in length frequency measurements taken for this project, nor in previous records of this time series, the methods described here do not give the resolution needed to decipher useful insights on any presence of morpho, sub species, or closely related species of this genus at this study location. It seems what was called *E. Minustimma* for beginning of this study is most likely a single species.

As this project is a different methodology to what was done for the first part of the time series, there are two areas that should be addressed. Transect length: possible error is most apparent in the latest measurement (06.12.12) where the transect length was only 400 meters, where other transects in time periods of high abundance were conducted for 1 km or higher, in conjunction with the transects from the previous studies (Ruhl 2008). The error in using smaller transects may approx. + or - 0.01 individuals per  $m^2$ , based on the observed differences between calculation of abundances per non-combined transects versus combining all transects for the fall of 2011.

Methodology: the loss function was considered one and most likely video screen viewing did not produce any loss in detection. Further study should test the variability of transect width, as this is where significant errors in density measurement could occur. Errors in measurement in abundance estimates may not be significant in the larger context of fluctuations in population abundances, as the most important comparison in a larger temporal context is shifts from low to high abundances at inter-decadal to decadal time scales. But should be considered in future correlative analysis of POC flux and climate indexes.

The decadal fluctuation of the density's of *Elpidia*, is best understood in the context of fluctuating POC, and with the basin decadal scale environmental variability to climate variation, i.e. El Nino and La Nina. The increase from the period of low abundance to extremely high abundance, with a subsequent drop, describes a pattern which indicates the species was approaching its carrying capacity passed it and is returning to a less intense oscillation.

Despite the very clear differences in population structure between the periods of low abundance and high, difficulties arise in trying to determine what the population structure means for this animal because comparatively little is known about its life span or reproductive habitats. It may be that small size classes represent a net input of larval settlement, or it may be that the relative stable size structure of the population indicates a form of stasis in the population structure where animals are not able to consume the resources needed for growth or reproduction. As for reproductive capability, the best guess is that this species is a pelagic lecithotroph based on the occurrence of 250

um - 280um lecithrophic eggs in a congener (possibly juvenile) taken from cold-water Greenland fords (Young 1994). If this is true it may lie some where in the middle of the spectrum of planktonic to brooding that is represented in this phyla. This coupled with the relatively small but body sized mediated feeding apparatus and intestine length give some insight into the size fluctuations associated with a growing population structure.

Based on the observations presented in this study and the large body of work on gelatinous holo-plankton of multitude of distantly related taxa, i.e. salps, medusa cnidarians, ctenophores, pelagic polychaetes, etc. It is worth mentioning a possible evolutionary trend than can be inferred by this animals physiology and possible response to environmentally variation; It may be that decreased internal organ structure (especially absence of respiratory tree), do to above sediment lifestyle and physiological adaptations to moving across the abyssal plain and respiratory diffusion through integrated water-vascular system and thin dermis, (Gould & Lewontin, 1979) may have allowed more flexibility in body plan that is apparent in the elasipoids, and provides the phylogenetic inertia for the adaptive radiation of this order of relatively soft bodied animals in abyssal plain environments.

Directed response to food variability at both seasonal and decadal pulsation through more efficient resource allocation and greater body plan plasticity as an indirect requirement of proper gas diffusion, and more flexibility in body plan suggests a commonality of convergent evolution, in which a body structured primarily around the aqueous medium in which these metazoans live propagates diversity in coupled oceanic abyssal habitats that are defined by fluctuations in the dominant environmental resource. Therefore this organism in this environment, seems to present an example of the potential of a novel Baupläne radiation in the context of dominant environmental forcing.

## **CONCLUSIONS/RECOMMENDATIONS**

For this population of animals there exists an obvious decadal fluctuation of abundance in this upwelling abyssal plain ecosystem. Further analysis of other holothurians is need to see if this species is representative of the ecosystem as a whole, as

the time series progresses and if this can be correlated to the POC Flux, localized upwelling indices and the NOI index. Population size structure differences in periods of high and low abundance could use further analysis as these temporal dynamics could represent a selective force which could explain sympatric speciation in abyssal plains.

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