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A year in Barkley Canyon: A time-series observatory study of mid-slope benthos and habitat dynamics using the NEPTUNE Canada network

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ABSTRACT

Understanding long-term trends in species abundance and distribution represents an important challenge for future research in the deep sea, particularly as management of human impacts becomes a more important concern. However, until natural higher frequency variability is better understood, it will be difficult to interpret any long-term trends that may be apparent in data sets. We present here the results of the first year of observations at the NEPTUNE Canada cabled observatory site in Barkley Canyon, off the coast of Vancouver Island, in the northeast Pacific Ocean. Presence/absence and abundance data for 28 faunal groups were extracted from daily video records from an observatory camera. Concurrent CTD and current meter data were collected from co-located instruments. Water mass properties, currents and faunal community composition exhibited notable seasonal trends. Distinct seasonal faunal groupings were observed, together with summer and winter trends in temperature, salinity and current patterns. Variations in abundance of decapod crustaceans and fishes were responsible for most differences between faunal groups. We suggest that faunal composition may have been responding to seasonal variations in food availability, together with direct and indirect physical influences on predator and prey abundance.

1. Introduction

The study of deep-sea benthic ecosystems has traditionally relied on the collection of data and physical samples by oceanographic vessels and submersibles (Thiel et al., 1994). Ship-based surveys have been essential to the development of our understanding of the biodiversity and distribution of deep-sea organisms, culminating in the recently completed Census of Marine Life. Knowledge of processes that shape and change deep-sea benthic communities has advanced at a slower pace. Several studies have reported long-term, inter-annual trends in species composition and abundance (reviewed in Glover et al. (2010)), but causation is difficult to determine without experimentation or continuous observation. Deep-sea ecosystems are subject to a variety of environmental influences from cyclic phenomena such as tides, to disturbances acting at multiple temporal and spatial scales. These influences act on biological processes at corresponding time scales. Semi-diurnal tides are known to affect the behavior and activity of fishes and benthic invertebrate species (Aguzzi et al., 2011a). Over several days, benthic storms, generated by changes in current structure or biological activity can resuspend sediment, which in turn can affect biogeochemical exchanges at the sediment–water interface (Thistle et al., 1991; Yahel et al., 2008). Seasonal scale variations in organic matter input from the surface ocean control food availability for deep-sea benthic organisms and influence reproductive cycles (Billett et al., 2010). At decadal scales, variations in environmental conditions related to phenomena such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO; Blanchard et al., 2010) may cause changes in species abundance, as may changes in ocean climate related to global warming. Understanding decadal and longer-term trends in species abundance and distribution represents an important challenge for future research in the deep sea, particularly as management of human impacts becomes a more important concern. But until natural higher frequency variability is better understood, it will be difficult to interpret any long-term trends that may be apparent in data sets (Smith et al., 2008).

Variability in particulate food input from the photic zone is an important driver of seasonal and longer-term change in deep-sea benthos. Surface productivity and related food supply are widely studied in deep-sea ecology and have been shown to shape benthic communities from the continental slope to the abyssal plain, including submarine canyons (Cunha et al., 2011; Billett et al., 2010; Leduc et al., 2012). Much of our understanding of seasonal variability in deep-sea faunal communities comes from work at long-term study sites such as Station M in the eastern

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North Pacific Ocean and the Porcupine Abyssal Plain in the North Atlantic, where researchers have used a combination of seasonal sampling and autonomous instrument platform deployments (Gage and Tyler, 1992; Smith and Kaufmann, 1999; Billett et al., 2001; Ruhl and Smith, 2004). These studies have identified seasonal variations in the quality and quantity of food imports and some temporal trends in faunal composition and abundance (Billett et al., 2010). However, literature contains few integrated studies that examine the influence of multiple environmental variables on the composition and abundance of deep-sea benthos (Mamouridis et al., 2011). Some progress in understanding the relationship between multiple habitat variables and faunal properties has also come from habitat mapping studies that use cameras to examine megafaunal distribution in relation to environmental factors (Buhl-Mortensen et al., 2012).

Time series observations can also be used to study the influence of multiple environmental variables on benthic communities in the deep sea. The recent development of cabled seafloor observatories, with real-time communications and 'unlimited' power capabilities is providing new opportunities for time-series studies of deep-sea ecology. Cabled observatories are being established or are currently in operation in several areas of the world ocean. Some have seismic or single discipline missions while others are multidisciplinary. The NEPTUNE Canada and VENUS networks, operated by Ocean Networks Canada, are examples of multi-disciplinary cabled observatories that support the simultaneous observation of benthic fauna and habitat variables. In their first months and years of operations, continuous imagery and data from these networks have been used to study seasonal and higher frequency variability in benthic ecosystems (Matabos et al., 2012; Aguzzi et al., 2011b; Matabos et al., in preparation). As observatory data accumulate, high-resolution studies of longer-term trends will become possible.

The NEPTUNE Canada (NC) cabled undersea network, off Vancouver Island, Canada supports continuous observations of faunal and habitat variables at several deep-water sites. Instrument platforms connected to the NC network have been recording daily data and video imagery since May, 2010. The pilot study presented here examines the first complete year (2011) of data from a NC site in Barkley Canyon (800–1000 m depth), a submarine canyon that incises the continental shelf off Vancouver Island. The NC community science experiment in Barkley Canyon was designed specifically to study benthic-pelagic coupling in a submarine canyon, mid-slope setting. The primary goal of this study was to develop baseline knowledge of the seasonal dynamics of the benthic faunal communities inhabiting the Barkley Canyon site and to explore their relationship to environmental factors over an entire year. A companion study (Matabos et al., in preparation) examined hourly-scale variability in habitat and faunal properties at this same site, during the month of December, 2011. The specific goals of this study were to:

(i) identify temporal patterns in the composition of the epibenthic megafauna from daily video observations,
(ii) quantify variability in the physical environment using continuously recorded data, and
(iii) examine relationships between physical processes and observed biological patterns.

Previous studies of seasonal and inter-annual variability in megafaunal composition and abundance in the deep ocean and on continental shelves and slopes have used sample data and imagery from camera tows or time-lapse camera deployments. At abyssal depths echinoderms, especially holothurians, are known to exhibit substantial temporal differences in abundance and biomass (Billett et al., 2010; Lauermann and Kaufmann, 1998), whereas abundance changes of more mobile organisms such as fishes and crustaceans appear to be the most prominent feature of megafaunal dynamics on continental shelves and slopes (Sardà et al., 1994; Moranta et al., 2008; Aguzzi et al., 2009; Papiol et al., 2012). We therefore hypothesized that these latter groups would dominate seasonal scale changes in abundance of the Barkley Canyon megafauna, and that these changes would be related to seasonal shifts in water mass properties that could be measured by the in situ instruments at this site. Waters off Vancouver Island, as elsewhere along the northwest coast of North America, are influenced by summertime northerly winds that cause intermediate depth, oxygen-depleted water that lies along the continental slope, to upwell onto the shelf, particularly through submarine canyons (Hsieh et al., 1995; Keeling et al., 2010).

2. Methods

2.1. Study area

The NEPTUNE Canada Barkley Canyon node supports four instrument arrays (sites): an upper slope site outside of the canyon (396 m depth); a mobile, tracked instrument platform in a gas hydrate field; a pair of instrument platforms near the base of the north wall of the canyon (890 m depth); and a single platform in the canyon axis (Fig. 1). Each instrument platform carries a suite of instruments for environmental and biological data acquisition (Table 1). This study used data acquired by the paired platforms (Pods 3 and 4), which were installed in May, 2010. Several previous studies have documented the physical oceanography and biological productivity of the water column in and around Barkley Canyon (Freeland et al., 1984; Thomson and Allen, 2000; Allen et al., 2001).

Instruments are maintained once a year; during this study Pods 3 and 4 were lifted to the surface, cleaned, failed instruments swapped, and redeployed at the same location. Environment Canada maintains a surface meteorological buoy on La Perouse Bank, located NNE of the Barkley Canyon study area.

2.2. Data collection

Data from all instruments are archived and available online in near real-time using the Oceans 2.0 software interface (dmas.uvic.ca). The cameras can be operated by investigators from shore or set on automated schedule. All videos and still imagery are archived and available through Oceans 2.0. Temperature (°C), salinity (psu), density, pressure (dbar), chlorophyll fluorescence, and turbidity were acquired by instruments deployed on the canyon wall benthic platforms at 890 m depth (Table 1). The two platforms were separated by 70 m. Each instrument sampled at a rate of one measurement per minute. An upward-looking 150 kHz ADCP provided information on water column currents.

Images were collected using a 470 Line ROS Inspector low light, color camera, equipped with an 18 × optical zoom. A pan/tilt unit allowed complete coverage of seafloor (± 90° Tilt and ± 180° Pan) and light was available on demand from two Deep-Sea Power and Light variable intensity lamps.

Following a commissioning phase, data acquisition from this site began in December, 2010 and continued until the camera failed in January, 2012. A replacement camera was installed in June, 2012 but not used in this study. Videos were recorded daily, except during the maintenance cruise (8–27 July, 2011). Since the camera was being tested by several research projects, there was no standardized image acquisition protocol during this first year. The length of video records varied from 9 s to 1 h and 57 min in the period from December 29, 2011 to January 2, 2012. Some videos included a full sweep of the area, while for others the camera remained in a fixed position. Zoom level was also variable over the