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Diel behavioral rhythms in sablefish (*Anoplopoma fimbria*) and other benthic species, as recorded by the Deep-sea cabled observatories in Barkley canyon (NEPTUNE-Canada)

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ABSTRACT

Recent advances in cabled observatory video-imaging now enable faunal monitoring over extended periods of time. These platforms can be used to avoid biases in population and biodiversity assessments due to behavioral rhythms (i.e. massive population displacements). In this study we used video monitoring to examine the interplay between day–night and internal tidal cycles in regulating the behavior of sablefish (also referred to as black cod; *Anoplopoma fimbria*), hagfish (*Eptatretus* spp.) and crabs. We counted the number of animals in 50 s video-recordings taken at 30 min intervals with 3 NEPTUNE-Canada cameras located in Barkley canyon at approximately 1000 m depth (one in the axis and two on the wall of the canyon). Current data just above the seafloor was recorded as an indicator of the local internal tidal regime. Chi-Square periodogram analysis did not show significant ($p < 0.05$) day–night or tidal-based rhythms for the three species. The same analysis conducted for the sablefish (i.e. the most abundant) at each camera separately revealed different and significant ($p < 0.05$) 12- and 24-h based periods. Waveform analysis for these time series showed a temporal phase shift among cameras, suggesting diel displacements within the canyon axis. Our results highlight how some Deep-sea fish may present diel rhythmic displacements along canyons according to the day–night and internal tidal temporization. In this context, bathymetric networks of cabled video-stations can be an effective sampling tool to monitor this kind of behavior.

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1. Introduction

The deep sea is the vastest ecosystem on Earth, with depths below 200 m representing 65% of the total surface of the planet (Ramirez-Llodra et al., 2010), but faunal exploration is still at its early stages (Gage and Tyler, 1991; Jamieson et al., 2010; Yeh and Drazen, 2009). As a result of technological advances, new observational tools provide important data on faunal composition and behavior of species residing in different Deep-sea benthic ecosystems such as canyons, cold seeps and hydrothermal vent fields (Glover et al., 2010). Traditional sampling methods such as trawling are progressively being replaced by direct means of visual observation. Imaging systems on technological platforms can be broadly subdivided into mobile (i.e. Remotely Operated and Autonomous Underwater Vehicles — ROVs and AUVs), semi-fixed (i.e. deployable landers with different degrees of temporal autonomy), and fixed (i.e. cabled observatories) systems (reviewed by Aguzzi et al., 2012a).

While mobile and semi-fixed platforms allow higher spatial coverage with a reduced observational frequency, the reverse is true for cabled observatories. These platforms are bearing new video-imaging based technologies and other habitat sensors that are providing a new horizon of data collection on the ecology of Deep-sea species, especially in relation to behavior. For example, recent studies with video-imaging systems installed on cabled observatories are showing the occurrence of population activity rhythms at a diel (i.e. 24-h based) scale in the aphotic deep sea (reviewed by Aguzzi et al., 2011). Unexpectedly, these rhythms seem to be ruled by both internal tidal and inertial (i.e. atmospheric driven) currents (Aguzzi et al., 2010). These data are promising from the perspective of chronobiology (i.e. the science that studies biological rhythms), since they are extending our knowledge of the biological clocks of marine species from shallow waters to the deep sea. In addition, these data will allow quantifying potential sampling-related biases in our perception of marine communities' composition (Naylor, 2005). On the other hand, variations in the rate of activity of Deep-sea

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animals may in turn affect the chance of observing a species at any given location (Bahamon et al., 2010). Massive population displacements occur in benthic and pelagic taxa at different strata depths of the water column and the continental margin, in response to regulatory mechanisms and changes in habitat conditions that are still poorly described (reviewed by Naylor, 2010).

In Deep-sea species, the study of rhythmic behavior at diel scale requires coupled acquisition of videos/images and environmental parameters at high frequency, over larger periods of time. In this study, we used three Deep-sea NEPTUNE-Canada cameras located within the Barkley canyon at aphotic depths, in order to study the rhythmic behavior of sablefish (*Anoplopoma fimbria*) and other abundant and video-discernible species. For the sablefish, we also explored the use of such video-technology for the measurement of class-size frequency distribution as a replacement to more destructive and traditional sampling systems (i.e. trawling or creeling). Finally, we attempted an evaluation of biasing errors in animal counting due to intermittent illumination exposure during image acquisition.

2. Material and methods

The North-East Pacific Time-Series Undersea Networked Experiments NEPTUNE Canada (www.neptunecanada.ca), as part of the Ocean Networks Canada Observatory, located off Vancouver Island (British Columbia, Canada), is currently one of the most advanced technological multiparametric cabled platforms for Deep-sea ecological studies (Barnes et al., 2011). Its deployment occurred within a strategic global effort for the continuous and prolonged monitoring of Deep-sea communities and associated oceanographic dynamism (Priede and Solan, 2003). Installed sensors allow linking animal behavior (and hence rhythms) with concomitant habitat variations. The network includes five main nodes deployed at different depths (Fig. 1) within a diversified set of geologically active and ecologically relevant sites, including a submarine canyon (Barnes and Tunnicliffe, 2008). These nodes are powered and linked together by over 800 km of electro-optic cables, covering part of the Juan de Fuca plate (Northeast Pacific).

2.1. Cabled network specifications

Synchronous videos were acquired using three different instrument platforms in the Barkley canyon area. POD 1 was located in the canyon axis (latitude: 48°19.0027′N, longitude: 126°03.0077′W, depth: 987 m), while POD 3 (latitude: 48°18.9052′N, longitude: 126°03.5252′W, depth: 892 m) and POD 4 (latitude: 48°18.8923′N, longitude: 126°03.4804′W, depth: 896 m) were located on the canyon flank (at North West of POD 1), in the vicinity of an outcropping gas hydrate field. Horizontal reciprocal distances of these platforms, knowing their coordinates were: POD1–POD3, 670 m; POD1–POD4, 675 m; and finally, POD3–POD4, 50 m.

On POD 1 images were acquired with a black and white Multi-Sea Cam 1060 low-light (0.01 lx) video camera. POD 3 bore a 5 Megapixel Axis P1347 color network camera. POD 4 was equipped with a 470 Line ROS Inspector color zoom low-light camera equipped with a 10× optical zoom. For all cameras light was available on demand from two 100 W bulbs (Deep-Sea Power&Light) with adjustable intensity. Two 10 mW red lasers provided a 10 cm separation scale to the video-images.

In order to link activity rhythms to internal tides, oceanographic sensors on Pod 1 were used to represent the three different study locations. A high resolution bottom-mounted upward-looking 2 MHz ADCP was used to determine the near sea-floor currents. Current velocities from a depth 20 cm above the seabed were harmonically analyzed for the significant tidal constituents (i.e. K1, M2, N2, and S2).

2.2. Data acquisition and time series processing

We acquired 50 s duration videos in MP4 format at 30 min intervals over a month (12:00 on 14th October to 00:00 on 14th November, 2011, Canadian local time). The cameras were fixed in a downward orientation at 45° in order to record a constant field of view of approximately 2 m^2 of seabed.

Observed animals were classified according to the lowest taxonomic level possible using the NEPTUNE-Canada Faunistic Guide (Gervais et al., 2012). For each video-segment, we recorded the number of individuals of the most abundant and discernible species (i.e. depending on the resolution of the camera and the distance from the camera lens). In those time intervals where videos were missing because of technical problems, we replaced data gaps with a 3-step moving-average (i.e. by averaging the values immediately before and after the gap). That procedure was used since periodogram analysis (see below) requires continuous data collected at a constant sample interval (Refinetti, 2006).

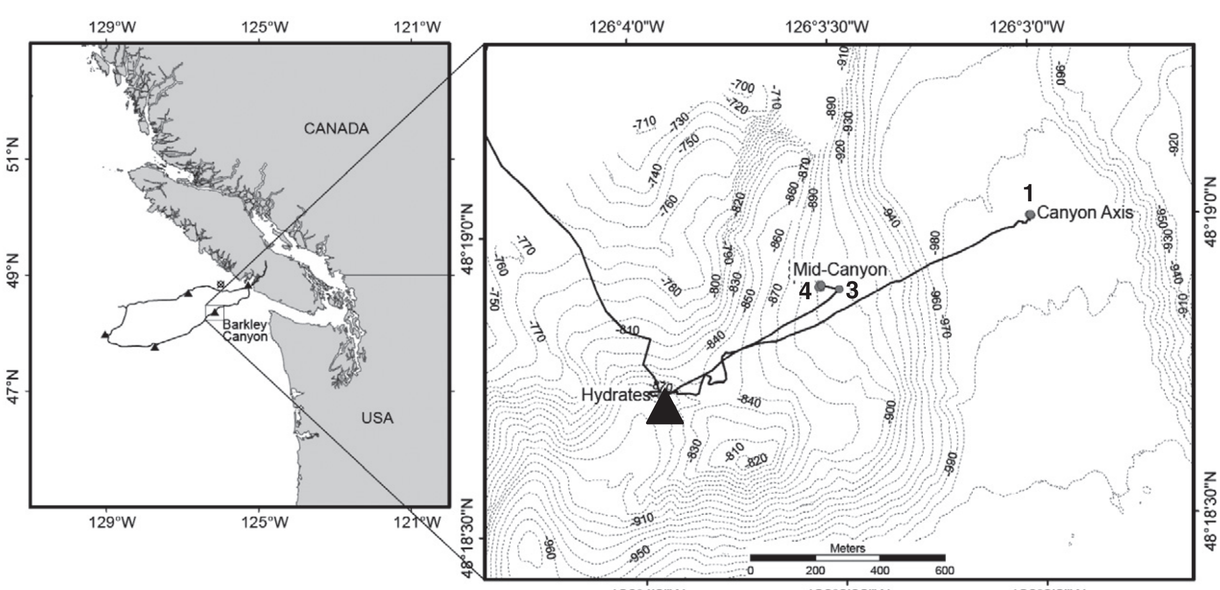

Fig. 1. Coarse bathymetric map of the Barkley canyon site, showing the locations of video-stations POD 1, POD 3 and POD 4, as part of NEPTUNE-Canada seafloor observatory infrastructure. Camera platforms (black dots) are powered by a local node (black triangle) through extension cables. Isobaths (dashed lines; in meters) account for the local canyon morphology.

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