"Mysteries of the Deep" a temporary exhibit of deepwater animals of Monterey Canyon.

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Introduction

David packard's fascination with the deep canyons located in Monterey Bay led the Monterey Bay Aquarium to start early investigations into the animals living in this unique environment. Our goal was to study the possibility of collecting and displaying these deep-sea animals to the public. Early work started in 1987 with mid-water tows on research vessels from Scripps Institution of Oceanography, Moss Landing Marine Laboratories and finally utilizing research vessels of the Monterey Bay Aquarium Research Institute, MBARI. Their unique remotely controlled underwater vehicle was key to the success of the aquariums goals in making both observations and collections of deep sea creatures.

The "Mysteries" team began with a list of 80 potential animals for possible consideration for the temporary exhibit; the final number was about 60. These 60 animals were robust and long-lived as well as being new and of unusual appearance making them suitable for aquarium exhibit.

Early efforts of keeping animals from the deep taught the collectors and aquarists that special equipment and techniques would be needed to keep these animals in good health for long periods of time. Specialized holding and display tank designs, water temperature and light control as well as maintaining correct oxygen levels,very low dissolved oxygen in some cases for certain animals. Correctly thought-out collection techniques and ship-board care were shown to be critical to long-term survival.

The final exhibit featured a wide range of diverse animals collected from sheer canyon walls, mid-water and from the sea-floor, pom-pom anemones, predatory tunicates, sponges, mid-water eel pouts, ratfishes and catsharks represent a selection of the exhibit. The Mysteries of the Deep was open to the public in March of 1999 and remained popular to 2003 when it was closed. Collection, care, modified exhibit life support systems and the species displayed will be discussed Hamilton et al., 2001.

Collection locations and methods

Early work began offshore of San Diego collaborating with Scripps Institution of Oceanography, (SIO). We collaborated with researchers at SIO and in retum were given ship time to make mid water

collections. We later utilized ship time from Moss Landing Marine Laboratory which is located next to the Monterey Canyon. These collections utilized a modified mid-water trawl with an insulated cod-end (collection container that holds the specimens) that could be chilled to avoid temperature shock to the collected specimens. These mid-water collections ranged in depth from 300 to 350 meters. All surviving specimens were transferred to refrigerated, coldwater aquaria designed for supporting deep-sea fishes and invertebrates.

Collections evolved to utilizing remotely operated deep-sea vehicles (ROV) belonging to the Monterey Bay Aquarium Research Institute. The majority of the collections utilizing the ROV were made at depths to about 1000 meters, and the collections focused mainly on invertebrates found on the canyon walls and the canyon seafloor. The ROV utilized grabber claws for picking up rocks with attached animals, suction hoses for swimming or floating specimens and sediment traps. All of the collected specimens were transferred to refrigerated trays designed to hold the newly collected animals. Collections made by the ROV were placed in chilled or refrigerated tanks for trarisfer back to the Monterey Bay Aquarium (MBA).

Experimental holding facilities

Dedicated laboratory space with controlled lighting, red filtered lights with low luminosity, cold air-conditioning and specialized aquaria were utilized where temperature and oxygen content could be modified and controlled to meet the specialized biological requirements of the collection. Low oxygen content, 1.5mg O^2/1 at 6°C was found to be essential to survival for predatory tunicates and droopy sea pens. A system was devised where oxygen could be removed by bubbling nitrogen through the aquarium water which drove off the dissolved oxygen. This process was controlled through the use of oxygen sensing electrodes which regulated the release of nitrogen enabling the aquarists to maintain oxygen content at a desired level or range.

Specially designed tanks, circular or Kreisel types were used for maintaining and displaying mid-water animals such as eel pouts and mysid shrimp.

All of the display exhibits were maintained at 5-6°C, and each had its own dedicated life support system for maintaining proper water quality.

Exhibits

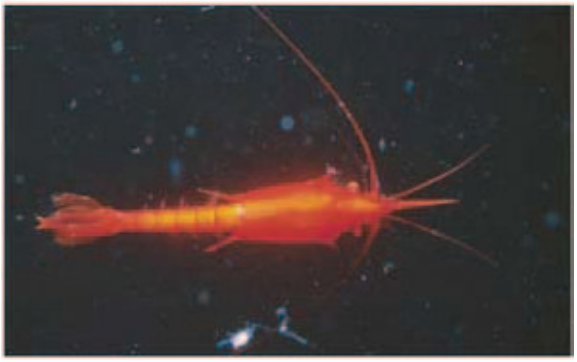
The special exhibit for the deep sea marine life of Monterey Canyon featured displays that focused on the Mid-water, Canyon Walls and the Canyon Seafloor. Mid-water animals represented by eel pouts, (*Melanostigma pammelas*, Fig. 1a) red mysid shrimp, (*Gnathophausia ingens*, Fig. 1b), Black Prince copepod, (*Guassia princes*, Fig. 1c) and various species of copepods proofed to be difficult to keep for longer periods of time and required frequent collections.

The Canyon Wall collections lent themselves to community species exhibits and featured a wide arry of species that if collected with care were long lived in an aquarium situation. A representative list would include: Red sea fans, (*Swiftia kofoida*, Fig. 1d), Mushroom soft corals, (*Anthomastus ritteri*, Fig.

1e), Predatory tunicates, (*Megalodicopia hians*, Fig. 1f), and a variety of sponges (Fig. 1g) frequently found with catshark eggs attached.

Canyon seafloor species were displayed as single species and as community exhibits depending on compatibility and the delicate nature of the species to be displayed. Squat lobsters, (*Munida* sp, Fig. 1h) and Spiny king crabs, (*Paralithoides rathbuni*, Fig. 1i) File tail catsharks, (*Paramaturus xaniurus*, Fig. 1j), Rat fishes, (*Hydrolagus colliei*, Fig. 1k), Longspined thorney head rockfish (*Sebastolobus altivelis*, Fig. 1l) and Apple anemones (*Stomphia didemon*, Fig. 1m) are found together and were compatible together in a community exhibit format. Pom-pom anenomes (*Liponema brevicornis*, Fig. 1n), Fragile pink sea urchin, (*Allocentrotus fragilis*, Fig. 1o) and Pacific hagfish (*Eptatretrus stoutii*, Fig. 1p) being more delicate or sensitive needed to be displayed with other animals that would not disturb them such as Droopy sea pens (*Umbellula lindahli*, Fig. 1p) and Johnson's sea cucumbers, (*Parastichopus johnsoni*, Fig. 1q).

a. Eel pouts (*Melanostigma pammelas*)



b. Red mysid shrimp (*Gnathophausia ingens*)

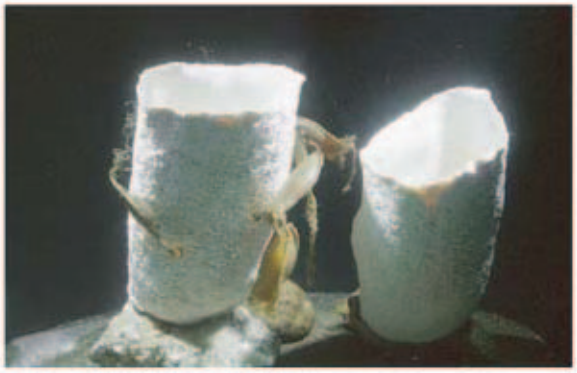
c. Black Prince copepod (*Guassia princes*)

d. Red sea fans (*Swiftia kofoida*)

Fig 1. Display deep-sea species in the Monterey Bay Aquarium.

e. Mushroom soft corals (*Anthomastus ritteri*)

f. Predatory tunicates (*Megalodicopia hians*)



g. Sponges (species?)

h. Squat lobsters (*Munida* sp.)

i. Spiny king crabs (*Paralithoides rathbuni*)

j. File tail catsharks (*Paramaturus xaniurus*)

k. Rat fishes (*Hydrolagus colliei*)

l. Longspined thorney head rockfish (*Sebastolobus altivelis*)

Fig 1. Continued.

m. Apple anemones (*Stomphia didemon*)

n. Pom-pom anemones (*Liponema brevicornis*)

o. Fragile pink sea urchin (*Allocentrotus fragilis*)

p. Pacific hagfish (*Eptatretrus stoutii*)

q. Droopy sea pens (*Umbellula lindahli*)

r. Johnson's sea cucumber (*Parastichopus johnsoni*)

Fig 1. Continued.

Care and feeding

Many of these animals are filter feeders and are fed by directing a weak current of water across the feeding apparatus of the animals. This was accomplished by using a rubber squeeze bulb attached to a small diameter plastic tube, food (brine shrimp naupuli, adult brine shrimp (*Artemia* sp.) and krill, (*Euphausia pacifica*) were the most common food type. These items were used for most filter feeders including Red sea fans, Mushroom soft corals, Predatory tunicates, Apple anemones, Pom-pom anemones and Droopy sea pens. Active feeders such as, File tail catsharks, Rat fishes, Squat lobsters, Spiny king crabs and Pacific hagfish were presented with pieces of fish or squid. Other active feeders; Fragile pink urchins and

Johnson's sea cucumber remove organic matter from the sandy bottom through the use of sticky feeding appendages.

Future deep sea exhibits

A major remodeling of MBA's Outer Bay Exhibits is now under process and the new exhibit theme will focus on seamounts and the ecological significance that they play in maintaining species biodiversity, adding to primary productivity through ocean current modifications by diverting nutrient rich deep water to the surface and the contribution of broad-cast spawn from large species-assemblages to the zooplankton community, which then become available as food to other species.

Two deep sea community exhibits are planned: one representing the Davidson Seamount located 120 km southwest of Monterey County. The other planned exhibit is to be a tropical seamount modeled after Espirtu Santo Seamount in Baja California, Mexico, The species lists for these two exhibits are: Davidson Seamount; Mushroom Soft Coral, Red Sea Fan, Peppermint Gorgonian (*Paragorgia arborea*), Red Licorice Gorgonian (*Euplexaura marki*), Apple Anemone, Scarlet King Crab (*Lithodes couesi*), Red Vermillon Crab (*Paralomis verrillis*) and Thornyhead Rockfish.

Espirtu Santo Seamount; Elegant Coral (*Pocillopora elegans*), Orange Cup Coral (*Tubastraea coccinea*), Yellow-polyp Black Coral (*Antipathes galapagensis*), Red Gorgonian (*Eugorgia daniana*), Longnose Hawkfish (*Oxycirrhites typus*) and Coral Hawkfish (*Cirrhitichthys oxycephalus*),

Deep sea communities as a food source for epipelagic fishes

Documentation of deep dives presumably directed at foraging have been made for various members of the Billfishes, Tunas and Lamnid sharks, dives exceeding 1000 meters have been recorded for tunas and dives of 300-600 meters for swordfish, marlin and white sharks (Boustany et. al., 2002; Block et al., 2001; Milliman et al., 1967). Recent investigations utilizing retrieved data from surgically implanted archival tags document feeding events with the associated peritoneal temperature rise in Pacific bluefin tuna.

Feeding events recorded at 300 meter depths are illustrated in figure 2; the temperature rise and duration are considered to be proportional to the energy content of the ingested prey item(Walli et al., 2007).

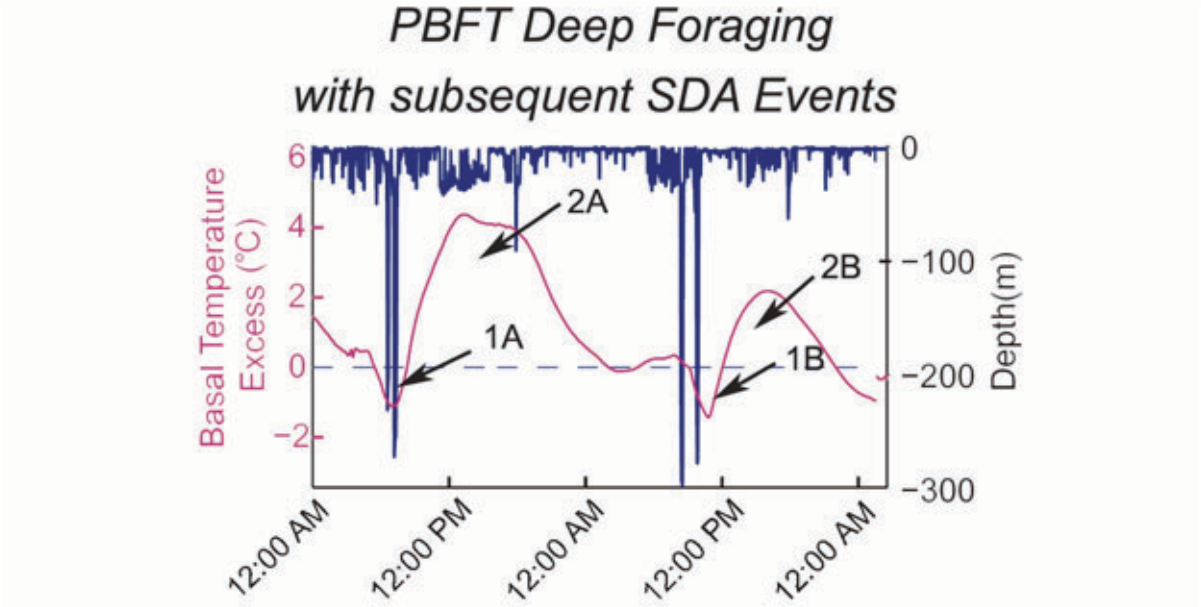


Figure 2. Temperature signal for two feeding events in deep-diving Pacific bluefin tuna. Blue-dotted line is the recorded basal body temperature; the solid red line represents core temperature changes associated with ingestion and digestive processes. All temperatures were recorded by an implanted archival tag which was recovered after the fish was commercially landed. The solid blue line represents daily diving record. Arrows 1A & 1B illustrate the core temperature drop resulting from ingesting an ectothermic prey item that is at ambient water temperature. Arrows 2A & 2B point to the rise in core temperature resulting from the metabolic processes associated with digestion. This is referred to as Specific Dynamic Action (SDA).

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