Monterey Bay National Marine Sanctuary Technical Report 2012-1

Monterey Bay National Marine Sanctuary:

Davidson Seamount Management Zone Threats Assessment

Photo credit: NOAA/MBARI

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http://montereybay.noaa.gov

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INTRODUCTION

Davidson Seamount is an undersea mountain off the Central California coast, with its crest (summit) approximately 1,250 m below the sea surface and its base in approximately 3,500 m of water. The Davidson Seamount Management Zone (DSMZ) of the Monterey Bay National Marine Sanctuary (MBNMS or Sanctuary) is a protected area bounded by a square approximately 30 nautical miles (nm) per side, centered on the crest of the Davidson Seamount. The zone's surface area is approximately 585 square nm, and the submerged lands there under are included within the DSMZ (NMSP 2008). This portion of the Sanctuary is located approximately 65 nm off the coast of San Simeon, San Luis Obispo County. The DSMZ is bounded by coordinates West: 123.0°W; East: 122.5°W; North: 35.9°N; South: 35.5°N (Fig. 1). The DSMZ possesses several special characteristics that make it a priority for resource protection. These characteristics include a relatively pristine, physically undisturbed seafloor, sizable microhabitats of large (some over eight feet tall) and old (some over 200 years) deep-sea corals and vast sponge fields, and relatively high numbers of rare and undescribed benthic species. As a result, Davidson Seamount has been called "An Oasis in the Deep." Though seamount habitats are relatively poorly understood, Davidson Seamount is one of the best studied (Clague et al., 2010).

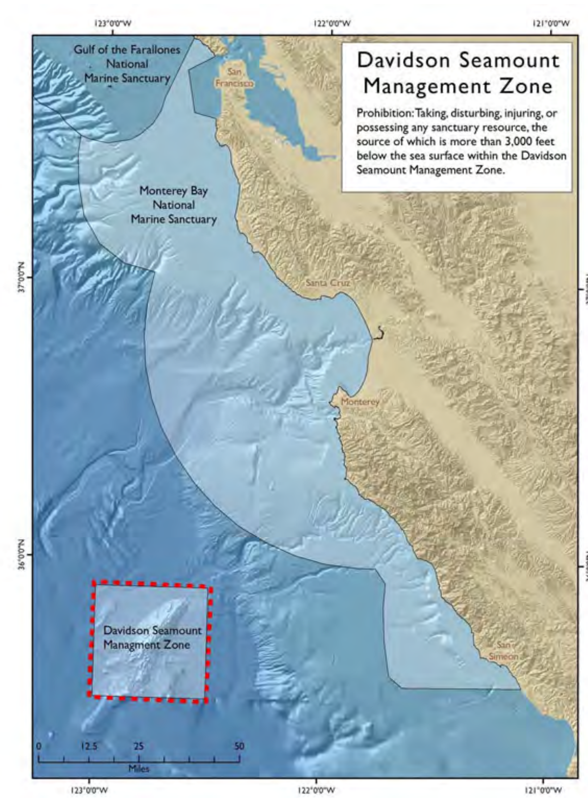


Figure 1. Location of the Davidson Seamount Management Zone in relation to the Central California coast and the remainder of the Monterey Bay National Marine Sanctuary. Map credit: NOAA.

Many of the biological communities of the DSMZ are particularly vulnerable to damage. The abundance of long-lived species within the management area, coupled with the dominance of large, fragile, slow-growing organisms, means that anthropogenic disturbances are likely to result in extremely long recovery times. Although many seamount communities exhibit endemism rates over 50%, researchers have found little evidence to support the seamount endemicity hypothesis at Davidson Seamount (Stone et al., 2004; McClain et al., 2008). Seventy-one percent of the species observed in the DSMZ are cosmopolitan (i.e., distributed on seamount and non-seamount habitats), 12% are potentially confined to seamounts and 7% are potentially confined to Davidson Seamount (McClain et al., 2008). If these percentages are assumed to represent the actual level of endemicity in the DSMZ, they still imply a substantial number of unique species. Particularly compelling is the difference in frequency of species observations between Davidson Seamount and the nearby deep-sea environment of Monterey Canyon. Only 70 nm apart, Monterey Canyon is a less optimal habitat, with species on Davidson Seamount exhibiting greater abundance and biomass (Fig. 2; Clague et al., 2010).

Of the estimated 33,452 isolated seamounts with elevations greater than 1,000 m in the world, only 350 have been sampled thus far, and Davidson is one of less than 100 that have been sampled in any detail (Yesson et al., 2011; CenSeam, 2011). Protection of the physical and biological resources at Davidson Seamount is thus even more important, as the local science community has demonstrated their ability to conduct extensive deep-sea research in the DSMZ. Increases to our understanding of Davidson Seamount have been, and will continue to be, significant to humanity's knowledge of seamount environments in general. The DSMZ possesses unique resources that could suffer irrecoverable losses if not guarded against direct and indirect human impacts. MBNMS management must anticipate all possible risks that may place the DSMZ under increased pressure, and strive to minimize those risks (NOAA, 2009b).

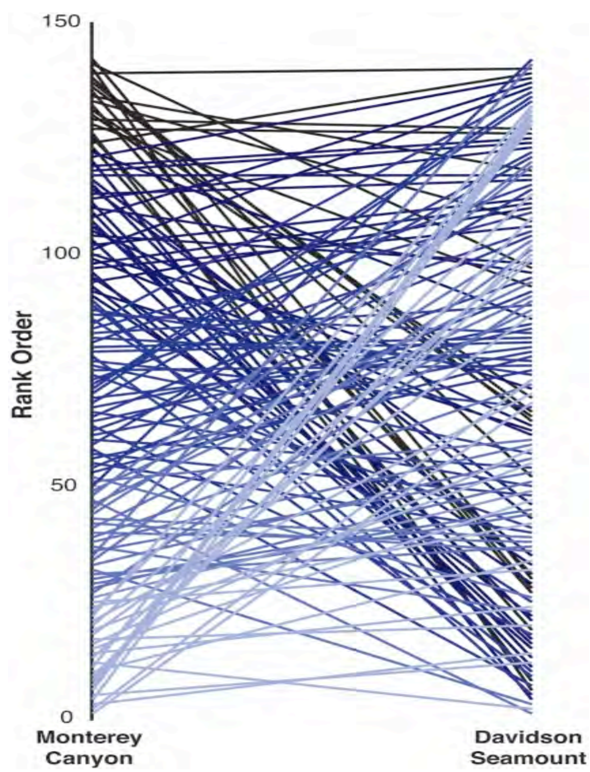


Figure 2. Rank orders based on frequency of species observations in Monterey Canyon and Davidson Seamount. Lines connect the rank orders of a species at the two localities. Source: McClain et al., 2008.

Activity 3.1 of the DSMZ Management Plan (version 5.0, July 2009) describes the importance of *Continuously Characterizing the Potential Threats to Davidson Seamount*. Specifically, Activity 3.1 states:

> A threats and protection plan will be developed based on a thorough literature review, workshops with experts, and a socioeconomic and biological characterization.

This document begins to accomplish the objective in Activity 3.1 by first summarizing existing measures that have been taken to protect Davidson Seamount. It then describes many of the known existing and potential threats to the DSMZ. Our description of the pressures on the seamount is based on observations from expeditions to the DSMZ, knowledge of human activities in the surrounding areas, and documentation of human impacts to other seamount environments found in the literature. It should be noted that many of the threats listed below relate to phenomena of a global nature and will require regulation at larger geographical scales beyond the jurisdiction of Sanctuary management. However, compiling them here will allow managers within and beyond the MBNMS to anticipate and respond to these pressures.

EXISTING PROTECTIONS

The DSMZ is a recent addition to the MBNMS (March 2009), as part of the adoption of the Final MBNMS Management Plan in October 2008 (NOAA, 2008b). Standard MBNMS regulations apply within the DSMZ (without the exemptions for seabed alteration); and moving, removing, taking, collecting, catching, harvesting, disturbing, breaking, cutting, or otherwise injuring or possessing biological or non-biological sanctuary resources below 3,000 feet within the DSMZ is prohibited without a permit (NOAA, 2008b). Additionally, in June 2006 fishing with bottom contact gear (or any other gear) below 3,000 feet was prohibited in the Davidson Seamount Essential Fish Habitat (EFH) area designated by the National Marine Fisheries Service (NMFS). The EFH shares the same boundaries as the DSMZ and was created to address potential threats to the seamount and natural resources (U.S. Code of Federal Regulations, 2010).

Monitoring compliance with these regulations has focused on assessing commercial and recreational vessel traffic and fishing activities. The U.S. Coast Guard (USCG), NOAA Office of Law Enforcement, and the California Department of Fish and Game have collaborated to establish surveillance and response capabilities for the area. Patrols have taken place on USCG aircraft and NOAA ships. In addition, the Sanctuary Aerial Monitoring and Spatial Analysis Program (SAMSAP) and other aerial surveys have been important tools for monitoring vessel traffic and fishing activity.

EXISTING AND POTENTIAL THREATS

Vessel Traffic

Maritime transportation around the globe is increasing and so is the number of boats and vessels at sea. In the late 1990s, prior to the addition of the DSMZ to the Sanctuary, the MBNMS Vessel Traffic Workgroup met to create a vessel traffic management system that aimed to maximize protection of Sanctuary resources while allowing for the continuation of safe, efficient and environmentally sound transportation. A key strategy of the workgroup was shifting large commercial vessels away from nearshore waters and enhancing the predictability of their locations to reduce collisions and interference with smaller fishing or recreational vessels. The workgroup established recommended tracks for four categories of vessels. Tracks for large commercial vessels, barges, and ships containing hazardous materials were set within 30 nm of shore, while tankers carrying crude oil, black oil, or other persistent liquid cargo in bulk were set at more than 50 nm from shore. Final international approvals for the Sanctuary's vessel traffic management system were announced on May 31st, 2000. Implementation of the 50 nm offshore track for tankers has involved negotiation of an industry agreement covering all foreign and domestic carriers of crude oil. As a result of this agreement, the northeast corner of the DSMZ is bisected by shipping tracks of oil tankers (Fig. 3).

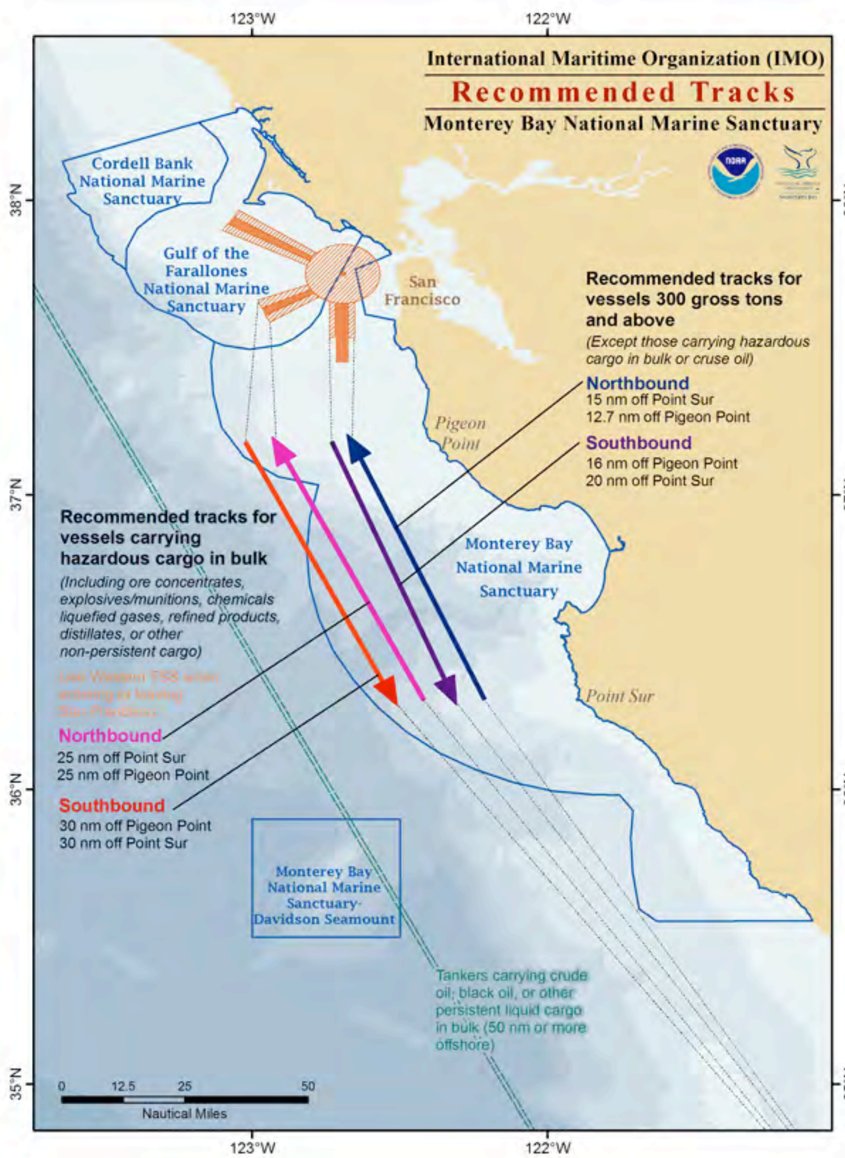


Figure 3. Recommended shipping tracks through the Monterey Bay National Marine Sanctuary, including tracks of oil tankers through the Davidson Seamount Management Zone. Source: http://montereybay.noaa.gov/intro/maps/vessel_lanes1_lg.jpg

Given the DSMZ's location more than 70 nm offshore, the risk of accidents and spills as a result of collisions and groundings are less likely than in coastal waters. However, spills can potentially occur from any transiting vessel carrying crude oil, bunker fuel, or other hazardous materials. Oil or chemical spills would introduce toxic substances to the environment and would result in the coating of birds, marine mammals, and other species. Long-term impacts may include a decrease in growth rates and, in severe cases, species decline and death. Future studies of Salt Dome Seamount, a shallower seamount in the Gulf of Mexico surveyed by NOAA in 2004 and located only 16 miles from the site of the 2010 Deepwater Horizon oil spill, may yield greater knowledge about specific impacts of oil spills on seamount communities. In the event of a ship sinking, leakage of fluids and cargo from the sunken vessel would also be a serious consideration.

Another class of threat related to vessel traffic is the possibility for cargo from container ships to be lost at sea. Each year, more than 10,000 containers fall overboard and spill their cargo into the ocean (Podsada, 2001; Standley, 2003; IMO, 2004; BBC, 2010; Countryman and McDaniel, 2011; Hohn, 2011; ITTS, 2011). Storms are often the cause. An 8-foot by 40-foot shipping container (2.4-meter by 12.2-meter) can carry up to 58,000 pounds (26,000 kilograms) of cargo, which in the event of loss at sea can either remain self-contained or escape and float freely (Podsada, 2001). Thus, even if containers fall from ships transiting shipping lanes closer to shore than the DSMZ, the containers and their contents could travel to seamount waters and sink there. Impacts of lost cargo can include the threat of habitat crushing or smothering, the introduction of foreign habitat structure, entrapment of organisms, ingestion of foreign materials by marine life, and the introduction of chemical pollutants.

In February 2004, 24 containers fell overboard from the M/V *Med Taipei* when the vessel was traveling on rough seas from San Francisco Bay to the Port of Los Angeles, California. The containers, 40 feet long by 8 feet wide by 10 feet tall, contained a variety of cargo including furniture, thousands of tires, several hundred thousand plastic items, miles of cyclone fencing, hospital beds, wheel chairs, recycled cardboard and clothing items. A U.S. Coast Guard report revealed the containers were inappropriately loaded on board the vessel. In a 2006 settlement, the owners and operators of the vessel agreed to pay $3.25 million to the MBNMS to fund habitat restoration for long-term damages incurred for the loss of 15 of these containers in the Sanctuary, one of which was found at 1,281 meters (U.S. Dept. of Justice, 2006). The location of only one of the containers thus far speaks to the difficult nature of finding, much less recovering, such potentially damaging cargo.

Davidson Seamount is also vulnerable to various other types of pollution from passing vessel traffic. Away from the coasts, ship-based pollution tends to be less controlled. Further out at sea, black water and gray water tanks are often cleaned, and oil and chemical residues deliberately discharged overboard. Such operations represent the largest sources of pollution from ships (Van den Hove and Moreau, 2007). The exchange of large volumes of ballast water constitutes yet another threat to seamount resources, given the increased risk of introduced species traveling through the water column from the surface to the seamount. Unfortunately, the regulation of effluents from ships remains difficult to enforce, especially when discharges take place in offshore areas (Van den Hove and Moreau, 2007).

Finally, noise pollution is another threat posed by passing vessel traffic. The low frequency sounds produced by vessels have acoustic impacts that are not confined to coastal waters, but penetrate into the waters of the deep sea. Impacts of this type of pollution on cetaceans and other species that spend a large part of their life in the deep sea and use sound to communicate, navigate, feed and sense their environment remain uncertain (Van den Hove and Moreau, 2007).

To protect DSMZ resources, managers should consider whether the subject of recommended tracks for vessel traffic – especially the shipping track for oil tankers that passes directly above the seamount – should be revisited. The 2008 Sanctuary Final Environmental Impact Statement

(FEIS) notes that during scoping several individuals recommended moving the vessel traffic lanes further offshore to further reduce the threat potential to Sanctuary resources (NOAA, 2008a).

Submerged Vessels

Seven miles offshore of Point Piedras Blancas and less than 70 nm away from the boundary of the DSMZ, an oil tanker has rested on the seafloor in approximately 275 m (900 feet) of water since 1941. The S.S. *Montebello*, a 457-foot shelter deck tanker, was torpedoed by an Imperial Japanese submarine on December 23, 1941 and sank, presumably taking its cargo of three million gallons of Santa Maria crude oil down to the seafloor (MBARI and DFG, 2010).

The site was first visited in 1996 on an expedition funded by NOAA's West Coast National Undersea Research Center and using Delta Oceanographic's *Delta* submersible (CINMS, 2003). As there were no observations of oil being introduced into the water column over the course of four videotaped reconnaissance dives, researchers assumed the oil was still entombed in the tanker. MBNMS and Channel Islands National Marine Sanctuary staff returned to the site for more reconnaissance dives in September 2003 and confirmed that the hull appeared intact (CINMS, 2003).

In August 2010, a three-day expedition using an MBARI autonomous underwater vehicle (AUV) collected sonar images of the ship and surrounding seafloor (MBARI and DFG, 2010). In September 2011, the U.S. Coast Guard awarded a contract to Global Diving and Salvage, Inc. to use a remotely operated vehicle (ROV) to determine if oil was present aboard the sunken ship. The survey was conducted in October 2011, at which time a Unified Command led by the U.S. Coast Guard and California Department of Fish and Game's Office of Spill Prevention and Response assessed both cargo and fuel tanks. It was determined that there is no substantial oil threat from the S.S. *Montebello* to California waters and shorelines (U.S. Coast Guard, 2012).

This research was important for Davidson Seamount resource protection. If oil remained within a vessel like the S.S. *Montebello*, it could eventually escape, posing an oil pollution threat to MBNMS waters including the DSMZ. The MBNMS Submerged Cultural Resources Study of 2001 includes a database of 463 reported vessel losses that lie within the jurisdiction, or adjacent to the boundaries, of the Sanctuary (Smith and Hunter, 2003). An inventory of shipwrecks posing environmental threats to the DSMZ should be established. Monitoring these wrecks and coordinating with partners to reduce threats, as was done with the S.S. *Montebello*, should be initiated as needed.

Military Activity

The DSMZ is adjacent to the military's Warning Zone 285 (Fig. 4). Warning Zone 285 is in frequent use for both air and surface training by the U.S. Navy. Air activities include aircraft carrier takeoffs and landings, and low-level air combat maneuvering. This activity results in the expenditure of smoke markers, sonobuoys and non-explosive ordnance in the Warning Area (NOAA, 1992). Independent of NMS regulations, this area has flight restrictions for civilian aircraft because it is used for naval air operations including low level fighter jet and helicopter operations (NOAA, 1992).

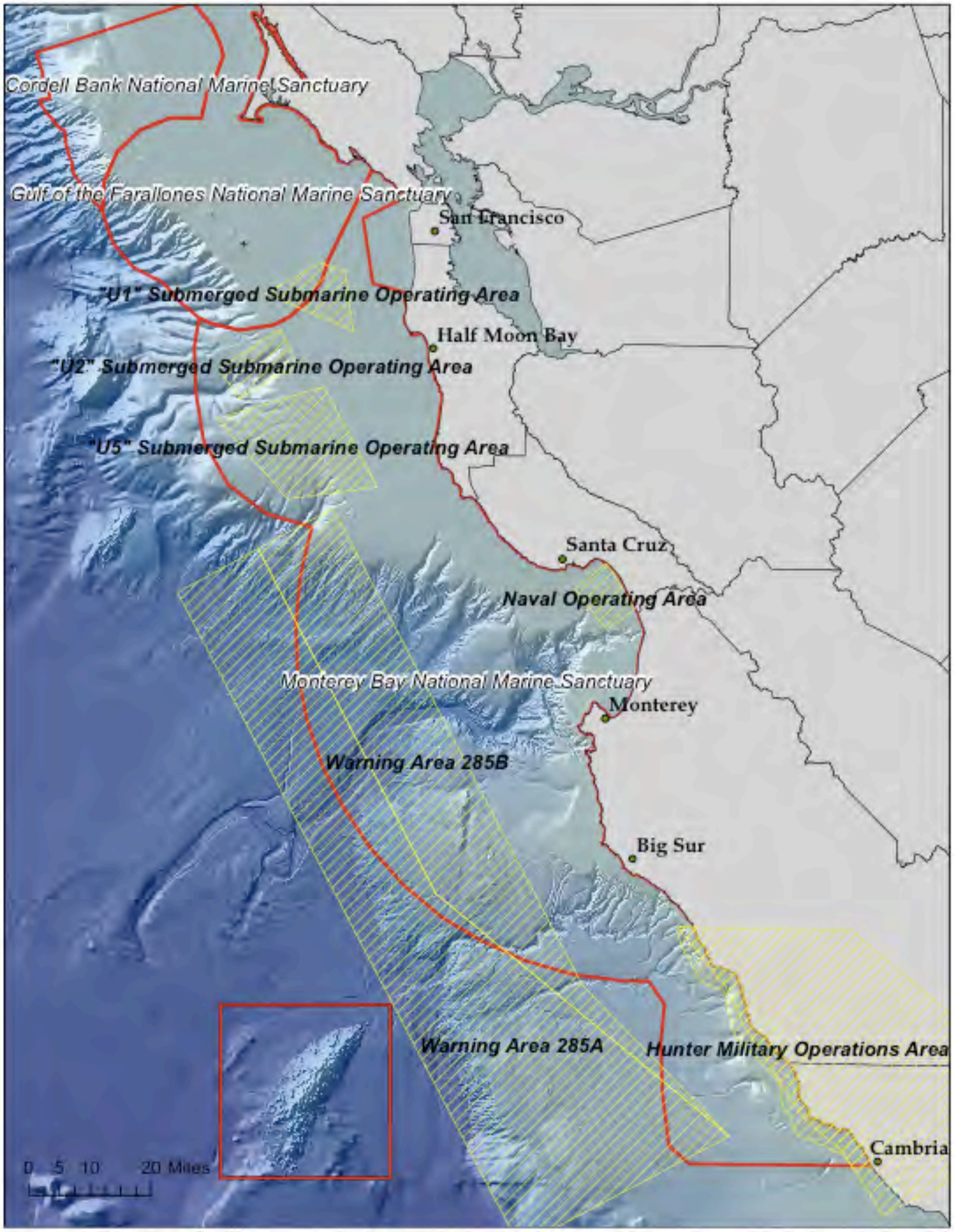


Figure 4. Location of military zones in the Monterey Bay National Marine Sanctuary. Warning Area 285 is adjacent to the boundaries of the Davidson Seamount Management Zone. Map credit: Chad King, MBNMS.

Additionally, the DSMZ was home to a U.S. Navy tomography experiment from July 1998 to December 1999 (Onofre, 1999). Phase-modulated signals from a transmitter at 1,270 m on Davidson Seamount were transmitted 66 km northeast to a receiver on Sur Ridge at 1,359 m.

The transmitter produced signals with a source level of 180 dB re 1μPa, center frequency of 400 Hz, and a bandwidth of 100 Hz. Data received on Sur Ridge was then sent via underwater cable to the Naval Postgraduate School's Point Sur Ocean Acoustics Observatory, where it was recorded (Onofre, 1999). The acoustic impacts of such experiments on deep-sea species are not yet fully understood.

In accordance with Sanctuary regulations, all Department of Defense activities must be carried out in a manner that avoids to the maximum extent practicable any adverse impacts on Sanctuary resources and qualities. The prohibitions in paragraphs (a)(2) through (12) of the *Prohibited or otherwise regulated activities* section of the MBNMS regulations do not apply to existing military activities carried out by the Department of Defense and identified at the time of Sanctuary designation. For purposes of the DSMZ, these activities were listed in the 2008 FEIS and include air, surface, and underwater activities. The use of non-explosive ordnance, sonar, and smoke markers, the temporary placement of objects for torpedo firing or sonar location training, aircraft carrier takeoffs and landings, low-level air combat maneuvering, and U.S. Navy submarine operations are all exempted from Sanctuary prohibitions (NOAA, 2008a). New activities may be exempted from Sanctuary prohibitions by the ONMS Director after consultation with the Department of Defense.

However, the general nature of the pre-existing military activities identified and named in the 2008 FEIS leave many unanswered questions, including:

What specific discharges or deposits may have occurred or may be occurring within the DSMZ and surrounding areas?
Military sources contribute some of the most dangerous wastes intentionally dumped at sea, and data about past activities can be difficult to access (Van den Hove, 2007). Better information about past military activities is critical to our understanding of the cumulative impact that military debris and toxicants may be having on DSMZ habitats and marine life.

To what extent is ongoing military use of underwater acoustic devices having an adverse impact on DSMZ marine life?
Active-sonar, specifically low frequency (100-500 Hz) and mid frequency (2.8-3.3 kHz) active sonar used in military activities are of particular concern, as they may impact marine mammals in a variety of ways, including causing physiological damage, masking communication, or disrupting important migration, feeding or breeding behaviors (NOAA, 2008a). Although anthropogenic sources of underwater noise are not regulated by NMS regulations, the MBNMS has been involved in evaluating and requesting limits or alterations of specific proposals to use acoustic devices in the region. Provisions in Strategy MMST-6 (Assess Impacts from Acoustics) of the MBNMS Marine Mammal, Seabird and Turtle Disturbance Action Plan should be sure to address possible cumulative noise impacts in the DSMZ.

Bio-prospecting

Many deep-sea species offer promise in the quest to develop new medicines and enhance human health services. Given the adaptations of many deep-sea species to live in extreme conditions of temperature, darkness, and pressure, their genetic resources are of great interest for industrial and medical applications. The search for substances and genetic materials with potential industrial or commercial uses is termed bio-prospecting, or sometimes bio-discovery (Van den Hove and Moreau, 2007). At the same time as remote deep-sea areas have become more accessible, developments in molecular technology and bioinformatics have accelerated research on little known deep-sea genes, proteins, and other compounds. Most international chemical and pharmaceutical corporations are now involved in developing new products from deep-sea biodiversity (Van den Hove and Moreau, 2007).

Sea fans contain high concentrations of prostoglandins, used to treat heart disease and asthma; some corals contain pseudopterosins, a class of painkiller; and gorgonians can yield antibiotics (NOAA, 2008b). Some deep-sea sponges have been used in clinical trials of anti-tumor drugs, while sponges from the Chatham Rise (400 km off the coast of New Zealand) are being investigated as possible sources of cytotoxins (Van den Hove and Moreau, 2007) . Other possible applications of seamount biodiversity include uses as biological anti-fouling compounds, anti-freeze agents, anti-coagulants, food conservatives, cosmetics, pesticides, and nutritional supplements such as anti-oxidants (Synnes, 2007).

To date, only a small handful of products have been successfully marketed. Deep-sea substances have been incorporated into sunscreen lotions to yield a higher UV protection (Van den Hove and Moreau, 2007). Two American firms, New England Biolabs and Diversa, sell DNA polymerases isolated from deep-sea vents that can increase thermostability and improve proofreading capabilities for the polymerase chain reaction. The French company Sederma discovered a radical scavenging enzyme in extremophile bacteria from the Gulf of California, which it markets as a skin protection product (Arico and Salpin, 2006).

The wide range of potential commercial possibilities emerging from the genetic wealth in the deep-sea promises increasing future profits, and the sector has been referred to as 'blue gold.' Global sales of marine biotechnology products, including antivirals, antibiotics and anti-cancer compounds, were estimated at about US$2.4 billion for the year 2002 alone (Arico and Salpin, 2006). Such a strong market encourages further exploration, and companies such as San Diego-based Diversa maintain active deep-sea research programs (Arico and Salpin, 2006). Several states, including Papua New Guinea, Fiji, New Zealand and Norway have developed national policies governing marine scientific research and bio-prospecting (Arico and Salpin, 2005).

The growing number of species new to science within the DSMZ, ranging from an unknown mollusk, long-lived corals, basketball-sized red jellyfish *(Tiburonia granrojo)*, and massive sponge communities, make it an attractive destination for the bioprospectors of the future (NOAA, 2008a). The yellow sponge *(Staurocalyptus* sp. nov.) is one Davidson species that has already been the subject of a preliminary bioassay. The Seamount also possesses several species of "precious corals" similar to those already collected in other parts of the world for use in jewelry. The coral jewelry industry is further discussed below in the Commercial Harvesting section.

Naturally, the collection of sensitive species could damage the fragile ecosystem of the DSMZ, and this type of activity has already led to overexploitation of seamounts on the high seas, where a regulatory vacuum exists. However, existing MBNMS regulations as described above prohibit this type of resource extraction within the DSMZ. Even without these protections, bioprospectors at Davidson Seamount would be faced with difficult access and high costs, making extensive harvesting seem unlikely. More plausible would be the retrieval of small numbers of specimens for testing, screening, and further study, with subsequent synthesis of compounds and/or culture of organisms of interest (Van den Hove and Moreau, 2007). Using non-specific sampling techniques, such operations would tend to be sporadic in nature, with highly localized impacts. Although the industry is poised for rapid growth, given the sheer number of samples that would have to be collected, the chances of discovering something of high commercial value within the DSMZ seems low. Only if extensive unregulated harvesting were to occur would bio-prospecting represent a severe ecological threat.

Given the scientific and public attention Davidson Seamount has received since incorporation into the MBNMS, it is likely to continue being a subject of marine research. Going forward, the distinction between bio-prospecting and scientific research that may analyze genetic resources is apt to become blurred, as biotechnology firms are increasingly beginning to partner with public research institutes. By operating as public private partnerships, companies are able to lower their costs by sharing the use of expensive specialized equipment and human resources. The Sanctuary's requirement of permits for the taking or disturbance to Sanctuary resources below 3,000 feet offers a way to guard against unwanted exploitation of these resources for commercial purposes. In issuing permits, MBNMS management will need to be aware of this issue and distinguish between bio-prospecting and pure scientific research by asking what the end use of the research will be. Additionally, since the passage of the Convention on Biological Diversity (CBD) in 1992, governments have had the ability to negotiate contracts with scientists when they give them access to national land and water (including deep-sea) resources (Arico and Salpin, 2006). Thus, if Sanctuary management decides to approve research with possible bio-prospecting applications, they can use such a contract to prohibit the patenting of discoveries or the realization of financial gains.

Cumulative Research Collection

Over the past decade, there has been increased interest in studying and often collecting deep-sea corals and other slow-growing deep-sea species. Data on seamount ecosystems worldwide remain limited. Further research is needed to determine the key factors that drive community structure, diversity, and endemism at multiple scales: seamount chains, whole seamounts, and individual habitats within seamounts (Morato et al., 2010). Other questions that will require more research to answer revolve around understanding the main processes that cause differences between seamount and non-seamount regions and differences among seamounts, the resilience of seamount communities, and the structure of energy flows through the trophic levels (Morato et al., 2010).

A study of seamounts of the Lord Howe Rise and Norfolk Ridge, located between Australia and New Zealand, found that increased sampling effort revealed an increase in species richness. These results led to the conclusion that the number of undiscovered seamount species far exceeds the number of species already discovered, and implies that research efforts will continue to intensify as resources allow (Arico and Salpin, 2005). Research interest is particularly high for deep-sea corals such as gorgonians since they can live for centuries and have a worldwide distribution, thereby providing a source of isotopic and geochemical data that can help reconstruct historical changes in oceanographic conditions and ocean climate (Tsounis et al., 2010).

The small number of seamounts worldwide protected for conservation includes some of the world's most accessible seamounts and these will likely be the focus of much of the future research effort. Davidson Seamount and other protected deep-sea areas have the potential to demonstrate the benefits of implemented management measures and to act as baselines for recovery. This unique capacity will likely encourage continued research interest and monitoring within the DSMZ (Morato et al., 2010). Davidson is recognized as one of the better-explored seamounts in the world; it has been observed on 32 dives by the ROV *Tiburon*, which collected over 280 rock samples and nearly as many benthic animals (Clague et al., 2010). Potential research equipment that scientists could use to further explore Davidson Seamount is illustrated using the Condor Seamount scientific observatory schematic (Fig. 5).

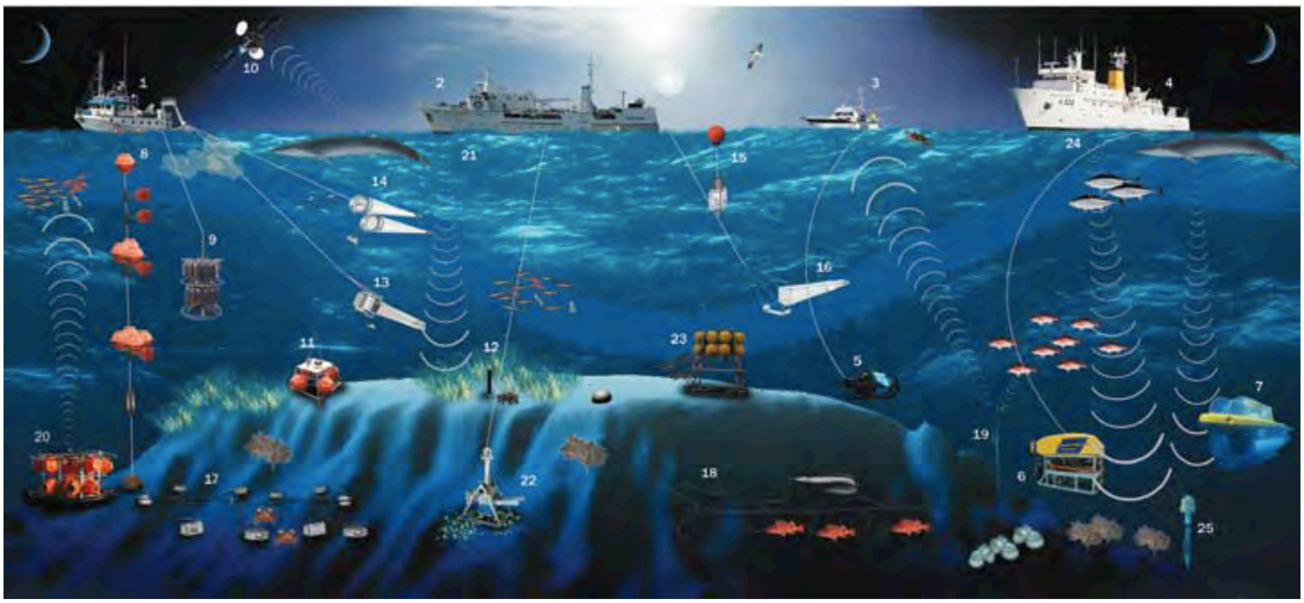


Figure 5. Scheme of the Condor Seamount scientific observatory in the Azores. Equipment and main platforms in use and planned to be used include: several research vessels (1–4), two remotely operated vehicles (5, 6), a manned submersible (7), oceanographic instruments (8–12), biological sampling gear (13–16), fishing gear (17, 18), telemetry instruments (10, 19), acoustic instruments for biomass estimations (20, 21), sediment sampling (22), other imagery instruments (23), seafloor mapping (24), and animal sounds recording (25). Components of the figure are illustrative and not to scale. Source: Morato et al., 2010.

Davidson Seamount has several rare, slow-growing coral species including large pink gorgonian bubble gum coral (*Paragorgia arborea*), bamboo coral (*Keratoisis* sp.), and precious coral (*Corallium* sp.) (Andrews et al., 2005, 2009); similar specimens of which have already been collected in Hawaii. Over time, unmanaged research activities – especially collection of limited populations of these slow-growing species – can pose a variety of threats to DSMZ ecosystems including unsustainable collection rates, habitat destruction by vessels and equipment, alteration of local hydrological and environmental conditions, unintended introduction of pollutants, and light and noise impacts (Arico and Salpin, 2005). It can be difficult to quantify the damage caused by such research on seamount ecosystems, but MBNMS should follow a precautionary approach when awarding permits for future research activities that feature collection as a primary method. One way to ensure that extraction of seamount resources is maintained at sustainable levels would be to always direct research collection proposals through a scientific peer review process.

Commercial Harvesting

Waters above Davidson Seamount

Globally, prey species are often concentrated around seamounts, creating productive fishing grounds for a wide range of seabirds, marine mammals, and larger fish (CBD, 2008). Species diversity of marine predators often peaks in the vicinity of prominent topographic features like seamounts (CBD, 2008). In the DSMZ, the surface habitat hosts albatross, shearwaters, jaegers, sperm whales, killer whales, albacore tuna, and ocean sunfish among other species (NOAA, 2004). Although there is no published evidence that species composition above Davidson Seamount differs from adjacent areas, the surface waters of the DSMZ are typically regarded as having a higher abundance and diversity of marine mammals and seabirds than immediately adjacent areas absent of significant bathymetric features (King, 2010). Additionally, fishermen have reported that the Seamount may enhance albacore fishing in some years (NOAA, 2004).

Two commercial fisheries operate in the top 150 ft (46 m) of water in the DSMZ, about 3,951 ft (1,204 m) above the Seamount summit, and target highly migratory pelagic species. Albacore tuna, which travel in loose knit schools at the surface and are most common off California from June to January, are caught both commercially and recreationally by trolling lures or live bait. Albacore landings increased as the size, speed, and technological capabilities of fishing vessels increased, but a decline in total landings and fishing effort has occurred since the mid 1980s (Starr et al., 2002). In recent years, gear restrictions in state waters have been responsible for pushing the albacore fishery further offshore, to places such as Davidson Seamount (Starr et al., 2002). There is no limit on the recreational albacore catch.

Swordfish and sharks, both caught primarily with drift gillnets, comprise the other fishery above Davidson Seamount. Historically, the swordfish fishery within the MBNMS has been substantial, with landings at ports associated with the Sanctuary averaging 741,000 lbs/yr from 1981-2000, with a peak in 1984 of 1.6 million lbs (Starr et al., 2002). Beginning in 1985, state regulations restricting the use of drift gillnets have shifted the fishing effort further off the coast, towards the DSMZ. Fisheries for thresher and shortfin mako sharks experienced a similar trend during the period assessed by Starr et al. (2003), with landings at MBNMS ports declining since a high of nearly 700,000 lbs in 1983. The recreational fishery for these shark species is sizable. Despite a catch limit of two per day, there are no size limits for mako sharks, leading to a large juvenile catch (Starr et al., 2002).

Since the implementation of the Highly Migratory Species (HMS) Fishery Management Plan (FMP) in April, 2005, all of these fisheries have been actively managed by the Pacific Fishery Management Council (PFMC). The FMP prohibits longliners from fishing in the EEZ or targeting swordfish due to concerns about endangered sea turtle bycatch, and requires that commercial fishermen obtain a permit from NMFS to fish for HMS and maintain logbooks documenting their catch (PFMC, 2010). A possible threat to the DSMZ is that reductions in other fisheries (like groundfish) could push more participants toward targeting HMS species, as they comprise one of the few remaining open access fisheries on the West Coast. Unless PFMC institutes a limited-entry program as an amendment to the FMP, this will likely increase the fishing pressure above Davidson Seamount. The NMFS Integrated Ecosystem Assessment (IEA) model may be able to address ecosystem impacts to deep-sea communities from the loss of pelagic predators (Levin et al., 2008).

Deepwater Fisheries

Worldwide overexploitation of seamount fisheries poses the greatest risk to seamount habitats (Morato et al., 2010). Harvests of primary and secondary seamount fish species have increased dramatically in recent decades, with worldwide seamount trawl fisheries exceeding 2.25 million mt annually (CBD, 2008). The availability of GPS and other technologies has allowed for deeper and more distant fishing destinations to be easily located. Several factors make benthic fishing on seamounts ecologically problematic. Long-lived, slow-growing, low-fecundity deep-sea fish species associated with seamounts are intrinsically vulnerable to fishing, and seamount fisheries have been shown to collapse faster and recover more slowly than non-seamount fisheries (CBD, 2008). The collapse of the orange roughy (*Hoplostethus atlanticus*) off the coast of Australia and New Zealand is a classic example.

While longlines, gillnets, traps, and pots can all impact seafloor habitats, bottom trawling is most recognized for causing considerable seafloor impacts (Morato and Clark, 2007). Bottom trawling can quickly smother and destroy communities of sponges, other sessile invertebrates, and cold-water corals (Fig. 6). The substrate of Tasmanian seamounts subjected to heavy trawling has been severely scarred and reduced to over 90% bare rock and sand (CBD, 2008). Other indirect effects of benthic fishing on seamounts include sediment re-suspension and mixing, discharge of processing wastes, and unsustainable bycatch of non-target species (Santos et al., 2010). Stone et al. (2004) reported that un-fished seamounts have twice the biomass of fished seamounts, with certain impacts on community structure and ecosystem health.

Figure 6. Seafloor images from a (a) heavily fished seamount and (b) lightly fished seamount off the east coast of New Zealand. Source: Clark and Koslow, 2007.

Fishing pressure is more likely at seamounts such as Davidson that are relatively accessible from nearby ports. Presently, there is no known commercial benthic fishing activity occurring within the DSMZ. Historically, even the top of the seamount, at 1,250 m, was considered too deep for most trawling technology. However, today deep-sea bottom fishing gear is being deployed across steeply irregular, and often boulder-strewn, sea floor surfaces at depths up to 2,000 m (CBD, 2008; Gregory, 2009). The likelihood of future exploratory fishing at Davidson Seamount seems low considering species observations that have been made to date. Quantitative video transect data collected at depths of 1,246 – 3,289 m (90% of the seamount's depth range) during a 2006 MBNMS/MBARI expedition to Davidson Seamount described very low fish density and no aggregations of fishes (Lundsten et al., 2009). Moreover, the majority of fish identified to date during sampling efforts have not been species with high commercial value. Macrouridae (rattails or grenadiers) have been the most frequently sighted fish family (Fig. 7). Since the mid-1990s, an important fishery for Pacific grenadier has developed in the Monterey Bay region (Andrews et al., 1999), suggesting that grenadier could be the most likely target of fishing around the DSMZ in future years.

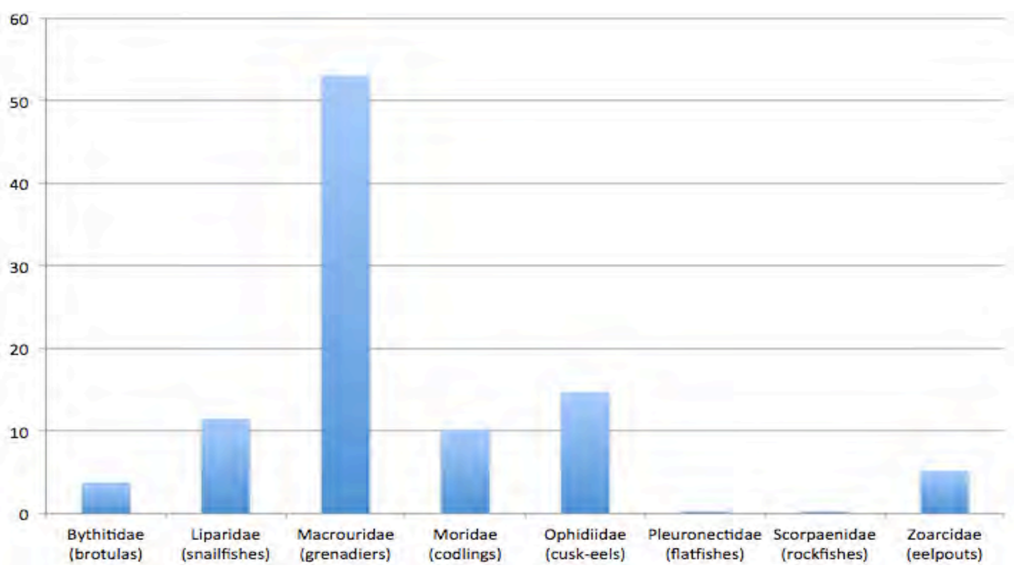


Figure 7. Observation of 8 dominant fish families (%) at Davidson Seamount from 40 video transects collected in 2006. Data from Lundsten et al., 2009.

While existing observations seem to suggest that there are limited populations of fish to support deepwater (>500 m) fisheries, future exploration may identify aggregated populations of invertebrates or Macrourid or other fishes that may be economically viable to exploit. Efforts at future exploratory fishing seem most likely in the diverse crest habitat (1,250-1,500 m), which includes large gorgonian coral (*Paragorgia* sp.) forests, vast sponge fields (many undescribed species), crabs, deep-sea fishes, shrimp, and basket stars. Given that a single test trawl could wipe out ancient corals for hundreds of years and that new benthic harvesting techniques could severely impact long-lived species, the DSMZ's potential deep-water fisheries should continue to be managed in accordance with the precautionary approach. Davidson Seamount is the only Essential Fish Habitat (EFH) bottom contact closed area designated within the MBNMS, and this designation – though not permanent – should offer protection from impacts due to benthic fishing gear.

Coral Harvesting

Despite the protective regulations already in place for the DSMZ and its relatively inaccessible location, it is conceivable that commercial species such as precious corals could motivate attempts at seabed harvesting. Seven species of Family Corallidae (*Corallium* spp. and *Paracorallium* spp.) have high commercial values due to their hard calcium carbonate skeletons. These red and pink coral species are often confused with the family's other 24 species, placing all 31 Corallidae species at risk of exploitation.

Precious corals have been used by humans for making jewelry, statues, and other decorative objects for over 25,000 years, and their industrial exploitation began many centuries ago (Tsounis et al., 2010). Coral beds have frequently been depleted by overfishing, and significant harvest has come from seamounts (NOAA, 2008b). The limited supply and high demand of these corals makes them one of the most valuable marine resources, with the ethnic, tourist, and high-end fashion markets (Fig. 8) driving prices to $240 USD/kg for small coral branches and $1,500 USD/kg for high-quality raw colonies of *Corallium rubrum* (Tsounis et al., 2010).

Figure 8. Red and pink coral jewelry in a New York City shop window. Source: www.flickr.com/photos/RedXdress

Harvest of Corallidae species peaked at roughly 450 tons/year in the 1980s (CITES, 2007). ROVs have been used for the exploration of new coral beds in Japan since 1983 (CITES, 2007). In 1980, about 20 Taiwanese coral trawlers poached about 100 mt of *Corallium* from seamounts within the U.S. EEZ in the Northwest Hawaiian Islands (Tsounis et al., 2010). It is not clear whether the designation of the Papahānaumokuākea Marine National Monument in that area has fully curbed the reoccurrence of poaching, although overexploitation has caused the global harvest to decline to roughly 50 tons/year over the past decade (CITES, 2007). The United States continues to be the largest importer of precious corals (Tsounis et al., 2010).

Precious corals are extremely vulnerable due to their fragility, and their life history characteristics severely limit their recovery from exploitation. Many species live to be more than 100 years of age, and grow at rates usually less than 1 mm in thickness per year (Andrews et al., 2005). To date, only four Corallid species have been included in the Convention on International Trade in Endangered Species (CITES) Appendix III. All four species are found in Chinese waters, leaving species within the U.S. EEZ unprotected (UNEP-WCMC, 2012).

Figure 9. Precious coral *(Corallium* sp.) and basket stars *(Gorgonocephalus* sp.) on the Davidson Seamount at 1692 meters. Photo credit: NOAA/MBARI

At Davidson Seamount, approximately 20 deep-sea coral taxa were observed during 90 hours of ROV dives in 2002. Most corals were observed on ridge areas, and all had other obvious megafauna associated with them. Corallidae taxa appear to be fairly abundant; 14.6% of the 396 framegrabs collected in 2002 had *Corallium* sp. taxa present (DeVogelaere et al., 2005). Polychaete worms, isopods, shrimps, crabs, basket stars, crinoids, brittle stars, and anemones were all found on Corallidae species (Fig. 9). Davidson's corals also provide habitat for adjacent species including rattails (Macrouridae), thornyhead (*Sebastolobus alascanus*), sponges, other corals, seastars, clams, sea cucumbers, and octopi (*Graneledone* sp.) (DeVogelaere et al., 2005; Burton and Lundsten, 2008). Since coral harvesting has occurred at depths of up to 1,500 m off Japan, Taiwan, Midway Island and the Emperor Seamounts, illegal harvesting on the rich crest habitat of Davidson Seamount is not out of the question. Sanctuary enforcement measures must anticipate this potential threat and vigilantly guard against future poaching attempts.

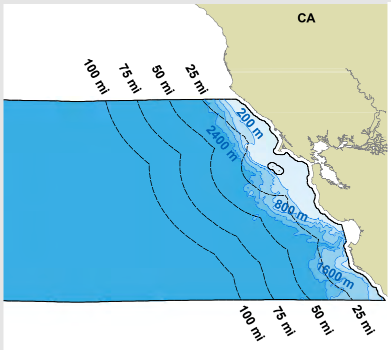
Exploitation of Non-Living Resources

Oil and Gas

Development of a permanent prohibition on new offshore oil and gas activity was one of the major reasons for designation of the MBNMS (NOAA, 2002). Oil and gas exploration and development are prohibited in the three Central California sanctuaries, and no oil or gas development presently occurs in the surrounding waters or in the Davidson Seamount area. Although there are no discovered oil and gas resources in the sanctuaries, there are substantial proven and undiscovered conventionally recoverable oil and gas resources nearby. Proven reserves within California's federal Outer Continental Shelf (OCS) have been estimated at 726,316,000 barrels (115,475,000 m^3) of oil, or approximately 3.1% of total U.S. reserves (California Natural Resources Agency, 1995). These reserves supply California's current oil and gas production: total oil production in state waters and the federal outer continental shelf (OCS) averaged 42,100,000 barrels (6,690,000 m^3) from 2003-2007, while total natural gas production in California waters and the federal OCS was 34,000,000 million cubic feet (962.8 km^3) in 2006 (California Natural Resources Agency, 2008). Minerals Management Service estimates of undiscovered technically recoverable California offshore oil and gas resources, shown in Fig. 10, indicate that incentives still exist for future oil exploration and development in the waters to the south of the MBNMS and Davidson Seamount.

Should oil and gas exploration and development to the south of the MBNMS expand northwards in the future, there would be several associated threats to Davidson Seamount. Seismic surveys, used to approximate the sizes of offshore reserves, employ 'airgun arrays' to emit high-decibel sounds that can effect fish behavior, including migration, and may lead to whale beaching and stranding (Patin and Cascio, 1999). Drilling often involves the unregulated release of "drilling muds" containing toxic contaminants (zinc, benzene, arsenic, radioactive materials) that are used to lubricate drill bits and maintain pressure (Patin and Cascio, 1999). These contaminants can accumulate on the seafloor, potentially smothering organisms. Currents could carry oil spills and leaks northwards where they could have a major impact on DSMZ resources, and damage to fragile seafloor habitats south of the MBNMS could impact species that migrate between these deep-sea habitats and Davidson Seamount. Additionally, studies have shown that the high concentrations of metals found around drilling platforms often bioaccumulate in food chains (MMS, 2001).

A.

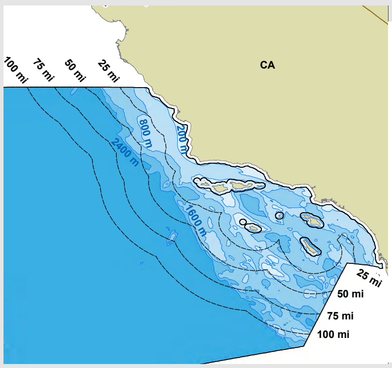


Resource Estimates Based on MMS 2006 Assessment Data

	Water Depth	Gas (Tcf) UTRR	Oil (Bbbl) UTRR
	0-200 meters	0.66 - 2.82	0.66 - 2.56
	200-800 meters	0.32 - 1.11	0.34 - 1.02
	800-1600 meters	0.10 - 0.25	0.14 - 0.27
	1600-2400 meters	Negligible	Negligible
	>2400 meters	Negligible	Negligible

Resource values are in trillion cubic feet of gas (Tcf) and billion barrels of oil (Bbbl).

B.



Resource Estimates Based on MMS 2006 Assessment Data

	Water Depth	Gas (Tcf) UTRR	Oil (Bbbl) UTRR
	0-200 meters	1.77 - 2.40	0.86 - 1.13
	200-800 meters	3.76 - 6.60	1.85 - 4.07
	800-1600 meters	0.54 - 4.81	0.45 - 2.83
	1600-2400 meters	0.01 - 2.23	0.01 - 1.16
	>2400 meters	Negligible	Negligible

Resource values are in trillion cubic feet of gas (Tcf) and billion barrels of oil (Bbbl).

Figure 10. September 2008 Minerals Management Service estimates of undiscovered technically recoverable resources by water depth range in a) Central California Planning Area and b) Southern California Planning Area. Source: Bureau of Ocean Energy Management, Regulation, and Enforcement, http://www.boemre.gov/revaldiv/NatAssessmentMap.htm

In the past 10 years the State of California has adopted legal restrictions to prohibit new oil and gas leasing and development. Temporary moratoria have been in place for federal waters since 1982. The June 1998 directive issued by the Clinton Administration under the OCS Lands Act prevented any leasing of new areas for oil and gas exploration and development through June 30, 2012 (NOAA, 2002). However, OCS presidential deferrals do not restrict development of already leased federal areas. There are 36 remaining undeveloped active OCS leases south of the MBNMS off the coast in San Luis Obispo and Santa Barbara counties. Should these sites eventually be developed, any potential spills could potentially cross Sanctuary boundaries and impact sanctuary resources (NOAA, 2002). NOAA should continue to work with the Department of the Interior's Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) and other agencies to manage potential impacts to sanctuary resources from exploration activities that may occur outside of the Sanctuary boundary.

Deep Sea Mining

Worldwide, an emerging new threat to seamount fauna is the possibility that deep-sea mining companies may target seamount areas for new extractive activities. Some firms have investigated the potential to extract cobalt-rich ferromanganese oxide (Fe-Mn) crusts and polymetallic sulphides from seamounts. If such activities were to occur, the potential for direct physical damages would also be considerable (Sarma et al., 1998). Specific types of impacts that mining could cause include the loss of fossil records due to physical damage, the release of metals that affect benthic fauna, high levels of dissolved nutrients in the water column, and the creation of sediment plumes and debris build-up at the base of the seamount (CBD, 2008). Strong boundary currents at seamounts might prevent the dilution of pollution associated with mining, and impacts to the water column could alter ecosystem structure and function (CBD, 2008). In US federal waters, BOEMRE would control potential mineral extraction.

Davidson Seamount, formed over 9.8 million years ago by volcanic eruptions, is primarily composed of basalts and other igneous materials. The seamount's surface is coated with thin mineral layers – including ferromanganese oxide crusts – that have precipitated out of seawater (NOAA, 2006). At most rock outcrops, these crusts, accumulated at incredibly slow rates, are as thick as several centimeters (Clague et al., 2010). As with oil and gas, NOAA prohibits mineral exploration, development, and production within the sanctuaries. Even with future technological advances that will likely expand the reach of deep-sea mining, enforcement of existing Sanctuary regulations should safeguard the DSMZ against such commercialization.

Marine debris / dumping

Levels of debris in the MBNMS and in all parts of the ocean are of growing concern. Various types of debris, including lost fishing gear, plastic bags, polystyrene foam, balloons, and other consumer goods, are widespread and known to have adverse effects on marine species. Debris degradation over time is dependent on a variety of factors such as material type, thickness, size, wave action, exposure to sunlight, temperature, and whether debris is floating, pelagic, or benthic. At Davidson Seamount, a combination of these factors (no exposure to sunlight, very cold temperatures, lack of agitation by waves) equates to extremely long decomposition times.

Plastics in the marine environment never fully degrade, and on the seafloor form an obstacle to benthic organisms and a barrier to gas and nutrient exchange (Van den Hove and Moreau, 2007). Although recognized to pose a particular threat to marine mammals, turtles and seabirds, recent studies have found that organisms at all levels of the marine food web are consuming plastics (NOAA, 2009a). After death of organisms that have ingested persistent plastic debris, the material is released to once again be picked up by other fauna. In addition to ingestion and suffocation, entanglement is a major problem associated with marine debris, and may lead to death for many organisms.

Lost or dumped fishing gear, estimated at 30% of all marine debris, can create long-term entrapment mechanisms that continuously kill mobile fauna for decades (Van den Hove and Moreau, 2007). Fishing nets are designed to be sturdy and durable, thus preventing the escape of trapped wildlife and causing sustained ecological damages. Nets and lost cage traps can physically scrape organisms off of deep-water reefs or sweep immobile invertebrates from sandy areas (NOAA, 2009a). Such "ghost fishing" phenomena have been documented in seamount environments that have experienced heavy bottom trawling, such as those off the continental slopes of Australia and New Zealand (Clark and Koslow, 2007). As described above in the Vessel Traffic section, commercial freight vessels also accidentally lose parts of their cargos at sea. A rough estimate of lost merchant freight at sea is 1.3 million tons per year (Van den Hove and Moreau, 2007). This debris can have substantial crushing and smothering impacts on fragile seamount habitats. In addition to ecological impacts, aesthetic impacts to the largely pristine

DSMZ environment are an important concern.

Prior to the passage of the Marine Protection, Research, and Sanctuaries Act of 1972, the Davidson Seamount area was not protected from targeted offshore dumping. Although enforcement of ocean dumping and discharge regulations has been the responsibility of the U.S. Coast Guard since that time, benthic habitats within the DSMZ exhibit evidence of cumulative intentional and accidental dumping. Both the 2002 and 2006 Davidson Seamount research cruises observed plastics, glass, and aluminum debris. Specific items observed include bottles, cans, brooms, newpapers, buckets, curtains, and a train wheel (Fig. 11). The legible condition of the newspaper clearly illustrates how the effects of pressure, temperature, darkness, and relatively calm waters deep within the DSMZ can preserve debris. The train wheel, believed to have been used as an anchor for U.S. Navy sound experiments, attest to the military's contributions to accumulation of marine debris. The debris discovered thus far is likely proportional to sampling effort, and future research expeditions are bound to uncover additional materials of anthropogenic origin.

Figure 11. Marine debris observed on dives to Davidson Seamount using ROV *Tiburon* in 2002 and 2006. Clockwise from top right: beer can; fabric from shower curtain; legible newspaper; train wheel likely used as anchor for U.S. Navy experiments; bucket; Korean Coke bottle. All photo credits: NOAA/MBARI.

The MBNMS Marine Mammals, Seabirds, and Turtle Disturbance Action Plan outlines a plan to address the threat of marine debris to wildlife by developing a marine debris database and working in cooperation with other agencies and municipalities to develop a notification and recovery program for lost fishing gear (NOAA, 2008b). The plan also includes a focus on conducting education and outreach programs to illustrate the impacts of marine debris on wildlife, and education about significant impacts at Davidson Seamount could strengthen this effort and potentially augment existing federal regulations regarding at-sea dumping (NOAA, 2008b). The Sanctuary is also collaborating with partners to implement a multi-year project to remove lost fishing gear from MBNMS waters. The dual purpose of the project is to help eliminate benthic and pelagic hazards to marine organisms posed by fishing debris lost on the bottom, and to provide outreach tools that will assist in the location of lost gear via reports from divers, researchers, fishermen and other parties (NOAA, 2009a).

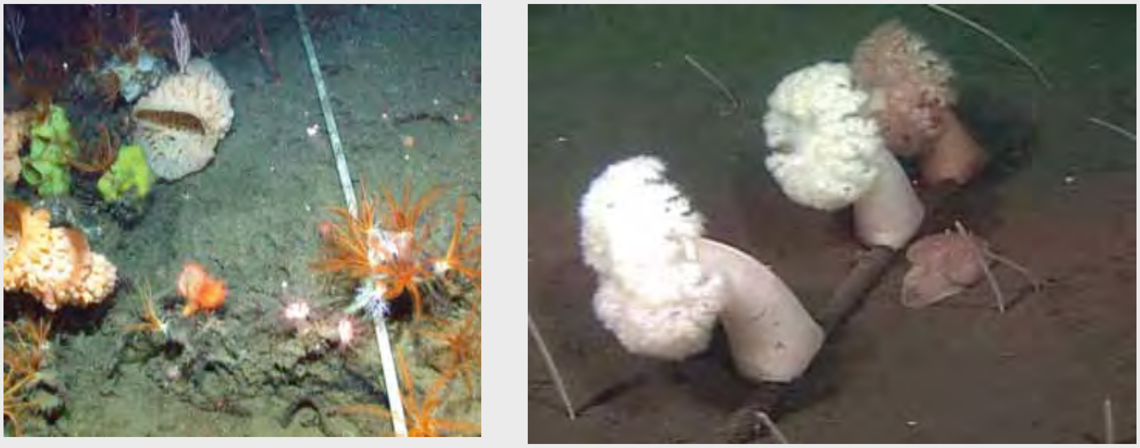
Because dumping from shipping, fishing, and cruise vessels is believed to contribute less debris to the marine environment than land-based sources, efforts to protect MBNMS resources including the DSMZ must also focus on human activities on land. Through its Urban Runoff Water Quality Action Plan, the Sanctuary is addressing the land-based runoff problems including marine debris. MBNMS is supporting efforts by cities and the state to ban use of some non-recyclable plastic consumer products (e.g., expanded polystyrene) and to encourage incentives for the use of compostable materials. Recently, a number of cities adjacent to the Sanctuary have implemented such bans, including Capitola, Santa Cruz, Carmel, Pacific Grove, Seaside, Monterey, Oakland, and San Francisco, which may reduce the amount of debris entering sanctuary waters (NOAA, 2009a). As currents can transport debris substantial distances from their sources of origin, these efforts are important to ensuring that quantities of debris settling on the seafloor in the DSMZ are reduced in the future.

Underwater cables

From sand mining to oil and gas production to telecommunications, human uses of the seabed have been increasing worldwide. In 1850, the first submarine cable – a copper-based telegraph cable – was laid across the seafloor of the English Channel (Carter et al., 2009). Today, over a million kilometers of fiber-optic cables cross the world's oceans, connecting continents and societies and enabling economic globalization (Carter et al., 2009). At water depths greater than 1,500 m, as at Davidson Seamount, deployment of cables directly on the seabed without burial is the preferred option (Carter et al., 2009).

Modern seabed mapping and navigation systems allow the submarine cable industry to identify benthic habitats with a high degree of detail and accuracy. Equipped with modern cable-laying techniques, the industry has the capacity to avoid areas that are either protected by regulations or unsuitable due to the risk of natural hazards. Seamount habitats are generally considered undesirable routes as they may be volcanically active, subject to landslides and hydrothermal venting, and may contain strong currents that could break or abrade cables (Carter et al., 2009).

However, listening arrays have already been installed on nearby seamounts, with commercial fiber optic cables situated nearby. Seamounts are popular locations for such installments, as uninterrupted distances to other features of similar height allow for undistorted long range acoustic propagation. Studies of the exposed Acoustic Thermometry of Ocean Climate (ATOC) cable that crossed the slopes of Pioneer Seamount found no major difference between the numbers of deep-sea species near the cable and the numbers of these animals in undisturbed areas (Kogan et al., 2006). Yet such a cable creates a hard substrate on a seabed that is otherwise soft. Fig. 12 shows how the ATOC cable created anemone habitat where it did not previously exist, which could lead to local changes in community structure. The process of cable installation could also be traumatic if the cable were to land on top of deep-sea corals or other fragile taxa.



A **B**

Figure 12. The ATOC cable, surveyed in 2003, after eight years on the seafloor a) on Pioneer Seamount and b) at depth of c. 140 m, in mud, with attached anemone *Metridium farcimen*. Photo credit: MBARI.

Although standard MBNMS regulations that now apply to the DSMZ prohibit the alteration of the seafloor and the construction of structures on the seafloor without a permit, researchers have found evidence of existing cable structures at Davidson Seamount. During a 2006 dive of the ROV *Tiburon*, researchers discovered a telecommunications cable that runs along the side of the seamount (Fig. 13). The purpose of this cable, how long it has been in place, whether it is still in use, and its routing are uncertain. Possible ecological impacts of the cable were not assessed during the 2006 cruise. Due to the damage that could be incurred to Davidson Seamount's large corals and other fragile species by future cable installations, Sanctuary management should remain alert to any projects that may involve laying of additional cables or other structures. Any permits issued for such projects should focus cable laying – and other activities that may disturb the seabed – in areas where corals are not expected.

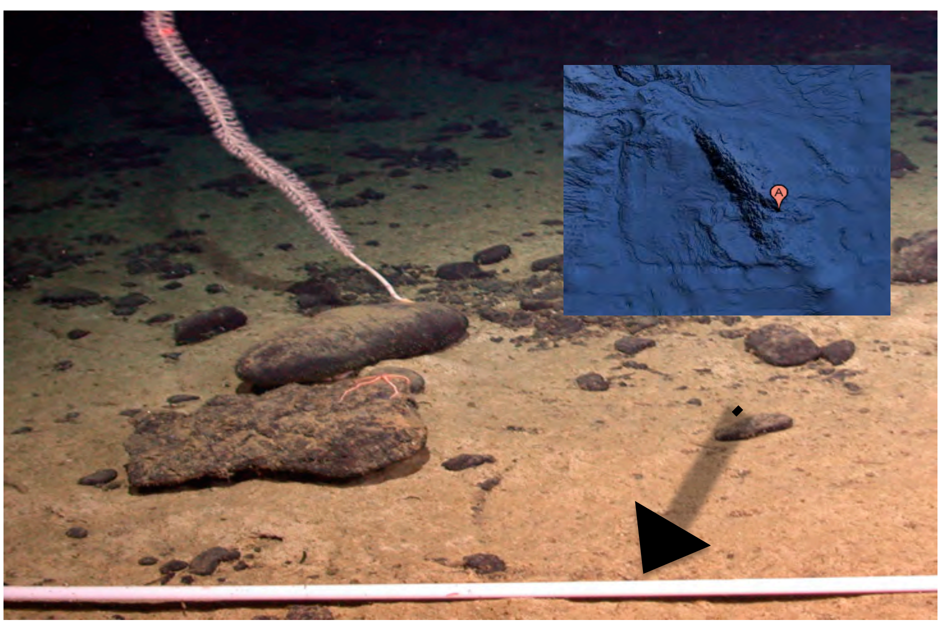


Figure 13. Cable found at a depth of 3287.4 m during a 2006 dive at Davidson Seamount. Inset shows the location of the photo at latitude 35.62368393, longitude -122.83390808. Photo credit: NOAA/MBARI.

Water quality

Davidson Seamount's depth and its distance from land of nearly 100 km do not prevent it from being impacted by point and non-point water pollution. Traces of the pesticide DDT, banned in the US since 1972 but still present in watershed sediments, were detected in sediments near the base of the seamount and were probably transported through Monterey Canyon sediment flow events (Charlie Paull, pers. comm.; Hartwell, 2008). DDT contamination can have far-reaching ecosystem impacts and caused the Palos Verdes Shelf in southern California to be declared an EPA Superfund site in July 1996. More locally, the Central Coast Long-term Environmental Assessment Network (CCLEAN) has found that all DDT measurements at Monterey Bay sites have exceeded the NOAA effects range low (ERL) and that infaunal abundances along the 80-meter contour in Monterey Bay have been negatively affected by DDTs (CCLEAN, 2011). On a regional scale, Monterey Bay has been shown to be a primary source of persistent organic pollutants (POPs), including DDTs, distributed across the continental shelf and slope and along the central California coast (Hartwell, 2008). Sediment samples collected in 2002 and 2004 at continental slope study sites just south of Point Sur had concentrations of total DDTs as high as 4.4-10.9 μg/kg dry weight (Hartwell, 2008).

Water quality in the DSMZ, as in the remainder of the MBNMS, faces a variety of threats. These include urban, suburban and agricultural runoff, aging sewer infrastructure systems, contaminated flows from creeks and rivers, marinas and boating, and unidentified sources. The land area drained by watersheds that flow into the MBNMS is enormous (Fig. 14). Included in this area of the Central Coast are agricultural lands that sustain a 5.6 billion dollar agricultural industry that produces over 200 types of crops. Runoff containing pesticides, synthetic and organic chemicals, and other anthropogenic contaminants from anywhere within this area has the potential to eventually settle in DSMZ sediments and affect the seamount community by accumulating in deep-sea food chains. Although there is limited knowledge of specific impacts on deep-sea species, the general risk of impact seems to support a precautionary approach (Santos et al., 2010).

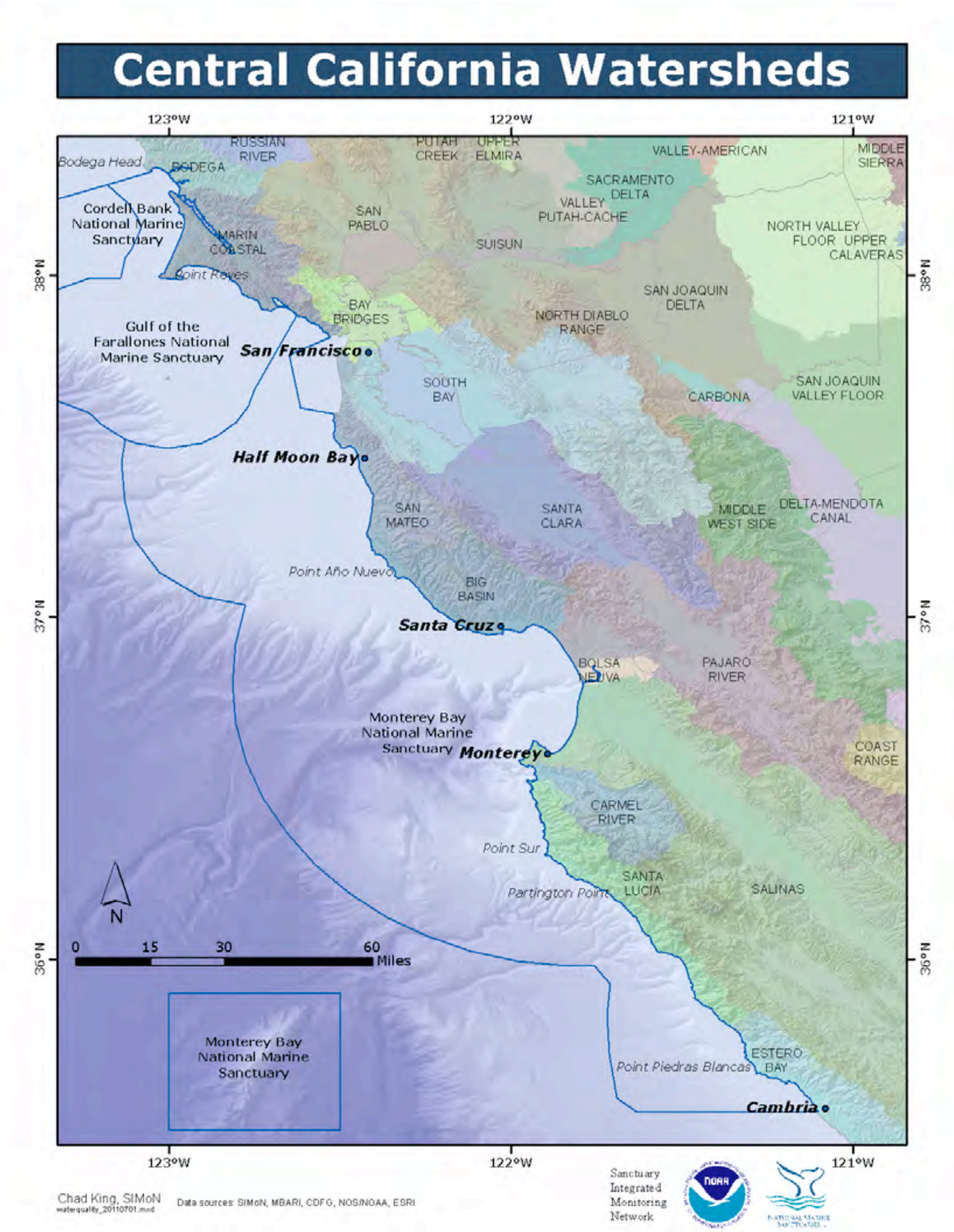


Figure 14. Major watersheds that lead to the Monterey Bay National Marine Sanctuary and the Davidson Seamount Management Zone. Colors and labels indicate the name of each watershed area. Map credit: Chad King, MBNMS.

Climate change

Seamount environments, rich with sensitive deep-sea corals, have been dramatically affected by natural climate change in the past (Rogers et al., 2007). Today's anthropogenic climate change threatens seamount environments such as those found at Davidson in numerous ways: through local and regional changes in primary productivity, through the repositioning of major ocean currents, through organic carbon flux, and via ocean acidification (Rogers et al., 2007). Because Davidson's corals provide habitat, are an integral part of the community structure and are likely to be most vulnerable to the effects of climate change, there is the potential for large-scale changes in faunal composition (Rogers et al., 2007). Following are descriptions of the main ways in which climate change may impact the DSMZ.

<u>Sea temperature rise</u>
Rising mean atmospheric temperatures associated with anthropogenic global climate change are being accompanied by alteration in temperatures in the marine environment (Levitus et al., 2009). A warming trend in the uppermost 700 m of the world's oceans since the 1950s has already been documented (Levitus et al., 2009). Seawater temperatures below 1,000 m (3,280 ft) tend to be relatively constant, with close to freezing temperature readings at Davidson Seamount, ranging from 0 to 5º C (32 to 41º F; NOAA, 2006). Cold-water corals, such as *Lophelia pertusa*, have been shown to be extremely sensitive to the physical characteristics of overlying seawater (Rogers, 2004). Any changes in water temperature, even within the narrow range described above, may adversely affect the biological functioning of corals and other seamount organisms. Warmer seawater could also reduce the ocean's overall primary productivity, thereby limiting the amount of organic matter that eventually falls to the seafloor and supplies deep-sea species with nutrients.

Changing sea temperatures will likely be the cause of associated changes in ocean currents – a phenomenon with potentially severe impacts on productivity patterns and the functioning of deep-sea ecosystems (Santos et al., 2010). Seamount communities such as those at Davidson Seamount often benefit from upwellings of nutrient-rich waters and eddies of water around their summits; large-scale changes in ocean currents could modify these water movements (CBD, 2008). Finally, a potential reduction in thermohaline circulation would diminish the supply of oxygen-rich water to the seabed (Schmittner and Stocker, 1999; Joos et al., 2003), which could kill extensive amounts of existing marine life in the DSMZ.

<u>Ocean acidification</u>
Another expected result of anthropogenic release of CO_2 is acidification of the world's oceans, with adverse consequences for biodiversity (Van den Hove and Moreau, 2007). Increases in seawater acidity caused by CO_2 dissolution are already occurring at unprecedented rates. Currently, our oceans and marine organisms are experiencing the greatest increase in acidification of the past 300 million years, and mean ocean pH is predicted to be at its lowest level in 20 million years by 2050 (CBD, 2008; Turley et al., 2007). CO_2 enrichment experiments have shown that deep-sea species in the Sanctuary such as crustaceans, urchins, and sea cucumbers are intolerant of short-term exposure to hypercapnic (pH reduced by 0.2 units) water (Barry et al., 2006; Pane and Barry, 2007). Although the full range of impacts that this drop in pH will have on deep-sea organisms remain unknown, the most profound effect involves acidic seawater de-saturating aragonite in water, limiting the ability of marine calcifying organisms that build their external skeletal material out of calcium carbonate. Since deeper waters at higher latitudes already experience a lowered carbonate saturation state, cold-water calcifying organisms like the corals and invertebrates found at Davidson Seamount may be among the most vulnerable to acidification.

Moreover, the depth at which aragonite dissolves could become shallower by several hundred meters, which would raise the prospect that environmentally stable areas that have historically been suitable for cold-water coral growth may become inhospitable in the future. This would further alter the distribution of animals reliant upon calcite, with particularly deleterious effects on deep-sea corals. A common prediction is that 70% of the 410 known locations worldwide with deep-sea corals may be in aragonite undersaturated waters by 2100 (CBD, 2008). Such a scenario would make sustained coral dissolution more likely than calcification. The problem could be compounded should incentives increase for commercial interests to develop CO_2 sequestration schemes that would 'fertilize' the seafloor and form deep-water carbon lakes (Santos et al., 2010). The extent of future problems associated with CO_2 sequestration at Davidson Seamount will be determined by technological advances, market forces, and regulation of areas adjacent to the MBNMS. Historically, cold-water corals have required at least several million years to recover from mass extinctions (Turley et al., 2007). Ocean acidification poses the threat of extinction before the scientific community has begun to fully understand deep-sea ecosystems.

To date, there have been few published experimental results on the specific impacts of higher seawater CO_2 concentrations on cold-water corals (Turley et al., 2007). Research on deep-sea corals has been identified as a major objective for better understanding ocean acidification. In collaboration with the MBNMS, James Barry (MBARI) initiated experiments in 2009 at Davidson Seamount that involved transplanting corals to deeper depths and shipboard collection of clams to study the effects of elevated CO_2 levels on these organisms. Future research in the DSMZ should continue to focus on increasing our understanding of this threat. The wide variety of species assemblages in the MBNMS and the many local marine research institutions that partner with the MBNMS puts the Sanctuary in an ideal position to lead in the coordination of efforts to better understand ocean acidification.

CONCLUSIONS / RECOMMENDATIONS

Although Davidson Seamount is one of the better-studied seamount environments in the world, the DSMZ's deep-sea habitats and ecological communities are just beginning to be understood by science. Due largely to its proximity to the coast, the DSMZ faces a number of anthropogenic threats. However, it is also one of the few seamount areas in the world to receive the level of protection afforded by the MBNMS. Sanctuary regulations provide important – although not comprehensive – defenses against the threats outlined in this report. Furthermore, the depth of Davidson Seamount's crest, slope, and base habitats make some forms of exploitation impossible or highly unlikely. To allow for comparison of the threat levels posed by each threat, we created a metric that allows each threat to be rated as "low," "medium," or "high."

To be assigned a threat level of "low," there must be a) existing regulations to protect against that threat, or b) the activity associated with the threat must be accepted to be currently impossible or highly unlikely.

To be assigned a threat level of "medium," there must be a) a possibility of threat activity occurring (either legally through a permitting process or otherwise) despite existing regulations to protect against that threat being in place, or b) no current protections against the threat, but also no known threat activity occurring.

To be assigned a threat level of "high," there must be no regulatory protections in place against the threat *and* the threat activity is known to be presently occurring or likely to occur.

Upon assigning these threat levels to each of the identified threats, vessel traffic, sea temperature rise, and ocean acidification appear to be the most severe threats to the DSMZ at this time (Table 1). Threats ranking in the "low" threat level category include activities that are presently prohibited and/or very unlikely to occur due to depth-related challenges. These include bio-prospecting, coral harvesting, oil and gas exploitation, and deep-sea mining. The "medium" threat level includes several threats that have already occurred at some level in the DSMZ or nearby, but are regulated. Continued assessment and/or enforcement is needed to appropriately manage these activities, minimize threats to the DSMZ, and provide a high level of protection to the many resources it contains.

Table 1. Threats to the DSMZ and the relative threat level associated with each one.

<table>
<tr><th></th><th colspan="3">THREAT LEVEL</th></tr>
<tr><th>THREAT</th><th>LOW</th><th>MEDIUM</th><th>HIGH</th></tr>
<tr><td>Vessel traffic</td><td></td><td></td><td style="background:#ff2a00"></td></tr>
<tr><td>Submerged vessels</td><td></td><td style="background:#ffff00"></td><td></td></tr>
<tr><td>Military activity</td><td></td><td style="background:#ffff00"></td><td></td></tr>
<tr><td>Bio-prospecting</td><td style="background:#00ff00"></td><td></td><td></td></tr>
<tr><td>Cumulative research collection</td><td></td><td style="background:#ffff00"></td><td></td></tr>
<tr><td>Commercial harvesting:
Waters above seamount</td><td></td><td style="background:#ffff00"></td><td></td></tr>
<tr><td>Commercial harvesting:
Deep-water fisheries</td><td style="background:#00ff00"></td><td></td><td></td></tr>
<tr><td>Commercial harvesting:
Coral harvesting</td><td style="background:#00ff00"></td><td></td><td></td></tr>
<tr><td>Oil and gas exploitation</td><td style="background:#00ff00"></td><td></td><td></td></tr>
<tr><td>Deep-sea mining</td><td style="background:#00ff00"></td><td></td><td></td></tr>
<tr><td>Marine debris / dumping</td><td></td><td style="background:#ffff00"></td><td></td></tr>
<tr><td>Underwater cables</td><td></td><td style="background:#ffff00"></td><td></td></tr>
<tr><td>Water quality</td><td></td><td style="background:#ffff00"></td><td></td></tr>
<tr><td>Sea temperature rise</td><td></td><td></td><td style="background:#ff2a00"></td></tr>
<tr><td>Ocean acidification</td><td></td><td></td><td style="background:#ff2a00"></td></tr>
</table>

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